THE PRINCIPAL WORKS

OF

SIMON STEVIN

EDITED BY

ERNST CRONE, E. J. DIJKSTERHUIS, R. J. FORBES
M. G. J. MINNAERT, A. PANNEKOEK

AMSTERDAM
C. V. SWETS & ZEITLINGER

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ENGINEERING

EDITED BY

R. J. FORBES

MUSIC

EDITED BY

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CIVIC LIFE

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SIMON STEVIN

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The following edition of the Principal Works of SIMON STEVIN has been brought about at the initiative of the Koninklijke Nederlandse Akademie van Wetenschappen (Royal Netherlands Academy of Sciences and Letters) by a committee consisting of the following members:

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PREFACE

This volume V concludes our edition of the Principal Works of Simon Stevin. It is primarily devoted to his works on engineering. To these we have added his interesting treatise on the Theory of Music, in order to show the variety of subjects treated by our author. Finally the Precepts for the Citizen bring a more personal approach to Stevin, the man.

For the publication of the Principal Works a period of sixteen years proved necessary, extending from 1950 to 1966. With great gratitude and admiration we remember the late Professor E. J. Dijksterhuis, who by his publications and lectures stimulated the interest in Simon Stevin and stressed the importance of a re-issue of his principal works, with introductions and explanatory notes. At the proposal of Professor A. Pannekoek the Royal Netherlands Academy of Sciences and Letters at Amsterdam in 1950 took the initiative and instituted a commission which was to carry out the project. Professor Dijksterhuis became its chairman, edited the first volume, and gave shape to our edition. Thanks to his scholarly competence and to his wise experience he was able continually to inspire and to advise the commission. It is a sad thought that he has not been able to witness the completion of our enterprise.

We further gratefully remember the late Professor Pannekoek, who edited the first part of Volume III and also had an important part in our work.

We render thanks:

to the Royal Netherlands Academy of Sciences and Letters at Amsterdam, which instituted our commission and gave its moral support;

to all scientific bodies and organizations which by their subsidies made the publication possible, and more especially to those who gave us their confidence at the moment the enterprise was started;

to the authors, translators, publishers, and printers;

to the directors of libraries and archives which kindly allowed us the use and the reproduction of their rare originals.

We express the wish that this edition may stimulate the interest in the fascinating personality of Simon Stevin and will contribute to our knowledge of science about 1600.

The Stevin Commission of the Royal Netherlands Academy of Sciences and Letters.

THE WORKS ON ENGINEERING

OF

SIMON STEVIN

EDITED BY

R. J. FORBES

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INTRODUCTION

The editing of Simon Stevin's patents and treatises on engineering subjects is no simple task. The modern engineer is seldom at home in both mechanical and hydraulic engineering, to mention but two fields in which Stevin operated. Moreover, Stevin confronts us with the problem of finding equivalents for his seventeenth-century terminology in the English technical literature of those days, if the translation is to do full justice to his work. In subjects peculiar to the Low Countries such equivalents did not even exist at that time and we have to content ourselves in finding more general terms to translate Stevin's accurate nomenclature. Co-operation with various experts has therefore been essential.

In several chapters, good use has been made of E. J. Dijksterhuis' book on Simon Stevin (1943). We would express our gratitude here for the valuable advice given by Ing. G. Doorman concerning Stevin's patents, and his discovery of important illustrations pertaining thereto. The late Dr. J. van Veen has been so kind to review our presentation of the essays on hydraulic engineering and the introduction to them. Ir. A. Havinga has lent very valuable assistance in editing the material on mills and (partly together with Mr. I. J. de Kramer) designing the plates which enable us to compare Stevin's mills with those of his contemporaries. Dr. E. Wiersum has the merit of having unearthed the specification for the Kralingen mill of 1589. Prof. A. W. Skempton (University College, London), Mr. L. T. C. Rolt (Winchcombe) and the late Mr. L. E. Harris have supplied valuable critical contributions on Stevin's hydraulic engineering work. To Mr. Rex Wailes (Beaconsfield) is due the honour of having contributed a considerable part of the commentary on, and the translation of, *On Mills*. If it were not for him and for Prof. Skempton an adequate translation of Stevin's texts would have been virtually impossible. This cooperation has, we hope, contributed to a volume which will enable us to appreciate Simon Stevin as an engineering genius of his day.

Amsterdam, 1966 *R. J. Forbes*

CHAPTER 1

THE SAILING CHARIOT

THE SAILING CHARIOT

Dutch tradition has for many generations coupled the fame of Stevin with his sailing chariot, which, however, plays but a minor part in his achievements as an engineer and which might well have been forgotten without any loss to us.

Stevin's sailing chariot does not deserve this prominent place in the tradition concerning this great engineer, for he was certainly not the inventor of the sailing chariot, which had a long history behind it in Stevin's days. He does not refer to it in any of his works and any data we possess about this chariot and its performances do not seem to convey much information. Actually they are so incomplete and so full of phantasy and exaggeration that they can hardly be said to constitute serious historical and technical information. Hence we do not know very much more about the chariot than that it existed and that it could transport persons.

Stevin probably never heard of the most ancient example of a sailing chariot that we know. It was actually excavated in Medînet Mâdi on the southern rim of the Fayum, the large depression in the desert west of the Nile [1]). Here a temple was found built by Amenemhat III and IV (about 1800 BC) [2]) in the precinct of the holy of holies of which the remains of the sailing chariot were found. In the early period of this temple ancient Egyptian gods and goddesses were worshipped there in whose cult no sailing chariot played any part, but a religious ceremony called "sailing on the land" (Egyptian *ḫnt nt t3*) was then known [3]). We know that this involved transporting the statue of a god in a boat with a sail, though we are not sure whether such a boat on a frame with wheels was actually handled like a sailing chariot.

This was certainly current tradition in Hellenistic days when a priest, Isidorus, in the temple of Medînet Mâdi inscribed a poem on one of the entrance pylons of the temple glorifying its founder Amenemhat III and saying:

> "I have heard something marvellous and paradoxical from others
> That he sailed in the mountains (desert) on axles and sails
> Studious scholars have assured me of it
> And I have written it all down
> Proclaiming the might of the god and king to the Greeks
> More than any mortal was the power he obtained"

The actual remains of a sailing chariot found there probably date from this same Hellenistic period. They consist of a sycamore frame (209 x 123 cm, distance between the axles 170 cm) held together with iron pegs and nails. It had carried a mast and holes were found in this frame, some of which must have been

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1) Dittmann, *Der Segelwagen von Medinet Mâdi* (Mitt. Dtsch. Archaeol. Instit. Kairo, Vol. 10, 1941, pp. 60—78).
2) Vogliani, *Primo e secondo Rapporto Scavi .... Madinêt Mâdi* (Milano 1936/37).
3) Ann. Serv. Ant. Egypte vol. XLXIX, 1939, p. 379.

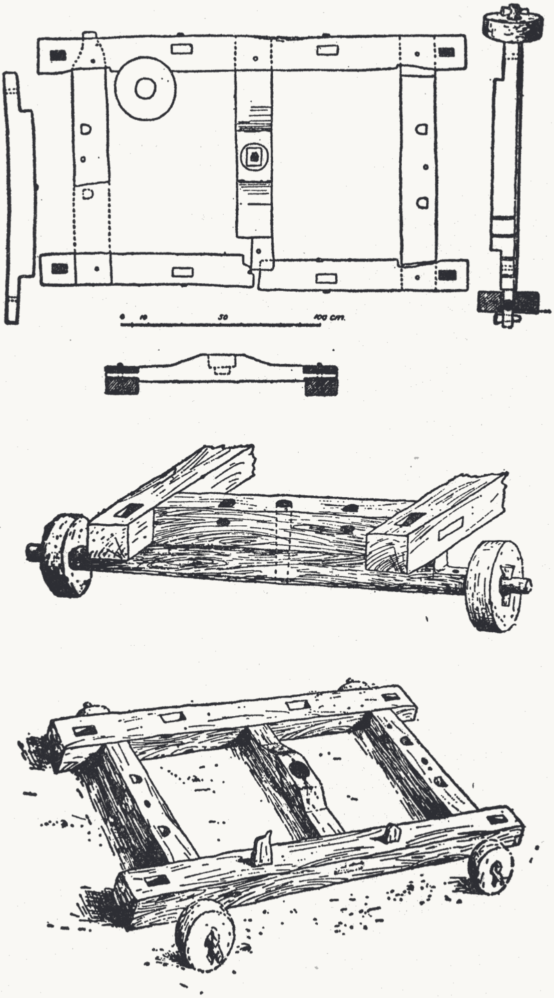

Fig. 1

used to draw the frame, others to fix the rigging of the sail (Fig. 1).The frame also had seats in the middle, probably for those working the sail and steering the chariot.

During Hellenistic times the goddess Isis was held to have introduced navigation. Coins of Delos depict her on a raft with a sail and in several processions in honour of this goddess of the sea and the winds a holy sail was carried about. The chariot at Medînet Mâdi probably served on such occasions and during other ceremonies continuing the more ancient "sailing on the land" of the days of Amenemhat III.

This ancient Egyptian tradition and ceremony was, however, forgotten in the days of Stevin. He may have derived his information from Jan Huygen van

Linschoten [4]), who tells us that "the Chinese are great artists and very clever as is shown by all the works that come from there. They make and use chariots with sails, like boats, and wheels of such excellent construction that they are propelled by the wind on a flat plain as if they were in the water". They also used a small sail to help their wheelbarrows along. Duyvendak has made it clear [5]) that Van Linschoten probably took his information from Juan Gonsalez de Mendoça's *Historia de las Cosas mas notables, ritos y costumbres,* a Dutch translation of which was published at Alkmaar in 1595 [6]).

The six important testimonies on Stevin's sailing chariot will now be discussed:

1. Hugo de Groot, who as a boy took part in the trip to Petten which we will discuss later on and described it in a Latin poem *Iter currus veliferi* [7]). It inspired him to write 22 Latin epigrams [8]).

2. In his *Parallelon Rerumpublicarum* [9]) Grotius makes the following remark: "A short while ago we started to sail on land too: for we possess chariots, which are driven by the wind, provided with sails and speeding thrice as rapidly as a ship: for they have not to struggle with waves which beat against them; but they fly over the plains with an incredible speed, and crediting me as an eyewitness you must believe me when I say that they nearly escape the winds which move them. I was present when one covered in less than two hours fourteen of our miles, each of which contains the distance of an hour". He also remarks that sailing chariots were used "by the Chinese, the cleverest of all peoples . . . who enjoy the sun and the sky in a way equal to ourselves". By this latter sentence he seems to mean that they live in the same geographical latitude, and he takes this as the reason why they so often invented the same things as the Dutch did. He also mentions the ice-sledges constructed on the model of the sailing chariots.

3. Gassendi [10]) tells us in his biography of Nicolas Claude Fabri de Peiresc (1580-1637), a French scientist who by his voluminous correspondence was a potential influence in early seventeenth century science, that de Peiresc when travelling in Holland had also visited Scheveningen (in 1606) to inspect the sailing chariot invented a few years earlier, in which Prince Maurice, according to his reports, had driven in two hours from Scheveningen to Putten (read Petten),

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4) J. Huygen van Linschoten, *Itinerario. Voyage ofte Schipvaert van Jan Huygen van Linschoten naar Oost ofte Pôrtugaels Indien, 1579—92.* Uitgegeven door H. Kern. Eerste deel. 's-Gravenhage 1910, p. 65 (Linschoten Vereniging II).

5) J. J. L. Duyvendak, *Le chariot à voiles de Stevin* (Grotiana vol. IX, 1941/42, pp. 3—7).

6) J. J. L. Duyvendak, *Grotius et la Chine* (Grotiana vol. VIII, 1940, pp. 25—29).

7) Hug. Grotii, *Poemata Omnia,* 4th impr. Lugduni Batav. 1645. Farraginis Liber 1, pp. 164—166.

8) Hug. Grotii, l.c. *Epigrammatum Liber II,* p. 278—287. Some of these epigrams are reproduced in Dutch translation on the back of the picture of the sailing chariot in Blaeu's atlas.

9) Hugonis Grotii, Batavi, *Parallelon Rerumpublicarum. Liber Tertius: De moribus ingenioque populorum Atheniensum, Romanorum, Batavorum. Vergelijking der Gemeenebesten* door Hugo de Groot. Derde Boek: *Over de Zeden en den inborst der Atheniënseren, Romeinen en Hollanderen.* Uit een echt handschrift uitgegeven, in het Nederlands vertaald en met Aanmerkingen opgehelderd door Mr. Johan Meerman, Heer van Dalem en Vuren. Derde Deel. Haarlem 1802. Hoofddeel XXIII, pp. 18—19 (Latin text); pp. 27—28 (Translation), see also the elaborate notes by Meerman, pp. 228—238 with a translation of the poem *Iter currus veliferi.*

10) *Petri Gassendi Diniensis Opera. T.V. Miscellanea.* Lugduni, 1658, pag. 265 a.

a distance of fourteen hour-miles. Peiresc himself had also made a trip with it and "he later often mentioned the amazement that overtook him when moved by a very strong wind he did not feel it (since he moved as quickly as the wind) and when he observed that the gulls they encountered flew past, that they only touched the surface of the pools of water, that they seemed to see foot passengers who walked in front of the chariot move backwards, and things that seemed at a great distance were passed but a moment later".

4. In the text which accompanies the first edition of the drawing by De Gheyn (Fig. 2) an elaborate description of the trip to Petten is given, which, no doubt, was the source of the many stories current at a later date. We are told here that Count Frederik Hendrik of Nassau, the French ambassador de Busanval and the Admirant of Arragon, Franciscus de Mendoça (a prisoner from the battle of Nieuwpoort) were among the 28 persons accompanying Prince Maurice on his trip. There was a strong south-easterly wind. The Prince himself took the helm. The chariot gathered such speed that it seemed to fly rather than roll and disappeared from sight almost at the moment it was sighted. "At one moment, for fun and in order to play a trick on the gentlemen, his Excellency steered the chariot into the sea, which movement struck many with great fear; but as he moved the helm in good time the chariot struck the beach again and speeded along its former course." None of the sources mention when this trip took place, but it must have been between July 1, 1600 (the battle of Nieuwpoort) and May 29, 1602 (the extradition of the Admirant Mendoça).

5. There are several records of later trips undertaken, it seems on the occasion of the visit of eminent foreign visitors: thus on May 17, 1613 for the Palatine Elector [11]), in 1621 for the Venetian ambassador Trevisano [12]), in 1633 for the Queen-Dowager of France [13]). The last record of this kind relates to a demonstration at the marriage of the Princess Louise, daughter of the Stadtholder Willem V, to the Hereditary Prince of Brunswick in 1790. The chariot does not seem to have functioned properly on that occasion [14]).

6. The sailing chariot of Stevin is mentioned in many foreign publications of the seventeenth and eighteenth centuries. Beck [15]) cites Henrich Zeising's *Theatrum Machinarum* (1612-1614) and Bishop Wilkins' *Mathematical Magick* (1648); van Dokkum [16]) mentions Zeiler's *Topographia Germaniae Inferioris* (Frankfurt, 1659). It must have been well-known in Great Britain as is proved

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[11]) G. D. J. Schotel, *De winterkoning en zijn gezin.* Tiel, 1859, pag. 33.
It is typical of the repetition of details in the stories about the sailing chariot that we hear again of Prince Maurice steering the chariot into the sea. Or was this a standard trick of the prince?

[12]) The *Register van Ordonnantien* of the States General of 1615—1630, page 165 v. mentions a bill of 14 pounds 12 shillings of Gerrits Gerritsz, captain of the sailing chariots of Scheveningen "for fitting the two sailing chariots of Scheveningen according to the orders of their High Mightinesses to serve master Trevisano, ambassador of the Most Serene Republic of Venice and his company".

[13]) P. de la Serre, *Histoire de l'entrée de la Reyne Mère du Roy très-chrestien dans les Provinces Unies des Pays-Bas.* Londres 1639. Cited by Th. Morren. Dossier Simon Stevin. (Municipal Records of The Hague).

[14]) *Gedenkschriften van een voornaam Ned. beambte, medegedeeld door Mr. H. van A.,* page 167, cited by Th. Morren (see 13).

[15]) Th. Beck, *Beiträge zur Geschichte des Maschinenbaues.* Berlin 1899.

[16]) J. D. C. van Dokkum, *Een stukje voorgeschiedenis van het rijwiel,* De Navorscher. Vol. 55, 1905, pp. 81—95).

by the often-cited passage from the famous novel by Sterne, *Tristram Shandy,* in which [17]) uncle Toby mentions that Peirescius walked from Paris to Scheveningen and back to see it and discusses its invention by "Stevinus, the great mathematician and engineer" and the value of such inventions in general.

One of these records and the drawing by De Gheyn (fig. 2) inform us that there were two sailing chariots, the larger of which certainly undertook the trip to Petten. Meerman [9]) says that Prince Maurice is shown on the back bench of the smaller chariot, but we do not know on what grounds his conclusion is based. The reader will have to take it on trust that this vehicle actually moved for two hours at a speed of some 40 km/hour over the beach and that it responded so well to the helm that one could run it into the sea for a short moment and immediately afterwards make it continue its way along the beach again. At any rate there must have been a very strong wind and the undertaking seems to have been a very risky one!

In his dairy of a trip to Brabant and Liège in the year 1782 Martinus van Marum tells us that "in the afternoon of July 11,1782 (while staying at The Hague) we made a trip to Scheveningen, where the famous sailing chariot is kept, which Stevin invented in the days of Prince Maurice. With this chariot an unbelievably long distance was covered in a very short time. However one should ride the wind and not beat up against it."

In the nineteenth century both Meerman, the translator of Grotius' *Parallelon,* and the Rotterdam poet R. H. van Someren [18]) tried hard to find out what had happened to the sailing chariots. They agree that at least one was still to be seen at Scheveningen early in the nineteenth century. Meerman believed this to be the small one. He claims to have seen the chariot in the first house to the left in the Keizerstraat (Scheveningen) (coming from The Hague). In 1795 its price was said to have been *f* 180,—. It was made of plain, unpainted oak, 15 feet long and about 5-6 feet wide.

Van Someren believed it to be the larger one; his story is too curious not to reproduce it, it runs thus: "It is well known that two sailing chariots existed. The smaller one has been missing for a long time, but the larger one survived until 1811, when it was demolished by its owner, a poor fisherman or helmsman of a fishing smack, after the collapse of the shed in which it was stored. This fisherman had bought the chariot for a small sum at an official sale of public property during the French domination. He had bought it speculating on the return of the House of Orange, in which many steadfastly believed in those dark times, in order that he might return to them this memorable relic of Stevin's genius. Later, however, perhaps in days of great poverty, this man spoiled his chances by demolition; for when King William I landed again in Scheveningen in November 1813, one of his first inquiries was whether the chariot still existed. No wonder the King was so interested: all his ancestors had sailed in it and made ceremonial trips in it in honour of Prince Maurice and Stevin. Reliable old men (*e.g.* Mr. Baak of Scheveningen) asserted that they had often seen Prince William V and his court sailing in it and attaining an incredible speed (like that of the modern railways).

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[17]) *The works of Laurence Sterne.* I. *The Life and Opinions of Tristram Shandy. Gent.* Vol. I, London, 1798, pp. 203 ff.

[18]) Prudens van Duyse. *De Zeilwagen van Simon Stevin.* De Eendragt. Vol. I, 1846—1847, pp. 70 b—71 a.

The above-mentioned gentleman once even saw 28 persons take their places in it and travel, "driven by a strong south-westerly wind, nine miles in a straight line along the beach in less than two hours".

This shows us that "reliable old men" are not always trustworthy witnesses. Mr. Baak no doubt confused the memory of a story about Prince Maurice's trip with an event from his own youth.

Sailing chariots of this type are still in action on the Belgian beaches to-day. The above-mentioned data lead us to the conclusion that Stevin was not the inventor of the sailing chariot but must have picked up the idea from contemporary books discussing the Chinese sailing chariots (Fig. 3). Like the Hellenistic engineers in their day, Stevin may have constructed such chariots to satisfy a whim of Prince Maurice, but he was certainly not very proud of such a mechanical toy and never bothered to mention it in his books and notes.

CHAPTER II

CONTENTS AND HISTORY OF

THE PATENTS OF SIMON STEVIN

THE PATENTS OF SIMON STEVIN

I. *Patent granted by the States of Holland* (and West Friesland) *on February 17, 1584* (Copied from the Minutes of the States of Holland (Alg. R. A. No. 336).

Simon Stevin of Bruges applied for patents for three inventions:
1. to bring all sorts of ships across shallow waters;
2. to bring ships across dams;
3. to raise water by other means than those used so far (to drain polders, harbours, etc.).

The patent was granted, "it being forbidden to any person .... to use such instruments or means as are utilized by the applicant, without the latter's consent" under pain of seizure of the instruments and a fine of *f* 2,000,— (one half for the applicant, one quarter for the 'town officer' and one quarter for the commonweal). The provision was made that the applicant should reduce his invention to practice within one year.

We have no details of the first invention, but it should be considered in connection with the difficulties encountered by the Amsterdam shipping trade. The waterway from the harbour to the North Sea was via the Y, the Zuider Zee, and then through the Marsdiep or Vlie. Unfortunately, in the south-west corner of the Zuider Zee, shallows (the Pampus) had to be crossed to reach the Y. We may assume that Stevin proposed some means of lessening the draught of the laden ships as they traversed the Pampus, perhaps similar to those described by N. Tartaglia in his *Regola generale di solevare ogni fondata nave ed navilii con Ragione,* 1562. A better method was found a century later by Meeuwis Meindertsz Bakker, namely, the "ships' camels" 1).

The second invention related to some improved type of navigation weir or *overtoom. Overdraghs* and *overtooms* for towing a ship's cargo or the whole ship over a dam were well known in Holland, e.g. in 1317 2). Dijksterhuis 3) has suggested that for this purpose Stevin intended to use the "Almighty" which he described in his *Weeghdaet* (Work VIa, prop. X). The third invention may have been some form of drainage mill, a machine which was to occupy Stevin's attention for many years. Doorman 4) has suggested that it may have been a drainage mill working with a piston pump.

According to Stevin's son Hendrik (XVI B, *Boeck* XII, page 23), Stevin invented a piston pump, the piston being fixed at the lower end of a vertical rod,

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1) G. Doorman, *Patents for Inventions in The Netherlands during the 16th, 17th and 18th Centuries*, 1942, page 60.

2) H. G. Hamaker, *De rekeningen der Grafelijkheid van Holland onder het Henegouwsche Huis,* 1876, I, pages 53 and 60.

3) E. J. Dijksterhuis, *Simon Stevin,* 1943, page 190, note 3.

4) Doorman *l.c.*; page 168.

with suction and delivery chambers underneath. At the bottom of these chambers there were two lateral apertures, the one provided with a suction valve, the other with a delivery valve. Hendrik states that, in the times before this invention appeared, such pumps were often made with one foot valve only. The pump rod was outside the vertical ascension pipe; the piston entered this pipe at the bottom and was connected to the pump rod by means of a bent rod; moreover, the part of the ascension pipe above the pump part proper was narrowed down, because it was thought that this would make the pump work more easily, since less water thus pressed on the top of the piston. Stevin put an end to this misconception by his development of the science of hydrostatics, and moreover constructed a pump with lateral inlet and outlet, and without a valve in the piston.

It is possible, but not quite certain, that the invention described above was the subject matter of patent I.

It should be borne in mind that a good deal of what was known in antiquity had to be re-invented; this was probably the case with the double-acting plunger pump invented by Ctebisios, which was used in the first centuries A.D. (Forbes: *Bitumen and Petroleum,* Leyden 1936, page 97, Fig. 53, gives an illustration of this pump after a photograph from the British Museum).

II. *Patent granted by the States General on February 22, 1584.*

The full text of the patent is not to be found in the Acts of the States General, but the following extract from the Minutes (Alg. R.A. No. 11, Fol. 55) shows that the patent was granted for a drainage mill which was probably identical with the one mentioned in patent I, sub 3, and then granted for the province of Holland only, whereas this new patent covers the whole of the United Provinces:

"Petitioner Simon Stevin applies for a patent allowing him to have an instrument installed to withdraw water from land, with prohibition of others doing so, in accordance with the patent granted him by the States of Holland. The States General confirm the patent granted to petitioner by the States of Holland and agree to the letters patent being despatched."

III. *Patent granted by the States General on November 24, 1586.*

From the Resolutions of the States General, Vol. 13, Fol. 212 and 221 *verso,* we learn:

On the 24th of November, in compliance with Simon Stevin's request (the petition had been received on the 17th of November and referred to Vosbergen for advice), it was decided to grant him the patent, on condition of his applying instruments other than those in respect of which patents had previously been granted to others, and on the proviso that he should produce the *pourtraicture* (drawings) of his instruments, in order that such drawings could be attached to and sealed on the letter patent.

The drawings here mentioned must have been handed on the selfsame day, for the patent was granted that day, after the "project" had been appended to it. Stevin had applied for a thirty-year patent, but the term granted to him was twenty years only. Unfortunately the original patent and the drawing have been lost, but we have a copy of the text (Archives of the Rekenkamer of Holland No. 12, Fol. 51 white register with the red rose) which, however, does not mention any details, except that the patent was concerned with a type of drainage mill which was to have a "larger pumping capacity and would drain the land more quickly than those in common use at that moment."

IV. *Patent granted by the Earl of Leicester on February 23, 1588.*

On September 15, 1588, the *Rekenkamer* (Audit Office) of Holland registered both the patent granted to Stevin by the States General in 1586 (our Patent III) and one granted to him by the Earl of Leicester on February 23, 1588, dealing with the same subject as the former patent. This new patent of Stevin's "amplified" his former one — a patent-technical term which might refer to technical as well as legal amplifications of the original patent. It would seem that there Stevin added to the older patent certain inventions of his made between November 1586 and February 1588, probably when experimenting with the mill at the *Duyvelsgat* at Delft, which we shall refer to below.

This new drainage mill was to pump five times the amount of water pumped by the ordinary mill. Its special merits lay in the fact that the cogs of the brake wheel engaged the staves of the wallower throughout their length, and that one disc of the wallower was larger than the other (and hence the wallower was conical!). Then the older patent granted by the States General was amplified by a clause which forbade anyone to make a drainage mill with a scoop-wheel more than 50% larger than the largest built up to that date.

In his book (XVI B, *Boeck* X) Hendrik Stevin (Simon's son) makes mention of the fact that the patent granted by the States General related to a water wheel with only six blades (large, rectangular, 6 feet long and 3 feet wide), provided with leather strips sliding along floor and sides, so that — in spite of the slow speed of this wheel — no water could flow back.

In this connection he also mentions a notarial act (Notary Public P. Viruly, September 26, 1591) and a deed of the civic authorities of the City of Delft dated August 29, 1590, declaring that in 1588 Simon Stevin altered the drainage mills on *the Duyvelsgat op te Vesten teynde de Geerwech* according to his invention, and in 1590 also the mill on the *Vesten t eynde de nieuwe lange Dyc,* so that these mills "now make the water scour better and cause more agitation in it" (circulation in the canals). In his letter addressed to the civic authorities of the City of Delft (XVI B, *Boeck* X, page 30) Simon Stevin recommends the use of a wheel with 6 blades, 7 feet long and 16 feet wide, or wider still if the place or ditch permits. The wheel runs on a round floor, which has a diameter such that one blade is always within its circumference. It was to be driven by a horse. Apparently wheels of such great width had never been applied before, but just there they were preeminently suitable, since the difference in level was only very small.

These documents will be discussed in more detail in the introductory chapter to Stevin's essay *On Mills.* They are reproduced in Appendices I & II to the essay.

In order to apply this new invention Stevin entered into a contract on August 23, 1588, with his friend Johan Cornets de Groot, of Delft, who was to have an equal share in the rights and proceeds of the two patents. This deed of conveyance was registered at the *Rekenkamer* of Holland on the same date as the patent granted by the Earl of Leicester. Their full text was found in a file of

Stevin's documents composed by Mr. Morren and now in the archives of The Hague.

It would seem that Stevin and De Groot had already been building mills according to this new design, or rebuilding old ones, for some time past. On August 22, 1588, the city authorities of Delft agreed to pay De Groot and Stevin a fee of one hundred crowns for the "new work on the drainage mill at the Duyvelsgat (on the town wall at the end of the Geerweg)", on condition that they should, if required, also "install a new invention of the said Mr. Simon Stevin in the drainage mill on the town wall, at the end of the Langendijck" (a street in Delft). These two mills were meant to improve the circulation of the water in Delft's canals. On June 15, 1590, this sum was actually paid in cash, and therefore the condition must have been fulfilled by Stevin and De Groot (J. Soutendam, *Mededeelingen uit het archief van de stad Delft*. Delft, 1862, page 26).

In addition, the magistrates of Delft, at the request of Stevin, gave him a testimonial on August 29, 1590, confirming that the two mills mentioned, "rebuilt according to the art of the said Stevin, have scoured at least thrice as much water as the two former mills usually did". Stevin and De Groot also applied their inventions in the mills of Stolwijk and Cralingen, as is proved by the testimonials which we have appended to the essay on drainage mills (see page 391).

The Resolutions of the States of Holland of January 18, 1590 show that Stevin had lodged a complaint of infringement of his patent of 1586 by Cornelis Dircxz Muys, to whom several patents — *inter alia* for the invention of what is known as the Amsterdam mud mill — had been granted in this period. Stevin's patent in the case is said to be for an invention *van vertragende proportie der gaende werken* (reduction gearing), which reminds us of Patent V, point 8. However, the date of Stevin's patent is clearly stated to be 1586, so that it must be patent III, in which we seek in vain for an improved gearing, although some invention of gear wheels was added to the version of 1588 (Patent IV). Muys obtained the appointment of a committee of four authorities to investigate Stevin's complaint. As no further documents on the matter are known we have to assume that a happy solution was reached, or that Stevin's complaint was found to be invalid.

V. *Patent granted by the States General on November 28, 1589.*

This last patent granted to Stevin covers no fewer than nine inventions.

Until lately we had only the rather vague text of the patent itself, but Doorman recently discovered a file entitled *Verscheyden Inventien van Simon Stevin* in the States Archives (*Alg. Rijksarchief, Staten Generaal, Loketkas Vlaanderen No. 29)*, which contained Stevin's explanations of his patent, together with original drawings, which we shall translate here to elucidate his nine inventions:

1. A series of two, three or four drainage mills working in tandem, each mill raising the water stepwise to a higher level, which is the low-water level of the next mill in the series (*molengang*). The mills are also able to work independently if necessary. Stevin may have been the pioneer propagator of this popular tandem arrangement and he described a very practical and simple installation of this type. Leeghwater used the tandem arrangement for the first time in 1609, maybe because Stevin's patent expired in that year (Fig. 4).

This is Stevin's explanation:
"Given several mills, each working separately: how to set about making them pump in tandem in series of two or three.
Given a polder with several drainage mills, their watercourses can be arranged in such a way that, by opening or closing a gate, they will work in tandem or each separately, as desired, in proportion to the strength of the wind and the level of the water (in the polder). In order to explain this, let *AB* (Fig. 5) be the *boezem* (reservoir), and the circles *C, D* two mills or sites of mills on the dike encircling the polder, which pump into the *boezem AB*. And from mill *D* to mill *C* there is a ditch, in which there is a gate like the watergate of a drainage mill but wider, which I indicate by line *E*, which door can close against point *F*. Furthermore the encircling dike is cut at *G*, in which cut there is also a gate, *H*, which can close against point *J*. Such a door is also to be found at *K*, which closes against point *L*. The dotted areas indicate water. With the help of these three gates the mills *C* and *D* can be made to pump without difficulty and immediately, separately or, if desired, in tandem, as required. For if the mills are to work in tandem, the gate *E* will be opened and kept open by means of an iron hook. But if it be desired that each pumps separately one has but to undo this hook, leaving other things alone, and what one desires will come to pass thus: if gate *E* is open and is kept open by means of an iron hook, the water flows from the *boezem AB* and, wanting to enter the hole *G* and the polder, it closes gate *H*, since it is higher than the inner water. The gate *K* also closes itself, since the water which mill *D* pumps into the ditch between the two mills is higher than the water in the polder. In such a way mill *D* supplies the water to mill *C*, that is they pump in tandem and raise the water to double the height. But if the iron hook at gate *E* is unfastened, each mill will pump separately: for mill *D*, pumping its water to the level of the outer water, will close gate *E*, because the water level on the other side is lower. Therefore, gate *E* being shut, the two other doors *H* and *K* open of themselves, that is, gate *H* because of mill *D* and gate *K* because of mill *C*, and hence each mill pumps separately. The example described above has been taken for two mills to be built on the dike encircling the polder, from which example it is sufficiently clear how to proceed in other situations, for if they stood one behind the other, as is often required by the lay of the land and the ditches, what has been said above can also be effected as shown in Fig. 6, where one mill is behind the other, for which case the above explanation also holds good. It is also clear from what we have proved in the case of two mills how three or more mills can be made to pump in tandem, for when a mill is placed with its gates behind mill *D*, in the way *D* is placed behind *C*, one has a third mill in the series, etc.
It should also be realized that the mill *C* needs longer scoops than *D*, for if the scoops of the two mills are immersed to the same depth when working separately, the scoop-wheel shaft of *C* must be higher than that of *D* when they work in tandem. The gates should open on the side indicated in the drawing, so that they may be closed by the pressure of the high water level."

2. Drainage mills of a type which not only can drain a polder but will also permit water being introduced into such drainage units in dry periods.
This is Stevin's explanation:
"How drainage mills which pump the water from the polders can be made to pump the water back again if the outer water level is lower.

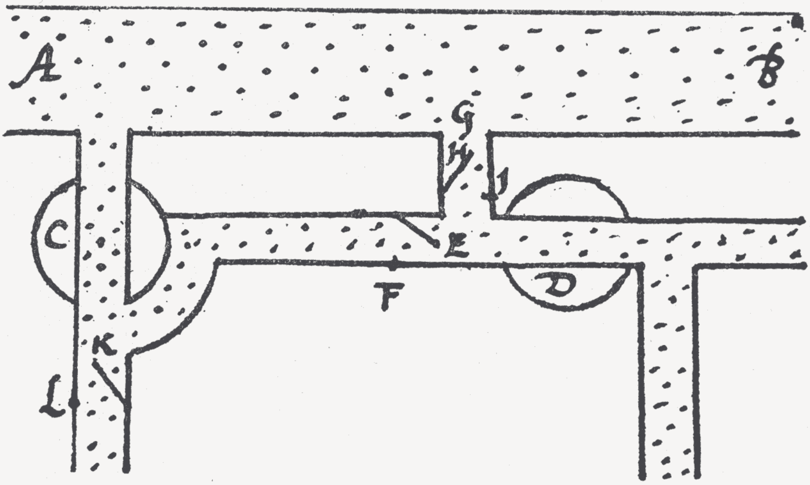

Fig. 5

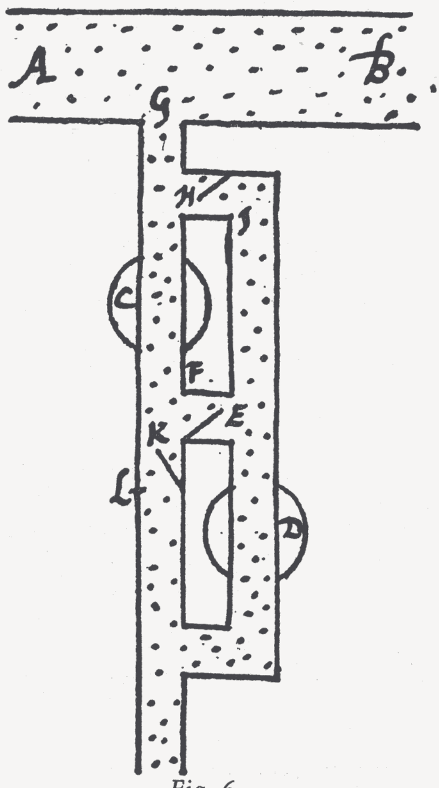

Fig. 6

It happens in certain parts during dry seasons, that the outer water table is lower than the inner water, in such a way that the meadows grow far too dry and the cattle cannot obtain water to drink. The means of pumping such outer water back into the polders with the same mills is this: let the outer water, mill site, etc., be drawn as below (Fig. 7) as usual, but the mill ditch with two bends as at *A* and *B*. Furthermore *C* in the watercourse indicates a gate like a wide sluice gate, opening towards the mill and closing at point *D*. And *E* is a similar gate behind the watercourse, opening from the mill towards the inner water and closing against point *F*. Also, through the ends of the quays of the mill site which protect the inner water against outer water two tubes should be built, *G* and *H*, each with a small gate as commonly used in several places where it is desired to let in the outer water, through such tubes, into the polder. This being arranged, and the mill working, the outer water will be pumped back into the polder, as we shall prove thus: when the scoop wheel turns the gate *C* will close of itself, because the water between the scoop wheel and the gate is higher than the outer water, and gate *E* also closes of itself, as the water between the scoop-wheel and the gate *E* is outer water, entering through tube *G*, and being lower than the inner water on the other side of the gate. In such a way all the water the mill pumps passes through tube *G*, then through the mill ditch *J*, then to the back of the watercourse, through it, through tube *H* and through the mill ditch *K*, and thus into the polder. It should also be noted that if the water is pumped the other way, out of the polder, the gates *C* and *E* should each be kept open with an iron hook, or these gates might be lifted from their hinges and stored in the mill until they are required again. As regards the tubes *G* and *H*, these, when not needed, can be filled with earth or clay against leakage, as is usual with other tubes in different polders".

3. A system of pumps such as "had been used recently to drain the Rapenburg at Leyden". Six men working in turns are said to do twice the work of three horses, hence "each man performs as much work as would one horse". One of the features of these pumps seems to have been "movable packing on the rim of the plungers" and the "possibility of coupling as many pumps as needed".

Stevin's comments are as follows:

"Explanation of the ditch-bailers [1]) with which the water of the Rapenburg at Leyden was drained lately in the month of May.

The instrument is shaped as shown below (Fig. 8), where *A* and *B* are two square tubes, inner width one foot. In these square tubes two pistons go up and down over a length of 5½ feet; their size, like that of the tubes, is one foot. On the rims of these pistons wooden laths are fixed with greased leather, in such a way that the pistons can move up and down, and when rising brush the sides of the tube as tightly as the pressure of the water above them effects, but without jamming. *C* indicates an iron-wire grid through which the water enters, but which keeps out timber, stones, etc., which might hinder the piston or lower valve. The two aforesaid pistons are raised by winding at *D*, to and fro with the two cranks *E* and *F*, in such a way that one rope over the pully *G* is wound on one side of the shaft and the other over the pully *H* on the other side, so that as one piston is raised the other falls, and one piston is always working. The above-mentioned

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[1]) Stevin here calls his pumps "ditch-bailers" (*slootoosers*). See also Inventions Nos. 6 and 9.

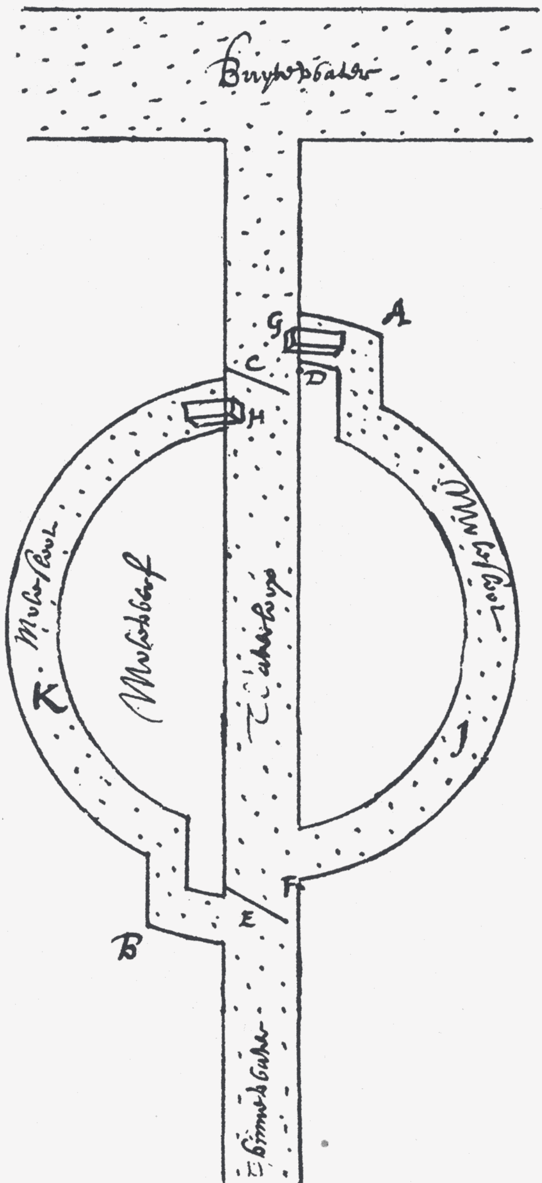

Fig. 7

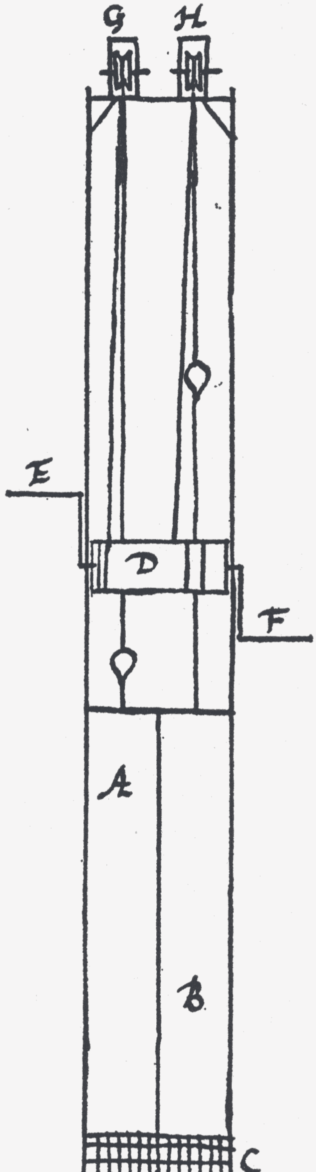

Fig. 8

tube *D* is fixed to an iron shaft through its centre, from which shaft it can be removed, and thicker or thinner tubes can be fixed to the shaft according to the level of the water which has to be raised and the number of men put to work, *i.e.* when one begins to draw, a thicker tube, and as the water falls a narrower and narrower one. In the afore-mentioned draining of the Rapenburg the first tube was 10 inches wide and after the water had fallen one foot, a tube of 7 inches was used, and then after a fall of another foot a tube of 5 inches, then one of three inches."

The pumps which Stevin describes here are of a very primitive type. The flaps fixed by means of greased leather to the four sides of the square pistons moving up and down the pump cylinder (which has a square section) are intended to play the part of valves and packing. As the piston moves down, the water rises between the cylinder wall and the piston-rim. When the piston rises the weight of the water is supposed to press the flaps against the walls of the cylinder, and thus the water prevents its own escape back to the space below the piston whence it came. If a hole is made in the wall of the cylinder the water can be made to flow away sideways into a drain pipe.

According to Invention 6 the same type of apparatus can be used for removing mud. In that case two such "ditchbailers" can be fixed to a scow; the mud barges and the scow can then be slowly moved forward in the channel to be dredged by means of two winches, as indicated by Stevin and as still used by dredgers.

In Invention 9 the piston rods of the pumps are provided with cogs. The rods are raised and released by means of what Stevin calls "half-cogwheels", *i.e.*, cog-wheels which have cogs on one half of their circumference only and thus release the piston rod after half a revolution. These cogwheels are fixed on the scoop-wheel shaft of a windmill or on the shaft of a horse mill.

Stevin claims that this simple dredging apparatus was used with success in the Rapenburg, one of the main canals of the town of Leyden.

4. The use of a large dredge net "twice as large as used before", which could be opened at the bottom and which was drawn athwartships along the bed of the canal or river by means of two ropes. One rope was manipulated by a man on the port side; the other rope ran underneath the bottom of the vessel, *via* a number of adjustable pulley blocks, to starboard, where it was wound in by a second man by means of a tackle.

This is further explained in this way:

"Explanation of a method of drawing clay, sand and similar solid materials in great quantities and economically from harbours and the bottom of water-courses. *A* (Fig. 9) represents a large net, holding more clay than 25 of the common dredging nets, and having two semicircular iron rings at its bottom, which open and close on two hinges at *B* and *C* and close in the middle by means of a lock. This net is drawn full of clay by means of the winch *D* and a rope running from this winch *via* the pulley *E* and thence to the pulley *F* and the net. Pulley *F* is fixed on a stick which can be raised and lowered in order to let the rope *FA* come as near the ground as desired when dredging. When the net is full of clay the crank is pulled from the winch *D* and put on the winch G, from which winch a rope leads *via* pulley *H* and the net, and the net is raised by means of this until it is over the rim of the barge one wants to fill, which is anchored alongside the scow in such a way that its centre is at the end of the scow at *J*. The net being thus suspended above the barge, a stick is pushed into a round eye *K,* thus opening

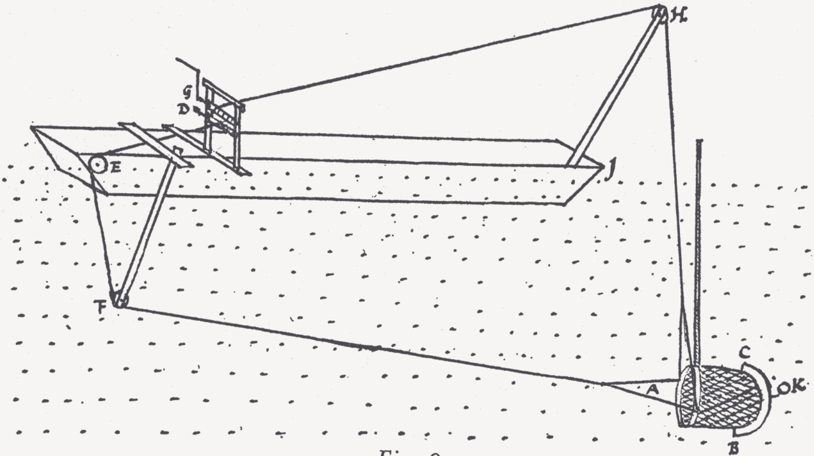

Fig. 9

the lock, and by the weight of the clay the two semi-circles *B* and *C* separate and the clay falls into the barge.

Note also that if such an instrument be used the winches *D* and *G* will be moved by "Almighties", as described in the 10th proposition of the *Weeghdaet,* which "Almighties" for brevity's sake have not been shown here. It should also be noted that a similar net and winches will be placed at the other end of the scow, on the one hand in order that the scow shall not be overturned or dip too much if a large net comes out of the water with its load, for if there be such a net on each side of the scow, it will remain in equilibrium; on the other hand, one can then fill two clay barges at a time from one scow."

Such an apparatus is also illustrated by Hendrik Stevin (Work XVI B, *Boeck* XI, page 64); it was a large float or scow no more than one foot above the water level. It was used to deepen the harbour of Dantzig. In the same book proposals made by Stevin for its use at Elbing, Braunsberg, and Calais (*Cales*) are also mentioned. This entire subject is discussed in detail on page 79.

5. Discharging sludge (obtained in dredging) from a mud barge by means of flaps in the bottom of the barge.

"How the ships loaded with sand and clay, which have to be discharged into the water, can be discharged easily. Because much time and labour are wasted in throwing the drawn-up clay or sand overboard with spades in the usual way, which means great expense to the towns where the harbours are to be dredged, the way in which such ships can be easily unloaded is this: it is to be noted that the central part of the ship which contains the clay is separated from the two end-compartments, in such a way that these two compartments remain dry and empty. The bottom of the central part shall be broken open and provided with a bottom like a trapdoor or flap, hanging on one side on two strong hinges; the other end should be held up by two ropes on a winch or shaft, and being wound up, should be fastened with a falling iron latch, in the same way as the sluice gates are lifted in Delft and other places and are kept in position by a falling latch. Now, as the bottom of the central part of the ship will be built lower than the level of the water in which the ship lies, the water will run through the cracks in the flap, but because the water has to make way for the clay as this enters, it will run out through the cracks, and one might also drill holes in the sides of the ship to this end. The water entering the ship does not make it sink, the ship is being kept floating by her two closed end-compartments, like a watership [1]). The ship being full of clay or sand, and having been brought to the place where one wishes to discharge the latter into the water, one has but to raise the latch and the flap will open because of the great weight of the clay, and the clay will fall at once to the bottom of the water. The flap then being drawn up again and closed with the latch the ship will be ready for another refill. Hence the discharging of this ship will not demand more labour than is required in sailing to and fro, for the release of the latch can hardly be said to demand time or labour".

A similar type of ship was widely used in the nineteenth century, but it had hinged sidewalls. It was patented by S. T. Kater Czn. in 1830 (compare the drawing in Doorman's *Het Nederlands Octrooiwezen,* page 173).

6. Raising sludge obtained in dredging by means of tubes, the mechanism for which is driven by men or animals.

"How mud, peat, and similar fluid material is to be dredged from harbours and bottoms of watercourses with great profit. Let rectangle *A* (Fig. 10) be a scow and the square areas *B* and *C* the sites of two dredging devices, such as the "ditch bailer" which we have just described, but having their ironwire grid through which the mud enters not on their sides but straight below. In front of these two dredging devices two barges *D* and *E* will be placed, one to be filled by each pump, which is to be effected by turning the winches now one way, now the other, as in the draining of the Rapenburg discussed before. But if the scow always stayed in one spot while dredging was being carried out, water would follow the mud and therefore the scow has to move on a little, which may be effected by means of two winches *F* and *G,* for while *F* is wound, *G* will unwind, and the ships will be drawn to the side of *F.* And while *G* is wound, *F* will unwind, and the ships will be drawn towards *G.* It should also be noted that the dredging devices *B* and *C* can each be raised and lowered with winches, according to need or changes in the situation such as rise and fall of the tide, depth of the mud, and the like.
What has here been described as performed by human labour can also be performed with horses which, going in treadmills, will effect what has been explained above."

7. Discharging this fluid sludge by means of the flaps in the bottom of a mud barge or pumping it through pipes on to the land.

"How to unload easily ships filled with mud and similar floating material, which has to be discharged into the water or on the land. Thin fluid mud which has to be discharged into the water, cannot be dropped as easily by the method of discharging clay described before because the mud will escape through the cracks in the trapdoor and the holes in the side of the ship and sink into the water. It should be done in this way: if the bottom of the central compartment of the mud barge is not as high as the water, or not half an inch higher (*i.e.,* when the barge is empty) than the water in which the barge floats (some bottoms are that high, but others lower), another bottom should be laid half an inch or less above the water level (the barge being empty). This being so, one should make a hole in this bottom some

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[1]) "Waterships" were used to provide the breweries in the towns with fresh water from elsewhere, after the water in the canals of the town had become unsuitable.

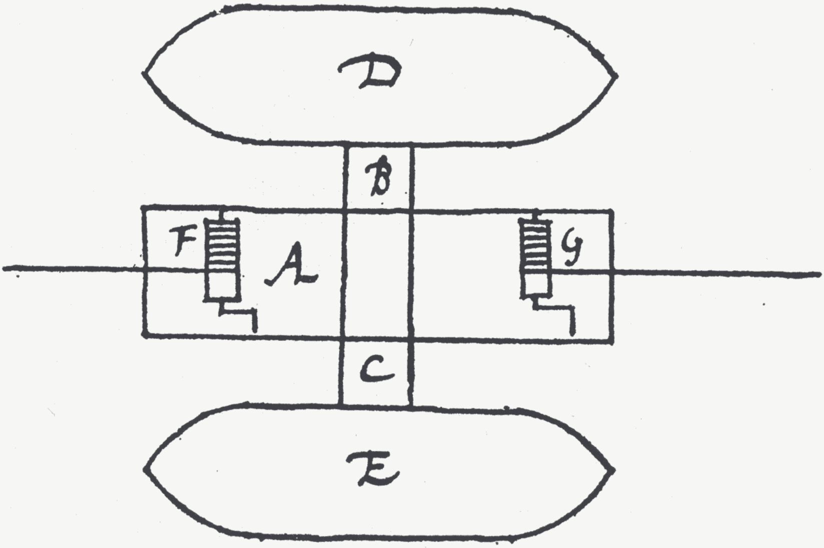

Fig. 10

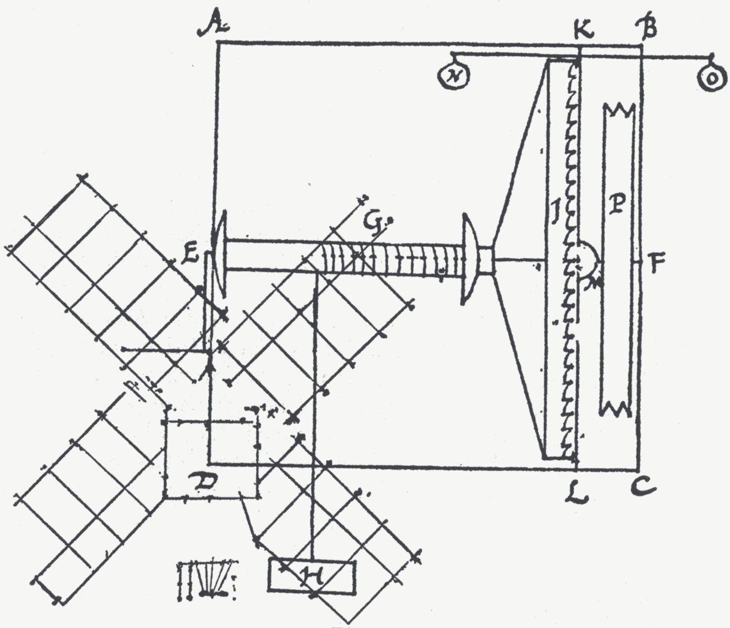

Fig. 11

two feet wide, into which fits a trapdoor. This barge being full of mud the trapdoor will be closed (although the ship sinks deep into the water) by the pressure of the mud over it, because the sludge is heavier than water. The barge having arrived at the site for discharging, this trapdoor will be opened by drawing a rope and all the mud will fall into the water through it. But if the mud has to be discharged onto the land, it should be drawn up by a dredging device (*Slijcktrecker*) as described before, which discharges into a channel leading to the spot indicated. This mud dredger or mud pump should be placed on another ship, together with a winch, by which it can be drawn up and down over some two feet in order that the mud barge can sail under it. One might also fit out the mud barge itself with a small mud pump (if need be), to discharge it."

It will be seen that Stevin is trying to cope with the problem of transporting mud in liquid form in his Inventions 6 and 7. He wants to use his "ditch-bailer" in order to discharge the mud into a drain leading to the land on which it is to be dumped. Hence, these inventions contain the germs of the suction dredger, which could only become a success when a good centrifugal pump was available.

8. A roasting spit turned for three hours by means of a mechanism with a balance or balance-wheel, and moved by a weight falling slowly. A similar mechanism could also "drive clockwork for twelve hours or rock a cradle for half an hour or more". Stevin gives the following details in Va:

"Explanation of the mechanism of the roasting-jack, which has only one wheel but works for three hours without being wound, also serving for a clockwork running for twelve hours without winding; thirdly, for a cradle-rocking mechanism running for half an hour without winding. *ABCD* (Fig. 11) is a square iron frame, about one foot long and wide, in which is the shaft *EF* with an iron cylinder *G,* on which the counterweight *H* is wound. On this shaft there is a cogwheel *J,* which moves the balance *KL,* the shaft of which has a hole at *M* through which the shaft passes, *N* and *O* represent the lead weights of the balance. *P* is a wooden disc in which several grooves have been cut, as many as the number of spits one wishes to turn, for instance two or three, for in these grooves cords have to hang, at the lower end of which the spits should be placed, each with its disc. This iron frame with its contents is placed on a wooden foot about 4½ feet high. This roasting-jack indicates the hours when no roasting takes place, by the falling weight *H,* as the hours are indicated on one of the stiles of the wooden foot. But if one wants to rock with it, the lead weights *N* and *O* are removed and in those places two thin cords are attached, running over two fixed pulleys to the cradle, and the balance moving to and fro will also rock the cradle."

This type of mechanism was very popular in Stevin's day. Montaigne tells us in his *Journal de Voyage* (Paris, 1774) that he saw one at Brixen in 1580.
Generally such mechanisms were not driven by clockwork but took the form of a fan, the blades of which were moved by the hot air rising in the chimney of a fire-place. Such a hot-air turbine in its turn moved gears which turned a spit on which meat was roasted. Early designs are found in the notebooks of Leonardo da Vinci (A) and Sangallo (B), and in a German cookery book of 1507 (C). The

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A) Cod. Atl. fol. 51 *verso a.*
B) Sangallo, *Quaderno Senese* (*Codice Magliabechiano*).
C) *Küchenmaistrey* (Augsburg, 1507).
D) J. Cardan, *De Varietate Rerum* (Basel, 1557).
E) G. Branca, *Le Machine* (1629).

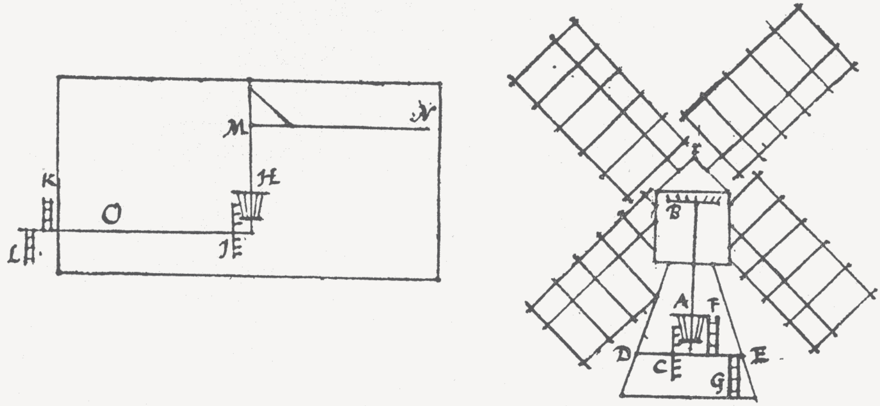

Fig. 12

mechanism became known as the "chimney wheel", "draught mill", and "smoke jack" and is illustrated by Cardan (D), Zonca (1607), and Branca (E). The latter even wanted to make it drive a roller mill for iron bars. The only important point in this eighth invention is the clause stipulating that the inventor "will mark the iron parts of this apparatus with his common trade-mark, called the *clootcrans,* which is the first figure belonging to the nineteenth proposition of the First Book of the *Art of Weighing*". This shows that Stevin considered the figure, which he also used as the vignette of the *Art of Weighing* and which occurs in many of his works, as his special trade-mark.

9. Drainage mills with pumps capable of moving a large volume of water, such as were used in the Rapenburg at Leyden. Stevin gave the following details of this invention:

"Invention of mills for pumping water by means of such tubes with pistons as described in the third invention, with which the Rapenburg was drained.
In this mill (Fig. 12) let *A* be the crown wheel, and *B* the wallower, but *C* the pit wheel through which passes the shaft *DE* and attached to it two half-cogwheels *F* and *G,* one on this side, one on the other. Then the rods which raise the pistons in their tubes should have cogs in the manner of the toothed rack of a hanger. With these cogs the two half-cogwheels should engage in such a way that, as one piston descends, the other rises. These pistons should move slowly up and down and should be very large, there should also be four pistons together, so that now two, now four, can be used as desired according to the wind and the actual water level.

This method of working can also be arranged for horse traction, as the other figure indicates, where *H* is the disc wheel and *J* the cogwheel, *K* and *L* the half-cogwheels, *M, N* the pole revolved by the horse, which horse will cross over the shaft *O* as in any other horse mill".

Here we have the complete mechanism of Stevin's mud pumps, on which we commented in describing his third invention (V.3).

Note the conical crown wheel in Stevin's drawing. We do not know whether such conical lantern-wheels were ever built as early as 1600, but it is very doubtful,

APPENDIX TO CHAPTER II

The original text of Stevin's patents

I. *Octrooi verleend door de Staten van Holland op 17 Februari 1584.*
Afschrift uit de Minuten-Resolutiën der Staten van Holland (Alg. R.A. Nr. 336):

„Octroy voor Simon Stevin om nieuwe inventien"

„Opt versouck van Simon Stevin van Brugge versouckende Octroy voor twintich jaeren omme te mogen practiseren drie inventien, d'eerste omme over d'ondiepe waeteren allerhande schepen te brengen, de tweede omme de selve schepen over dammen te voeren ende de derde omme het water te verheffen ende op te trecken deur andere middelen als nu ter tijt gebruijckt worden, dienende niet alleene omme de wateren uut den platten Lande te trecken, maer oock als het water buyten dijcx hoger is dan binnen 't selffde niettemin in grooter quantiteijt te doen loosen, jae oock omme in corter tijt de geheele Haven drooge te maecken ende anders, is geappostilleert de Staten van Hollant hebben omme redenen in desen geroert gegunt ende geoctroyeert, gunnen enden octroyeren bij deze dat de supplt alhier binnen den Lande van Hollant sal mogen practiseren ende gebruijcken sijne inventie, cunste ende instrumente tot de welcken in dese geroert voor dengeenen die met den supplt. diesaengaende sullen begeeren te handelen ende 't accorderen tot dienste vanden Lande, sonder dat ijemant binnen voorsz. Lande alsulcke instrumenten ofte middelen als hij suppt. daer toe gebruyckende is, sal moghen te wercke stellen, buijten des suppts wille ende consent, binnen den tijt van vijfftien jaeren eerstcomende, opte verbeurte vande selve instrumenten ende de peyne van twee duysent guldens, 't appliceren d'eene helft tenbehouve vanden supplt, ende de ander helft voorden Officier van der plaetse voor d'eene helft ende d'ander helft tot behouff vande gemeene saecke, mits dat den supplt sijne voorn. inventie ende cunste binnen s jaers int werck stellen sall."

II. *Octrooi verleend door de Staten-Generaal op 22 Februari 1584.*

In de Minuten-Resolutiën (Alg. R.A. Nr. 11 fol. 55) is er het volgende van te lezen:

„Reqte Simon Stevin versoeckende octroy om te moghen doen oprichten zeker instrument om water uuten Lant te malen met inhibitie van dat nymant anders sulx soude moghen doen, conforme d'octroy bij de Staten van Hollant hemb ghegunt."

„De Generale Staten conformeren sich metten octroy vande Staten van Hollant den supplt. ghegunt, accorderende tot dy ende de brieven ghedepescheert mogen werden."

III. *Octrooi verleend door de Staten-Generaal op 24 November 1586.*

De Minuten-Resolutiën dier Staten vermelden ervan in Deel Nr. 13 fol. 212, 17 November 1586:

„Opde requeste van Simon Stevin is geco(mm)itt(ee)rt dheere Vosbergen om metten suppl. te co(mmun)iceren opde vonden inden requeste geruert."

En in Deel Nr. 13 fol. 221v, 24 November 1586:

„Opde requeste van Simon van Stevin is geapp(ostilleer)t dat den supp(lian)t wordt geaccordeert het versocht octroy, behoudelycke dat hij sal wercken met andere nyeuwe instrumenten dat dan daervan hiervoorn aen anderen octroyen zijn verleent ende sal alhier exhiberen de pourtraicture van zijn instrumenten om door het octroy getransfixeert te worden ende dat voir den tijt van twintich jaeren."

Uit het Register Nr. 12 (met de rode Roos) der Rekenkamer van Holland, fol. 51 valt af te leiden, dat de tekening nog diezelfde 24 November is ingediend, want het octrooi werd dien dag verleend na aanhechting (transfixering) van het „project". Helaas zijn geen copiën van Stevin's tekeningen bij de octrooien bewaard. De text van het octrooi blijkt uit het onderstaand afschrift uit het Register der Rekenkamer:

„Octroy om enige nieuwe waetermolen te mogen maeken, voor Symon Stevijn."

„Die Staeten Generael der geunieerde Nederlantsche Provintien, allen dengheenen die dese letteren sullen sien oft hooren lesen saluijt, wij hebben ontfangen die supplicatie aan ons gepresenteert ende overgegeven bij Symon Stevijn inhoudende dat hij van wille was stracx te maecken eenen watermolen door welcken t water in meerder menichte ende op corter tijt uytet landt gemalen zal mogen worden dan door degheene diemen alsnu gebruyct. Ende nadyen sulcx tot slants dienste ende tsijnen laste geschieden zal soe heeft die voorgeschreven suppliant versocht dat wij hem souden gunnen octroy dat nyemant binnen dartich jaren naestcomende zijne inventie in sulcx sal mogen naemacken noch gebruycken sonder sijn toelaten oft bevel opte verbeurte van tzelve werck ende daerenboven van duysent guldens, d'eene helft ten behoeve van de gemeene saecken ende den officier van der plaetsen daer de contreventie bevonden zal worden ende d'ander helft ten behoeve van de suppliant ende hem daerop te doen depescheeren onze behoorlijcke brieven van octroy daertoe dienende. Waerom zoe eest dat wij de voors. zaecke overgemerct genegen wesende ter beede des suppliants wij den voorgeschreven Symon Stevijn gegunt, toegelaten ende geoctroyeert hebben, gunnen, laten toe ende octroyeren mitsdezen dat hij voor de tijt van twintich jaren naestcomende zijne voorgeschreven inventie ende wercken op den voet van het project door dese getransfixeert in de geunieerde landen sal mogen te wercke stellen ende gebruycken (zoe verre hier voorens aen andere om gelijcke wercken met gelijcke instrumenten te maecken geen octroy verlient ende gegeven is, twelck wij mits desen nyet en verstaen te derogeren ende prejudicieren) sonder dat yemanden van wat qualityet oft conditie hij zij zal geoorloft oft toegelaten zijn gelijcke inventie ende wercken nae te maecken ofte gebruycken gedurende den voors. tijt van twintich jaeren dan bij consent van den voorschreven Stevijn opde verbeurte van tselve werck ende van duysent guldens d'eene helft ten behoeve van de gemeene saecke ende dander helft tot behoeff van den suppliant."

„Ontbieden daeromme ende bevelen allen officieren, justicieren, magistraten ende ingesetenen deser vereenichde provintien die dit eenichsints sal mogen aengaen den voorschreven Simon Stevyn van dezen onsen jegenwoordigen consente ende octroy, rustelijck, vredelijck ende volcomelijck voor den tijt voor geruert te doen ende laten genyeten ende gebruycken sonder hem te doen ofte laten geschieden eenich hinder oft belett ter contrarien in eeniger manieren, want wij tot meesten dienst van den landen sulcx hebben bevonden te behooren."

„Des toorconden hebben wij onsen zegel hier aen doen hangen ende bij onsen griffier doen onderteyckenen. Gegeven in de vergaderinge van den voors. Staten-Generael in 's-Gravenhaghe den vierentwintichsten Novembris anno XVc zes en tachtich, geparapheert Wijnbergen."

„Vt op ploye stondt aldus: Ter ordonnatie van de voornoemde Staten-Generael ende was onderteyckent Aerssens ende begesegelt met een groot segel van rooden wasse vuythangende in dubbelen steerte. Naer dat dese opene brieven van octroye ten burele van der Camere van de Reeckeninge in Hollant zijn gepresenteert geweest, soe zijn dzelve aldaer ter ordonnatie van de luyden derzelver reeckeninge geregistreert int witte register met die roode roose fol. LI. Acten ten Burele voors. desen XVen Septembris anno XVc acht ende tachtich. Mij jegenwoordich ende was onderteyckent C. van der Goes."

IV. *Octrooi verleend door Graaf Leycester op 23 Februari 1588.*

Afschrift uit voornoemd register der Rekenkamer van Holland:

„Octroy dat nyemant die molens inden voorsz. octroye" (dat is bovenstaand octrooi III) „verhaelt, zal mogen binnen xviii jaeren naemaecken, om denselven Stevyn".

„Robert, grave van Leycester, baenderheere van Denbich etc., lieutenant van Haere Majesteit van Engelant, gouverneur ende capiteyn generael van de Vereenichde Nederlantsche Provintien, Allen den gheenen die desen gethoont sullen worden saluyt, doen te weeten dat wij ontfanghen hebben de supplicatie van Simon Stevyn inhoudende, onder andere, dat hij door sijne pracktique middel gevonden heeft om met eenen molen die hij naer zijn inventie sal weeten te maeken soo veel waters vuytet landt te malen als vijff watermolens die gemaect zijn naede maniere diemen tot nochtoe gemaeckt heeft. Ende want tzelve strecken soude tot groot voordeel, geryff ende dienste vande lande soe heeft hij suppliant oetmoedelijck versocht hem hier van gedepescheert te werden onse opene brieven van octroy, teneynde hij suppliant bij anderen nyet gefrustreert en werde vande vruchten van zijn inventie, costen ende moyten bij hem ter oorsaecke vandien gesupporteert. Waerom zoe eest dat wij de saecke voorschreven overgemerct ende hyer op gehadt t advys van de luyden van de Reeckeninghe in Hollandt mitsgaders van de Bailliu van Rijnlandt, hebben bij advys ende deliberatie van de Raede van Staete neffen ons wesende, den suppliant geoctroyeert, geaccordeert ende geconsenteert, octroyeren, accorderen ende consenteren bij desen dat nyemant wye hij sij de voors. inventie welcke es van cammen die met haer gantsche breede tseffens de staven geraecken wyens schijffloops d'ene schijf grooter es als d'ander met de reste in zijn suppliants propositien hieraen gehecht breeder verclaert en sal mogen maecken noch gebruycken, sonder des suppliants will ofte toelaten, ende dit voor den tijt van achthyien jaeren beginnende van huyden date deser, ende dit opde verbeurte vant zelve werck ende van duysent gulden, tappliceren deene helft ten behouve van de gemeene saecke ende dander helft ten behouve van de suppliant. Amplierende voorts des suppliants voorgaende octroy bij de Heeren Staten Generael van de geunieerde provintien verleent. Verbieden ende interdiceren expresselijck eenen yegelijken wye hij sij geen schepradt aen heurlieder watermoelens te maecken excederende de helft van de grootste schepraden diemen tot nu gemaect heeft, sulx dat men de schepraden niet meer als de helft grooter en sal mogen maecken dan die grootste die tot nu gemaect zijn als vooren, opdat den suppliant nyet gefrusteert en werde van t'effect van zijn voorgaende octroy. Mits dat hij gehouden werdt in erkentenisse van desen te betalen jaerlicx tot proufytte van de Graeffelicheyt van Hollandt drie ponden te xl grooten, ende dat hij desen mitsgaders zijn voorgaende octroy sal presenteren ten burele van de Reeckencamer in Hollandt omme aldaer geinterineert ende geregistreert te worden, naer behooren op pene van te verlyesen t'effect vandyen. Want wij tzelve bevonden hebben te behooren. Gegeven in 's-Gravenhage den XXIIIen February XVc acht ende tachtich, geparapheert . . . . ."

„Op de plycke stont aldus: Bij mijnen genadighen Heere den grave ende was onderteyckent Gilpin ende was besegelt met een segel van rooden wasse vuythangende in dubbelen steerte ende daerenboven gecachetteert met het cachet van Zijne Excellentie. Naer dat dese opene brieve van octroye ten burele van der Camere van der Reeckeninge in Hollandt zijn gevisiteert geweest, soe zijn dzelve aldaer ter ordonnantie van de luyden ter voors. reeckeninge geregistreert int Witte Register met die Roode Roose fol. LI verso. Actum ten burele voors. desen XVen Septembris anno XVc acht ende tachtich. Mij jegenwoordich ende was onderteyckent C. van der Goes."

De octrooien III en IV zijn in mede-eigendom overgedragen aan Mr. Johan de Groot (vader van Hugo de Groot), een vriend van Stevin, later burgemeester van Delft. De acte is eveneens ter aangegeven plaats bij de Rekenkamer ingeschreven en wel als volgt:

„Accord tussen den voorsz. Stevyn ende eenen Mr. Johan de Groot gemaeckt bero(erende) de voorsz. twee octroyen."

„Op huyden den XXIIIen Augusty anno XVc acht ende tachtich compareerde inde secretarie der stadt Delft Simon Stevyn verclaerende ende bekennende dat hoewel ende nyettegenstaende twee distincte brieven van octroy, deen bij hem geimpetreert van mijnen heeren den Staten Generael der Vereenichde Nederlandtsche Provintien van date den vierentwintichsten Novembris anno XVc sesentachtich ende d'andere bij hem verworven van den grave van Leycester als Gouverneur ende capiteijn generael vande zelve provintien gedateert den XXIIIen February XVc acht ende tachtich beyde inhoudende ende vermeldende van seeckere molens binnen eenen geprefixeerden tijt nyet nae te moeten maecken alles breder volgende den selven brieven ende den projecten daeraen gehecht alleenlijck luyden opten naeme ende ten behouve van hem comparant nochtans hij comparant deselve verworven ende geimpetreert heeft, zoe wel ten behouve ende prouffytte van Mr. Johan de Groot, als van hem comparant sulcx dat alle de gerechticheyt vandien ende alle trecht twelckmen vuyt crachte derzelver soude mogen genyeten soe wel den voornoemden De Groot als hem comparant es competerende ende van die respective dagen dat deselve geimpetreert sijn geweest gecompeteert heeft. Cederende mede voor zoe vele het noot zij ten behoeve ende proufitte vanden zelfden De Groot die gerechte helfte van alle recht ende gerechticheyt derselver brieven aen hem selven reserverende de wederhelft vandyen. Actum utsupra, ende was onderteyckent J. Groenhout."

Naar aanleiding van Stevin's klacht over inbreuk op dit octrooi heeft Cornelis Dircxz Muys een bezwaarschrift bij de Staten van Holland ingediend, zoals blijkt uit het navolgend afschrift uit de Resolutien dier Staten van 18 Januari 1590:

„Op t versoeck van Symon Stevin, Ingenieur, ten eynde syne inventie van vertragende proportie der gaende wercken niet en soude worden in eeniger manieren gecontrefaict dan met contentement van den suppl., volgende syn octroy de anno lxxxvi gesien hebbende t ernstigh versouck van Cornelis Dircxz Muys, Stadts Timmerman tot Delff, hebben de Staten van Hollandt gecommitteert den Heere van Poelgeest, Joost de Menyn, eene van Delff en den Burgemeester Dirck Dircxz 't Hoen, de Requeste van beyde partyen te visiteren ende partyen te doen vereenigen, indien t doenlyck is, indien niet, de Staten van alles te doen rapport, omme voorts in de saecke gedaen te mogen worden als na behooren."

V. *Octrooi verleend door de Staten Generaal op 28 November 1589.*

Afschrift uit het Actenboek dier Staten (Alg. R.A., Nr. 3328 fol. 9).

„Die Staten Gen. allen dengenen die dese tegenwoordige zullen sien ofte hooren lesen saluyt. Wij hebben ontfangen de supplicatie aen ons gepresenteert by Simon Stevin, inhoudende zoo dat hy gecomen was tot verscheyden inventien streckende tot grooten dienst des landts."

„Ten Eersten om watermolens alst noodig is malcander te doen toemalen twee drye oft vier hooge en alsmen wilt (te weten als er luttel verheffingge van water is oft dat die wint sterck genoeg waeyet) dat dan elck der zelver met veel meerder voordeel alleen male."

„Ten tweeden dat in moelens die t water uut die polders malen oyck t water wederom cunnen inde polders malen twelck tot sommige plaatsen op drooge jaerscharen zeer noodich valt."

„Ten derden om t water uuyt slooten en grachten te trecken door menschenaerbeyt na de manier nu onlancx tot Leyden op Rapenburch gebruyckt daer een prouve gedaen is op twee eve groote wateren alwaer sesse mannen malcander ververschend geduerig meer dan noch eens zoo vele deden als drye peerden malcander ververschend twelck door eens mans aerbeyt meer waters geloost was als door een peerts arbeyt."

„Ten vierden om met overvloedicheyt te trecken cley sant en diergelycke fyne stoffe uuyt havens en vaerten."

„Ten vyffden om de voorz. fyne stoffe als cley ofte sant int water te lossen op soo corten tyt en met soo luttel aerbeyts dattet voor tyt noch arbeyt te rekenen en is."

„Ten sesten om uuyte voornoempte wateren te trecken vlietende stoff als baggaert, moer en diergelycke."

„Ten sevenden om de boven gesegde vlietende stoffe met groote lichticheyt te loosen soo opt landt als int water."

„Ten achtsten van een braetspit alleenlijk hebbende een rat van cleynen cost nochtans gaende sonder opwinden tot dattet gebraet genoech is dreye uren lanck en dat met een twee ofte meer speten hetwelcke alst niet en braet voer een uuerwerck mach gebruyckt worden wyzende de uren twelff uren lanck zonder opwinden, ende niet bradende noch uren wyzende verstrecken om een kint te wiegen en dat een halff ure ofte soo men wil een heele ure lanck eer men t gewichte weder moet opwinden."

„Ten negenden: van watermolens met twelcke t water uuytgemalen wordt door cokers met suygers na de figuerlucke verclaringe des negensten artyckels, welcke Inventien alsoo die tot grooten nut des landts zullen strecken en dat hy suppl. daertoe niet gecomen is dan door grooten cost en moeyte heeft dezelve suppl. ons versocht dat wy hem en naer hem zyn erffgenamen ofte actie van hem vercrygende ofte vercregen hebben zouden willen gunnen dezelve alleen te mogen doen maken."

„Soo eest dat wy den voorsz. suppl. geconsenteert en geoctroyeert hebben, consenteren en octroyeren hem mets desz de voorsz. kunsten en instrumenten (waar-)van de figuerlicke verclaringen door dese zyn getransfixeert, zoo verre dezelve nieuwe inventien zyn binnen voorz. geunieerde provintien alleen te mogen maken en gebruycken in deser voegen."

„In den eersten, dat nyemandt door t behulp van verscheyden dueren en sal mogen maken dat watermolens malcander toemalen twee ofte meer hooch ende dat selve oyck elck alleene male alsmen wil, na de maniere int eerste artykel figuerlyck verclaert."

„Ten tweeden, dat niemant en sal mogen door t behulp van verscheyden dueren maken dat t water mette selve molens wederomme te rugge in de polders gemalen word."

„Ten derden, dat niemant tot het uuytoosen door cokers niet alleen tot ydelinge van slooten en vaerden maer oock voor bronwateren en alsins en zal mogen gebruycken bewegende cegels aen canten der suygers noch verscheyden cokers aen as steken om alsoo de gewelt te vermeerderen of te verminderen nade eysch van hoochde die t water of andere stoffen opgetrocken moeten worden en na de menigte deswelcks datmen int aerbeyden gebruycken wil."

„Ten vierden, dat niemant tot het uuyttrecken van cley sant en diergelycke en zal mogen gebruycken een zoo grooten baggaert net noch dat van onder doen open en begaen met een slot noch oock dat baggaert net voltrecken deur tbehulp van een as, noch het trecken (-de) tau alsoo lancx den gront doen streken deur tbehulp van een stock met catrol aen t eynde welcke stock naer veranderinge der watergetyden diepten ofte ondiepten des grondts hooger ofte leeger kan gestelt worden, ende opdat van grootheyt des nets seker maet genoempt sy, dat men t soo groot zal mogen gebruycken alsmen tot nogtoe gedaen heeft en boven dyen d'een helft meerder maer niet daerover comen."

„Ten vijffden, dat niemant en zal mogen lossen int water fyne stoffe als cley sant en diergelycke door opgaende deuren in den bodem vant schip gemaeckt daer de stoffe door int water valt noch na de maniere int voorsz. getransfixeert geschrift breeder verclaert."

„Ten sessen, dat niemant en sal mogen trecken baggaert en diergelycke vlietende stoffe deur cokers na de maniere als int selffde geschrift met menschenarbeyt noch met peerden."

„Ten sevenden, dat niemant de voorsz. stoffe en zal mogen loosen int water met sinckinge deur den gront des schips noch opt land deur optreckinge met cokers oft buysen nade verclaringen van t voorsz. geschrift."

„Ten achtsten, dat niemant en zal mogen van ijzer noch andere stoffe braetspitten (maken) met een onrust oft schakelrat daer in ende alzoo tzelve braetspit oock en streckt voor een uuyrwerck en wiegen als geseyt is, dat niemant en zal mogen maken uuyrwercken met alleenlyck een rat wijzende de uuyren met zijn dalend gewicht, dat oock niemant en sal mogen wiegen doen gaen deur behulp van een schakelrat offe onruste, welcke braetspeten, uuyrwercken en wiegers de suppl. zal moeten doen teeckenen int ijzer met zijn gewoonl(yk) teecken de clootcrans genaempt hetwelcke d'eerste figure is vant negenthienste voorstel des eersten boucx zijnder Weeghconste."

„Ten negenden, dat niemant en zal mogen naemaken zijn inventie des negenden artyckels welcke is van watermolens met sulcke cokers ende suygers als int derde article verclaert zijn, waerinne t voornaempste point van zijn inventie is dat zij een groot lichaem waters lancksamelyck doet voort gaen, waer aff hij den onbekenden aert van t voordeel der perssing des volgenden waters met een veroirdende proportie des gaenden werck alreede geopenbaert heeft int bescreven werck daer Rapenburch mede uuytgemalen wiert,

„binnen den tyt van twintich jaeren naestcomen(de) dan met consent des voorsz. Simon Stevins op pene van verbuerte van zulcke gecontrefeyte en nagemaeckte instrumenten end daerenboven van (de) somme van dusent gulden d'een helft daervan tot behoeff van den suppl.,

„bevelen ende ordonneren allen officieren, justicieren, magistraten end inwoonders der Nederlantsche Vereenigde Provintien ende elcken van henlieden dat zy den voorsz. Simon Stevin doen en laten genieten het effect van desen onsen octroye consent en privilegie vryelyck ende paisivel(yk), cesserende alle empechementen ter contrarie, want wy tzelve voir den lande dienstlich hebben bevonden."

„Gegeven in sGraven Hage den XXVIII Novembris XV^{c} LXXXIX."

Verscheyden Inventien van Simon Stevin
(Alg. Rijksarchief, Staten Generaal No. 29)

Ten 1en

Malende verscheyden molens elck besonder: Hoemen te weegh sal brenghen, datse, alsmen wil, malcander toemalen, twee of drie hoogh.

Wesende een polder met verscheyden molens, men can haer waterslooten alsoo vervoughen, datse met een duerken open te stellen of toe te doen, alsnu malcander toemalen, alsdan elck besonder, soomen wil, na de stercke wint, ende verheffing des waters dieder voor handen is. Om twelck te verclaren, soo laet AB (fig. 5) den boesem beteeckenen, ende de ronden C, D, twee molens, ofte plaetsen der molens, staende ande kade des polders, welcke malen inden boesem AB. Ende vanden molen D, tot de molen C is een sloot, waerin een duerken is, als het schotduerken van een watermolen, doch breeder, dat ick beteecken met de lijn E, welck duercken sluyten can teghen tpunt F. Voort is de kade duergraven an G, in welck gat oock soodanighen duerken staet, te weten H, twelck sluyten can teghen tpunt J. Derghelycke duerken is oock an K, twelck sluyten can teghen tpunt L. Met de ghetippelde plaetsen wort water beteeckent. Door tbehulp van dese drie duerkens canmen de molens C, D, sonder moeyte, ende opde staende voet, elck alleen doen malen, of, soomen wil, malcander toe doen malen, twee hooch, na de nooticheyt dieder voorhanden is. Want soomen wil dat deen molen dander toemael, men stelt het duerken E open, alsoo dattet met een yser haecxken open ghehouden blyft. Maer soomen wil dat elck alleen mael, men ontdoet alleenlick dat haecxken, latende alles syn loop hebben, ende men heeft tbegheerde, twelck aldus bethoont wort: Als het duerken E open is, ende alsoo met een yser haecxken gheduerich open blyft, soo comt het water uyt den boesem AB, ende willende duer tgat G inden polder loopen, het sluyt het duerken H, om dattet hoogher is dan tbinnewater. Het duerken K gaat oock van selfs toe, overmits twater dat de molen D opmaelt inde sloot tusschen beyde de molens, hoogher is dan twater des polders: Inder voughen dat de molen D toemaelt ande molen C, dat is sy malen twee hooch. Maer alsmen het yser haecxken ant duerken S ontdoet, dat elcke molen dan alleen maelt, wort aldus bethoont: Malende de molen D haer water soo hooch als tbuytewater, soo moet de duer E daerom sluyten, want huer water over dander syde leegher is: de duere E alsoo ghesloten synde, dander twee dueren H en K gaen van selfs open, te weten de duere H van weghen de molen D, ende de duere K van weghen de molen C, inder voughen dat elcke molen alsdan alleen maelt.

Tvoorbeelt hier boven beschreven is ghenomen op molens die beide staen ande kade langs den boesem streckende, waer uyt de manier om alle ander ghestalt van molens daer toe te brenghen ghenouch bekent is, want soo sy achter malcander stonden, ghelyck de ghelegentheyt der plaets van slooten en landt dicwils eyscht, tghene boven gheseyt is, can aldaer oock te weghe ghebrocht worden, ghelyck de form hier nevens uytwyst (fig. 6), alwaer deen molen achter dander staet, tot welcke de boveschreven verclaring oock dienen can.

Tis oock openbaer uyt het ghene wy hier bewesen hebben, met twee molens, hoemen alsoo malcander sal connen doen toemalen drie ofte meer molens, want vervoughende een molen met haer duerkens achter de molen D, ghelyck D achter C ghestelt is, men heeft een derde molen ende soo voort met ander.

Tis oock te weten dat de molen als C, langher lepels behouft dan D, want soo de lepels van deen en dander evediex ghinghen als elck alleen maelt, soo behouft de wateras van C hoogher te ligghen dan van D, teghen datse malcander sullen moeten toemalen.

De duerkens moeten oock over sulcke syden open gaen als gheteyckent is, op datse duer de persing van thoochste water dicht sluyten.

Ten 2en

Hoemen maken sal dat de molens die twater uyt de polders malen, sullen twater, alst buyten leeghst is, daer wederom in connen malen.

Tghebuert tot sommighe plaetsen op drooghe iaerscharen, dattet buytewater leegher wort dan tbinnewater, inder voughen dat de weyen veel te drooghe worden, ia dat de beesten an gheen water en connen gheraken om te drincken. De middel om sulck buytewater met de selve molens weder te rugghe te doen malen inde polders, is dusdanich (fig. 7): Latet buytewater, molewerf, ende al de rest, gheteyckent syn als hier onder, na de ghemeene ghebruyck, doch de molesloot met twee bochtkens, als ter plaets van A en B. Voort soo beteeckent C voor de waterloop een duerken als een breede schotduer, open gaende na de molen, sluytende teghen tpunt D. Ende E een derghelycke duerken achter de waterloop, opengaende van de molen na tbinnewater, sluytende teghen tpunt F. Voort sullender duer deinden der kaen ande molenwerf die tbuytewater van tbinnewater schutten, ligghen twee cokers als G en H, elck met een duerken ghelyck inde ghebruyck is tot veel plaetsen daermen tbuytewater duer cokers in de polders wil laten. Dit aldus bestelt synde, de molen draeyende, soo sal tbuytewater te rugghe inde polder ghemaelt worden, twelck wy aldus bewysen: Draeyende tscheprat, soo gaet de duere C van selfs toe, overmits twater tusschen tscheprat ende de duere hoogher is dan tbuytewater, ende de duere E sluyt oock van selfs, overmits twater tusschen tscheprat ende de duere E, buytewater is, incommende duer de coker G, twelck leegher is dan tbinnewater over dander syde vande duere. Inder voughen dat al twater dat de molen maelt, comt duer de coker G, van daer duer de molesloot J, van daer achter inde waterloop, duer de waterloop, duer de coker H, duer de molesloot K, ende alsoo van achter na de polder toe.

Merct dat alsmen twater ter contrarie uyt de polder maelt, soo mach men de dueren CE elck met een yser haecxken vast open stellen, oft andersins men machse van haer ganghen trecken, die inde molen legghende, welcke men weder tot haer plaets hanghen mach, alsmense behouft. Aengaende de twee cokers GH, die mach men, wanneer mense niet en besicht, vullen met eerde ofte cley tegen tleken, na de ghebruyck van derghelycke cokers in ander polders.

Ten 3en

Verclaring van tmaecksel des slootoosers, daer mede twater van Rapenburch tot Leyden inde maent van Meye lastleden uytghetrocken is.

Tinstrument is van form als hier onder (fig. 8), alwaer A, B, twee viercante cokers beteeckenen, van binnen elck een voet wyt. Inde selve cokers gaen twee suyghers 5½ voeten hooch op en neer, ende syn int viercante ghelyck de cokers oock een voet; de selve suyghers hebben an haer canten houten reghels, die met vetleer ghehecht synde, over en weer connen gaen, waer duer te weghe ghebrocht wort, datse int opgaen dicht teghen de canten des cokers strycken, soo styf als duer topligghende water veroirsaeckt wort, nochtans sonder klemmen. C beteeckent een yserdraten traeylle, daer twater duer incomt, schuttende nochtans hout steen en dierghelycke dat inde suygher oft onderclapper belet mocht doen. De voornomde twee suyghers worden ghewonden opden as D, alsnu over deen alsdan over dander syde, met de krucken E, F, alsoo dat deen tou over tcaterol G op deen syde van den as opghewonden wort, ende dander tou over tcaterol H op dander syde vanden as, ende dit tot dien ende, op dat te wyle men deen suygher opwint, dat dander dale, ende altyt een suygher int werck sy. De voornomde coker D stekende door haer middelt an een yser spille, can daer af ghetrocken worden, ende men mach in die plaets dicker of dinder cokers steken, na de hoocheyt van water datter moet opghewonden worden, ende na tvolck dat men int werck stelt, te weten alsmen eerst beghint te trecken, dicker, daer naer twater dalende, dinder en dinder: Als inde voorgaende watertrecking van Rapenborch, soo was deerste coker 10 duym dick, ende twater een voet ghedaelt synde, soo stack men een ander coker daer an van 7 duym, ende naer noch een voet daling, een coker van 5 duym, daer naer een van 3 duym.

Ten 4en

Verclaring van een manier om cley, sant of dierghelycke vaste stof, met overvloet ende voordeel uyt de havens ende gronden van wateren te trecken.

A (fig. 9) beteeckent een groot net, meer cleys vervatende dan 25 ander ghemeen baggaertnetten, tselve heeft inden bodem twee halve yser rynghen, die open en toegaen op twee carnieren an B en C, ende sluyten int middel met een slot. Dit net wort vol cleys ghetrocken duer den as D, met een tau vanden selven as commende over tcaterol E, ende van daer over tcaterol F, van daer ant net. Tcaterol F staet in een stock, welckmen hoogher en leegher steken can, om het tou FA te wyle men treckt, altyt langs de gront te doen strecken, soo naer alsmen wil. Tnet alsoo vol cleys ghetrocken wesende, soo treckmen de kruck vanden as D, ende men steeckse anden as G, van welcken as een ander tou comt over tcaterol H, tot ant net, ende tnet wort daer mede opghewonden soo hooch tot dattet boven de cant van tschip is datmen vullen wil, welck schip gheleyt wort nevens de schauwe, alsoo dat syn middelt comt omtrent teinde der schauwe an J. Tnet alsoo boven dat schip hanghende, men steeckt met een stock in een ront oogh K daer mede tslot open springt, ende duer tghewicht des cleys, soo wycken die twee halve ringen B, C, van malcander, ende de cley valt daer duer int schip.

Merckt dat als dese saecke int werck ghestelt wort, soo sullen de assen D, G, ghedraeyt worden duer almachtighen, naer de leering des 10en voorstels der Weeghdaet, welcke almachtighen hier om cortheyt niet gheteeckent en syn. Tis oock te weten dat sulck net en assen op dander syde vande schauwe mede syn sullen, eensdeels op dat de schauwe niet om en slae, ofte te seer en helle, als dat een groote net gheladen buyten twater comt, want over elcke syde sulcken net hanghende, soo sal de schauwe in haer evewichticheyt blyven. Ten anderen om met een schauwe twee cleyschepen tseffens te mueghen vullen.

Ten 5en

Hoemen de schepen met cley of sant gheladen, die int water moeten ghelost syn, met lichticheyt ontladen sal.

Wantmen veel tyts ende aerbyts behouft, om de ghetrocken cley of sant met schuppen over boort te werpen na doude ghewoonte, streckende tot groote cost der plaetsen daermen de haven diepen wil, soo is de manier om sulcke schepen met lichticheyt te ontladen dusdanich: Tis te weten dattet middel der cleyschepen daer de cley inlight, afgescheyden is van byde de einden des schips, alsoo dat beyde die einden dicht en drooch blyven, daerom salmen den bodem van dat middelste deel uytbreken, ende maken in die plaets een bodem als een duer, hanghende op deen syde an twee stercke ghanghen, op dander syde sal mense opwinden met twee tauwen op een boom, ofte as, ende opghewonden synde, sal met een vallende yser clyncke vast blyven, ghelyck te Delft ende elders de sluysdueren opghewonden worden, ende met een vallende clynck vast blyven. Nu alsoo den bodem van dat middelste deel des schips leegher ghebauwet sal syn dan twater daer tschip inlight, soo sal twater wel tusschen de garren der duere in dat middelste deel loopen, maer want dat water, alsser de cley incomt, voor de cley wycken moet, soo salt duer die garren weder daer uyt loopen, ja men sal tot dien einde duer de canten des schips noch gaetkens mueghen booren. Oock en can tschip om dat inloopende water niet syncken, wantet ghelyck een water schip op beyde syn dichte einden opghehouden wort. Dit schip vol cleys of sants ghetrocken wesende, ende ghebrocht synde ter plaets daerment int water loosen wil, men sal alleenlick die clynck optrecken, ende de duere om tgroot ghewicht des cleys, sal neervallen, ende de cley sal met eenen set al tseffens ten gronde vant water syncken. De duer daer naer weder opghewonden synde, ende met haer clyncke ghesloten wesende, tschip sal bereyt syn om wederom ghevult te mueghen worden.

Inder voughen dat tottet loosen van dese schepen niet meer arbeyts en sal behouven, dan het over enweer varen, want het optrecken van die clinck voor gheen aerbyt noch tyt te achten en is.

Ten 6en

Hoemen baggaert, veen, ende dierghelycke vlietende stof, uyt havens ende gronden van wateren met groot voordeel trecken sal.

Latet vierhouck A (fig. 10) een schauwe beteeckenen, ende de viercante percken B, C, de plaetsen van twee slycktreckers, lyckformich ghenouch anden slootooser hier vooren beschreven, doch hebbende haer yserdraten traeylle daer de baggaert duer comt, niet ter syden als de voorgaende, maer recht van onder. Voor dese twee slycktreckers salmen legghen twee baggaert schepen, D, E, voor elck een, om vol ghetrocken te worden twelck te werck sal gaen draeyende de crucken nu op deen dan op dander syde, ghelyck int voornomde watertrecken op Rapenborch. Maer soo dese schauwe altyt op een plaets bleve te wyle men treckt, soo soude na den baggaert haest het water volghen, om teghen twelck te voorsien, soo sal de schauwe daerentusschen wat moeten voortvaren, twelck onder ander manieren geschien mach duer twee spillen of assen als F, G, want te wyle men F draeyt, soo sal G ontdraeyen, ende de schepen sullen na de syde van F ghetrocken worden. Ende gelycx te wyle men G draeyt, soo sal F ontdraeyen, ende de schepen sullen na de syde van G ghetrocken worden. Tis oock te weten dat de slycktreckers B, C, elck met een as hoogher en leegher sullen mueghen ghewonden worden, na de nootlicheyt ende veranderinghen dieder voor handen syn, als rysing en daling van tgetie, diepte des baggaerts en dierghelycke.

Tghene hier duer menschen aerbeyt anghewesen is, sal oock duer peerden ghedaen worden, welcke gheduerlick int ronde gaende, tgene sullen te weghe brenghen dat boven verclaert is.

Ten 7en

Wesende de schepen met baggaert of derghelycke vlietende stof gheladen, die int water of op tlandt moeten ghelost syn: Hoemen met lichticheyt die ontladen sal.

Dunne vlietende baggaert die int water moet uytghestort syn, en can duer de voorgaende manier van cleylossen, soo bequaemlick niet ghelost worden als de cley, overmidts den baggaert duer de reten van de duere, ende die gaetkens inde cant van tschip, int water syncken soude. De manier dan sal dusdanich syn: Soo den bodem van tmiddeldeel des baggaert schips niet soo hooch, ofte gheen halve duym hoogher en waer (welverstaende als tschip ledich is) dan twater daer tschip inlight (sommighe bodems ligghen wel soo hooch sommighe leegher) men sal boven den bodem legghen noch een ander bodem, soo hooch dat dien bodem (tschip ledich synde) een halve duym ofte min hoogher sy dan twater; Twelck soo wesende, men sal duer den bodem een gat maken, een voet of twee groot, daerop een vallende veinsterken commen sal. Dit schip vol baggaert ghetrocken synde, dat veinsterken (hoe wel tschip diep int water sinckt) sal toegheperst worden vande baggaert daer op ligghende, ende dat overmits de baggaertstof swaerder is dan twater. Tschip dan ghecommen synde ter plaets daerment ontladen wil, men sal dat veinsterken open trecken, ende al de baggaert sal daer duer int water syncken.

Maer soo de baggaert opt landt moest ghelost syn, men sal die met een slycktrecker als vooren beschreven is, om hooghe daeruyt trecken, die latende duer een gote loopen, ter plaets daer mense begheert. Dese slycktrecker sal ghestelt worden in een ander schip, met een as daer by, waer duer mense een voet of twee hoogher en leegher can winden, om teen baggaertschip na tander met lichticheyt daer onder te commen. Andersins salmen int baggaert schip selver mueghen een cleen slycktrecker stellen, daer te noot eyscht om daer mede tontladen.

Ten 8en

Verclaring vande ghedaente des braetspits, hebbende alleenlick een radt, nochtans drie uyren lanck gaende sonder opwinden, oock verstreckende voor een uyrwerk gaande 12 uyren sonder opwinden: Ten derden voor een wiegher, gaende een half uyr lanck sonder opwinden.

ABCD (fig. 11) beteeckent een viercant yser raemken, lanck en breet ontrent een voet, waer in comt den as EF, met een yser cokerken daer an als G, waer op tghewicht H ghewonden wort. Anden voorn. as is een schakelradt J, twelck donrust KL doet gaen, wiens spille ter plaets van M een gat heeft, om den as duer te commen, N ende O beteeckenen beyde de loon der onrust, P is een houte schyf waer in verscheyden kerven ghedraeyt worden, soo veel alsmen speten tseffens int braden ghebruycken wil, als twee of drie, want in de voornomde kerven moeten taukens hanghen, waer in beneden de speten commen te ligghen elck met haer schyf. Dit yser raemken met datter in is, wort ghestelt op een houte voet ontrent 4½ voeten hooch. Dese braetspit wyst de uyren alsmen niet en braet, met het dalende ghewicht H, ende dat op een der stylkens vanden houten voet daer de uyren op gheteeckent staen. Maer alsmen daer mede wieghen wil, soo weert men de loon N, O, ende men bindt tot die plaets twee dunne coordekens, commende over twee seker catrollekens tot ande wieghe, ende donrust overenweer gaen.

Ten 9en

Inventie van molens om twater te malen duer sulcke cokers met suyghers als inde derde inventie beschreven is, daer Rapenburch mede uytghemalen wiert.

Laet in dese molen gheteyckent worden (fig. 12) met A tschyfloop onder ande spille, ende B tcroonrat boven, maer C tcamrat beneen, daer duer steect den as DE, ende anden selven as twee schyfloopen als F en G, teen over deen syde, tander over dander. Voort sullen de roen daer de suyghers in haer cokers mede opghetrocken worden, tanden hebben, bycans na de manier des heughels van een heughelspit. In die tanden sullen die twee halfschyfloopen draeyen, alsoo dat deen suygher neergaende, dander sal opcommen; Dese suyghers sullen lancsaemlick op en neer gaen, ende seer groot syn, daer sullen oock sulcke vier suyghers neven malcander staen, om somtyts twee, somtyts vier te mueghen ghebruycken, na de wint ende verheffing des waters dieder voorhanden is.

Derghelycke manier van werck sal oock veroirdert worden om duer peerden ghewrocht te worden, ghelyck dander figuer anwyst, alwaer H tschyfloop beteeckent, end J tcamrat, K en L de halfschyfloopen. MN den boom daer tpeert aen trect, welck peert over den as O gaen sal ghelyck in ander peerdemolens.

CHAPTER III

ON COGS AND STAVES

INTRODUCTION

The extracts made by Beeckman from the papers left by Stevin contain the following marginal note (fol. 201 *recto*), which seems to indicate the relation between these various treatises. It runs:

Cortbegrip. Eerst de gestalte des molens int gemeyn. Daerna vant gaande werck: camrayen ende schijfloopen. Ten derden van de persingh des waters. Ten vierden van de windt, vant roersel des waters, ubi nulli proportio (alwaer geen evenredenheyt is).

That is: "Summary. First, of the form of mills in general. Then the machinery: gears and pinions. Thirdly, the pressure of the water. Fourthly, the wind, then the flow of the water, where there is no proportionality."

In the table of contents of the *Huysbou* at the end of his *Materiae Politicae* of 1649 Hendrick Stevin says: "Waerby noch gevoucht is *Weechdadelicken Handel van Cammen en Staven in Watermolens en Cleytrecking*" ("to which is also added Essay on the Principles of the *Weeghdaet* Applied to Cogs and Staves in Drainage Mills and the Drawing of Clay").

Like Beeckman, Hendrick Stevin seems to infer that Simon Stevin had intended to add these essays to his *Huysbou,* but there is no indication whatever that such was the case, for the *Huysbou* does not deal with any hydrodynamical engineering matter. We simply do not know what Simon Stevin intended to do with these essays.

Hendrick Stevin in reproducing his father's notes on cogs and staves used Beeckman's notes freely for the paragraphs in his Book VI of his *Wisconstigh Filosofisch Bedrijf* of 1667, but as Beeckman's notes are in part much fuller we have tried to complete Hendrick Stevin's passages as far as possible in order to give full scope to Simon Stevin's ideas. De Waard gives the following concordance of Beeckman's and Hendrick Stevin's passages on cogs and staves:

Title	*Beeckman's extract*	*Wisc. Filos. Bedrijf 1667*
Wesende gegeven een camrat, waertoe een schyfloop begeert wort, des schyfloops steeck te vinden.	Fol. 199 *recto, ll.* 1-10	VI *Boec,* p. 5, *ll.* 19-25
Wesende gegeven de halfmiddellyn eens camradts en schyfloops, diens assen van malcander onevenwydich syn, oock de dickte des staafs met de breede des cams, dat camrat en schyfloop so te maken dat de cammen met haer gansche breede tseffens de staven geraken.	Fol. 201 *verso, l.* 6-202 *recto, l.* 40	VI *Boec,* p. 7, *l.* 17-p. 9, *l.* 15
Bequaemste standt der cammen en steeck der staven te vinden.	Fol. 199 *recto, l.* 29-Fol. 200-*verso, l.* 7	VI *Boec,* p. 6 *ll.* 5-19 et *l.* 30-p. 7, *l.* 9

There is no doubt that gears and toothed wheels had been in use for many centuries before Stevin, though we have reason to believe that they came into use not much earlier than early Hellenistic times (300 B.C.) [1]) mainly for man- or animal-driven water-raising machinery.

Gears are actually first described properly by Aristotle in his Mechanical Problems (*Mechan.* 848a, 24) as "tools that set many circles in motion simultaneously by means of a single circle" and their study is more or less linked up with the solution of the mechanics of celestial movements as presented by the Greek astronomers. Classical engineers like Heron, Philon of Byzantium, Ctesibios and Vitruvius (IX.8.4) make regular use of cogwheels and lantern wheels. An example of the latter kind of wheels dating back to about 125 A.D. was found in the Saalburg, and they figure in all vertical water wheels.

Pappos (Book VIII, *cap.* XI-XXV) deals with the transmission of energy by means of gears in general [2]), and Oribasius (362 A.D.) makes an intelligent use of such gears in machinery. They were applied to the paddle-wheeled vessel described by the anonymous author of *De Rebus Bellicis* about 370 A.D. [3]). Along with the other classical heritage they were transmitted to the mediaeval engineers of Western Europe.

As far as we know cogwheels and lantern wheels were always made of wood, the teeth being simply wooden pegs, slightly rounded-off at the top and projecting perpendicularly from a disc-wheel.

As such they appear in the mechanical chisel described by Theophilus Presbyter (abt. 1100 A.D.) and in the machinery described by Villars de Honnecourt in 1245. For the cogwheels in the clock built for Padua in 1344, saw teeth were used but usually one finds the traditional peg form, for instance in the *Codex Latinus* 197 of the Monaco Library (abt. 1430) and the mss. of Philip Mönch in the Heidelberg University Library (dated 1496). They appear in the machinery of a paddle-boat delineated in the mss. of Donaueschingen of 1410. Fractions of seconds were measured by counting the teeth of cogwheels of the clockwork which Bernard Walter of Nuremberg built for Regiomontanus 1472.

The great progress of mechanical engineering in the sixteenth century is demonstrated by the many well-known handbooks of the period [4]). The cogwheels and lantern wheels of such authors as Jacques Besson (1565), Ramelli (1588), Lorini (1592), Zonca (1600), Zeising (1612-1614), and Verantio (1613) are of the simplest kind. Agricola (*De Re Metallica* Book VI) forms an exception in proposing iron cogwheels with steel teeth screwed in for certain mining machinery. In general toothed wheels were cast solid (from c. 1750) or made of wood. In the latter case the teeth were replaceable if they became worn. Lanterns, which were mostly small, drum-shaped pinions with bars instead of teeth, usually had wooden frames. Teeth, mostly hardly more than pegs, were not cut with faces on an epicycloidal curve, which gives a rolling instead of a sliding contact, for this was a refinement not yet discovered. Hence they did not engage properly but their contact was such that they must have lost efficiency to a considerable extent through

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1) R. J. Forbes, *Studies in Ancient Technology,* Vol. II (Leyden, 1964, 36).
2) Beck, *Beiträge zur Geschichte des Maschinebaues,* Berlin, 1899, 20.
3) E. A. Thompson, *A Roman Reformer and Inventor,* Oxford, 1952.
4) A. P. Usher, *History of Mechanical Inventions,* Harvard Univ. Press, 1954.
W. B. Parsons, *Engineers and Engineering in the Renaissance,* Baltimore, 1939.

friction. Still they answered the requirements of the time and were already vastly superior to anything else that had existed. They made possible the transmission and multiplication of power, even though losses of energy through friction are not yet studied and no constructional discussions of gears occur in these handbooks. Still many of the terms we now use, like *teeth, lanterns* and *arbors* go back to old French terms of this period. Though terms such as force and energy were as yet imperfectly understood, the engineers of this period knew that speed and power were inversely proportional. They geared large wheels with small ones to reduce the number of revolutions of the operating shaft, as compared with the driving shaft, obtaining greater power if they reversed the arrangement and sought high speed.

Little attention, however, was paid to the construction of the toothed wheels and pinions, because machinery was not yet conceived as a unit built up of machine parts, each bit of machinery being considered more or less independently. Few people wasted many words on the form of the cogs and staves. Few approached this problem from the point of view of applied mechanics. Here Leonardo da Vinci should again be mentioned as a pioneer. From his notebooks we gather that he had planned to write on applied mechanics [5]) and to deal with wheels and cog-wheels:

"You will speak of wheels that turn and return
Speak of a wheel that augments
Speak of the perpetual screws
Speak of mills and other machines that move and throw
Speak of teeth
You will speak of poles
Then of wheels and battens without teeth
Then of wheels and battens with rope and with teeth
And you will say what teeth are most praiseworthy
in nature and movement and setting" (*Cod. Atl.* 155*v.*)

Amongst his many detailed drawings one finds pictures of crown wheels with oblique teeth, the profile of cogs (*Cod. Atl.* 61*v.*), cogwheels with a trapezoidal section (Ms. B. Fol. 73*v.*), chain-and-screw transmissions (*Cod. Atl.* 16*r.* 357*r.*) and many irregularly shaped gears. Tantalizing as some of his hints may be, he never finished these books.

Cardanus in his *De Rerum Varietate* [6]) of 1557 is more explicit. He begins with a discussion of the transmission of energy from the floats of a water wheel to machinery by means of cogwheels, explains how more speed may be gained by the proper choice of the number of cogs in gears and warns his reader that too high a speed may cause breakage of the cogs. However, most of his discussions are devoted to the regulation of the proper revolutions of wheels in clocks and watches, in which he gives pioneer instructions, without entering too much into structural details of the toothed wheels themselves. Here he discusses, in the same order as Stevin, transmission between parallel, perpendicular and finally

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[5]) Irma A. Richter, *Selections from the notebooks of Leonardo da Vinci,* London 1953, 78.

[6]) Cardanus, *De Rerum Varietate, Lib. IX. cap.* 47, page 185. Paris 1663.

oblique shafts. His toothed wheels still show the cylindrical peglike cogs, slightly rounded at the top and more widely spaced than seems necessary to us. Though his discussions have contributed essential elements to clock making, they can hardly be considered to be of importance to such technical machinery as that of windmills and water wheels.

Still it was in this field that improvements were most necessary, and the heavy wear and breakage of toothed wheels made them a major worry of the engineers of Stevin's days.

From the patents issued by the States General of the United Provinces and the States of Holland [7]) it is perfectly clear that Stevin's contemporaries were searching for gears and cogs of a better construction. In 1614 Claes Wolbrantsz van den Tol, carpenter, citizen of Delft, was granted a patent (Doorman's G. 133) covering improved teeth for cogwheels, "staves slightly thinner at the end, cogs slightly longer and rounded as shown in the appended model". The heavy wear and tear of the cogs and staves, which together with the vibration owing to irregular transmission absorbed nearly two-thirds of the energy from the windshaft in the windmills of those days, prompted inventors to look for a remedy of this evil. Thus Emanuel Byrck was granted a patent in 1646 (Doorman's G. 424) which among other items, included "the invention of new cogs and wheels to last 1½-2 times longer, without breakage of the top of the cogs".

Simon Stevin was well aware of these defects of the cogs and staves of his day. His essay must date back to about 1590 when he was engaged in building new windmills according to his own design, which above all included his invention of an inverted oblique transmission from the windshaft to the upright shaft of the mill, placing a conical lantern-wheel on the windshaft and a cogwheel on top of the upright shaft, contrary to the practice of his day. Hence the entire composition of this essay leads up to this problem [8]).

Stevin begins by discussing the way in which to find the pitch of the lantern wheel which enables the cogs to press against the staves in such a way that their sharp edge does not wear them off too quickly. He first solves the problem for the case of parallel shafts, then for perpendicular shafts and finally for oblique transmissions, as in the caps of windmills. He finds that in the first case the solution is to set cogs obliquely, slanting backwards, the proper angle being found by a graphical method of which he gives the details. In the latter two cases the pinions should be conical and this is the form of the lantern wheel which he proposes to attach to the windshaft.

Looking at Stevin's theories and practical applications in retrospect we have to state that he could never have achieved smooth transmission of energy because the number of cogs and staves which he uses for his gears was far too small. He was thus unable to avoid great vibration of the machinery and wear of the cogs and staves.

Neither did he have mathematical tools that would have enabled him to calculate the proper form of the teeth. It was only after cycloid and epicycloid had been discovered and studied early in the seventeenth century that Olaf Roemer [9])

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[7]) G. Doorman, *Patents for Inventions in the Netherlands during the 17th and 18th Centuries, The Hague, 1942.*

[8]) Cf. the drawings in the chapter *On Mills,* fig. 21, 22 and Plates I—III.

[9]) *Wolfii Opera Mathematicis,* 1674.

introduced (1674) epicycloidal teeth for cogwheels. Some twenty years later Philippe de la Hire wrote his *Traité des Epicycloides et de leur Usage en les Machines* (1694) [10]; they were then universally propagated by Smeaton (1759) [11]. Finally Euler dealt very fully with the use of evolvent curves for the designs of cogs (1760) [12]. They did much to correct the great losses of energy during transmissions in the days of Simon Stevin. Still, Stevin deserves our admiration for his attempt to solve a mechanical problem logically, a thing which few of this contemporaries had tried to achieve except by experiment. His practical experience is ably used in this essay to lead up to the particular problem he wants to solve, and we can only regret that he never finished and published it [13]).

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[10]) *Mémoires de l'Académie de Paris,* Vol. 9, p. 341.

[11]) John Smeaton's *Reports,* Vol. I & Vol. II.

[12]) *Comment. Petropol.,* 1754, 1755 (published only in 1760).

[13]) The entire history of the toothed wheel is now ably discussed by Robert S. Woodbury in his *History of the Gear-cutting Machine* (Cambridge (Mass.) 1958).

VAN ALDERVOLMAECSTE CAMMEN EN STAVEN

ON THE MOST PERFECT COGS AND STAVES

VAN ALDERVOLMAECSTE CAMMEN EN STAVEN.

Wesende gegeven een camrat, waertoe een schyfloop begeert wort, des schyfloops steke te vinden.

De molenaers noemen steke een ront twelck gedeelt in sooveel deelen als de schyfloop staven moet hebben, dat de wyde tusschen die deelen even sy aen de wyde tusschen de cammen op haer middelt, welck ronts omtreck tgene is daer t' middel der staven op sal moeten passen.

Indervougen dat het begeerde dezes Voorstels is [1]); Een ront te maken, in diens omtrec so veel punten evewydig van malcander gestelt zijnde, alser staven wesen moeten, de rechte van het eene tot het andere, even sy aen de rechte tusschen der cammen aensichten, berekent opt middel der cammen. Ende dat ront sal des schyfloops grote wesen, berekent opt middel der staven, ende die wytte van het een tottet ander punt, de begeerde steec. Welk werc van kleen gewichte zijnde, wy laeten het by dit vermaen berusten. Te meer also het by den Molenmeesters gemeen is, en by ons niet nagevolgt en sal worden, als geen wisconstige gront tot dat werc zijnde.

abcd (Fig. 14) is den omtreck eens rats deur tmiddel der kammen, welke kammen wyde is *ab* ende syn sulck 21. Men begeert te vinden de steeck eens schyfloops met acht staven, dat is: wy moeten een ront vinden diens omtreck in achten ghedeelt synde, dat de wyde van t' een punt tot het ander even sy aen de wyde *ab*.

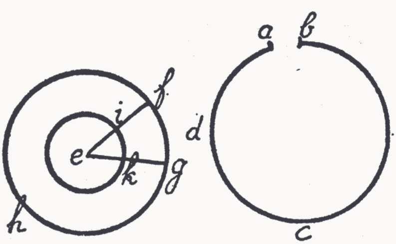

Fig. 14

T'ront *ikl* is t' begeerde ende *ei* syn half middellyn ende wijde *ik*. Syn steeck synde even aen *ab* doordien dat t' ront *fgh*, wat grooter genomen synde, door *fg* in achten gedeelt is. Ende men heeft met de passer de wyde van *ab* gesocht tusschen *ef* ende *eg*.

Wesende gegeven de halfmiddellyn eens camraets ende schyfloops, diens assen van malcanderen onevenwydich syn, oock de dickte des staefs met de breede des cams, dat camrat ende schyfloop so te maken dat de cammen met haer ganse breede tseffens de staven geraken.

Eerst moet men weten te doen in assen op malcanderen rechthoeckich ende dan op malcanderen cromhoeckich. In de Hollanse watermolens is de wateras ende spille op malcanderen rechthoekich, de wieckas ende spille op malcanderen scheefhoeckich, in welcke form de cammen vant onderste wiel geraken int aenkommen: eerst met haer bovenste kant teghen de staven, daernae int afgaen met haer onderste kandt, waeruyt haest diep gekerfde inslythinghen volghen.

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[1]) Henric Stevin (XVIB, Book VI.5.19—VI.6.3) adds this second paragraph to the first, of which he gives only a shortened version.

ON THE MOST PERFECT COGS AND STAVES

Given a cogwheel for which a lantern-wheel is desired, to find the pitch of the lantern-wheel.

Millers use the term pitch for the circle which has been divided in as many parts as there are staves on the lantern-wheel, in such a way that the distance between these parts is equal to the distance between the cogs at half their height, the circumference of this circle having to fit the middle of the staves.

The proportion to be solved is therefore: To draw a circle on the circumference of which as many points are set out equally as there should be staves, the distance between each pair being equal to that between the cogs, calculated at their pitch line. Then this circle will be the size of the lantern-wheel, calculated at the pitch line of the staves, and the width from one point to the other is the desired pitch. This work (calculation) being of little importance, we will leave the matter at this statement, the more so as it is generally known to millwrights; and we will not pursue it in details, because it does not involve mathematics.

abcd (Fig. 14) is the circumference of a wheel through the cogs at their pitch line: the cogs are *ab* wide and there are 21. It is required to find the pitch of a lantern-wheel with eight staves, i.e.: we have to find a circle divided into eight parts in such a way that the distance from one division to the other be equal to the width *ab*.

The circle *ikl* is the required one, its radius is *ei*, and its width *ik*. Its pitch is equal to *ab*, because the circle *fgh*, having been taken somewhat larger, is divided into eight parts by *fg*. And with compasses the width of *ab* has been sought between *ef* and *eg*.

Given the radii of a cogwheel and lantern-wheel, the shafts of which are not parallel, also the width of the staves and cams, construct the cogwheel and the lantern-wheels in such a way that the cogs engage the staves with their full width.

First one should know how to act in the case of shafts that are perpendicular to each other and then of those at an oblique angle. In Dutch drainage mills the scoop-wheel shaft and the upright shaft are perpendicular to each other, and the windshaft and the upright shaft are at oblique angles, in which position the cogs of the lower wheel are when engaging first with their upper side against the staves, then in disengaging with their lower side, which gives rise to heavily carved grooves owing to wear.

Laet *ABCDEF* (Fig. 15) een schyfloop beteeckenen, oft om eygentlicker te segghen, laetet wesen de teyckeningh blyvende int plat, sniende den schyfloop evewydich met de schyven deur d'uyterste geraeckselen der cammen ende staven, ende GH sy de gemeen snee van dat plat ende tplat deur d'uyterste ejnden der cammen, ende *IK* sy tcamrat, (doch overkandt gesneen twelck dan een rechte lyn gelaet), waerop de dry cammen *L, M, N,* rechthoeckich staen. Ende de steeck der cammen sy ten eerste even an de steeck der staven, te weten dat de lyn *LM* even is aen een rechte lyn van tmiddelpunt des rondts *B*; ende tcamrat *IK* sy doender, beweegende van *I* na *K*.

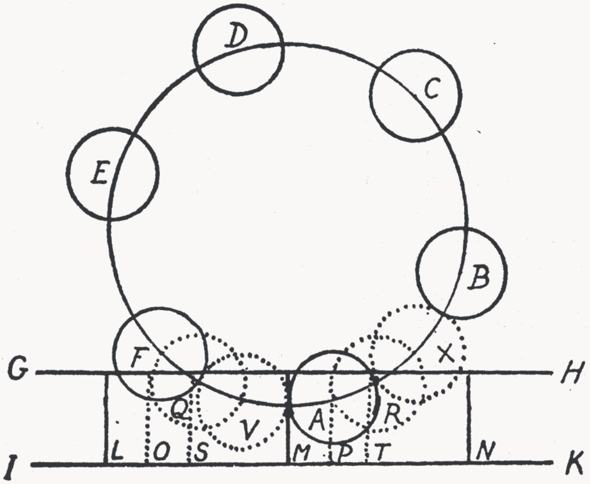

Fig. 15

Dit so wesende, de cam *L*, die haer staef *F* noch niet en geraeckt, sal wel genoech ankommen met haer platte syde teghen de staef, maer niet also int afscheyden. Om welcke dinghen te bewysen, so laet de cam *L* gekommen syn ter plaets van *O*; ende alsdan sal de cam *M* gekommen syn ter plaets van *P*, also dat *LO* even is an *MP*, of *OP* even an *LM*, ende de staef *F* sal gekommen syn ter plaets van *Q*, ende de staef *A* ter plaets van *R*, alwaer ick meen yder cam syn staef te genaken. Twelck so wesende, daer nu de cam *O* geraeckt teghen de staef *Q*, daer is t'punt des eersten genaecksels int ankommen, ende van goeder gestalt, want de cam met haer platte syde teghen de staef aenkompt. Maer met het afscheyden ist anders gestelt. Om twelck te bewysen, so laet de cam *L* nu noch voorder gekommen syn dan tot *O*, te weten tot *S*, ende alsdan sal de cam *M* gekommen wesen ter plaetse van *T*, also dat *ST* even is an *LM*, ende de staef *F* sal gekommen syn ter plaets van *V*, ende de staef *A* ter plaets van *X*. Dit so synde, de cam *S* en geraect haer staef niet; daerom geraeckt de cam *T* haer staef *X*, maer met haer uyterste kandt, also datse daermede thoudt van de staef wech scrabt ende haerselven beschadicht, totdatse malcanderen verlaten.

Dit is een voorbeelt van rechtstaende cammen uyt de even steeck. Maer soo men de steeck der rechtstaende cammen een kennis [1]) kleynder maeckte dan die der staven, so souder wel een vrye losingh uytvolghen, maer een gebreckelycke ankommingh, te weten de staef teghen de cant des cams. Maer soomen de steeck der rechtstaende cammen noch wyder maeckte dan even, so soude teerste ongeval, te weten qua loosingh, noch merckelicker syn dan hiervooren van de even steeck bewesen is. Daeraf wy bysonder voorbeelden souden moghen schrijven, ten waer

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1) Sic.

Let *ABCDEF* (Fig. 15) represent a lantern-pinion or, to express it more properly, let it be (the drawing being in one plane) a section of the pinion parallel to its discs through the outer points of contacts of cogs and staves, and *GH* be the common section of that plane and the plane through the tops of the cogs, and *IK* be the cogwheel (but a cross-section, which results in a straight line), to which the three cogs *L, M, N,* are perpendicular. And let the pitch of the cogs be firstly equal to that of the staves, *i.e.* the line *LM* equal to a straight line from the centre of the circle *B*; and let the cogwheel *IK* be the driver, moving from *I* to*K*.

This being the case, the cog *L* which does not yet touch its stave *F*, will engage the stave sufficiently with its flat side incoming, but will not do so in parting. In order to prove this, assume the cog *L* to be at *O*; and then the cam *M* will be at *P*, so that *LO* is equal to *MP*, or *OP* equal to *LM*, and the stave *F* has moved to *Q*, and the stave *A* to *R*, where I believe each cog will meet its stave. This being so, as now cog *O* touches the stave *Q*, this is the point of the first contact, and in a good position, because the cog engages the stave with its flat side. But disengagement is different. In order to prove this, let the cog *L* move beyond *O*, *viz.* to *S*, and the cog *M* will be at *T*, so that *ST* is equal to *LM*, and the stave *F* will have moved to *V*, and *A* to *X*. This being so, the cog *S* does not touch its stave *V*; therefore cog *T* touches its stave *X*, but with its outer edge, so that it scrapes the wood of the stave with it and damages it until they disengage.

This is an example of straight cogs with equal pitch. But if the pitch of the straight cogs were made slightly smaller than that of the staves, a free disengagement would result, but a defective engagement, i.e. of the stave against the rim of the cog. But if the pitch of the straight cogs were made wider than above, the first defect, *viz.* poor disengagement, would be even greater than with the equal pitch mentioned. We might detail special examples of this, but anyone may try een yghelick by synsleven sulckx wel versoecken kan deur tgene hiervooren gesydt is. De cammen dan en meughen niet recht staen, oock niet voortwaert hellen, want sulck ongeval dan noch merckelicker soude syn, nootsakelick dan moetende achterwaert hellen, daeraf wy nu segghen sullen.

Laet andermael een forme syn met een even steeck, geteeckent met letteren als de voorgaende, wiens cammen nu scheef staen (Fig. 16). Alwaer blyckt dat de cam *L* teghen de staef ofte omtreck van *F* met haer platte syde an sal kommen. Want *L* gekommen synde ter plaets van *O*, so is de staef *F* ter plaets van *Q*, alwaer sy aenkompt ende eerst geraeckt teghen de platte syde des cams. Tblyckt oock dat de afscheydingh op de platte syde geschieden moet, want alsdan sal de cam *M* gecommen syn ter plaetse van *P* ende de staef *A* ter plaets van *R*, inder voeghen dattet raecksel des cams *P* ende staefs *R* aldaer hun laetste geraecksel is ende dat se daer opt punt der afscheydinghe syn, geschiende teghen tplat der staef. Maer om noch mackelicker te sien dat dit het punt der afscheydinghe was, so laet *L* noch wat voorder gekommen syn dan tot *O*, ick neem tot *S*, ende *M* sal gekomen syn tot *T* ende de staef *F* tot *V*, maer de staef *A* tot *X*, alwaer blyckt dat de cam *T* de staef *X* verlaten heeft.

Tot hiertoe hebben wy de saeck so genomen alsof de cammen *L, M, N* van malkanderen int aensien des deursichtichs evewyt stonden. Maer daer is, om eyghentlick te spreken, eenich verschil, hoewel so cleen dattet dickmael met het oogh nau merkelick en is. Doch om sulckx in volkomenheyt te beschryven, so laet getrocken worden de rechte lyn vant middelpunt *Y* des schyfs, rechthoekich op *K*, sniende *IK* in *Z*. Voort so laet uyt de halfmiddellyn des ronts deur d'uyterste ejnden der cammen (welcke halfmiddellyn ick neem $Z\alpha$ te wesen) [1]) beschreven worden tront $\beta\gamma$ ende getrocken worden de lyn $M\delta$ evewydich met $Y\alpha$ sniende $\beta\gamma$ in ε; laet voort van ε tot ζ geteeckent worden de langhde van *LM* ende getrocken worden de lyn $\zeta\eta$ evewydich met $Y\alpha$ alwaer dat het punt η niet vallen en sal in *L*, maer van *L* een weynich naer *M*, inder voeghen dat de steeck der kammen, even genomen aen *LM*, en sal int werck maer so groot vallen als ηM, twelck verschil seer cleyn is. Doch so kan men d'uytkomst daermede ondersoeken gelyck met dander steeck gedaen is.

Te vinden hoeveel de sleet des cams in de staef langher sal syn dan de breede des cams.

Want ons voornemen is de staven niet langher te maken dan tot een beet ofte sleet noodich is. Welcke sleet op de staef wat langer vallende dan =de= [2]) breede des cams, so sullen wy die eygentlicke langhde des sleets verclaren, opdat men weet hoeveel dieshalven de staef langher behoeft te wesen dan de breede des cams.

T'GHEGEVEN: Laet *ABCDEF* (Fig. 17) een schyfloop beteeckenen ende *GH* t' camradt met twee cammen [3]) daerin *I, K*. Ende *LM* sy een lyn uyt het middel des schyfloops rechthoeckich op *GH*, ende de genaeckselen der cammen ende staven in de punten *N, O*, (gevonden duert bovenschreven voorstel) syn de punten der genaeckselen int ankommen ende afscheyden.

T'BEGEERDE. Hiermede moeten wy t'inhoudt des voorstels vinden.

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[1]) No parentheses.
[2]) =de= omitted.
[3]) The mss. has *staven*.

out for himself what has been demonstrated above. The cogs therefore should be neither straight nor inclined forward, for then such defects would be even more perceptible; therefore they must needs incline backward, as we shall now discuss.

Let us again draw a figure with equal pitch, with the same lettering as the preceding one, whose cogs now incline backwards (Fig. 16). This shows that the cog L will engage the stave or circumference of F with its flat side. For L having moved to O, the stave F is at Q, where it first touches the flat side of the cog. It also appears that the disengagement must take place on the flat side, for then the cog M has moved to P and the stave A to R, so that the point of contact of the cog P and stave R is also their last contact and they are on the point of disengaging, which takes place on the flat side of the stave. But to see more clearly that this is the point of disengagement, let L move on a bit beyond O, say to S, then M will have moved to T and the stave F to V, but the stave A to X, which shows that the cam T has disengaged from the stave X.

Up to now we have put the case as if the cogs L, M, N were at equal distances in relation to the section. But properly speaking, there is some discrepancy, though so small that it is often barely perceptible with the naked eye. But in order to describe this correctly, draw a straight line from the centre of the disc Y, perpendicular to IK, cutting IK at Z. Further describe the circle $\beta\gamma$ from the radius of the circle through the tips of the cogs (which radius I take to be $Z\alpha$) and draw the line $M\delta$ parallel to $Y\alpha$, intersecting $\beta\lambda$ in ε, also draw from ε to ζ the length of LM and draw the line $\zeta\eta$ parallel to $Y\alpha$, where the point η will not coincide with L, but will fall slightly beyond L towards M, so that the pitch of the cogs, having been taken equal to LM, will in practice be equal to ηM only, which difference is only slight. But the result can be tested, as has been done for the other pitch.

To find how much longer the „bite" of the cog with the stave must be than the width of the cogs.

It is our intention to make the staves no longer than needed for the "bite" (*beet* or *sleet*). This bite being slightly longer on the stave than the width of the cogs, we will demonstrate the true length of the bite in order that everyone may know how much longer the stave should be than the width of the cogs for this particular purpose.

SUPPOSITION: Let $ABCDEF$ (Fig. 17) represent a lantern-pinion and GH the cogwheel with two staves I, K. Let LM be a line from the centre of the pinion perpendicular to GH, then the points of contact of cogs and staves at N, O (found by the above-mentioned proposition) are the points of contact of engagement and parting.

REQUIRED: With these data we have to find the proposition given above.

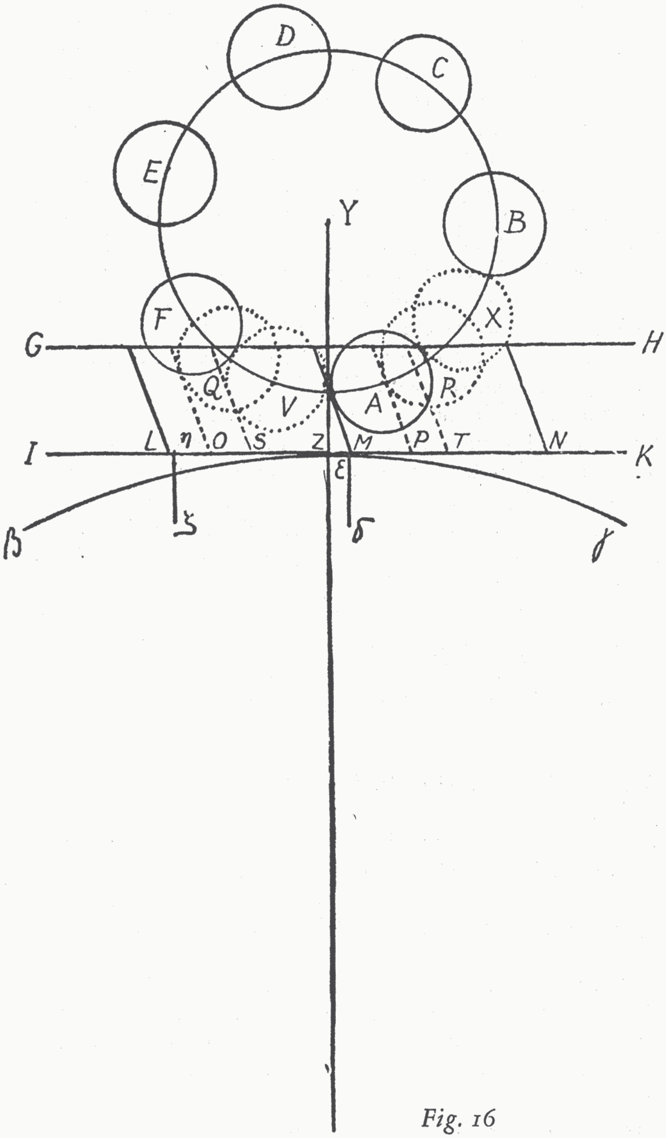

Fig. 16

T'WERCK: Men sal nemen de halfmiddellyn des ronts deur d'uyterste der cammen, daermede beschryvende opt punt als *M* deur een der punten *N*, *O*, dat verst van de lyn *LM* is, als deur *N*, trondt *PQ*, sniende *LM* in *R*; daerna treckende *NS* rechthoekich op *LM* ende *RS* blyft my tbegeerde. Want soveel sal de sleet in de staef langher [1]) syn dan de breedte des cams.

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[1]) *Langhe.*

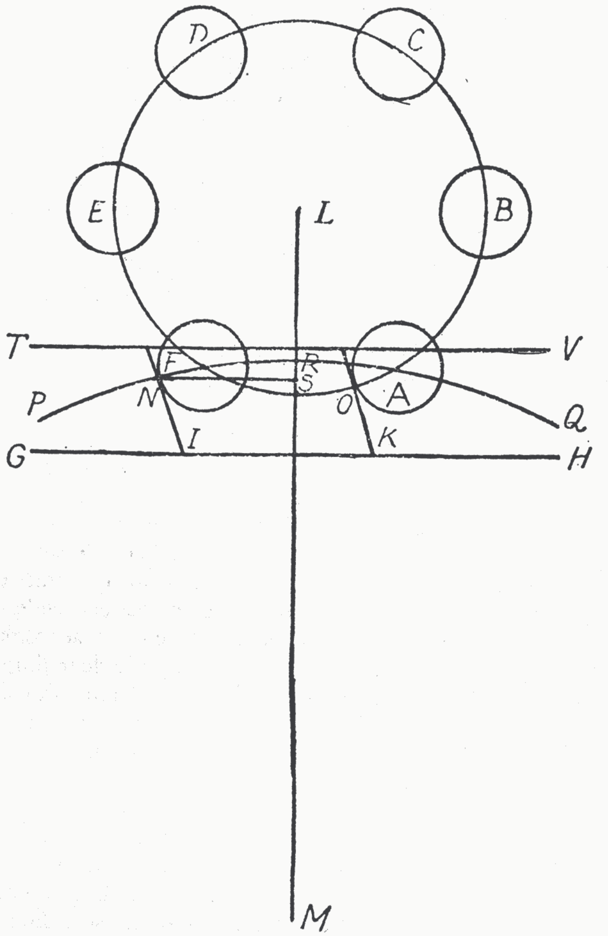

Fig. 17

PROCEDURE: Take the radius of the circle through the tips of the cams and construct the circle *PQ* from *M* through one of the points *N*, *O*, furthest removed from the line *LM*, *viz.* through *N*, intersecting the line *LM* at *R*; then draw *NS* perpendicular to *LM*, then *RS* gives the desired length. For so much longer the bite in the stave will be than the width of the cog.

T'BEREYTSEL: Laet getrocken worden boven *R* de lyn *TV*, rechthoekich op *LM*, beteeckenende een schyf des schyfloops.

T'BEWYS: Aengesien den omtreck *GH* deur d'uyterste syden der cammen streckt, so sal t'uyterste des cams an *N* wesende, verder van de schyf *TV* syn dan als de cam aen *R* compt; ende soveel *N* verder is van de lyn *TV* dan *R*, twelck verschil *SR* is, soveel moet het punt *N* voorder van *TV* syn dant punt =*R*=[1]) is. Daerom oock is de leeghste syde des cams ter plaets *N* soveel verder van de schyf *TV* dan ter plaets *R*, als *SR*; ende vervolgens so is de sleet soveel langher in de staef dan de breede des cams an *SR*, twelck wij bewysen moesten.

Merck noch om de saeck groottelicker te roeren, dat de langhde *SR* deursichtelick aengesien wort, welcke eygentlick soveel langher is als de scheefheyt der cammen veroorsaeckt.

T'BESLUYT. Wy hebben dan gevonden hoeveel de sleet des cams in de staef langher sal syn dan de breede des cams, na de begeerte.

Bequaemste stant der cammen en steec der staven te vinden [2]).

De bequaemste stant der cammen en steec der staven, is als de staven tegen d'eynden der cammen niet aan en commen noch af en scheyden: Want die scherpe canten, daerenboven tegen den draet des houts gaende, doen de staven, ooc haer selve haest morselen, splyten, slyten en onsacht gaen. Maer de staven tegen tplatte der cammen aencommende en afscheydende, gaen also metten draet des houts veel sachter en gedueriger. Hierin feylen sommige Molenmeesters, ende dat deur dien de plaetsen der genaecselen van de cammen en staven, int aencommen ende afscheyden, haer niet grondelic bekent en zijn. Want by die deur linigetrec int plat, van te voren, eer hy thout bereyt, sien can, hoedanig d'uytcomst van sijn werc soude zijn, en sal met een quade steec niet voortgaen. Om dan totte sake te comen, so sullen wy eerst betonen de rede waerom de cammen opt rat niet recht en mogen comen, maer een seker cromheyt achterwaerts moeten hebben in deser vougen. En hebbende hier op deur eenige formen, naer sijn meyning, omstandig bewesen waerom de cammen niet recht en mogen staen, ooc niet voorwaerts hellen, om dattet voornoemde ongeval, so hy segt en waer is, dan noch merckelicker sou syn (welc bewijs wy niet nodig geacht en hebben hier over te dragen, om redenen hier na te doen merken). Nootsakelic dan, segt hy, moeten se achterwaerts hellen: daer af wy nu seggen sullen.

Maer want dit seggen, sonder het gene hier voren verswegen is, van niet veel bescheyts en sou zijn, ja dat by het gene wy daer af in het volgende leren sullen, blyken sal de cammen nootsakelic recht te moeten staen, so sullen wy het mede achterlaten: Alleen sijn besluyt op de sake verhalende, twelc dusdanich is: Hier nu verstaen zijnde, hoe dat men deur een verziert roersel der cammen en staven, de eygentlicke gedaente des waren roersels bekent, so ist openbaer, dat men daer deur, in alles sal mogen van te voren sien, al wat totte sake nodig is; Als (boven het gene wy voren geseyt hebben) de bequaeme langde der cammen, welke te cort of te lanc, en oirsake sijn dat haer canten de staven schaden. Men mach ooc hier deur den stant der cammen totte rechtheyt so naer brengen en so weynich laten hellen, als tot bequaeme aencomming en losing behouft: Want meer te laten hellen dant nodich is, brengt achterdeel by. Men can ooc sien dat een schyfloop met veel

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[1]) "R" missing.

[2]) This paragraph is given by H. Stevin (XVIB, Book VI.6.5—VI.7.9.).

PRELIMINARY: Draw above *R* the line *TV*, perpendicular to *LM*, designating a disc of the pinion.

PROOF: As the circumference *GH* passes through the outer side of the cogs, this outer side of the cog, when it has moved to *N*, will be further from the disc *TV* than when the cog moves to *R*; and so much further as *N* is from the line *TV* than *R* (which difference is *SR*) so much beyond *TV* the point *N* should be than the point *R*. Therefore the lowest side of the cog at *N* is so much further from the disc *TV* than at *R*, *viz. SR;* and again so much longer is the bite in the stave than the width of the cog at *SR*, which we had to prove [1]). Note also, to put the matter correctly, that the length *SR* is seen in perspective, and is in reality the longer as the cogs are more oblique.

CONCLUSION: We have thus found how much longer the bite of the stave should be than the width of the cogs, as required.

To find the best position of the cogs and pitch of the staves.

The best position of the cogs and pitch of the staves is when the staves do not touch the ends of the cogs nor disengage from them. For these sharp edges (which also put against the grain of the wood) soon cause pulverization, splitting, wear, and rough running of these staves and the cogs themselves. But if the staves engage the flat side of the cogs and part therefrom, they run smoother and more constantly with the grain of the wood. Here some millwrights fail, and that because the points of contact of the cogs and staves in engaging and disengaging, are not known thoroughly to them. For those, who drawing lines on the flat wheel in advance, before preparing the timber, can see how the outcome of good work will be, will not proceed with a wrong pitch. In order to come to the point, we will first discuss the reasons why the cogs should not stand straight on the wheel but should have a certain oblique backward inclination. (And having here, according to his opinion, demonstrated in detail by some figures why the cams should not be straight, nor should lean forward, because then the aforesaid defect would be more perceptible, as he states and as is true, which proof we (Henric Stevin) do not believe it necessary to give here, for reasons to be stated hereinafter he (Simon Stevin) says that of necessity they must lean backward;) and this we will demonstrate from now on.

(But as this demonstration, without that which we have left out before, would not give much more information, and even, as we shall teach in the following pages, as it will appear that the cogs must of necessity stand upright, we will omit this demonstration and relate only his conclusion on this point, which is:) It being understood now how one learns to know the real structure of the actual machinery through an imagined machinery of cogs and staves, it will be clear that in this way one will be able to foresee all that might be necessary in such a case, such as (over and above what we have remarked above) the proper length of the cogs, which, if too short or too long, will be the cause of damage to the staves by their sides. One may also in this way bring the position of the cogs as close to the perpendicular and as far from obliquity as suits a proper engagement and parting. For more oblique cogs involve disadvantages. One may also see that a pinion with many staves will engage less deeply than one with few staves, and how much less deeply.

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[1]) This proof is not clear and hardly convincing.

staven, ondieper mach commen, dan met weinig staven, ende hoe veel ondieper. De rechte dicte der cammen mach deur teyckening achter de linien die de aensichten beduyden ooc bekent worden, te weten so dic als men se krygen can, doch vrij tusschen de staven uyt en ingaende. Dese dingen en diergelijke dieder meugen ontmoeten, cammen te voren sien, eermen aent werc comt, om alles versekert te maken.

Inder vougen, dat het verhael, twelc wy tot hier toe wegens ons Vader, angaende cammen en staven gedaen hebben, alleenlic is, om aen te wijsen, syn ernst omtrent die sake gepleecht, als bewegende oirsake vande onse. Maer daer hy de const anders treft, en van een seltsaem bestel der cammen en staven (hoewel de aldervolmaextheyt die wyer hier na toedoen sullen, niet treffende) vermeerdert, dat is in dusdanig werc stuc:

Wy [1]) hebben hier voren wel bewesen, hoe dat men tot alle voor te stelle macht, cammen en staven can maken seer weynig insluytende, ende dat deur formen daer de cammen, met haer hele brede tsevens, de staven geraken; te weten, deur camrayen en schyflopen diens assen van malcander evewydich zijn: maer men soude dese breetheyt der cammen, sonder beter kennis des gronts van haer gedaente, dander tot noch toe geweest is, niet connen te werc stellen in assen die van malcander onevewydich zijn, als onder anderen in de hollantsche watermolens comen de wateras en spille op malcander rechthoekich; Ende de wiecas en spille op malcander scheefhoekich. In welke form de volcommenheyt niet getroffen en is, overmits des cams gehele brede tsevens haer staef niet en genaect. Want de cammen vant onderste wiel, geraken int aencommen, eerst met haer bovenste cant tegen de staven, en daer na int afgaen, met haer onderste cant; waer uyt haest diepgekerfde inslytingen volgen, die de staven niet lange laten dueren. Ten anderen, so en souden de cammen, om haer grote brede, tusschen de staven niet connen comen, overmits de formen der plaetsen tusschen de staven niet evenwydich en steken mette aensichten der cammen. Om dan dese volmaectheyt te treffen, en te doen naer den eysch des voorstels, so sullen wy daer af twe voorbeelden beschryven: het eerste van assen op malcander rechthoekich, het ander van cromhoekich.

1. *Voorbeelt van assen op malcander rechthoekich* (Fig. 18).

T'GEGEVE: Laet *A* de halfmidlini eens camerats tot 44 cammen zijn, te weten vant middenpunt des ronts, tottet midpunt des aensichts vande cam. Waer toe gevonden zijnde de steec des schyfloops van 9 staven deur het Voorstel, comt de halfmidlini vant schyfloop even aen *B* te zijn; en *C* sy de dicte des staefs opt middel der cam en *D* de brede des cams.

T'BEGEERDE: Wij moeten hier toe een camrat en schyfloop so maken, dat de cammen met haer gansche brede tsevens de staven geraken.

T'WERC: Ic trec de lini *EF* en teyken daer in het punt *G*, so dat *FG* even sy aen *A*, en trec rechthoekig op *EF* de lini *GH* even aen *B*, en deurt punt *H* de lini *FI*, en deurt selve punt *H*, rechthoekig op *FI* de lini *KL* even aen *C*, ooc so dat *HK* even sy aen *HL*: Daerna deur de punten *K,L*, de linien *FM, FN*, ooc *FO* in sulken wijte van *FN*, als men het uyterst des cams tusschen de staven wil laten diep commen; ende dese *FO* snyt *HG* in *P*. Nu neem ic uyt *FO*, de lini *OQ* even aen *D*, so dat *PO* even sy

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[1]) This passage from H. Stevin (XVIB, Book VI.7.17— VII.9.15) is not amongst Beeckman's notes, nor has he used the original lettering in the drawing.

The right width across the cogs can also be found from the drawing, which gives a section of the gearing, *i. e.* they should be as wide as possible, but still permit free engagement with and parting from the staves. These things and similar problems which one might encounter can be provided for before setting to work in order to be quite sure.

[We (Hendric Stevin) have given these extracts up to now merely to prove that our father in dealing with cogs and staves treated such matters seriously, and moved us to do the same. But he has a different way of treating this art and adds to it a rare interplay of cogs and staves (though not attaining to the extreme perfection we shall discuss later on), which we here give in detail:]

In the foregoing pages we have duly proved how one can make cogs and staves suitable for all proposed powers, showing little wear, and this by such shapes that the cogs engage at once over their full width with the staves, to wit, by cogwheels and pinions, whose shafts are parallel. But one could not apply this width of the cogs, without better knowledge of the reasons for their shape than acquired until now, in shafts that are not parallel, such as the scoop-wheel shaft and the upright shaft in Dutch drainage mills, which are perpendicular to each other, while the wind-shaft and the upright shaft are at oblique angles. In this shape perfection is not reached since the cog does not engage at once with its stave over the full width. For the cogs of the lower wheel in engaging touch the staves with their upper edge first, and then, when parting, with their lower edge, which may soon cause deeply grooved slits, which reduce the life of the staves. Secondly the cogs, because of their great width, would not enter between the staves, since the forms of the spaces between the staves would not be parallel (but oblique) to the sections of the cogs. In order to achieve perfection, and to meet the requirements of the proposition, we will describe two examples: the first of shafts perpendicular to each other, the other of shafts at oblique angles.

1. *Example of shafts perpendicular to each other* (Fig. 18).

SUPPOSITION: Let *A* be the radius of a cogwheel with 44 cogs, *i.e.* from the centre of the circle to the centre of the cog. The pitch of a lantern-pinion with 9 staves having been found by means of the proposition (mentioned above), the radius of the pinion will be equal to *B*, and *C* is the width of the stave at the middle of the cog, and *D* the width of the cog.

REQUIRED: We have to construct a cogwheel and a pinion in such a way, that the cogs engage with the staves over their full width.

PROCEDURE. I draw a line *EF* and mark the point *G* on it, in such a way that *FG* be equal to *A*, and perpendicular to *EF*. I draw the line *GH* equal to *B*, and through point *H* the line *FI*, and through the same point *H*, perpendicular to *FI*, the line *KL* equal to *C*, also in such a way that *HK* be equal to *HL*. Then through the points *K*, *L*, I draw the lines *FM*, *FN*, and also *FO* at such a distance from *FN* as we wish the tips of the cogs to penetrate between the staves; and this *FO* intersects *HG* in *P*. Now I take from *FO* the line *OQ* equal to *D*, thus making *PO* equal to *PQ*.

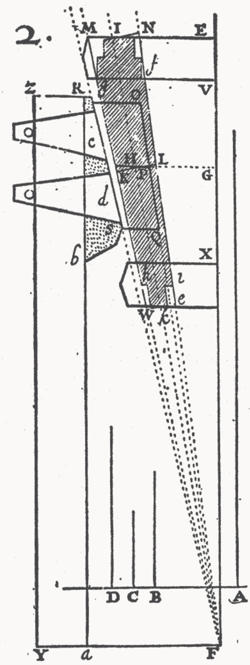

Fig. 18

aen *PQ.* Daer na trec ic de lini *FR,* so wijt van *FM,* als ic plaets wil laten, tusschen de velgen ende de staef. En uyt die *FR* neem ic de lini *RS,* so veel langer dan de brede des cams, als de velge breder behouft te zijn: wesende des cams zijden *RO, SQ,* rechthoekig op *EF.* Daer na teyken ic de halve schyven *MEVR, WX,* rechthoekig op *EF,* so wijt buyten de staven comende, en so dic als nodig valt. Daerna trec ic de lini *FY* rechthoekig op *EF*, en daer op *YZ*, en *aR* evewijdig met *EF*; also dat *Ya* de dicte des kruyserms vant camrat beteykent; en *RSb* de noodige dicte en form der velge. Voorts volmake ic de cam, of om inde ployen cleynder gaten te maken, die de ployen so seer niet en crencken, twe cammen als *c* en *d.*

Daer na volteyken ic de staef met haer pennen als blijkct; te weten, de bovenste pen rechthoekig in de schyf, maer de onderste naer den loop des staefs; op dat, als men de onderste pennen eerst in het schyf steec, dat alsdan de bovenste pennen ooc in haer schyfloop geraken mogen; twelc niet en soude connen geschien, so die bovenste pennen in de schyf niet rechthoekig en quamen gelijct geteykent is. Voorts so trec ic deur beyde d'uytersten der twe pennen de linien *MN, We,* rechthoekig op *FI.* Dit so wesende, *MN*, *We*, beteykent de malle vant viercant hout, dat men bereyden moet, om een staef daer uyt te maken. En *fghi* is het deel datter ront gedraeyt moet wesen, en *i*, *k*, de punten daer men se op drayen sal. Ende de form hier in staende, betekent de malle des staefs met haer pennen. De plaetsen der formen en nesten inde schijven, staen ooc betekent; also ooc doet de mallen der cammen. *EF* betekent het middel van den as of der spille deurt schijfloop stekende; en *FT* middel van den as deurt camrat stekende. Dit so wesende, ic seg dat de cam *ROSQ*, mette gansche brede tsevens de staef geraken sal: tWelc wy hier onder bewijsen sullen. [Doch, segt Beecman, Ic en vinde het niet.]

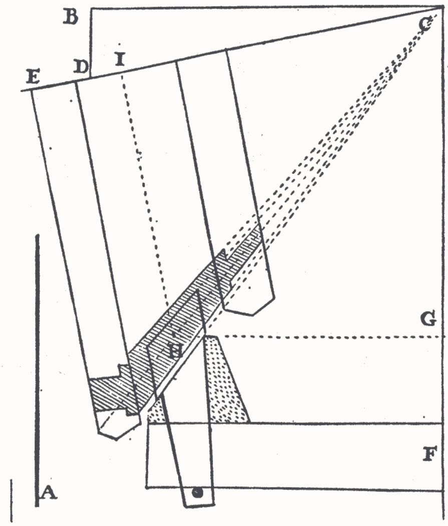

Fig. 18 bis

Then I draw a line *FR* as far from *FM* as I wish to leave space between the rims and the staves. And from this *FR* I take the line *RS*, as much longer than the width of the cog as the rim should be wider, the edges of the cog *RO, SQ* being perpendicular to *EF*. Then I draw the line *Fy* perpendicular to *EF*, and then *yZ* and *aR* parallel to *EF*, in such a way that *ya* is the thickness of the cross arm of the cogwheel, and *RSb* the necessary thickness and shape of the rim. Then I complete the cog or, in order to make smaller holes in the rim and not to weaken it too much, provide two cogs *c* and *d*.

Then I complete the drawing of the stave and its pegs, as is shown, *i. e.* the upper peg perpendicular to the disc, but the lower one according to the position of the stave; so that, if one puts the lower pegs in the disc first, the upper pegs can still be inserted into the pinion, which would not be possible if the upper pegs were not perpendicular, as is shown here. Then I draw through the ends of the two pegs the lines *MN, We* perpendicular to *FI*. This being so *MN, We* show the form of the square timber from which the staves should be made. And *fghi* is the part that should be turned circular, and *i, k* the points where they should be turned. And the form given here is the template of the stave and its pegs. The place of the forms and "nests" in the discs is also shown, and also the template of the cogs. *EF* is the centre of the shaft through the pinion and *FT* the centre of the shaft through the cogwheel. This being so, I say that the cog *ROSQ* will engage the stave at once over its full width, which we shall prove below (But, says Beeckman, I do not find it).

2. *Voorbeelt van assen op malcander scheefhoekich commende* (Fig. 18 bis).

Het werc deses voorbeelts en vinden wy niet, nochte by de voornoemde Beecman, noch ooc elders: Doch de form en enige aentekeningen van dusdanige sin:

Ic teyken de halfmidlini *A* des croonrats (dat is des camrats dat boven aen de spille commen moet) van 20 cammen. Daer op gevonden de steec, ooc van 20 staven, so sal des staefrats halfmidlini even aen de halfmidlini des camrats zijn, en sulx elc even aen *A*. Dit so zijnde, ic trec *BC* als der waterpasse stant; ende daer op rechthoekig *BD*, even aen het vijfdedeel van *BC*. Daer na *CE* deur *D*, als middel vande wint of wiecas. Daer naer *CF* rechthoekig op *BC* als middel vande spil. Voorts *GH* rechthoekig op *CF*; en *HI* rechthoekig op *CE*; so dat *GH* en *HI* elck even aen *A* zijn: Ende dese sal staen als staefrats, en die als camrats halfmidlini tot op middel der cammen en staven. Daer na de lini van *C* deur *H* en alle d'ander, die wy besonderlic niet aen en wijsen, als der selver beteykening deur het eerste voorbeelt licht uyt te vinden wesende.

Dese mallen van cammen en staven hebben ons (al voren totte volgende aldervolmaextheyt te comen) gedient tot een kleen molentgen, als model van een grote achtcante.-

2. *Example of shafts at oblique angles* (Fig. 18 bis).

(We have not found the text of the proposition either in Beeckman or elsewhere. But we have the figure and a few notes on this matter:)

I draw the radius *A* of the crown wheel (i.e. the cogwheel that has to be built on the top of the upright shaft) of 20 cogs. The pitch then being found, also of 20 staves, the radius of the lantern-pinion will be equal to the radius of the cogwheel, each being equal to *A*. This being so, I draw *BC* as the horizontal, and perpendicular to it *BD*, equal to one fifth of *BC*. Then *CE* through *D*, being the centre of the windshaft. Then *CF* perpendicular to *BC* being the centre of the upright shaft. Then *GH* perpendicular to *CF*, and *HI* perpendicular to *CE*, in such a way that *GH* and *HI* are equal to *A*. And the latter will be the radius of the lantern-pinion and the former of the cogwheel up to the centre of the cogs and staves. Then I draw the line from *C* through *H* and all the others, which we will not detail, because their construction will be easily read from the first example.

(These templates of cogs and staves have served us for a small mill, a model for a large octagonal mill, before we found the following most perfect design).-

CHAPTER IV

HYDRAULIC ENGINEERING

1. INTRODUCTION

Simon Stevin has left us two works on this subject, his *New Manner of Fortification by means of Pivotted Sluice Locks* of 1617 and his *Waterscouring*, which was not published until after his death as Book XI of his son Hendrick's *Wisconstich Filosofisch Bedrijf* (1667). Stevin is not a civil engineer in our sense of the word, he is mainly a military engineer with a great interest in hydraulic engineering. In his days this entailed the regulation of rivers, the construction of artificial waterways to supplement the works of nature and the drainage and protection of low parts of a country. This work, in which monastic orders like the Benedictines, Praemonstratencians and Cistercians had played a vital part during the earlier stages, included the problems of stream flow, the improvement of rivers to make them navigable, control to keep them in defined channels and to prevent them from overflowing adjacent territory, the protection of banks and structures against the damage of floods, the construction of sluices and locks and machinery for draining low parts of the country, and the maintenance of such improvements.

It should be realized that all this was still a matter of practical engineering and that no theory or quantitative considerations were yet involved. It is true that Heron and Frontinus had studied the flow of water from a narrow opening but the earliest hydrodynamic laws were deduced after the death of Stevin by Castelli [1]) (1640), Torricelli [2]) (1644), Mersenne [3]) (1644) and Mariotte [4]) (1686).

Modern hydraulic engineering begins much later with Belidor's famous *Architecture Hydraulique* (Paris, 1738-1742, 4 vols), Chézy's basic equation on the flow of water in open channels (1775), Pitot and others.

Practical hydraulic engineering dates back to the great civilizations of the Ancient Near East, whose life depended on irrigation agriculture. Experimental knowledge of irrigation, drainage and water supply problems can be gleaned from many classical authors such as Heron and Vitruvius (Book VIII), though irrigation played but a small part in classical agriculture, and drainage or river regulation problems were then more prominent. The Arabs introduced irrigation agriculture in Italy and Spain, along with the cultivation of rice, oranges, sugar cane and cotton. From the tenth century onwards the attack on forests, marshes and the sea began in Western Europe.

Thus by the fifteenth century practical hydraulic engineering had evolved on specific lines in different parts of Europe [5]). In Italy the main rivers are pre-

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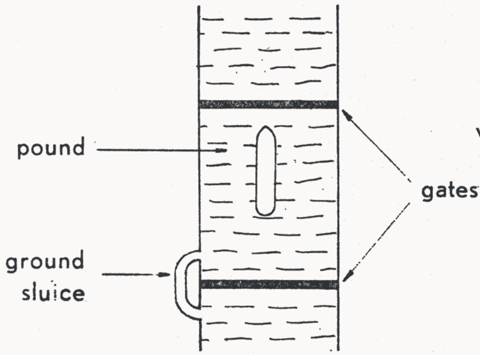
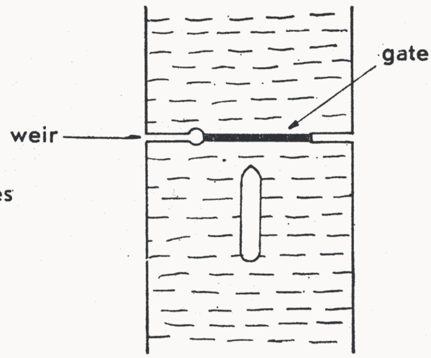
1) *Della misura dell'acqua correnti: Nuova raccolta,* Parma, 1766, I & VII.
2) *Del moto di Gravi,* Firenze, 1644.
3) *Phaenomena hydraulica pneumatica,* Paris, 1644.
4) *Traité du Mouvement des eaux,* Paris, 1686, 441.
5) R. J. Forbes, *Studies in Ancient Technology,* Leiden, Vol. II, 1964.
W. B. Parsons, *Engineers and Engineering in the Renaissance* (Baltimore, 1939).

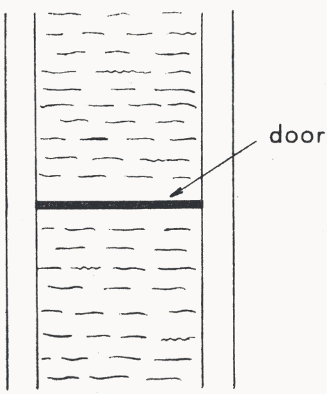
Pound Lock



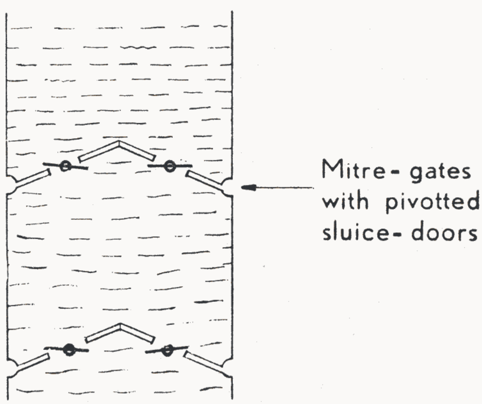
Flash Lock



Sluice



Stevin's „Spilsluizen"



cipitous in their upper parts, the waters being largely derived from accumulated snow. The seasonal rainfall varies greatly and hence the rivers are now torrential now dry. The problem here is to keep them navigable, protect the banks and regulate local irrigation. In France, where the rivers flow more quietly and regularly the problem was mainly to make them navigable and to connect them with canals to further inland navigation and transport. In the Low Countries the problems were entirely different. First strips of low country washed by the sea or rivers were embanked and drained regularly, then lower parts including inland lakes were drained, the large rivers were regulated and a permanent drainage organization was slowly built up. Hence it is natural that much local development took place and that constructions such as locks and sluices had independent evolutions in different areas until sixteenth-century handbooks started to pool such practical experience. Stevin is not interested in all aspects of contemporary hydraulic engineering; he is not a typical civil engineer like Andries Vierlingh [6]), the first Dutch author on embankment and drainage (1507(?)-1579) the greater part of whose handbook has survived (unfortunately without the original drawings), and who contrary to Stevin does not discuss fortifications or the mechanism of drainage mills, but land reclamation and river regulation only. However, Stevin made some very important contributions to hydraulic engineering which we shall now discuss in detail.

2. SLUICES AND LOCKS

The military aspects of Stevin's essay on a *New Manner of Fortification by means of Pivotted Sluice Locks* were discussed in Volume IV, p. 235-246 of this edition. Here we will deal with it from the civil engineer's point of view. It describes a phase of the evolution of sluices and locks which is of great importance. Because of the ambiguous use of technical terms on the part of Stevin and his contemporaries we must start out to define some of these more closely, the more so as the Dutch language has only *sluis*, where the English has "sluice" (*spuisluis*) and "lock" (*schutsluis*), even if the earlier Dutch texts sometimes refer to the former as *spui*. A lock always means a device in a river or canal through which a vessel can pass. We distinguish two types of locks, "pound locks" and "flash locks". The first type consists of a "pound" or chamber enclosed at each end by gates. The second type consists of one gate, set in a weir which, when the water makes a level, can be swung open to pass boats and which can also be used for "flashing" (flushing or scouring) the reach below and assisting craft over the shallows. All the locks which Stevin advocates are "pound locks". He usually calls the chamber *verlaet*, but he also uses the later Dutch terms *sas* or *kolk*. His contemporaries in England often refer to "locks" meaning sometimes one type and sometimes the other. The locks have "gates", the construction of which forms part of Stevin's essay. "Sluices" are devices for controlling the outfall of water from a river or canal or a drainage channel which is not constructed to pass

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[6]) Andries Vierlingh, *Tractaet van Dijckagie,* 1570 (edited and published at The Hague, 1920).

vessels. The movable portion of a sluice which controls the outfall has been rendered consistently by "door" to distinguish it from the gates of locks. The devices for admitting water to, or releasing it from a pound lock are called "paddles" or "lock sluices". There are two types, both of which are mentioned by Stevin. "Ground sluices" employ a culvert constructed in the lock walling to conduct the water from one side of the gates to the other. "Gate sluices" comprise a movable portion of the lock gate. Stevin's essay is mainly devoted to the discussion of sluice doors within the lock gates which are used for scouring and controlling the water level. Stevin's *spilsluizen* should therefore actually be called "pound locks with mitre gates fitted with pivotted sluice doors" but for convenience sake we have termed them "pivotted sluice locks".

Hellenistic papyri refer to sluices in Ptolemaic Egypt, and such devices may have been in use much earlier in Egypt and Mesopotamia as some ancient terms seem to indicate, but we have no exact description of their construction and use. In Western Europe they crop up during the first phase of land recovery and embankment. As the lower parts of the country (but still above ebb-tide) were embanked weirs or sluices were built into the dikes and canals to throw the excess water into the sea. Documents such as the *Notitia vel commemoratio de illa ewa quam quae se ad Amorem habet* (about 800 A.D.) or the Life of Gregory of Tours (c. 580 A.D.) refer to a *sclusa* when they mean a weir or a dike. Such weirs were of course a hindrance to shipping and vessels had to be towed over these weirs by man-power or with the aid of winches. Sometimes the boats shot the weir on the current. These lifts for ships gradually take the form of inclined planes (*overtoom* or *overdragh)* over which vessels were hauled which are illustrated by Zonca [7]) and other Italian engineers and which are still in use in the Netherlands. In certain cases a sluice was built into the weir. Such a "flash lock" or "navigation weir" is referred to by Stevin in his *Waterscouring* (p. 223) as a "weir through which ships will enter."

The history of the pound lock shows what we suspect to be an independent evolution in Italy and in the Low Countries. In the Netherlands sluices were known from the early Middle Ages onwards. There was a sluice in the Rotte in the "Oude Dijk" near Krooswijk in 1065. By 1116 there was also a sluice in the river Scarpe which was to be opened on certain times by order of the Count Baldwin of Flanders. During the twelfth century many new canals were built, the "New Rhine" near Utrecht (1148), the Veurne-Dixmuiden canal in Flanders (1183), and that from the Abbey of St. Bertin to Poperinghe (1187). Near Nieuwpoort there was a large sluice (*magnum slusam*) supervised by the *Fatribus de Dunis* (1184), which also served navigation.

In 1168 a row of sluices were built in the Zwin at Damme, when 1000 workmen from Zeeland and Holland came to help to embank and regulate this branch of the sea and the river Reie leading to the town of Bruges, which was by now silting up seriously [8]). From 1394 to 1396 this row of sluices at Damme was replaced by a real masonry pound lock, which had a *soute deure* (salt gate) and

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[7]) V. Zonca, *Novo Teatro di Machine et Edificii,* Padua, 1656, 58—60.

[8]) Edw. Gaillard, *Inventaire des Archives de Bruges, Table Analytique* (1883/5). L. Gilliodts van Severen, *Inventaire des chartes,* 1ère série, Introduction (1878) and sect. I, Vol. III.

varsche deuren (fresh gates), and these 34 ft. wide gates were 100 ft. apart. The floor of this lock was 200 ft. long. The walls extended 50 ft. beyond the gates and were strengthened with buttresses. The gates were vertical lifting gates with lead counterweights [9]).

It is often claimed that this was the first pound lock in this area. However, in 1226 by a decision of the law courts the bishop of Utrecht is entrusted with the upkeep of three sluices at Spaarndam [10]) and we have an edict of count William II of Holland of April 5, 1253 which mentions the plan to build a 24-foot sluice (*een spoye of een gat*) at Spaarndam, connecting the embanked area of Rijnland with the open water near Amsterdam and Haarlem. This sluice may have been destroyed by floods in 1277 for in 1285 the Spaarne is mentioned as being in open communication with the sea. However, in 1315 a tax for vessels using locks at Spaarndam is fixed. More data on the existence of this pound lock at Spaarndam and its handling have been found for the years 1407, 1425, 1437 and 1441. In 1449 an accident happened, when Claes Dircxsoon having to repair the pound let the gate fall on top of a vessel sailing through and thus wounded Willem Claessoon. Vierlingh gives the estimate of the new pound lock of Spaarndam built in 1567 with three pairs of mitred swivel gates, the central pair being used only in times of danger. An edict of Count William of February 20, 1413 speaks of "locks and pounds at Amsterdam and such as the authorities of Rijnland will construct at Haarlem and Gouda".

By the end of the fourteenth century the advantages of the pound lock, the basin or chamber of which was sometimes formed by part of the town ditch or canal between two pairs of gates, seems to have been recognized throughout the Low Countries and a series of new ones were built at Delfshaven (1389), Brielle (1394), Damme (1395), Schiedam (1395), Gouda (1398) and even in a canal near the Hanse town of Lübeck (1391-1398) which had close trade relations with the towns of Holland.

The evolution of the pound lock in Italy runs somewhat parallel, but it falls in the fifteenth century. In the twelfth century the canals of Milan had *conches,* single barriers or weirs to make them navigable. These navigation weirs had "flash locks", single gates like the flood gates and sluices of the Low Countries, which were opened at certain specified times when the boats plunged downwards or were drawn against the current by man-power or with the aid of windlasses. In 1445 we hear that "a lower lock (in the *Naviglio Grande*) was recently constructed" and thus the operation was made far easier, the pool between these two flash locks being used as a large lock-chamber.

This experience seems to have led to the suggestion of dividing rivers and canals with too large a gradient into pools by means of such flash locks. In a manuscript [11]) written about 1459-1463 by a practical engineer and annotated by Leonardo da Vinci this is worked out, and shows that each pool was handled as a true lock-chamber when boats had to be guided through them. A clearer description

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[9]) On the history of locks see also:
G. Doorman, *Octrooien van Uitvindingen in de Nederlanden uit de 16e—18e Eeuw,* The Hague, 1940, page 278.
G. Doorman, *Techniek en Octrooiwezen in hun aanvang,* The Hague, 1953, 81.

[10]) S. J. Fockema Andreae, *Willem I, Graaf van Holland en de Hollandsche hoogheemraadschappen* (Wormerveer, 1954, page 43).

[11]) *Trattato dei pondi, levi e tirari, Codice Laurenziano* No. 361, Florence.

of the pound lock can be found in Leon Battista Alberti's *De Re Aedificatoria* (1455). Such locks were actually constructed by Bertola da Novate for Francesco Sforza in several canals around Milan between 1452 and 1458. Leonardo da Vinci is said to have completed six locks at Milan in 1487, he invented the mitred gates and the wicket. His note-books illustrate the vertical, horizontal and mitred gates together with many details of the construction of sluice-doors and the proper mechanism for opening, closing and installing them [12]. He illustrates mitre gates with turning sluices in his *Codex Atlanticus* (240 r-c). Stevin and his colleagues enlarged the latter until they occupied the larger part of the mitred gates. Therefore Leonardo deserves the title of the true father of the modern pound lock later described by Zonca and Stevin, though we have no indication that the latter was inspired by foreign examples rather than by developments taking place in his own country. He may have known the French and Flemish locks of the sixteenth century, descriptions of which are still extant [13], but then his compatriot Vierlingh discusses sluices and locks too.

The greater part of Book II of Vierlingh's treatise [14] deals with this subject, but Vierlingh is mainly interested in embankment and drainage problems, and hence he discusses sluices more in detail. Most of the sluices he describes are timber structures, with timber floors and sheet piling along the sills to prevent the water from penetrating below the foundation or entering the sluices from the sides. Vierlingh discusses the foundation of locks at some length. After the cut in the dike has been made the bottom should be properly excavated and filled with clean sand, even if water does well up from the bottom this seems to him the best solution. In some cases he also recommends the use of dried clayey peat (*derrie*). He does not trust pile foundations, for though they are good in principle the vibrations of the water rushing through the sluice are apt to loosen the piles and thus open the possibility of water penetrating underneath the foundation. A well-consolidated clayey peat layer on top of an unstable quicksand or marshy soil would provide a proper foundation for the construction of the timber floor and casing of the sluice. In certain cases water welling up might be stopped with ox-hides.

In order to decrease the pressure of the body of the dike on the sluice channel, layers of well-compacted reed up to 2½ feet below the top of the dike are propagated by Vierlingh. The types of doors described by Vierlingh cover the entire range known to the Italian engineers of his times. Their description is none too clear but they certainly consist of mitre and quoin posts with the appropriate horizontal (and diagonal) members. On the upper side of the frame a sheathing of planks is attached. The joints of the main timbers are framed and strengthened by iron straps, the joints of the sheathings and casings are often "mossed", i.e. filled with Irish moss to obtain a watertight seal. He does not favour the use of doors folding down on the bottom of the sluice, which cause all kinds of trouble in raising and closing and propagates the use of vertical doors. Vertical lift doors are described in detail, but Vierlingh prefers sliding doors which are slid into a recess built into the body of the dike on revolving discs built into the groove of the sluice sill. We do not know whether this construction was ever applied.

Another good alternative is a vertical swinging door, for which a recess in the

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12) *Codex Atlanticus* 7 v.b., 240 r.c.; 33 v.a.; 151 v.b.; 341 v.b.; see also A. W. Skempton in Singer c.s., *A History of Technology,* Vol. III, pages 438—470.

13) *Douai archives* Nos. DD 20, 30 & 439.

14) Vierlingh, *l.c.,* pages 170—264.

chamber of the sluice had to be built in order to prevent a decrease of the section of the sluice area. By means of wooden clamps (*wakers*) or springs (*tijveeren*) precautions were taken to place the doors slightly obliquely to the axis of the sluice and thus obtain better closing. These springs have proved beneficial to give some extra outlet in case of strong drainage as Vierlingh argued. In many cases he propagated the use of two doors, however, his advice to put a third outer or "salt" door on the outside of the sluice chamber may help inspection but involves trouble owing to frost in winter time.

Vierlingh prefers masonry sluices over timbered ones, but he says that corruption in his day often provided "better" arguments for the building of timbered sluices, "masonry sluices yield only dirty refuse, but timbered sluices often throw off a new window-frame to replace an old mouldered one or the like" (*steenen sluysen, diewelcke niet dan vuylicheyt aff en worpen, van houten sluysen crycht men somtyts een nyeuw casynken voor een oud vermuft, ende sulx gelyke*). Economically masonry constructions seem more efficient to him. He also favours the building of small oblique groynes on the outlet channel of a sluice in order to keep this channel well-scoured and he recommends the building of a basin or pool on the inner side of the sluice to obtain regular and efficient drainage. Scouring of this channel, as advocated by Vierlingh is now no longer done.

The size of the sluices depends largely on the area to be drained. Vierlingh advises to build 8-9 foot sluices for areas up to *1000 gemeten* (400 HA),, those of 1500-2000 gemeten should have a twin set of sluices of the above size. The proper adjustment of the sill of the sluice is of prime importance. Vierlingh advises that it be built at the low water level in summer time during an east wind. The doors of sluices will move more easily if a small wickergate (*winket*) be built into them.

This short survey of Vierlingh's discussion of sluices shows that in his day the mitre gate of Leonardo was well-known and was used for drainage purposes too.

If we now turn to Stevin, we find that he begins by describing two devices, which, as they cannot pass vessels, are sluices, one with doors lifting vertically, the other with swinging doors. He then gives details of a pound lock for passing vessels fitted with ground sluices. However, Stevin is not primarily interested in sluices and locks, but he wants to explain how with a few changes they can be used for scouring, and so he goes on to describe his invention and how it was evolved.

First some unnamed person has constructed a sluice at Brielle in which the sluice door itself is pivotted in a vertical axis, these pivots being slightly offset from the centre line of the door. Water pressure holds the door against the groove in the sluice frame until it is raised vertically about three inches by a winch, when, the door being freed, it pivots 90° owing to water pressure acting on the larger side of the door.

Second, Adriaen Jansz, master carpenter of Rotterdam, has constructed a sluice door in a similar way except that he has dispensed with the need for lifting by winch, by substituting an arrangement of locking bars secured by a catch which, when released, allows the sluice door to pivot. In this case the sluice door is mounted in a second swing door which, when opened, clears the channel completely. This frame makes it impossible for such an arrangement to be used for navigation. Jansz. obtained a patent from the States of Holland on 14/12/1594 (Doorman's H 12). In the minutes on this patent (Archives of States of Holland

Vol. 355) a drawing is given, which fortunately partly replaces the missing drawing of the patent itself.

Then Stevin himself constructed mitre-gates for pound locks equipped with very large sluice doors sliding vertically in grooves in the gate frames and lifted by means of winches. Such "guillotine" gates would be satisfactory from the navigation point of view, but the scouring effect would be limited because the sluice doors could not be lifted very far before fouling the winch barrels. Indeed the great depth of the sluice doors was very largely useless. Adriaen Diericxsz. of Delft finally solved the problem by adapting the lever-locking pivotted sluice door of Jansz. to the mitre-gates of Stevin, creating what Stevin then calls "pivotted sluice locks". Diercxsz. obtained a patent for this type of gate and two such sluices were built at Maaslandsluis and Hellevoetssluis.

Later Pieter Adriaensz. (Adriaen Jansz's son) with Claes and Doe Pietersz., his sons, all carpenters and residents of the town of Vlaardingen improved this invention (See States of Holland 2/9/1608 fol. 208 and 21/12/1608 fol. 14) but they obtained no grant of patent since the States were of the opinion that this sluice had already become too widely known, though whoever wanted it constructed had to pay them seven Flemish pounds yearly during a period of seven years.

Stevin was not the only one to wax enthusiastic for the use of sluices to scour harbours. Several of his contemporaries were of the same opinion [15]), however, Constantijn Huygens [16]) voices a strongly negative (but not quite well-founded) opinion in a letter to the hydraulic engineer Michel Floris van Langren, who was engaged in designing a canal between the harbour of Mardijk and Dunkirk. He warns him against the opinion that water dammed up behind a sluice might be used to wash sand away, saying "Stevin has put this heresy into our minds by his essay *On the Pivotted Sluice Locks* but rest assured that we have always found an opposite effect" (*Stevin nous a mis ceste heresie en teste par son traicté Van de Spilsluysen, mais soyez bien asseuré que nous en avons tousjours esprouvé un effect tout contraire*). He recalls what happened at the locks between Amsterdam and Haarlem, where the sometimes very strong current did not cause depth but where silting up was found to occur, and he mentions several other cases too. This is in flat contradiction with the statement by Bélidor who says that good scouring was thus effected in the canal from Bergues to Dunkirk. This type of scouring sluice is no longer used very frequently.

Stevin also mentions the type of lock designed by Cornelis Dircksz. Muys, using folding gates and ground sluices. We have several patents taken by Muys between the years 1583 and 1590 (Doorman's H1, H2, H4, H5, H7 and H9), but none of these has any bearing on the locks mentioned by Stevin, who also tells us that such constructions were built at Vlaardingen, Schiedam and Wynnocxberghen (in Flanders). Muys was of course well-known to Stevin, because he was Town Carpenter of Delft, where Stevin had so many good friends. However, he ran into some conflict with Muys over the latter's patent on a new watermill of 31/10/1589, which he first believed to infringe his own patents. The matter seems to have been settled to the satisfaction of both.

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[15]) H. J. Nuijs, *Redenen en Middelen van Verdieping en Verzanding der Rivieren en Havens* (Zwolle, 1686). See also: Belidor, *Architecture Hydraulique, Seconde Partie, Tome* I (Paris, 1750), p. 337.

[16]) *Briefwisseling van Constantijn Huygens, uitgegeven door Dr. J. A. Worp,* Vol. V; Rijks Geschiedkundige Publicatiën, Vol. 28, 1916, p. 323.

3. PILE FOUNDATIONS AND COFFERDAMS

Before turning to the practical application of his locks Stevin has some further points to settle. The first is the proper foundation of dams and groynes, for which he favours pile foundations. It should be remembered that foundation mattresses made of willow twigs seem to have been invented by Cornelis Claes Pietaels, though his patent of 1631 on *zinksluyzen en zinkstukken* is not very explicit. In Stevin's days pile foundations were used for dams and sluices, though Vierlingh was not very keen on them as we saw. About 1650 the architect Pieter Post gives a description of the construction of the foundation of the locks on the river IJ near Swanenburg. Here Claes Heynderiksen of Assendelft, "notable and skilful craftsman" used the following method. At the entrance of the locks on the IJ-side a timber floor (*stortebedde*) was lowered and fastened on both sides with rows of piles which were thicker around the middle than the holes in the floor through which they passed. The piles were then rammed in through these holes in the floor until this thick part pushed the floor down to its proper level. In the floor four holes were topped by cylinders, which allowed proper earthing after which piles with rounded tops could be driven through these four holes [17]).

In Stevin's day pile-drivers were usually hand-driven (Fig. 19). Two uprights or leads on a frame with inclined back braces kept them rigid. Between the leads ran the hammer, raised by a rope running over a pulley. At the end of this rope there were as many handlines as well required for sufficient manpower to raise the hammer. Driving piles in water was effected by a similar device mounted on a scow. Piles were sometimes shod with iron to facilitate penetration into hard soil and banded at the top to prevent splitting under the hammer's blows.

A mechanical driver is shown in B. Lorini's *Delle fortificazioni* (1596), The hammer is raised by two men turning a crank and released by a locking catch as still used in our pile drivers, where, however, this catch is unlocked automatically as the hammer is raised. Stevin discusses a new feature of loading the pile while it is being driven in, a device which he says he picked up while staying at Melring.

Steichen, Brialmont and Doorman have claimed that Stevin was the inventor of the cofferdam. This is certainly not true for they are already illustrated in Ramelli's *Diverse et artificiose machine* (Paris, 1588). Ramelli shows square piles, cut with mortise and tenon joints, interlocking closely and reasonably tightly against moderate water pressures. This is the fundamental idea of modern sheet-piling either in wood or in metal. The water was then bailed out by hand or by pumps. In one instance Ramelli shows double rows of interlocked piles, the outer surfaces being covered with cloth to reduce leakage and the inner space between the two walls left to be filled with clay puddle. Cofferdams were used in the construction of the piers of the Santa Trinità Bridge, Florence (1584), the Pont Notre-Dame at Paris (1500-1507), the Pont Neuf in the same town (1578), and a series of stepped cofferdams was used in the construction of the Pont Neuf of Toulouse (1540-1632). Hence Stevin cannot claim to be the inventor; though he did give the first intelligent discussion of cofferdams, as his compatriot

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[17]) W. H. Schukking, *Iets over het voormalige kasteel te Harlingen en over paalfundeeringen in de 16e en het begin der 17e eeuw.* (De Ingenieur 1936, no. 25, Algemeen Gedeelte).

Vierlingh knows no better method of draining of foundation pit than the construction of a retaining dam, which he calls *vingerlinck*.

We should here remind the reader of the instrument which Stevin devised "to raise water" in order to "drain the country" or to "empty a harbour" described very inadequately in his patent of 1584, it was probably a piston pump of some kind (see p. 11).

Having discussed the construction and foundation of his "pivotted sluice locks" Stevin proceeds to explain their application to fortification problems. Wherever ditches of fortified towns fall dry at low tide or where there is reason to believe that such ditches will silt up gradually and facilitate the enemy's approach to the foot of the walls, Stevin wants to build his locks at fortitious points in order to convert stagnant waters and dead corners into waterways which can be kept at their proper depth by scouring. He deals with the various possibilities in a systematic way discussing towns on the sea, on rivers, and those cut by a small river giving into a larger one. In some cases he suggests that the waters pent up by his locks can also be made to turn the water-wheels of cornmills supplying the town concerned.

After this more or less theoretical discussion of the application of his locks in various cases Stevin then turns to some practical examples in the fourth chapter. The five main cases discussed in the previous chapters are now here shown to benefit the fortification of many Dutch towns of the period. Rather detailed plans for Calais, Flushing and Deventer are included. Stevin shows that he had some correspondence with the governor of Calais, Dominique de Vic (1551-1610), who commissioned him to submit plans, but though they were approved they were never executed, since the king did not care to spend so much money. We have no indication that Stevin's ideas were ever applied in his day, but they were applauded by many of his contemporaries and by later authors such as Brialmont and Jähns.

4. THE FORMATION OF PEAT AND NEW LAND

Stevin in the third chapter of his New Manner also discussed the application of his locks to the scouring of the canals in low areas like the Dutch polders and peat districts and that of the channel between the mainland and islands, which tends to silt up gradually. His suggestions on the formation of peat owing to the decay of trees which crashed down in forests which have long since disappeared is worth reading. They are supplemented by the discussion of land formation in some passages of his *Stercktebouwing* [18]), and in a less clear discussion of the stratification of new land in his essay on *Waterscouring*.

These passages are but digressions from the main theme here, for Stevin deals in fuller detail with this subject in one of his other books the *Eertclootschrift* [19]), printed as part of his *Wisconstighe Gedachtenissen.* The second book of this essay deals with what Stevin calls *stofroersel des eertcloots* (the movement of matter on our globe). Here Stevin points to wind and water as the main factors in the

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[18]) Work IX, pp. 83—86. This edition, Vol. IV, pp. 215—221.
[19]) Work XI, i, 2.

displacement of matter on the surface of the earth. Large rivers carry stones, loam, clay and sand from the mountains to lower parts of the globe and thus building up new land and silting up certain stretches of water. The sea forms dunes. Wind and sun act on the deposited materials, causing it to rot and change into the types of soil we know and use to our benefit.

Stevin is quite modern in the way in which he appeals to natural forces only in explaining the changes in the surface of the earth. Some of his remarks can be found in earlier authors, but we do not know whether he knew and consulted them. Nor is it clear whether his exposition is the earliest essay on the subject. However, his views on the formation of new land, the forms of quicksand (so troublesome in civil engineering works) and the way in which a river changes its course become important when we turn to the second essay by Stevin translated in this volume.

Stevin's second important work on hydraulic engineering is his *Waterschueringh,* which was published posthumously by his son Hendrick. Stevin himself seems to have intended to add this treatise to his *Huysbou* for he says: "As so many houses, redoubts and towns are built on embanked land, where the knowledge of the general properties of scouring is advantageous, I will now, as it belongs to the *Building of Houses,* say something on it". Indeed Hendrick Stevin mentions this essay as Chapter 17 in his table of contents of the *Huysbou*, at least a series of subjects belonging to it. Stevin himself had of course mentioned several points already in his *New Manner of Fortification* of 1617. Somehow the essay got detached from the *Huysbou*, but we have no indication of the manner in which Stevin wanted to publish his reflections on the subject of scouring. Hendrick Stevin also points to his father's *Eertclootstofroersel,* which contains similar notes.

Certain portions can be dated. The letters to the governor M. de Vic on the fortress of Calais must have been written in the years 1596-1598, when this town was occupied by the Spaniards. Stevin's projects for Danzig must have antedated the years 1619 to 1623 when Willem Jansz Benning, alias Ketel, and Adriaen Olbrantsen, both from the town of Alkmaar built a navigation weir or flash lock in the Mottlau where it touched the town, not far from the Theerhof. This they built by basing themselves on a plan already in existence, which may have been that of Stevin. The primitive type of dredging apparatus which Stevin recommends to be used at Danzig may also go to show that this part was written before the rapid evolution of dredging apparatus in the Netherlands in the first decades of the seventeenth century. However, we are still in the dark as to when the main body of this essay was written.

De Waard gives the following table showing where certain passages of the *Waterschueringh* can be found in the *Journal* of Isaac Beeckman (Vol.II,pp.XIV, XV and pp. 417, 418):

Title	*Extract in I. Beeckman's Journal*	*New Manner of Fortification 1617*	*H. Stevin Wisc. Fil. Bedrijf 1667*
Een riviere haer in tween scheydende en die deelen tot een ander plaets weerom versamelende, het corste heeft de snelste stroom en meeste schuering.	Fol. 206 *verso*, *ll.* 15-17; Fol. 206 *verso*, *l.* 18-207 *recto* *l.* 5		Bouc XI, p. 38, *l.* 8-p. 40, *l.* 29.
Te verclaren de gemeene regel van schuering door wantyen.	Fol. 207 *recto*, *ll.* 6-8 et 9-12		p. 41, *l.* 15 seq.
	Fol. 207 *recto*, *ll.* 13-27.		p. 42, *l.* 11-p. 43, *l.* 16.
	Fol. 207 *recto*, *ll.* 28-29		p. 44, *ll.* 19-25
	Fol. 207 *verso*, *ll.* 1-7		p. 45, *ll.* 3-18.
Van de schuering met sluysen.	Fol. 207 *verso*, *ll.* 8-14		p. 46, *ll.* 4-20 p. 47, *ll.* 6-28
	Fol. 207 *verso*, *ll.* 15-26.		p. 48, *ll.* 12-16 p. 48, *l.* 36-p. 49, *l.* 14.
	Fol. 207 *verso*, *ll.* 27-38	p. 5 *l.* 20-p. 12 *l.* 10. Cf. p. 58 *ll.* 23-38.	p. 49, *l.* 22-p. 51, *l.* 23.
	Fol. 207 *verso*, *l.* 39-208 *recto* *l.* 14.	Cf. p. 59	p. 52, *l.* 6-p. 53, *l.* 2.
	Fol. 208 *recto*, *ll.* 15-19	p. 57, *l.* 43-p. 58, *l.* 2	p. 53, *ll.* 24-29.
	Fol. 208 *recto*, *ll.* 20-25		Boec. XI, p. 53, *l.* 30--p. 54, *l.* 4.
	Fol. 208 *recto*, *ll.* 26-37		p. 54, *ll.* 7-19
	Fol. 208 *recto*, *ll.* 37-40		p. 54, *ll.* 20-33
	Fol. 208 *verso*, *ll.* 1-4		p. 54, *ll.* 34-37

Beeckman's notes are mostly paraphrases or greatly abridged versions of the text given in the *New Manner of Fortification by means of Pivotted Sluice Locks* (1617) and Hendrick Stevin's edition of his father's notes on waterscouring in his *Wisconstich Filosofisch Bedrijf*, Boec XI (1667).

5. ON THE SCOURING ACTION OF WATER

In his *Waterscouring* Stevin extends and applies some of the doctrines he developed in his hydrographic chapters of the *Eertclootschrift*. There he had not only discussed the deposition of all types of materials from rivers both along their course and in their delta, but he had also explained the gradual changes in the course of rivers. He had argued that on the outer side of a river bend (*schoor*) the strong current causes great depth and tends to wash away the banks, at the inner side of such a bend (*strant*) one finds shallows and new land forming. Hence a river will become more and more sinuous until it breaks through its banks forming a new short-cut course and a dead river-arm. The great merchant towns on the out bend of a river, such as Antwerp, London, Cologne, Nijmegen and Rotterdam, profit by these circumstances.

The shallows in front of a river's mouth are explained by Stevin from a decrease of the velocity of the current and partly from the gentle sloping of the coast owing to the decreased scouring effect of the current. In his *Waterscouring* he goes into further detail on the effects of the current in a river-bed and its practical use for engineering works. He discloses the reasons for the silting-up of a branch of a tidal river, which later meets the main river again. These effects of a neaptide (*wantij*) can be counteracted.

He also explains why creeks in open communication with the sea are deeper as they are wider, in contrast to rivers, which are deeper as they are narrower. He proves this by pointing to the creek which forms the harbour of Sluys and by a discussion of the "large creek between France and England", which connects the Spanish Sea (The Atlantic) and the German Sea (the North Sea).

Stevin now applies his theories to several cases detailed in this essay. The first is the case of a town sufficiently close to the sea for the tides to reach it. Two canals are now dug from the sea harbour to the town ditch which serves as a water reservoir. When sluices or locks are built in these canals the low-water level at low tide can now be used to effect proper scouring of these waterways. Such examples of this are the towns of Bruges, Middelburg and Leyden.

The second case concerns towns on the sea shore. Here the water reservoir is built inland and the two canals either give into the sea separately or they end in a sea harbour. The latter solution has certain hydrographic advantages but also may cause difficulties to the fortification of such towns. The examples discussed by Stevin are Ostend and Calais.

The rest of the essay is devoted to the detailed discussion of plans for engineering works for Danzig, Elbing, Braunsberg, Deventer and Zutphen, Rheinberg, Schiedam, Lingen and Calais. In the case of the latter town we know that these plans were never realized for lack of money. We have no idea what happened to the other plans made by Stevin.

6. DREDGING

The float manned with workmen effecting hand-dredging, which Stevin recommends for use at Danzig is the most elaborate form of dredging mentioned by him. It is curious that he nowhere mentions the more effective dredging machinery that was known in his later days.

The oldest mechanical dredger used in the Low Countries was the *krabbelaar* ("scratcher"), a vessel carrying iron harrows attached to its bottom. At ebb-tide it was used to loosen the bottom of the channel and harbour entrances, aided by sails and by under-water wings which could be spread to catch the current. This primitive mechanical dredger also called "Water-Harrow", "Water-Plough" or "Mole", was in use in the town of Middelburg by 1435 in connection with a tidal reservoir, and such *krabbelaars* continued in use for several centuries (Veere, 1800). It is possible that a patent granted to Mertten Teunissen in 1602, relates to an improved form of *krabbelaar* (Doorman's G 70).

The rapid development of such machinery in the early seventeenth century was studied in detail lately [20]). In 1589 Cornelis Dircksz Muys, well-known to Stevin, patented the so-called Amsterdam mud-mill (Doorman's Nos. H5 and G6). The term of this patent was from 1589 to 1601 and the conditions for its application by the towns of Holland were fixed by the States of that province. A series of boards on a chain push the mud up a wooden gutter. This chain-dredger was pivotted at one end, the other could be lowered to the river bottom by means of a hand-winch. The chain was driven by men operating a treadmill. These mudmills remained in use for some 250 years, but they were further mechanized, horses were substituted for the men providing the original driving power.

This horse-driven mud-mill with two series of 35 buckets was patented by Jacob Jacobsen in 1622 (Doorman's patent No. G. 209). A well-known picture of the man-driven chain-dredger, sometimes ascribed to Breughel was in reality drawn by the Dutch painter R. Savery somewhere between 1600 and 1620. It clearly shows the two huge treadwheels moved by human power. The first clear description of buckets applied in the chain-dredger occur in a story on the deepening of the river Maas near the little town of Heusden (Brabant) in 1623. The buckets were made of copper, the chain dredger was still moved by manpower. Jan van der Heyde, often mentioned as the inventor of the fire-engine, in 1674 built a large wheel-dredger for the town of Amsterdam at the cost of fl. 6000,—.

A patent granted to Pieter Hendricxz and Jacob Willemsz. of 1603 probably refers to a ladle-type dredger (Doorman No. G. 80). The ladle-dredger, the model of which is still to be found at the office of the *Hoogheemraadschap van Rijnland* at Leyden, is probably identical with that granted to Dominicus van Wesel (Doorman No. G. 278) in 1627. The oldest type of wheel-dredger in the Low Countries can be traced back to the patent of Coenraerdt van Neurenborch of Dordrecht (probably a German) (Doorman No. G 93), granted in 1603. The patent granted to the Venetian P. Venturino in 1561 does not refer to a chain-dredger, but to a grab-dredger (Doorman No. K 2) like the "mud-ship" (*slickschip*) discussed by a law-court at Dordrecht on November 26, 1562 [21]).

It seems therefore rather strange that Stevin neither mentions nor applies any

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[20]) G. Doorman, *Hollandse oude Baggermolens* (De Ingenieur 1951, pages A 413—417 and 428).
G. Doorman, *De Amsterdamsche Moddermolen* (Mbl. Amstelodamum, 1951, pages 147—151).
G. Doorman, *Cornelis Dircksz. Muys, de uitvinder van de Amsterdamsche Moddermolen* (De Ingenieur 1952, pages A 83—85).

[21]) T. Jansma, De economist 1941, page 679.

of these mechanical dredgers in his projects. He does of course mention the vessels collecting the mud thus dredged and transporting it to the sea or other spots where it could be dumped. In his patent of 1589 after describing his "dredge-net" recommended for the Danzig project, he also mentions such a vessel which could be unloaded by opening flaps into its bottom (see page 21).

CHAPTER V

NIEUWE MANIERE
van
STERCTEBOU DOOR SPILSLUYSEN

NEW MANNER OF FORTIFICATION
by means of
PIVOTTED SLUICE LOCKS

NIEVVVE MANIERE
VAN
STERCTEBOV,
door Spilsluysen.

Beschreven door *Symon Stevin* van Brugghe.

TOT ROTTERDAM,
By Ian van VVaesberghe, inde Fame.
ANNO 1617.

AEN DE

HOOCHMOGHENDE
HEEREN DE GENERALE STATEN DER VEREENICHDE NEDERLANDEN.

TIs kennelic, *Hoochmoghende Heeren*, dat de VVaterſteden, gheleghen aen Zeen en groote bevaerlicke Rivieren, op beyde de eynden aen den waterkant kranc zijn, hebbende tot die plaetſen of drooge Grachten, of Beeren, buyten welcke men met leeghe wateren drooch voets aende mueren of wallen kan komen: Maer want door de nieuwe vondt der ſchuerende Spilſluyſen onlancx te voorſchijn ghekomen, de krancke plaetſen bequamelic verſterct konnen worden, en datmen daerenboven de Grachten tot diepe Havens kan ghebruycken, ooc ten tijden van ijsganc de Schepen daer in berghen en verwinteren, ſtreckende niet alleen tot verbetering der Steden en des ghemeenen Landts, maer ooc tot behoudenis van lijf en goet der varende Menſchen: Zoo heeft my oorboor ghedocht daer af te doen deſe korte beſchrijving. Tis wel zoo, dat eenighe die my vermaent hebben, de zake van *Sterctebou* te laten uytgaen, daer af een volkomender beſchrijving verwachten: Maer my heeft goet ghedocht voor eerſt dit ghedeelte daer uyt te trecken, op dattet niet ſtaende onder veel ander ſtoffen die niet yghelicx gading en zijn, te beter van velen mocht ghéleſen worden, en voornaemlic van

 zulcke

TO THEIR HIGH MIGHTINESSES, THE STATES GENERAL OF THE UNITED NETHERLANDS

It is obvious, Your High Mightinesses, that water-side towns on seas and large navigable rivers are vulnerable at both sides on the edge of the water, since they have either dry town-ditches or dams at those places, through which one can approach the wall with dry feet at low-tide. But because by the recent invention of scouring pivotted sluice-locks these vulnerable places can easily be fortified and moreover the town-ditches can be used as deep harbours, even in times of ice-drifts, to shelter vessels or to winter them, which not only improves the towns and the commonwealth, but also benefits the safety of the sailors, it seemed profitable to me to give this short description of it. It is true that some people have counselled me to treat it as part of the problem of *fortification* expecting a fuller description of it, but I preferred first to extract this part, so that it might not be included amongst zulcke diens oordeel totte zake ghelt, om het dadelic ghebruyc daer uyt te doen volghen : Tot dien eynde iſt ooc, dat ic deſen handel uwe *Hoochmoghentheden* toeeyghen, die ic, hopende dat ſy myn goede meyning int goede zullen nemen, wenſche voorſpoedighe regiering.

Gheſchreven inden HAEGH, den 21 December 1617,
door uwe *Hoochmoghentheden* onderdanighen Dienaer

Symon Stevin.

many other matters which do not interest everybody, and thus might be read better by many and especially by those who have proper judgement to apply it in practice. To this end, your High Mightinesses, I dedicate this treatise to you, hoping that you will take in good part my good intention and I wish you a prosperous reign.

Written in The Hague, December 21, 1617 by Your High Mightinesses' obedient servant

Simon Stevin

KORT BEGRYP DESES HANDELS.

AEnghezien deſe nieu manier van STERCTEBOV, gheſchiet deur een nieu manier van Sluyſen onlancx ghevonden, die daerom aen velen onbekent is, zoo zal daer af, metſgaders vande verſtijving der gronden eerſt verklaring ghedaen vvorden. Daer na zal volghen de manier en ghemeenen reghel der ſchuering van Stadtsgrachten en Havens, die door de voorſchreven Sluyſen in ſtof van STERCTEBOV gheſchieden kan: Maer vvant daer toe ghenomen vvorden voorbeelden met een Stadt van oordentelicke form, als bequaem zijnde tot verklaring des voorſchreven ghemeenen reghels, en dat nochtans het dadelic ghebruyc moet gheſchieden met Steden van zulcken form alſſer voorvallen, zoo zal daer af int laetſte ghezeyt vvorden, alles vervanghen zijnde in vier Hooftſtucken, diens opſchriften zijn als volght:

Het 1 HOOFTSTVC *vande nieuvve vondt der ſchuerende Spilſluyſen.*

Het 2 HOOFTSTVC *vande verſtijving der gronden van Sluyſen en Beeren.*

Het 3 HOOFTSTVC *inhoudende ghemeenen reghel, van der Steden nieu manier van verſtercking, door ſchuerende Spilſluyſen.*

Het 4 HOOFTSTVC *inhoudende voorbeelden, hoemen eenighe Steden die dadelic in vveſen zijn, door de ghemeene reghelen des 3 Hooftſtucx kan verſtercken.*

SUMMARY OF THIS TREATISE

As this new manner of fortification is executed by means of a new type of lock-gates recently invented, which is therefore unknown to many, we shall first explain them as well as the consolidation of the foundations. Then we shall treat of the manner and general rule of the scouring of town-ditches and harbours, which can be achieved with the above-mentioned lock-gates in the field of fortification. But as we shall take a town of a regular form as an example, which allows of an exposition of the above-mentioned general rule, and the results will have to be applied in practice to towns of such forms as happen to occur, we shall deal with the latter cases in the last chapter, our subject being dealt with in four chapters, the headings of which are as follows:

CHAPTER 1.

Of the new invention of scouring pivotted sluice locks.

CHAPTER 2.

Of the consolidation of the foundations of locks and dams.

CHAPTER 3.

Containing the general rule of the new manner of fortifying towns by means of scouring pivotted sluice locks.

CHAPTER 4.

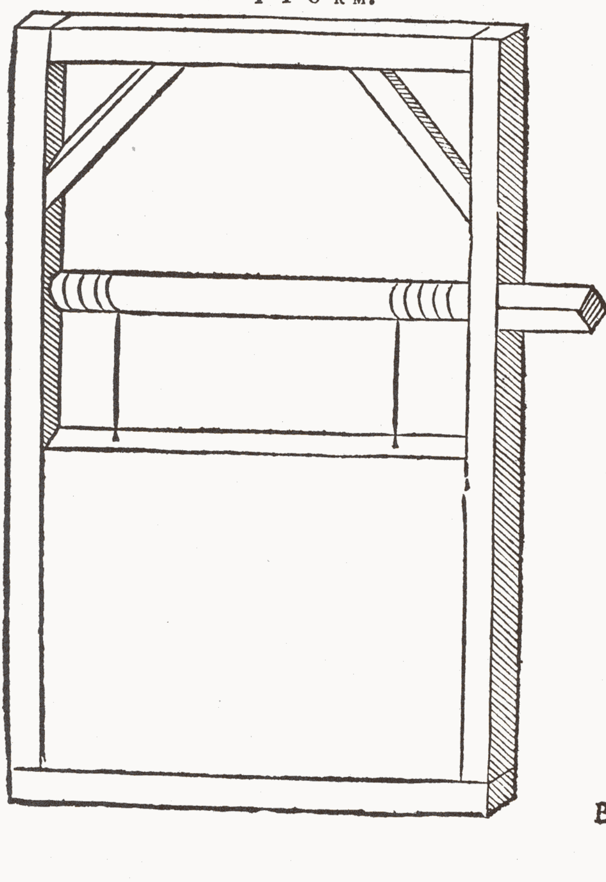
Containing examples of how certain existing cities might be fortified by the general rules laid down in chapter 3.

I HOOFTSTVC,

Vande nieuvve vondt der schuerende Spilsluysen.

OM grondelicker te verklaren waer in dese nieuwe vondt der Sluysen gheleghen is, zoo zegh ic voor eerst 'tghebruyc van Sluysen te bestaen in drie voornamelicke verscheydenheden: Als om Havens te schueren: Leeghe Landen te drooghen: En Schepen met staende masten door te varen: Tot welcke drie verscheydenheden in dese Landen ghebruyct worden driederley soorten van Sluysen: D'eerste verscheydenheyt vande Havenschuering, heeftmen langhen tijt beqnamelicxt ghedaen met optreckende Sluysdeuren, ghelijc aenghewesen wordt met dese 1 form, waer af 'tghebruyc dusdanich is: De Sluysdeur opghewonden zijnde, en 'tvloetwater inden houder loopende, tot dattet ten hoochsten is, men laet de deure neervallen, en ghesloten blijven tot dat d'ebbe ten leeghsten is, en alsdan de deure om hooch ghewonden zijnde, zoo valt dat opghehouden water inde drooghe leeghe Haven daer in diepte schuerende. Anderzins wort dese schuering ooc wel ghedaen met opghehouden regenwater, ooc met water van kleene Rivierkens, 'twelc hooch ghenoech vergaert zijnde, zoo wort daer me de schuering ghedaen als voren: Doch en konnen deur zulcke Sluysen gheen groote Schepen met staende mastẽ varẽ, om dat de deure en dẽ as daermense me opwint inde wegh zijn.

1 FORM.



Benevens

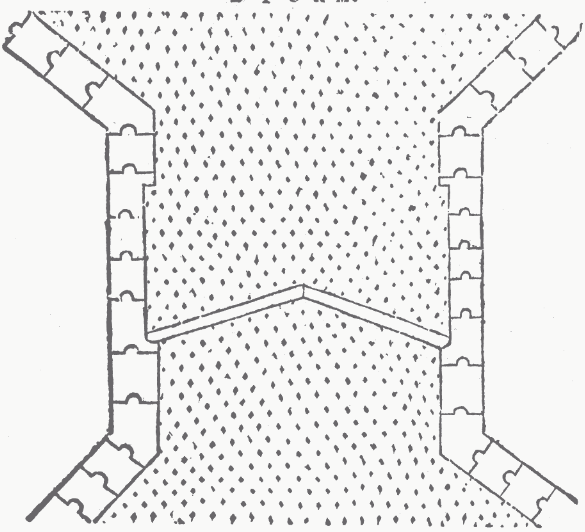
CHAPTER I

On the new invention of scouring pivotted sluice locks.

In order to explain more clearly what is the essence of this new invention of locks, I would first state that locks are used for three main different objects: To scour harbours, to drain low areas, and to allow vessels to pass through with upright masts; for which three purposes three kinds of sluice or locks are used in these countries. The first object, that of scouring harbours, has long been satisfactorily achieved by means of vertical sluices such as shown in Figure 1, which are used as follows: The sluice door having been raised by hoisting, and the floodwater having flowed into the chamber until it has reached its highest level, the door is lowered and kept closed until low tide, and then, the door having been raised, the pent-up water scours and deepens the dry and empty harbour. This scouring is also effected with stored rain-water and also with water of small rivers, stored until the level is sufficiently high, the scouring being effected in the same manner. But no large ships with upright masts can sail through such sluices, since the doors and the (windlass) shaft with which they are raised are in the way.

Aengaende de tweedde ſoorte van Sluyſen,dienende tot het droogen der leeghe Landen, daer toe ghebruyctmen bequamelicxt Sluyſen met puntdeuren (die zommighe noemen ſwaeydeuren en ſteecdeuren) welcke geleyt worden onder de Dijcken, waer af de grontteyckening is ghelijc de volghende 2 Form uytwijſt, weſende zoodanich dat het buytenwater leeghſt zijnde, de deuren van zelfs open gaen en water looſen,maer het buytenwater hooghſt wordende,ſluyten van zelfs. En hoewel zommighe hier toe ghebruycken optreckende deuren, als die des 1 Forms, zoo en zijnſe tot dien eynde niet de bequaemſte, want het moeyelic valt daer dagelicxſche ebbe en vloet is, dach en nacht gade te ſlaen de deuren t'haerder tijdt open en toe te doen; ooc is het opwinden beſwaerlic: boven dien en machmenſe zoo wijt niet maken, om veel water te looſen, overmits dat de deuren al te ſwaer en moeyelic zouden vallen om op te vvinden: Zulcke ſteecdeuren hebben het achterdeel,datter gheen groote Schepen met ſtaende maſten deur varen en konnen, om dat den Dijc daer op ligghende, belet doet: Ten anderen, datſe de Havens niet zeer diep en ſchueren, om dattet water niet van hooch inde drooghe leeghte en valt, als van d'eerſte ſoorte, maer allencxkens daelt.

2 FORM.



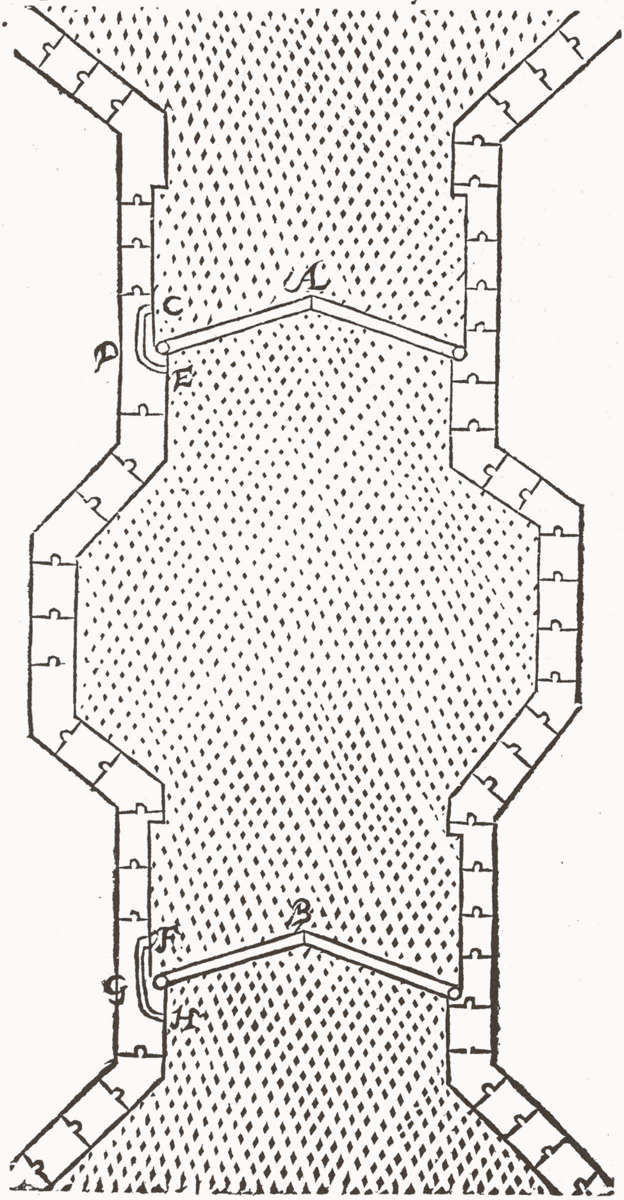
Zoo veel belangt de derde ſoorte van Sluyſen, dienende tot het deurvaren der groote Schepen met ſtaende maſten, dat wort te weghe ghebrocht met twee paer ſteecdeuren, die niet onder den Dijc en ligghen als de tweedde ſoorte, maer inden Dijc zoo hooch komen als den Dijc zelf,zulcx datſe van onder tot boven voor Dijc verſtrecken, om alle hoochſte wateren te ſchutten, waer af de grontteyckening aenghewesen wort mette navolghende 3 Form, daer af 'teerſte paer deuren is A, het tweedde paer B, vervanghende tuſſchen beyden een kolc, ſas, of verlaet, met twee waterloopkens inde zijmueren ghewrocht,diemen ſlecken noemt, als C,D,E, en F, G, H, hebbende elc een Sluysdeurken. Anderzins maectmen wel kleene optreckende Sluysdeurkens inde groote puntdeuren. Tghebruyc hier af is dusdanich: Wanneer een Schip met ſtaende maſten van buyten in wil komen, als van A na B, en dattet buytenwater hoogher is dan het binnenwater, zoo laetmen deur de ſlecke

For the second type of lock, serving to drain low areas, the most suitable are sluices with swivel-doors (which some call swaying or mitred doors), which are built into the dikes, as the groundplan in Figure 2 shows, and which are constructed in such a way that the doors open automatically when the outer water stands at its lowest level, thus draining the water, but close automatically when the outer water rises to its highest level. And though for this some people use vertical doors, like those in Figure I, these are not so suitable for this purpose, for where high tide and low tide occur every day it is difficult to watch them day and night in order to open and close them in due time; the hoisting is also difficult, and moreover they should not be made too wide for draining much water, since it would then become hard and difficult to raise the doors by hoisting. Such swivel-doors have the disadvantage that no large vessels can pass through them with upright masts, because of the dike running over them. Secondly, they do not scour the harbours to a great depth, because the water does not fall from a height into the dry and empty harbour, as in the first type but flows away gradually.

As regards the third type of lock, serving for the passage of large vessels with upright masts, they are constructed with two pairs of swivel-gates, which are not built under the dike, like the second type, but which extend in the dike up to its top, so that they reach from the bottom to the top of the dike in order to dam up the highest water, as is shown by the ground plan in Figure 3, in which the first pair of gates is *A*, the second pair *B*, the two enclosing a chamber (*kolk, sas,* or *verlaat*) with two ground sluices built into the side-walls, called *sleck, CDE* and *FGH*, each having a small sluice door. Sometimes small sliding sluice doors are built into the large gates. They are used in this way. When a ship with upright masts wants to enter, *i.e.* from *A* to *B,* and the outer water level is higher than the inner level, the sluice *CDE* is used to fill the chamber up to the level of the

C D E het kolc vol waters loopen, 'twelc zijnde ter hoochde van t buytenwater, de twee deuren aen B zijn toeghegaen, maer die aen A konnen metter handt open ghetrocken worden, en komen de Schepen die deur moeten varen int kolc, welcke daer zijnde, men ſluyt de ſlecke C D E, ooc het paer deuren aen A, en men opent de ſlecke F G H, latende het vvater des kolcx uytloopen, tot dattet is ter leeghte van't binnenwater, zulcx datmen de deuren aen B metter hant open doet, en varen de Schepen voort te landewaert in. Deur 'tghene ic hier ghezeyt heb van't inkomen, kanmen ghenoech verſtaen de manier van't uytvaren.

3 FORM.



outer water; the gates at *B* have closed, but those at *A* can be opened by hand, and the ships which want to pass through enter the chamber. When they have arrived there, the sluice *CDE* is closed and also the pair of gates at *A,* and the sluice *FGH* is opened, draining the water from the chamber until it has reached the level of the inner water so that now the gates at *B* are opened by hand and the vessels sail in. From what has been explained about their entry, the reader will understand sufficiently how the ships sail out.

Benevens de voorgaende manieren van deuren zijn noch wel gemaeċt gheweeſt ander die mette ebbe van zelfs neer komen te ligghen op't ſtortebedde, en mette vloet van zelfs opgaen, ooc deuren diemen zijdeling int landt treċt, maer en worden int ghebruyc niet de bequaemſte bevonden.

Tot hier toe is verhaelt 'tghene over lanc int ghebruyc heeft gheweeſt, om daer me grondelicker den nieuwen vondt te verklaren, als volght:

Nadienmen zach deſe groote breede ſteecdeuren der 2ᵉ en 3ᵉ Form, zeer goeden dienſt te doen int drooghen der Landen, en deurvaren der Schepen met ſtaende maſten, en datter om daer me groote ſchuering te maken, niet en ghebrac dan middel door vvelcke men de groote deuren bequamelic mocht open doen, als 'twater op d'een zijde ten hoochſten, op d'ander ten leeghſten vvaer; Zoo hebben verſcheyden perſoonen hun daer me ernſtelic bekommert, voornamelic hier in Hollant, alwaer in Steden, Dorpen, en platte Landen, zoo grooten menichte van Sluyſen ghemaeċt is, en gheduerlic ghemaeċt vvorden, zoo vvel zeer koſtelic met goede voordachticheyt veroordent, als middelbare en ſlechte, dat ic meen alſnu op den Aerdtbodem gheen Landt te vveſen met meerder ervarenheyt in dit ſtof, noch daer meer kloecke verſtanden doende zijn met verbetering van Sluyſen te zoecken en te vinden: Door de zelve is metter daet int ghebruyc gherocht de manier die ic hier verklaren zal, en my alſnu beſt bevalt:

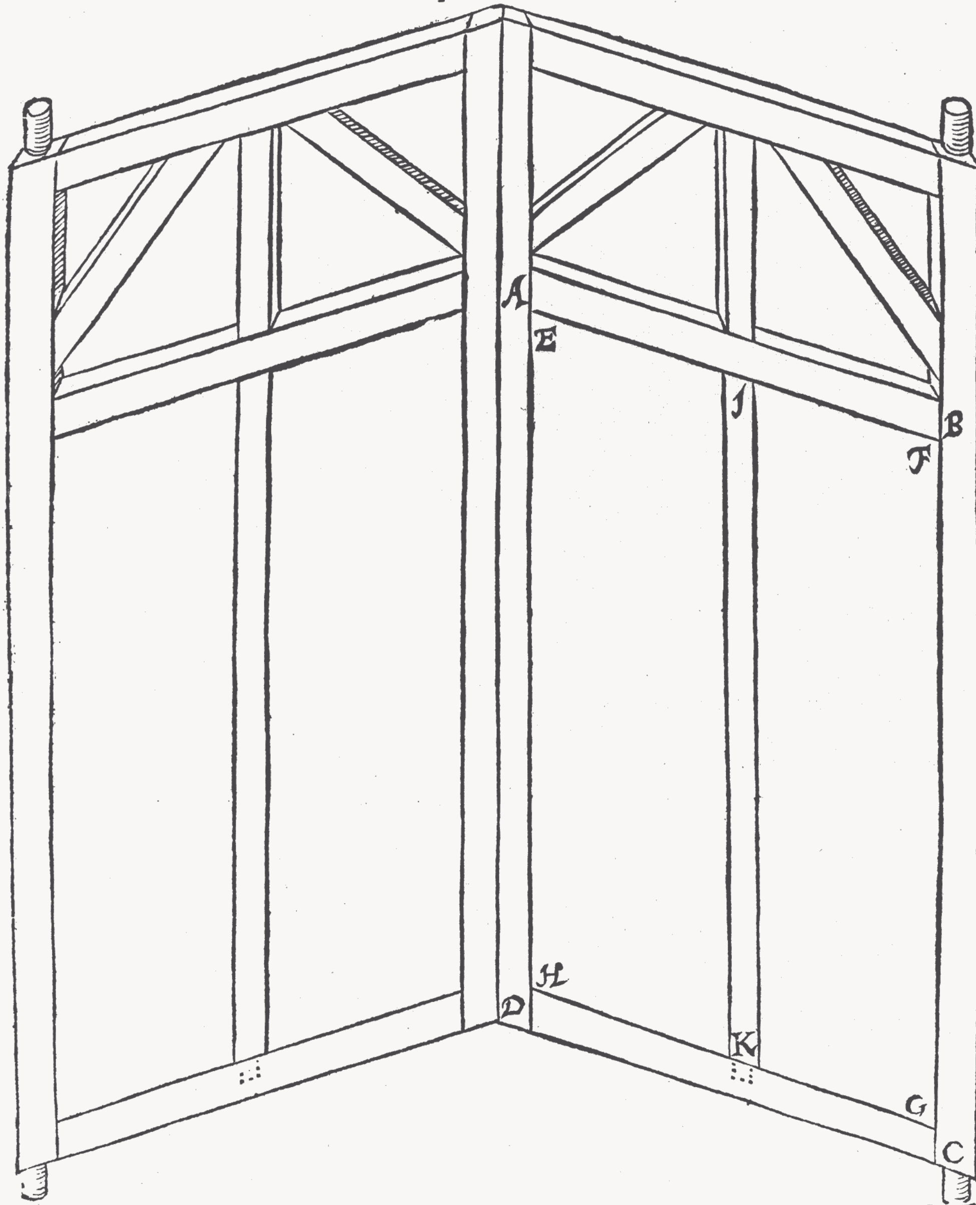
Laet tot dien eynde door deſe 4 Form een Sluyſe beteyckent zijn met twee ſteecdeuren van deſer ghedaente: A B C D is een vierhoeckich raem, daer in ſtaet een deure als E F G H, draeyende op de ſpille I K, by 'tmiddel des raems, zoo dat het deel I F G K is ontrent 5 of 6 duym breeder dan het deel I E H K, of zoo veel meer of min, als de grootheyt der deuren mocht vereyſſchen, ooc zoo dat des kleenſten deels drie zijden I E, E H, H K komen te ſteken teghen ſponden, die inde binnenzijde des raems ghewrocht zijn: Maer het grootſte deels drie zijden I F, F G, G K, en komen teghen gheen ſponden, zulcx dattet hoochſte vvater teghen beyde deſe deelen druckende, zoo zoude de deure E F G H (deur dien teghen 'tmeeſte deel de meeſte drucking komt) omkeeren, tot datſe quaem overkant te ſtaen: Maer om die toe te houden, en weerom lichtelic open te doen na datmen't begheert, zoo wort dat te weghe gebrocht met een yſeren draeyboom, die als een ſpille overeynde ſtaende, en omgedraeyt zijnde, komt voor des deurens kant F G, die vaſt gheſloten houdende.

Apart from the foregoing types of sluice doors others have been constructed which sink down automatically at ebb-tide onto the floor of the lock and rise automatically during flood-tide, and also doors which are drawn into the land sideways, but in practice they have not been found very suitable.

Up to now we have described what has been in use for a long time, in order to explain the new invention more completely, as follows. As it was found that the large and wide swivel gates of Figures 2 and 3 were eminently suitable for the drainage of land and the passage of ships with upright masts, and that in order to use them for deep scouring the only difficulty lay in opening the large gates easily when the water was at its highest level on one side and at its lowest on the other side, several people seriously studied this problem particularly in Holland, where in towns, in villages and in the country such large numbers of locks have been built and are still being built, very excellent and well-designed ones as well as indifferent and poor ones, so that I believe that now no country on earth has more experience in these matters and that there is none where more right minds are seeking and finding improvements in locks; through these people gradually the type has been evolved which I will explain and which I prefer.

Let Figure 4 represent a lock with two swivel gates of this shape: *ABCD* is a square frame in which there is a sluice door *EFGH*, pivotted on the spindle *IK* through the middle of the frame, in such a way that part *IFGK* is about 5 or 6 inches wider than part *IEHK*, or so much more or less as the size of the gates demands, and that the three sides *IE, EH* and *HK* of the small parts rest in the rabbets made in the inner side of the frame; but the three sides *IF, FG,* and *GK* of the larger part do not rest in such rabbets, so that, when the highest water-level pushes against these two parts, the door *EFGH* would turn (since the greater pressure will be exerted against the large part) and take up a position at right angles to the frame. But as to keeping it closed, and opening it easily, if desired, this is effected with an iron upright shaft, which when turned round, touches the side *FG* of the sluice door and keeps it firmly closed.

4 FORM.



Maer om 'tzelve opentlicker te verklaren, zoo verteyckene ic andermael de 4 Form, ghelijc in dese 5 Form te zien is, daer nu by vervoeghende den bovenschreven draeyboom als L M, komende voor de zijde F G, vvelcke omgedraeyt vvort metten reghel M N, hebbende aen't eynde N een yser klincke vallende in een

But in order to explain this more clearly, again I draw Figure 4, as shown in Figure 5, and now add the above-mentioned shaft or spindle *LM*, placed in front of the side *FG*, which is turned with the rod *MN*, which has at its end *N* an iron catch falling into an iron "nose", secured at the top of the frame. Now the inner een ysere neuse, vast ghemaeckt aende bovenste zijde des raems: Als nu het binnenwater hoochst zijnde, teghen de deurens binnenzijde perst, en dat den draeyboom op de buytenzijde met haer klincke ghesloten staet, zoo heeft de heele deure E F G H een groote vasticheyt, om zonder vvijcken te konnen dragen de perssing des vvaters, want de drie zijden I E, E H, H K, komen aen tegen de sponden des raems, als voren ghezeyt is, en de zijde H G teghen den draeyboom L M: Boven dien valter noch verstijving met des draeybooms twee reghels M N, O P, die teghen de buytenzijde der deuren aen komen. Zulcx als ic hier ghezeyt heb van d'een steecdeur, is van d'ander ooc alzoo te verstaen, te vveten datse heeft dierghelijcken raem, spildeur, en draeyboom.

Noch staet t'aenmercken dat de spildeuren niet hoogher en behoeven te wesen, dan de hooghe vvateren en komen daermen me schueren wil, als van D tot A, maer want de Sluysdeuren int gheheel een kennis hoogher moeten zijn, te weten ter hoochde des Dijcx, om te weerstaen alle onghewoonlicke hooghe vvateren, die zelden ghebeuren, zoo machmen de rest van A opwaert maken ghesloten met corbeels, als aen S en T, om het raem A B C D vasticheyt te gheven, dattet niet en ontzette, 'twelc lichtelic konde gheschien allser de verstijving niet en vvaer.

Om nu van't ghebruyc te zegghen, ghenomen het binnenwater ten hoochsten, en het buytenwater ten leeghsten wesende, en datmen de deuren wil openen om te schueren: Hier toe en heeftmen anders niet te doen dan de klincke aen N op te lichten, en den draeyboom te doen omkeeren, ghelijcmen ander draeyboomen opent, 'twelc ghedaen zijnde, en den kant F G vry wesende vanden draeyboom L M, zoo draeyt de deure E F G H op de spille I K al zachtkens om, tot datse overkant staet, 'twelc zoo zijnde, het opghehouden water loopt uyt op beyde de zijden der spille, en doet syn schuering: Daer na de twee deuren met haer raem open ghestelt zijnde, zoo moghen de Schepen met staende masten daer deur varen. Noch staet t'aenmercken, dat den loop des waters belet gedaen wort met des raems twee overeyndstaende zijden A D en Q R, metsgaders de dicten der twee spildeuren die overkant staen, en 'tgat der Sluyse zoo veel verkleenen als die t'zamen bedragen: Dit belet kan gheweert worden mette ramen (als 'twater op syn loop is) teghen stroom open te trecken of winden, 'twelc lichtelic gheschieden kan, om dattet water dan van achter en voren even hooch is.

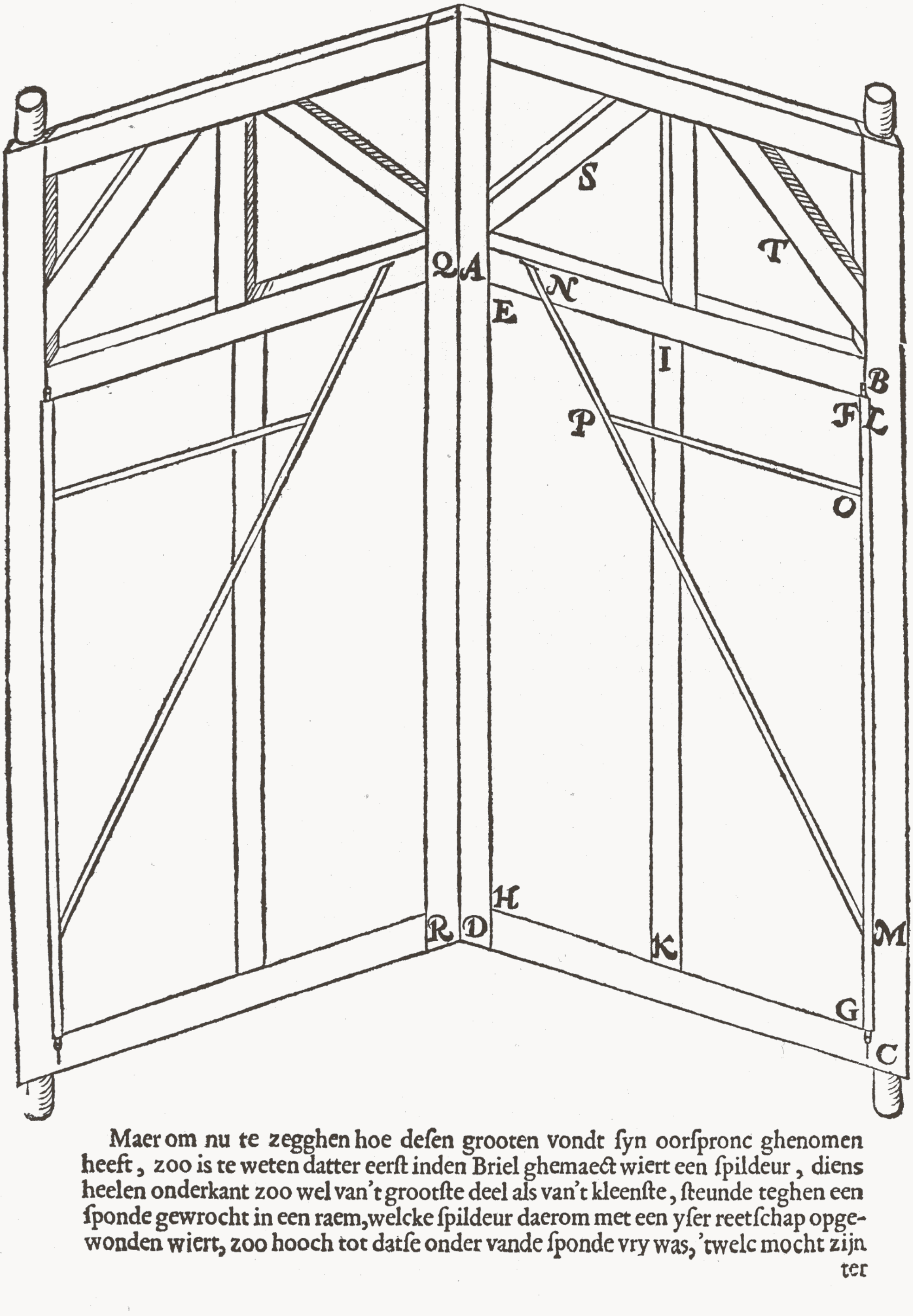
Maer

water having risen to its highest level, presses against the inner side of the gates and the shaft is on the outside with its catch closed, the entire door *EFGH* has great strength, so that it is able to resist the pressure of the water without giving way, for the three sides *IE, EH,* and *HK* press against the rabbets of the frame, as said above, and the side *FG* against the shaft *LM;* moreover the two rods *MN* and *OP* of the shaft make for greater rigidity pressing against the outside of the sluice doors. What I have said here of one gate, also holds for the other, *i.e.* it has a similar frame, pivotted sluice door and shaft.

We should add that the sluice doors need not be higher than the water with which we want to scour, that is from *D* to *A,* but because the gate frames themselves should be a bit higher, to wit as high as the dike in order to resist exceptional floods, such as occur seldom, the rest (of the gate) from *A* upwards can be made of solid beams, such as *S* and *T*, in order to give the frame *ABCD* strength to prevent its distortion, which might easily occur if this stiffening were not present.

Discussing now its use, if we assume that the inner water is at its highest and the outer water at its lowest, and we want to open the doors to scour, we have but to lift the catch at *N* and make the gate swing round in the way we open other swing-gates, whereupon, the side *FG* being clear of the rod *LM,* the sluice door *EFGH* will pivot slowly on its spindle *IK* until touching the opposite side; this being so, the water flows out on both sides of the spindle and performs its scouring action. Then, the two gates and their frame being opened, the vessels with upright masts can pass through. We should add that the flow of water is impeded by the two upright sides of the frame, *AD* and *QR,* and also by the width of the two lock-gates which are at right angles and reduce the opening by their joint width. This obstacle can be overcome if the frames, when the water flows, are opened or hoisted against the current, which can be achieved quite easily, because the water is equally high behind and in front.

5 FORM.



Maer om nu te zegghen hoe desen grooten vondt syn oorspronc ghenomen heeft, zoo is te weten datter eerst inden Briel ghemaect wiert een spildeur, diens heelen onderkant zoo wel van't grootste deel als van't kleenste, steunde teghen een sponde gewrocht in een raem, welcke spildeur daerom met een yser reetschap opgewonden wiert, zoo hooch tot datse onder vande sponde vry was, 'twelc mocht zijn ter

But in order to tell how this great invention originated, it should be known that a pivotted sluice door was first constructed at Brielle, the lower side of which (the smaller and the larger wing) rested against a rabbet in a frame, which sluice door was therefore hoisted with an iron winch until it was clear of the rabbet below, ter hooghde van ontrent 3 duym, want alſdoen keerdeſe van zelfs om, looſende haer vvater.

En wanter tot die tijt (ghelijc ooc noch teghenwoordelic) onder Meeſter Timmerlieden veel ghezeyt wiert van ſchuerende Sluyſen, om Schepen met ſtaende maſten deur te varen, zoo iſt ghebeurt dat ic van die ſtof ter ſpraec komende met Adriaen Ianſz overleden Stadtmeeſter van Rotterdam, en Cornelis Dircxſz Muys overleden Stadtmeeſter van Delf, elc van ons drien zeyde wat verdocht te hebben, dat hy meende goet te weſen, en overquamen met malkander dat elc ſyn vondt verklaren zoude, met voorwaerde, dat zooder profijt of ſchade af quaem, dat wy't ghelijckelic deelen zouden, en malkander behulpich zijn. Den vondt van Adriaen Ianſz was, dat hy in plaets van't opwinden der ſpildeur uyt de ſponde, (als inde voorſchreven Sluyſe ten Briele) vervoechde daer aen een draeyboom, als hier boven ghezeyt is (maer niet ghesteld in een opengaende raem) met eenighe ander verandering die hy daer in brocht.

Myn vont was van 2 ſteecdeure, elcke met een optreckende deur na de gemeene manier, ghelijc de volgende 6 Form aenwijſt, want daer deur varen konden groote Schepen met ſtaende maſten, en ſchuering ghedaen worden in drooghe Havens.

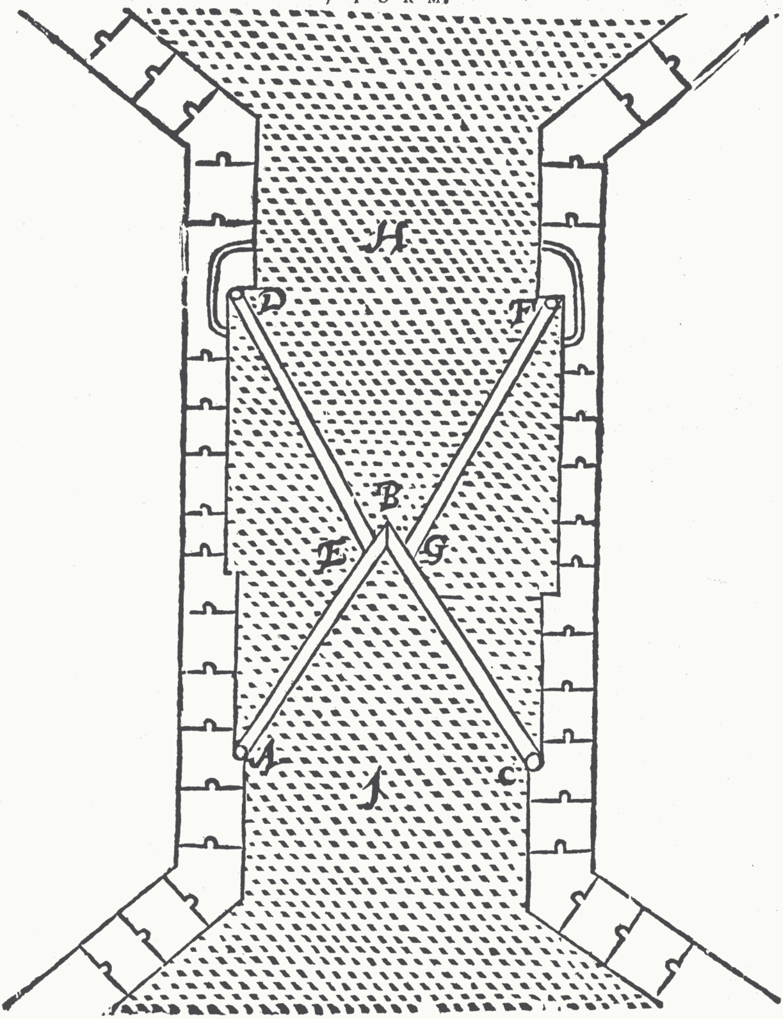
6 FORM.

which was about three inches, for then it would pivot automatically, spilling its water. And because at that time (as also at present), Master Carpenters often spoke about scouring locks, which would allow ships with upright masts to pass through, as I discussed this matter with the late Adriaen Jansz, Town Carpenter of Rotterdam and with the late Cornelis Dircxsz Muys, Town Carpenter of Delft, each of us three said he had invented something which he thought useful, and we agreed that each of us should explain his invention on condition that if profit or loss should result, we were to share it equally and cooperate with each other. The invention of Adriaen Jansz was that instead of the sluice door being raised by winding from its rabbet (as in the above-mentioned sluice at Brielle) he added to it a swing-gate, as described above (but not placed in a frame to be opened), with a few minor changes which he made.

My invention was that of the two swivel-gates, each with a vertical sluice-door to be raised in the usual manner, as is shown by Figure 6 for through it could sail large ships with upright masts, and dry harbours could be scoured.

Cornelis Diericſz vondt was,ghelijc mette volghende grontteyckening aenghewesen wort: Laet A B en B C beteyckenen twee puntdeuren,t'zamen komende aenden punt B: En noch een ander paer puntdeuren, als D E en F G, tuſſchen welcke komt den voorſchreven punt B. Voort zijnder twee ſlecken, d'een by D, d'ander by F: Op de zijde H is het leegh afgheloopen buytenwater,en op de zijde van I het hoogh opgehouden binnenwater. Om nu d'opening deſer Sluyſe te verklaren,zoo is eerſtelic te weten dattet water inde twee driehoecken A E D, C G F, ſtaet ter hooghde van't hooghſte binnenwater I, waer me de twee deuren D E, F G perſſen teghen den punt B der twee deuren A B, C B, die daerom t'zamen metten anderen geſloten blijven; Maer het water der voorſchreven twee driehoecken A E D, C G F, uytghelaten zijnde deur de twee ſlecken by D en F, zoo en iſſer dan gheen perſſing teghen de twee deuren D E, F G, als te voren, maer komt tegen de twee deuren A B, C B, die daerom open gaen, en d'ander twee deuren D E, F G, ooc open dringen, looſende alzoo 'twater dat de ſchuering maect.

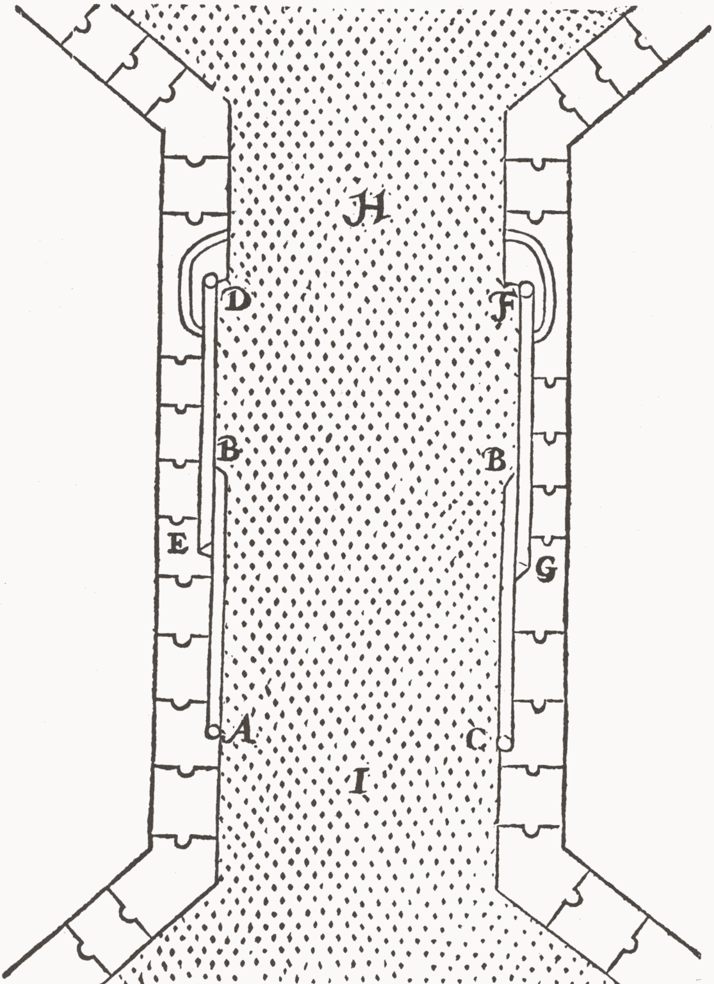
7 FORM.



Cornelis Diericsz' invention was as is shown in the following ground-plan (Fig. 7): Let *AB* and *BC* represent two swivelgates meeting at the point *B*, and another set of swivel gates, *DE* and *FG*, between which falls the said point *B*. Furthermore there are two ground sluices, one at *D*, the other at *F*. On the side *H* there is the low outer water and at *I* there is the inner water that has risen to the highest level. In order to explain the opening of this lock, it is first to be known that the water in the two triangles *AED* and *CGF* is at the same level as the high inner water *I*, owing to which the two doors *DE* and *FG* press against the point *B* of the two doors *AB* and *CB*, which therefore remain closed with the two others. But when the water of the two-above-mentioned triangles *AED* and *CGF* has been drained by the two bypasses at *D* and *F*, there is no longer any pressure against the two doors *DE* and *FG*, as before, but against the two doors *AB* and *CB*, which therefore open and also force open the two doors *DE* and *FG*, thus spilling the water that will effect the scouring.

Maer om de ghestalt van die openstaende Sluyse te vertoonen, zoo teycken ic daer af dese 8 Form.

8 FORM.



De bovenschreven manier van Adriaen Iansz, wiert daer na verbetert door Adriaen Diericxsz Timmerman tot Delf, en vervoecht in twee stekende spildeurẽ, ghelijc voren verklaert is door de 5 Form, daer af hem by de *Hoochmoghende Heeren Staten* Octroy verleent wiert, van die alleen te moghen maken: Na de zelve wijse isser twee ghestelt tot Maeslandtsluys; en noch een te Hellevoetsluys.

Maer na de manier der 7 Form isser drie ghemaect; een te Vlaerdinghen, d'ander tot Schiedam, de derde tot Wijnnocxberghen in Vlaender.

Doch alsser gheschil vvaer vvelcke deser twee manieren de beste is, en dat ic myn ghevoelen daer af zeyde, het zelve zoude zijn de spildeuren der 5 Form my voor d'ander te bevallen: Ten eersten, om dat elc der vier deuren vande 7 Form, ontrent noch eens zoo lanc ghemaect vvorden, als elcke der spildeuren vande 5 Form,

 uyt

But in order to show the appearance of the opened sluice doors, I draw thereof this Figure 8.

The above-mentioned type of Adriaen Jansz. was later improved by Adriaen Diericxsz, Carpenter at Delft, and incorporated in two mitred swivel-doors, as explained earlier in Figure 5, and in this form he obtained a patent on it from the States General, which allowed him to make them exclusively. According to this patent two were built at Maeslandtsluis, and another at Hellevoetsluis.

But according to Figure 7 three were built: one at Vlaardingen, the other at Schiedam, and the third at Wijnnocxberghen in Flanders. But if it were queried which of these two types is the best, and if I were to give my opinion on this point, it would be that the swivel gates according to Figure 5 please me better than the others. Firstly, because each of the four doors in Figure 7 has to be made twice as long as the swivel gates of Figure 5, because the angle *DEA* in uyt oorzaec dat den hoec als D E A inde 7 form, zeer plomp moet wesen om die te konnen open doen, vvelcke opening onmoghelic zoude zijn, als dien hoec recht vvaer, zulcx dat de deuren zoo lanc vallen als de Sluyse vvijt is, 'twelc tot Schiedam is van 30 voeten, daer in die plaets de spildeuren met haer raem elc maer en behoeven ontrent 16 voeten. De groote langde der deuren veroorzaect groot ghewicht, zulcx datmense tot Schiedam doet gaen op koper schijven inden onderkant vande ramen der deuren ghewrocht, en draeyende op yser platen, geleyt int stortebedde: Inder voeghen, dat alsmen spildeuren zoo lanc vvilde maken, de Sluyse zoude ontrent noch eens zoo vvijt konnen vallen. Ten anderen is het openen der Sluyse alleenlic met een klincke op te lichten, veel bequamer als d'ander manier.

2 HOOFTSTVC,

Vande verstijving der gronden van Sluysen en Beeren.

NAdien hier gezeyt zal vvorden van Beeren, die zommighe noemen Dodanen, eenige Daudanẽ, ander Daudeynen, ooc Audanen, en dat haer beteyckening aen velen onbekent mach zijn, zoo zal ic daer af eerst wat verklaring doen: De steenen gestichten diemen inde Stadtsgrachten leght om Rivierkens tusschen beyden deur te loopen, ooc om twater inde grachten op te houden, hebbende boven een scherpen kant ghelijc den rugge van een Swijn, 'twelcmen gelubt zijnde, Beer noemt, zoo vvordense Beeren geheeten: En vvantse ooc gelijckenis hebben metten rugghe van een Ezel, zoo noemense de Fransoysen Dodanes, dat is, *dos de asnes*, beteyckenende Ezels rugghen, daer af door 'tmisbruyc dat van uytheemsche vvoorden ghemeenelic valt, by de Duytschen ghezeyt vvordt Daudanen, en ooc Daudeynen, en Audanen.

Die naem dan verstaen zijnde, zoo is te weten, dat hoewel in dese Landen de gronden van Sluysen en Beeren met goede voordachticheyt en groote kost ghemaect vvorden, nochtans en heeftmen tot gheen zulcken zekerheyt konnen gheraken, dat daer af niet dicwils groote ongheval len en gheschieden, deur de hooghe vvateren, daer de gronden zomwijlen zoo me vvech ghespoelt vvorden, dat de Sluysen vruchteloos ligghen, de Beeren omvallen, ooc neerwaerts zincken diep onder vvater het landt verdrinckende. Maer nadien dit zoo ghebeurt met Sluysen die op veel na zulcken breede diepte en schuering niet en hebben, als dese voorgenomen spilsluysen, daer de grootste diepstvarende Schepen zouden deur komen, zoo mocht ymant niet zonder reden twijffelen, of dese onvolkomenheyt der gronden niet oorzaec en mocht vvesen, van eyntlic niet te konnen volghen 'tghene men verwacht: Maer want myn ghevoelen daer af anders is, zoo zal ic om 'tzelve vvel te verklaren, eerst beschrijven d'oorzaec der ontgronding, op dat door kennis van dien dese manier van verstijving te beter voortganc mocht nemen.

Laet tot dien eynde A stantteyckening zijn eens steenen Beers, B het buytenwater, C het binnenwater of de gracht, D E den grondt daer den Beer op light. Dit buytenwater B komende tot by het opperste des Beers als aen F, ghelijct altemet ghebeurt, zoo zijnder tweederley voornamelicke oorzaken die hem doen omvallen: D'eerste de diepe schuering die met zulcke onghewoonlicke hooghe vvateren zomwijlen komt aenden voet des Beers, daer te voren gheen en vvas: Dese schuering dieper vallende dan het steenwerc des Beers, en daer na onder den Beer komende, zoo wort hy ontgront, en valt om: En hoewel zulcke schuering niet en ghebeurt alsmen den Beer achterwaerts leght, zoo verre vande mondt des grachts, datter gheen stroom der Rivier teghen en loopt, zoo isser alsdan met leegh vvater een drooch eynde grachts vanden Beer tottẽ mont, hinderlic totte stercte der Stadt. D'ander oorzaec is de perssing, die met zulc ongewoonlic hooch vvater zoo uyter maten sterc vvordt, dat de syping des hooch vvaters onder den Beer van B door

D E, tot

Figure 7 must be very obtuse to open the doors, which opening would become impossible if the angle were right, so that the doors would be as large as the width of the chamber, which in Schiedam is 30 feet, since in that town the swivel-gates with their frame are but 16 feet each. The great size of the doors causes heavy weight; therefore at Schiedam they are made to pivot on copper discs, fixed to the lower part of the frames of the doors and turning on iron plates inserted in the foundation bed. Therefore, if one wanted to make the swivel-gates so long, the locks would become twice as wide. Secondly, the opening of the sluice-doors by the lifting of a catch is much easier than the other way.

CHAPTER 2

Of the consolidation of the foundations of locks and dams

As we shall here discuss dams (*beeren*), which some call *Dodanen,* a few *daudanen,* others *Daudeynen* and as their meaning may be unknown to many, I will first explain this a little. The stone dams which are laid in the town-ditches in order to force small rivers to run between them, and also to raise the water in the ditches, having a sharp edge at the top like the back of a pig, which, if castrated, is called *beer,* they are called *beeren*; and because they also resemble the back of a donkey, the French call them *Dodanes,* that is *dos des asnes,* meaning "back of donkeys", on account of which, owing to the usual mispronounciation of foreign words, the Dutch say *Daudanen*, and also *daudeynen* and *audanen*.

This term now being understood, it should be known that though the foundations of locks and dams are made in these countries with great forethought and expense, still it has not been possible to attain such certainty that they will not often cause considerable difficulties, due to the high waters, by which the foundations are sometimes washed away so that the locks are useless, the dams collapse and sink deep into the water, drowning the land. But as this happens with locks having nothing like the depth and scouring of the swivel-gates proposed, which allow heavy-draught vessels to pass, one might doubt, not without reason, whether the imperfection of the foundations could not be the reason why the expectations are not fulfilled; but as my opinion on this matter is different, I will, in order to explain it properly first describe the cause of the destruction of the foundations, so that through such knowledge this method of consolidation may be achieved the better [1]).

Let *A* be a vertical cross-section of a stone dam, *B* the outer water, *C* the inner water, or ditch, *DE* the foundation or soil on which the dam is constructed. This outer water reaching up to the top of the dam at *F,* as happens now and then, there are two primary causes which may make it collapse. Firstly, the deep scouring which, during such exceptionally high tides, may sometimes take place at the foot of the dam, where before there was none, the scouring taking place at a greater depth than the masonry of the dam, and then penetrating beneath the dam, its foundation is washed away and it collapses. And though such scouring does not take place if the dam is built so far back from the mouth of the town-ditch that the

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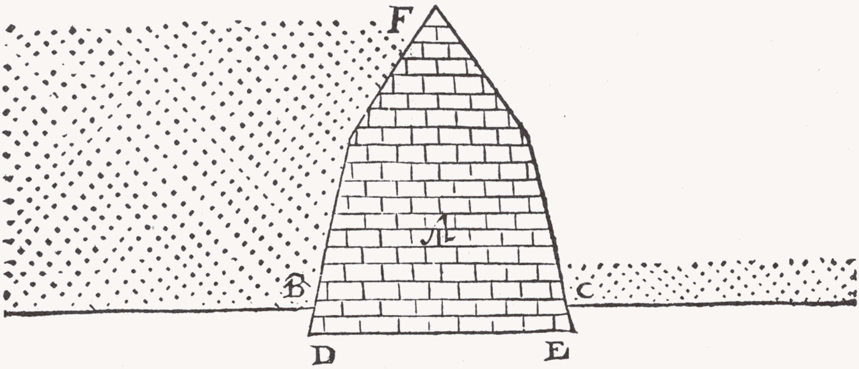
1) Stevin uses the word *verstijven* (to stiffen, to render rigid).

D E, tot int leegh vvater C, de macht krijcht het zandt te beweghen, 'twelc daer toe komende, de beweghing vvort ſtracx grooter en grooter, voortgaende ghelijc den brant inde huyſen, die met een kleen vyerken beghinnende, terſtont vermeerdert: Inder voeghen, dat den gront vvechſpoelende, den Beer vvort krom te ſtaen, te breken, en zomwijlen vvel heel onder vvater te zincken. Aen zommighe Beeren ghebeuren deſe twee oorzaken t'zamen, die hen dan te lichterlicker doen vallen.

Aengaende heyinghe van palen deur rooſters tot verſtijving des grondts der Beeren, daer me en vvorden deſe twee ongheuallen niet voorkomen, ghemerct de vvechſchuering van het zandt, metſgaders de deurperſſing des vvaters, evenwel ſyn voortganc neemt tuſſchen de palen: Zulcx dat d'oorzaec deſer ongevallen meer ſchijnt te komen door datter geen beſtandigen reghel gevonden en is, dan door faute van d'Aennemers en Wercliedē, die zomwijlen t'onrecht beſchuldicht vvorden.

1 FORM.



Maer want men deſe twee ongheuallen beter kan voorkomen, dan myns wetens tot noch toe gheſchiet is, en dat met inghcheyde palen, die aen malkander inde langde ghehecht vvorden met ſvvalueſteerten, zoo ſtel ic daer af hier deſe 2 Form, vvaer in verſtaen vvort de breede eens ſvvalueſteerts te vveſen ontrent het derdendeel vande dicte der pael, de onderſte eynden zijn ſchuyns afghehouwen, om elcke pael int heyen altijt te doen drucken teghen de pael dieder gheheyt is.

Merct noch, dat hoewel deſe palen om de ghevoeghelicheyts vville vierkant geteyckent zijn, nochtans vry te ſtaen, alleenlic de twee zijden daer de ſwalueſteert en groeve aen komen, plat te maken, latende de boomſche rondtheyt van d'ander twee zijden blijven, om alzoo meer houts te behouden, met minder koſt van arbeyts loon. Ten anderen machmen de ſwalueſteerten van bezonder houten reghelen maken, die naghelende teghen d'een platte zijde der pael, en teghen d'ander zijde twee bezonder ghenagelde reghels, die de groeve tuſſchen beyden begrijpen, vvant alzoo heeft de pael op de twee zijden meer hout, met minder koſt van arbeyts loon, dan of de reghels door afhouwing van het hout der pael ghemaect waren.

De voorſchreven palen machmen nemen van vuyren maſten, want die zijn lanc, recht, onder water als onverganckelic, en van kleenen prijs. Noch is kennelic, dat zouden de gheſwalueſteerte grontpalen aen malkander houden na 'tbehooren, zoo moetenſe onder en boven even dic weſen, maer de boomen waſſen boven dunder dan beneden, 'twelc oorzaec zoude zijn (alſſer niet teghen voorzien waer) van op't dicſte eynde zoo veel te moeten af houwen, als die meerder dicte vereyſchte, 'twelc de palen zeer zoude verſwacken, en tot meerder koſt van arbeydts loon ſtrecken: Maer om die ſwaricheyt te voorkomen, machmen de bovenſchreven drie houten reghels aen't een eynde zoo veel dicker maken als de zake vereyſcht, om den boom haer dicte te laten behouden.

current of the river does not touch it, there will then be at low tide a dry part of the ditch from the dam to the mouth of the river, an impediment to the fortification of the town. The other cause is the pressure, which at such exceptionally high tides becomes so very strong that the percolation of the high water under the dam from *B* through *DE* into the low water *C* will be able to move the sand, which movement, once started, becomes stronger and stronger, proceeding like fires in houses, beginning with a small fire but swiftly increasing in size. In this way then the soil, washing away, makes the dam lean over, break, and sometimes sink under water altogether. With some dams these two causes combine, making them collapse more readily.

Driving piles through gratings [1]) in order to consolidate the foundation of the dams will not obviate these two difficulties, since the scouring-away of the sand and the percolation of the water proceed just as well between the piles. Thus the cause of these difficulties seems to be the fact that no fixed rule has been found rather than the mistakes of contractors and workmen, who are sometimes blamed unjustly.

But because these two difficulties can be avoided much better than has been done up to now, as far as I know, and that with piles driven in, which are dovetailed together over their full length, I show this in Figure 2 in which the width of a dovetail is taken to be about one-third of the width of a pile, their lower ends being cut off obliquely, in order to make each pile, as it is being driven in, press invariably against the pile already driven-in.

It is also to be noted that though in the drawing these piles have been represented as square, one is left perfectly free to plane only the two sides which have dovetails and grooves, keeping the circular cross-section on the other sides, in order to save more timber with lower labour costs. The dovetails may also be made of special wooden strips, which are nailed against one flat side of the pile, and two special nailed strips on the other side, which contain the groove between them, for thus the pile has more timber on these two sides with lower labour costs than if the dovetails are made by cutting them into the pile's timber.

The aforesaid piles can be made of pines, for these are long, straight, practically indestructible under water, and cheap. It is also clear that if the dovetailed piles are fit together as they should, they should be equally thick above and below, but trees grow more slender at the top than below, which would then necessarily mean (if there were no other solution) that they would have to be cut down as much at the thick end as the greater thickness necessitated, which would weaken the piles very much and involve greater labour costs. In order to overcome this difficulty, the three above-mentioned wooden strips can be made so much thicker at one end as is needed to let the pine keep its thickness.

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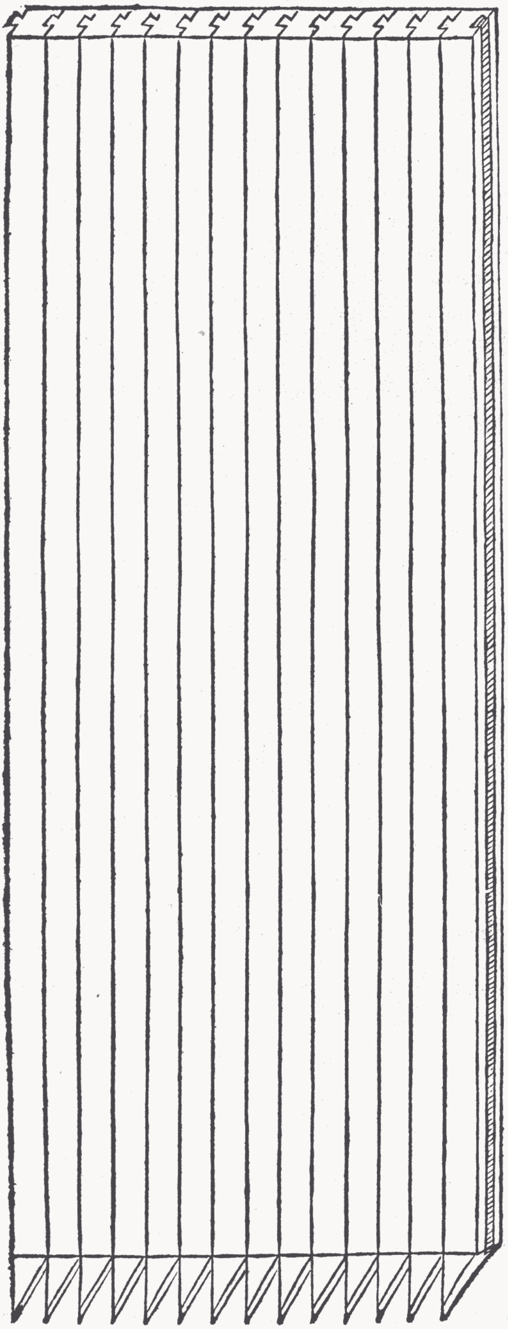
[1]) In order to space them equally?

2 FORM.



Om nu te verklaren hoe met dese ghefwaludefteerte palen de gronden van Beeren konnen voorzien worden, zoo ftel ic daer af eerft de grondtteyckening defer navolghende 3 Form, in vvelcke A den grondt des Beers bediet, vvefende een vierhoec vervangen in ghefwaludefteerte grondtpalen, die in den grondt zeer diep gheheyt zijn, en daer af alleenlic de kruynen ghezien vvorden, B is het buytenwater, C het binnenwater, D den Dijc: Tghene dat inden vierhoec A is, als zant, veen, of baggaert, vvort uytgehaelt onder vvater met haecken of baggaertnetten, ghelijct toegaet met turf, datmen alzoo vvel 20 voeten diep uyttrect, (ic heb hier ghezeyt onder vvater, 'twelc is ten eynde het zandt, niet op een vvelle) in dien vierhoeckighen put A vvorden onghefwaludefteerte palen gheheyt, om de metfelrije te draghen zonder zincken, daer na vultmen de ledighe plaetfen tuffchen de palen met goede kley.

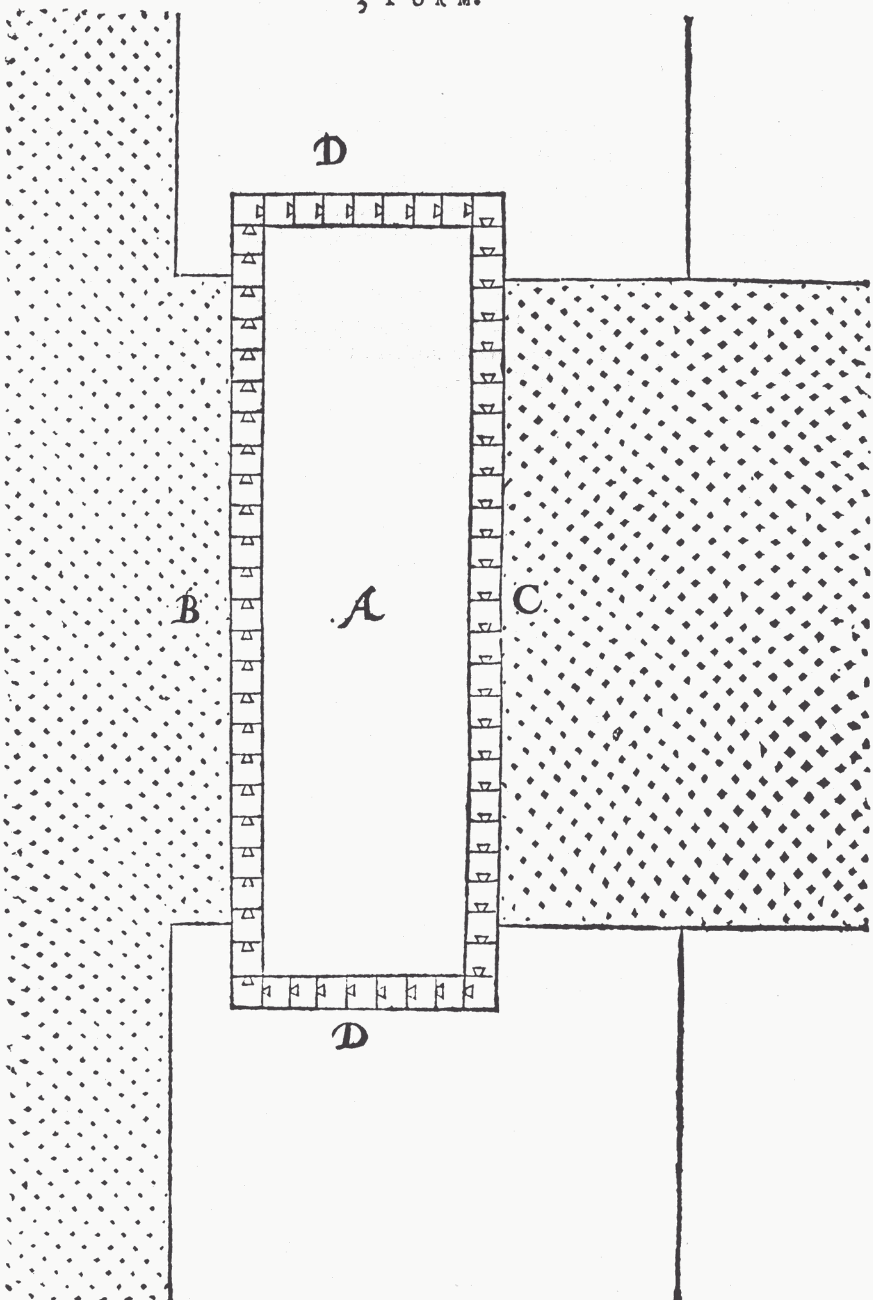
Merct noch dat defen Beer op beyden eyndē aen D komt inden Dijc, en niet flechtelic daer teghen aen, op dat door de vveynicheyt van ftof daer niet zulcken zijdelinghe deurperffing en valle, ghelijcker om de vveynicheyt van ftof onder den Beer komt, daer hier voren af ghezeyt is by de 1 Form.

Om

In order to explain now how with the aid of the dovetailed piles the foundations of the dams may be reinforced I first give the ground-plan in Figure 3, in which *A* represents the base of the dam, being a rectangle enclosed by dovetailed piles, which have been driven quite deep into the subsoil and of which only the tops are visible, *B* is the outer water, *C* the inner water, *D* the dike. What is contained in the rectangle A, such as sand, peat or slush, is excavated under water with hooks or with dredge-nets such as used for peat, which is thus excavated to a depth of as much as 20 feet. (I have here said "under water", lest the sand should start to flow). Into this rectangular pit *A* are driven non-dovetailed piles in order to support the masonry instead of mattresses; then the empty crevices between the piles are filled with good clay.

It is also to be noted that this dam penetrates into the dike at *D* at both ends and does not just lean against it, lest because of the modicum of earth there should be such a percolation as there may arise underneath the dam through the modicum of soil, as we have discussed for Figure 1.

3 FORM.



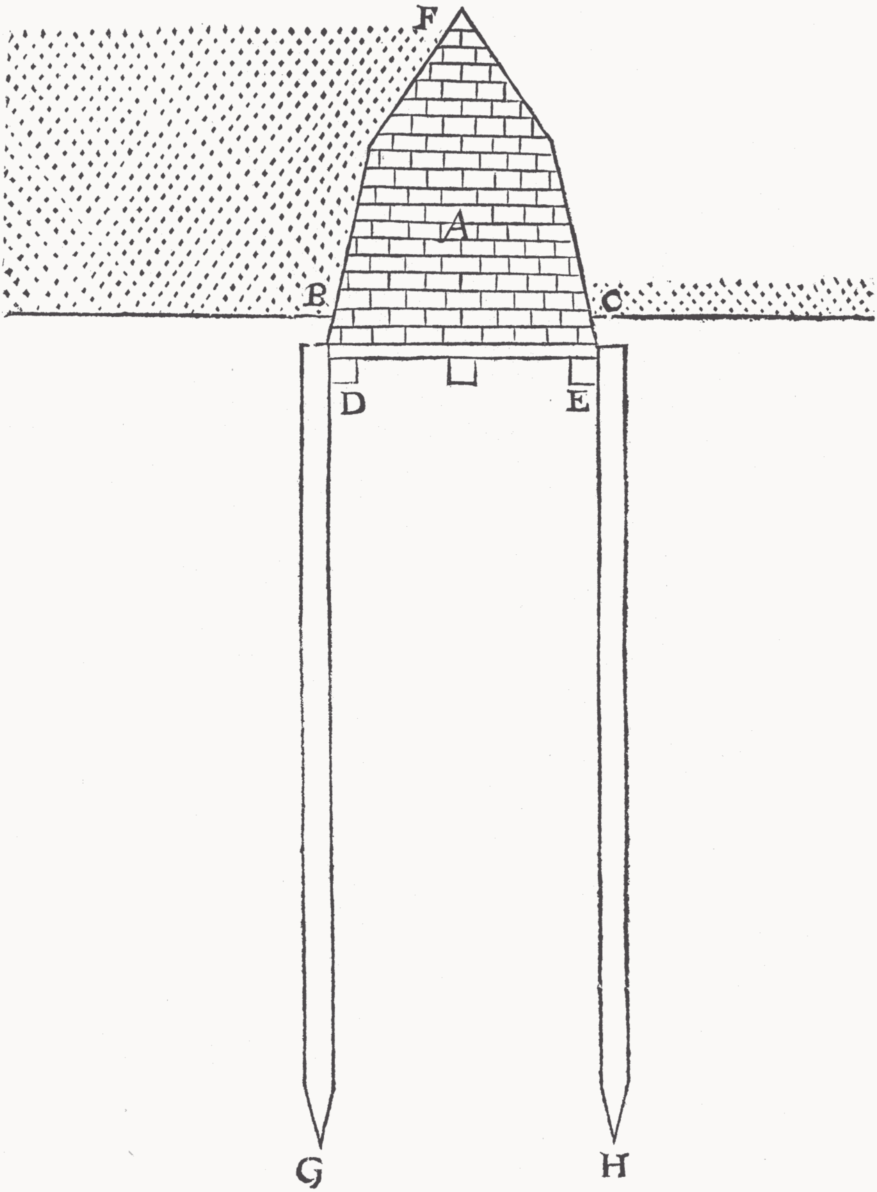
Dit zoo

Dit zoo zijnde, op desen grondt wort den steenen Beer ghemetselt, daer af de stantreyckening is als dese 4 Form uytwijst, in vvelcke A B C D E F zijn van beteyckening als inde 1 Form, vvaer by noch ghevoecht zijn de gheswaluesteerte grondtpalen B G, C H: Inde zelve kanmen zien de bovenschreven twee oorzaken voorkomen te vvesen, vvant voor den Beer schoon al een schuering ghekomen zijnde van 20, 30, of 40 voeten diep, en dat de palen noch drie of vier voeten int zandt blijven, zoo en kan den Beer niet ontgrondt worden, maer blijft staende: En na dien hooghen stroom is ghemeenelic de Rivier van zelfs gheneycht weerom zant in de diepte te brenghen ghelijct te voren was. Aengaende de tweedde oorzaec vande wechperssing des grondts, die is hier ooc verhindert, want zoude het zandt onder den Beer eenighe deursyping krijghen, dat zoude moeten zijn onder de gheswaluesteerte grondtpalen, als by G en H, maer dat en kan niet vvel zijn, om het groot lichaem kley en zant van B tot G, van G tot H, en ooc van H tot C opwaerts, 'twelc in zoo grooten diepte zoude moeten beweghen: En al waert ooc van B tot by G wech gheschuert, zoo en zoude de groote menichte zants van B tot H, en van H opwaert tot C, niet lichtelic konnen beweghen.

Aengaende ymant nu zegghen mocht, dat vvanneer voor de grondtpalen van B tot G, een meerder diepte schuert dan de palen lanc zijn, en de schuering voorts komt onder den Beer, den gront wech spoelende, dat alsdan den Beer mette palen en al datter binnen is zal omvallen. Hier op wort gheantwoort, groot verschil te vvesen tusschen een gront als dese, die niet wech spoelen en kan dan met voorgaende diepe schuering, en een grondt die vvech spoelt alleenelic deur perssing, zonder voorgaende schuering, als die des 2 Forms: Ooc mede, dattet zelden ghebeurt zoo groote diepten te schueren, als langhe grondtpalen bereycken konnen.

Ic heb dit myn ghevoelen van langhe dicke gheswaluesteerte grondtpalen vvel verhaelt teghen eenighe Ingenieurs; daer uyt ghevolcht is, dat voor zommighe vvaterkantsche wercken in dese Landen planchen gheslaghen zijn 4 of 5 voeten diep, en alleenelic twee duym dic, met meskanten in malkander ghevoecht, maer zulcke plancken en konnen den heybloc niet verdragen, om tot behoorlicke diepte ghesleghen te worden, myn meyning is van zulcke gheswaluesteerte grondtpalen als ic voren verklaert heb.

4 FORM.



Dit ghezeyt zijnde vande gronden der Beeren, ic zal nu komen totte gronden der Sluysen, stellende tot dien eynde de grontteyckening deser 5 Form, die als de 3 Form ooc bestaet in rijen van gheheyde grontpalen, (welverstaende datter noch zoo veel onghesvaluesteerte palen by moeten komen, als de dicte der mueren en

 freyten

This being so, the stone dam is now built on this foundation, as the vertical cross-section in Figure 4 shows, in which *A*, *B*, *C*, *D*, *E*, and *F* have the same meaning as in Figure 1, but to which have been added the dovetailed piles *BG* and *CH*. In this we can see that the two above-mentioned difficulties have been avoided, for even if ahead of the dam there should occur scouring to a depth of 20, 30 or 40 feet, provided the piles stick another three or four feet into the sand, no destruction of the foundation of the dam can result, but it will remain standing. And after such high floods the river will usually automatically bring sand again into the depths until they fill up. As to the second cause of the washing-away of the foundation, this has been prevented as well, for if there should be some percolation through the sand beneath the dam, this would have to be underneath the dovetailed piles at *G* and *H*, but this is not very well possible because of the large body of clay and sand from *B* to *G*, from *G* to *H*, and also upwards from *H* to *C*, which would then have to move at such great depth. And even if the soil had been scoured away from *B* to *G*, the large mass of sand from *B* to *H* and from upwards to *C* would not be apt to move.

And if somebody should say that if ahead of the piles *B* to *G* there is a deeper scouring than the length of these piles, and the scouring would penetrate the dam, washing away the soil, the dam and its piles and all between would collapse, I would answer that there is a great difference between a foundation like this one, which cannot be washed away except with previous deep scouring and a foundation which is washed away by pressure alone, without previous scouring, as that shown in Figure 2; also that it seldom happens that scouring takes place to such great depths as our foundation piles can reach.

I have talked over my ideas of long, thick, dovetailed piles with some engineers; this resulted in some civil engineering works in these countries being reinforced by driving in planks 4 to 5 feet deep, and only 2 inches thick, being joined with knife-edges; but such planks can not be pile-driven in order to penetrate to adequate depths; as I have explained above, I prefer dovetailed piles.

The foundations of dams having thus been explained, I will now discuss the foundations of locks, and to this end I draw Figure 5, which, like Figure 3, shows rows of driven piles (it should be understood that as many non-dovetailed piles should be added as are needed for the support of the thickness of the walls and ſtreyten vereyſcht, om daer op te ruſten) waer in A B C D de twee kaken bedien, en de plaets daer tuſſchen begrepen den waterloop, E F G den voordorpel, H I K den achterdorpel, A L, C M voorvleughels, de plaets daer tuſſchen begrepen het voorſte ſtortebed, B N, D O de achtervleughels, de plaets daer tuſſchen begrepen het achterſte ſtortebed; Noch zijnder de twee rijen L N, M O.

Deſe palen gheheyt weſende, dat zoo wel de bovenſte kruynen als de onderſte punten haer behoorlicke diepte hebben, zoo zalmen uythalen al de ſtof (ghelijc voren inde 3 Form metten Beer ghedaen wiert) van zant, veen, modder, of zulcx alſt weſen mocht, en vullen die ledighe plaetſen weerom met kley, elcke tot haer behoorlicke hoochte, te weten den waterloop en twee ſtortebedden zoo diep blijvende als t'beſtec vereyſcht, om daer op te brenghen de houten vloer en metſelrije, maer de twee plaetſen L A B N, M C D O, zoo hooch van kley als den Dijc.

Om nu te verklaren de vaſticheyt van zulcken grondt, ic zegh aldus: By aldien men neemt de palen der rije L M diep te ſtaen 40 voeten, zoo volght daer uyt dat al ſchuerde het water uytvallende over de zelve L M een put van 30 voeten diep, zoo blijft het ſtortebed L A E F G C M, en al de reſt in ſyn vaſticheyt. Ten tweedden, al waert dat met lancheyt van tijdt, de kley begrepen tuſſchen de voorſchreven gheſwalueſteerte grontpalen zeer diep uytſpoelde (diemen weerom vullen kan) zoo zal nochtans de Sluyſe dicht zijn, want de deuren toe weſende, zoo maken de gheſwalueſteerte grondtpalen over al dicht ſlot.

Noch is t'aenmercken, oorboor te weſen datmen by't eynde van't ſtortebedde legghe groote ſteenen, zoo ſwaer datſe door den val van't water niet en wijcken, om daer me den grondt te bewaren, want het konde ghebeuren dattet zandt dieper wech gheſchuert wierde, dan de gheſwaludeſteerte grontpalen lanc waren, 'twelc ghebeurende, den grondt van't ſtortebed zoude wech ſpoelen, en ander ongheval konder uyt volghen.

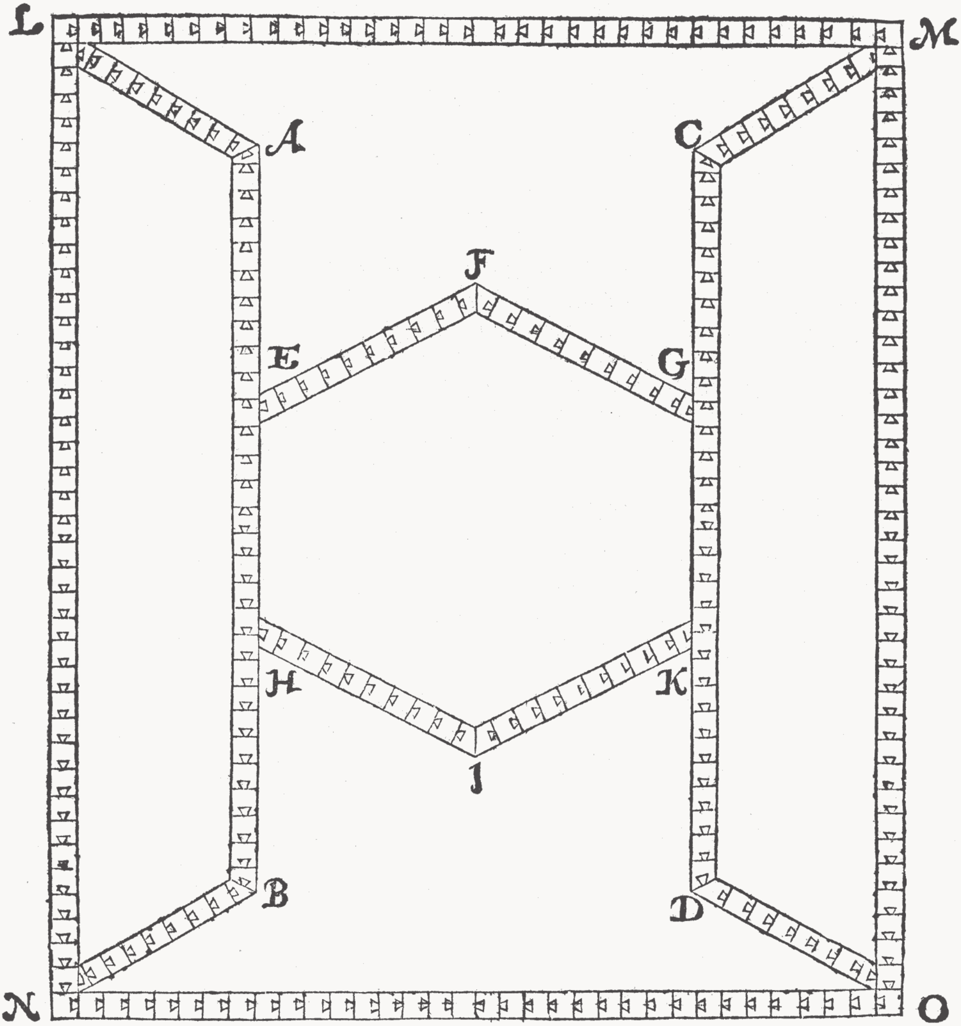
Merct

stones), in which *AB* and *CD* represent the two jaws and the space between the water-channel, *EFG* the front sill, *HIK* the rear sill, *AL* and *CM* the front wings, the space in between the front mattresses (*stortbed*), *BN* and *DO* the rear wings, the space in between being the rear mattresses, and there are the two rows *LN* and *MO*.

The piles having been driven in until both their tops and their lower tips are at the right depth, all the soil should be excavated (as proposed for the dam in Figure 3), *i.e.* the sand, peat, slush, or whatever it may be, and the empty space should be filled with clay, each space to its proper level, *i.e.* so that the water-channel and the two mattresses remain as deep as the specification requires in order to build upon it the wooden floor and the masonry, but the two spaces *LABN* and *MCDO* with as much clay as the height of the dike.

In order to explain the stability of such a foundation, I say: If the piles of the row *LM* are taken to be 40 feet deep, it is clear that even if the water scoured over the space *LM* a pit 30 feet deep, the mattresses *LAEFGCM* and all the rest would remain stable. Secondly, even if in the course of time the clay in between the aforesaid dovetailed piles should be washed away very deeply (and one could fill this up again), the lock will nevertheless be closed, for as long as the gates remain closed, the dovetailed piles shut out the water completely everywhere. It should also be noted that it will be advantageous if at the end of the mattress there are laid large stones, so heavy that they will not give way to the fall of the water, in order thus to protect the foundation, for the sand might be scoured away deeper than the length of the dovetailed piles and in that case the foundation of the mattress would be washed away and other difficulties might result from this.

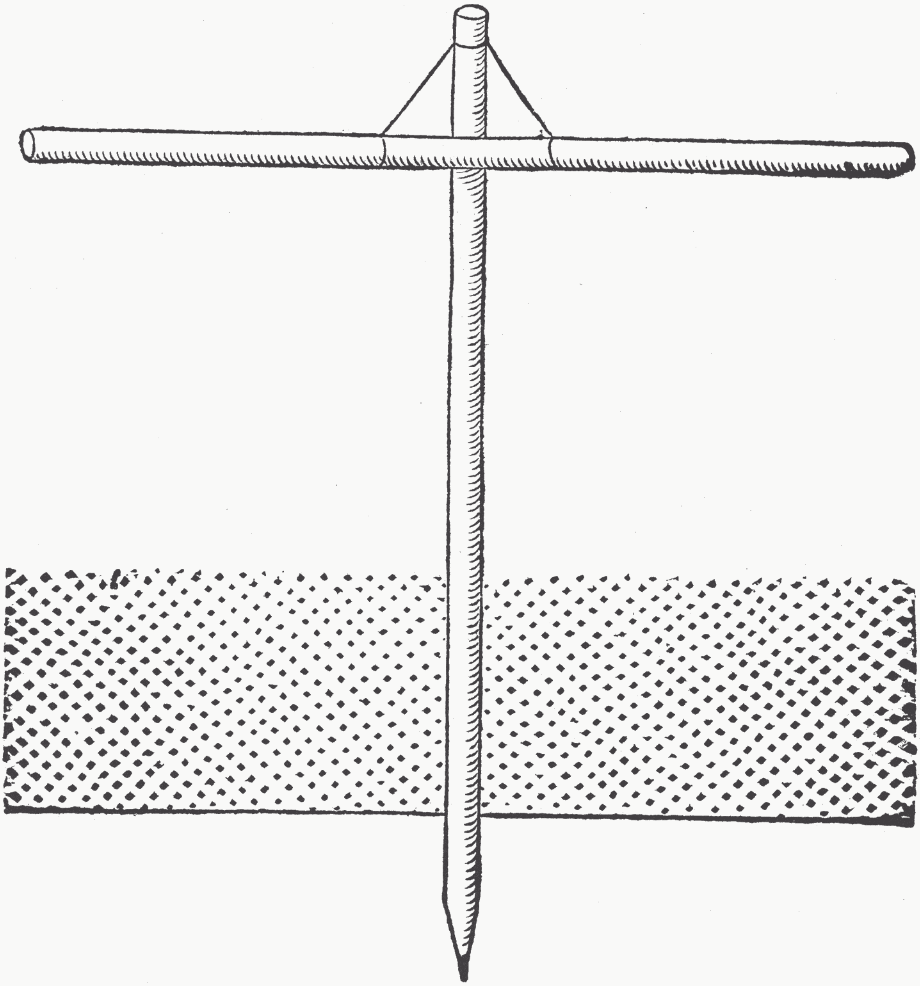
5 FORM.



Merct noch, dat hier wel ghezeyt is gheweest vande verzekering der gronden met palen ingheheyt zijnde 40 oft 50 voet diep, maer ymandt mocht dencken dat zulcx over al onmoghelic is, deur dien de palen aen't welzandt komende, niet dieper in en willen. Hier op dient tot antwoordt zulcx in dese Landen wel een ghemeen zegghen te wesen, en ghelooft te worden, maer het is anders daer me ghestelt, want boven aende grontpael ghewicht ghenoech hanghende, sy worden diep deur het welzant gheheyt zonder daer na op te rijsen of om te vallen. Dit heeft int ghebruyc gheweest alzoo ghedaen te worden ('twelc noch ghedueren mach) tot Melving in Pruyssen, alwaer den Stadtboumeester ghenaemt meester Maerten, wesende van Haerlem, my zeyde zulcx gheleert te hebben van een Polens Arbey-

Note also that we have here spoken of the protection of the foundation by piles driven in some 40 or 50 feet deep, but somebody might believe that this is impossible, because the piles, when reaching the sand strata, will not penetrate deeper. To this we say that although a common saying in these countries and a common belief, yet reality is different, for if a sufficient weight is attached on the top of the pile, it will penetrate deep into the sand stratum without afterwards rising or collapsing. This has been common practice (and may still be) at Melving in Prussia, where the town architect, named Master Maerten, a native of Haarlem, told me that he had learned this from a Polish labourer, who drove in piles to-der, die benevens ander me heyde, vvelcke ziende datmen op hielt van heyen, om datmen aen't vvelzant ghekomen vvas, en niet voorder en konde, zeyde, en toonde metter daet hoemen in ſyn Landt dede, 'twelc toeghinc met een der palen die int vvater laghen te hanghen aende grontpael diemen heyde, ghelijc deſe 6 Form uytwijſt, vvaer by men verſtaen mach, dat hoemen meerder gewicht aende pael hangt, hoe beter voortganc, want men houdt daer me niet alleenelic 'tghene men met elcken ſlach vvint, maer boven dien gaet de pael met elcken ſlach te dieper in.

6 FORM.



Daer vviert int belegh van Oſtende ghebruyct een manier van palen int zandt te krijghen door vvriggheling, te vveten trecking met touwen ter eender en ter ander zijde, en dat zonder ſtilhouden, tot datſe haer behoorlicke diepte hadden, vvant zoo langhe ſtil ſtaende dattet zandt ſyn zate ghenomen heeft, men kan de pael daer

na niet

gether with others and, seeing that they stopped as they reached the sand stratum and could not proceed, said and showed by practice how they did this in his country, which was by hanging one of the piles floating in the water on to a pile that was being driven in, as will be clear from Figure 6. It is obvious that the more weight one attaches to the pile, the better its penetration, for not only is the effect of each stroke thus preserved, but the pile also penetrates deeper with each stroke.

During the siege of Ostend a method was used of driving piles in by wriggling, *i.e.* by pulling with ropes on one side and on another side, and that continually, until the proper depth had been reached, for if it is kept still until the sand has na niet weerom beweghen: En ſtaet noch te ghedencken, dat de voorſchreven aenhanghing van ghewicht aen de pael hier ooc zeer voorderlic is. Deſe manier nam haer oorſpronc daer uyt, dattet vverc by nacht moeſt geſchien, zonder metten val des heyblocx gherucht te maken, daer den Vyandt na ſchoot: Maer deſe palen en kanmen met zulcke wriggheling niet in krijgen, deur dienſe met ſwalueſteerten aen malkander ghehecht zijn, zulcx dat dit hier alleenelic vermaent wort tot ghedachtenis; Ooc is te vveten, datmen met deſe vvriggheling zich niet behelpen en kan alſſer onder het zandt light dari, kley, veen, of dierghelijcke vaſte ſtof, deur vvelcke men de palen heyen moet.

3 HOOFTSTVC,

Inhoudende ghemeenen reghel, van der Steden nieu manier van verſtercking, door ſchuerende Spilſluyſen.

KORTBEGRYP VAN DIT HOOFTSTVC.

INt Kortbegrijp deſes handels ghezeyt vveſende van't onderſcheyt int gemeyn tuſſchen dit 3^e en 'tvolghende 4^e Hooftſtuc, zoo zullen de bezonder Opſchriften der voorbeelden van dit 3 Hooftſtuc dusdanich zijn.

1 *Voorbeelt, van een Stadt aen't ſtrandt gheleghen, daer de Duynen of Dijcken op beyde zijden teghen de vvallen aenkomen, en verbetering vereyſcht.*

2 *Voorbeelt, vande verbetering der Stadt des 1 Voorbeelts, deur het legghen van tvvee Spilſluyſen.*

3 *Voorbeelt, van't legghen der ravelins voor de Spilſluyſen.*

4 *Voorbeelt, van't legghen der VVatermolens nevens de Sluyſen, en der ravelins voor beyde t'zamen, metten oorboor daer uyt volghende.*

5 *Voorbeelt, vande meerder ſterckte, en ander bequaemheden, die de voorſchreven Stadt krijcht door het omgraven van noch een gracht.*

6 *Voorbeelt, inhoudende ſchuering der grachten van Steden niet aen ſtranden gheleghen als de voorgaende, maer zoo verre daer af, datmen tuſſchen beyden kan Legher ſlaen.*

7 *Voorbeelt, van ſchuering diemen doen kan in grachten van Steden, gheleghen aen Zee of groote Rivieren zonder ebbe en vloet, maer hebbende een kleyn Rivierken dat aen de Stadt komt.*

8 *Voorbeelt, van ſchuering diemen doen kan met een groote bevaerlicke Rivier, zonder ebbe en vloet, ooc zonder kleyne Rivierkens aen de Stadt komende.*

9 *Voorbeelt, inhoudende ſchuering der grachten van Landtſteden verre van Zee of van groote bevaerlicke Rivieren, maer hebbende een kleyn onbevaerlic Rivierken datter aen komt.*

settled in its place, the pile cannot be moved anymore. It should also be remembered that the above-mentioned loading of the pile is also most advantageous here. This method arose from the fact that the work had to be done at night, without making a noise with the pile-driver, so that the enemy could aim and shoot. But our piles cannot be driven in by such wriggling because they are dovetailed, so that we have mentioned it here only for curiosity's sake. It is also to be noted that one cannot use the wriggling method if beneath the sand there should be light slush, clay, peat, or other solid matter, through which the piles have to be driven.

CHAPTER 3

Containing the general rule of the new manner of fortifying towns by means of scouring pivotted sluice locks.

SUMMARY OF THIS CHAPTER

In the summary of the treatise we have dealt with the general difference between this third and the following fourth chapter; the special headings of the examples in this third chapter will be as follows:

Example 1, *of a town on the seaside, the dunes or dikes coming up to the walls on either side, and improvement being required.*

Example 2, *of the improvement of the town of Example 1, by the construction of two pivotted swivel-gate locks.*

Example 3, *of the construction of the ravelins in front of the locks.*

Example 4, *of the construction of water-mills by the side of the locks, and of ravelins for both, and the advantage resulting from this.*

Example 5, *of the greater strength and other advantages which the above-mentioned town acquires by the digging of another ditch.*

Example 6, *containing the scouring of the ditches of towns not on the sea-side like the preceding, but so far from it that a camp might be pitched between them.*

Example 7, *of the scouring of the ditches of towns on the seaside or large non-tidal rivers, having a small river coming up to the town.*

Example 8, *of the scouring that might be brought about with large, navigable non-tidal rivers, even without small rivers coming up to the town.*

Example 9, *of the scouring of ditches of inland towns far from the sea or large navigable rivers, having a small non-navigable river coming up to them.*

10 *Voorbeelt, vande verbetering der Houders of Boesems, diemen ten platten Lande ghebruyct, zoo tot schuering der Havens, als tot drooghing der Landen.*

11 *Voorbeelt, vande schuering der Vaerden door venen daermen Turf steect.*

12 *Voorbeelt, vande manier der bequame schuering vande Vaerden tusschen twee Eylanden, of tusschen vast landt en Eylandt daer ebbe en vloet is.*

1 VOORBEELT,

Van een Stadt aen't strant gheleghen, daer de Duynen of Dijcken op beyde zijden teghen de wallen aen komen, en verbetering vereyscht.

LAet tot dien eynde A deser 1 Form een Stadt wesen, ligghende aen't strant B, zulcx dat de Zee of groote Rivier C die ebbe en vloet heeft, met haer hooch water daer teghen aen slaet, zonder tusschen het water en de Stadt plaets te zijn daermen mach Legher slaen: Met D en E worden beteyckent de Duynen of Dijcken op beyde zijden teghen de Stadtwallen aenkomende. Zoodanighe Steden hebben tot noch toe het ongheval ghehadt, datmen die niet behoorlic en heeft konnen verstercken, om datmen ter plaetsen van D en E gheen deurgaende grachten maken en kan, want daer zandighe Duynen zijnde, de diepte diemender in graeft en kan niet blijven, maer wordt terstont door het Zeewater met zandt gevult ter hooghde van't strant, waer op de winden noch meerder hooghde van Duynen brenghen. Maer ter voorschreven plaetsen van D en E Dijcken zijnde, die teghen de wallen aenkomen, sy vervullen de grachten: En daer schoon steenen * Beeren gheleyt wesende, ghelijc gheteyckent zijn by F en G, zoo ist van daer af als langs het strant van F tot G drooghe, voornamelic met leeghe wateren en aflandighe winden.

* *Dodanen,* dat's dos de asnes.

Om

Example 10, *of the improvement of the basins or reservoirs used in the country, both for the scouring of harbours and the drainage of land.*

Example 11, *of the scouring of the canals through the moors where peat is cut.*

Example 12, *on the method of the proper scouring of the channels between two islands, or between the mainland and an island, if there is ebb and flow.*

EXAMPLE 1

Of a town on the seaside, the dunes or dikes coming up to the walls on either side, and improvement being required.

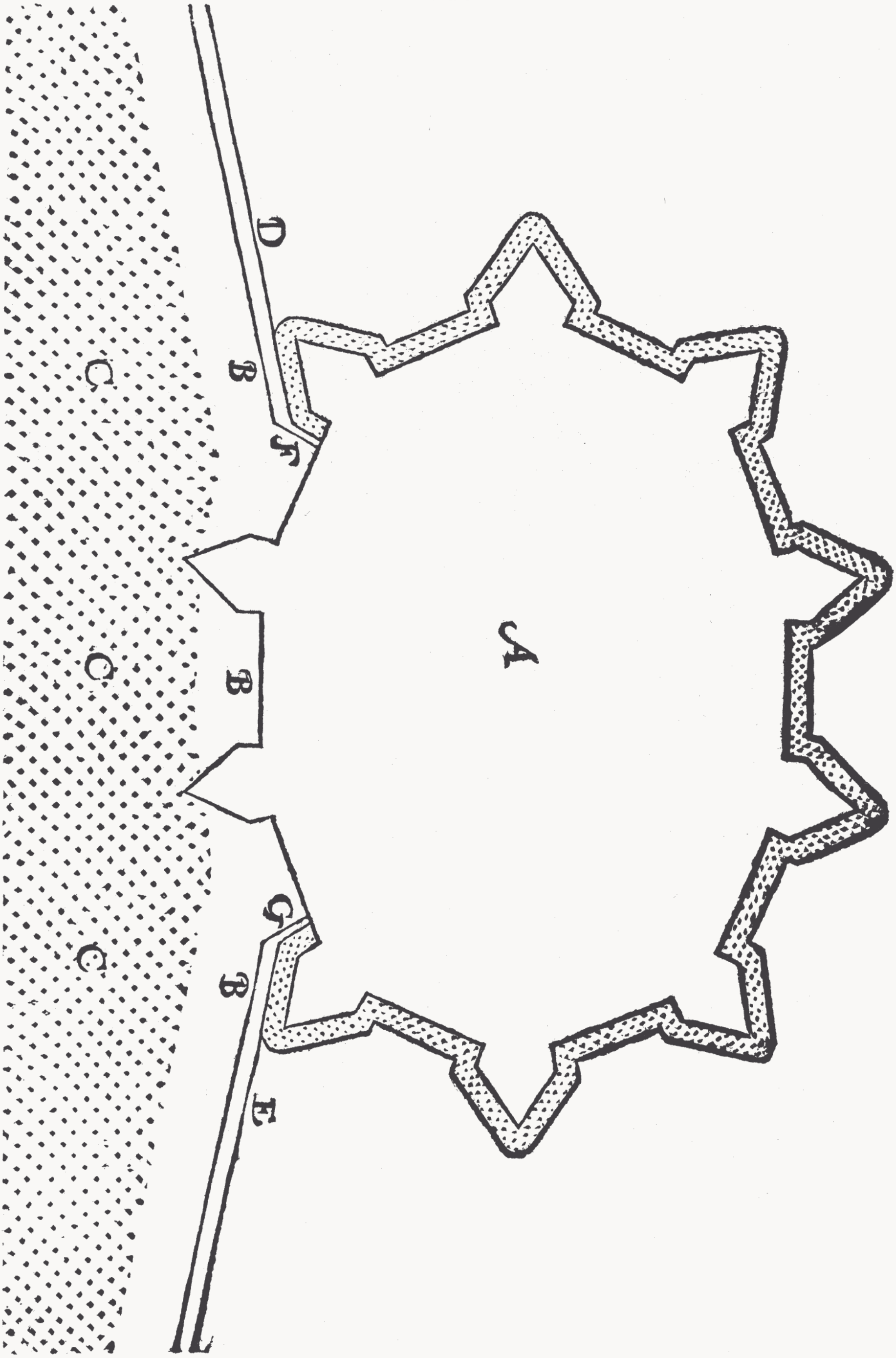
For this purpose let *A* in Figure 1 be a town on the shore *B*, in such a way that the sea or large river *C*, being tidal, at high tide reaches it without there being space between the water and the town where an army might camp: *D* and *E* represent the dunes or dikes coming up to the town walls on either side. Such towns up to now had the disadvantage of having no proper possibility of fortification, because at *D* and *E* no continuous ditches could be dug, for with sandy dunes the depth of digging cannot be maintained, but is immediately filled with sand by the sea to the level of the beach, where the winds accumulate it to form even higher dunes. But if there are dikes which come up to the walls in the above-mentioned places *D* and *E*, they fill the ditches. And even if stone dams are laid there, as shown at *F* and *G*, the beach will be dry there from *F* to *G*, especially at low tide and with offshore winds.

In order to remove these disadvantages in the town of Example 1, I will now explain my above-mentioned plan, first giving examples of little expense and great ease, then of greater expense, in order to make the choice of the improvement depend on the extent of the requirements and the financial means available.

EXAMPLE 2

Of the improvement of the town of Example 1, by the construction of two pivotted swivel-gate locks.

I FORM.

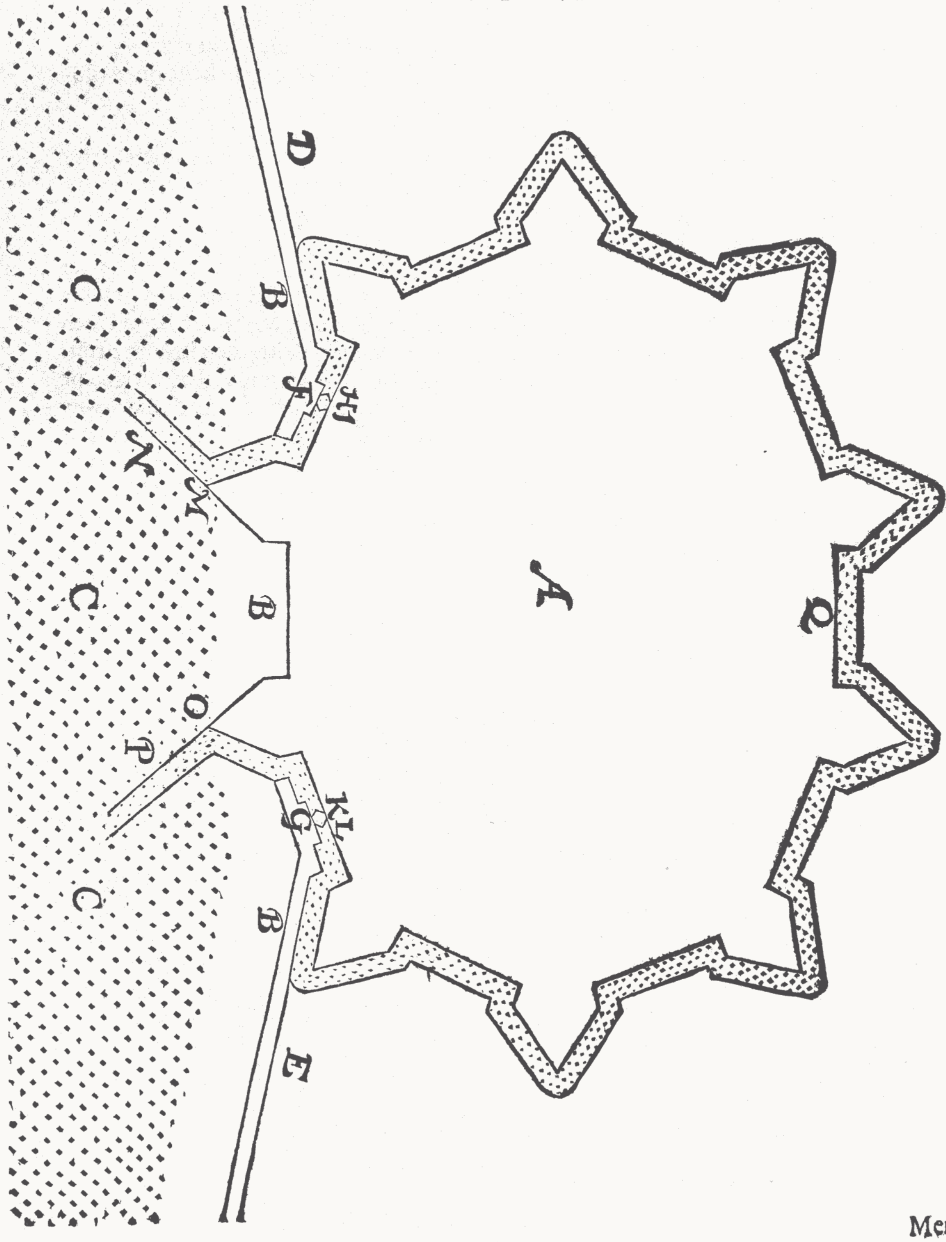


Om dese onghevallen vande Stadt des 1 Voorbeelts te verbeteren, zoo zal ic nu myn bovenschreven voornemen verklaren, stellende eerst voorbeelden vande kleenste kost, en meeste lichticheyt, daer na van meerder kost, om na gheleghentheyt des noots en der middelen van ghelt, zich int verbeteren te moghen richten.

2 VOORBEELT,

Vande verbetering der Stadt des 1 Voorbeelts, deur het legghen van twee Spilsluysen.

2 FORM.



Men

MEn zal de twee Beeren F, G, des 1 Voorbeelts vvech doen, en ſtellen by elcke dier plaetſen een Spilſluyſe, vvijt neem ic 50 voeten, met twee paer deuren, als in deſe 2 Form ter plaets des Beers F de twee paer deuren H en I: En ter plaets des Beers G de twee paer deuren K, L, vveſende van form ghelijc het Sas tot Vliſſinghen, dat breet is 40 voeten 10 duym Rijnlantſche maet, hebbende ooc twee paer ſteecdeuren: Voort zalmen't van die deuren af tot aen't vvater der Zee of Rivier deurgraven zoo verre het noodich is, ghelijc aengheweſen vvort mette twee grachtkens of Havens M N, O P, vvelcke zoo gheleyt zijn, dat by aldienſe door 'tghedacht voortghetrocken vvaren tot datſe malkander raecten, zouden een rechthoec maken, en dit tot zulcken eynde als ic hier na zegghen zal. Ooc is te vveten, dat deſe twee Havens met hoofden dienen bezet te vveſen, zoo lanc alſmen den noot bevint te vereyſſchen, om de Havens in die form te blijven, en int ſtrant beter ſchuering te maken.

Dit zoo zijnde, ic zal nu 'tgebruyc verklaren: Het hoogh water des vloets mette ghesloten deuren H L opghehouden zijnde, en daer na het buytenwater mette ebbe ten leeghſten ghekomen vveſende, zoo zalmen d'eenmael de ſpildeuren L openen, en H toelaten, en zal alſdan al het opgehouden water des grachts H O L uytloopen door de deuren L, ſchuerende het grachtdeel K O P, een andermael zalmen de deuren H openen, en L toelaten, en zal alſdan het vvater des grachts L O H uytloopen deur H, ſchuerende het grachtdeel I M N, en boven dien zal de heele gracht geſchuert vvorden, om dattet vvater zeer ſtercken ſtroom heeft. Noch ſtaet hier t'aenmercken, dat hoewel om de ſtercke ſtrooms vville inde gracht goede ſchuering komt, datſe nochtans daer zoo gheweldich niet en is als inde twee buytenſte grachtdeelen of Havens H M N, L O P, overmits dattet vvater daer in van hooghe inde ledighe leeghte valt: Maer om zulcke manier van ſchuering ooc inde gracht te krijghen, dat vvort aldus ghedaen: Het vvater mette ebbe inde gracht ten leeghſten ghekomen zijnde, men zal de deuren K, I, toedoen, daer na het buytenwater metten vloet ten hooghſten ghekomen weſende, zoo zalmen het een paer deuren ic neem I openen, en zal alſdan het hooch buytenwater vallen in de ledighe gracht, daer in veel dieper ſchuerende dan na d'eerſte vvijſe: En hoewel hier me het zant ghebrocht vvort van H over O na K, aldaer vergarende zonder voor dat mael uyt de gracht te gheraken, om dat K ghesloten blijft, zoo kan dat daer na mettet hooch grachtwater op leegh buytenwater uytgheſchuert vvorden door L, na de manier als voren ghezeyt is. Zulcke wijſe van dieper ſchuering des grachts d'een mael met opening der deuren I blijvende K ghesloten, mach een ander mael ghedaen vvorden met opening der deuren K, blijvende I ghesloten.

Met deſe manier is de Stadt gantſchelic in vvater omvangen, zonder de droochten aende Beeren F G te hebben, vvant in tijt van noot de deuren open gheſtelt zijnde, en met ſtercke ſloten teghen de zijden vaſt ghemaeċt, zoo iſſer tot die plaets de breedde van 50 voeten grachts van grooter diepte, al iſt ooc op leegh buytenwater, vvaer benevens noch t'aenmercken ſtaet, dat voor deſe Sluyſen tot meerder verzekertheyt moghen ravelins gheleyt vvorden, daer af ic int 3 Voorbeelt verklaring zal doen.

Noch mach hier tot voorbeelt dienen, dat bykans door zulcke manier van doen de Stadt Oſtende de vaſticheyt kreech, daer me ſy het vermaert langduerich belegh vveerſtont, vvant te voren vvaſt (ghelijc zoodanighe Steden ghemeenelic zijn) een krancke plaets, die mettet deurſteken van haer twee uyterſte zandighe eynden haer ſterċte bequam.

Noch is te vveten, dat boven de ſterċte die deſe Stadt aldus krijcht, zoo is zulcke

The two dams *F* and *G* of Figure 1 should be removed and in each of these places pivotted locks should be built, whose width I take shall be 50 feet, with two pairs of gates, as in Figure 2, in the place of the dam *F*, the two pairs of gates *H* and *I*; and in the place of the dam *G* the two pairs of gates *K* and *L*, having the form of the Lock of Flushing, which is 40 feet 10 inches (Rhineland standard) wide and also two pairs of mitred gates. One should also dig from these gates up to the sea or river, according to need, as is shown with the two ditches or harbour *MN* and *OP*, which are built in such way that if they were produced in imagination until they touched each other they would include a right angle, this for the purpose I will explain below. The two harbours should also have piers, as long as is found to be needed, to keep these harbours in the same form and to cause better scouring in the beach.

This done, I will now explain the application: The water of the high tide having been dammed up by the closed gates *H* and *L*, and the outer water having fallen to the lowest level at low tide, at one time the swivel-gates *L* should be opened and those at *H* kept shut, and then the pent-up water of the ditch *HQL* will flow out of the sluice doors *L*, scouring the part *KOP* of the ditch; at another time the doors *H* will be opened and *L* kept shut, and then the water of the ditch *LQH* will flow out of *H*, scouring the part *IMN* of the ditch, while moreover the entire ditch will be scoured, because the water has a strong current. It is also to be remarked that though this strong current will scour the ditch properly, the scouring will not be as strong there as in the two outer parts of the ditch or harbours *HMN* and *LOP*, since there the water falls from above into the emptiness below. But in order to obtain a similar scouring in the ditch one should act thus: When at low tide the water in the ditch has reached its lowest level, the gates *K* and *I* should be closed; then, when the outer water has reached its highest level at high tide, a pair of sluice doors, say *I*, should be opened and the high outer water will then fall into the empty ditch and scour it to a much greater depth than in the first case. Although the sand will thus be brought from *H* via *Q* to *K*, accumulating there without being flushed from the ditch, because *K* remains closed, it can be washed with high ditch-water into low outer water through *L*, as already explained. This way of scouring the ditch more deeply at one time by opening the sluices at *I* and keeping those at *K* closed, at another time may be effected by opening the sluices at *K* and keeping those at *I* closed.

In this way the entire town is completely surrounded by water, without having dry places at the dams *F* and *G*, for if the gates are opened in times of danger and fixed with strong locks to the sides, in this place there is a width of 50 feet of ditches of greater depth, even at low tide of the outer water, while it should also be noted that the locks can be better protected by building ravelins in front of them, as I will explain in Example 3.

Furthermore it should be said here that the town of Ostend probably derived from this its strength, with which it withstood the famous long siege; for previously it was (as such towns usually are) a weak town, which by cutting its two extreme sandy ends acquired its strength.

It is also to be noted that apart from the strength which a town thus acquires, gracht bequaem tot Haven, om in tijdt van beleghering Schepen in te komen, en alle nootdruft in te brenghen: Voort om in tijdt van vrede, of daer gheen vreese des Vyants en is, koophandel te drijven: Ooc om teghen ijsganc Schepen te verberghen, en in te verwinteren, streckende niet alleen tot groot voordeel der Steden, maer ooc, ghelijc voren ghezeyt is, tot groot gherief en zekerheyt van Schip, lijf en goet der varende menschen: boven dien, daer het te voren vuyle stinckende stilstaende grachten moghen gheweest hebben, zijnse aldus van die swaricheyt ontslaghen.

Voorts nadien de Havens N M, P O door 'tghedacht voortghetrocken zijnde, een rechthoec maken, zoo volght daer uyt, dat by aldienmen neemt d'een Haven als M N te strecken na het Noorden, zoo streckt d'ander Haven P O na het Westen, waer uyt men besluyten mach, datmen bykans met alle wint uyt en in kan varen, en nimmermeer heel tegen wint te hebben, mits datmen die Haven verkiese daer de wint het meeste voordeel in doet, zulcx dat zoodanighe gracht is een bequame ree, daer in de Schepen met zekerheyt na goede wint konnen wachten, en deur het een of't ander gat uyt komen.

Maer want ymant twijffelen mocht aende groote diepten dieder ghezeyt worden te zullen schueren door de Duynen, als ter plaets van N M, P O, zoo is daer af voorbeelt te zien onder anderen aende Havens tot Calis, Duynkercke, Nieupoort, Ostende, en meer ander die met kleene opwindende Sluysdeuren door de Duynen schuerende ghemaeckt zijn, en onderhouden worden, die ooc zonder de zelve Sluysdeuren (hoewel sy by dese vergheleken zeer kleyn zijn) in korter tijdt verzanden zouden. Voort zietmen veel Havens binnen verscheyden Steden zeer diep gheschuert te worden met kleene Sluyskens en luttel opghehouden water: Als tot Vlissinghe, alwaer men d'oude Haven schuert met een deure tusschen de stijlen, breet zijnde alleenelic 3 voet 3 duym, en met een molenwater alleenelic ontrent 55 roeden lanc en breet, dat haestelic daelt, schuerende nochtans de Haven tot zulcken grooten diepte als blijckt: De schuerdeure vande nieuwe Haven is tusschen de stijlen van 6 voet 2 duym. Waer wt men mercken kan wat grooter schuering volghen moet met Sluysdeuren breet 50 voet, daer de heele gracht voor Houder verstreckt, die zoo haestelic niet en daelt als de kleene.

Noch valt deur dese manier van oordening een groote bequaemheyt inde zake van Watermolens, daer int volghende 4 Voorbeelt af zal ghezeyt worden.

3 VOORBEELT,

Van't legghen der ravelins voor de Sluysen.

HOewel zommighe Steden die gheen krijch en hebben, d'onkosten van ravelins int eerste niet doen en willen, latende de Sluysen liever bloot liggen, ghelijc int 2 Voorbeelt, nochtans voor de ghene diese begeeren, stel ic hier dese 3 Form, waer in voor de Sluysen H I en K L, gheteyckent zijn de ravelins F en G, diens voorzijden ghestreken vvorden uyt de nevenstaende bolwercken, ghelijcmen ziet.

Maer

such a ditch is suitable as a harbour, for ships to enter into in times of siege and bring all the provisions. Also in times of peace and when there is no fear of an enemy, for trade. Also to shelter ships against ice-drift and to winter them, which is not only of great advantage to the towns, but also, as stated before, of great convenience and safety for the ships, and the lives and possessions of the sailors; moreover, what may have been dirty stinking ditches will thus have been relieved of this disadvantage.

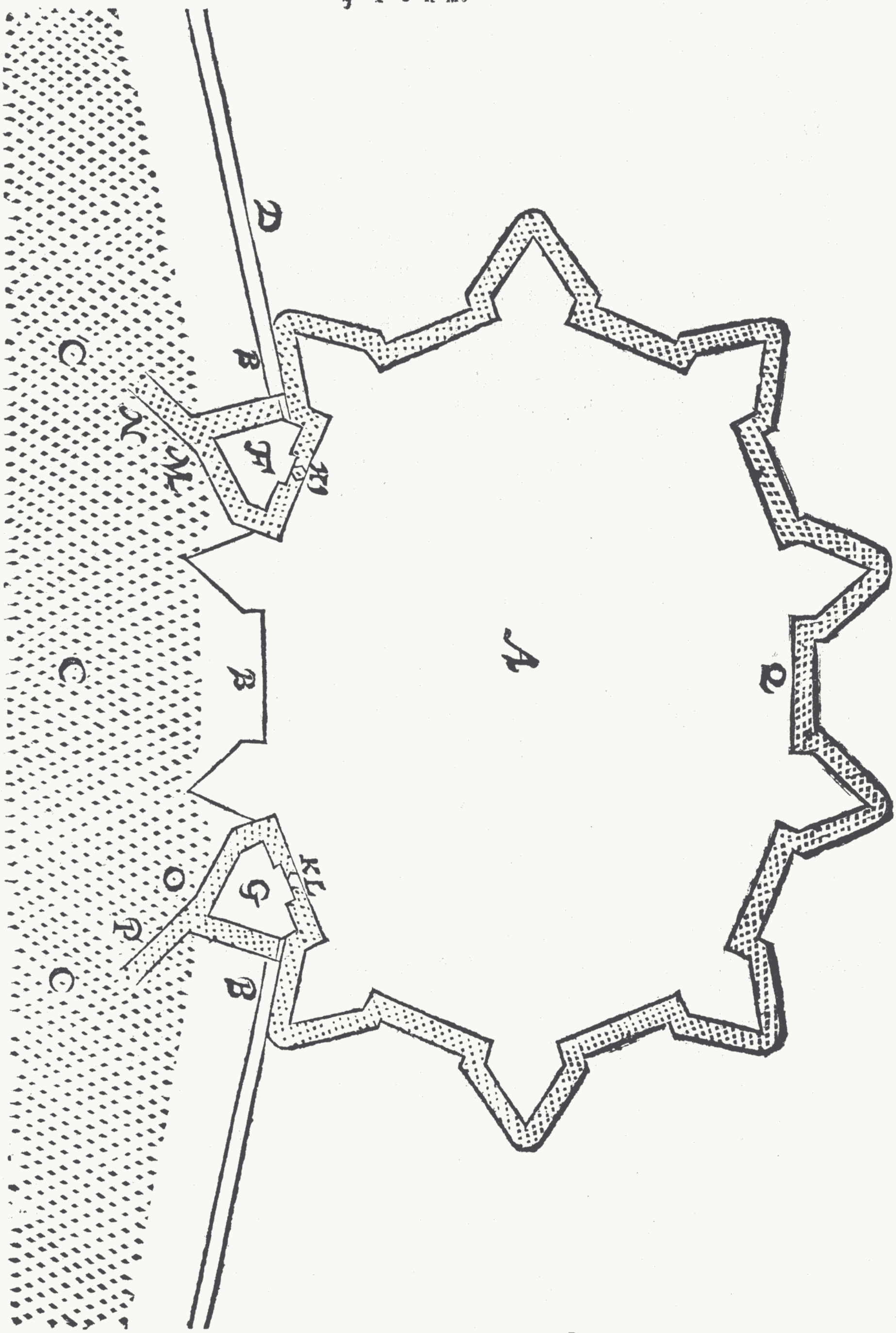
Furthermore, as the harbours *NM* and *PQ*, if produced in imagination, form a right angle, the result is that if we take the one harbour *MN* to point North, the other *PO* will point to the West, from which it may be concluded that one can sail in and out with practically any wind, if one chooses the harbour where the wind is most favourable, so that such a ditch is a suitable roadstead, where ships may wait in safety for a favourable wind and may enter by one harbour or the other. But because one might doubt the great depth which has been said to be scoured through the dunes near *NM* and *PO*, we point to the examples of the harbours at Calais, Dunkirk, Nieuwpoort, Ostend, and others, made and maintained with small vertical gates scouring ditches through the dunes, which would get blocked with sand in a short time without these gates (though they are small compared with ours). Furthermore there are seen many harbours in various towns which are scoured to great depths by small locks and a small body of pent-up water, as at Flushing, where the old harbour is scoured with a sluice, which between the posts is but three feet three inches wide, and that with a drainage area some 55 roods long and wide only, which falls quickly and yet scours the harbour to such great depth. The scouring sluice of the new harbour is 6 feet 2 inches wide between the posts. From this we may conclude how much greater the scouring will be with sluice-doors 50 feet wide, for which the entire ditch serves as a basin, which does not fall as quickly as the small one. This arrangement also produces great advantage for water-mills, as will be discussed in the fourth example below.

EXAMPLE 3

Of the construction of ravelins in front of the locks.

Though some towns, which are not at war, do not care to spend money on ravelins, preferring to leave the locks unprotected, as in Figure 2, yet for those who desire it, I give Figure 3 in which the locks *HI* and *KL* are protected by ravelins *F* and *G*, the fronts of which are commanded by the bulwarks next to them, as can be seen.

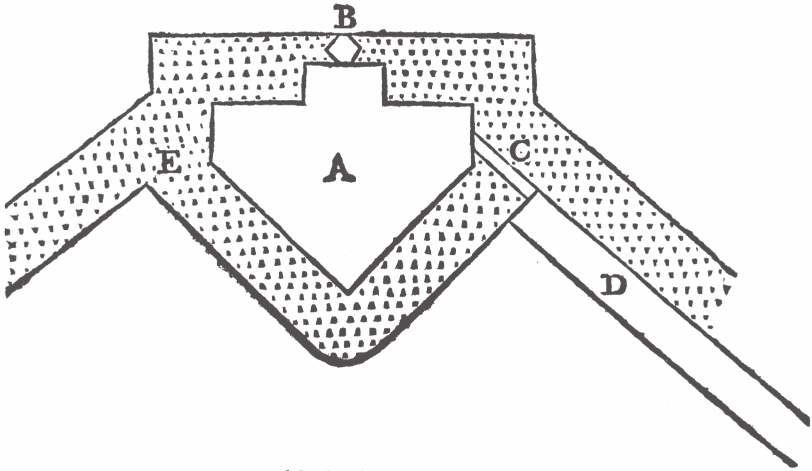
3 FORM.



 Maer

Maer op dat de meyning deur grooter form beter verklaert vvorde, zoo ſtel ic hier deſe 4 Form van het ravelin A alleen,gheleyt voor de twee paer Sluysdeuren by B, voort bediet C een Beer aenden Dijc D, in welcken Beer verſtaen wort (ghelijc ooc inde Beeren der volgende Formen) gewrocht te zijn een optreckende Sluysdeurken, alleenelic een voet breet, om te ſchueren den ravelins gracht van C tot E. De ghetippelde plaetſen zijn het grachtwater.

4 FORM.



4 VOORBEELT,

Van't legghen der VVatermolens nevens de Sluyſen, en der ravelins voor beyde t'zamen, metten oorboor daer uyt volghende.

DE Watermolens hebben na de manier diemen tot noch toe ghebruyct heeft aende verſtercking der Steden hinderlic gheweeſt, want malende met water dat ebbe en vloet heeft, haer Houder is buyten of binnen de Stadt: Daer buyten zijnde, de gracht heeft voor eerſt twee hinderlicke dammen.

Ten tweedden, den Houder afgemalen vveſende, zoo light de zelve (zijnde deel des grachts) drooghe.

Ten derden, zoodanighen Houder vvaſt zeer aen, zulcx datſe eermenſe verdiept vveynich vvater begrijpt, en ſtreĉt de verdieping tot groote koſt.

Ten vierden, by aldienmen den Houder binnen de Stadt veroordent, zoo en komen uyt oorzaec van dien gheen dammen inde gracht, maer het is inde Stadt een groote ledighe plaets, diemen alſſer gheen Houder en waer, zoude moghen bebouwen, ooc is zoodanighen Houder onderworpen ghelijc d'ander den aenwas, ondiepte, weynich vvater, en groote onkoſten van zomwijlen te diepen.

Ten vijfden, malende de Molens niet met ebbe en vloet als voren, maer met loopende Rivierkens, en datſe inde Stadt liggen, de loopende Rivierkens worden deur de gracht gheleyt tuſſchen twee hinderlicke dammen.

Ten zeſten, zoomenſe buyten de Stadt leght, en de Rivierkens deur de grachten doet loopen, ſy verzanden de grachten.

Ten zevenden, zoomen de Rivierkens doet loopen buyten de gracht, en de Molens daer aen leght, ſy ſtaen ten tijde van oorlogh in perijckel van afghebrant te vvorden.

Maer

But in order to explain the intention better by a larger drawing, I here give Figure 4 of the ravelin *A* alone, laid in front of the two pairs of gates at *B*; *C* represents a dam at the dike *D*, in which dam (as also in the next figures) we suppose has been made a small sliding sluice-door, only one foot wide, in order to scour the ditch of the ravelin from *C* to *E*. The dotted areas represent the water of the ditch.

EXAMPLE 4

Of the construction of water-mills by the side of the locks and of the ravelins for both, and the advantage resulting from this.

The water-mills, according to the manner in which they have been used up to now, have formed an obstacle to the fortification of towns, for when draining with tidal water, their basin (mill-pond) is inside or outside the town; if outside, the ditch firstly has two dams, which form obstacles.

Secondly, when the mill-pond has been emptied, the latter (forming part of the ditch) will be dry.

Thirdly, this basin fills up easily, so that it will hold only little water unless it is dredged, and this involves great cost.

Fourthly, if the mill-pond is inside the town, there will accordingly be no dams in the ditch, but in the town there will be a large empty space, which might have been built up if there had been no basin; furthermore such a basin, like the one mentioned, tends to silt up, become shallow, have little water, and will involve great expense for periodical dredging.

Fifthly, if the mills are not moved by the tides as above, but by flowing rivers, which run through the town, the flowing rivers are led through the ditches between two dams, which form obstacles.

Sixthly, if they are outside the town, and the rivers are led through the ditches, they will silt up the ditches.

Seventhly, if the rivers are led outside the ditch and the mills are built there, in time of war they are in danger of being burnt down.

Maer alsmen de Watermolens veroordent nevens de spildeur (gelijcmense ghemeenlic leght nevens haer optreckende schuerdeur, daermen de hooghe vvateren me looft) zoo zijn daer me de bovenschreven onghevallen voorkomen: Want eerstelic en zijnder gheen hinderlicke dammen inde grachten.

Ten tweedden en kan zulcken Houder op een ghetije niet afghemalen vvorden, noch drooch ligghen, vvant om haer grootheyts vville zal het vvater op dien tijdt vveynich dalen.

Ten derden, en zal zoodanighen Houder niet aenwassen, noch met groote kost zomwijlen moeten verdiept zijn, maer gheduerlic diep blijven, of om de gheduerighe schuerings vville noch dieper vvorden, en veel vvaters begrijpen.

Ten vierden, en ist niet noodich Houders binnen de Stadt te veroordenen, die een groote onbewoonde plaets in nemen, en boven dien ghelijc d'ander onderworpen zijn den aenwas, ondiepte, vveynich vvater, en groote onkosten van zomwijlen te verdiepen.

Wat belangt de voorkoming der ongevallen van Molens malende met loopende Rivierkens, daer af zal ghezeyt vvorden int 7 Voorbeelt.

Aengaende d'inkomst der Schepen uyt de Havens M N, O P inde gracht, 'sghelijcx d'uytkomst uyt de gracht inde zelve Havens, die mach zonder het malen te verhinderen daghelicx gheschien zoo langhe als de vloet loopt inde gracht, ooc zoo langhe als gheduert den stilstant van't hooghste, en stilstant van't leeghste buyten en binnenwater, de Sluysen open zijnde.

Tot hier toe is ghezeyt vande Watermolens gheleyt nevens de Sluysen, ghelijcmense ghemeenelic leght nevens haer optreckende schuerdeuren, daermen de hooghe vvateren me looft, maer om daer af noch naerder verklaring te doen, metsgaders van't ravelin voor beyde t'zamen liggende, zoo stel ic hier de grontteyckening deser 5 Form, vvaer af den zin dusdanich is:

A Overwelfde ganc door den vval, om te gaen na de Molen en na het Ravelin, dienende ooc tot * uytvallen. *Sorties.

B Molenhuys, 'twelc alsser een * leeghe vval is, mach in des zelven ganc ligghen. *Fausebraye.

C Plaets des vvaterrats met syn schotdeur.

D D'een zijde der Spilsluyse.

E De twee paer deuren der Spilsluyse.

F Ravelin, diens voorzijden ghestreken vvorden uyt de twee nevenstaende bolwercken, daermen in tijt van noot buytenwacht op houden mach, en bequamelic gheleghen zijnde om deur den wal daer in te komen, zonder de Stadtpoorten te openen.

G Steenen Beer.

H Dijc.

But if the water-mills are built adjacent to the swivel-gates (just as they are commonly built adjacent to the sliding scouring sluice-door, which serves to drain the high waters), the above drawbacks are avoided.

Firstly, there will be no dams forming obstacles in the ditches.

Secondly, such a basin cannot be used up during one tide nor become dry, for because of its volume the water will fall only little during that period.

Thirdly, such a basin will not silt up or need to be dredged at great cost periodically, but will constantly remain deep, or even become deeper owing to the constant scouring, and will therefore hold much water.

Fourthly, it will not be necessary to construct mill-ponds inside the town, which take up a large inhabitable area and are also liable to silting-up, shallowness, lack of water and great cost of periodical dredging.

As to the avoidance of drawbacks produced by water-mills operated by small flowing rivers, this will be dealt with in Example 7.

As to the entry of ships from the harbours *MN* and *OP* into the ditch, as well as their passing from the ditch into the harbours, this can take place daily without interference with the operation of the mills for as long as the flood-waters run into the ditch, or during the period of rest at the highest tide, and that at the lowest level of the outer water and the inner water, the locks being open.

Up to now we have discussed water-mills built adjacent to the locks, as they are commonly built adjacent to the sliding sluice-doors, which serve to drain off the high water, but in order to explain this in even greater detail, as well as the ravelin built in front of the two, I give the ground-plan in Figure 5, which shows the following:

A Vaulted corridor through the wall to reach the mill and the ravelin, also serving for sorties and sallies.

B Mill-house, which, if there is a faussebray, can be housed in it entirely.

C Site of the water-mill and its sluice-door.

D One side of the lock chamber.

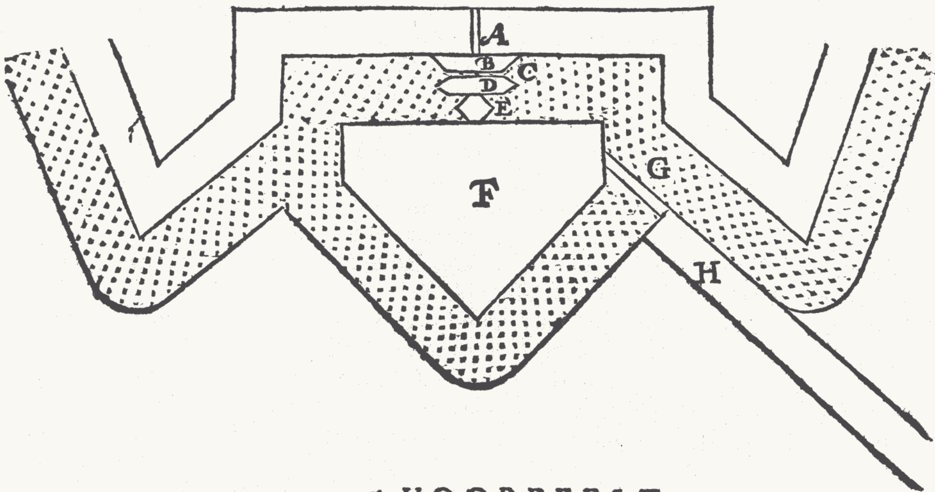
E Two pairs of gates of the lock.

F Ravelin, the fronts of which are commanded by the two nearest bulwarks, in which sentries can be kept in time of danger; and which is conveniently situated for approach from the walls without opening of the town gates.

G Stone dam.

H Dike.

5 FORM.



5 VOORBEELT,

Vande meerder stercte, en ander bequaemheden, die de voorschreven Stadt krijcht door het omgraven van noch een gracht.

DE bovenschreven Voorbeelden zijn gheweest met een Stadtsgracht, die ooc voor Haven verstreft: Doch hebben zoodanige Steden in tijt van oorloogh drie onghevallen: Het eerste, dat de Schepen daer in bloot ligghen, om van de Vyant te konnen beschoten worden: Het tweedde, dat de Vyant daer droochs voets aen kan komen, en de Schepen in brant steken: Het derde, dattet zorghelic is de Schepen aende Stadts wallen te ligghen, om datmen daer uyt lichtelic op de wallen kan klimmen, en door verraet of aenslach de Stadt innemen.

Nu hoewel veel Steden dat perijckel willen lijden, nochtans de ghene die d'onkosten begheeren te doen, zullen om dese onghevallen te voorkomen rondtom de Stadt langs de gracht mogen graven een ander gracht of Haven, vverpende d'aerde dieder uyt komt tusschen beyden, daer af makende een borstweer van bedecte wegh, ter hoochde datter de Schepen achter konnen verborghen ligghen, en met zulcken afdaking dattet vande vvallen overal kan ghezien en ghestreken vvorden, ghelijc aengewesen is met dese 6 Form, in vvelcke rondtom een Stadt daer de Zee of groote bevaerlicke Rivier teghen aenslaet (als vande 3 Form) ghebrocht is noch een Haven met haer twee Sluysen, waer af 'tghebruyc zal zijn als mette voorgaende: Doch is kennelic datmen dese twee Havens M N, O P met meerder overvloet van vvater dan de voorgaende tzeffens kan schueren, om datmen beyde de Sluysen op elcke Haven uytkomende, ghelijckelic kan openen, zulcx dat zoodanighe vier Sluysen elcke vvijt 50 voeten, zouden t'zamen maken een breedde van 200 voeten, vvaer me de Havens al anders zouden konnen ghediept vvorden, dan daermen hier te voren af ghehoort heeft.

Hier me is ooc openbaer, dat in tijdt van oorloogh de voorschreven drie swaricheden voorkomen zouden zijn: Ten eersten, om dat de Schepen, gheduerende een beleghering, gheleyt moghen vvorden inde binnenste gracht, alwaer sy metter hooch borstweer beschermt zijn teghen het schieten des Vyants: Ooc teghen het branden, alzoo hy om de buytenste grachts wille daer niet aen komen en kan, en hoewel de Schepen dan ligghen tegen de Stadts wallen, dat is zonder perijckel van daer uyt beklommen te worden, eensdeels om datter in zulcken tijt zeer nauwe toezicht op de Schepen is: Ten anderen, dat sy als binnen de Stadt liggen om de buytenste

EXAMPLE 5

Of the greater strength and other advantages which the aforesaid town acquires by the digging of another ditch.

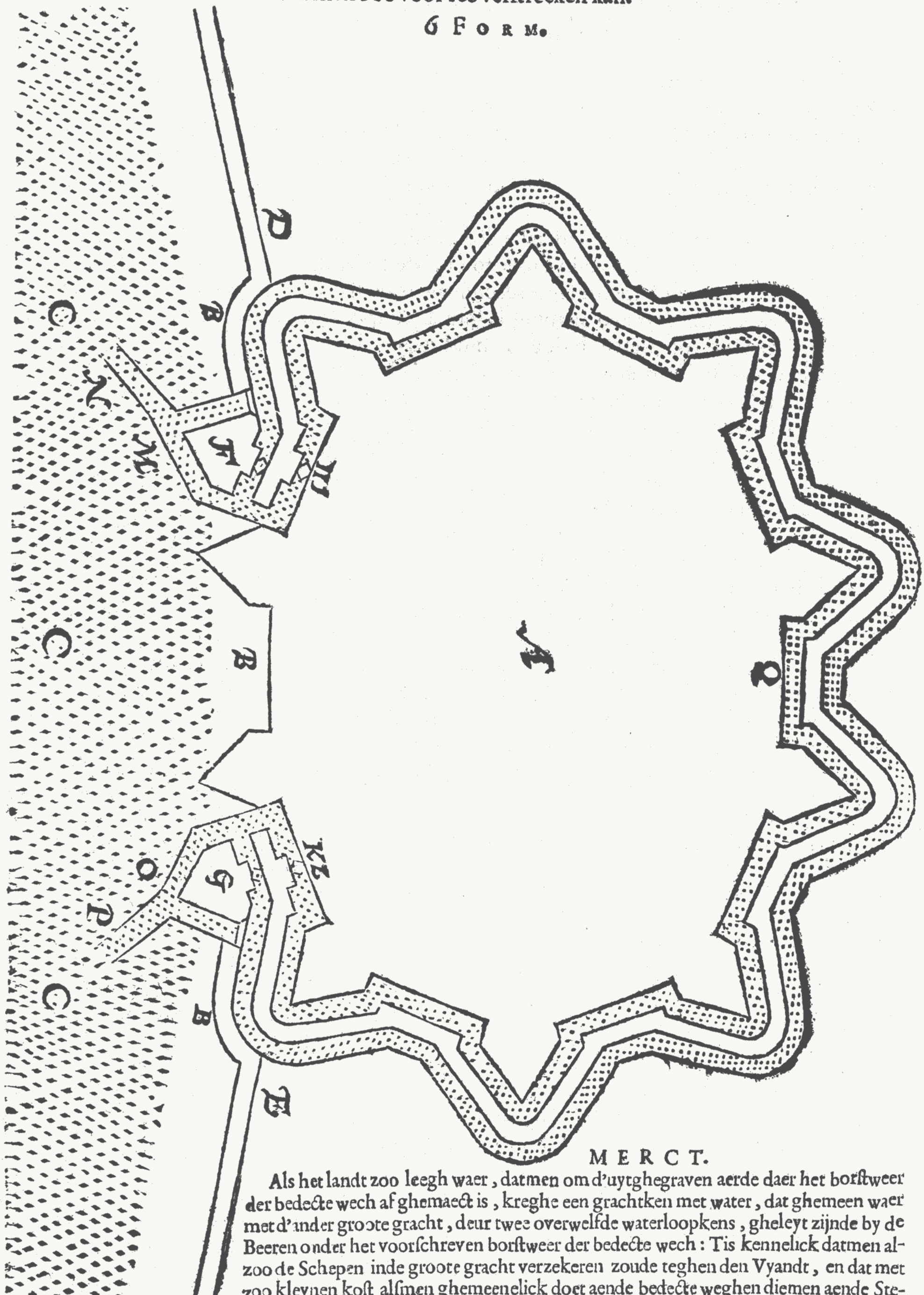
The above examples referred to a town ditch which also served as a harbour. But such towns in time of war have three disadvantages. Firstly, the ships therein are exposed to possible enemy fire; secondly, the enemy may approach them at low tide and set the ships on fire; thirdly, it is risky for the ships to lie close to the town walls, because it is thus easy to scale them and by treason or attack to take the town.

Now though many towns will take the chance of this disadvantage, still those who wish to go to the expense in order to obviate these difficulties may dig around the town by the side of the ditch a second ditch or harbour, casting the excavated earth in between the two and shaping it into a parapet with a covered way, so high that ships may lie completely hidden behind it and with a gradient such that from the walls it can be seen and commanded everywhere, as is shown in Figure 6, in which around the town which is touched by the sea or a large navigable river (as in Figure 3) has been added another harbour and its two locks, which will be used as before. But it is evident that these two harbours *MN* and *OP* can be scoured with a greater excess of water than those mentioned before, because it is possible to open both sluices giving on each harbour at the same time, so that these four sluices, each 50 [1]) feet wide, would add up to a width of 200 feet, with the aid of which the harbours can be scoured in a way far superior to what has been said before. It is thus also manifest that in time of war the three aforesaid difficulties would be avoided. Firstly, because the ships during a siege can be anchored in the inner ditch, where they are protected by the high parapet from the enemy's fire and also against fireships, since they cannot get at them because of the outer ditch, and though the ships are then anchored against the town wall, there is no danger of their being scaled from there, on the first hand because during such a period a close watch is kept on the ships and on the other hand because they anchor in the

[1]) Cf. the figure on fol. 13 (Dutch text).

tenste Havens wille. Maer in tijt van vrede, of alsser gheen vreese des Vyants en is, machmense tot gherief des koophandels laten ligghen inde uyterste Haven, die om de bovenschreven redenen ooc voor ree verstrecken kan.

6 FORM.



MERCT.

Als het landt zoo leegh waer, datmen om d'uytghegraven aerde daer het borstweer der bedecte wech af ghemaect is, kreghe een grachtken met water, dat ghemeen waer met d'ander groote gracht, deur twee overwelfde waterloopkens, gheleyt zijnde by de Beeren onder het voorschreven borstweer der bedecte wech: Tis kennelick datmen alzoo de Schepen inde groote gracht verzekeren zoude teghen den Vyandt, en dat met zoo kleynen kost alsmen ghemeenelick doet aende bedecte weghen diemen aende Steden en Stercten maect, en krijghende 'tvoorschreven grachtken syn schuering na 'tbehooren.

town itself, because of the outer harbour. But in time of peace or when there is no fear of the enemy, they can be anchored in the outer harbour to oblige the trade, which harbour may also serve as a roadstead for the reasons detailed above.

NOTE C

If the land were so low that because of the earth excavated to build a parapet with a covered way a small ditch with water would be formed, which would communicate with the other large ditch, by means of two vaulted channels, laid out near the dams underneath the above parapet with covered way, it is evident that the ships in the large ditch would thus be protected from the enemy and that with as little expense as that usually involved in the construction of the covered ways for towns and fortifications the aforesaid small ditch thus being properly scoured.

6 VOORBEELT,

Inhoudende schuering der grachten van Steden niet aen stranden gheleghen als de voorgaende, maer zoo verre daer af, datmen tusschen beyden kan Legher slaen.

ZVlcke Steden kanmen wel heel omgraven zonder Beeren inde grachten te legghen, brenghende de Dijcken zooder zijn buyten om de gracht, inder voeghen dat haer afdakinghen vande vvallen konnen ghestreken vvorden, en voor borstweeren van bedecte vveghen verstrecken, maer alsdan en moghen inde Stadt noch gracht gheen Schepen komen, door dien se zoo syder quamen, mette leeghe vvateren drooch zouden ligghen, zulcx dat alsmender de Scheepvaert begheert, zoo heeftmen tot noch toe Beeren inde grachten moeten legghen, als te Middelburch, inden Briel, en dierghelijcke Steden: Maer om te verklaren hoe zulcx zonder Beeren gheschien kan, zoo teycken ic dese 6 Form met haer twee Sluysen H I, K L als voren, maer met een gracht van d'een tot d'ander: Wt dese gracht loopt na het groot vvater toe een Haven, die in tween ghedeelt is mette twee deelen M N, O P, op malkander rechthoeckich komende, waer af 'tghebruyc door de bovenschreven voorbeelden openbaer is.

Maer want ten tijde van beleghering het uyt en invaren der Schepen door zoodanighen Haven zoude konnen belet worden, overmits de Vyant aen de kanten droochs voets komen kan, zoo zijn hier nevens de Haven ghegraven twee grachtkens als R en S, met vvelcker aerde op de binnenkant gheworpen, verstaen worden borstweeren ghemaect te vvesen. Aengaende men vermoeden mocht, dattet water door dese twee grachtkens loopende, te zeer verminderen mocht het water der middelste groote Haven, die daerom te luttel diepte konde krijghen: Hier teghen staet te bedencken, datmen den mont of inkomst dier twee grachtkens zoo nauwe mach maken alsmen wil, want al en warense elc maer twee voet breet, zoo kan daer schuering ghenoech door komen: Zulcke vier voeten, alwaert ooc vijf of zes, hebben luttel te bedien, vergheleken zijnde by 'tgat der 100 voeten vande twee Sluysen, en noch min alsser zulcke vier Sluysen zijn, ghelijc int 5 Voorbeelt.

Noch ist oorboor aen de mont des Havens te legghen een Schans, ghelijc aenghewesen is met T, tusschen welcke en de Stadt de voorschreven borstweer ender twee grachtkens (heel recht ghetrocken zijnde) konnen ghestreken worden, zoo wel uyt de twee bolwercken der Schans, als uyt de Stadt. Merct noch dat, al waerder tusschen de Stadt en de Schans 1500 voeten langde, zoo schijnet datter gheen ander Schans tusschen beyden en zoude behoeven, maer de plaets al te lanc zijnde, men mochter een of meer tusschen legghen.

7 Form.

EXAMPLE 6

Containing the scouring of ditches of towns not on the seaside like the preceding, but so far from it that a camp might be pitched between them.

Such towns can easily be protected by an encircling ditch without building dams therein, placing the dikes, if any, outside the town in such a way that their slopes can be commanded from the walls and can serve as parapets of covered ways, but then no ships should enter the town or the ditch, for if they came there they would be stranded at low tide, so that, if shipping is to be possible, up to now dams had to be constructed in the ditches as at Middelburg, Brielle and similar towns. But in order to explain how this can be done without dams, I draw Figure 6 with its two locks *HI* and *KL* as before, but with a ditch reaching from one to the other; extending from this ditch to the large water is a harbour, which is divided into two parts, *MN* and *OP*, at right angles to each other, the use of which is clear from earlier examples [1]).

But because during periods of siege the passage of ships into and out of such harbours may be impeded, since the enemy could approach their sides with dry feet, by the side of the harbour two narrow ditches have been dug, *R* and *S*, it being understood that with the excavated earth, thrown on the innerside parapets can be constructed. As to the supposition that the water running through these two narrow ditches might diminish the water in the central large harbour too much, which would thus become too shallow, it should be remembered that the mouth of these two ditches can be made as narrow as desired, for even if they are only two feet wide, there will be enough scouring. Four, or even five or six feet are of little account if compared with the opening of 100 feet of the two locks, and of even less if there are four such locks as in Example 5.

It is also advantageous to build a redoubt at the mouth of the harbour, as shown at T, between which field-work and the town the aforesaid parapet and two ditches (drawn straight) can be commanded both from the two bulwarks of the redoubt and from the town. Also note that even if there are 1500 feet between the town and the redoubt, it seems that no other redoubt need be built between the two, but if this length is excessive, one or more may be inserted.

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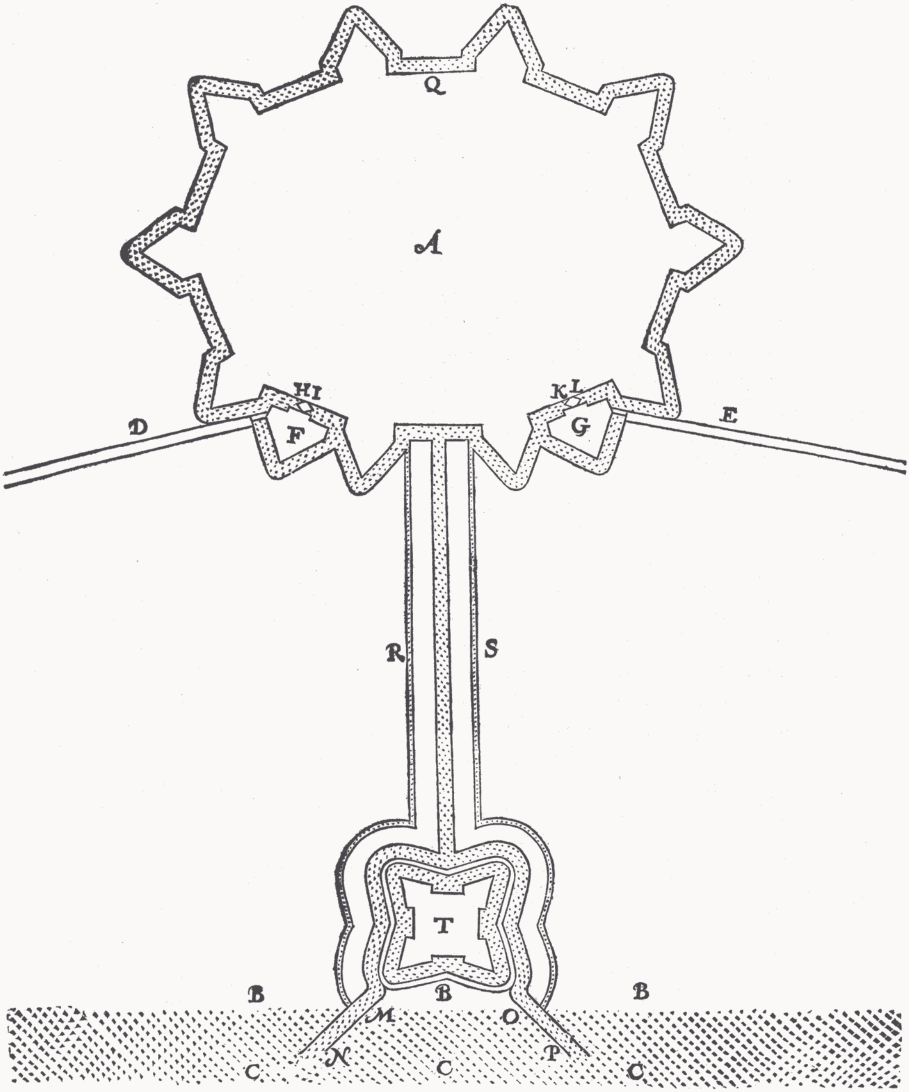
[1]) This description refers to the figure 7 on the next page, here erroneously mentioned as Fig. 6 and bearing the erroneous title *1 Form.*

I FORM.



7 VOORBEELT,

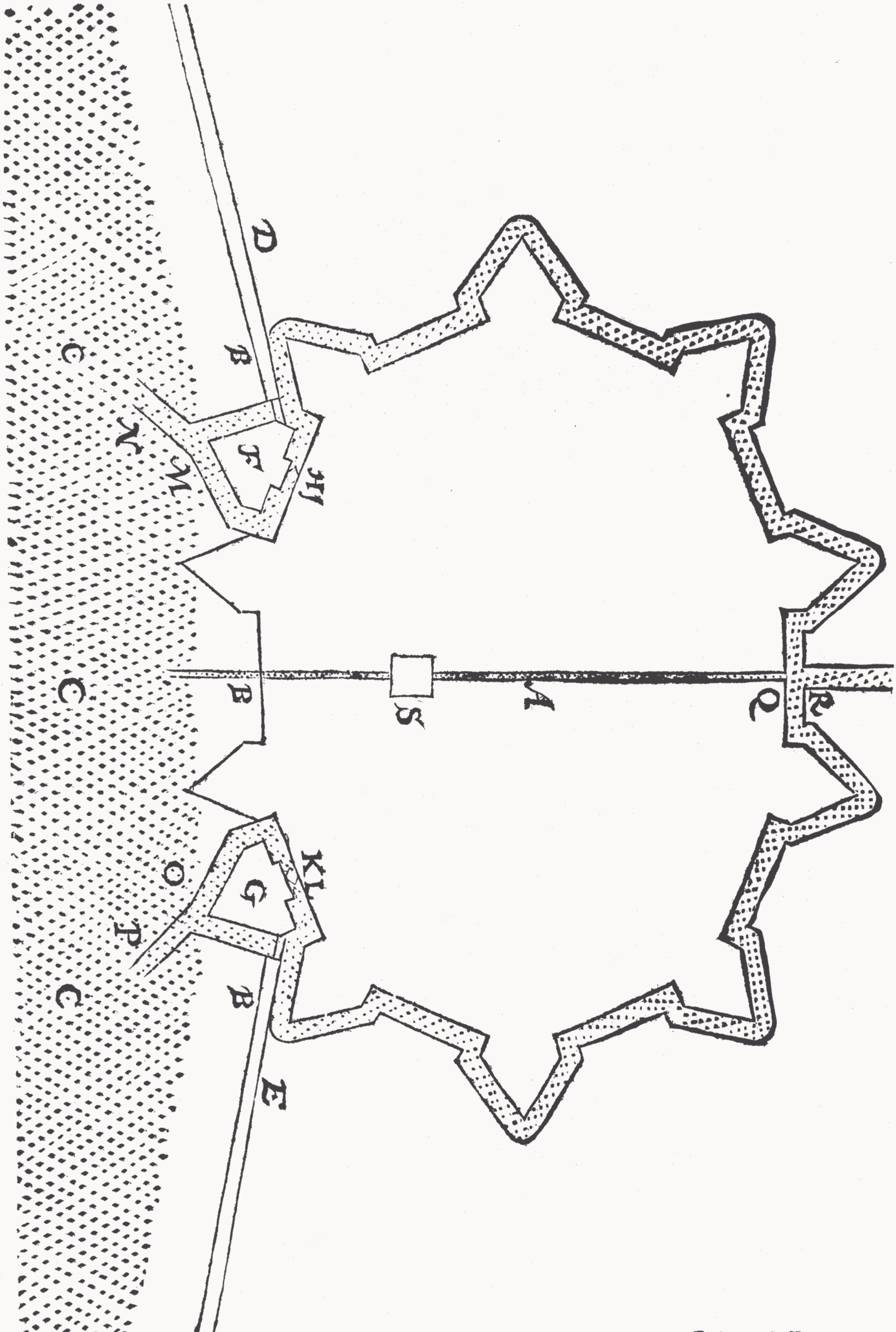
Van schuering diemen doen kan in grachten van Steden, gheleghen aen Zee of groote Rivieren zonder ebbe en vloet, maer hebbende een kleyn Rivierken dat aen de Stadt komt.

TOt hier toe is ghezeyt van Steden gheleghen aen Zee of groote bevaerlicke Rivieren met ebbe en vloet: Maer want in veel Zeen en groote bevaerlicke Rivieren gheen ebbe en vloet en is, zoo en konnen de Steden aen de zelve gheleghen, daer af mette schuering na de voorgaende manier niet gheholpen worden: Doch kanmense te weghe brenghen met kleene Rivierkens, die ghemeenelic aen veel Steden komen, om 'tgroot gherief dat de Burgherije trect, zoo van schoon versch water tot hun ghebruyc zeer noodich, als ooc om Watermolens die daer deur malen, en dierghelijcke: Maer beneffens zulc gherief, hebben zoodanighe Rivierkens tot noch toe het ongheval meghebrocht, van hinderlic te zijn aende versterking, want by aldienmense doet loopen door de grachten, sy vervullen die met zandt, leytmense door de Stadt tusschen Beeren of Dammen, zonder voorder inde gracht te komen, zoo zijn de Watermolens inde Stadt wel verzekert teghen het afbranden des Vyants, ooc krijcht de Burgherije 'tgerief van't water, maer de gracht heeft vier krancke gevulde plaetsen: Leytmen de Rivierkens buyten om de gracht, zoo worden de Watermolens ten tijde van oorlooch afghebrant, ooc en heeft de Burgherije 'tgherief van't water binnen de Stadt niet. Maer om nu te verklaren hoemen al dese onghevallen voorkomen kan, zoo laet in dese 8 Form gheteyckent zijn het Rivierken R, komende inde Stadtsgracht by Q zonder Beeren, en van daer ooc deur de Stadt tot aende Watermolen S, en ten laetsten van daer voort deur de Stadts wallen na B tot int groot water ghelijct, neem ic, te voren gheloopen heeft. Tghebruyc hier af is dusdanich: De twee paer deuren L H ghesloten zijnde, en het water van het Rivierken R gheduerlic aenkomende, de gracht vergaert vol waters, zoo hooch als deur ervaring bevonden wort de Landen met haer vruchten te moghen lijden: Dat water alzoo ten hoochsten wesende, men doet daer me de schuering, ghelijc te voren mettet opghehouden tije-water ghedaen wiert, daer int 2 en 3 Voorbeelt af ghezeyt is, te weten, datmen d'eenmael de deuren L opent, en H toelaet, een andermael de deuren H opent, en L toelaet, waer me al het zandt dattet Rivierken mette hooghe wateren inde gracht brenght wech ghe schuert wort.

Tot hier toe is ghezeyt van schuering met volle grachten, dienende voornamelicxt totte dieping der Havens M N, O P; Maer de dieping der grachten kan noch verbetert worden door schuering met ledighe grachten, of daer 'twater ten leeghsten in is, leggende noch een Sluyse ter plaets daer het Rivierken inde gracht komt, als gheteyckent is by R, want de Sluyse ghesloten zijnde, en het grachtwater t'eenemael afghelaten door de Sluysen H I, K L, en het opghehouden water van R opwaert dan vallende door de Sluyse by R inde drooghe grachten, het doet daer in dieper schuering dan door de voorgaende manier. En is ooc kennelic, dat ten tijde als de groote Rivier ten leeghsten is (ghelijct ghebeurt in drooge Zomers, en 'sWinters na lange vorst) dat dan zulcke schuering bequaemst kan zijn, om dat de grachten dan drooger konnen afloopen. Doch staet hier t'aenmercken vereyscht te zijn, dat de Stadtsgrachten die aldus met kleene Rivierkens geschuert worden, van eenvaerdiger wijdde behooren te wesen, zonder ongheregheldе breetheden, ghelijct om de ghelegentheyt des oorts zomwijlen gebeurt, want die plaetsen van krancke stroom zijnde, zouden moghen verzanden of aenwassen.

Noch is kennelic, dattet water des Watermolens staende inde Stadt aen S, syn val en loosing zal hebben om te konnen malen ghelijc te voren, alsser dese manier van schuering niet en was.

8 Form


D
B
C
N
M
F
H
B
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S
A
Q
R
KL
G
O
P
B
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EXAMPLE 7

Of the scouring of the ditches of towns on the seaside or large non-tidal rivers, having a small river coming up to the town.

Up to now we have dealt with towns situated on the seaside or on large navigable tidal rivers. But as many seas and large navigable rivers are not tidal, they are of no assistance to the town situated thereon as regards the scouring according to the method already described. But it can be done with the aid of small rivers, which often come up to many towns, to the great advantage of the inhabitants in point of fresh clean water, much needed for their use, as well as with a view to the water-mills and the like, turning by this means. But apart from this advantage, such small rivers have hitherto involved the disadvantage of impeding the fortification, for if they are led through the ditches, they fill these with sand, and if they are led through the town between the dams without entering the ditches, the water-mills in the town are indeed protected from being set afire by the enemy, and the inhabitants can also make use of the water, but the ditch has four weak places. If the rivers are led round the ditch, the water-mills are set on fire in time of war, and the inhabitants of this town cannot make use of the water. In order to explain how all these disadvantages can be avoided, in Figure 8 let the small river be *R*, falling into the town-ditch at *Q* without dams and thence passing through the town as far as the town walls at *B* to the large water (passing the water-mill *S*) as it presumably flowed before. Its use is now as follows. The two pairs of gates *L* and *H* being closed and the water of the river *R* arriving constantly, the ditch fills up with water as high as according to experience the fields and the crops have been found to tolerate. When this water has thus reached its highest level, it is used for scouring, as was formerly done with the pent-up tidal water, as mentioned in Examples 2 and 3, *i.e.* at one time the sluice-doors *L* are opened and the doors *H* are kept closed, and at another time the doors *H* are opened and the doors *L* are kept closed, by which means all the sand the small river brings into the ditch at high tide is scoured away.

What has been discussed above was the scouring with full ditches, serving for the deepening of the harbours *MN* and *OP*. But the scouring of the ditches themselves can be improved further by scouring with empty ditches or at low tide, as is shown at *R*, for when the lock is closed and the ditch-water drained by the locks *HI* and *KL* and then the pent-up water upstream of *R* falls down through the sluice at *R* into the empty dry ditches, it will scour them to a greater depth than in the above-mentioned way. It is also evident that when the large river is at its lowest level (as happens during dry summers or in winter after a long period of frost), such scouring will then be most effective, because the town-ditches will then be drained more thoroughly. But it should be noted here that the town-ditches which are thus scoured by means of small rivers should be of uniform width, without irregularities, as sometimes happens in some towns, for such spots where the flow is weak silt up or become blocked with sand.

It is also evident that the water of the water-mill at *S* in the town should have its difference of level and the fall necessary for grinding as before, when there was no such scouring.

8 VOORBEELT,

Van schuering diemen doen kan met groote bevaerlicke Rivieren, zonder ebbe en vloet, ooc zonder kleyne Rivierkens aen de Stadt komende.

GHenomen dat de Stadt deser 9 Form ligghe aen een groote bevaerlicke Rivier zonder ebbe en vloet, ooc zonder kleen Rivierken, daer me men het water des grachts zoude moghen verhooghen, als inde 8 Form: Om hier me inde gracht en twee Havens M N, O P schuering te maken alleenelic mettet water der groote Rivier, dat ic neem te loopen van N na P, zoo machmen doen als volcht:

Om voor eerst te schueren de Haven O P na het leegher eynde der Rivier, dat zal gheschien mettet water des grachts ten hoochsten te brenghen, dattet komen kan, sluytende het een paer deuren aen L, en het ander paer deuren aen I open stellende: Twelc zoo zijnde, het water zal eyntlic op de binnenzijde der Sluysdeuren L, zoo veel hoogher komen dan op de buytenzijde, als bedraecht het verval der Rivier op de langde van I tot L: Daerom de deuren aen L gheopent zijnde, zoo zal het opghehouden hoogher water schueren door de Haven O P, en ooc door de heele gracht I Q K: Maer het schueren vande Haven M N na het hoogher eynde der Rivier, dat zal gheschien mettet water des grachts ten leeghsten te brenghen, dattet komen kan, sluytende het een paer deuren aen I, en het ander paer deuren aen L open stellende: Twelc zoo zijnde, het water zal eyntlic op de binnenzijde der Sluysdeuren I zoo veel leegher komen dan op de buytenzijde, als bedraecht het verval der Rivier op de langde van I tot L, daerom de deuren aen I gheopent zijnde, zoo zal het hooger buytenwater der Rivier na de leeghte schieten, en schueren door de Haven M N, en ooc deur de heele gracht I Q K.

Noch ist openbaer, dat langhe Steden daer d'onderste Sluyse verre vande bovenste light, meer verval en verschil van buyten en binnenwater krijgen, dan daerse naerder malkander zijn, want ghelijc meerder tot minder langde, alzoo na genoech meerder tot minder verschil des vervals.

Ooc is kennelic, dat Rivieren met snelle loop meer vervals hebben, dan die traghelic afloopen; waer uyt te verstaen is, dat zulcken manier van schuering stercker zal zijn ten tijde als de Rivieren hooch zijn, dan leeghe wesende, daerom de Stadtsgracht ten tijde der hooghe vloeden zoo diep gheschuert zijnde, datter de Rivier ten tijde als sy ten leeghsten is door loopen kan, zoo en zal daer na gheen verzanding noch verslibbing, maer meerder diepte te verwachten staen, en dat zonder Beeren te legghen, 'twelc anders noodich valt, om dat de grachten verzanden zouden.

Noch staet hier te ghedencken, dat tot zulcken manier van schuering als dese, de twee paer deuren aen H en K als int bovenschreven 2 en 3 Voorbeelt onnoodich zijn.

Merct noch, dat alsser inden Dijc verre genoech vande Stadt opwaert laghe een Spilsluys als ter plaets van R, van welcke een sloot quaem tot inde Stadtsgracht, als van R tot S, 'tis kennelic dat daer me 'tverschil van't hoochste en leeghste water zoo veel grooter zoude worden dan te voren, als bedraecht 'tverval der Rivier van R tot nevens S. Dierghelijcke verschil van hoochste en leeghste water zoudemen ooc krijghen alsmen zoodanighen Sluys leyde inden Dijc vande Stadt neerwaert. Maer alst waer hooch onbedijct lant, ghelijct tot zommighe plaetsen ghebeurt, dan zoudemen de gracht van R tot S moghen graven, zonder aen R een Spilsluyse te leggen, doch veroordenende (om bekende redenen) d'inkomst als R aen een verdiepende bocht der Rivier ghelijc T, en niet aen een aenwassende bocht als V.

9. Form.

EXAMPLE 8

Of the scouring that may be brought about with large navigable non-tidal rivers, even without small rivers coming up to the town.

Let us assume that the town of Figure 9 is situated on a large navigable river (non-tidal) even without a small river that might serve to raise the water in the ditch, as in Figure 8. In order to scour the town ditch and the two harbours *MN* and *OP* in such a case with water from the large river alone, which runs, I say from *N* to *P*, one should proceed as follows.

First, to scour the harbour *OP* at the downstream end of the river; this should be done by raising the water of the ditch to the highest possible level, closing the one pair of gates at *L* and opening the second pair of gates at *I*. This being so, the water will ultimately rise so much higher on the inside of the lock-gates *L* than on the outside as the fall of the river over the distance from *I* to *L* amounts to. Therefore, when the sluice-doors at *L* have been opened the pent-up waters will scour the harbour *OP* and also the entire ditch *IQK*. But the scouring of the harbour *MN* at the upstream end of the river is to be effected by draining the water from the ditches as far as possible, closing the one pair of gates at *I* and opening the other pair of gates at *L*. This being so, the water will ultimately fall so much lower on the inside of the lock-gates at *I* than on the outside as the fall of the river over the distance from *I* to *L* amounts to; therefore, when the sluice-doors at *I* have been opened, the high outside water from the river will fall into the low level, and scour the harbour *MN* and also through the entire ditch *IQK*.

It is also obvious that in the case of elongated towns, where the lower lock is far from the upper lock, a greater fall and difference between inner and outer water will be obtained than if they are closer together, for as the greater is to the smaller distance, so approximately is the greater to the smaller fall.

It is also evident that rivers with a strong current have a greater fall than those which run more sluggishly, from which it is to be understood that such scouring will be stronger when the rivers are high than when they are low; therefore, if at times of high flood the town-ditch is scoured to such a depth that the river will be able to flow through it when at low level, there will be no silting-up with mud or sand, but greater depth is to be expected, and this without the construction of dams, which would otherwise be necessary because else the ditches would silt up.

It should also be remembered that for such scouring the two pairs of gates at *H* and *K*, as in Examples 2 and 3, will not be required [1]).

Note also that if there were a swivel-gated lock in the dike far enough from the town, at the spot *R*, from which a ditch should run into the town-ditch, as from *R* to *S*, the difference between the high and the low level of the water would become so much greater than before as the fall of the river from *T* [2]) to *S* amounts to. A similar difference between high and low level would also be obtained if such a lock were built in the dike down-stream of the town. But if the land were

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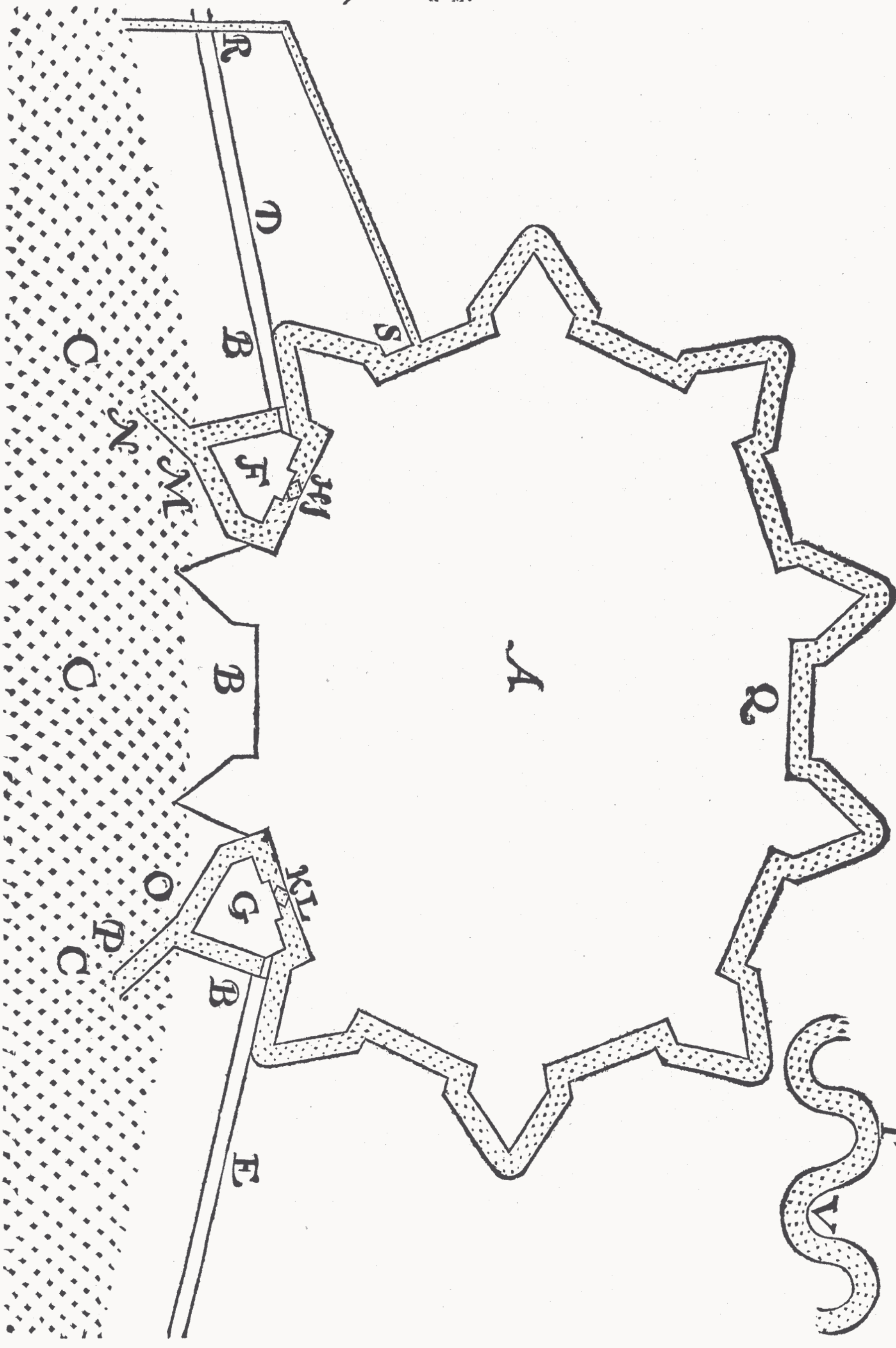
[1]) Except for purposes of navigation of course.

[2]) Point *T* is not shown in the main plan 9, but as an inset in the bottom right-hand corner.

9 FORM.



high and un-diked, as happens in some places, the ditch might be dug from *R* to *S* without a lock being built at *R*, but (for well-known reasons [1]) its intake *R* being laid at a bend of the river where it deepens, such as *T* and not at a bend where the river silts up such as *V*.

[1]) Because on the inside of a bank, as at *V*, the ditch entrance would soon become silted up and in that case there would be no sluice to scour it.

9 VOORBEELT,

Inhoudende schuering der grachten van Landtsteden, verre van Zee of van groote bevaerlicke Rivieren, maer hebbende een kleyn onbevaerlic Rivierken datter aen komt.

LAet in dese 10 Form A een Landtstadt zijn, verre van Zee of van groote bevaerlicke Rivieren, doch hebbende een kleyn onbevaerlic Rivierken B C, komende aldaer inde gracht: De verkrancking der Steden, en de swarichеden die zulcke Rivierkens mebrenghen, 'tzij datse gheleyt worden door de Stadt, of inde grachten, of buyten om, zijn verhaelt int 7 Voorbeelt, alwaer ooc wel ghezeyt wiert hoemen die voorkomen zal, maer het was van een Stadt ligghende aen Zee of aen een groote bevaerlicke Rivier, tusschen welcke en de Stadt geen droochte en valt als hier, daerom vereyscht dese schuering des grachts een ander manier van doen, die dusdanich zijn mach:

Men zal aenden mont van't Rivierken daer't inde gracht komt, als ter plaets van B, legghen een Spilsluyse ghelijc daer aenghewesen is: En ter plaets daer het Rivierken uyt de gracht loopt, 'twelc zij aen D E, zalmen graven een eynde grachts, als D E F G van drie of vier hondert voeten lanc, en ontrent zoo breet als d'ander Stadtsgrachten, daer na zalmen trecken de grachtkanten, als van F tot H, en van G tot I, wijt van malkander wijckende, als van F tot H, en van G tot I, zulcx dat H I vijf of zesmael zoo breet is als F G, en wort verstaen van H tot I gheleyt te wesen op waterpas een waterschutsel, tot zulcken hooghde, dat de Stadtsgracht altijt ten minsten 6 voeten waters mach houden: Daer na zijn ghetrocken H K en I L, zulcx dat I H K L beteyckent een breede ondiepe gracht, ten eynde van welcke als ter plaets van K L, gheleyt is op waterpas noch een waterschutsel vande zelve hooghde als H I. Het water daer over komende, datmen na het kleyn Rivierken toe syn loop zal laten nemen zoo't valt, maect een form, neem ic, als van K L na het kleyn Rivierken aen M.

Dit zoo zijnde, en de schuering mette Sluys B ghedaen wesende zoo dicwils alsmen oorboor vindt, zoo zalmen daer me komen tottet begeerde, want de gracht is zonder Beeren, wordende overal gheschuert: En hoewel het by G F ondiep zal zijn, dat en hindert niet, ghemerct datter by D E diepte is: Het vierhoeckich perc I H K L zal zeer ondiep zijn, en den aenwas daer in komen, misschien ter hooghde der waterschutsels I H, K L, om den slappen stroom die het water daer hebben zal, doch en gheeft dat gheen hinder, maer heel verkeert voordeel, want zoo den Vyant het grachtwater daer deur wilde afleyden, hy zouder eerst moeten deurgraven. En hoewel dit onbequaem zoude zijn tot Scheepvaert, zoo ist zonder swaricheyt, ghemerct datter, ghelijc voren ghezeyt is, gheen zijn en zal.

Noch staet te ghedencken, dattet voorderlic is het bovenwater van B C opwaerts, zoo veel by de handt te krijghen, alsmen na gheleghentheyt der plaets kan te weghe brenghen, op dattet alsmen de grachten schuert niet terstont te zeer en dale.

Merct noch, dat zoomen ter plaets tusschen D E leyde een Spilsluyse, ghelijc aenghewesen is mette twee deuren aldaer gheteyckent, die met een ravelin konnen beschermt worden, men zoude daer me de gracht dieper doen afloopen dan te voren, en met meerder verschil van buyten en binnenwater moghen schueren. Het konde tot zommighe plaetsen ooc ghebeuren, datmen een kleyn onbevaerlic Rivierken door zulcke manier bevaerlic maecte, of Rivierkens diemen met kleyne Schepen bevaert, met grooter bevaerlic wierden.

10 Form.

EXAMPLE 9

Of the scouring of ditches in inland towns, far from the sea or navigable rivers, having a small non-navigable river coming up to them.

In Figure 10 let *A* be an inland town, far from the sea or from large navigable rivers, but having a small non-navigable river *BC*, running there into the ditch. The weakening of such towns and the difficulties caused by such small rivers, no matter whether they are led through the town or into the ditches or round them, have been discussed in Example 7, where it has also been stated how they can be avoided, but in that case the town was situated on the seaside or on a large navigable river, between which and the town there is no dry land, as in the present case; the scouring of the ditches therefore calls for a different procedure, which may be as follows:

At the mouth of the river, where it gives into the ditch, *i.e.* at *B*, a pivotted sluice should be built as shown there; and where the small river leaves the ditch, which shall be at *DE*, a stretch of ditch *DEFG* should be dug some 300 or 400 feet long and about as wide as the other town-ditches; then the sides of the ditches should be dug from *F to H*, and from *G* to *I*, so as to diverge widely, *viz.* from *F* to *H* and from *G* to *I*, in such a way that *HI* is five to six times as wide as *FG*, and from *H* to *I* there should be made a horizontal flood-control dam, at such a level that the town-ditch will always keep at least six feet of water. Then *HK* and *IL* are dug, in such a way that *IHKL* represents a wide shallow ditch, at the end of which, at *KL*, another horizontal flood-control dam is laid at the same level at *HI*. The water overflowing it, which will be allowed to find its way as it may into the small river, will take a course, say, as from *KL* to the small river at *M*.

This being so, and the scouring being effected with the sluice *B* as often as needed, the object will thus be attained, for the ditch is without dams and yet is scoured throughout. And though it will be shallow at *GF,* that does not matter, since there is depth at *DE*. The rectangular section *IHKL* will be very shallow and will silt-up, perhaps to the height of the weirs *IH* and *KL*, because of the slow flow of the water there, but this does not matter, on the contrary, it even presents an advantage, for if the enemy should want to drain off the ditch-water through it, he would have to excavate it first. And though this would be an obstacle to navigation, that is no difficulty, seeing that, as said before, there will be none.

It should also be remembered that it would be an advantage to get as much of the upper water from *BC* upstream as the local situation permits, in order that it will not fall too rapidly when the ditches are scoured.

Note also that if between *D* and *E* a swivel-gated lock were built, as is shown with the double gates [1]), which could be protected by a ravelin, the ditch might be emptied to a greater depth than before and the ditches might be scoured with a greater difference between outer and inner water level. It might also happen in some places that a small non-navigable river might thus be made navigable, or that rivers in which small vessels can sail might be rendered navigable for larger ones.

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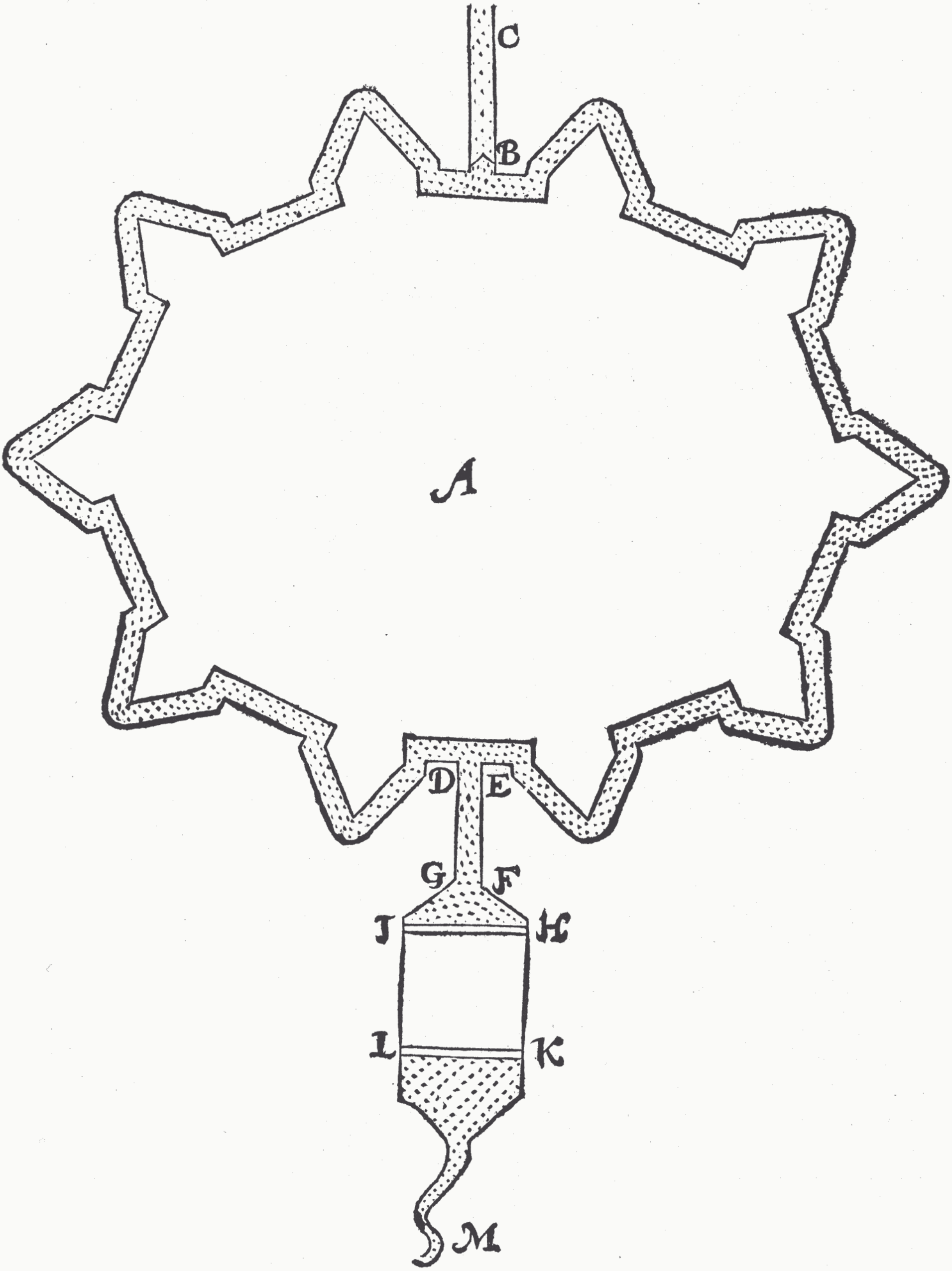
[1]) Not shown in the figure!

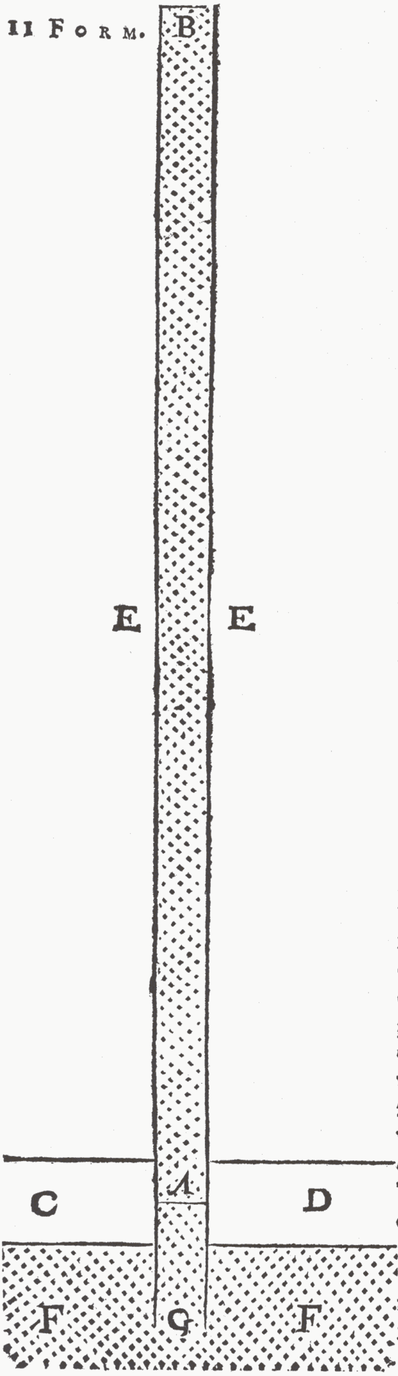
10 FORM.



10 VOORBEELT,

Vande verbetering der Houders of Boesems, diemen ten platten Lande ghebruyct, zoo tot schuering der Havens, als tot drooghing der Landen.

11 FORM.



HIer voren is ghezeyt, hoe de Stadtsgrachten met groote bequaemheyt voor Houders konnen verstrecken, zoo wel tot Havenschuering en maling, als tot der Steden versterckking: Maer hier benevens zijn buyten de Steden ten platten Lande veel Houders, dienende niet alleen om te schueren de Havens daer Schuyten en Schepen door inde Landẽ en Dorpen varen, maer ooc om Watermolens die het landt droogen daer in te malen zonder tijt-verlies, ter wijle het water buyten hoogher is dan binnen. Maer want myns bedunckens de form der zelve Houders zeer mach verbetert worden, en dat ic myn meyning door het voorgaende lichtelic verklaren kan, zoo zal ic daer af myn ghevoelen zegghen.

Laet tot dien eynde in dese 11 Form A B een Houder beteyckenen, gelijc tot noch toe ghemeenelic ghemaect worden, die tot zommighe plaetsen ettelicke duysent roeden of ooc wel eenighe uren gaens lanc zijn, C D bediet den deurgaenden Dijc, daer onder een optreckende sluysdeur light aen A, voort is E het landt, F het buytenwater, als Zee of groote Rivier, A G de Haven die mettet opgehouden hoochwater A B geschuert wort, als het buytenwater F ten leeghsten is.

Zoodanighe Houders hebben het ongheval datse gheduerlic zeer aenwassen, en alder eerst en meest aen't eynde B, om dattet water daer gheen deurganc en heeft, zulcx dat sy weynich waters begrijpende, te weyniger schuering maken. Ten anderen, en moghender gheen Sluysen aen gheleyt worden om de landen E te drooghen, of geleyt zijnde, gheen of weynich dienst doen. Ten derden, en moghender gheen Molens aen gheleyt worden om 'twater in te malen, of gheleyt zijnde, helpen weynich, door dien sy 'twater veel hoogher moeten opdragen, dan sy zouden, als den Houder goede diepte hadde. Ten vierden, alsmen door noodt tottet verdiepen komt, het graven en gheschiet niet zonder groote kost.

Om al dese onghevallen te voorkomen, machmen doen als volght: Ghenomen dat in dese 12 Form, den Houder ghegraven zij

vande

EXAMPLE 10

Of the improvement of the basins or "boezems" used in the country, both for the scouring of harbours and for the drainage of the land.

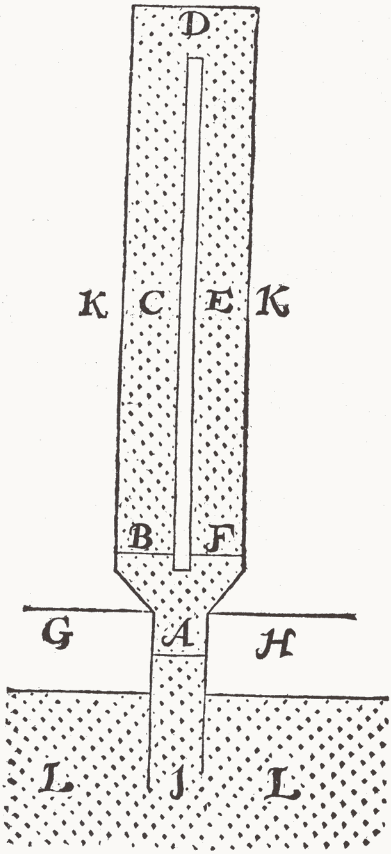
It has been stated above how town-ditches can be used with great profit as basins, for harbour-scouring and drainage, as well as for town fortification, but outside towns, in country districts, there are many basins, which not only scour the harbours through which vessels and ships sail inland and to villages, but also serve for drainage-mills to spill the water they drain from the land without loss of time, when the water outside is higher than inside. But as in my opinion the form of such basins might be greatly improved, and as I can easily explain my ideas in connection with the above discussion I will now give my views on them.

In Figure 11 let *AB* denote a basin, as they have usually been made up to the present, which in certain places are several thousands of roods or several hours long; *CD* is the circular dike, in which has been built a vertical sluice-door at *A*, *E* is the land, *F* the outer water (sea or large river), *AG* the harbour, which is scoured with the pent-up water *AB*, when the outer water *F* is at its lowest level.

Such basins have the disadvantage that they silt up constantly, and firstly and mostly at *B* because the water cannot pass through, so that, as it contains little water, it will not be properly scoured. Secondly, no sluice-doors must be built to drain the land *E* or, if they have been built, they are not of much use, if any. Thirdly, no drainage-mills must be built on them, to pump the water in, or if they have been built, they are not of much use, since they have to raise the water much higher than if the basin had its proper depth. Fourthly, if excavation is begun because of dire need, the digging and dredging involves great expense.

In order to avoid all difficulties one may proceed as follows: Let us assume that in Figure 12 the basin has been dug from the sluice-door *A* via *B* and *C* to *D*, half vande optreckende Sluyſe A over B en C tot D, half zoo lanc als A B der 11 Form: Daer na ſy van D al gravende weerom ghekeert over E en F tot A, blijvende een riem landts tuſſchen C en E: Voort wort met G H beteyckent den deurgaenden Dijc, daer d'optreckende Sluys A onder light, A I is de Haven, K het landt, L het buytenwater: Ter plaets van B is een deure, alzoo ooc is ter plaets van F. Tghebruyc hier af is duſdanich: De Sluyſe A opgetrocken zijnde met een hoochſte binnenwater en leeghſte buytenwater, zoo zal daer mede ſchuering ghedaen worden, d'een mael door F, blijvende B geſloten, d'ander mael door B, biljvende F geſloten, zomwijlen ſtaende de twee deuren B en F t'zamen open, alſmen met meer waters t'zeffens de Haven A I dieper ſchueren wil, gelijcmen dat altemael opentlicker verſtaen kan door 'tghene van 'tghebruyc der Spilſluyſen gezeyt is int 2 Voorbeelt deſes Hooftſtucx: Door 'twelc ooc te verſtaen is, datmen noch dieper ſchuering inden Houder kan maken, mettet hooch buytenwater te doen vallẽ int binnenwater alſt ten leeghſten is.

12 FORM.



Aengaende de twee deuren die ghezeyt zijn te ligghen aen B en F, dat en behoeven gheen ſware koſtelicke wercken te zijn, ghemerct datter gheen val van water en is, ghelijc aende Sluysdeur A, en dattet water aen de gheſloten deuren B F van voren en achter bykans even hooch is, waer af men voorbeelt kan zien aen zulcke deuren die binnen Delf aen zommige bruggen ghemaect zijn, om het vvater daer voorby te doen loopen als de Molens het vvater ververſchen.

Merct noch, dat hoewel hier voorbeeltſche vvijſe de riem landts tuſſchen C en E heel lanc en ſmal gheteyckent is, nochtans vry te ſtaen zulcken form te mogen hebben als na gheleghentheyt der plaets beſt te pas komt, lanc of breet, recht of krom, nemende zulcke vvateringhen tot voordeel alſmen oorboor bevint.

By aldien't in eenighe Landen ghelegender viel den Houder na by de Haven te ligghen, zonder zoo verre daer af te loopen, ghelijc tot veel plaetſen ghebeurt, en nochtans vvaters ghenoech houdende, dat zoude konnen gheſchieden ghelijc in deſe 13 Form, vvaer in de letters van zulcke beteyckening zijn als inde 12 Form, maer doende het vvater vande deuren B en F beghinnende, over elcke zijde een keer meer, zulcx dat d'eenmael gheopent de deure B, d'andermael F, daer komt overal ſchuering door den gantſchen Houder.

13 Form.

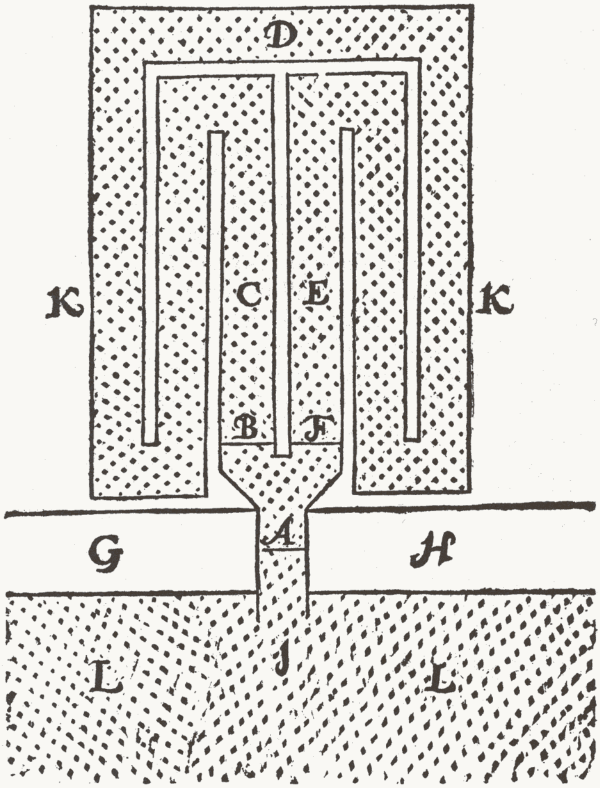
the length of *AB* in Figure 11, then from *D* one should return *via E* and *F* to *A,* leaving a belt of land between *C* and *E. GH* is the dike, into which the sluice-door *A* has been built, *AI* is the harbour, *K* the land, *L* the outer water. At *B* there is a sluice-door and at *F* too. This system operates as follows: When the door *A* is raised at the highest level of the inner water and the lowest level of the outer water, scouring will be effected, one time through *F,* while *B* remains closed; sometimes the two doors *B* and *F* will be opened, if more water is wanted to scour the harbour *AI* to a greater depth, as will be obvious after what had been explained about the use of swivel-gates in Example 2 of this chapter, from which it will also be clear that even deeper scouring can be obtained in the basin when the high outer water is caused to fall into the inner water at its lowest level.

As to the two doors which are located at *B* and *F,* these need not be heavy and expensive structures, since there is no fall of water, as at A, and the water is practically at the same level on the inside and the outside of the closed doors *B* and *F,* examples of which can be seen in the form of such doors at certain bridges at Delft, which handle the water that is provided by the mills draining the canals.

Note also that though the strip of land between *C* and *E* has here been drawn very long and narrow by way of example, still everyone is free to shape it as best suits the local situation, long or broad, straight or crooked, choosing such drainage as is found advantageous.

If in some areas it is found more advantageous to build the basin close to the harbour, so that it does not extend far away from it, as usual, and still contains enough water, this might be done as shown in Figure 13 where the letters have the same meaning as in Figure 12, but the waters starting from the doors *B* and *F* will run the length of one more side, in such a way that when at one time the sluice-door *B* is opened, at another time the door *F*, there will be scouring throughout the basin.

13 FORM.



Maer alſmen over elcke zijde noch een keer meer wilde doen, dat zoude mogen toegaen als in deſe 14 Form, vvaer in de letters ooc vande zelve beteyckening zijn, zulcx dat d'eenmael gheopent de deure B, d'andermael F, daer komt overal ſchuering door den gantſchen Houder.

Met deſe 13 en 14 Form zietmen ghenoech de meyning, alſmen op zulcke wijſe de Houders noch meer vvaters vvilde doen begrijpen.

Door 'tghene hier voren ghezeyt is, ſchijnt moghelic te zijn, niet alleen den aenwas te beletten dieder komt inde Houders der 11 Form, maer boven dien zoo diep te konnen gheſchuert worden, datmen tot ettelicke plaetſen met veel kleene onkoſtelicke Sluyskens daer in te doen uytvvateren, de landen veel vroegher zal konnen doen drooch vvorden dan te voren, en ooc met min Watermolens, die zullen moghen malen inde diepe Houders, te vvijle ſy leegher zijn dan het buytenwater: De Houders die tot vaerden dienen, zullen tottet varen bequamer zijn om de meerder diepte vville: Ooc en valter gheen onkoſt van verdieping met ſchuppen.

Tot hier toe is gezeyt vande ſchuering der Houders mette optreckende Sluyſen dieder nu zijn, waer by ghenoech kennelic is, dat Spilſluyſen met grooter deuren noch veel beter dienſt zouden doen.

14 Form.

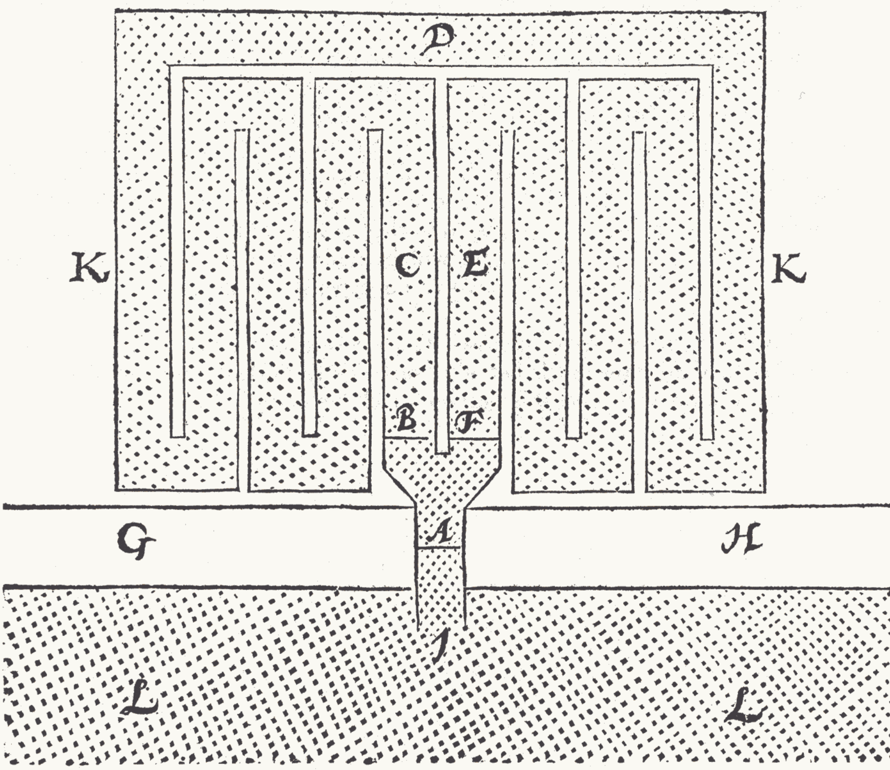
But if it should be desired to have it run the length of yet one more side, this might be achieved as shown in Figure 14, where the letters again have the same meaning, in such a way that when now door *B* is opened and now door *F*, there will be scouring throughout the basin.

These Figures 13 and 14 show clearly enough what is the intention if it should be desired for the basins to contain even more water in this way.

From what has been said above it seems possible not only to avoid the silting-up that will occur in the basins of Figure 11, but also to scour to such depth that by draining in several places through small, inexpensive sluices the land can be drained much sooner than before, and also with fewer drainage-mills, which can now pump into the deep basins, because they are lower than the outer water. The basins which are used as waterways will be more suitable for navigation because of their greater depth and will involve no expense on account of dredging with scoops.

Upto this point we have discussed the scouring of basins with vertical sluice-doors, as they are now used, but it is sufficiently evident, that swivel-gate locks with larger doors will serve this purpose much better still.

14 FORM.



II VOORBEELT,

Vande schuering der Vaerden door venen daermen Turf treckt.

DEn Turf vvort in dese Landen op tweederley wijse uyt het landt ghekregen, d'eene onder vvater met baggaertnetten, tot zommighe plaetsen vvel 20 voeten diep en meer: D'ander vvijse boven vvater diemen met spaden steeckt of graeft. Hier toe bevintmen oorboor door de venen een vaert te maken, dienende tot twee voornamelicke eynden, het een om de Schepen met Turf gheladen zijnde, door te komen inde groote Rivier of Zee, en van daer voort te varen tot verscheyden plaetsen daermense begeert: Het ander eynde is, dattet vvater uyt de venen in die Vaert zackende, zoo worden de venen daer me zoo drooch, datmen den Turf bequamelic boven vvater steken kan: Maer want de meyning is van dese laetste manier hier voornamelicxt verhael te doen, zoo is te weten, dat veel dier Vaerden het ongheval hebben van droochte, zulcx datmen tot verscheyden plaetsen Verlaten maeckt daer het vvater me opghehouden wort. Dit zoo zijnde, en om de swaricheyt van ondiepte te voorkomen, men zal de Sluysdeuren der Verlaten doen draeyen op spillen, na de manier hier voren beschreven, en mettet opghehouden vvater vande hoogher deelen der Vaert, zalmen de leegher deelen diepen, vvaer me het inkomende zant t'elckens en gheduerlic vvechschuerende, meer-

G der

EXAMPLE 11

On the scouring of the canals through the moors where peat is cut.

Peat is obtained in these regions in two ways, one under water with dredge-nets, in some places at a depth of 20 feet or more; the other consists in cutting or digging above water-level with spades. For this purpose it has been found useful to dig a canal through the moors, which serves two main ends, the first being to carry ships loaded with peat to the large river or the sea, and thence to the various towns where it is wanted; the other end is that since the water drains from the moors into the canal, the moors become so dry that the peat can be cut conveniently above water-level. But because it is my intention to deal primarily with this last method, it is to be noted that many such canals suffer from running dry, so that in several places weirs are built to dam the water. This being so, and in order to avoid the difficulty of shallows, the weirs should be equipped with swivel-gates, as described before, and with the pent-up water in the higher parts of the canal the lower parts should be deepened, by which means, the inflowing sand being continually scoured der diepte zal ghekreghen vvorden d'ander te voren was, niet alleenelic bequamer tottet varen, maer ooc tottet Turf steken en drooghing der landen: En hoewelmen ten tijde van langhe droochte gheen vvater en heeft om te schueren, maer opghehouden moet vvorden tottet varen der Schepen, zoo machmen te dicwilder schueren alsser overvloet van vvater is. Merct noch, datter om dese meerder diepte wille, in zulcke drooghe tijden te min ghebrec van vvater is om te varen: Ooc dat daerom het water inde Vaert ten tijde van langhe droochte, leegher zal moghen afghelaten vvorden dan te voren, en nochtans de Schepen tottet varen diepte ghenoech behoudende. Al dit aenghemerct, en daer benevens de kleene onkosten van de voorschreven verandering der Sluysdeuren, zoo heeft my ghedocht dit vermaen oorboor te konnen zijn.

Maer want ymant dencken mocht, dese zake van zoo kleen belangh te wesen, dattet de moeyte niet weert en schijnt daer af zulcken verhael te doen, zoo is te weten datter in dese Landen zommighe onvruchtbaer venen, in koop veel meer ghelden dan de beste zaey-landen, waer by noch tot ettelicke plaetsen ghebeurt, dat de venen die te voren onvruchtbaer landen waren uytghetrocken wesende, daer onder goede zaey-landen en weyen bevonden worden, zulcx datter veel een grooten rijcdom uytghehaelt hebben, en in ander landen uyt halen konnen alsser de kennis af waer.

Dit vande venen aenghemerct, en niet buyten reden schijnende, datmen tracht haer herkomst te weten, om dat zulcke kennis totte zake voorderlic mocht wesen, zoo zegh ic tot dien eynde de venen gheweest te hebben groote dicke bosschen, en dat alle teghenwoordighe groote dicke bosschen met lancheyt van tijdt venen worden zullen, welverstaende als de menschen de bosschen niet uyt en roeyen, maer daer de natuer haren loop heeft. Om dit te bewijsen, zoo is voor eerst openbaer dat de boomen metter tijdt vergaen, hoewel d'een af komst langher duert dan d'ander, als eycken boomen worden ghezeyt ontrent drie hondert jaren te staen, te weten hondert jaren vvassen, hondert jaren in stant blijven, en hondert jaren vergaen: Nu dan ghenomen dat den eycken boom de langstduerende zij ghelijc zommighe meynen, zoo ist nootzakelic dat van alle boomen dieder nu wassen, binnen drie hondert jaren gheen zijn en zullen. Aengaende hier op ghezeyt mach worden, dat vande eyckelen en ander vruchten of zaden die in d'aerde vallen, weerom nieuwe boomen wassen, en dat daer me de bosschen gheduerlic in wesen blijven: Hier op wort gheantwoort zulcx ooc een eynde te nemen, om dese redenen: Men ziet inde bosschen, dat de tackē mette groote stormē zoo tegen malkander slaen datse breken, en 'tlant onder de boomen overal bedecken, zo wel met groote houten als met kleene rijselinghen, die daer na verrotten; Maer zulcx jaerlicx dicwils ghebeurende, en dat veel hondert jaren lanc gheduerende, het maect een groote menichte van verrotte tacken, die ghemorselt op malkander vergaren ettelicke voeten dic, waer by ten laetsten noch komen de heele vervallen en verrottende boomen zelf, al 'twelc houte stof is zonder aerde, daer eyckelen en ander zaedt van boomen in vallende, niet wassen en kan. Dit zoo verre ghekomen zijnde, de bosschen gaen heel te niet, en blijven dorre onvruchtbaer landen die wy venen noemen.

Aengaende ymant dencken mocht hoe het toegaet mette voorschreven eerste soorte van veen, dat met baggaertnetten over de 20 voeten diep onder water uytghetrocken wort, alwaer het schijnt gheen bosschen te hebben konnen wassen, dat meyn ic aldus te ghebeuren: Bedijcte landen en wassen na de bedijcking niet hoogher, de bosschen daer in staende worden venen als voren ghezeyt is, maer de buytenlanden wassen gheduerich aen, 'twelcmen tot veel plaetsen bevint op twintich of dertich jaren twee of drie voeten en meer te bedraghen, maer met lancheyt van tijdt away, greater depth will be obtained than before, which is more suitable not only for navigation but also for the cutting of peat and the drainage of the land; and though there is no water available for scouring in long periods of drought, but all the water has to be pent-up for navigation, scouring can be effected more frequently when there is plenty of water. Also note that because of this deeper scouring there will be less water shortage for navigation in times of drought, and also that draining can proceed to lower levels in long periods of drought, and yet ships will have sufficient draught for sailing. In view of all this as well as the small expense involved in the aforesaid modification of the swivel-gates it seemed useful to me to make these remarks.

But if anyone should think this matter of so little account that it does not seem to be worth while to discuss it in such detail, it should be noted that in this country there are certain infertile moors which sell at higher prices than the best arable land, while in some places it happens that moors which at first were arid land after being dug were proved to have excellent arable soil underneath, so that many people gained great wealth from them, while this might be done in other areas, if it were known.

Having said this about moors and because it does not seem unreasonable to try to know their origin, because such knowledge may be profitable for our subject, I say that such moors at one time were large, dense forests and that all now existing large, dense forests in the course of time will become moors, at least if men do not uproot the forests, but leave nature to take its course. The proof is that firstly it is common knowledge that trees decay in due course, though one species will live longer than another, oak trees being said to stand for three hundred years, *i.e.* they grow for a hundred years, stand for a hundred years, and decay for a hundred years. Assuming the oaktree to be the most long-lived of trees, as some believe, it is beyond doubt that of all the trees now growing none will be left within three hundred years. Any objections to the effect that new trees will grow up from the acorns and other fruit or seeds that fall on the earth, by which means the forests are constantly preserved, may be answered in the sense that even this will come to an end, for the following reasons. It is seen in forests that during a great storm branches will hit each other so violently that they break and cover the soil underneath the trees all over, both with large branches and with small twigs, which then decay. As this often happens every year, and during many hundreds of years, this gives rise to a large mass of decayed branches, which accumulate in a broken state to a depth of several feet, to which are finally added the whole fallen and decaying trees, all of which is wooden material without soil, in which acorns and other seeds of trees, falling on it cannot grow. When this process has gone thus far, the forests will be destroyed altogether and the barren infertile lands will be left, which we call moors.

And if anyone should consider how the aforesaid first type of peat is formed, which is collected with dredge-nets at depths of over 20 feet under water, where it seems that no forests can have grown, I believe this to have happened as follows: Embanked lands do not grow higher after the construction of the dikes, the forests therein become moors, as explained above, but the outer parts will grow constantly, which is found in many places to amount to two to three feet or more in twenty or thirty years, but since in course of time this difference is so great that the bottom tijdt zulc verschil zoo groot zijnde, dat den grondt der Rivier veel hoogher is dan de bedijcte landen, ghelijc tot veel plaetsen dadelic bevonden wort, en daer ic eyghentlicker afgheschreven heb int 13 voorstel van't stofroersel des aertkloots, zoo en konnen de bedijcte landen haer reghenwater niet loosen, maer blijven verwoest, en het buytenwater daer in loopende, de venen die van houten stof zijn, rijsen op zoo hooch alst vvater, en zinckende het zant mette kleyighe stof der hooghe vvateren door het veen tot op den gront, zoo wast het landt op zulcker voeghen weerom inde hoochte, vlottende het veen op't vvater, 'twelc ooc d'oorzaec is waerom de diepe venen daveren alsmen daer op gaet, even ghelijc houten zagheling int water gheleyt, waer op ghedruct wesende, sy vvijct neerwaert, maer van dat drucsel vry zijnde rijst vveerom op : En uyt zulcke venen kanmen met baggaertnetten Turfstrecken zeer diep onder vvater, ghelijc ic voorghenomen hadde te verklaren.

De boomen diemen al gravende ghemeenelic onder inde venen vindt, gheven ooc ghetuychnis die bosschen gheweest te hebben : De reden waerom zulcke boomen tot gheen verandering in veen gherocht en zijn gelijc ander, schijnt dese, datse voor het verrotten metten voorschreven nieuwen aenwas bedect vvordende, en bedect blijvende buyten vorst en Sonne schijn, daer na niet en verrotten, maer gheduerlic harder worden : Van welcker dinghen oorspronc ic voorghenomen hadde myn ghevoelen te verklaren, by aldiender de zake niet ghenoech me ghetroffen en is, 'tmach beghin zijn om naerder daer op ghelet te worden.

12 VOORBEELT,

Vande manier der bequame schuering vande Vaerden tusschen tvvee Eylanden, of tusschen vast landt en Eylandt daer ebbe en vloet is.

DAer vvort teghenwoordelic tot verscheyden plaetsen deser Landen, voorgheslaghen van diepte te maken tusschen twee Eylanden, of tusschen vast landt en Eylandt, daer me sy mochten van malkander ghescheyden blijven zonder toe te vvassen: Als de Nieuwerhavensche Vaert langs Cadzant en de Groe: De Rivier Eendrecht of Vosmeer langs ter Tolen : De Roovaert by de Klunder: De Vaert door het Schorre nevens ter Muyden, en meer ander. D'oorzaec vande ondiepten zoodanigher Vaerden is tweederhande : Ten eersten, om het vvantije, daer den vloet van vvederzijden d'een teghen d'ander komt: Ten tweedden, om de groote herdijcking der Landen kortelic deur het Bestandt gheschiet, diens Dijcken ten tijde van d'oorloogh deurghesteken vvaren, van welcke Landen het ebbewater nu niet inde Vaert en zact noch en schuert, ghelijct voor de bedijcking dede. De reden waerom datmen die diepten zoo zeer begheert, zijn verscheyden : Ten eersten, om daer deur te varen : Ten tweedden, om datse de Landen zouden verzekeren teghen den Vyant: Ten derden, want d'onbedijcte Landen op vvederzijden der Vaert zeer aenwassen, en dat daerom mette daghelicsche ebben te vveynigher water inde Vaert zact, zoo staet het gheschapen zulcke Vaerden op korter tijdt toe te vvassen, en de Landen in tijt van krijch niet te konnen onder water ghebrocht worden: Tis vvel zoo, dat der onbedijcte Landen voor der aenwassinghen door dijckage belet vvorden, maer alsdan is den aenwas der Vaert te grooter, om datter gheen aenzacking en is van't voorschreven ebbewater der nevenligghende Landen: Ten vierden, vvant dese voorghenomen manier van verdieping gheschiet met bedijcking der Landen, zoo zoude daer uyt te verwachten staen 'tprofijt dat uyt de bedijcking valt, blijvende boven dien de Landen bequaem, om door haer Sluysen, of met deursteking der Dijcken, het Landt onder vvater te konnen stellen, alst noot is: Ten vijfden,

 als de

of the river is much higher than the embanked lands, as is found in practice in several places and as I have discussed more properly in the 13th proposition of the *Stofroersel des Aertcloots* [1]), the embanked lands cannot drain their rainwater, but remain waste, and when the outer water runs into them, the moors, being of woody material, rise as high as the water, and the sand and clayey material of the flood waters sinking through the peat onto the soil, the land will grow higher again, the peat floating on the water, which also causes peat to shake if one walks on it, just as wooden sawdust, when laid in water, will sink when pressed down, but will rise again when the pressure is released. And from such moors peat can be dredged with dredge-nets deep under water, as I set out to explain.

The trees commonly found on the bottom of the moors during digging also prove that there have been forests. The reason why such trees have not been converted into peat like others seems to be that, being covered before decaying by the aforesaid fresh accumulation and remaining protected from frost and sunshine, they do not decay, but harden more and more. I had proposed to give my views on the origin of these things, as they do not seem to have received enough notice, but this may be the prelude to better observation of such matters.

EXAMPLE 12

On the method of the proper scouring of the channels between two islands, or between the mainland and an island, if there is ebb and flow.

Nowadays it is proposed in several places in this country to deepen the channels between two islands or between the mainland and an island, so that they may be separated from each other without silting up: such as the *Nieuwerhaven Vaart* along *Cadzand* and the *Groe*: the river *Eendracht* or *Vosmeer* along *Tholen*, the *Rovaert* near *Klundert*, the *Vaart* through the *Schorre* near *Ter Muiden*, and others. The causes of the shallows in such channels are twofold: Firstly, the neap-tide, when the high tide from one side meets that from the other, secondly, the great re-embankment of the lands that took place shortly after the Truce, the dikes having been cut during the war, the low-tide from these lands no longer falling into these channels or scouring as it did before the embankment. The reasons why these depths are desired are various: Firstly, for purposes of navigation; secondly in order to protect the lands from the enemy. Thirdly because unembanked land on either side of the channel tends to rise quickly and thus at low-tide too little water will sink into the channel, such channels are bound to silt up in a short time and it would become impossible to inundate the land in time of war. It is true that unembanked land may be protected from accretion by building dikes, but then the channels silt up even more quickly, because the low-tide no longer deposits its silt on the surrounding land. Fourthly, this method of deepening taking place with the embankment of the land, it might be expected to involve the advantage resulting from embankment, while it would moreover be possible to inundate the land, if need be, by means of the sluices or by cutting the dikes. Fifthly if the

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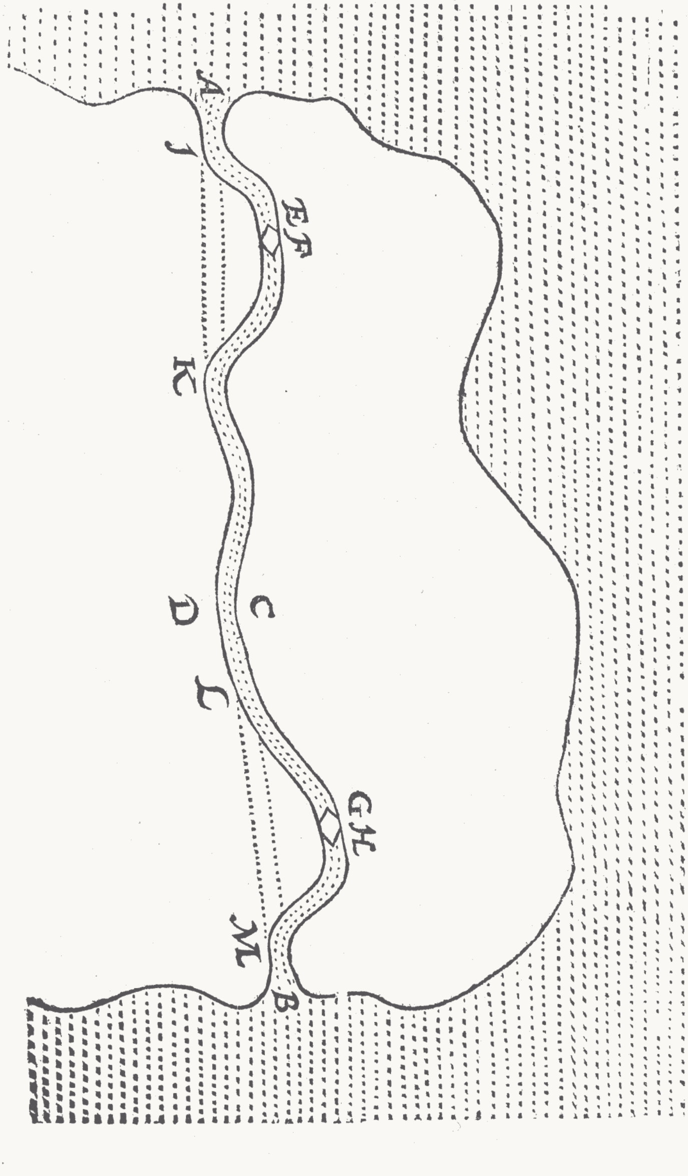
[1]) Work XI, i, 22; not published in our edition.

als de Vaerden diep gheſchuert worden, zoo konnen de nevenligghende Landen door haer Sluyſen daer in overvloedelic uytwateren, vroech drooch vvorden, en laet drooch blijven, dat zoo niet en valt als de Vaerden toewaſſen, om welc voordeel men met goede reden de Bedijckers me mach doen draghen d'onkoſten der Spilſluyſen en haer Schantſen die daer toe noodich vallen.

Om de bovenſchreven profijten te ghenieten, en ſwaricheden te ſchouwen, zoo zoude den ghemeenen reghel daer toe duſdanich zijn:

Laet A B beteyckenen een Vaert, tuſſchen het Eylandt C, en het Eylandt of vaſtlandt D, welcke Landen onbedijct zijnde, zoo valt de daghelicſche ebbe na de diepte A B, daer in makende groote ſchuering, maer ſy wert om de bovenſchre-

15 FORM.



channels are scoured deeply, the adjacent land can drain abundantly through its sluices, become dry much sooner, and remain so for a long time, which will not be the case if the channel will silt up, on account of which advantage the dike reeves may with good reason be required to contribute to the cost of the swivel-gate locks and the ravelins that may be needed.

In order to profit by the above advantage and avoid difficulties, the general rule would be as follows: Let *AB* be a channel between the island *C* and the island or mainland *D*; these lands being unembanked, the daily low-tide falls back as far as *AB*, scouring it properly, but, because of the reasons described above, it becomes shallower every year, as experience proves.

ven redenen jaerlicx ondieper, zoo d'ervaring leert. Om dit te voorkomen, en de diepte dieder is niet alleen te behouden, maer te vermeerderen, zoo zalmen (de Landen eerſt bedijct zijnde) aen beyden eynden der Vaert Spilſluyſen legghen, elcke met twee paer deuren, als E F en G H, daer ſchuering me ghedaen kan vvorden op tweederley vvijſe: D'eene mettet hooch vvater der Vaert ghelooſt inde leeghe Zee: D'ander mettet hooch vvater der Zee gheflooſt inde leeghe Vaert: Want de Vaert metten vloet ten hoochſten vveſende, men ſluyt de twee paer deuren F en G: De ebbe daer na ten leeghſten zijnde, men opent d'een mael het een paer deuren als F, d'ander mael het ander paer als G, en zal het water ſchuering maken zonder vvantije t'ontmoeten. Maer om na de tweedde wijſe te ſchueren mettet hooch water der Zee inde leeghe Vaert, men ſluyt, als d'ebbe ten leeghſten is, de twee paer deuren E H: De vloet daer na ten hooghſten zijnde, men opent d'eenmael het een paer deuren als E, d'andermael het ander paer als H: En hoewel hier me gheen zandt uyt de Vaert en gheraect, maer aen't een eynde zal mogen vergaren, zoo kanmen dat mette volghende ebbe na d'eerſte manier voorder uyt ſpoelen, alzoo van derghelijcke ghezeyt is int 2 Voorbeelt deſes 3 Hoofſtucx.

D'eerſte vvijſe van ſchuering der voorſchreven twee, en is inde Vaert zoo ſterc niet als de tweedde, om dat de Dijcken tot zommighe plaetſen verre van malkander ligghen, en dattet hooch water daer tuſſchen zeer breet is, en daerom int beghin der looſing traghelic loopt: Maer het maect weerom ſtercker en langduerigher ſchuering inde Zeedorpels voor de twee monden der Vaert: Waer benevens noch t'aenmercken ſtaet, dattet buytenlandt tuſſchen de Dijcken en de Vaert gheduerich aenwaſt, zulcx dattet op korten tijt begraeſt zijnde, de ghemeene hooghe wateren zullen dan in een nauwe Vaert beſloten, ſtercker ſchuering maken.

De tweede vvijſe van ſchuering is inde Vaert ſtercker, om dattet hooch buytenwater int leegh drooch en enghe kiel valt. Wt deſe tweedde vvijſe vande ſluyting der deuren E H op een leegh vvater, kan noch een ander merckelic voordeel volgen inde droochmaking der Landen, om dat de Sluyſen der zelve Landen inde leeghe Vaert zoo veel vvaters looſen als die verſwelghen kan, zonder hindernis der vvaſſende vloet.

Maer aenghezien door deſe 15ᵉ Form mette volghende 16ᵉ, lichtelic kan verklaert worden noch zeker ander voordeel, en ooc wat achterdeels, ſpruytende uyt deſe manier van dijcking, zoo zegh ic daer af aldus: By aldien het landt van E tot H op beyden zijden der Vaert zoo hooch waer, als de ghemeene hoochſte vloeden daermen me ſchueren wil, zoo en behoeftmen op de zelve twee zijden der Vaert gheen Dijcken te maken, diemen anderzins zonder zulcke Sluyſen legghen moet, daer af de koſten groot vallen wanneerder van E tot H groote langde is: Bovendien is men ontſlaghen vande jaerliſche onderhouding, en van 'tperijckel der inbrake datter op dijcken loopt: Maer dat voorſchreven landt tuſſchen E en H leegher weſende dan de hoochſte vloeden daermen me ſchueren wil, zoo leghtmen alleenelic Kaeydijcxkens zoo hooge als ghenoech is totte zelve hoochſte vloeden, zonder te maken hooghe ſware Dijcken tegen alle ſtorm en extraordinaire hooge wateren. Doch ſtaet weerom daer teghen te ghedencken, datmen aldus doende de Vaert tot twee plaetſen als by I en M, niet zonder groote koſten moet ſtoppen metten Dijc daer deur gaende, 'twelc na d'ander wijſe van dijckage niet en ghebeurt, inder voeghen dat teghen al de bovenſchreven voordeelen dit achterdeel int overſlaen der onkoſten bedocht dient.

Tot hier toe de manier der ſchuering verklaert zijnde, zoo dient daer noch by bedocht, dat ter wijle men de Sluyſe maect, het varen der Schepen niet belet en

In order to avoid this, and to maintain the present depth or even increase it, after the embankment of the lands swivel-gate locks should be built at both the ends of the channel, each with two pairs of gates, *EF* and *GH*, which will serve to scour in two ways: One, with high tide in the channel, drained into the low sea; the other, with high tide in the sea, drained into the low channel. For when the channel has reached its highest level at high tide, the two pairs of gates *F* and *G* are closed; when afterwards the ebb-tide is at its lowest, now one pair of gates at *F* is opened, now the other pair at *G*, and the water will scour without meeting neap-tide. But in order to scour according to the second method with the high sea-water into the low channel the two pairs of gates *E* and *H* are closed when the ebb-tide has reached its lowest level. When afterwards the flood-tide has reached its highest level, now one pair of sluice-doors, say *E*, is opened, now those at *H*, and though sand is not thus removed from the channel but may accumulate at one end, this can be scoured out by the first method at next ebb-tide as has been explained in Example 2 of Chapter 3.

The first method of scouring is not as strong in the channel as the second, because the dikes in some places are far apart and the high water in between may be very wide, and therefore at the start of the scouring will flow slowly. But on the other hand it will cause stronger and more prolonged scouring over the sills to seaward in front of the two mouths of the channel, while it is also to be noted that the land between the dikes and the channel will grow constantly, so that it will soon be covered with grass and the common high tides, now being contained in a narrower channel, will cause stronger scouring.

The second method of scouring is stronger in the channel, because the high outer water falls into a low, dry and narrow channel. By this second method of closing the gates *EH* against low water yet another considerable advantage can be obtained for the drainage of the lands, because the sluices of these lands drain as much water into the low channel as it will take, without being impeded by the rising tide.

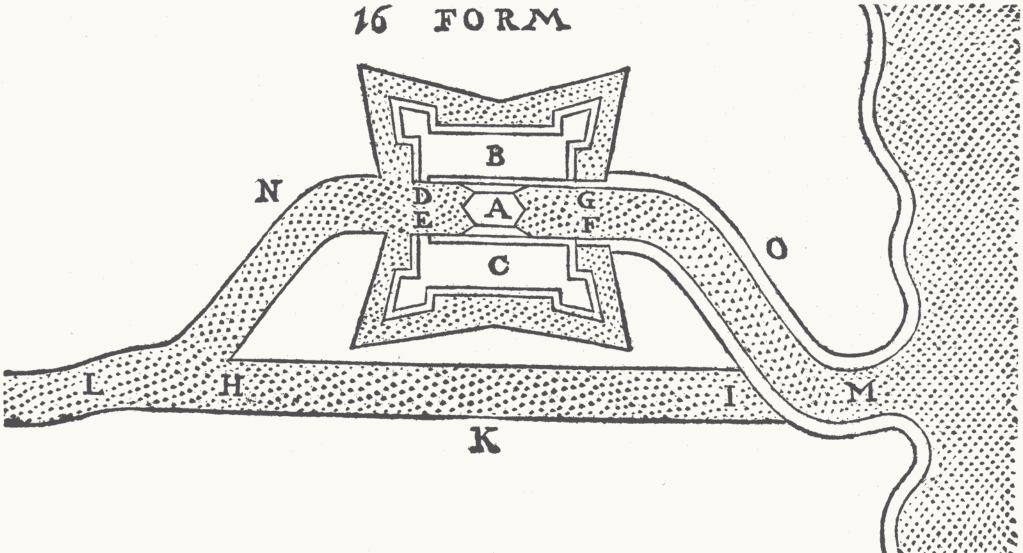
But as Figure 15 and the following Figure 16 show clearly another advantage, and also some disadvantages resulting from this form of embankment, I say as follows: If the land from *E* to *H* on the two sides of the channel were as high as the common highest tides by which the scouring is to be effected, there would be no need to make dikes on the said two sides of the channel, which would otherwise be necessary without the use of locks, the cost of which is great if the distance from *E* to *H* is great. Moreover one is thus relieved of the necessity of annual maintenance and the danger of the bursting of the dikes. But if the land between *E* and *H* were lower than the highest flood-tide with which the scouring is to be effected, embankments are made which are only just high enough for the said highest flood-tides, without high and heavy dikes having to be built against all storms and excessive high flood-tides. But against this it has to be borne in mind, that, if this is done, the channel has to be filled up at great expense in two places such as *I* and *M* with a dike extending through it, which is not done when the other embankment method is applied so that this disadvantage should be weighed against the advantages in the calculation of the expenses.

Up to now we have discussed the method of scouring, but it should also be remembered that while the locks are being made, ships should not be prevented from vvorde, 'twelc tot groote schade der Landen strecken zoude: Om 'tzelve te weghe te brenghen, zoo laet de ghetippelde linien van I tot K, en van L tot M, beteyckenen den loop des Vaerts, ghelijc die was voor het legghen der Sluysen, te weten van A rechtuyt door I K, en van daer tot L, en voorts door L M tot B, wesende alsdan het landt ter plaets der Sluysen zonder vaert: Dit zoo zijnde, men zal op dat landt binnens dijcx de Sluysen legghen, als ter plaetsen van E F en G H, ('twelc ooc noodich is, om datmense niet en behoort te leggen tusschen I K en L M inde diepe weecke gront des Vaerts) welcke ghemaect zijnde, men zal op elcke zijde der Sluyse graven een nieuwe diepte, zoo verre tot datmen inde Vaert komt, en stoppen daer na d'oude Vaert met den deurgaenden Dijc, als ter plaets van I en L: Al 'twelc ghedaen kan worden zonder het varen der Schepen een dach verhindert te vvesen.

Merct noch, dat uyt dese manier vande nieughegraven bocht daer het varen der Schepen me vry blijft ter wijle men de Sluysen maect, noch een ander voordeel volght: Om van 'twelc naerder verklaring te doen, metsgaders vande manier der Schantsen ghelijc die voor de Sluysen zouden mogen veroordent worden, zoo stel ic hier de volghende 16 Form van een Sluys alleen, met haer Schants, alwaer A de twee paer spildeuren beteyckent, B en C zijn twee borstweerkens zoo hooch als de Dijcken, belettende datmen van buyten inde Schants niet ghezien en worde: Op beyden eynden dier borstweerkens by D en E zijn openheden, daermen deur gaen mach om langs den barm te komen aen de Sluysdeuren, om die open en toe te doen, ooc om van daer over, een gancxken op de deuren ghewrocht, te komen van het een deel der Schants int ander: F G zijn twee Beeren ten eynde der Dijcken, daer sy aende Schants gheraken: H I is d'oude Vaert, aen het eynde I toegedamt met de deurgaende Dijcken: K is het landt daer de Vyant mach aenkomen: Zulcx dat met desen bocht L A M, I H aenghewesen wort in grooter form dan inde 15 Form, 'tghene het deel A E F K, of L G H B M aldaer beteyckende.

Het voordeel volghende uyt dese nieugegraven bocht L A M, is datse (benevens datmen zoo doende, de Scheepvaert niet en verhindert ter wijle men bouwet) belet de Sluysdeuren van buyten gezien of beschoten te worden, want van op d'ander zijde der Vaert als ter plaetsen van N en O, daermen neemt de Vyandt niet te konnen komen, staen de Sluysdeuren heel bloot.

16 FORM



sailing, which would cause great loss to the land. In order to achieve this, let the dotted lines from *I* to *K* and from *L* to *M* denote the course of the channel as it was before the building of the locks, *i.e.* from *A* straight through *IK*, and thence to *L* and thence through *LM* to *N*, the land where there are now locks having no channel. This being so, the locks should be built on the land inside the dikes, *i.e.* at *EF* and *GH* (which is necessary because they should not be built between *IK* and *LM* in the deep, soft bottom of the channel), and when they have been built, a new channel should be dug on either side of the lock until the channel is reached, and then the old channel should be filled up with a continuous dike at *I* and *L*. All this can be done without the sailing of the ships being impeded for a single day.

Also note that this method of digging a new channel, thus leaves navigation free while the locks are being built, has another advantage. In order to explain this and also the way in which the ravelins might be arranged in front of the locks, I give the following Figure 16 of a single lock with its ravelin, in which *A* designates the two sets of swivel-gates, *B* and *C* the two parapets as high as the dikes, preventing one from being seen in the ravelin from without. At both ends of these parapets at *D* and *E* are openings through which one may pass along the lock walls to the lock gates, in order to open and shut them, and also to get from one part of the ravelin into the other by a gangway built on the gates, *F* and *G* are two dams at the end of the dikes, where they come up to the ravelin; *HI* is the old channel, dammed up at the end *I* by the continuous dike; *K* is the land where the enemy may arrive, in such a way that by this bend *LAM*, *IH* is shown, on a larger scale than in Figure 15, that which was there represented by *AEFK* or *LGHBM*.

The advantage resulting from the cutting of this new bend *LAM* is that (apart from not impeding navigation during the building period) the lock-gates are prevented from being seen from without or fired at, for on the other side of the channel, at *N* or *O*, where it is assumed that the enemy cannot come, the lock-gates are quite unprotected.

Merct noch, dat zooder int beghin als de Spilſluyſen eerſt gheleyt zijn, niet diepte ghenoech inde Vaert en waer, en datmen by nachte aenſlach des Vyandts vreeſde, men zoude het hooch water inde Vaert moghen by nachte ophouden, en altijt by daghe ſchueren, zoo langhe tot datter op leegh vvater diepte ghenoech vvaer.

Noch is te weten, datmen in zeer langhe Vaerden zoude moghen legghen een derde Spilſluyſe, met twee paer deuren ontrent het middel des Vaerts, en ſchueren d'een leeghe helft met d'ander hooghe helft, nu ter eender dan ter ander zijde.

Deſe ſchuering alleenelic eens ter weke ghedaen zijnde, of zoo dicwils alſmen noodich bevonde, en daer op oorden gheſtelt ghelijc inde Steden daermen de Havens ſchuert, zoo en zoude de daghelicſche deurvaert der Schepen daer me niet verhindert worden dat te bedien hadde.

Nu dan de Landen der 15 Form aldus bedijct weſende, en zullen niet meer aenwaſſen, konnende daer na alſt noot valt met opening van Sluyſen of doorſteking van Dijcken onder water gheſtelt worden : De diepe Vaert belet d'overkomſt des Vyants : Sy is bequaem totte Scheepvaert : En zeer oorboor totte waterlooſing der bedijcte Landen daer voren af ghezeyt is : Sulcx dat hier me het voornemen deſes 11 Voorbeelts ghenoech verklaert ſchijnt.

4 HOOFTSTVC,

Inhoudende voorbeelden, hoemen eenighe Steden die dadelic in vveſen zijn, door de ghemeene reghelen des 3 Hooftſtucx kan verſtercken.

1 Voorbeelt van Calis.

DOor de Voorbeelden des 3 Hooftſtucx, is ghenoech verklaert de meyning hoemen Steden of Schantſen diemẽ van nieus oordentelic maect, met Spilſluyſen zoude verſtercken, maer want het voornaemſte ghebruyc beſtaet in zulcx aen oude ghemaecte Steden te vverc te ſtellen, na den eyſch der omſtandicheden, zoo zal ic daer af dit bezonder Hooftſtuc beſchrijven.

Calis weſende een Stadt van groot belang, daer de Zee met ebbe en vloet teghen aen ſlaet, heeft op d'Ooſtzijde Duynen, daer over men droochsvoets teghen de vvallen kan aenkomen : Om deſen krancken oort te verſtercken, iſſer ghemaect een hoogen ſteenen muer, en een hooch ſteenen bolwerc, van zoo grooten koſt (na dat my ghezeyt is vande ghene dieder kennis af hadden) dat ic't hier onbeſchreven wil laten, doch alles met vveynich verbetering, want nadienmen droochsvoets, als ghezeyt is, daer aenkomen mach, zoo en kan't teghen d'approchen of naerderinghen diemen nu ghebruyct niet langhe teghenhouden, noch voor * leer-aenſlaghen verzekertheyt hebben. **Eſcaladen.*

Maer alzoo den Gouverneur *Monſeigneur de Vic* zalig[r]. hier me ongheruſt en bekommert was, heeft onlancx voor ſyn overlijden begheert, dat ic daer ter plaets op de ſtercking der Stadt zoude willen letten, 'twelc gheſchiedde, en vviert nevens de bezichting my ghelevert een grontteyckening, als deſe 1 Form, waer in A beteyckent den voorſchreven Ooſthoec, daermen zonder gracht teghen de vvallen aen komt, B den Weſthoec.

1 Form

Also note that if, when the pivotted locks have just been built, there should be insufficient depth in the channel and a night-attack by the enemy were feared, one might keep the high-water level in the channel at night and scour always in the daytime, until there should be sufficient depth at low-tide. It is also to be noted that in very long channels a third lock might be built, with two pairs of gates about halfway up the channel and one low half might be scoured with the other high half, now in this direction, then in the other.

If this scouring were effected only once a week, or as often as is found necessary, and by-laws were issued about this, as in towns where harbours are scoured, the daily passage of ships would not be appreciably impeded. The lands of Figure 15 thus having been embanked, they will no longer have accretion so that in an emergency they can be inundated by opening the locks or cutting the dikes; the deep channel will prevent the enemy from crossing, it is suitable for navigation and very useful for the drainage of the embanked lands discussed above. In this way the intention of Example 11 seems to be sufficiently explained.

CHAPTER 4

Containing examples of how certain actually existing towns can be fortified by the general rules of Chapter 3.

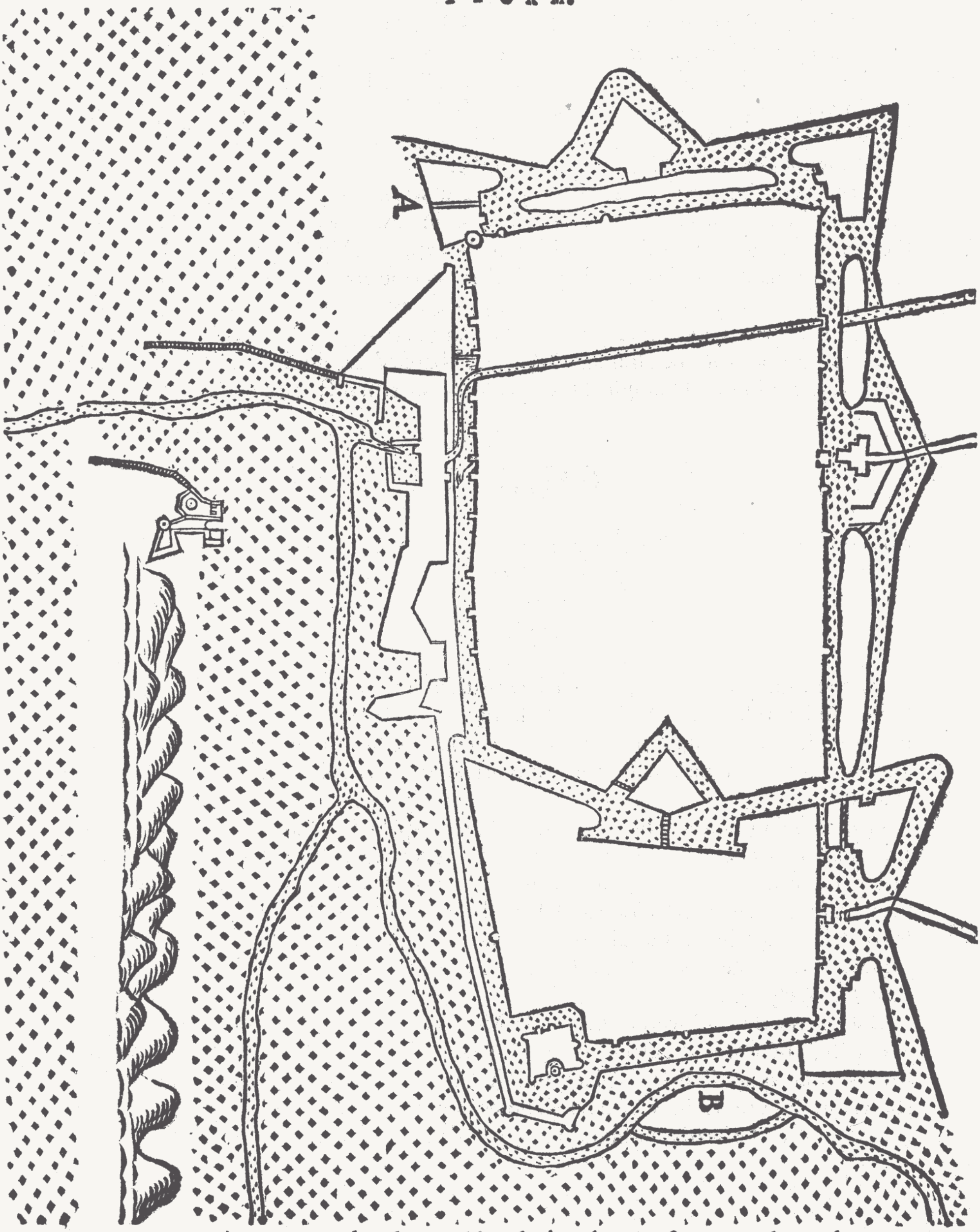
Example 1, of Calais

By the examples in Chapter 3 I have sufficiently explained my views as to how towns and ravelins which are newly built can be fortified with pivotted locks, but because the most important application consists in providing this in old towns already built, as required by the circumstances, I will describe this in this special chapter.

Calais, being a town of great importance, washed by the sea at low and high tide, has dunes to the east, over which one may reach the walls with dry feet. In order to fortify this weak point, a high stone wall and a high stone bulwark have been built at such great cost (as I have been told by those who knew) that I will leave this undescribed, but all to little avail, for as one can arrive there dry-shod, it cannot give protection for long from the methods of approach now used, not provide safety against escalades.

But as the late Governor-General, Monsieur de Vic, was uneasy and worried about this, he ordered before his death that I should study the fortification of the town on the spot. This took place and during this visit I received a ground-plan, as shown in Figure 1, in which *A* denotes the aforesaid eastern corner, where one can approach the walls without crossing a ditch, *B* the western corner.

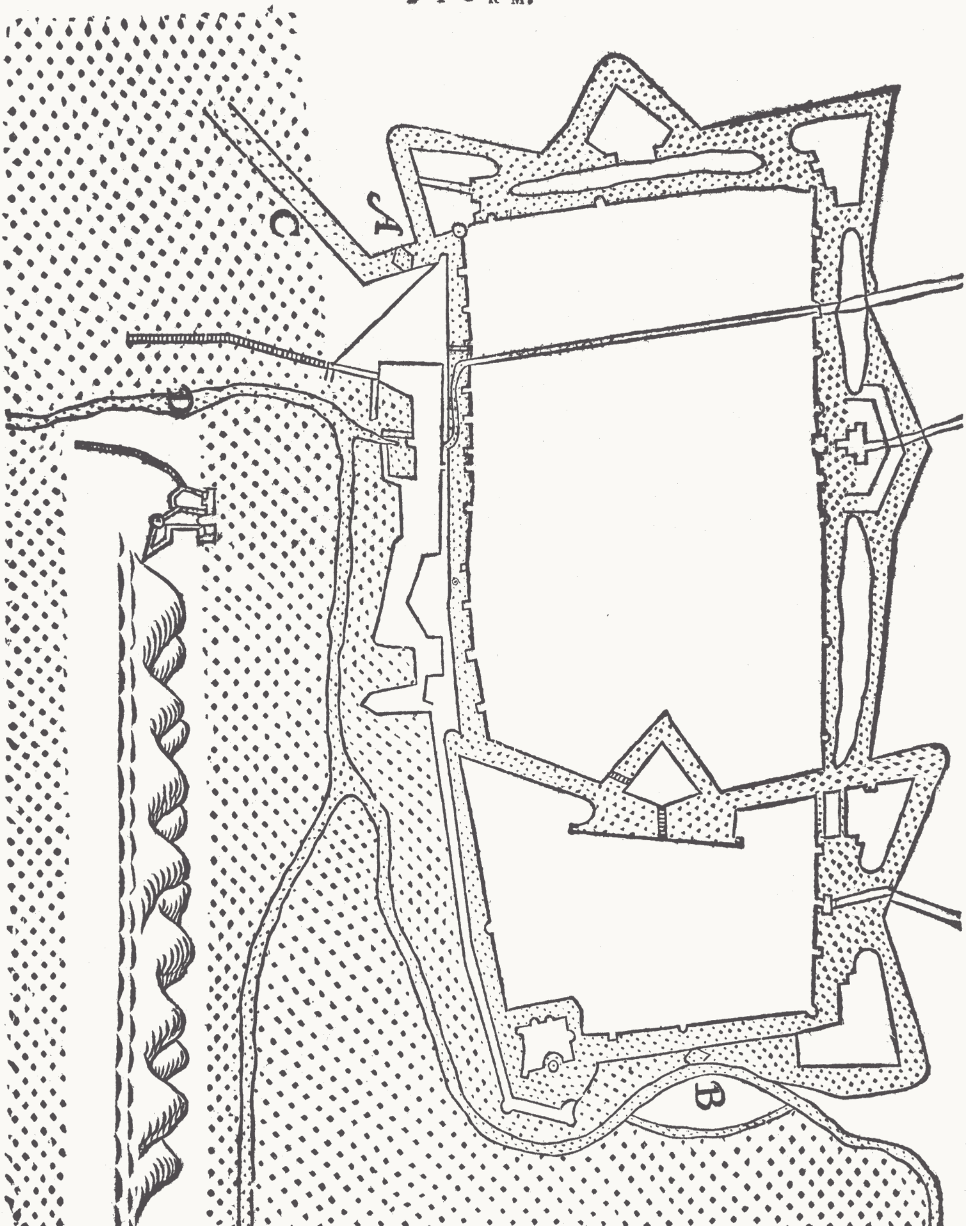
I Form.



Waer op ic myn goetduncken verklaerde, 'twelc was, datmen volgens den voorgaenden reghel van't 2 Voorbeelt des 3 Hooftstucx, zoude legghen twee Spilsluysen, d'een aen A, loosende haer vvater door een nieuwe Haven diese maken zoude, als C, d'ander aen B, loosende haer vvater door d'oude Haven D, ghelijc aenghewesen is inde volghende veranderde grontteyckening der 2 Form.

2 Form.

2 FORM.



Waer me zoude konnen gedaen worden een ſchuering volgens de manier, breeder verklaert int bovenſchreven 2 Voorbeelt des 3 Hooftſtucx, die zeer gheweldich zoude zijn, om 'tgroot verſchil tuſſchen hooch en leech water, vveſende daer op ghemeene getijen van ontrent 15 voeten. Hier benevens ſtaet noch t'aenmercken, dat voor dese Sluysen tot haer bescherming ravelins met haer Molens mogen gheleyt vvorden, daer bezonderlic af ghezeyt is int 3ᵉ en 4ᵉ Voorbeelt des 3 Hooftstucx, maer vvorden kortheyts halven ongheteyckent ghelaten.

Nu, alzoo den voorschreven Gouverneur (vvesende een Man van groot verstant, en in krijchszaken zeer ervaren) vastelic gheloofde, dat daer uyt volghen zoude een goede versterckıng van die twee krancke oorten, en ooc der Stadt int gheheel, metsgaders groote verbetering des koophandels, en dat met onkosten die vergheleken by de grootheyt der zake zeer kleen zouden zijn, zoo is hy ghetrocken by den Koninc om hem totte onkosten te beweghen; Doch eyntlic en konde de zake daer toe niet brenghen: Maer want veler menschen kennis van 'tghene ghezeyt is, daer toe zoude konnen behulpich zijn, zoo mochtet ghebeuren dat dit vermaen daer toe hier namaels voorderlic viel.

2 Voorbeelt van Vlissinghe.

METte linien der volghende 3 Form van A over B tot C, worden verstaen de nieuwe wercken van wallen en grachten, diemen te Vlissinghe gemaect heeft: De linien van C over D E F G, bedien d'oude wercken dieder onvermaect ghebleven zijn, daer af 'tperc D E F G is den Houder of het Molenwater; De ghetippelde linien van C over H I K beteyckenen de verandering diemender in toekomenden tijdt tot volbrenghing des oordentelic wercx meynt by te maken.

3 Form.

I then suggested that according to the rule of Example 2, Chapter 3, two swivel-gate locks should be built, one at *A*, draining its water through a new harbour *C* which was to be built, the other at *B*, draining its water through the old harbour *D* as is shown in the following modified ground-plan in Figure 2.

By this means, scouring might be achieved as explained in more detail in Example 2 of Chapter 3, which would be very powerful, because of the great difference between high and low water-level, which with average tides is about 15 feet. Apart from this it should be noted that in front of these locks, ravelins and their mills can be built for their protection, as has been discussed in detail in Examples 3 and 4 of Chapter 3, but for the sake of brevity we have not drawn them.

Now, since the above-mentioned Governor (being a man of great intelligence and very experienced in military affairs) believed firmly that this would lead to a good fortification of the two weak places, and also of the town as a whole, involving great improvement of trade, and that the expense would be very small as compared with the importance of the matter, he went to the king to induce him to pay the cost. But finally he was unable to accomplish the matter. But because, if many people were acquainted with the above, this might further the matter, this discussion may in the future be conductive thereto.

Example 2, of Flushing

The lines in the following Figure 3 from *A via B* to *C* designate the new fortifications of walls and ditches which have been built at Flushing. The lines from *C via DEFG* denote the old works, which have not been altered, the area *DEFG* is the basin or mill-pond. The dotted lines from *C via HIK* designate the future changes planned to be made for the completion of a good plan..

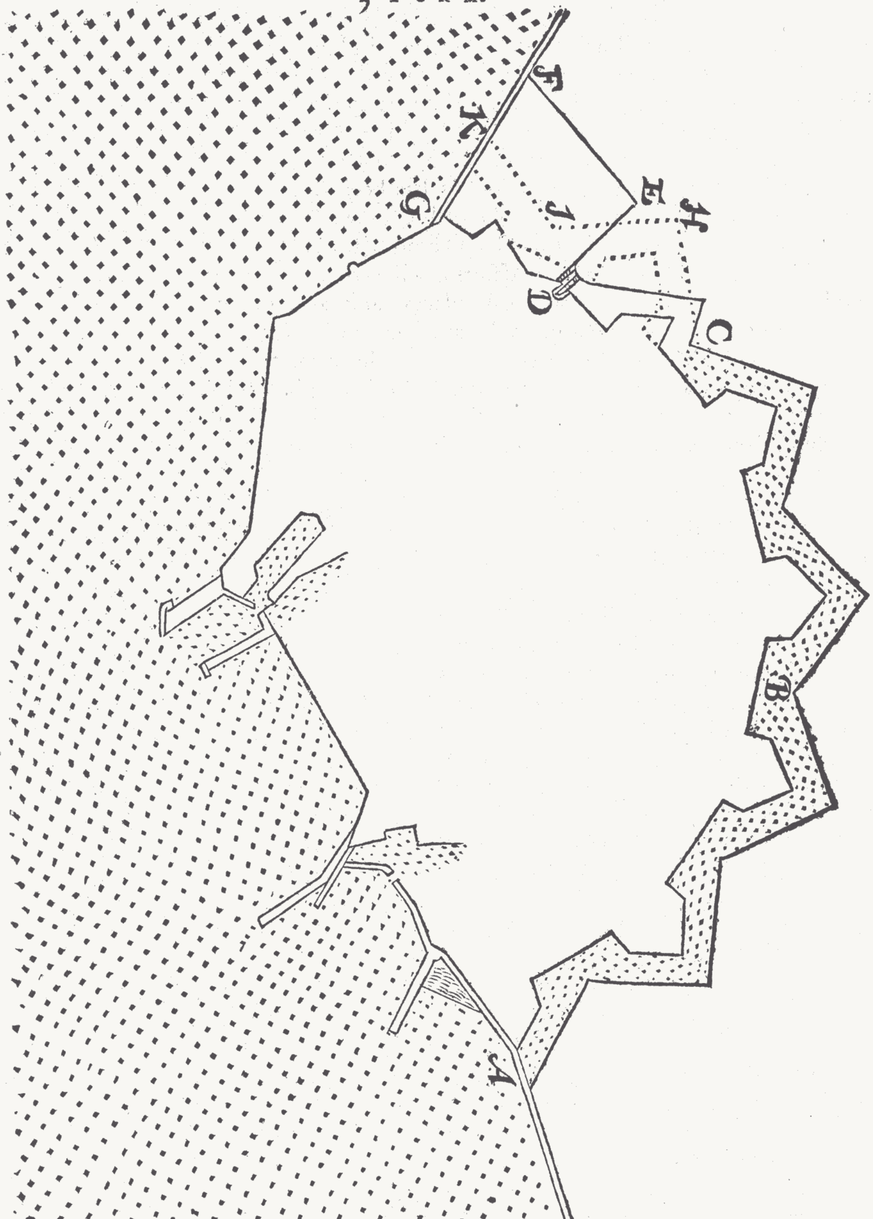
But if this plan were carried out and scouring swivel-gate locks were desired to be put into operation the three dams at *A*, *G*, *D* of Figure 3 might be dug away and two swivel-gate locks might be built at *L* and *M*, as in Figure 4, taking the place of the mill-pond *DEFG*, operating as explained in Example 4 of Chapter 3. And if the ships were preferred not to be left in the ditch, but rather to be anchored inside the town, this might be achieved by means of an entrance through the wall or through the old harbour. We might also discuss more fully here the details, to be noted in this matter, listening to the information of those who have to decide on it, but as this general rule has not been understood or allowed to be used, nor any decision as to rebuilding has been given, it might be that I should waste my time; I will therefore leave it at this short remark.

Example 3 of Deventer

Deventer at present has the form shown in Figure 5

And though the river IJssel, which flows along it, is not tidal, still the scouring can be effected powerfully with the small river *AB*, called *Schipbeek*, which often has great plenty of water, which allows of frequent scouring and would produce great depth of ditches and harbours, without the two ends silting up as in Figure 5, but in their places two deep harbours, and that according to to the general rule of Example 7 of Chapter 3, *i.e.* the two dams *C* and *D* of Figure 5 to be taken away, and two swivel-gate locks to be built as in Figure 6, at *E* and *F*, or in other places, if found more suitable. The ships might also anchor and shelter against ice-drift in the old ditch *GH* within the town, which might be deepened by the common scouring, if the end at *G* were cut through.

3 FORM.

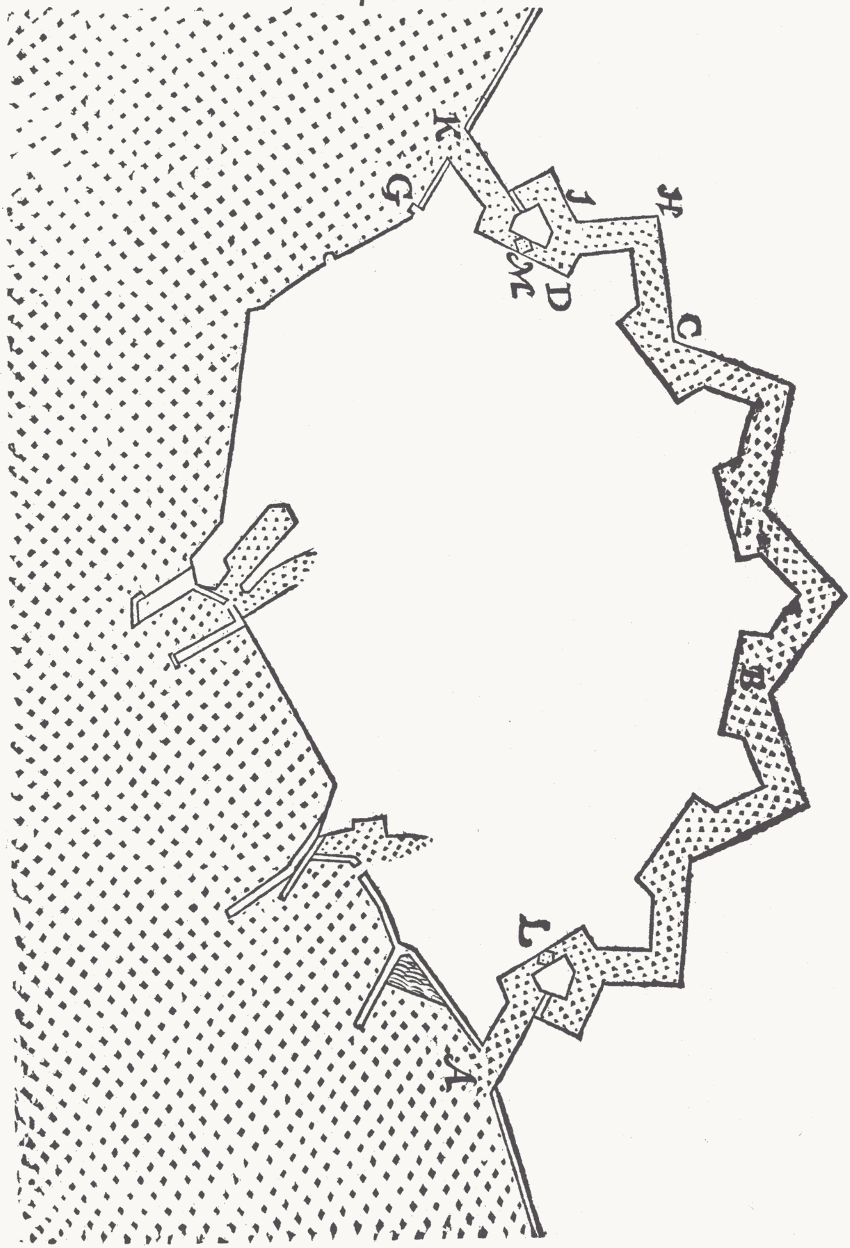


Maer alst daer toe quaem, en datmen schuerende Spilsluysen, wilde te werc stellen, zoo zoudemen de drie Beeren by A G D, der 3 Form moghen uytgraven, en legghen twee Spilsluysen aen L en M, als inde volghende 4 Form, doende het Molenwater D E F G te niet, malende na de manier verklaert int 4 Voorbeelt des 3 Hooftstucx. En zoomen de Schepen inde gracht niet en wilde laten, maer binnen de Stadt doen ligghen, dat konde ghescheiden met een inkomst door den

 vval,

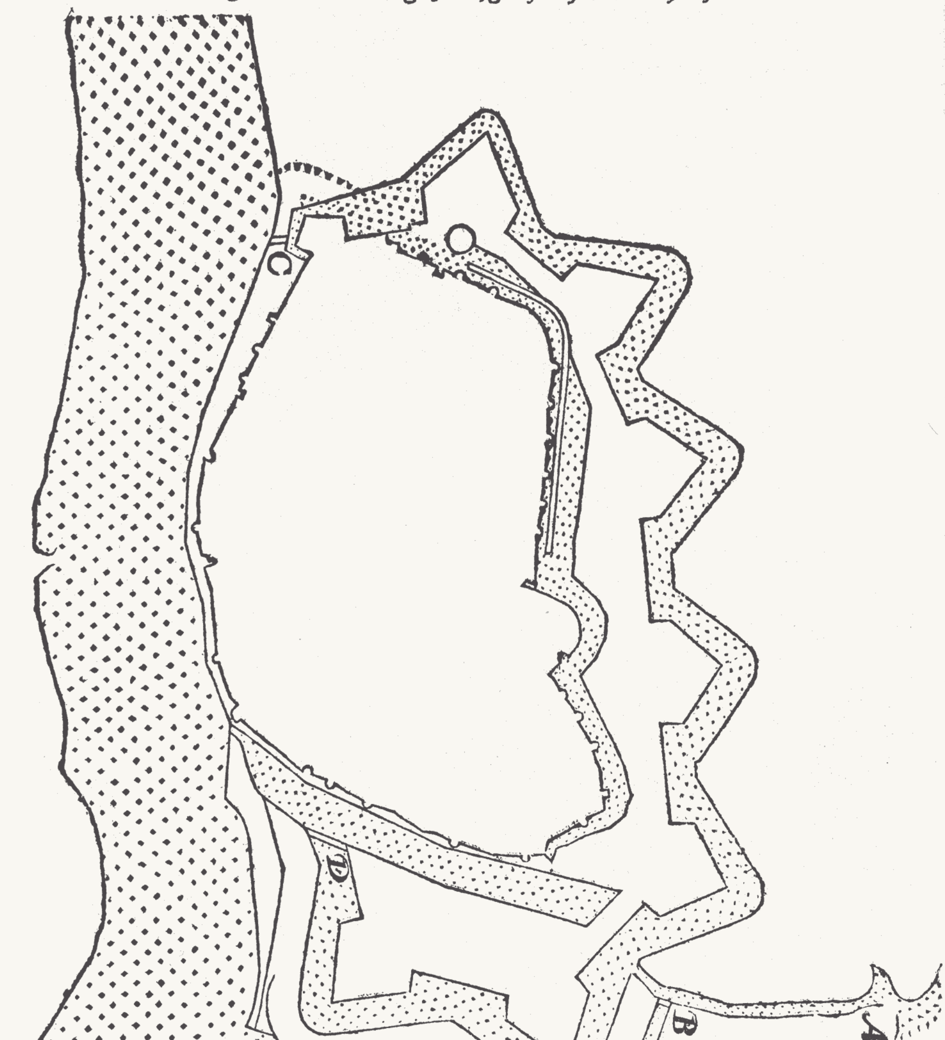
vval, of door d'oude Havens. Voort zoudemen hier breeder mogen zeggen vande bezonderheden die in dese zake t'aenmercken vallen, daer op hoorende naerder onderrichting vande ghene die daer toe te zegghen hebben, maer desen ghemeenen reghel niet verstaen noch toeghelaten zijnde, noch besluyt van verandering gheschiet wesende, 'tmocht zijn dat icker verloren arbeyt in dede, zal't daerom ghenoech laten zijn, met dit vermaen daer af ghedaen te hebben.

4 FORM.



3 Voorbeelt van Deventer.

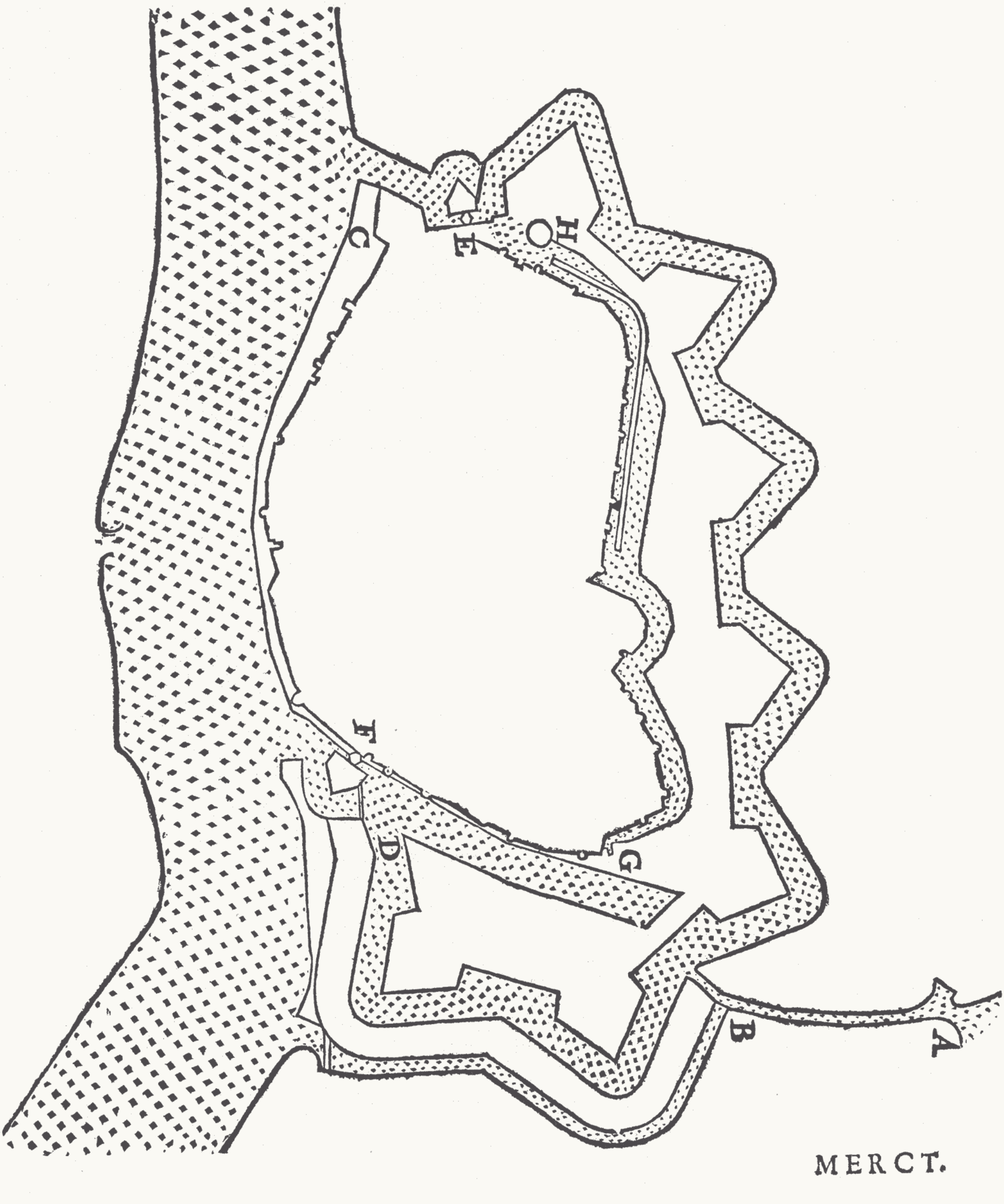
Deventer is teghen woordelic van gheſtalt, ghelijc deſe 5 Form uytwijst.



En hoewel d'Yſſel dieder teghen aenloopt gheen ebbe en vloet en heeft, nochtans kan de ſchuering gheweldelic ghedaen worden mettet Rivierken A B ghezeyt Schibbeke, dat dicwils groote overvloet van water gheeft, om dicwils daer me te ſchueren, en groote diepte van grachten en Havens te krijghen, zonder twee verzandende eynden als inde 5 Form, maer in die plaets twee diepe Havens, en dat na

 den ghe-den ghemeenen reghel van het 7 Voorbeelt des 3 Hooftstucx, te weten, datmen wech nemende de twee Beeren C D der 5 Form, zoude leggen als inde volgende 6 Form, twee Spilsluysen ter plaets van E F, of elders zoomen't oorboorder verstonde. De Schepen zouden ooc konnen ligghen en teghen ijsganc haer verberghen binnen de Stadt in d'oude gracht G H, die mette ghemeene schuering ooc zoude konnen verdiepen, alsmen het eynde aen G deur stake.

6 FORM.



MERCT.

MERCT.

MYn eerste meyning was van dese versterc king der Steden die dadelic in wesen bestaen, meer Voorbeelden te stellen d'ander beschreven zijn, maer ziende dattet meer tijts zoude vereysschen, dan my ghelegen valt daer aen te besteden, dat boven dien zulcke verbetering diwils gheen voortganc en mach nemen, om de gherechticheden, pretensien en oppositien van omligghende Landen en Steden, zulcx datter veel verloren arbeyt in mocht gedaen zijn; Zoo heb ic voor my ghenomen de zake daer by te laten berusten, en in die plaets wat int ghemeen te zegghen, als volght:

Steden gheleghen aen groote vvateren met ebbe en vloet, als in dese Landen, Sluys, Ysendijcke, ter Tolen, ter Vere, Zierickzee, Willemstadt, Geertruyden Berghe, Rotterdam, Dordrecht, Enchuysen, Amsterdam, en dierghelijcke konnen met Spilsluysen versterct worden na de manier des 2, 3, 4 en 5 Voorbeelts van't 3 Hooftstuc: Ghelijc ooc Steden by groote wateren zonder ebbe en vloet, maer hebbende kleene Rivierkens daer aen komende, als Aernhem, Zuytphen, Deventer, Swolle, en dierghelijcke.

Steden gheleghen by groote vvateren met ebbe en vloet, doch zoo verre daer af, datmen Legher tusschen beyden kan slaen, als Berghen op Zoom, Middelburch, den Briel, Schiedam, en dierghelijcke, konnen met Spilsluysen versterct worden na de manier des 6 Voorbeelts van't 3 Hooftstuc: Ghelijc ooc konnen zulcke Steden by groote wateren zonder ebbe en vloet, mits datter een kleyn Rivierken aen komt, als Dousburch met dierghelijcke.

Steden gheleghen aen groote Rivieren zonder ebbe en vloet, ooc zonder kleyn Rivierken daer aen komende, als Worckum, Heusden, Bommel, Kampen, Emmeric, Reez, en dierghelijcke, konnen met Spilsluysen versterct worden na de manier des 8 Voorbeelts van het 3 Hooftstuc.

Landtsteden verre van groote wateren, doch hebbende kleyne onbevaerlicke Rivierkens, als Breevoort, Moers, den Haech, en dierghelijcke, konnen met Spilsluysen versterct worden na de maniet des 9 Voorbeelts van't 3 Hooftstuc: Ghelijc ooc konnen Landtsteden verre van groote wateren met kleene bevaerlicke Rivierkens, die met Sluysen heel verstopt zijn, als Breda met dierghelijcke.

Steden met luttel ebbe en vloet, doch hebbende kleeene Rivierkens; als Harderwijc en dierghelijcke, daer konnen die twee t'zamen, te weten het kleen Rivierken mette kleene ebbe en vloet, de schuering stercker maken, met meerder verschil van hoochste en leeghste water, dan van't ghetije komt.

Hoewel den gront der hooghe gracht van Aernhem, ontrent 14 voeten hoogher mach ligghen dan den grondt buyten haer Beeren, zoo houde ic't nochtans voor moghelic (midts dattet inde gront niet te rootzich of te hardt en zij) die door Spilsluysen zoo diep te konnen wechgeschuert worden, datmen zonder Beeren rontom de Stadt met Schepen zoude moghen varen: Want hoewel den Rhijn daer gheen ebbe en vloet en heeft, nochtans om de gheleghentheyt van haer kleyn Rivierken ghenaemt de Beke, daermen het vvater zeer hooch me kan vergaren, meyn ic datmen zulcx te weghe zoude konnen brenghen: De redenen die my dat te vrijelicker doen ghelooven, zijn d'ervaring tot Linghen ghebeurt, voor welcke Stadt ten tijde doen syn *Vorstelicke Ghenade* die in nam, hooghe berghen aende grachten laghen, die over de Stadt bevalen, maer door de voordachtighe leyding der hooghe wateren van't Rivierken ghenaemt de A a, zijn de berghen wech ghespoelt wel tot duysent voeten vande gracht, en dat met zeer kleynen kost: Twelc gheen droomen wesende te vastelicker mach ghelooft vvorden, om dat de Burgherije diewils

quam

NOTE

My first intention was to give more examples of this fortification of actually existing towns than have been described, but seeing that this would require more time than I can afford to spend on it, and such an improvement is often impossible because of the decisions, claims, and oppositions of surrounding lands and towns, which would mean much labour lost, I have decided to leave the matter as it is, and instead to make a general statement, as follows:

Towns on large tidal waters, such as Sluys, IJzendijke, Tholen, Veere, Zierikzee, Willemsstad, Geertruidenberg, Rotterdam, Dordrecht, Enkhuyzen, Amsterdam and the like in these regions can be fortified with pivotted sluice-locks according to the methods of Examples 2, 3, 4 and 5 of Chapter 3, as also towns on large non-tidal waters, but having small rivers coming up to them, such as Arnhem, Zutphen, Zwolle, Deventer, and the like.

Towns near large tidal waters, but so far away from them that a camp may be pitched in between, such as Bergen op Zoom, Middelburg, Brielle, Schiedam and the like, can be fortified with pivotted sluice locks according to the method given in Example 6 of chapter 3, as also such towns near large non-tidal waters, provided a small river comes up to them, such as Doesburg and the like.

Towns on large non-tidal rivers without any small river, such as Workum, Heusden, Bommel, Kampen, Emmerich, Rees and the like, can be fortified with pivotted sluice-locks according to the method of Example 8, Chapter 3.

Inland towns far from great rivers, but having small non-navigable rivers, such as Breevoort, Moers, The Hague, and the like, can be fortified with pivotted sluice locks according to the method of Example 9 of Chapter 3, as also inland towns far from large waters, with small navigable rivers, which have silted up. with locks, such as Breda and the like.

In towns with slight tides, but having small rivers, such as Harderwijk and the like, the two together, the small river and the slight tide, may increase the scouring, with more difference between highest and lowest water-level than results from the tides.

Though the bottom of the high ditch of Arnhem may be about 14 feet higher than the bottom outside its dams, I still believe it possible (if the bottom is not too hard or rocky) to deepen it so much with pivotted sluice-locks that ships would be able to sail around the town without any dams, for though the Rhine is non-tidal there, because of the small river called the Beek, the water of which may be dammed up very high, I think this may be effected. The reason which makes me believe this the more readily is the experience at Lingen, in front of which town, at the time when His Princely Grace took it, high mounds lay along the ditches, which commanded the town, but by the judicious use of the high waters of the small river called the Aa the mounds were washed away up to 1000 feet from the ditch, and that at very low cost. Which being no dream, may be believed the more quam uytgheloopen om te zien vallen de berghen die van onder uytghespoelt zijnde, omvielen. Tis wel zoo, dat dit t'eenemael zantbergen waren, daer in de schuering lichter voortgaet dan in vaster stof, doch kanmen hier uyt syn profijt trecken, om na gheleghentheyt der omstandicheden zich me te behelpen. Door 'tghene hier ghezeyt is van Aernhem, machmen dierghelijcke verstaen van ander Steden die zoodanighe gheleghentheyt hebben.

Tis gebeurt over ettelicke jarē, dat die van Leyden begondē te maken een Sluyse by Katwijc, om daer deur te varē van Leyden in Zee, ooc om de binnenlantsche wateren te loosen, maer de Nederlandtsche beroerten opkomende, 'tbleef daer by steken, zulcx dattet begonnen werc den naem behoudē heeft van't Mallegat: Maer om van zulc voornemen myn ghevoelen te verklaren, ic zegh aldus: By aldienmen tot die plaets maecten drie Spilsluysen nevens malkander, elcke breet 50 voeten, makende t'zamen een gat van 150 voeten, en buytens Duyns twee langhe Hoofden na 'tbehooren, ic houdet daer voor, dattet zoude worden een vande vermaerde goede Havens daermen nu af spreect, die ooc zulcke verandering van aenwassende bancken, platen, en dorpels, niet en zoude onderworpen zijn, als de Havens die door Rivieren veroorzaect worden, daer af ic hier onder eyghentlicker zegghen zal: Maer alsmen by de Stadt noch leyde ander Spilsluysen na 'tbehooren, men zoude konnen te weghe brenghen datter gheen vermenghing en gheschiedde van't Zeewater mettet versch Stadtswater, 'twelc ooc ten tijde dat de windt zeer langhe aen eenen oort blijft staen, syn daghelicxsche verversching zoude krijgen beter dan zoo't nu ghebeurt.

Noch zal ic hier wat zegghen van ettelicke eyghenschappen die in stof van Sluysen dienen gade gheslaghen: Zommighe en achten niet oorboor de spendeur eens Houders metten eersten heel boven vvater te trecken, om dat de schuering dan terstont ghedaen is, maer beter te zijn, datmen die allencxkens hoogher en hoogher opwint, om den loop te matighen, en de schuering langher te doen dueren: Maer my bevalt beter de manier der ghene, die 'twater metten eersten t'eenemael af doen loopen, zoo ras alst moghelic is: Om van 'twelc reden te gheven, zoo zegh ic by voorbeelt aldus: Ghelijc een Cortoukogel van 48 ℔, rollende in een gote schuyns ghestelt, en die ten eynde loopt, neem ic, in een hoop eerden potten, daer in meerder brake zal doen op haer korte tijt, dan kleene Musquetkoghels, wegende t'zamen 48 ℔, en rollende d'een na d'ander inde zelve gote op langher tijt: Alzoo zegh ic zal een groot opghehouden water tzeffens vallende deur een groot gat in een zandighe gront, daer in meerder brake of schuering doen op haer korte tijt, dan 'tzelve vvater vallende lanczamelic deur een kleyn gat op den zelven gront op haer langen tijt: Twelc ghenoech schijnende in reden te bestaen, zal't daer by laten blijven, en komen tot een ander gheschil.

Men heeft dicwils bevonden, met een nauwer Sluyse meerder vvaterloosing of landtdrooghing gheschiet te vvesen, dan daer te voren met een vvijder gheweest had, of dat veel Sluysen nevens malkander, te voren min vvaters loosden, dan vveynich Sluysen diemen daer na maecte: Als onder anderen ter plaets vande vijf Sluysen by Schiedam, vviert ghemaect een groote Sluys, doch veel minder dan die vijf t'zamen, nochtans veel beter dienst doende dan de vijf voorgaende gedaen hadden, vvaer uyt zommighe met schijnbaer redenen zouden moghen besluyten, dat de breetste Spilsluysen daer wy zoo zeer na trachten, de meeste schuering niet en maken. Tot antwoort van desen is te weten, dat int veroordenen dier vijf Sluysen, met dierghelijcke daer zulcke swaricheyt in ghevallen heeft, faute gheschiet is, daer men int legghen vande Spilsluysen zich voor vvachten moet: Om welcke faute te verklaren voor de ghene diese onbekent mach zijn, zoo ist openbaer, dat by aldien

'tgat

firmly because the citizens often turned out to see the mounds, which had been undermined, collapse. It is true that these were sand dunes, which can be scoured more easily than more solid material, but still one may take account of this and make shift according to the circumstances. From what has here been said about Arnhem one may draw similar conclusions for other towns in similar circumstances.

It happened several years ago that the Leyden citizens started building locks at Katwijk in order to pass from Leyden to the sea and also to drain water from inland, but the disturbances in the Netherlands starting, the enterprise stagnated and the work already started kept the name *Mallegat* (Foolish Hole). But in order to explain my views about this work, I say: If in that place three pivotted sluice-locks were laid side by side, each 50 feet wide, thus producing an opening of 150 feet in all, and in front of the dunes two long piers in the proper way, I take it that this would become one of the famous excellent harbours now talked about, which would not be subject to such changes, like growing sandbanks, flats or bars, as the harbours formed by rivers, which I will discuss below more properly. But if near the town other pivotted sluice locks were laid, the mixing of seawater and fresh water from the town might be avoided, which latter water would be refreshed daily more adequately than is now the case, even at times when the wind should blow from one direction for a long period.

I will here add something about several properties which should be observed in the matter of sluices. Some do not deem it suitable to draw the sluice door of a basin at once right out of the water, because the scouring is then complete at once, but believe it better to wind it gradually in order to slow down the flow and to prolong the scouring. But I prefer the method of those who release the water at once, as quickly as possible. In order to explain this, I give this example: Just as a cannon ball of 48 lbs, rolling down in an inclined groove and ending, say in a heap of earthen pots, will cause more breakage in this short time than small musket shots, weighing together 48 lbs, rolling one after the other through this groove during a longer time. Thus, I say, a large amount of pent-up water, falling simultaneously through a large aperture onto a sandy soil will cause more abrasion or scouring therein in this short period than would the same water falling slowly through a small hole onto the same soil during a long period. Since this seems reasonable enough I will leave it at this and pass on to another point of issue.

It has often been found that with a narrower sluice more discharge of water and drainage of land is effected than previously with a wider sluice, or that many sluices in a row at first drained off less water than a smaller number of sluices made later. Thus instead of the five sluices at Schiedam was made one large sluice, much less wide than the five together, but which nevertheless served its purpose much better than the five former ones had done from which some people with some appearance of logic might infer that the widest pivotted sluice locks which we advocate so seriously, do not effect the best scouring. By way of reply it is stated that in planning those five sluices, and in similar cases involving such difficulties, mistakes have been made such as should be avoided in building pivotted sluice locks. In order to explain those mistakes to those who are not acquainted 'tgat van een Sluyse, of al de gaten der Sluysen t'zamen, zoo breet vvaren als de ghemeene breedde des Canaels of Vaerts daer de Sluys of Sluysen op staen, alsdan naturlic te wesen, dat inde Sluyse zulcken ondiepte kome, en zoodanich zandt of slijc vergadert ghelijcker is aen beyde zijden des Vaerts langs het landt voor en achter de Sluyse, uyt oorzaec dat de stroom inde Sluyse niet stercker en is dan daer buyten int Canael: Maer het zandt alzoo vergaderende binnen en voor de Sluysdeuren, sy blijven vast staende, zonder te konnen open en toegaen, en vervolghens zonder het Landt te konnen dienen: Tis wel zoo den reghel vast te gaen, dat de meeste Sluysgaten de meeste schuering maken, maer 'tverstaet hem midts dat de deuren zulcken ongheval niet en hebben: Daerom moetmen int legghen der Spilsluysen toezien, 'tgat van dien altijt zoo veel smalder te maken dan de breedde des Canaels of Houders, datter zulcken verstopping niet en kome.

By 'tghene tot hier ghezeyt is, zal ic noch dit vervoeghen: Te weten, dat de Havens ghemaect door schuering der Spilsluysen met Zeewater, zonder Riviet daer in te komen, minder aenwas voor haer mondt krijghen dan de Havens gemaect door Rivieren, uyt oorzaec dat daer alleenelic aenwas valt van het zandt dat onder vvater zomwijlen mette groote stormen die de grondt beweghen, int Canael komt, en daer na mette schueringhen der Spilsluysen weerom uytghespoelt wordt: Maer den aenwas voor den mondt der Rivieren is boven dien noch zoo veel grooter, als veroorzaken haer hooghe vvateren die van boven het zandt elcke mael mebrengen, zoodanich zijnde, dat de dorpels en platen t'elckens mette hooghe Rivierwateren zulcke veranderinghen krijghen, datmen de meeste diepte zeer dicwils zoect om de Baectonnen te verlegghen: Ia is dien aenwas zoodanich, dat daer af komen de groote Eylanden diemen aende monden der Rivieren ziet aenwassen, als voor de Schelde d'Eylanden van Zeelandt, en voor de Maes de Hollantsche Eylanden, als vande Vooren, Briele, Goeree, Beyerlandt, en veel ander dieder ten tijde van *Ptolemeus* niet en waren, en zedert zeer groote verandering ghekreghen hebben, ghelijc door syn Kaerten, en die des teghenwoordighen tijdts te zien is: Ia zoo, dat veel Steden, die doen Zee-steden waren, zedert Landt-steden gheworden zijn: Men ziet ooc, dat voor de Havens ghelijc van Marceille, Genua, Napels, en dierghelijcke daer gheen Rivieren door in Zee en loopen, zulcken aenwas niet en komt als van d'ander: Inder voeghen, dat de Havens der Steden ligghende aen Zee verre van Rivieren, en gheschuert met Sluysen, dies aengaende zulcken swaricheyt niet te verwachten en hebben als d'eerste soorte der Steden aen Rivieren ligghende. Aengaende ymandt hier teghen zegghen mocht, dat Steden aen groote bevaerlicke Rivieren gheleghen, benevens de buytenvaert in Zee, noch hebben de binnenlantsche vaert te Rivierwaert op, en dat zulcken voordeel de Steden zonder Rivier niet en hebben: Hier op machmen antwoorden, dat van die Steden totte groote Rivier toe binnenvaerden zijnde, met Spilsluysen inde Dijcken, zoo konnen de Schepen daer deur inde Rivier komen, en te landewaert in varen, ghelijc oftse aende Rivier lagen: En by aldiender zulcke binnenvaerden niet en waren, zoo kanmense daer't de gheleghentheyt toelaet van nieus graven.

Aldus in dit 4 Hooftstuc beschreven zijnde, eerst Voorbeelden hoemen eenighe Steden die dadelic in wesen bestaen, door Spilsluysen zoude moghen verstercken; en daer na van die stof noch in't ghemeen gezeyt hebbende, zal daer me desen handel besluyten.

EYNDE.

with them, it is obvious that if the hole of one sluice, or the holes of all sluices together were as wide as the overall width of the canal or channel on which the lock (or locks) is built, it is natural that such locks will silt up and the same amount of sand or mud will accumulate as on either side of the channel along the land before and behind the lock, because the current in the locks is not stronger than outside in the channel. But if the sand thus accumulates within and without the lock-gates they will jam and be unable to open or close, and thus cannot drain the land. It is true that the fixed rule is that the largest sluice doors give the best scouring, but only if the gates do not have this difficulty. Therefore in building pivotted sluice locks one should see to it that the sluice area is always so much narrower than the width of the canal or basin that such silting-up cannot occur.

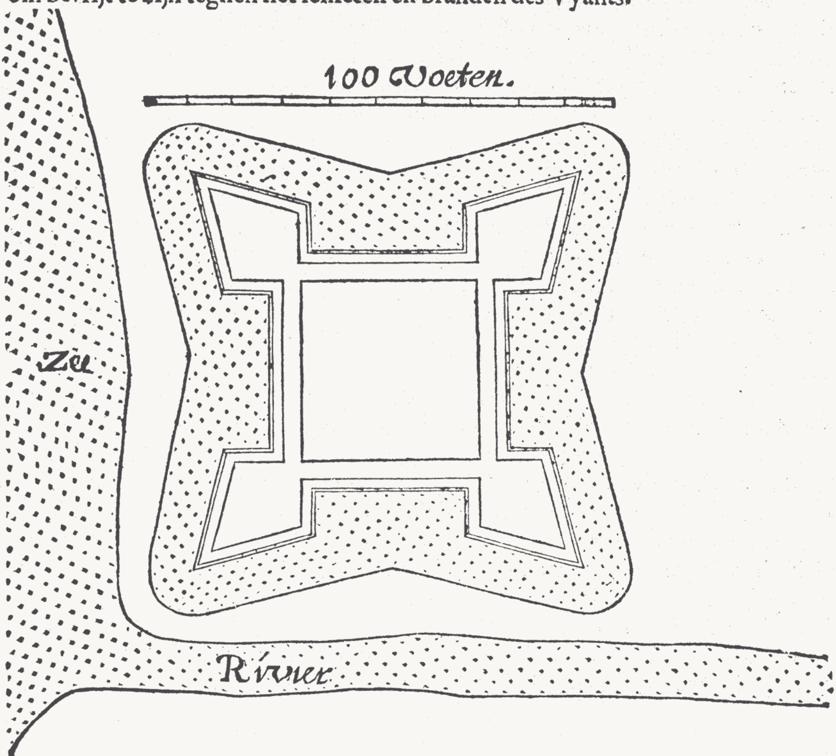
To what has been said so far I would like to add the following: The mouths of harbours formed by the scouring of pivotted sluice locks with sea-water, without rivers giving into them, silt up less than do harbours formed by rivers, because their silting-up is caused only by the sand below water-level which sometimes enters the channel owing to great storms, which move the soil, and is afterwards scoured out again by means of the pivotted sluice locks. But silting-up in front of the mouths of rivers is greater still owing to the high tides, which everytime bring in sand from upstream, in such a way that bars and flats change with every high river water in such a way that the best draught must be constantly sought in order to change the beacons. This silting-up is even so great that large islands are formed at the mouths of the rivers such as the islands of Zeeland in front of the Schelde, and the islands of Holland in front of the Maas, such as Voorne, Brielle, Goeree, Beyerland, and many others which did not exist in the days of Ptolemy and which changed greatly after that time, as may be seen from a comparison of his maps and those of the present; even to the extent that many towns that used to be seaside towns now lie inland. It is also seen that in front of harbours like those of Marseilles, Genoa, Napels and the like, where no rivers give into the sea, no such silting-up occurs. So that harbours of towns on the sea, far from rivers and scoured by means of sluices need not expect such difficulties as the first type of towns on rivers. And if anyone should object that towns on large navigable rivers have, beside sea navigation, inland navigation up the river, and that towns not lying on rivers do not have this advantage, the answer may be that if from these towns to the large rivers there are inland canals with pivotted sluice-locks in the dikes, the ships can pass thus into the river and sail inland as if the towns lay on the river. And if there were no such inland-canals they might be dug a new if the circumstances permitted it.

Thus having described in Chapter 4, first, examples of how certain actually existing towns might be fortified with pivotted sluice-locks and then having discussed this matter in general, I will now conclude this treatise.

END

AENHANG.

HET is ghebeurt doenmen bezich was mettet laetste deses Handels te drucken, datter grontteyckening ghemaect wiert van een groote vierhoeckighe Schants, als inde volghende eerste Form, diemen in voornemen is op zeker plaets nieu te veroordenen, hebbende d'een zijde langs een Rivier, d'ander zijde langs de Zee, en rontom een gracht, die zoo na by de voorschreven Rivier en Zee gheteyckent is, datter gheen plaets en blijst om Legher te legghen: Welcke manier men voor beter verstaet, dan de Zee oft Rivier teghen de bolwercken te doen slaen, om redenen in't voorgaende ghenoech verhaelt: Zulcke plaetsen zijn onder anderen Gorckum, Aernhem, Thiel, de Schants op de Vooren, S. Andries Schants, Lilloo, Liefkens Hoec, en meer ander in Vlaender. De voorschreven grontteyckening wiert my vertoont, om daer op myn ghevoelen te zeggen, 'twelc my oorboor ghedocht heeft hier by te voeghen, als volcht: Voor eerst ist wel zoo, dat zulcke manier van grachten geen Beeren en behoeven, om het grachtwater op te houden: Maer weerom daer teghen en konnender gheen Schepen inde grachten komen, om daer verzekert te ligghen, 'twelc nochtans in tijt van beleghering zeer noodich is, om bevrijt te zijn teghen het schieten en branden des Vyants.



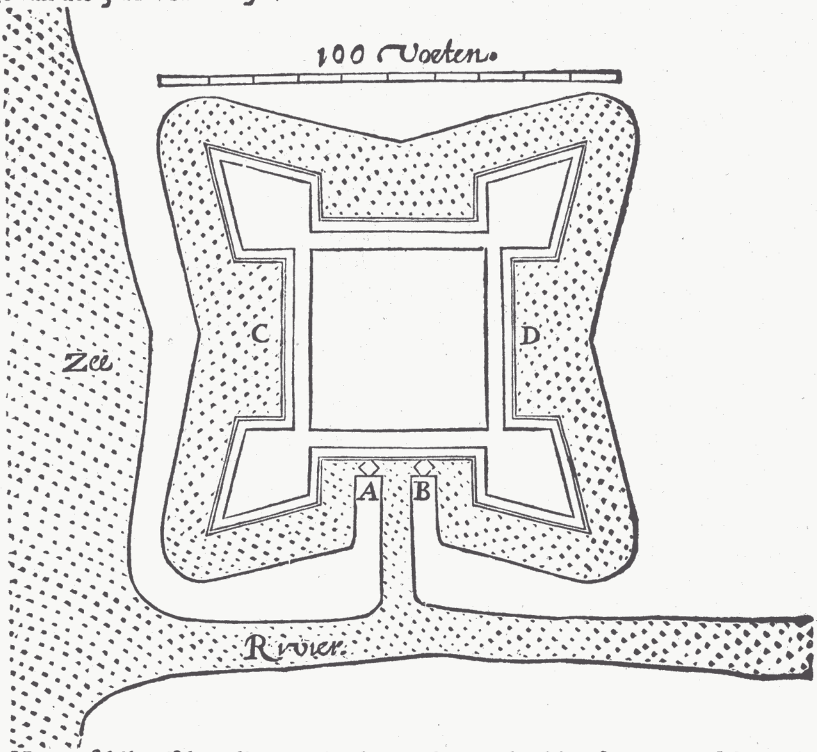
Dese swaricheden kanmen wel voorkomē met Spilsluysen, na de manier beschreven in't 3e Hoofstuc; Maer want dit Voorbeelt wat breeder verklaring schijnt te ver eyschen, zoo stel ic tot dien eynde vande zelve Schants de volgende grontteyckening, alwaer A d'een Spilsluys, B d'ander bediet, beyde gheleyt tusschen twee bolwercken voor een zelve gordijne, doende de schuering door de Haven C, d'eenmael met A blijvende B ghesloten, d'andermael met B blijvende A ghesloten, na de manier breeder verklaert in't 3e Hoofstuc: Wort ooc verstaen, dat des grachts contre-

APPENDIX

It happened that as the last part of this essay was being printed a ground-plan was drawn of a large rectangular redoubt, as in the following Figure 1, the erection of which is contemplated in a certain place, having one side along a river, the other side along the sea and surrounded by a ditch, which has been drawn so close to the aforesaid river and sea that there is no space for a camp to be pitched in between, which method is considered better than having the sea or the river wash the bulwarks, for reasons sufficiently explained above. Such places are, among others, Gorinchem, Arnhem, Tiel, the redoubt in Voorne, St. Andries-schans (St. Andrews redoubt), Lilloo, Liefkenshoek, and many others in Flanders. The aforesaid ground-plan was shown to me and my opinion was asked, which I have deemed it suitable to add here, as follows: Firstly, it is true that such ditches need no dams to dam their water, but on the other hand no ships can enter the ditches so as to be protected there, which is nevertheless necessary in times of siege, in order for them to be safe from the enemy's firing and burning.

These difficulties can be avoided by means of pivotted sluice-locks, as described in Chapter 3. But as this example seems to call for a more detailed explanation, I give this redoubt the following ground-plan, in which *A* is one lock, *B* the other, both built between two bulwarks in front of the same curtain, scouring the harbour *C*, one time with *A* while *B* remains closed, the other time with *B* while *A* remains closed, according to the method explained in more detail in Chapter 3.

It is also assumed that the counterscarp of the ditch will have its covered way, with its own ditch in front behind which the ships are protected in the manner contrescharpe oft buytenkant zal hebben haer bedecte wech, met haer grachtken daer voor, om de Schepen achter bevrijt te wesen, na de manier beschreven ten eynde van des 3e Hooftstucx 5e Voorbeelt.



Het verschil tusschen dit Voorbeelt, en de Voorbeelden des 3e Hooftstucx, is dat hier de twee Spilsluysen beyde t'zamen veroordent zijn tusschen twee bolwercken voor een zelve gordijne, daer d'ander elc ligghen voor een bezonder gordijne, waer af de reden dusdanich is: By aldienmen elcke Spilsluys hier ligghende aen A en B, gheleyt hadde voor het middel van een gordijne als ter plaets van C en D, ghelijcse inde Voorbeelden des 3e Hooftstucx gheleyt zijn, 'tis kennelic datmen maer d'een helft des waters vande gracht tot schuering en zoude konnen ghebruycken, daermen't aldus altemael heeft: Ten anderen zijn de twee Spilsluysen A en B by malkander beter beschermt met haer nevenstaende bolwercken na de Rivier toe daermen gheen beleghering en verwacht, en zonder Ravelin te behoeven, dan een Sluyse aen D ligghende, daer de beleghering vande landtzijde vallen kan, en wel een Ravelijn tot haer bescherming vereysschen zoude: Inder voeghen, dat om dese reden de Spilsluysen in kleene Stercten met luttel bolwercken, vereysschen by malkander te ligghen voor een zelve gordijne, welverstaende daer het water der Zee oft Rivier teghen de Stercte niet aen en slaet, in welcken ghevalle de Spilsluysen na d'eerste wijse willen gheleyt zijn.

D'oorzaec waerom ic dit Voorbeelt niet en stelde by d'ander des 3e Hooftstucx, was dattet my alsdoen openbaer ghenoech docht, en dat ieghelic zulcx wel by syn zelven bedencken zoude, zonder daer af breeder uytlegging te behoeven: Maer tot de zaec komende, en teyckening doende van een chants diemen van wille is dadelic te maken, zoo heeft my dese breeder verklaring oorboor gedocht: Zulcx dat icse daerom in desen Aenhang vervoecht heb; in meyning zijnde, van dierghelijcke te zullen doen met zoodanighe ander die my voortaen mochten bejeghenen.

EYNDE.

described at the end of Example 5 in Chapter 3. The difference between this example and those of Chapter 3 is that here the two locks have been built between two bulwarks in front of one curtain, whereas in the other case each lock lies in front of its own curtain, the reason of which is this: If each of the locks here placed at *A* and *B* had been built in front of the middle of a curtain, at *C* and *D*, as in the examples in Chapter 3, it is evident that only one half of the water of the ditch might be used for scouring, whereas now the whole of the water is available. Secondly, the two pivotted sluice-locks *A* and *B* close together are better protected with their adjacent bulwarks towards the river, where no siege is expected and where no ravelin is needed than a lock at *D*, where the siege may be conducted from the landward side and a ravelin would be required to protect it. Therefore the locks in small fortresses with few bulwarks should be close together in front of one curtain, provided the fortress is not washed by the water of a river or the sea, in which case the locks should be built according to the first method. The reason why I did not give this example among the others in Chapter 3 is because I thought it obvious enough and that everybody would consider it for himself without further explanation. But since a drawing was made of a redoubt, which is intended to be actually built, I though it suitable to give this more detailed explanation, so that I added it in this Appendix, intending to do the same for any others I might come across in future.

END

CHAPTER IV

VANDEN HANDEL DER WATERSCHUYRING

THE ESSAY ON WATERSCOURING

WISCONSTICH
BEDRYF
Van *Hendric Stevin* Heer van Alphen,
van Schrevelsrecht, &c.

XI. BOEC,
VANDEN HANDEL
DER
WATERSHUYRING
Onſes Vaders SIMON STEVIN.

XI. BOEC
VANDEN HANDEL
Der
WATERSCHUYRINC
Onſes Vaders SIMON STEVIN.

EERSTE ONDERSCHEYT
Vant 10 *Boec*
Vande Waterſchuyring int gemeen.

ANgeſien veel Huyſen, Schanſen ende Steden, gebout worden op bedijckte landen, alwaer kennis vande gemene eygenſchap der ſchuyring vorderlick is, ſoo ſal ic nu daer af als totten huysbou gehoorende, wat ſeggen.

Sommige anſiende de ſeltſame gewelt der Zee en groote Rivieren, houden ſulx als deur gemeene regel voor Godts werck, daer de menſchen te vergeefs hun me becommeren. Waer opgeſeyt wort, dat alles Godts werc te weſen openbaer is, maer al te eenvoudelic te gelooven, dat de menſchen hun daer me te vergeefs becommeren, is onnut, want ſy doen ſomwylen groote Rivieren haer loop veranderen, als met yet deur te graven, hoofden te leggen en diergelijcke behendicheden: Een menſche alleen (ic laet veel varen) can met een dyc deur te ſtekẽ, maken dat op weynig uyren een vrugtbaer bewaſſen, betimmert lant, verandert in een volle zee: groote Lantſchappen worden deur menſchen handen bedyct, bedampt, becribt, becramt, vruchtbaer gemaect en bewoont, daer anders de hooge wateren over ſouden loopen, die verwoeſtende.

De onderſoecking dan der oirſaken deſer dingen niet ſulke onnutte becommering weſende, gelijc ſommige deur al te gemene regel meynen; Wy meugen met reden ons daer in oeffenen ſo veel als oirboir ſchynt.

Tis te weten datmen ſomwylen meynt met yet deur te ſteken, diepe ſchuyringe te maken om bequame havens, vaerden, grachten van Steden en diergelijke te crygen, maer datter eyntlic ſulke ſchuyring niet

 uyt

BOOK XI, OF THE ESSAY ON WATERSCOURING BY OUR FATHER SIMON STEVIN

CHAPTER 1 OF BOOK 10

On waterscouring in general

As many houses, redoubts and towns are built on embanked lands, for which knowledge of the general properties of scouring is helpful, I will now say something on this matter, since it pertains to architecture.

Some people, seeing the extraordinary power of the sea and large rivers, take this on the whole to be God's work, about which men trouble themselves in vain. To which we say that it is evident that all is God's work, but it is useless to believe too simply that men trouble about this in vain, for they sometimes divert the course of large rivers, *e.g.* by making a cut, by building piers, and similar skilful actions. One man alone (to mention only a few instances) by cutting a dike can turn a fertile, cultivated, and built-up land into a full sea within a few hours. Large areas are embanked, dammed, strengthened, rendered fertile, and inhabited by the hands of men, over which areas in other circumstances the high waters would flow, laying them waste.

The study of the causes of these things thus not being a useless trouble, as some people believe by an excessive generalization, we may with reason pursue this study as much as seems suitable.

It is to be noted that it is sometimes believed that by making a cut, one may effect deep scouring, in order to get useful harbours, waterways, canals, town-ditches, and the like, but that ultimately no such scouring will result, though it uyt volgen en wil, die nochtans tot ander plaetsen van dergelijke gestalt schynt te gebeuren; maer wanttet een gemene regel is, dat gelijke oirsaken gelijke daden wercken, soo moeter in sulke eenige ongelijcheyt zijn: de selve canmen dicwils bemerken, de sake wel genoech overdocht zijnde; En van dese verscheydenheden is myn voornemen hier nu te seggen, eerst beschryvende een vertooch om daer na als gemeen bewys te gebruycken.

VERTOOCH.

Een Rivier haer in tween scheydende, en die deelen tot een ander plaets weerom versamelende, het corste heeft de snelste stroom en meeste schuyring.

T *Gegeven* Laet in dees 1 form A B C D E een Rivier zijn, haer in tween scheydende an B, diens twe delen B C D en B F D weerom versamen an D, maer B F D ist cortste. *T begeerde*: Wy moeten bewysen dattet selve cortste deel B F D, snelder stroom heeft dant langste B C D. *Tbewys*: Angesien B gemeen begin is der twe deelen, en D haer gemeen eynde, so ist openbaer twater vant een en tander deel eveveel vervals te hebben; twelc ic neem te wesen 5 voet, en B C D vijf mael so lanc als B F D: dit soo zijnde, tis daer voor te houden dat yder vijfdedeel van B C D een voet vervals heeft; Maer B D evelanc met B G heeft 5 voeten vervals; daerom twater loopt trager van B tot G, dan van B tot D. Maer so traech het water loopt opt vijfde deel B G, so traech loopet op elc der ander vijfde deelen, dat is deurgaens van B over C tot D toe, daerom het cortste deel B E D heeft snelder stroom dant langste B C D. *T besluyt*: Een Rivier dan haer in tween scheydende, en die deelen tot een ander plaets weerom versamende, het cortste heeft de snelste stroom en meeste schuyring, twelc wy bewysen moesten.

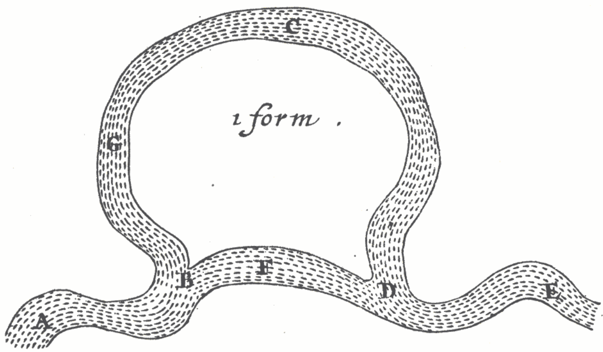
1 *MERCT.*

Tis kennelic, dat so de incomst an B des deels B F D seer eng waer, en daer achter tot D toe seer breet, of int middel veel dieper dan an B of D, dat sulx sou connen veroirsaken den stroom B F D trager te wesen does seem to happen in other places of similar kind, but because it is a general rule that like causes produce like effects, there must be some difference in such a case. This can often be observed if the matter is sufficiently considered, and of these differences I now intend to speak, first describing a theorem and then using it as a general proof.

THEOREM

A river dividing itself into two parts, and these parts meeting again in another place, the shorter part has the faster current and the stronger scouring.

Supposition: In Figure 1 let *ABCDE* be a river, dividing itself in two at *B*, the two parts *BCD* and *BFD* meeting again at *D*, but *BFD* being the shorter. — *Required:* We have to prove that the said shorter part *BFD* has a faster current than the longer part *BCD*. – *Proof:* As *B* is the common starting-point of the two parts and D their common end, it is evident that the water has the same fall in one part and the other, which I take to be 5 feet, and *BCD* five times the length of *BFD*. This being so, it is to be assumed that every fifth part of *BCD* has a fall of one foot. But *BD*, which is as long as *BG*, has a fall of 5 feet; therefore the water runs more slowly from *B* to *G* than from *B* to *D*. But as slowly as the water flows in the fifth part *BG*, so slowly it flows in each of the other fifths, *i.e.* from *B via C* to *D*, and therefore the shorter part *BED* has a faster current than the longer part *BCD*. — *Conclusion:* A river therefore dividing itself in two parts, and these parts meeting again in another place, the shorter part has the faster current and the stronger scouring; which we had to prove.



NOTE 1

It is obvious that if the entrance of *BFD* at *B* were very narrow and then up to *D* very wide, or much deeper in the middle than at *B* or *D*, this might cause the current *BFD* to be slower than *BCD*, just as the nature of the entrances in one sen dan B C D, gelijc ooc sou connen de gestalt der monden tot d'een plaets van B na G, neem ic, bequamer zijn om veel water tontfangen, als tot d'ander van B na F, gelijc inde 2 form. Want hoewel dese B F D corter is dan B C D, nochtans is het seer geneycht na B C D te willen loopen om de rechte incomst an B na C, en te min geneycht nae B F D te loopen, om de verkeerde incomst an B na E. Maer ic houdet voor openbaer datmen in desen gevalle, sonder begrypen nemen moet, de twe deelen elc over al eenvaerdiger breede en diepte te wesen, ooc de gestalt der monden vant een en tander deel behoorlicke gelijcheyt te hebben, en datmen in sulc ansien by gemene regel segt, de corste wech de snelste loop en meeste schuyring te hebben, gelijc int Voorstel.

2 *MERCT.*

Int Vertooch is geseyt van een rivierens twe deelen weerom versamende; de reden waerom dit niet int gemeen genomen en wort, ooc op twe delen niet weer versamende, is, dat sulke op eveveel langde niet nootsakelic eveveel vervals en hebben, wantmen het een somwylen veel snelder stroom siet hebben als tander; ja men bevint vvel sulke verandering te gebeuren dattet water tvvelc int een deel somvvylen leegste is, een andermael hoogste can zijn, om sulke redenen als tzijnder plaetse achter de 9 form, geseyt sal vvorden.

Deurt gene tot hier toe geseyt is, machmen verstaen en van te vooren weten ofeen nieuwe graving dieder gedaen moet zijn, schuyring sal hebben, of dattet versanden sou; Want een nieuwe vaert langer te delven dan de groote rivier, daer is versanding of verstopping te verwachten.

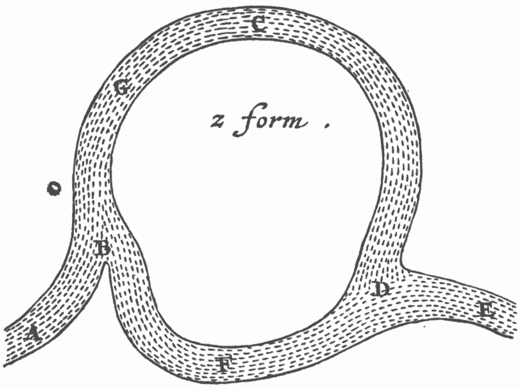
Dit Vertooch beschreven zijnde, wy sullen totte saec commen, stellende ettelicke voorbeelden vande verscheyden gedaente der schuyring.

Laet in dese 3 form A B een groote rivier of kreke zijn, waer uyt een cleen loopt an C, van daer na D, weer incommende an E. By aldien dese grote rivier altijt loopt van A na B sonder ebbe en vloet, so sal de clene altijt (uytgenomen eenich geval alwaer hier na afgeseyt sal worden) loopen van C over D uytcommende an E; Maer twater met ebbe en vloet zijnde, sulx en is niet nootsakelic, want tot eenige plaetsen sietn en de vloet op een selve tijdt so wel incommen an E, als an C, en de ebbe uytloopen so wel an C, als an E, maer niet overal, want in sommige stroomen

men

place from *B* towards *G* (I suppose) might be more suitable to receive much water than in the other place from *B* towards *F*, as in Figure 2.

For though this *BFD* is shorter than *BCD* still the water is greatly inclined to flow by *BCD,* because of the straight entrance at *B* towards *C*, and less inclined to flow by *BFD,* because of the nature of the entrance at *B* towards E. But I assume it to be evident that in such cases one should take it for granted that each of the two parts has uniform width and depth throughout, also that the mouths of the two parts are reasonably similar, and that in such circumstances the general rule is that the shorter way has the faster current and the stronger scouring, as in the proposition.



NOTE 2

In the theorem we have spoken of the two parts of a river meeting again; the reason why we have not taken this in a general way, also for the case that the two parts do not meet again, is that such parts of equal lengths do not necessarily have equal fall, for the one is often found to have a much faster current than the other; we even find such changes to take place that the water which in one part is sometimes lowest at another time may be highest, for the reasons that we will duly discuss after Figure 9.

From what has so far been said it may be inferred and known beforehand whether a new cut which has to be made will effect scouring or whether it will cause silting-up, for if a new waterway is built that is longer than the large river, silting-up or blocking is to be expected.

This theorem having been discussed, we will now come to the point and give several examples of various forms of scouring.

In Figure 3 let *AB* be a large river or creek, from which a small river branches at *C*, and thence runs to *D*, entering again at *E*. If this river always runs from *A* to *B* without ebb and flow, the small river (except in one case, to be discussed later) will always flow from *C via D* to *E*. But if the water is tidal, this need not be so, for in some places one sees the tide coming in at *E* and *C* at the same time and going out both at *C* and at *E*, but not everywhere, for some tidal rivers men met ebbe en vloet gadet gelijc mette rivieren die altijdt een selve wech loopen, te weten dat de vloet altijt in comt an C, en uytloopt an E, maer de ebbe incomt an E, en uytloopt an C. D'oirsaken hier af syn dusdanich; Ten eersten: de revier altijt een wech loopende van A na B en twaters oppervlac altijt hooger synde an C dan an D, en hooger an D als an E, en van C over D tot E altijt verleegende, so moetet die wech altijt henen loopen; Maer twater met ebbe en vloet zijnde, so gebeuret dat C D E drooch wesende, en de vloet daer na ancommende, de selve CDE niet so haest gevult en can worden of twater en blijft een tijt lanck leeger an C als an E, en so lang moettet soo wel an E als an C inloopen, niet tegenstaende dattet an E leger is dan an C. Sulcke inlooping des strooms so wel an E als an C, geduert langst in kreken die langst zijn, en noch meer daer veel plat lant by is dat mette vloet onder water comt, en dat om bekende oirsaken; Maer ander sulke kreken seer cort wesende sonder leeg lant daer nevens, indervougen dattet water hem daer in soo lichtelic verheft als inde groote rivier A B self, soo comt de vloet geduerich in an C, van daer over D deur E, en de ebbe geduerich in an E, van daer over D deur C, altijt met een loop gelijct groot water A B heeft.

Ic heb dadelic bevonden sulke inloping des waters so wel an E als an C te gebeuren op de langde alleenlic van vier of vijf hondert stappen.

Merct dat kreken daer de vloet op een selve tijt so wel an C als E incomt, gemenelic geen deurgaende diepe schuyring en hebben: Want ter plaets daer die twe stroomen malcander ontmoeten (hier te lande wantye genoemt) twelc ic neem te gebeuren an D en valt geen schuyring en vervolgens geen goe vaert, noch bewaernis van stercten. Ic seg hier boven gemeenelick, om datmen somwijlen tverkeerde siet gebeuren, of daert van selfs niet gevallen en is, men canter dickwils toe brengen. Om dan

Te verclaren de gemeene regel van schuyring deur wantyen.

Laet A B C D E in dees 4 form andermael van beteyckening sijn als inde 3. Maer buyten D sy gelegentheyt van bedyct lant datmen deur steken mach, of gorsing met kreken diemen tot bequame plaetsen stoppen can en elders tot malcander doen commen, en voort tot nodige plaetsen caden leggen boven de sprincvloeden commende, gelijker begrepen is

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flow similarly to rivers which always follow the same course, *i.e.* the high tide always enters at *C* and leaves at *E*, but the low tide enters at *E* and leaves at *C*. The causes hereof are as follows: Firstly: if the river always runs its course from *A* to *B*, and the water level is always higher at *C* than at *D*, and higher at *D* than at *E*, and constantly falls from *C* to *E via D*, it must always follow this course. But if the water is tidal, it may happen that *CDE* being dry and the high tide approaching it, the said *CDE* will not fill up as rapidly but the water will remain lower for some time at *C* than at *E*, and during this period it is bound to enter at *E* as well as at *C*, notwithstanding the fact that at *E* it is lower than at *C*. Such entry of the current both at *E* and at *C* lasts longest in creeks which are longest, and even longer in places where there is much flat country, which is flooded at high tides, and that for well-known reasons. But if such creeks are short and no low-lying land is found along them, so that the water will rise in it as easily as in the large river *AB* itself, the high tide constantly enters at *C*, flowing thence *via D* to *E*, and the low tide always enters at *E*, flowing thence *via D* to *C*, always flowing the same course as the large water *AB*.

I have found in practice that such entry of the water both at *E* and at *C* takes place only for a distance of four to five hundred paces.

Note that creeks where the high tide enters simultaneously at *C* and *E* usually have no continuous deep scouring: For in the place where the two currents meet (here usually called neap-tide), which I assume to happen at *D*, there will be no scouring, and consequently no good navigation and preservation of fortresses. I said above: usually, because sometimes the oppositie is found to happen or, if this has not happened, one may often cause it to happen. In order

to explain the general rule of scouring through neap-tides,

let *ABCDE* in Figure 4 have the same meaning as in Figure 3, but outside *D* let there be embanked land, which can be cut, or saltings which creeks which can be dammed in suitable places and be made to meet in other places, while also dams can be laid in the necessary places, such dams rising above the spring-tides, say as within the area between *D* and *F*, where the creeks have been joined by the ditches, say as from *D* to *G*, from *G* to *H*, from *I* to *K*, and any other such ditches as one might dig. In this way, when the high tide enters at the two openings *C* and *E* and runs through at *D*, thus filling the area *DF* and when the said water is thereafter forced to flow back at low tide again from *D* to *C* and *E*, one will thus check the above-mentioned neap-tide and effect good scouring; even so well that it will usually be necessary to provide the corners at *G* and *H* with piers, in order not to scour away over too great a width and thus loose the desired depth.

But it should be realized that in this bay *DF* constant silting-up is to be expected which in course of time will diminish this scouring, against which one may provide according to circumstances, which by the general rule might be done with the aid of locks, on which subject I will speak in detail hereinafter.

If the large river flowed as in Figure 5 from *A via B* to *C*, and if it were necessary to make a cut, *e.g.* from the steep bank *D* up to the steep bank *E*, we may suppose that it will have deep scouring (but for one exception, which I will deal with presently), because the water of the cut *DE* falls as much over a shorter int perc tusschen D en F, alwaer de kreken tot malcander gebrocht syn mette grachten als van D tot G, van G tot H, van I tot K, en diergelijke meer diemen graven mach; Sulx dattet vloet water incommende ande twe gaten C en E, en deurloopende an D, also vervullende 't perck D F, en daer nae 't selve water gedrongen synde mette ebbe weerom te loopen van D na C en E, men sal daer me het boveschreve wantye weeren, en goede schuyring connen maken; ja so sterc dattet gemeenelick nodich sal vallen de houcken an G en H met hoofden te voorsien, om niet te breet wech te spoelen en alsoo de begeerde diepte te verliesen.

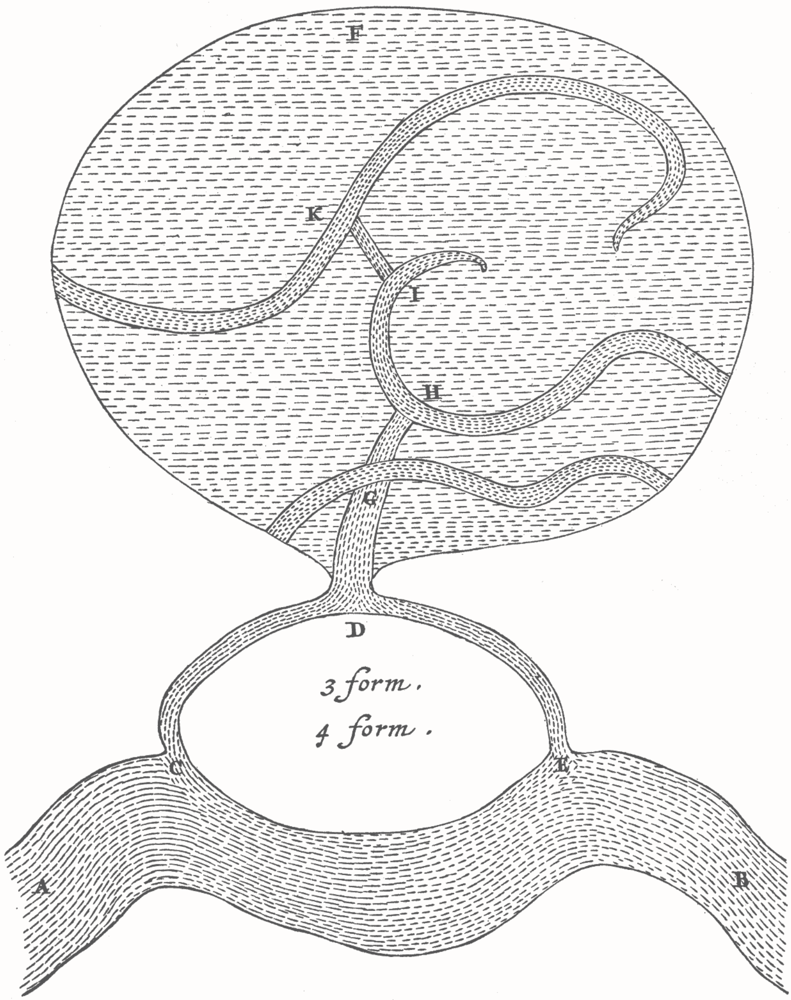
Doch staet te bedenken datmen in desen inham D F geduerigen anwas te verwachten heeft, die metter tijt soodanige schuyring verminderen mocht, waer tegen men voorsien can na gelegentheyt der omstandigen, twelc by gemeene regel deur sluysen geschien mach, daer af ic hier na eygentlic seggen sal.

By aldien de groote stroom liepe gelijc in dees 5 form van A over B na C, en dattet noodich waer daer in een snyding te doen, als vande schoorcant D totte schoorcant E, 't is daer voor te houden datse diepe schuyring crygen soude (ten waer om uytneming daer ic terstont af seggen sal) uyt oirsaec dattet water der deursnyding D E op corter wech so veel vervals heeft als 't groot water D B E op langer, twelc om bekende redenen des voorgaende vertoochs snelder stroom by brengt, maer trager, als de wech van sulke deursnyding langer is, gelijck inde 3 form.

Ic heb hier boven geseyt ten waer om uytneming, welke dusdanich is: By aldiender tusschen D en E so leeg lant waer, dattet, de deursnyding gedaen zijnde, mette vloet onder water quam, de schuyring en soude daer in so diep niet te verwachten staen om bekende oirsaken, te weten dat water in water syn schuyrende cracht verliest: Daerom waert goet in sulken gevalle de opgeworpen aerde der insnyding op beyde zijden so te leggen en voorsien, datter het hooch vloet water niet over en liepe.

Merct noch als voor gemeene regel, dat sulke insnyding behoort te beginnen en eynden an schoorcant gelijc D E in dese 5 form, en niet an strant zijde als de insnyding F G, want het sant of grunt daer willende wesen (om de redenen verclaert int 11 en 12 Voorstel vant 2 Boec des Eertclootschrifs) belet als dorpel het water met overvloet inde deursnyding diep te schuyren.

Tis ooc beter de incomst en uytganc der insnyding geformt te zijn



stretch as the large water *DBE* over a longer one, which for reasons known from the preceding theorem will result in a faster current, but a slower one if the length of such a cut is greater, as in Figure 3. Above I have mentioned an exception, which is the following: If the land between *D* and *E* were so low that, if the cut were made, it would be flooded at high tide, the scouring would not be as deep there as expected, for known reasons, *i.e.* that water in water loses its scouring power. Therefore it would be well in such cases to place the excavated earth of the cut on either side, in such a way, that, at high tide, the water would not overflow it. Note again that, as a general rule, such a cut ought to begin and end on a steep bank, such as *D* and *E* in Figure 5, and not on the low side, such as the cut *FG*, for the sand or gravel wanting to settle there (for reasons explained in Propositions 11 and 12 of the second Book of the *Eertclootschrift*), will form a bar preventing the water from scouring the cut deeply and abundantly.

It is also better if the entrance and the outlet of the cut are formed according na den eysch des grooten strooms gelijc vande boveschreve D E, dan verkeerdelic als de sne H I (hoewelse ooc an schoorcant begint en eynt) alwaer het water des grooten strooms niet so geneycht en is met sulken overvloet te vallen inde mont H, maer wilder meer voorbyloopen. En anden uytganc I valt de grooten stroom tegen de cleene, twelc openbaerlic hindering moet doen.

Maer want ons metter daet meer ander voorbeelden ontmoeten die tegen malcander schynen te stryden, d'een met schuyring, d'ander niet, waer af nochtans d'oirsaec bekent can zijn, en bevonden worden om natuerlicke reden te geschien, soo sal ic eenige van dien beschryven. Tis een gemeene regel dattet revier water sonder ebbe en vloet totte nauste plaetsen ten diepsten is, en totte breeder ondieper, gelijc d'ervaring leert, maer sy lyt int zeewater uytneming, alwaermen dicwils tverkeerde siet gebeuren, want clene creken van 3 of 4 voeten breet en connen op zeestrant naulix sienelicke grippen maken, dan worden mette vloeden so seer geeffent, alsse mette ebbe verdiepen; maer seer groote bree creken als by voorbeelt de Sluysche haven, crygt groote diepte; De oirsaec deser verscheydenheyt is dusdanich: Het water dat uyt de engte van een rivier int wyde valt, en ca daer niet overvloediger incommẽ dant deur de engte gelopen en heeft, en daerõ moeter de stercte syns strooms verminderen: Maer de zee int bree Sluysche gat vallende, en heeft daerom geen gevoelicke vermindering, waer deur de stroom daer so snel is als in enge creken; maer onder evesnelle stromen moeten de breetste diepst vvorden om dese redenen: Laet in dees 6 form A B C de stanteyckening bedien van een bree creke, deursneen met een plat, en DEF van een smalle, vvesende na hun gemene aert boven vvyder dan onder inden bodem (vvelc verschil int dryvende sant meerder is dan in vaste cley, om bekende redenen) sulx dat de zijde D E bycans evevvydich is met A B, en E F met B C: Dit haer gemeene eygenschap zijnde, so en can D E F niet diepen sonder verbreeden, voornamelic in sant en vervolgens sulke bree creken worden dieper dan smalle: Waer toe noch tot merckelic voorbeelt strecken can de groote kreke (op dat ic se so noem) tusschen Vrancrijck en Engelant, welke niet tegenstaende sy seer breet is, nochtans de Duytsche Zee een groote boesem synde daer de Spaensche met haer getye uyt en in schuyrt so is die kreke seer diep.

Doch en is dit geen gemeene regel, dan lijt uytneming, want hoewel

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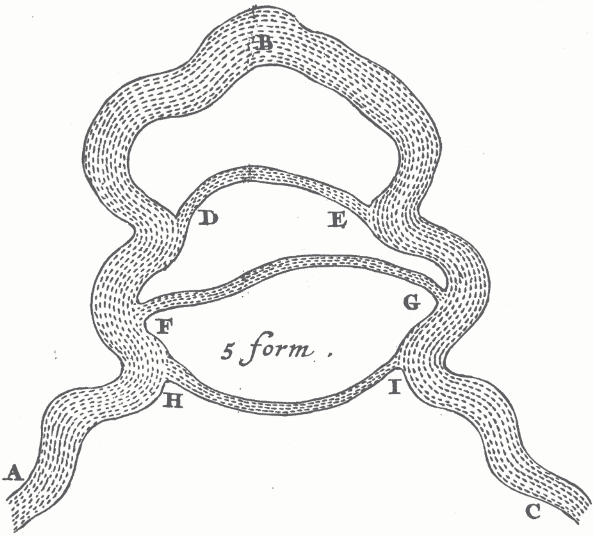

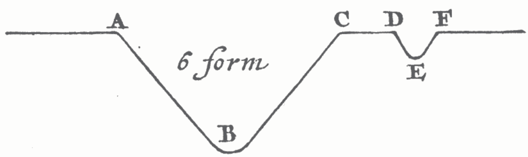

to the requirement of the large river, like the above-described *D* and *E*, rather than the reverse, like the cut *HI* (though it too begins and ends on the high side), where the water of the large river is not so inclined to enter the mouth *H* excessively, but tends to pass it by. And at the outlet *I* the large current collides with the weaker one, which obviously will form an obstacle.

But as we meet in practice more examples which seem to conflict, one with scouring, the other not, but the cause of which can nevertheless be known and be found to spring from natural reasons, I will describe some of them. It is a general rule that non-tidal river-water is deepest in the narrowest places and shallower in wider ones, as experience teaches, but sea-water forms an exception, where one often finds the opposite, for small creeks 3 or 4 feet wide can hardly make a visible impression on the sea-shore, or they are levelled out as much at high tides as they are deepened at low tide; but very wide, large creeks, such as the harbour of Sluys acquire great depth. The cause of these differences is as follows. The water which falls from the narrow channel of a river into wide channels cannot enter there more abundantly than it flowed through the narrow part of the channel, and therefore the strength of its current must diminish. But the sea falling into the wide bay of Sluys thus had no perceptible decrease, so that the current there is as fast as in narrow creeks; but among equally fast currents the widest must become the deepest, for these reasons: In Figure 6 let *ABC* be the section of a wide creek intersected by a plane, and *DEF* that of a narrow one, both according to their general nature being wider at the top than at the bottom de Zee geen gevoelicke vermindering en crijcht, soo can de breetheyt der creke wel oirsaec van ondiepte zijn, te weten wanneer des Waters ontfangplaets diemen hier boesem en colc noemt, achter de incomst van geen genoechsaem grootheyt en is, na den eysch van de crekens breede, wantter dan minder schuyring valt om bekende oirsaken; te weten dat dien boesem vveynich vvaters vervangende haest verhoocht en gevult vvort met slappe stroom.

Om van sulcke verscheydenheden en veranderingen noch breeder voorbeelt te stellen, ic seg aldus: Soder benevens de Sluysche haven gemaect vvierde seven ander, neem ic so breet en diep, al loopende in die verdroncken landen sonder die te vermeerderen deur ander inbrake van dycken: Tis kennelic dat de stroom en diepte vant Sluysche gat dan sou verminderen, uyt oirsaec dat de verdroncken landen deur die ander gaten met vvater terstont vervult zijnde, so souder dan vveyniger deur het Sluysche gat inloopen, en vervolgens minder schuyring en meerder versanding commen.

Merct noch dat alvvaer den boesem daer de zee incomt groot genoech, nochtans te connen gebeuren dat daer de creke naust is de diepste schuyring valt, als in dees sevende form, alvvaer A de zee beteyckent, B de incomst van een creecke aldaer nauvver zijnde als an C, en de boesem groot genoech sy D: Dit so vvesende, de creke is dieper ande nauvver plaets by B dan ande breede by C, vvant hoevvel de zee geen vvater en gebreect, noch merckelicke vermindering en crycht, so en can nochtans int bree by C niet meer waters commen dander deur de enger plaets an B ingeloopen en heeft, twelc an C slapper stroom moet maken als an B. Laet tot breeder verclaring de creec an E noch smalder zijn als an B: Dit so genomen, tsal an B dieper zijn als an C, om dattet an C wyder is, en ooc dieper dan an E, om dattet daer nauwer is. Sulx dat een selve plaets als B, om bekende oirsaken dieper can schuyren dan breder en smalder plaetsen nochtans al in een selve creke.

By de 4 form is geseyt hoemen deur tbehulp vant kolc D F schuyring can maken met ebbe en vloet ter plaets van wantye: Maer met rivieren die altijt een wech loopen, en wil dat so niet vallen: Doch het can tot ettelicke plaetsen op ander wyse angeleyt worden.

Om hier af verclaring te doen, laet A B in dees 8 form een rivier zijn, in tween scheydende an B, en loopende teen deel van B na C, tander

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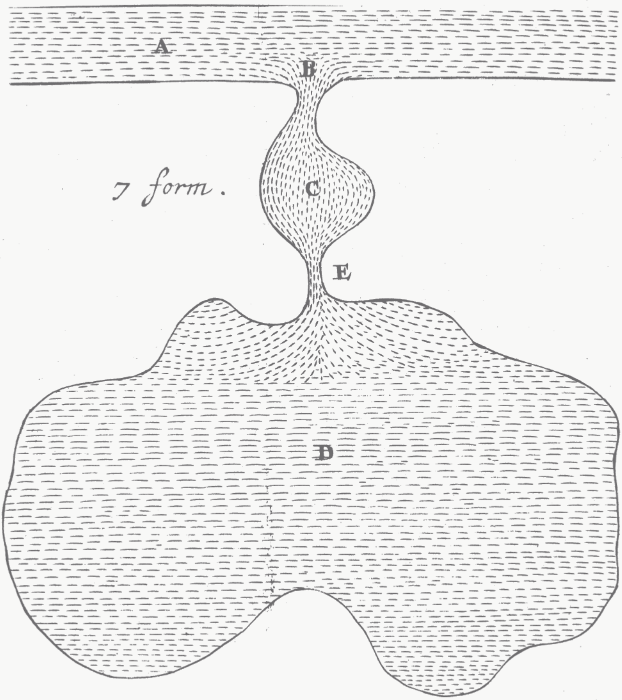
(which difference is greater in quick-sand, than in solid clay, for known reasons), so that the side *DE* is nearly parallel to *AB*, and *EF* to *BC*; this being their general property, *DEF* cannot deepen without widening, especially in sand, and consequently such wide creeks become deeper than narrow ones. As a striking example may be mentioned the large creek between France and England (I call it thus), for although it is very wide, yet the Dutch Sea (North Sea) being a large basin into and out of which the Spanish Sea with its tides scours, this creek (the English Channel) is very deep.

Buth this is no general rule without exceptions, for though the sea receives no appreciable decrease, the width of the creek may be the cause of the shallowness, *viz.* when the reservoir of water, here called *"boezem"* or basin, behind the entrance is not sufficiently large in relation to the width of the creek, for then there will be less scouring, for known reasons, *viz.* that this basin containing little water, quickly silts and fills up with slow currents.

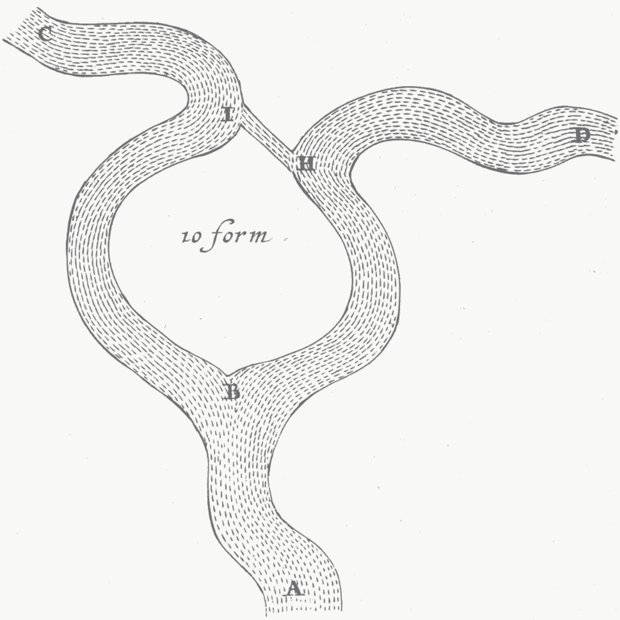
But in order to give further examples of these differences and changes, I say thus. If by the side of the Sluys harbour seven others were made, I say equally wide and deep, all running into the drowned lands without adding to them through more cuts in the dikes, it is obvious that the current and the depth of the Sluys bay would then diminish, because, the drowned lands being filled immediately with water by the other creeks, less water would flow into the Sluys bay and consequently less scouring and more silting-up would result.

Note also that even if the basin into which the sea flows were large enough, it might still happen that where the creek is narrowest the scouring will be deepest, as in Figure 7, where *A* denotes the sea, *B* the entrance of a creek being narrower there than at *C*, and let a sufficiently large basin be at *D*. This being so, the creek is deeper in the narrower place at *B* than in the wide place at *C*, for though the sea has no lack of water and is not appreciably diminished, still no more water can enter into the wider part at *C* than has flown in through the narrower place at *B*, which will cause less current at *C* than at *B*. For a further explanation let the creek be even narrower at *E* than at *B*: Assuming this, it will be deeper at *B* than at *C*, because of the greater width at *C*, and also deeper than at *E*, because it is narrower there. Thus in a place similar to *B*, for known reasons, scouring may be deeper than in wider and narrower places, though in the same creek. In figure 4 we stated how by means of the basin *DF* scouring could be effected with the tides in the place where neap-tide occurred. But this cannot be done with rivers with a constant flow, but it can be brought about in many places in a different way.

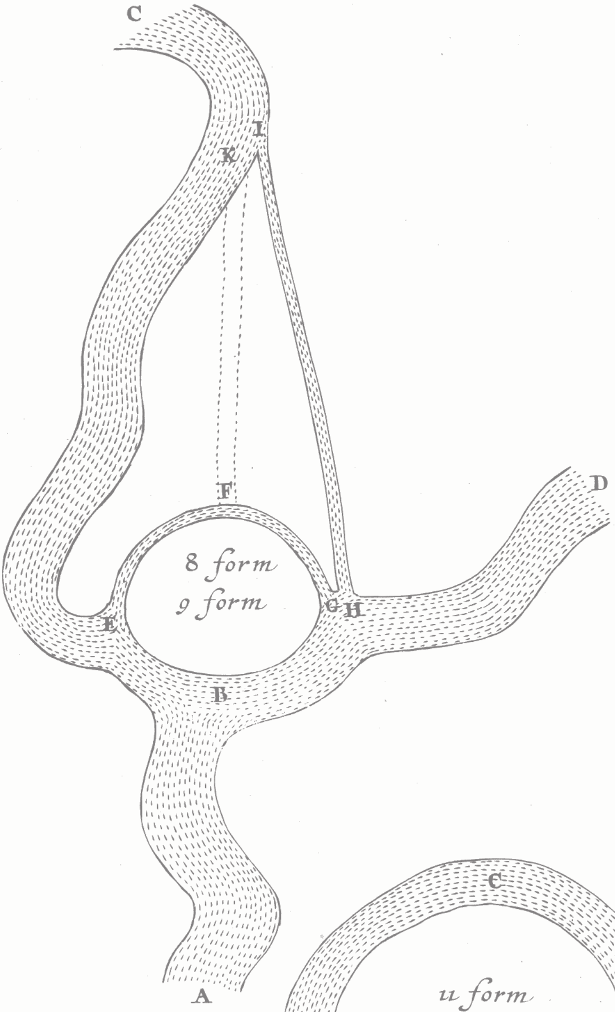
In order to explain this, let *AB* in Figure 8 be a river, dividing in two branches at *B*, one part flowing from *B* to *C*, the other from *B* to *D*. Let us assume at this

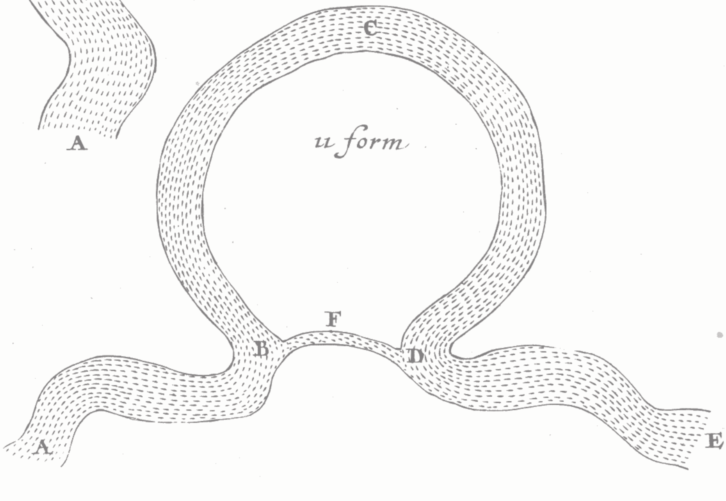


7 form.



10 form


C
I
K
F
D
8 form
9 form
G
H
E
B
A


C
11 form
F
B
D
A
E

van B na D : Genomen nu datmen op dese punt B, een sterckte wil leggen (gelijc tot veel plaetsen om sulke goede gelegentheyt gebeurt) daer de stroom rontom loopt. Tot desen eynde sy een gracht deur gesteken als E F G, vande schoorcant E totte schoorcant G : Maer dese twe wateren an E en G alfo incommende, de stromen sullen ontrent F tegens malcander stoten sonder schuyring te maken , sulx dattet daer sal versanden.

Dit soumen eenichsins meugen voorcommen met deursnyding tot een ander plaets te doen, als vande schoorcant H totte schoorcant I, lopende het water geduerlic een wech van H deur I, doch dat maect in dees form het lant an I met een scherpen hoec , cranc en onbequame form tot versterking.

Maer om nu te verclaren hoemen de schuyring can brengen op de geschicste form deur EFG,so laet A B C D E F G in dese 9 form andermael van beteyckening sijn als inde 8;dan van F sy nu gebrocht de deursnyding totte schoorcant K,doch so, dat de breede des grachts F K , ontrent even zy ande twe breden van E F en G F tsamen , want hier me crycht de gracht E F G over al schuyring,so wel an F als elders.

Ic heb gesien dat in een deursnyding (doch versandende) als E F G der 8 form, de stroom veranderde, loopende somwylen van E over F deur G, somwylen verkeert van G over F deur E : De oirsaec hier af vermoede ic te wesen de wint, deenmael wajende uyt den . . . . waer me het deel B C verhoocht,en B D verleegt, d'andermael uyt den . . . waer me heel verkeert het deel B D verhoocht en B C verleegt, en doende daer na op tselve letten, wiert bevonden dat . . .

Uyt het voorgaende is te verstaen dat de gracht E F G gemaect zijnde, en twater bevonden wierde meer te willen loopen van G over F na E, dan van E over F na G, dattet beter waer de insnyding als F K diemen daer na graeft,uyt te doen commen an schoorcant int deel B C,dan int deel B D : Maer tverkeerde gebeurende, alsdan beter die te doen uytcommen an schoorcant int deel B D.

Merct noch dat de form des lants tusschen de twe rivieren begrepen soodanich mocht wesen , datmen in een rechte deursnyding over al schuyring soude hebben , als in dese 10 form, alwaer A B C D H I van beteyckening is gelijc inde 8 form , maer het lant is so gestelt datmen vande schoorcant H totte schoorcant I mette deursnyding H I over al

schuyring

point *B* a fortress is to be built (as is done in many places because of the favourable situation), encircled by the river. To this end a ditch should be cut, as *EFG*, from the steep bank *E* to the steep bank *G*. The two currents thus entering at *E* and *G*, will meet at *F* without effecting scouring, so that they will cause silting-up.

One might prevent this to some extent by making a cut in a different place, say from the steep bank, the outer bank *H* to the steep bank *I*, the water constantly flowing from *H* to *I*, but then the land at *I* forms an acute angle, weak and incapable of fortification.

In order to explain how to effect scouring in the most suitable way through *EFG*, let *A*, *B*, *C*, *D*, *E*, *F*, *G*, in Figure 9 have the same meaning as in Figure 8; then from *F* the cut should be made to the steep bank *K*, but in such a way, that the width of the ditch *FK* be equal to the two widths of *EF* and *GF* together, for thus one achieves scouring throughout the ditch *EFG*, both at *F* and in other places.

I have seen that in a cut like *EFG* of Figure 8 (but silted-up) the current varied, running sometimes from *E* via *F* to *G*, sometimes conversely, from *G via F* to *E*. The cause I believe to be the wind, at one time blowing from . . . . ., which makes part *BC* higher and *BD* lower, at another time blowing from . . . . ., which conversely makes part *BD* higher and *BC* lower, and when this was observed, it was found that . . . . .

From the above it may be inferred that ditch *EFG* having been built and the water being found to tend to run from *G via F* to *E* rather than from *E via F* to *G*, it would be better to make the cut *FK*, which is dug afterwards, to end on the steep bank in part *BC* rather than in *BD*; but if the opposite should happen, it would be better to make it to end on the steep bank in part *BD*.

Note also that the shape of the land contained between two rivers might be such that a straight cut would give scouring throughout, as in Figure 10, where *A*, *B*, *C*, *D*, *H*, *I* have the same meaning as in Figure 8, but the land is so shaped that, the cut *HI* giving scouring throughout from the steep bank *H* to the steep bank *I*, the land will thus have a shape suitable for fortification.

schuyring hebbende, een lant begrijpt van form bequaem tot versterking.

Tgebeurt oock tot veel plaetsen datmen een bequaem ront stic lants gansch in stroom vervangen can, met een rivier niet in tween gedeelt als als de voorgaende 8, 9 en 10 formen, maer gelijc de volgende 11. alwaer twater genomen wort te loopen van A na B tot C, en voorts over D tot E: Hier in gedaen de deursnyding B F D, vande schoorcant B, totte schoorcant D, so is tusschen B C D F een ront stuc landts vervangen bequaem tot versterckіng rondtom met stroom.

Doch staet hier te anmerken, noodich te syn toe te sien dat de deursnyding B F D niet te breet en schuyr, want om dat haer stroom snelder is dan van B C D deur het voorgaende vertooch, so condet lichtelic gebeuren dat de hele stroom daer deur liepe, en het deel B C D versande sou. Om twelc te voorcommen twe hoofden geleyt mohten worden ande mont B, en de rest van daer over F tot D toe met hoofden crammingh of cribbing so voorsien als de saec vereyscht, om also het deel B F D in syn behoirlicke naute te houden, en twater vant ander groot deel B C D niet te seer te verminderen.

Vande schuyring met sluysen.

Tot hier toe is geseyt vande schuyring met ebbe en vloet, oock met rivieren sonder sluysen. Angaende schuyring met ebbe en vloet sonder rivier daer in te commen, sy en is niet langdurich om dat alle ingesteken landen geduerich verhoogen, en alle creken metter tijt vervullen, sulcx datmen hem dan met sluysen behelpen mach. Maer om van dese stof met beter kennis der oirsaken te handelen wy sullender wat breder af seggen. Eer de anwassende landen tot gorsingen geraken soo synse oneven slijck, daer de daegelicsche gemeene vloeden overcommen, welc water met ebbe vertreckende, het souct de leegte, en maect alsoo veel diepe killen of creken, welke hoese naerder de Zee commen, hoese gemeenlic dieper en breeder worden, uyt oirsaec dat daer meer waters deur loopt als by tander uyterste: Dese slijc so hooch gecommen wesende, datse lang drooch ligt en niet dan met hooge sprincvloeden onder water en comt, sy geraect tot sichteinderscher platheyt, cruyt daer op wassende, twelc men dan gorsing heet, en worden de kreken van achter geduerlic volder en smalder. T gebeurt dat men sulc gorsingen bedijct, It also happens in many places that a suitable round piece of land can be wholly surrounded by water, not by a river divided in two as in the preceding Figures 8, 9, and 10, but as in the next Figure 11, where the water is taken to flow from *A via B* to *C*, and then from *D* to *E*. When here a cut *BFD* is made from the steep bank *B* to the steep bank *D*, *BCDF* embraces a round piece of land, which can readily be fortified and surrounded by water.

However, it is to be noted that it is necessary to see to it that the cut *BFD* does not scour too wide, for as its current is faster than that of *BCD*, according to the preceding theorem, it might easily happen that the entire current should flow through it and *BCD* should silt up. To prevent this, two piers may be built at the mouth *B* and groynes may be provided from *B via F* to *D*, as circumstances require, in order to keep part *BFD* as narrow as it should be and not diminish the current of the other large part *BCD* too much.

On scouring with locks

Up to now we have discussed scouring with the tides or with rivers without locks. Tidal scouring without the aid of an inflowing river is not effective for long, because all the washed lands constantly rise, and all the creeks silt up in course of time, so that one may then make shift with locks. But in order to deal with this matter with better knowledge of the causes, we shall speak about it in more detail. Before the washed lands become saltings, they are uneven mud, washed by the daily ordinary tides, which water, falling at ebb-tide, seeks the low places and thus makes many deep channels or creeks, which, as they approach the sea, usually become deeper and wider, because there more water flows through them than at the other end. When the mud has risen so high that it is dry for long periods and is not submerged except at high spring-tides, it becomes horizontally flat, weeds growing thereon, and we call them saltings, the creeks becoming constantly more silted up and narrower at the further end. Such saltings are sometimes embanked and then they grow no further, which means that in a few years they will be lower than their foreshores, or outer saltings, which have in the meantime grown and risen further. Moreover the lands after having been embanked are drier than before, because the spring-tides can no longer submerge them, consequently they shrink and sink, and that, as some have en daer na en crygense geen anwas meer, waer uyt volcht datse binnen eenige jaren leeger syn dan haer voorlanden, of buyten gorssingen, die daer en tusschen noch meer anwas en verhooging gecregen hebben; Bovendien liggen de landen na haer bedycking drooger dan te voren, om datter de sprincvloeden dan niet op en commen, deur twelc sy incrempen en leegen, en dat so eenige seggen gageslagen te hebben wel . . . . Ooc is te vermoeden dattet gewas der vruchten die jaerlicx afgemaeyt worden, en de vetticheyt uyt d aerde trecken, de stof des lants verminderen en dat verleegen; Hier uyt volcht dat ettelicke bedyćte landen deurgesteken zijnde, met alle gemeene vloeden onder water liggen, en weerom slijckich worden, die nochtans ten tijde haerder bedycking hooger gorsingen waren, en niet dan met sprincvloeden en groote stormen onder water en quamen.

Maer gelijc voor de bedijcking, den anwas toenam, en metter tijt alle creken vervulden, alsoo moet der gelijke ooc gebeuren na de deur steking; vant welc ooc voor Sluys dadelic voorbeelt is, alwaer op . . . . jaren 4 ooc 5 voeten verhoochging des lants gecommen is: Op plaetsen naerder de groote rivieren, als hier te lande de Schelde, Maes en Yssel, bevintmen den anwas op sulken tijt hooger om bekende oirsaken: Sulx dat gelijc wy vooren geseyt hebben, de schuyring met ebbe en vloet sonder rivier daer in vermengt, en is niet langduerich, hoewel men sich in anstaende noot daer me behelpen mach: Maer niet vorder connende, men mach de bestandige wijse met sluysen gebruyken, daer af wy nu seggen sullen.

De schuyring diemen deur ebbe en vloet met sluysen tot noch toe int gemeen gebruyćt heeft, is dusdanich: Laet in dees 12 form A B de Zee beteykenen; in wiens gorsing of bedijćt lant de haven C D comt, en van den houder D E, hebbende een sluyse an D. Dese houder met hoog water gevult wesende, men laet de sluysdeur neervallen, vertoevende daer na tot dattet leegh water is, alsdan wort de sluysdeur opgetrocken, en dat op gehouden water valt vande hoogde in de leegde, de gront wech schuyrende tot buyten de haven en hoofden soser zijn. Doch desen houder D E moet verslemmen, en dat van achter meest, gelijćt hier voren geseyt is mette creken toe te gaen. Tis wel waer, datmender gemeenlic de meeste tocht van binnelantsch regenwater in brengt diemen crijgen can, maer het helpt luttel, gelijc dadelic tot veel plaetsen in Holobserved, as much as . . . . . We may also assume that the crops which are harvested every year and draw the fat from the soil will diminish and lower the soil of the land. Hence it follows that many embanked lands, being cut, are submerged at all ordinary tides and become muddy again, though they were high saltings at the moment of their embankment, and were submerged only at spring-tides and in violent storms.

But as before the embankment the alluvium increased and in course of time all the creeks filled up, this will also happen after the cutting, an example of which is found at Sluys, where in . . . . years the land was raised 4 to 5 feet. In places nearer to the great rivers, such as the Scheldt, the Maas, and the IJssel in this country, one finds an even greater accretion during such a period, for known reasons: As we have said before, tidal scouring without the aid of river-water is not effective for long, though one may do the best one can with it in an emergency. But since it is not possible to do so indefinitely, one may use the permanent method with sluices, which we shall now discuss.

Scouring by means of the tides with the aid of sluices as hitherto commonly used is thus: In Figure 12 let *AB* be the sea, in whose salting or embanked land there is a harbour *CD* and its basin *DE*, having a sluice at *D*. This basin having been filled at high tide, the sluice-door is lowered and left thus till low tide; then the sluice-door is raised and the pent-up water falls from a high to a low level, scouring away the soil outside the harbour and piers, if any. But the basin *DE* is bound to silt up and that at the rear end most, as it has been explained above to occur in the case of creeks. It is true that usually the largest possible amount of rain-water from the inland is introduced into it, but this is of little avail, as appears in practice in many places in Holland and elsewhere, where dredging is effected manually at great cost, and also discomfort as long as this work lasts, because then no ships can berth there and also because one cannot thus obtain sufficient depth for large loaded ships to berth there, but it may serve for the wintering of empty ones.

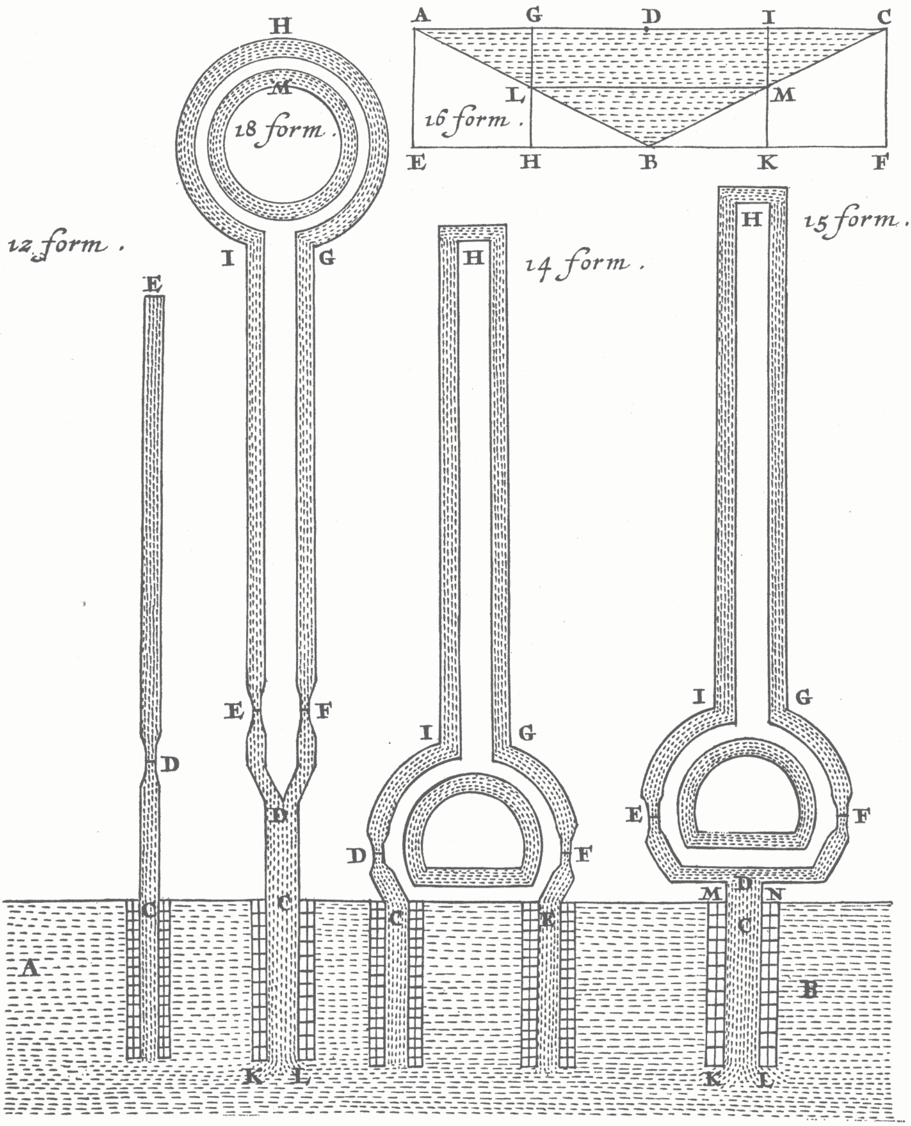
In order to avoid these difficulties and obtain depths in which the largest loaded vessels may sail, one should proceed thus: In Figure 13 let *AB* be the sea, in whose saltings of embanked land the harbour *CD* is built, and thence there is a basin towards *G, via H* and *I* to *E*, with two sluices, one at *E*, the other at *F*. This basin having been filled at high tide through the two sluices *E* and *F*, the sluice-doors are closed and left thus till low-tide. Then the sluice-door *E* is opened and that at *F* remains closed; there will then be scouring through the entire basin from *F* to *G via H* and *I* through the sluice *E* to the sea. But during the next scouring *E* should be kept closed and *F* opened (for if *E* was constantly opened and *F* kept closed, silting-up would take place at *F* and thence through the whole basin) so that the scouring will then take place through the entire basin from *E* to *I via H* and *G* through sluice *F* to the sea. As to scouring invariably with the two sluices simultaneously, this would cause silting-up, starting at *H*; but if the basin is sufficiently deep throughout the two sluices will sometimes be opened simultaneously, as often as deemed suitable, in order to scour the sand in the harbour *DC* deeper, for the two sluices will have greater effect than one alone. For this purpose it would be suitable to build two long piers at *K* and *L* at the harbour, for two important reasons: Firstly, in order that the scouring water may exert its power down to the end of these piers, where the sea becomes deep, which power it would otherwise lose, *i.e.* if the waters would fall into the sea without piers at *C* at the

Hollant en elders blijct, alwaer de verdieping mette lijve gedaen wort, tot grote cost, en ooc ongerief so lang het werc geduert, om datter dan geen schepen liggen en connen, en benevens al dat men can alsoo qualic diepte crijgen om groote geladen schepen in te liggen, maer mach meest dienen tot ledige te verwinteren.

Om dese ongevallen te voorcommen, en diepte te crijgen daer de grootste geladen schepen in meugen varen, men sal aldus doen: Laet in dees 13 form A B de zee beteykenen, in wiens gorsing of bedijct lant de haven C D comt, heur aldaer in tween scheydende, 't een deel na E, 't ander na F, en van daer voort is een houder na G over H en I, weerom commende tot E, met twee sluysen, d'een an E d'ander an F: Desen houder met hoogh water deur beyde de sluysen E, F gevult wesende, men doet die sluysdeuren toe, vertoevende voorts tot dattet leegh water is, en alsdan de sluysdeur E geopent en F toegelaten, soo sal de scheuring commen deur den helen houder van F na G over H en I deur de sluys E na de Z toe. Maer in de naest volgende schuyring salmen E toelaten en F openen (want datmen E geduerich opende en F toehielde, tsoude an F en daer na deur den heelen houder met anwas vervullen) sulx dat de schuyringe dan sal commen deur den heelen houder van E na I over H en G deur de sluys F na de Zee toe: Angaende van altijt met beyde de sluysen tsamen te schuyren, dat soude anwas maken van by H af beginnende; Maer de houder over al diep genoech zijnde, men sal dan somwylen so dicwils alsment oirboir bevint, beyde de sluysen tsamen openen, om de haven D C deur het sant dieper te doen schuyren, want de twee sluysen tseffens daer meer gewelt sullen doen dan een alleen; Tot desen eynde ist ooc goet ande haven twee lange hoofden te leggen als by K en L, om twe merkelicke redenen, d'eene dattet schuyrende water tot ant eynde dier hoofden daer de Zee diepte crijgt, syn schuyrende cracht can doen, diet anders verliesen sou, te weten als twater sonder hoofden by C ande mont der Zee int wijde comt. Ten anderen dat dese diepe kille inden Zeeouver met sulke hoofden beschermt is tegen het invallen des sants deur groote stormen, die geneycht syn het strant te effenen, en alle diepten te vullen.

Genomen nu het perc G H I een Stadt te beteyckenen, soo sietmen daer deur hoemen an Steden gelegen in bedijcte landen verre van Zee, als Brugge, Leyden, Middelburch en diergelijcke, havens en houders

can



mouth of the sea. Secondly, in order that this deep channel in the shore of the sea may be protected by such piers against inflowing sand owing to great storms, which tend to level out the beaches and fill all the deep places.

Assuming that the area *GHI* represents a town, it is thus seen how near towns in embanked lands far from the sea, such as Bruges, Leyden, Middelburg, and can maken met geduerige diepte, ooc tot haer versteercking streckende, want van I tot G een deursnyding gedaen, doch niet te groot, om de redenen van dergelijke verclaert inde 11 form, so is de Stadt met diepte omvangen; Bovendien canmen binnen den houder rontom de stadt noch een gracht met staende water delven als M, gebruyckende d'aerde tusschen beyde de wateren tot bedecte wech, waer me beneffens meerder sterckte het schuyren der bolwerken ooc soude belet zijn. Tot Brugge souden hier toe connen dienen de twe vaerden als soute en versche, die van daer tot Sluys toe gegraven syn en rontom de Stadt twe vesten: Tot Leyden soumen voor d een vaert connen gebruycken den Rijn van daer tot Catwyc streckende, en noch een ander nieuwe daer nevens graven, die bedijckende na 't behooren: Tot Middelborch soumen twe nieuwe vaerden behouven te delven vande Stadt noortwaert deur de duynen, want na de Vlaender cant en soude geen goede uytcomste te verwachten staen, om de grooten anwas die daer seer toeneemt, en alsoo tot ander plaetsen elc na de gelegentheyt. Men soude ooc meugen de twe sluysen E, F, tsamen in een stercke schans vervangen, om daer af altijt meester te blyven.

Maer om nu met een verclaring te doen van schuyring voor Steden inde platte landen niet verre vande Zee als de boveschreven, maer daer angelegen, als Ostende, Calis en diergelijke, so laet in dees 14 form A B de Zee beteyckenen, in wiens gorsing of bedijct lant of duyn de twee havens C D E F gegraven sijn deur de duynen, en van daer voort een houder F G H I D, met twe sluysen, d'een an D, d'ander an F, alwaermen siet goede geduerige schuyring te connen gemaect worde, so wel inden houder als haven, d'eenmael mette sluysen D, d'ander mael met F en de rest alsvooren.

Maer twe sluysen tsamen in een haven schuyrende als inde 13 form, maken beter diepte dan twe elc in een besonder, gelijc in dees 14: doch alsmen sulcx ooc begeerde an Steden op de Zeecant liggende, dat sou meugen gedaen worden als in dees 15 form, alwaer A B C D E F G H I K L van beteykening syn als inde 14. Dan dese twe hoecken M, N en soude niet soo bequaem tot stercte der Stadt vallen, deur dien de vyant daer achter opt Zeestrandt sou connen bedeckt zijn, en bequamelic naerderen.

Merct noch dit: Steden opt Zeestrandt liggende en verder uytsteken the like, harbours and basins can be made of constant depth, also serving to fortify them, for if a cut is made from *I* to *G*, but not too large, for reasons explained in Figure 11, this town will be surrounded by deep waters. Moreover one may dig around the town, within the basin, another ditch with stagnant water, such as *M*, using the earth between the two waters for a covered way, by which means, apart from greater strength, the scouring of the bulwarks would also be prevented. At Bruges for this purpose use might be made of the two canals, the salt-water canal and the fresh-water canal dug from there to Sluys, forming two moats around the town. At Leyden one might use the Rhine from there to Katwijk for one canal and dig another new one by the side of it, embanking it properly. At Middelburg two new canals would be needed from the town northwards through the dunes, for in the direction of Flanders no good outlet could be expected because of the great accretion, which increases there constantly, and similarly in other places according to the situation. It would also be possible to place the two sluices *E* and *F* together inside a strong redoubt, in order to keep them always in possession.

But in order to explain now the scouring in front of towns in flat countries not far from the sea, like those described above, but lying on it, as Ostend, Calais, and the like let *AB* in Figure 14 be the sea, in whose saltings or embanked lands or dunes two harbours *CD* and *EF* have been cut through the dunes, and thence also a basin *FGHID* with two sluices, one at *D* and the other at *F*, where one sees that good constant scouring can be effected both in the basin and in the harbour, now with the sluices *D*, now with *F*, and the rest as above.

But two sluices scouring a harbour together, as in Figure 13, produce better depth than two each in its own harbour, as in Figure 14; but if this were also desired for towns on the sea-shore, this might be done as in Figure 15, where *A, B, C, D, E, F, G, H, I, K, L* have the same meaning as in Figure 14. Then the two corners *M* and *N* would not be so suitable for fortification of the town, because the enemy might be protected behind them on the beach and approach easily.

Note this too: When towns lie on beaches and project beyond the general kende dan de gemene streke vande buytecant der duynen, als Ostende en diergelijke, sy costen veel van onderhouden tegen de geweldige schuyring der zeestroomen daer op vallende: Om tegen sulc ongeval te voorsien, men mocht de uyterste zijde der Stadtwerken leggen inde voorschreve gemene streecke vande buytecant der duynen, want veel meer innewaert liggende is onnodich, om dat de Zee dien inham met sant sou vullen, deur dicnse geneycht is een deurgaende rechtstrant te maken; maer alleenlic tot die streke comende, de Stadtwerken meugen alleeenelic ontrent sulke last lyden als de nevenstaende duynen. Doch valt hier tegen weerom te seggen dat de Stadt meer uytsteeckende, en wel onderhouden synde sonder cost te sparen, beter stercte veroirsaect, om datter meerder diepte of met leeg water smalder strant voor comt. Tis ooc te gelooven dat Ostende en dergelijcke Steden int begin niet alsoo uytstekende gebout en wierden, maer dat de Zee daer na op de duynen gewonnen heeft; En sulke vermindering mochtmen binnen eenige jaren ooc verwachten vande geene diens uytterste werken geleyt waren inde voorschreven gemeene streke vanden buytecant der duynen: Alle welke dingen int anleggen of veranderen van sulke werken souden meugen overdocht worden.

Tot hier toe verclaert zynde de wijse van geduerige schuyring int gemeen, wy sullen nu seggen van ander omstandigẽ dies angaende. Ten eersten, datmen met sluysen veel waters tseffens te loosen, hoe wel het niet so lang en liepe, nochtans de meeste schuyring maect. Ten anderen, vande bequame breetheyt der sluysen en havens tot een voorgestelde diepte. Ten derden, van de form der sluysen die my best bevalt.

Angaende het eersten, eenige meynen dat te groote openheyt van sluysen, voornamelic met cleene houders, totte schuyring achterlic is, om dattet water alsо haest uytgeloopen wesende, haest syn schuyrende werc laet: Maer deur een cleender gat langer lopende, dattet daer om te meer schuyrt: Ten desen eynde trecken eenige sluyswaerders de deur niet heel op, om alsoo het loopen te verlangen. Maer ick en meer ander met my, houdent voor openbaere dwalingen, want gelijc 400 pont gewichts lang in d'een schael eens waegs soude liggen, eerse 500 pont in d'ander op dede gaen, maer met 600 pont die strax doet rysen; Alsoo een cleender water syn uyterste macht der schuyring gedaen hebbende, en sal deur langer loopen dat niet veel meer diepen (want anders, alle regions of the dunes, such as Ostend and the like, their maintenance is expensive because of the powerful scouring of the sea-currents beating against them. In order to cope with such difficulties, the outer ends of the town-walls might be laid in the above-mentioned outer regions of the dunes, for laying them further more inwards is unnecessary, because the sea would fill the bay with sand, since it tends to form a straight continuous beach; but when they only reach as far as these regions, the town-walls will suffer only about the same damage as the adjacent dunes. But one might retort that when the town projects further and is properly maintained, no expense and trouble being spared, it would be stronger, owing to greater depth or a narrower beach at low-tide in front of it. We may also assume that Ostend and other similar towns were not originally built to project thus much, but that the sea afterwards encroached on the dunes. And a similar decrease might also be expected within a few years for those towns whose outer parts have been constructed in the above general region of the dunes. All these things should be considered when such works are constructed or altered.

Having explained up to now the method of constant scouring in general we will now discuss other circumstances. Firstly, that the best scouring can be achieved by sluicing much water at a time, though it would not flow for very long. Secondly, of the proper width of sluices and harbours for a proposed depth. Thirdly, of the form of sluices I like best.

As to the first point, some people believe that too large an opening of the sluices, especially with small basins, is not conducive to scouring, because the water having flown away rapidly, will rapidly stop scouring. But if it flows longer through a smaller opening, the scouring will be more effective. For this reason some sluice-keepers do not raise the sluice-doors altogether, in order to prolong the flow. But I, and others along with me, believe this to be an error, for as a weight of 400 lbs would lie a long time in one scale of a balance before causing 500 lbs in the other to rise, but will at once cause it to rise when the former contains 600 lbs, thus when a small amount of water has done its utmost scouring, it will not scour deeper if it runs longer (for otherwise all rivers constantly rivieren geduerlic loopende, souden oneyndelick altijt dieper en dieper worden, twelc tegen dervaring strijt) Maer een grooter water meer gewelt doende, can hoevvel de tijt des loopens corter waer, noch dieper commen.

De grootste waterloosing dan de meeste schuyring makende, soo volgt hier uyt dat sluysen te cleen wesende, belet van dieping zijn: En nochtans wordense somwylen te groot geleyt, ooc te veel in getale, en daerom niet te meer waters loosende ; maer veroirsakende benevens grooter onnodige costen sulc versandingh, datmense tot syn wille niet sluyten noch gebruycken can. Indervougen dat op de bequame breetheyt der sluyse, oock des havens en houders tot een voorgestelde diepte, gelet dient: twelc wesende het twede punt dat ic voorgenomen hadde te verclaren, segh daer op aldus: Alsmen een nieuvve sluyse legt daer een oude versandende gestaen heeft, tis kennelic datmense naeuvver moet maken, of cleender sooder tvvater te seer in vercropte. Maer te vooren daer geen geweest hebbende, so valter acht te nemen op de omstandige, voornamelic tot dese niewe wyse van werkẽ met dobbel houders niet vervullende, maer die vvy altijt in grote diepte willen houden. Inde ynckel houders vvelke men tot noch toe gebruyct heeft, en is dese trachting na 't meeste voordeel van haer diepte soo noodich niet gevveest, te vvyle sy verslemmen moesten, en somvvylen verdiept vvorden sonder datmen reeckening maecte die houders tot sulke haven te gebruycken als hier tvoornemen is. Om dan tot de saec te commen, laet in dees 16 form den drie houc A B C stantteyckening syn des vvaters eens houders, diens breede op de bovecant ten tyde van hooch vvater is A C, viervoudich ande grootste diepte van D tottet kiel B.

Soomen hier in een sluyse leyde als A E F C commende B int middel van E F, en hebbende de vvyte vande bovecant des houders, Tis openbaer datse versanden soude, sonder te connen gesllooten worden: Want nadien het sant langs den gantschen houder geneycht is hem te setten gelijc beteykent vvort mette tvve driehoucken A B E, C B F, so salt hem ooc alsoo setten binnen de sluyse, sonder datmen de deuren sal connen sluyten: Twelck gebeurt uyt oirsaec dattet vierhouckigh gat der sluys A E F C, , grooter is dan het driehouckig gat des houders A B C, te vveten 'teen dobbel an 'tander. En genomen datter sulc ongeval van onbruyckbaer te syn niet en vvaer, soo sietmen noch dat 't gene het gat der flowing would become deeper and deeper indefinitely, which is contrary to experience). But a larger mass of water exerting more power, even though the duration of the flow were shorter, may scour deeper still.

The greatest drainage thus resulting in the deepest scouring, it follows that sluices which are too small make scouring impossible. And yet they are sometimes made too large, or too many in number, though they do not therefore drain more water, but, apart from unnecessary cost, cause such silting up, that one can no longer close or use them as required. Therefore attention should be paid to the proper width of the sluices, and also of the harbour and the basin at the desired depth. This being the second point I had intended to explain, I say as follows: If a new sluice is built in a place where there was an old silted-up one, it is obvious that it should be made narrower or smaller if the water heaped up too much in it. But if there was none there before, one should pay attention to the circumstances, notably with regard to this new method of working with double non-silting basins, which we always want to keep at great depth. In single basins, as used up to now, this effort to achieve the greatest advantage as to their depth was not so necessary, since they would silt up and sometimes be dredged, without the intention of using these basins for such harbours as we here intend. Coming to the point, in Figure 16 let the triangle *ABC* be the section of water of a basin, whose width at the top at high tide is *AC*, being four times the greatest depth from *D* to *B*.

If here a sluice *AEFC* were built, *B* being the middle of *EF*, and the sluice having the width of the top of the basin, it is obvious that it would silt up, and could not be closed. For as the sand along the entire basin tends to settle as indicated by the two triangles *ABE* and *CBF*, it will settle in the same way inside the sluice, while the doors cannot be closed. This is due to the fact that the rectangular hole of the sluice *AEFC* is larger than the triangular hole of the basin *ABC*, the former being twice as great as the latter. Even if this difficulty of uselessness did not occur, one yet sees that the amount by which the hole of the sluices exceeds the other does not promote the scouring for through the basin der sluys groter is als tander, totte schuyring niet en voordert, want deur den houder en can daerom niet meer loopen dan 't gat des houders dats de driehouc A B C groot en is. De breede dan der sluys moetende nauwer syn dan de bovecant vant water des houders, soo laet getrocken worden de twee linien G H, I K, evewydich met A E, sulx dat A C, in vier even stucken gedeelt is, mette punten G, D, I, en den vierhouc G H K I genomen worden voor sluys: Dit soo zynde, tgat der selve is even ant gat A B C. Doch om meerder versekertheyt tegen versanding, soo vereyscht de reden datmen 't gat der sluys wat kleender neem als tander, want even synde opde bovecant A C berekent, soo salt groter vallen op leger water berekent, als neem ic op K L, want hoewel de sluysens vierhouc G H K I, even is met des houders driehouc A B C, soo is nochtans de sluysens vierhouc L H K M, grooter dan des houders driehouc L B M. Laet dan dit verschil sulx wesen dat G I het derdendeel sy van A C, waer mede rede dergaten op de bovecant A C bereeckent, comt van 3 tot 2. Gedenct noch dattet gat der sluyse te kleen te maken achterlic soude zijn, om dat weynich waters deur de nauwe sluyse in een seer breet commende, luttel gewelt can doen.

Dit boveschreven is genomen op AB, B C bycans als rechte linien te commen, gelijc des sants gemene genegentheyt is; maer in cley staen de canten steylder, gelijc ooc doen die met kribbeng en rijswerc gemaect en onderhouden worden, alwaermen int veroirdenen vande reden deser twe gaten, toesicht op sou meugen nemen.

Te gedencken dat hier moeten beschreven worden ettelic voorbeelden vande redens der gaten en ander omstandigen, die ick van verscheyden plaetsen noch besichtigen moet.

Nu rester noch het derde voorgenomen punt,

Vande form der Sluysen die my best bevalt.

Dese sijn by ons Vader beschreven in syn Nieuwe manier van Sterctebou deur spilsluysen.

Int voorgaende beschreven hebbende de schuring sonder sluysen met louter ebbe en vloet, ooc deur rivieren, daer na met sluysen, ic sal daer no more water can thus flow than is allowed by the size of the hole of the basin, *i.e.* the triangle *ABC.* The width of the sluice thus having to be narrower than the top of the water in the basin, let the two lines *GH* and *IK* be drawn parallel to *AE,* in such a way that *AC* is divided in four equal parts, by the points *G*, *D*, and *I*, and let the rectangle *GHKI* be taken as the sluice: This being so the opening is equal to the hole *ABC*. But in order to obtain greater security against silting-up logic demands that the opening of the sluice be taken somewhat smaller than the other, for if it is equal in relation to *AC*, it will be larger at low-tide, such as, say, at *KL*, for though the rectangle *GHKI* of the sluice is equal to the triangle *ABC* of the basin, still the sluice's rectangle *LHKM* is larger than the basin's triangle *LBM.* Let this difference be such that *GI* is one third of *AC,* on the basis of which the ratio of the holes, referred to the top *AC*, becomes 3:2. Also remember that making the opening of the sluice too small would be disadvantageous, because little water flowing from the narrow sluice into wide water will produce little power. The above has assumed *AB* and *BC* to be nearly straight lines, as will be the tendency of sand; but in clay the slopes are steeper, as are also those reinforced with groynes and fascine-work, which one might take into account when determining the ratio of the two openings.

(Remember to describe here several examples of the ratios of the openings and other factors, which I still have to inspect in several places.)

Now there remains the third point we intended to discuss.

OF THE FORM OF SLUICES I LIKE BEST

(These have been described by our father in his *New Method of Fortification by means of Pivotted Sluice-Locks).*

Having described in the foregoing pages the scouring without sluices, with the aid of the tides alone, also with rivers, and then with sluices, I will now af noch wat gemengt seggen, met verlijcking der voordeelen van d'een en d'ander.

Schuyring met louter ebbe en vloet in besloten dobbel houders, sonder rivieren daer in te commen, geven meer geriefs, en syn beter havens dan met rivieren in dit ansien.

Ten eersten, datse geen schadelicke ysganc onder worpen en syn gelijc de rivieren, maer meugen alle schepen daer in vryelic verwinteren, twelc geen cleen gerief noch voordeel en is, wantmen tot dien eynde in Hollant groote moeyte en cost doet op verscheyden plaetsen, onder welke de nieuwe haven te Delfshave een der voornaemste is daer swinters veel harincbuysen bevryt liggen; maer alsser dobbel houders gemaect waren als voren, ic meyn datter niet alleen ledige clene schepen en sou connen liggen, maer ooc geladen soo groot alsser deur de Maes commen, en dat sonder cost en tongerief der verdieping te behouven.

Ten tweden, dobbel houders deur het zeestrant schuyrende, en brengen geen sant aende haven dorpel gelijc de rivieren wel doen (hoe die dorpels voor alle havens wassen, is geseyt int 12 Voorstel vant 2 Bouc des Eertclootschrifts) want den besloten dobbel houder heeft alleenelic te schuyren deur het strant des ouvers, om dat open te houden, daer de rivieren bovendien, noch moeten overwinnen het sant datse self overvloedelic afbrengen, en ten eynde van crancke santstroom op de haven dorpels laten vallen: Ooc comter groote verandering deur den anwas der eylanden die inde mont der grote rivieren gemeenlic gebeuren, sulcx dat veel groote Coopsteden daer deur vergaen zyn: Maer schuyring deurt Zeestrant sonder grote rivieren daer ontrent, en is sulcken anwas niet onderworpen, gelijc overal de ervaring leert.

Ten derden, soumen d'een zyde des dobbel houders met haer sluysen meugen gebruycken tot incommende schepen, d'ander tot uytvarende, sonder malcander t'ontmoeten, twelc in de groote Zeesteden dickwils geen cleene swaricheyt en heeft.

Ten vierden, soder in d'een sluys eenige vermaking valt, sulx datmense een Somer lanc niet gebruycken en can, men mach daerentusschen d'ander besigen: twelc in havens met alleenlic een sluys so niet vallen en wil, streckende tot groote verhindering des coophandels.

Hier tegens syn de rivieren gemaecte havens sonder cost: Bovendien de Coopsteden gelegen an groote bevaerlicke rivieren, als hier de

Schelde,

discuss these together and compare the advantages of one as well as the other.

Scouring with the aid of the tides alone, in closed double basins, into which no rivers flow, is more convenient and gives better harbours, than with rivers, in view of this: Firstly, they are not subject to harmful ice-drifts like rivers, but all ships may winter there freely, which is no small convenience and advantage, for much money and trouble is spent for this purpose in Holland in several places, among which the new harbour of Delfshaven is one of the most important, in which many herring-boats lie protected in winter, but if double basins had been made, as above, not only empty small ships might anchor there, but also loaded ones as large as pass through the Maas, and that without the expense and inconvenience of keeping up the depth.

Secondly, double basins scouring through the beach do not deposit sand on the harbour bar, as some rivers do (how such bars in front of all harbours tend to grow has been told in the 12th proposition of the second Book of the *Eertclootschrift*), for the enclosed double basin has to scour only through the beach in order to keep it open, whilst rivers also have to overrun the sand they themselves bring along plentifully and at the end of a weak current drop at the harbour bars: Great changes also take place owing to the accretion of the islands which usually arise in the mouths of large rivers, with such results that many large merchant towns have decayed through this. But scouring through the sea-beach without large rivers in the neighbourhood is not subject to such accretion, as experience teaches everywhere.

Thirdly, one part of the double basin and its locks might be used for incoming ships, the other for outgoing ships, without their meeting, which often causes great difficulties in large sea-side towns.

Fourthly, if one set of locks has to be rebuilt and cannot be used during the whole summer, the other can be used, which cannot be done in a harbour with one pair of locks, which impedes trade considerably.

In comparison with this, rivers are ready-made harbours and cost nothing; moreover the merchant towns situated on large navigable rivers, such as the

Schelde, Maes en Rhyn, hebben tvoordeel van dobbel handel, so wel verre te lantwaert in, als over zee; En hoewelmen van Steden met houders inde open zee schuyrende, als Duynkerken en diergelijcke, tot die ander rivieren over zee commen can, nochtans en geschiet dat niet sonder ongerief, als van dicwils tot syn wille uyt de haven niet te connen raken, deur storm en tegenwint, daermen anders dagelix voort can commen: Boven dien dat de schepen gemaeckt tot riviervaert, niet bequaem over zee en zijn; Doch can de gelegentheyt tot sommige plaetsen sulx zijn, datmen vande besloten dobbel houder binnens lants mach commen inde rivier deur een verlaet, gelijcker in Hollant veel zijn: Als by voorbeelt soder tusschen Leyden en Catwijc nevens den Rhyn noch een vaert gedolven waer, tsamen een dobbel houder makende, incommende deur een haven inde open zee, op de wyse als geseyt is by de 13, 14 en 15 formen, men soude uyt dien houder binnens lants deurt verlaet na der Gouwe meugen inde Yssel commen, van daer inde Maes: Dit seg ic alleenlic by voorbeelt, want alsmen alles nae syn wille veroirdende, sonder hindernis der nabueren, men sou bequamer binnelantsche deurvaert connen maken.

Merckt noch een ander gedaente van schuyring, te weten datmen deurt behulp van rivierkens diemen lichtelic verleyden can, met cleene cost groote santbergen can wechschuyren, die altemet by stercte liggen tot haer groot achterdeel, en dat met kribbing en rijshoofdekens te leggen daer men twater me anden voet der bergen stiert.

Hier af is dadelic prouf te Lingen geschiet, alwaer syn *Vorstelicke Genade* also heeft doen wechschuyren veel hinderlicke bergen die eerst ande cant des grachts lagen, daert nu over de 1000 voeten plat landt is, en dat alleenelic op . . . Iaren gecost hebbende niet over de . . . guldens; En vielen die stucken der bergen soo groot af, dat menichte der Burgerye aldaer tselve met verwonderen dicwils quamen besien.

Noch een ander sake de schuyring angaende mach hier by gedacht gestelt worden, te weten dat veel schepen in een haven liggende die te seer verstoppende, de schuyring beletten: Men bevint ooc dadelic daer sulcx gebeurt, datter onder de schepen een meerder diepte comt dander te vooren was, want het water daer moetende deur een cleender gat loopen, doetter meerder gewelt. Om sulcx te voorcommen mochtmen oirden stellen, dat de schepen inden houder of haven niet nevens mal-

Scheldt, the Maas and the Rhine, have the advantage of double trade, both far inland and overseas. And though one can reach such a river by sea from towns with basins scouring into the sea, such as Dunkirk and the like, this is not effected without difficulty; thus it will often not be possible to leave the harbour because of storm or adverse winds, whilst elsewhere this can be done daily. Furthermore ships built for inland navigation are not fit to put to sea. However, in certain places the circumstances may be such that from the double basin one may pass inland into the river via a navigation weir, of which there are many in Holland. Thus, for example, if between Leiden and Katwijk a canal had been cut by the side of the Rhine thus making a double basin, to be entered via a harbour on the open sea, as explained in Figures 13, 14 and 15, from this basin one would be able to pass inland into the IJssel through the navigation-weir in the Gouwe, and thence into the Maas. This I say only by the way of example, for if one could arrange everything according to one's own wishes, without being prevented by neighbours, one might effect more efficient inland navigation.

Note also another form of scouring, *i.e.* that by means of small rivers, which can easily be diverted, it is possible to scour away at little expense large mounds of sand, which often lie near fortresses to their great disadvantage, and that by laying groynes and fascine-work, by which the water can be directed to the foot of these mounds.

This has been tested in practice at Lingen, where His Princely Grace in this way had many troublesome mounds scoured away, which were first on the other side of the ditch, where there is now more than 1000 feet of flat country, this having cost no more than .... guilders in .... years. And such large lumps of the mounds fell off, that a great many of the citizens often came to look at it with astonishment.

Yet another aspect of scouring should here be considered, *viz.* that if a large number of ships lie in a harbour, thus blocking it, they prevent the scouring. It is also found in practice, where this happens, that underneath the ships greater cander, maer d'een achter d'ander inde langde geleyt wierden. Of soomen ergens meerder diepte begeerde, op dat eenige seer groote geladen schepen met leeg water geen lant en raecten, daer mochtmense bevelen nevens malcander te leggen.

Noch mach hier dit bygevoucht worden tot dese stof der schuyring ooc behoorende:

Eermen int . . Jaer de Zype bedijcte, soo vergaerde het sant langs de zeeouver met cleene heuvelkens, maer wantse niet hooch genoech en waren, het water der groote noortwestsche stormen isser somwylen overgeloopen, heeftse wechgeschuyrt en't zant verre achterwaert op de gorsing gebrocht, sulx datse ten deele daer af bedect wiert. Maer den dijc daer na geleyt zynde, en het hooch water der stormen daer niet deur noch overloopende, ten conde het sant niet wech schuyren, dan vergaerde deur de stercke drooge winden voor den dijc tot hoge duynen; maer so tselve lant onbedijct gebleven waer, daer hadder uyt te verwachten geweest datter metter tijt van selfs brede duynen souden gecommen hebben, van achter allenx anwassende tot ant strant toe, aldaer hooger wordende, gelijct voor Hollant vander Heyde af tot Pette toe gestelt is, alwaer sulke dijckage niet en had gedaen geweest.

Dit vermaen doet my gedencken den dijc en duynen langs de Vlaemsche zeestrant, van gedaente wesende als die der Zype, te weten de duynen lanc en smal, den dijc daer achter an gerakende, twelc met reden vermoen geeft de selve alsoo ooc haren oirspronc genomen te hebben, te weten dat doen de zee met haer sprinckvloeden over de Vlaemsche gorsing spoelde, den dyc geleyt wiert eerder waterschuttende duynen waren, ooc daer naer de duynen angewassen zijn, en niet datter een dyc achter de duynen geleyt wiert als veel luyden meynen, want datse sonder dijck daer so cort en hooch soude vergaert hebben, sonder allenx met groote stormen wech te schuyren, en over de gorsing ongeregelt te verspreyden, tsoude tegen de boveschreven gemeene aert van sulke schuyring en anwas stryden. Ten anderen, dat de menschen de cost souden doen van een dijc te leggen achter duynen daermen de zee nimmermeer siet deur schuyren, sulx schijnt onnoodich, en wort selden gesien.

D'oirsaec dat veel gorsingen langs sandige Zeestranden met geen sant bedect en worden, is dat tot sulke plaetsen het strant cort synde en de diepte der Zee by wesende alle getye onder water comt en daerom nat blijft sonder gelijc het drooch tot stuyving en ophooping te geraken.

TWE-depth arises than there was before, for since the water is there forced through a smaller opening it exerts greater power. In order to prevent this it might be ordained that in the basin of the harbour the ships should not anchor side by side, but one behind the other, lengthwise. Or if greater depth were desired somewhere in order that certain very large loaded ships might anchor at low tide without running aground, they might be ordered to anchor side by side.

The following should be added, as pertaining to the subject of scouring. Before, in the year [1]). . . ., *de Zijpe* was embanked, the sand accumulated along the beach in small mounds, but because they were not high enough, the floods caused by the great north-westerly storms sometimes flowed over them, scouring them away and the sand was deposited far inland on to the saltings, so that they became partly covered with it. But when the dike had later been built, and the floods caused by the storms could not pass through or across it, they could not scour away the sand, but it then accumulated as high dunes in front of the dike owing to the strong dry winds; but if the land had remained unembanked, it might have been expected from this that in the course of time broad dunes would have formed automatically, growing at the rear up to the beach, becoming higher there, such as in front of Holland from Terheide up to Petten, where such dikes have never been built.

This discussion makes me think of the dike and dunes along the Flemish beach, which resemble those of Zijpe, *i.e.* long and narrow dunes, behind them the dike, which logically leads to the supposition that they also arose in the same way, *i.e.* that when the sea with its spring-tides washed over the Flemish saltings, the dike was built before there were dunes, forming a protection against the water and also that the dunes grew afterwards, and not that a dike was laid behind the dunes, as many people believe, for that they should have accumulated so high and so short without a dike, without being gradually scoured away by large storms and spread irregularly over the saltings, would be contrary to the above general nature of scouring and accretion. Secondly, it seems unnecessary and is rarely seen that people go to the expense of building a dike behind dunes, through which the sea is never seen to scour. The reason why many saltings along sandy beaches are not covered with sand is that in such places the beach, being narrow while the deep sea is nearby, is submerged at all tides and thus remains wet and is not like dry sand subject to being blown away and accumulating.

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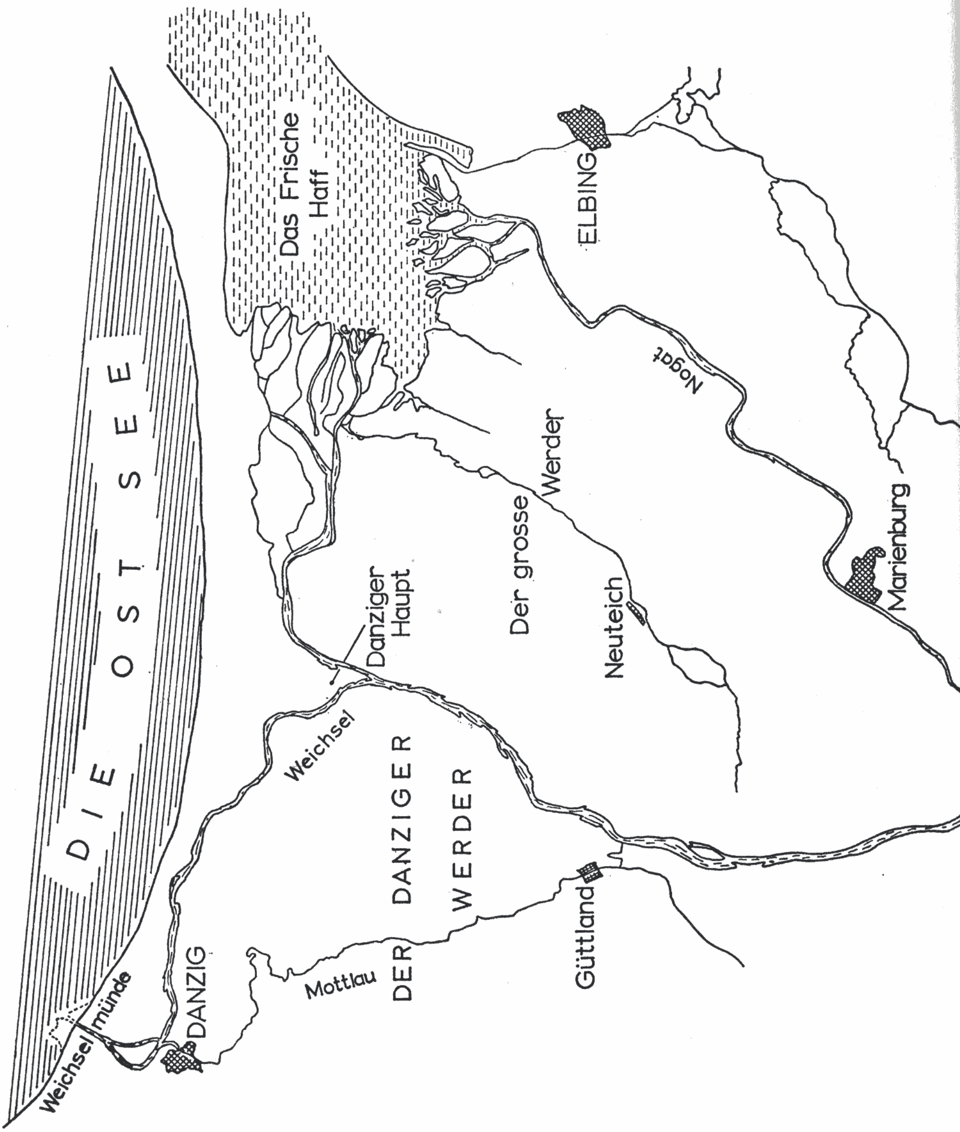
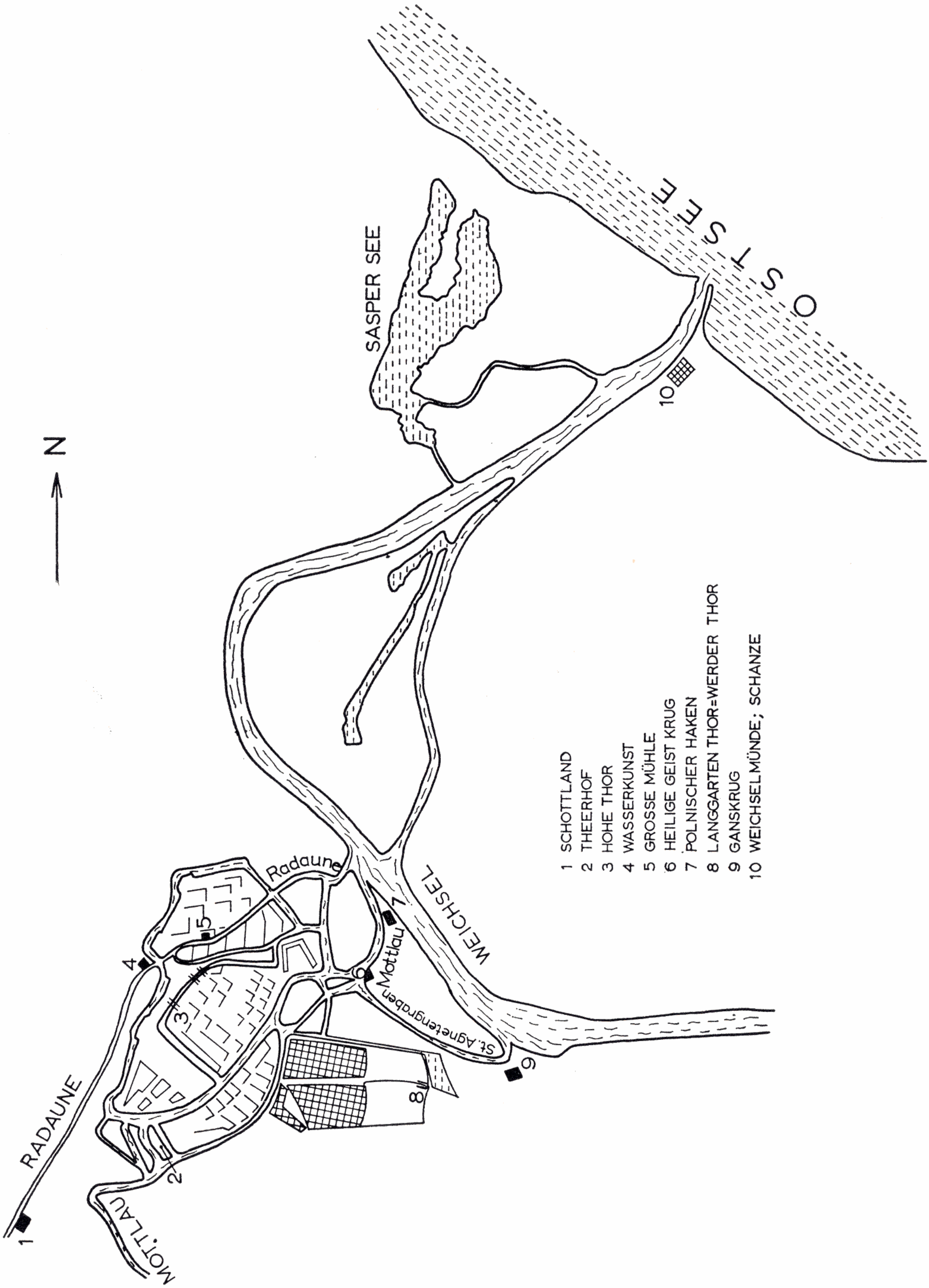
[1]) In 1957. Zijpe is a village of the province of North Holland, near Schagen.



Danzig and the Danziger Werder in 1577.

After G. Köhler, Geschichte der Festungen Danzig und Weichselmünde. (Breslau, 1893). - Erster Teil, Tafel XI (Simplified).



Danzig and Weichselmünde in 1577.

After G. Köhler, Geschichte der Festungen Danzig und Weichselmünde. Erster Teil. - Compiled from the maps X and XIII.

TWEDE ONDERSCHEYT

Vant 10 Boec.

Van sommige vonden onses Vaders tot verbetering van Steden en Landen deur Havens en waterschuering.

VOOR DANTZIC.

Verclaringe van Simon Stevin anden E: Raedt der Keyserlicke Stadt Dantzic, van seker syne inventien tot dienst der Stadt streckende.

TEn eersten, hoemen de santplate ande Polensche haecken wassende wech can doen, also datse daer niet meer anwassen en sal.

Ten anderen, hoe datmen te wege can brengen dat Stagneten vaert eens gediept zijnde, daer na niet meer versanden noch anwassen sal; dat sgelijx ooc niet doen en sal de Montlau vande Polensche haecken af tot de Heylichgeestcrouch toe.

Ten derden, hoemen de diepinge van boven can verbeteren bequamer dan sy te vooren geweest heeft, sonder datter die van Margenburch ofte Elbing yet tegen te seggen hebben.

Ten vierden, hoemen de Montlau inde Stadt ende voort de heele vaert deur veel dieper can maken.

Ten vijfden, hoemen de haven ter Munde tot een geduerige diepte brengen can.

Ten sesten, hoemen can maken dat de waterconst buyten het hooch door, niet meer vervriesen en sal.

Welc voorschreve inventien hy Stevin metten E: Raet overcommen is te verclaren, op sulke voorwaerde datse niet int werc gestelt en sullen worden int geheel noch ten deele, sonder dat den E: Raet an hem Stevin of an sijn volmachtige daer af eerst vernoegen sal.

1 ARTIKEL; Hoemen de santplate ande Polensche haecken wassende wech can doen, alsoo datse daer niet meer anwassen en sal.

De santplate wast ande Polensche haecken deur twe bekende oirsaken:

CHAPTER 2 OF BOOK 10

Of some inventions of our father's for the improvement of towns and lands with the aid of harbours and water scouring.

FOR DANZIG

Declaration of Simon Stevin to the Noble Council of the Imperial City of Danzig about certain of his inventions for the use of the city.

Firstly, how the sandbank growing at the Polish Haken can be scoured away, in such a manner that it will not grow again.

Secondly, how one can ensure that the St. Agnes Channel, once it has been scoured, will not silt up or grow again, and that neither will the Mottlau from the Polish Haken up to Heiliger Geist Krug.

Thirdly, how the above dredging can be improved as compared with what it was before without those of Marienburg or Elbing being able to object to it.

Fourthly, how the Mottlau can be deepened in the city and over its entire course.

Fifthly, how the harbour of Weichselmünde can be given constant depth.

Sixthly, how the waterworks outside the Hohe Tor can be kept free from freezing up.

Which above inventions he, Stevin, has agreed with the Noble Council to explain, on condition, that they shall not be put in practice either completely or partly unless the Noble Council shall have made a payement to him, Stevin, or his deputy.

SECTION 1.

How the sandbank growing at the Polish Haken can be scoured away, in such a manner that it will not grow again.

The sandbank at the Polish Haken grows owing to two known causes: Firstly ken : Ten eersten; van wegen het hooft, want achter sulke hoofden sant te wassen, is een gemeenen aert van al dergelijcke hoofden : Ten anderen, deur dien de Rodoen aldaer inde Wyssel commende, loopt met haer stroom te seer tegen den stroom vande Wyssel, twelc dat sant daer noch overvloediger doet vergaren.

Om hier tegen te voorsien, so salmen het eynde vande Rodoen verdelven, also dattet water scheutich loope over die plate, gelijc dese by gevoechde figuer anwyst.

Dit so wesende, men sal ant eynde vande Rodoen stellen twe of drie breede optreckende sluysdeuren, welcke toe zijnde, het water sal binnen inde Rodoen wel vijf of ses voeten connen hooger commen dan het buytewater inde Wyssel, sonder dat de Corenmolen inde Stadt sal verhindert zijn te malen.

Tgebruyc hier af sal (gelijc in Hollant en Zeelant seer gemeen is) dusdanich wesen: Die sluysdeuren toe zijnde, ende het water inde Rodoen so hooge gebrocht wesende alst commen can, so salmen die sluysdeuren tseffen op winden, ende het water vallende met een soo groote menichte ende van soo hooge, sal die santplate verschuyren.

Dese schuyringe salmen so dicwils daer na doen, als de ervaringe leeren sal noodich te wesen.

2 ARTIKEL; Hoe datmen te wege can brengen dat Stagnetenvaert eens gediept zijnde, daer nae niet meer versanden noch anwassen en sal. Dat sgelijx ooc niet doen en sal de Montlau vande Polensche haecken af tot de Heylichgeestcrouch toe.

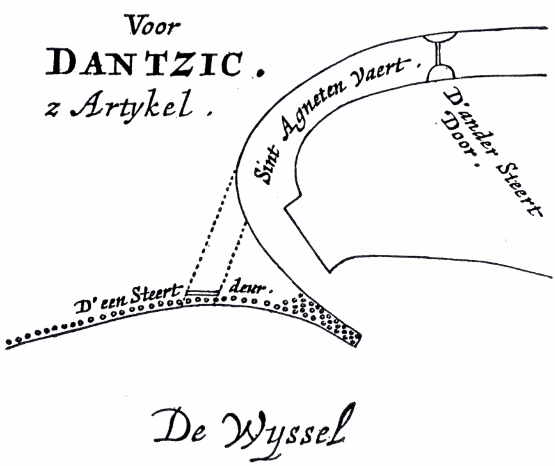
T'is kennelic dat voor den houten dam van Stagnetenvaert een groote diepte is, wel van (soo sy seggen) vier of vijf vademen, maer achter het hooft dat voor de vaert geleyt is, daer versandet nae den gemeenen aert van dergelijcke hoofden, daerom salmen de vaert an dat hooft toedammen ende graven na de diepte toe, geliijc dese bygevoechde figuer anwijst.

Daer na salmen leggen twe steertdeuren, d'een voor by de Wyssel, d'ander daer achter, vervatende tusschen beyden een colc daer thien of twaelf camen, of soo veel noodich sal bevonden worden, tseffens in connen because of the pier, for it is a general property of such piers that sand accumulates behind such piers. Secondly, because the Radaune, joining the Weichsel there, runs with its current up against that of the Weichsel, which causes the sand to accumulate there even more abundantly.

In order to cope with this, the mouth of the Radaune should be diverted in such a way that the water will wash the sandbank amply, as is shown in the annexed Figure. This being so, at the mouth of the Radaune two or three broad vertical sluices should be built, and when they are closed the water in the Radaune will be able to rise some five or six feet above that of the Weichsel, without the corn-mill in the town being prevented from operating. The application should now be (as is very common in Holland and Zeeland) as follows: The doors being closed and the water in the Radaune raised as much as possible, the doors should be raised simultaneously, and the water falling in so large a quantity from such a height will scour the sandbank away. This scouring should be effected as often as experience teaches it to be necessary.

SECTION 2.

How one can ensure that the St. Agnes Channel (St. Agneten Graben), once it has been scoured, will not silt up or grow again, and that neither will the Mottlau, from the Polish Haken up to Heiliger Geist Krug.



It is obvious that there is great depth in front of the wooden dam of the St. Agnes Channel, as much (so they say) as four or five fathoms, but behind the pier there built in the channel, sand accumulates according to the general nature of such piers; therefore the channel should be dammed at that pier and excavated to a great depth, as the annexed Figure shows:

Then two swing gates should be built, one on the Weichsel front, the other behind it, enclosing a chamber in which ten or twelve vessels, or as many as shall nen leggen. De selve twe deuren sullen open gaen tegen de Wyssel, ende sluyten elc met een slot, waer af yemant daer ontrent wonende de sleutel sal hebben.

Tgebruyc hier af sal dusdanich wesen: Commende eenige camen, bordingen, schepen of hout, men sal d'eerste deure open doen, ende sullen alle commen liggen int colc; daer zijnde, men sal die deur wederom toedoen en d'ander deur open, ende sullen alsoo na de Stadt varen, en desgelijx sullense vande Stadt weder daer uyt commen.

Dit soo wesende, 't is openbaer dat die vaert eens gediept zijnde, en mettet gene daer uyt comt de dammen gehoocht, daer naer niet en sal versanden noch anwassen, want het dic sandich water der Wyssel en sal daer deur nimmermeer loopen. Boven dien alst Wysselwater suyver en claer is, soo salmen beyde de steertdeuren open stellen en laten twater deur de vaert loopen, want sulc suyver water en sal geen anwas maer noch dieper schuyring maken, gelijc wy dat int volgende 3 artijkel noch breder verclaren sullen.

Hier mede sal ooc voorcommen worden de ondiepte tusschen de Polensche haecken en de Heylichgeeststrouch, want also de selve ondiepte haer oirspronc neemt uyt het sandich Wysselwater dat deur Stagneten vaert comt, twelc daer niet meer commen en sal, soo is die oirsaec geweert. Bovendien als het suyver water daer deur loopt, soo salt meerder schuyringe maken, en overvloediger commen dan het te vooren gedaen heeft, overmits dattet gat van Stagneten vaert int incommen vande Wyssel dieper sal zijn, en schootich sal staen om den stroom vande Wyssel te ontfangen, daert nu ter tijt ondiep en met een hooft bedect is, welc hooft het water afwyst.

3 ARTIKEL; Hoemen de diepinge van boven can verbeteren bequamer dan sy te vooren geweest heeft, sonder datter die van Mergenburch ofte Elbing yet tegen te seggen hebben: Ooc sonder het cleen Weerder in meerder perikel van ysganc te brengen.

Voor al so is te weten dat suyver water twelc met geen sant vermengt en is, geen anwas van santplaten en maect, maer eer dieper schuyringe, en dat de anwassende santplaten alleenlic veroirsaect worden deur het be found necessary can berth simultaneously. These two gates should swing open against the Weichsel, and each should be closed with a lock, the key of which should be held by someone living nearby.

Their use should be thus: When boats, punts, vessels, or timber arrive, the first gate should be opened and all should take berth in the chamber; when they have arrived there, the gate should be closed again and the other gate opened, and they should sail thus into the city; and in the same manner they should sail out of the city again.

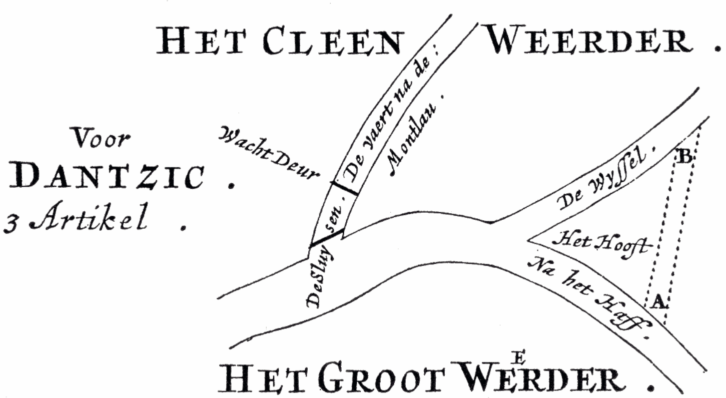
This being so, it is obvious that the channel once having been deepened and the dams having been raised with the excavated earth, the channel will neither silt up nor grow again, for the thick sandy water of the Weichsel will no longer run through it. Furthermore, if the Weichsel water is pure and clear, both swing gates should be opened and water should be allowed to run through the channel, for such pure water will not cause alluvion, but will effect even deeper scouring, as we shall explain more fully in the next section 3.

This will also prevent the shoals between the Polish Haken and the Heiliger Geist Krug, for since these shoals are due to the sandy Weichsel water running through the St. Agnes Channel, which will no longer get there, the cause has been eliminated. Furthermore, if the pure water runs through it, it will effect greater scouring and arrive more abundantly than before, since the mouth of the St. Agnes Channel will be deeper at the meeting point with the Weichsel and will be directed so as to receive the current of the Weichsel, where it is shallow now and covered by a pier, which pier holds back the water.

SECTION 3.

How the above scouring can be improved as compared with what it was before, without those of Marienburg and Elbing being able to object. Also without increasing the danger of ice-drifts in the Klein Werder.

It is to be known in the first place that pure water not admixed with sand will not raise sandbanks, but will rather scour deeper, and that growing sandbanks



dic sandich water des ysganx , snewaters , en regenstrooms, welcke het sant met grooter overvloet vande geberchten inde Wyssel brengen. Dit blyct metter daet ter Munde ande tonnen,alwaer de veranderende santplaten gebrocht worden ten tijde des ysganx en van ander groote stroomen , nae welcke de tonnen somwylen moeten verleyt worden. Maer buyten dien tijt,te weten soo lange het Wysselwater suyver afcomt sonder sant, soo blyven de voorschreve santplaten ande tonnen onverandert. Ten anderen, soo blycket in ettelicke angewassen landen , dat sy haer anwas niet en crygen dan deur dic water des regenstrooms, snewaters en ysganx , wantmen an ettelicke canten der stroomen yder ysganx ofte hoogestrooms anwas , d'een op d'ander siet leggen een duym dic , somwylen meer, somwylen min , na dattet dic water overvloedich afgecomen heeft. De oirsaec waerom die anwassen alsoo verscheyden op malcander liggen, is dattet gras en cruyt wassende deur een tegenwoordige anwas, en daer op verdorrende , so blyft dat selve gras en cruyt een onderscheyt tusschen dien anwas en den toecommende. Uyt dese dingen blyct segge ic , dat niet dan dic water des ysganx , snewaters en regenstrooms de ondiepte veroirsaect,en dat claer water niet dan meerder schuyringe en maect.

Dit verstaen wesende , soo sullen wy tot de saec commen : Men sal (alsoo dergelijcke in Hollant en Zeelant tot veel plaetsen gedaen wort) leggen inden dam van het cleen Weerder drie of vier sluysen , of so veel alst oirboir sal verstaen worden, al neven malcander met een verlaet, en dit ontrent Gutlant ter bequame plaetse daer de stroom der Wyssel tegen den dam van het cleen weerder loopt , en van die sluysen af salmen graven tot inde Montlau.

't Gebruyc hier af sal dusdanich wesen : Men sal dese sluysen toelaten soo lange het Wysselwater dic en sandich is,maer die open setten so lange het Wysselwater claer en sonder sant is: Ende om de redenen die hier vooren verhaelt zijn', soo en cander in Stadt noch elders geen sant noch ondiepte af commen, maer ter contrarie dieper schuyringe van die sluysen af deur de Stadt tot in Zee toe , want daer sal een groote menichte waters over de Dantzicker zijde getrocken worden die over d'ander zijde na het Haf soude loopen.

Angaende het luttelken sants , twelcmen vermoeden mocht dat ten tijde van claer stroom langs de gront mocht dryven, dat,soder eenich is, sal are caused only by the thick sandy water of ice-drifts, snow-water, and rain-water, which carry a larger quantity of sand from the mountains into the Weichsel. This appears in actual practice at Weichselmünde at the Buoy, where the shifting sandbanks are formed during periods of ice-drifts and other strong currents, in accordance with which the buoy sometimes has to be shifted. But beyond these periods, *i.e.* as long as the Weichsel carries pure water without sand, the above sandbanks at the buoy remain unchanged. On the other hand it is found in many newly formed lands that they only receive their alluvion from the thick water of the rains, snow-water and ice-drifts, for it can be observed on many banks of rivers that after each ice-drift or high flood, there is an increase of an inch, and sometimes more, sometimes less, according to the abundance of the thick water. The reason why these alluvions form such different strata is that, grass and weeds growing on a present alluvion and then withering upon it, the grass and weeds in question form a division between this alluvion and the next. From these things it appears, I say, that it is only thick water of ice-drifts, snow-water, and rain-water which causes the shoals and that clear water only causes greater scouring.

This having been understood, we will now come to the point. In the dam of Klein Werder three or four locks should be built (as is done in many places in Holland and Zeeland), or as many as shall be considered suitable, all of them side by side, with a navigation weir, and this somewhere near Güttlandt in a suitable place, where the current of the Weichsel runs against the dam of Klein Werder, and from these locks a cut should be made upto the Mottlau.

Its application will be thus: The locks should be kept closed as long as the Weichsel water is thick and sandy, but they should be opened as long as the Weichsel water is clear and free from sand. Then for the reason detailed above no sandbanks or shallows will result either in the town or elsewhere, but on the contrary deep scouring will be caused from these locks through the city to the sea, for a large amount of water will be drawn over the Danzig side, which would run by the other side of the Haff.

And as to the small amount of sand as one might expect to drift along the bottom in periods of clear water, if there is any, it will be washed over the sill sal vanden durpel der sluysen geschut worden en daer voor by moeten vlieten.

De camen, schepen en hout van boven commende, sullen deur de voorschreve sluysen door de Montlau meugen na de Stadt varen, sonder vande schepen die uyt Zee commen verhindert te zijn.

Soder camen, hout of schepen van boven quamen te vvyle de sluysen toevvaren, om het dic sandich Wysselvvaters vville, soo salmen die door 't behulp van het verlaet (gelijcmen in Hollant doet) in brengen, sonder dattet sandich vvater daer en tusschen inde Montlau loope.

Tis ooc te anmercken dat hoevvelmen aldus meerder vvater over de Dantzicker zijde crygt, nochtans so en sal den dam van het cleen Weerder geen meerder perickel van ysganc lyden dan sy nu en doet, vvant in tijt van sorgelicke ysganc, salmen (als in Hollant) de sluysen toelaten, en den ysganc sal daer voor by loopen gelijcse nu doet: Waer deur ooc de vier bruggen voor en achter de spyckers in geen perikel van ysganc staen en sullen.

De Montlau en sal om den ysganx vville, noch om het hooge vvater, niet seer veel hooger dammen behoeven danse nu en heeft, vvant als het vvater te hooch begint te commen, soo salmen de sluysen toe doen.

4 Artikel; Hoemen de Montlau inde Stadt en voort de heele vaert deur, noch veel dieper can maken dan boven geseyt is.

Men sal leggen inde Montlau by den Taerhof drie of vier optreckende sluysdeuren, al neven malcander, vvelcke van sulcke form meugen zijn als de bygevoechde figuer aenvvijst: sGelijx soo veel sluysdeuren inde Montlau ant Langegaersche Door.

Tgebruyc hier af sal dusdanich vvesen: Dese sluysdeuren toe zijnde, soo sal het vvater over d'een zijde der deuren soo veel hooger commen dan over d'ander zijde, als de dammen der Montlau verdragen meugen, uyt oirsaec dattet Wysselvvater ontrent Gutlant veel hooger is dan den Montlau byden Taerhof. Ten anderen, so sal dit vvater ooc verhoocht vvorden deur de Montlau selfs en de vvateren die daer in vlieten.

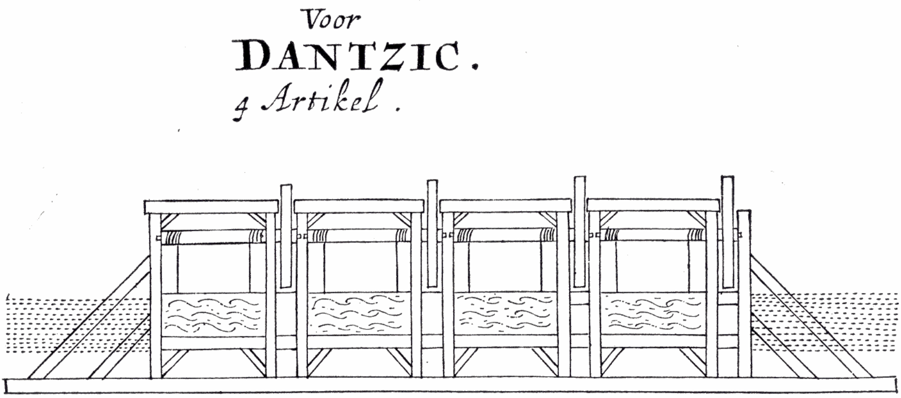
Dit buyte vvater so hooch zijnde als de dammen verdragen connen, gelijc geseyt is, soo salmen die sluysdeuren tseffens op vvinden, d'eenmael anden Taerhof, d'andermael ant Langegaertsche Door, nae dat de

 gelegentof the locks and will have to flow past them. The boats, vessels, and timber arrived from upstream, will be able to enter the city through the Mottlau, not being hampered by the vessels coming from the sea. If boats, vessels or timber arrived from upstream while the locks are closed, because of the thick sandy Weichsel water, they should be made to enter by means of the navigation weir (as is done in Holland), without the sandy water meanwhile entering into the Mottlau.

It should also be noted that though in this way more water will run on the Danzig side, still the dam at Klein Werder will not be subject to greater danger of ice-drifts than theretofore; for in periods of dangerous ice-drifts, the locks should be kept closed (as in Holland) and the ice-drifts will pass by, as they now do. And thus the four bridges in front and behind the "nails" will not be endangered by ice-drifts. The Mottlau will not need much higher dikes than it has now, neither on account of the ice-drifts nor because of the high water, for if the water rises too high, the locks will be closed.

SECTION 4.

How the Mottlau can be deepened much deeper than stated above, in the city and over its entire course.



In the Mottlau near the Theerhof three or four vertical gates should be built, side by side, which may have the shape shown in the annexed figure; and an equal number of doors in the Mottlau near the Langgarter Thor.

The application should be thus. These doors being closed, the water on one side of the doors will rise as much higher than on the other as the dikes on the Mottlau can bear, because the Weichsel water near Güttland is much higher than the Mottlau at Theerhof. Secondly, this water will also be raised by the Mottlau itself and the waters giving into it.

This outer water being as high as the dikes can bear, the doors should be raised simultaneously, now at Theerhof, now at the Langgarter Thor, as required gelegentheyt vereyscht, en het suyver water vallende van sulken hoochde en met sulken menichte, sal groote schuyringe maken niet alleen inde Stadt, maer ooc van daer voort deur de heele vaert tot in Zee toe.

Tis nut om groote schuyringe te maken, dit verheven water dicwils te laten afloopen alst vriest, want also d'ervaringe van dergelicke schuyringe in Hollant leert, het Ys telcken brekende en sleypende langs den gront, maect groote diepte.

5 ARTIKEL; Hoemen de haven ter Munde tot een geduerige diepte brengen can.

Tis kennelic dat dese ondiepte gecommen is deur vermindering van grooter stroom dieder voormael was, daerom soo is vermeerdering des strooms de eygen natuerlicke middel, daer deur de ondiepte tot haer voorige diepte can gebrocht worden.

Om dese vermeerderinge des strooms seer geweldich beneden de Wyssel te crygen, sonder dat den dam van het cleen Weerder deur ysganc in meerder perikel stae. Men sal de Zaspe Zee gebruycken tot een waterhouder (soo noemtmen dergelijcke in Hollant) leggende een dam over de zijde daert noodich is, begrypende een groote houder, hoe grooter hoe bequamer, voort salmen leggen ten eynde vande Westkisten int kiel, seven of acht of soo veel oirboir sal bevonden worden, brede optreckende sluysdeuren, al neven malcander in een selfde gat des dams, en alsoo vervoecht dattet water daer uyt commende, scheutich sy na den loop der kisten, gelijc de by gevoechde figuer anwijst.

Dese boveschreven sluysdeuren meugen alneven malcander staen, na de manier der voorgaende figuer des 4 Artikels.

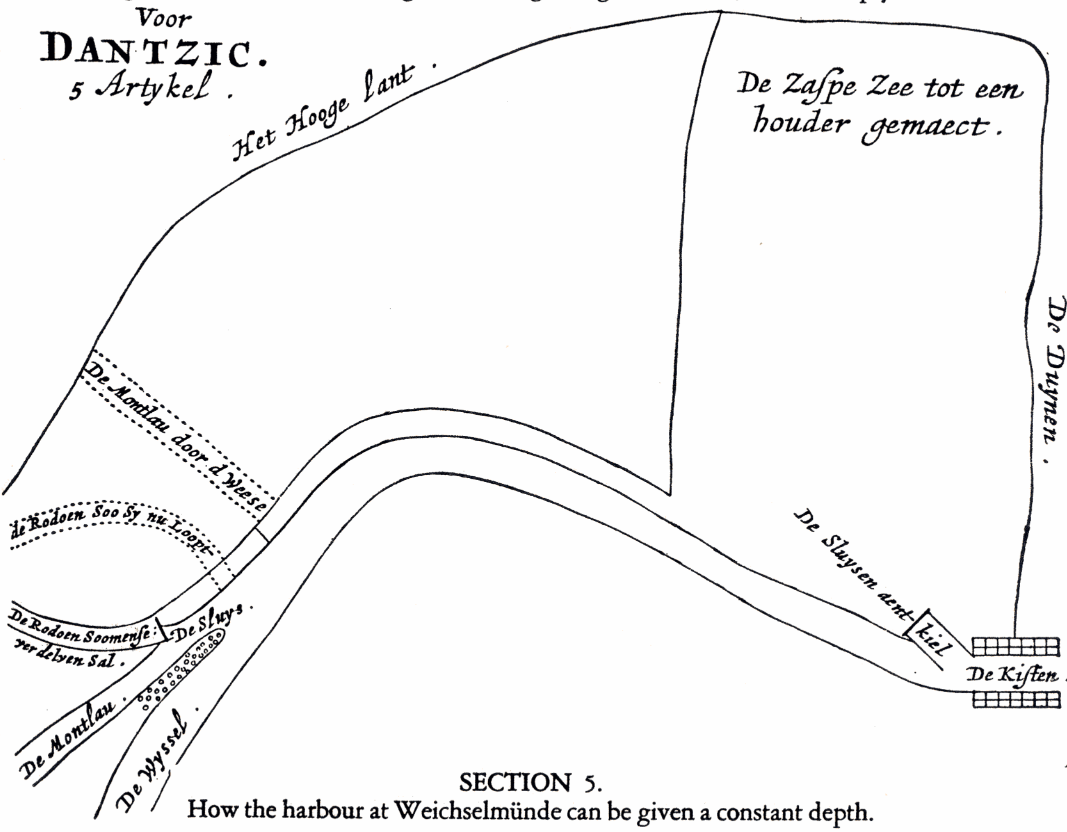
Dese houder aldus bereyt synde, soo salmen die vullen met twederley water: Ten eersten, met den Rodoen in deser vougen; Men sal leggen en dam langs de Wijssel van het kiel af tot anden Rodoen, en noch een dam daer nevens; en dese sluysen toe wesende, sgelijcx ooc de sluysen ande Polensche haecken, soo sal den Rodoen tusschen dese twe dammen inden houder loopen.

Ten anderen, soo salmen desen houder ooc vullen mettet Wijsselwater deur de Montlau commende op dese manier: De sluysdeuren anden Taerhof en ant Langegaertsche Door toe zynde, soo salmen het claer Wijsselwater dat deur de Montlau comt, doen loopen buyten om de

Stadt,

by the circumstances; the pure water falling from such a height and in such a volume, will scour heavily not only in the city, but also beyond it throughout the channel down to the sea.

It is useful in order to effect heavy scouring to let this high water run off frequently when it freezes, for as the experience of such scouring in Holland has taught, the ice, often breaking and sliding along the bottom, scours deeply.



SECTION 5.

How the harbour at Weichselmünde can be given a constant depth.

It is obvious that these shoals are due to a decrease of the strong current which existed there formerly; therefore an increase of the current is the proper natural remedy for scouring these shoals to their former depth again. In order to obtain a very strong increase of the current below the Weichsel, without endangering the dam at Klein Werder by ice-drifts, the Saspen See should be used as a basin (thus they call the like in Holland), a dike being built along the side where it is necessary, which thus embraces a large basin, the larger the better; furthermore at the end of the Westkisten wide, vertical sluice-doors should be built, all side by side, in an opening in the dike and that the water spilt by them shall be plentiful in the direction of the cofferdams; as shown in the annexed figure. The above doors may be placed side by side after the manner of the preceding Figure of Section 4.

Stadt deur de Stadt-vesten, welke daer toe van selfs al bereyt zijn, te weten voor by het Schotlansche Door, van daer voor by het Hooch Door, en so voort inde Stadt deur de Weese na de Houder, te weten na dẽ Zaspe zee, en want de Wijssel ontrent Gutlant veel hooger is dan ande kisten, soo salmen dien Houder daer deur op corten tijt connen so hooch brengen als de dammen verdragen meugen.

Voort om het claer Wijsselwater in de Zaspe zee veel hoger te brengen dan het onderste der waterraders vande Corenmolen in Stadt, sonder dat nochtans de selve Corenmolen sal verhindert syn te malen, ooc sonder dattet water binnen Dantzic op de gasse comme; Men sal leggen een schotdeur tusschen de twe dammen daer twater door na den Houder loopt, als ter plaets van A.

Tgebruyc hier af sal dusdanich wesen: Dese houder aldus vol zijnde, so salmen de sluysdeuren ant kiel al t'seffens opwinden (twelc schynt dat bequamelic sal connen gedaen worden, deur de Soldaten van het huys ter Munde;) Ende het water alsoo vallende met meerder menichte van hoger en snelder, dant daer noyt en viel, sal daer seer groote schuyringe maken.

Merct dat alst seer waeyt en stormt, alsso dattet sant ande tonnen inden gront beweegt wort, dan ist nut den Houder te laten afloopen, om grote diepte te crijgen: Sgelijcx salt ooc vorderlic syn desen Houder dicwils op den ysganc te loosen.

Tis ooc te weten dattet leege lant langs de Wijssel hier mede sou verbeteren, want het sou dan goet bedijct lant zijn.

Angaende den dam langs de Wijssel, die sou daer dobbel dienst doen, want men sou daer mede niet alleen het water vanden Rodoen en vande Montlau nae de Zaspe zee geleyden, maer sou ooc dienen om alst tegen wint is, de schepen met peerden nae de Stadt te trecken, en wort dien dam vande zeevarende Luyden daer seer begeert.

6 ARTIKEL; hoemen can maken dat de waterconst buyten het Hooch Door niet meer vervriesen en sal.

Ten eersten, soo is te weten dat ic vernomen hebbe hoe diep dattet hier ontrent Dantzick in de aerde vriest, my is berecht van de gene die inde aerde arbeyden, dattet ten diepste vier voeten diep vriest: Dit neem ic voor fondament, soot na breeder ondersouckinge bevonden wierde

 dattet

The basin thus being completed, it should then be filled with two kinds of water: firstly, with the Radaune, in this way. A dike should be built along the Weichsel, from the channel to the Radaune, and another dike parallel to it, and when the doors of the locks are closed, and so are the doors at the Polish Haken, the Radaune will run between these dikes into the basin.

Secondly, the basin should also be filled with the Weichsel water, running through the Mottlau in this way. The doors at Theerhof and at the Langgarten Thor being closed, the clear Weichsel water running through the Mottlau should be made to run round the town through the town ditches, which are by nature suited for this, *i.e.* past the Schottlander Thor, thence past the Hohe Thor, and thus through the town through the Weese to the basin, *i.e.* to the Saspen See, and because the Weichsel is much higher at Güttlandt than at the cofferdams the basin can be filled in a short time as high as the dikes can bear.

Furthermore, in order to raise the clear Weichsel water in the Saspen See much higher than the lowest waterwheel of the cornmill in the town, without preventing it from milling and without making the water in Danzig flood the streets, a sliding sluice-door should be built between the two dikes, between which the water runs into the basin, at *A*.

The operation will be thus. When the basin is full, the doors in the channel should be raised simultaneously (which might easily be done by the soldiers of Weichselmünde Castle); then the water thus falling in a large volume from a greater height and with greater speed than ever before will effect great scouring.

Note that when a gale is blowing so that the sand at the buoys is stirred at the bottom, it will be advantageous to let the basin drain itself in order to get greater depth. It will also be advantageous to drain the basin often during ice-drifts.

It is also to be noted that the low land along the Weichsel would be thus improved, for it would then be properly embanked. As to the dike along the Weichsel, it would serve a double purpose, for with its aid not only could the water of the Radaune and the Mottlau be conducted to the Saspen See, but it would also serve to draw ships with horses against the wind into the city, and such a dike is greatly desired by the sailors there.

SECTION 6.

How the waterworks outside the Hohe Thor can be prevented from freezing up.

Firstly, it should be noted that I learned to what depth the soil around Danzig freezes; I have been told by those who till the earth that it freezes to a maximum depth of four feet. I base myself on this; if after ampler study it should be found that it freezes to a greater or a lesser depth, one should act accordingly.

dattet dieper of ondieper vrieſt, men ſal ſich daer na rechten.

Genomen dan als geſeyt is, dattet inde aerde ten diepſten vier voeten diep vrieſt, ſoo ſalmen maken rontdom het huys daer de waterconſt in ſtaet, een vier canten thuyn van hout of van ſteen, de ſelve thuyn ſalmen ſetten vier voeten van het huys, en de ſpatie tuſſchen de thuyn en het huys ſalmen vullen met aerde tot boven toe. Voort ſal men boven int huys op de balken barderen leggen als een ſolder, en op dien ſolder onder het dac ooc aerde vier voeten dic.

Voort daer dit aerde becleytſel over het water comt, van vooren en van achter het huys, daer ſalmen tſelve aerde becleytſel doen genaken tot int water een voet of een halve voet diep, of daer ontrent, alſoo dat daer geen gaten en blyven deur welcke wint, coude of vorſt ſou meugen commen.

Angaende de deure daermen door int huys gaet, daer toe ſalmen inde aerde een open viercant gat laten ſo groot als de deur, ſtellende daer voor een ſeer dicke houte deure als een voet dic, dicht ſluytende, en een dergelijcke deure van binnen voort gat.

Dergelijcke gat ſalmen ooc meugen in d'aerde laten om de veinſter lucht daer door te crygen alsmen die wil openen, ſtellende alſulcke ſeer dicke houten veinſteren, dicht ſluytende van binnen en buyten dat gat.

De voorſchreve aerde ſchynt dat bequaemlixt ſal meugen genomen worden vande hoochde daer men de vellen op droocht by tſelve huys liggende.

Dit boveſchreven aldus volbracht zijnde, en het heel becleytſel dicker weſende dan vier voeten, te weten ſoo veel dicker als de muer van het huys en vanden thuyn bedraecht, ſo en cant in dit huys niet vrieſen, want de vorſt en can in d'aerde maer vier voeten diep commen (als vooren geſtelt is) ſoo iſt dan onmeugelic de vorſt deur meer dan vier voeten te geraken.

Beneven dat de vernuft dit leert, ſo iſſer ooc ervaringe eenſdeels in kelders; Ten anderen inder gelijke aerde becleytſelen, daermen tot ſommige plaetſen cruyden en ander waſſende ſaken, in bewaert tegen de vorſt.

EEN ANDER VOOR DIE VAN DANTZIC.

NA dien ic Simon Stevin hier tot Dantzic gecomen was om de ſantplaten ande tonnen, deur middel van inſtrumenten, wech te nemen, Assuming, as stated, that the soil freezes to a maximum depth of four feet, around the building accomodating the waterworks should be built a square fence of timber or stone; this fence should be built at a distance of four feet from the building and the space between the building and the fence should be filled with earth to the top. Furthermore in the upper part of the building boards should be placed on the timbers, in the way of a loft, and on this loft, underneath the roof, earth should be laid also four feet thick.

Further, where the protective covering of earth is athwart the water, in front and behind the building, the covering should approach to the water to a depth of one foot or half a foot or a similar depth, so that there shall remain no holes through which the cold or the frost might penetrate. As to the door through which one enters the building, for this purpose a square hole should be left in the earth as large as the door, a very thick wooden door (one foot thick, and closing perfectly) to be placed in front, and a similar door on the inside of the hole.

A similar hole may also be left in the earth in order that the windows may let through air if it is desired to open them, very thick wooden windows, closely fitting on the inside and outside of the opening, being provided. It seems that the aforesaid earth may taken most suitable from the mounds on which the skins are dried, near the building.

The above having been done and the entire covering being thicker than four feet, *i.e.* as much thicker as the wall of the building and of the fence, there can be no frost in the building, for the frost can penetrate only four feet into the earth as assumed, and thus it is impossible for the frost to get through more than four feet.

Apart from common sense teaching this, experience has also been gained, firstly in cellars, secondly in similar coverings of earth, in which in some places herbs and other crops are protected from frost.

ANOTHER SUGGESTION FOR DANZIG.

After I, Simon Stevin had arrived here at Danzig to remove the sandbanks at the buoys, by means of machinery, it was found, that there was a constant men, so bevont het sich, dattet was een geduerige anwas die haer jaerlicsche onderhouding sou behoeven, waer deur ic ander middelen verclaerde, diemen te wege sou brengen deur schuyring van op gehouden wateren, als tot ander plaetsen gebruyct wort; Doch alsoo den E: Raet geacht heeft dat de costen daer af te groot souden vallen, so en is eyntlic niet beslooten daer af yet gedaen te worden.

Dit angemerct, soo is myn voornemen den E: Raet andermael aen te dienen, dat ic presenteer te verclaren die voornoemde eerste middel, om het sant deur instrumenten te trecken; want hoewel datter een jaerlix onderhout sou moeten zijn, doch soo sullen de costen daer af seer cleen vallen.

De obgemelte verclaring presentere ic te doen, op sulke conditie, als ic seker ses ander articulen verclaert hebbe: Ende so de E: Raet naer die verclaring twijffelde ant effect, soo sal ic presenteren alles an te nemen tot myn perikel ende laste, soo wel instrumenten als aubeyt, ende dit voor ander half grosse opt last, waer voor ic de diepte geduerlic onderhouden sal op 7 ellen diep, en 6 roeden breet.

EEN DERDE VOOR DANTZIC.

Verclaringe van Simon Stevin anden E: Raedt der Stadt Dantzic, van syne inventie der santtreckinge, welcke verclaringe gedaen is op voorwaerde, datse niet int werc gestelt en sal worden sonder dat den E: Raet an hem Stevin, daer af eerst vernoegen sal.

Alsoo dese santplate seer cort is, soo can de diepte met weynich sant te trecken, lichtelic geholpen worden, alsser maer bequame middel toe gevonden en is. Om de selve middel te verclaren, soo isser voor al nodich een bequaem vastliggende schip of vat, soment noemen wil, twelc heel plat zijnde, nochtans deur de wachten van stercke winden dieder somwylen overcommen, niet en sincken? tselve sal aldus te wege gebrocht worden: Men sal maken een viercant vat, lanc 120 voeten, breet 25 voeten, hooch 5 voeten, tselve salmen vullen met ballast, als sant of steen, tot dattet diep gesoncken is 4 voeten, te weten datter maer 1 voet boors of daer ontrent buyten water en steect. Daer nae salmen dit alluvion, which would need annual attention, in view of which I explained other expedients which could be effected by the scouring of pent-up waters, such as are used in other places. But as the Noble Council judged that the expense would be too great, it was finally decided not to execute the aforesaid plans.

In view of this, I have the intention of announcing to the Noble Council once again that I offer to explain the aforesaid first expedient of removing the sand with machinery, for though this will require annual maintenance, it would involve very small expenditure.

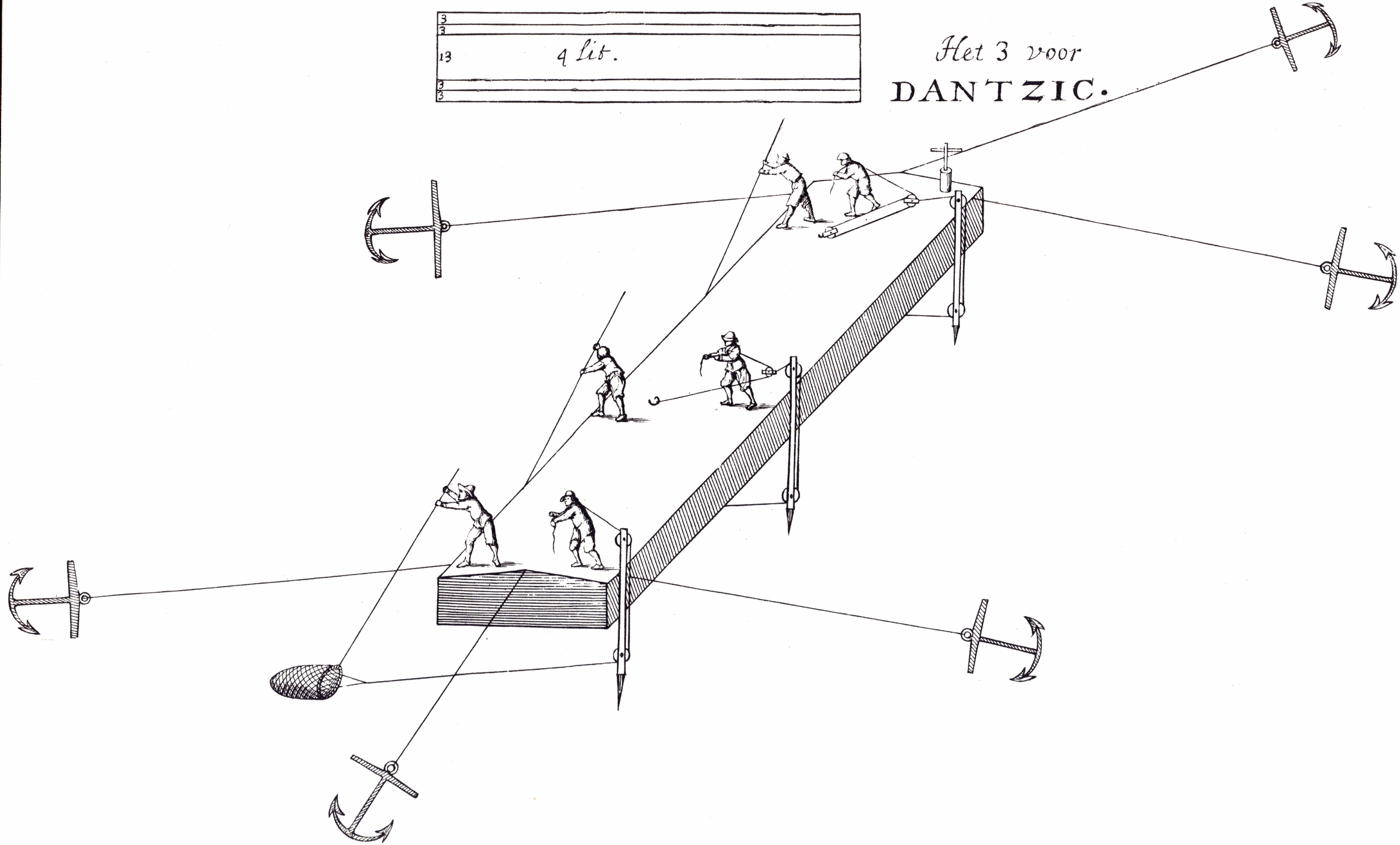
The above explanation I offer to give on the same conditions as those on which I explained six other articles. And if the Noble Council after this explanation should doubt the effect, I offer to contract everything at my own risk, both as to the machinery and as to the labour, at one a half *groschen* per *last,* for which sum I will constantly maintain the depth at 7 ells over a width of 6 roods.

A THIRD SUGGESTION FOR DANZIG.

Declaration of Simon Stevin to the Noble Council of the Town of Danzig about his invention of drawing sand, which declaration has been made on condition that it will not be put into practice without the Noble Council first giving him, Stevin, a compensation.

As this sandbank is very short, the depth can be easily improved by drawing little sand, if only the proper method has been found. In order to explain this method, the primary requirement is a good stable ship or vessel, as one likes to call it, which being very flat, and yet does not sink owing to the waves produced by strongs winds which will sometimes blow over it. This can be achieved as follows. A square vessel, 120 feet long, 25 feet broad, 5 feet high, should be made, which should be filled with ballast, such as sand or stone, until it has sunk to a depth of four feet, *i.e.* only one foot or thereabouts sticking out of the water. Then the top of this vessel should be covered, stopped, and

Het 3 voor
DANTZIC.



dit vat boven dicht toe decken, ſtoppen en picken, alſoo datter geen water in en can, ende ſal dit decſel int middel ontrent een voet hooger meugen zijn dan ande canten. Voort ſalmen daer op ſetten een pompe, om het deurdringende water, alſt noodich is, uyt te pompen, gelijcmen inde ſchepen doet.

Dit vat alſoo geladen, ſal in hem begrijpen 200 laſt, want 120 voet lanc, 25 breet, en 4 hooch, maken 12000 cubig voeten, waer af elc 60 voeten maken 12 tonnen waters, dat is een laſt, comt als vooren geſeyt is 200 laſt: Daerom ſal dit vat op een ſtil weder, ooc met zuyde wint ſoo vaſt liggen als een ſchip van 200 laſt met ſijn volle ballaſt, en noch ſtilder, eenſdeels om dattet ſoo top ſwaer niet ſyn en ſal, ten anderen om dattet op ſes anckers vaſt ſal liggen: Bovendien alcomter een ſtercke noorderſche wint dat de wacht over de canten ſlaet, ſoo en cant daer mede niet ondergaen, maer ſal boven water blyven als een tonne, en daerentuſſchen (ſo ſulcx gebeurt, meugen de werclieden in een ſchip treden dat daer toe veroirdent ſal zijn.

Op dit vat ſullen mogen ſtaen 50 mannen die ſant trecken, over elke zyde 25, te weten van ontrent 5 voeten tot 5 voeten een man.

Deſe 50 mannen ſullen elc hebben een ſant net van deſer geſtalt: Men ſal maken een yſer beugel diens rant lanc ſy ontrent 5½ voet. De ſcherpe zyde van deſen beugel ſal over al ſtaen na de ſnede van het ſant dat daer mede te trecken is, gelijc van dien beugel een cleene form van bley gemaeckt, hier by verthoont is anden E: Raet: an die beugel ſal hangen een net gevouder, met kaeſdouc.

Nu om met groot gewelt te trecken, en om veel volc op een cleene plaets bequamelic te gebruycken, ſoo ſalmen daer toe nemen catrolſtocken, welke ſtijf int ſant ſtekende, en tot 50 in getale zijnde, ſullen het vat noch meerder vaſticheyt geven: Tot yder catrolſtoc ſal een toutrecker zijn, diens touwe over ſoo veel catrollen ſal gaen als de hardicheyt van het ſant vereyſchen ſal, want een mans macht can daer mede ſo ſeer vermeerdert worden, als de macht van twe, drie of meer mannen, al twelc bequamelic toe ſal meugen gaen naer de manier als deſe bygevouchde figuer anwijſt.

Het ſant dat ſy trecken, ſullen ſy leggen boven opt decſel vant vat, twelc van daer geworpen ſal worden inde canen of bordingen diet wech dragen.

Maer

pitched so that no water can enter, and this cover may be one foot higher in the middle than at the gunwales. Furthermore a pump should be mounted on it, in order to pump away, if necessary, any water that should enter, as is done on board ships.

The vessel, being thus loaded, will contain 200 lasts, for 120 feet long, 25 broad, and 4 deep make 12,000 cubic feet, of which every 60 cubic feet equal 12 tons of water, that is one last; this makes, as said above, 200 lasts.

Therefore this vessel during calm weather and even with a southerly wind will be as stable as a ship of 200 lasts with its full ballast, and even more stable, firstly because it will not be so top-heavy, and secondly because it will be fastened to six anchors: Moreover, even though there should come a strong northerly wind, so that the waves wash the sides, it will not founder, but will remain above water like a buoy, and in the meantime, if such a thing should happen, the workmen may enter a boat laid in readiness for this purpose.

On this cask 50 men may stand to dredge sand, 25 on each side, *i.e.* one man at five feet distance from the other. These 50 men should each have a sand-net of the following shape. An iron brace should be made, the rim of which should be about 5½ feet. The sharp side of this brace should stand everywhere according to the cross-section of the sand that is to be dredged with it, like a small model of this brace, made of lead, which is herewith shown to the Noble Council; to this brace will be attached a net lines with cheese-cloth.

In order to draw powerfully and to use many workmen suitable on a small area, one should take pulley-posts, which being driven firmly into the sand, 50 in number, will give the vessel even greater stability. At each pulley-post there should be one man pulling the rope, which rope runs over as many pulley-sheaves as the hardness of the sand shall demand, for a man's power can thus be much enlarged, to the power of two, three, or more man, all of which may be arranged suitably in the manner shown in the annexed figure.

The sand they dredge should be put on the cover of the vessel, which should be thrown thence into boats or punters which carry it away. But if it should

Maer wilmen inde plaets van dit boveschreven vat nemen een deel vlotten, als 12 elc 2 roede lanc ende een roede breet, alsoo neven malcander gevougt datse maken een vlot 12 roeden lanc en 2 roeden breet, tselve vlot acht ic dat op een stil water ooc met tamelicke zuydersche winden ande tonnen vast genoeg liggen sal, twelc met cleyne cost lichtelic can ondersocht worden : Dit vlot machmen op syn ses anckers leggen en catrolstocken daer an steken,als voor van het vat geseyt is.

Om nu eenige rekeninge te maken vande menichte des sants dieder te trecken is , ten anderen hoe veel sants datter des daechs aldus can getrocken worden : Voort op hoe lange tijt het heele werc can gedaen zijn, en tot wat oncosten dat beloopen sal : Soo is te weten datmen met 91 vademen , dats ongeveer met 40 roeden, comt van 7 ellen tot 7 ellen diep. Als dese 40 roeden langde, gediept worden voor 't eerste ses roeden inde brede,soo sullen die maken 240 roede, want 6 mael 40 doet 240. Inder vougen datmen met te trecken 240 roeden sants een elle hooge,so salment over al wel $1\frac{1}{2}$ elle en meer dieper crygen dant nu is, want de rechte principalen ondiepte seer cort,en maer 6 of 7 roeden lanc en is ; Daerom somen sich wilde vernougen met alleen een elle dieper, tselve sou te doen syn met ontrent 42 roeden sants te trecken.

Om nu te berekenen de menichte des sants die daeghs can getrocken worden, soo is te weten dat een roede sant van 15 voet int viercant, en een elle hooch, in haer begrijpt 450 cubig voeten, der selver voeten sal een man met sijn toutrecker (volgende de prouve die ic daer af in Hollant gedaen hebbe) connen trecken ontrent 50 op een uyr, dat is op 9 uyren 450 voeten, te weten een roede, daerom soomen rekende sulcke 9 uyren op een dach , soo soude met yder santnet connen getrocken worden een roede sants sdaechs,daerom sal het heel werc van 240 roeden connen gedaen syn op 5 dagen tijts.

Wat de oncosten belangt, daer sullen toe behouven 50 mannen met santnetten , 50 mannen die de touwen trecken , Daer toe noch genomen 20 mannen die het sant wech voeren , maken tsamen 120 mannen: Genomen dat die elc sdaeghs winnen een halve marc, comt sdaechs 60 marc, die doen op de 5 dagen voor't geheele werc 300 marc. Maer somen sich wilde alleen vernougen met een elle dieper, waer toe datmen maer als geseyt is, ontrent 42 roeden sants en sou behoeven te trecken, tselve sal met veel weyniger cost te doen zijn.

be desired to take instead of the above vessel a set of rafts, for instance 12, each 2 roods long and one rood broad, joined together so as to form one raft 12 roods long and 2 roods broad, I believe that this raft will be stable enough at the buoys in quiet water, even with considerable southerly winds, as can be easily tested with little expense. This raft may be laid on six anchors and the pulley-posts secured to it, as has been explained before about the vessel.

In order to calculate the amount of sand to be dredged, and also how much sand can thus be dredged per day, and further in how much time the entire work can be done and what will be the cost, it is to be known that with 91 fathoms, *i.e.* about 40 roods, a depth of 6 to 7 ells is attained. If this length of 40 roods is dredged first over a width of six roods, this will make 240 roods, for 6 times 40 make 240. Thus by dredging 240 roods of sand one ell deep, one will obtain an increase in depth of 1½ ells or more as compared with the present depth, for the straight principal shoals are very short and only 6-7 roods long. Therefore, if one were to be content with an increase of depth of only one ell, it might be done by dredging about 42 roods of sand.

Now in order to calculate the amount of sand that can be dredged daily, it is to be known that a rood of sand of 15 feet square and one ell high contains 450 cubic feet. Of these feet, one man with his rope-drawer (according to results obtained by me in Holland) will be able to draw about 50 per hour; *i.e.* in nine hours 450 feet, being one rood. Therefore, if one reckons with nine hours in the day, with each sand-net one rood of sand might be dredged per day; thus the entire work of 240 roods may be finished in five days' time.

As to the expenses, there will be needed 50 men with sand-nets, 50 men to draw the ropes, then another 20 men to remove the sand, *i.e.* 120 men in all. Assuming that each of them will earn half a marc a day, this makes 60 marcs daily, which in five days for the entire work makes 300 marcs. But if one were content with one ell deeper only, for which, as explained, only about 42 roods of sand would have to be drawn, this might be done at much less expense.

En by aldien datter jaerlix soo veel sant getrocken wort als boven geseyt is, men sal in toecommende tyden meerder diepte crygen dan van 7 ellen en meerder brede dan van 6 roeden, want den anwas vant sant sal om die jaerlixsche treckinge nootsakelic verminderen.

Voor besluyt, want dese ondiepte seer cort is, soo canse deur de bovegemelde santtrecking, met seer cleene costen, op corter tijt jaerlix geholpen worden.

Verclaring op sommige punten die my Simon Stevin voorgeleyt syn angaende de diepinge ter Munde. Ende ten eersten hoemen het uytgetrocken sant bequamelic wech sal brengen.

Want het somtijts te wyle men arbeyt windich weder can zijn, somtijts stil, soo soumen hier toe in winderigh weder wel smacken connen nemen die zeylen, en diemen in stil weder voorttrecken mocht met schuyten; Maer hier wort op geseyt, dat die schuyten in storm tegen de smacken in sticken souden slaen. Om dit te voorcommen soo canmen doen maken drie of vier overdecte schepen die zeylen connen en diemen in stille weder ooc roeyen can, twelc sy seggen dat bequamelic om doen is, ooc dattet gedaen wort: Seggen ooc dat alsmen die schepen totte santtrecking niet en besichde datse souden connen prouftyt doen ende gebruyct worden als ander smacken.

Of soment immers met smacken doen wilde, soo soumen in windich weder de schuyten mogen inde smacke trecken, gelijcmen in ander schepen doet, en die in stil weder uytlaten.

Om haest over en weder te varen alsmen zeylt, soo machment passen datmen altijt met halve wint gaet en keert.

Ten 2, Wort gevraecht of het vat op syn anckers vast genoech leggen sou.

Ic heb gehoort van Schippers die over een jaer in Italien voeren, welcke niet kennende den aert vande Zee, aldaer hebben in storm getracht het lant te schuwen en na de Zee toe te varen; de selve Schippers beter onderricht zijnde vande eygenschap dier plaetse, hebben andermael in stormen vry by lant commen liggen, welc lant alsoot hooge

was,

And if yearly so much sand is dredged as stated above, in the near future a greater depth than 7 ells and a greater width than 6 roods will be obtained, for the accretion of the sand will diminish of necessity because of the annual dredging.

To conclude, because these shoals are very narrow, by means of the above-mentioned sand-drawing, they can be remedied yearly at very small expense in a short time.

Declaration on some points laid before me, Simon Stevin, about the dredging at Weichselmünde. And first how the dredged sand is to be removed easily.

As it may sometimes be windy weather while the work is going on, and sometimes quiet, in windy weather one might use smacks which sail and which might be towed by boats in calm weather. But to this it is retorted that these boats would be smashed to pieces against the smacks during storms. In order to avoid this, three or four covered vessels might be built, which are adapted to sail and which can also be rowed in calm weather, which they say is easily done and actually practised; they also say that if such ships were not employed in dredging sand, they might profitably be used like other smacks.

Or if it should yet be done with smacks, the boats might be drawn into the smacks during windy weather, as is done in other vessels, and put out again in calm weather. In order to go quickly back and forth while sailing, it should be so arranged that one always sails and turns having the wind on the beam.

Secondly, it is asked whether the vessel would be stable enough on its anchors.

I have heard from masters who sailed to Italy a year ago and, not knowing the nature of the sea, during storms tried to avoid the land and to sail out to sea; the same masters, after being better instructed on the properties of those places, the next time during a storm anchored close to the shore, which was, beſchermde de ſchepen voor de wint : T'is wel waer ſeyden ſy, dat de ſchepen daer lagen en keerden door de wachten 't een eynde opt ander eynde neder dattet ſcheen datſe in uyterſte noot waren, maer alles was ſonder perikel, uyt oirſaec dat de ſtercke winden het ſchip niet en geraeckten. Hier uyt blyckt metter daet dattet vat byde tonnen geen perikel van ſtorm en ſou lyden, overmits datter geen wint op vaten en can alſoot ſeer leege is, en dat de wachten daer over ſouden loopen.

T'is ooc te weten datmen de ſanttreckinge niet en behoeft te paſſen opt voorjaer om te verwachten het voordeel van het groot water dat dan afcomt, want de diepte blyft nae de groote ſtroom de ſelve dieſe te vooren was, of ſoder eenich verſchil comt, het can ſoo licht gebeuren datſe een duym of twe ondieper wort als dieper, gelijc de ervaringe leert. Daerom ſoumen meugen nemen het ſtilſte vande Somer: dan ſyn ooc de dagen langer.

Ten 3, Of het vat ſal connen verdragen het ſant datmen daer op legt.

Met 25 laſt op het vlot te leggen ſoo ſoudet een halve voet ſincken, daerom alſſer waren 50 mannen met ſantnetten, en dat elc getrocken hadde een half laſt ſant, twelc ongeveer ſou zijn een hoop van 4 tonnen, ſoo ſou het vat met 25 laſt ſant een halve voet geſoncken zijn, en noch een halve voet ſouder buyten water ſteken. Doch ſo de ervaringe leerde dattet nut waer meer ſant tſeffens op het vat te laten leggen eermen afſchupte, men ſou vande ballaſt meugen wat uytnemen tot dattet een halve voet hooger uytſtake. Angaende het perikel datmen vreeſt van ſincken, dat en can niet geſchieden, want al quam het water tot ande canten des vats, ſoo ſouder noch connen op leggen 25 laſt eert ſincken can, want het ſou int middel een voet hooger zijn tegen het afwateren, welcke heele voet aldaer, bedraecht anderſints een halve voet, vermogende op te houden 25 laſt.

Ten 4, Of op elke zijde vant vat ſou meugen ſtaen 25 mannen met netten, en ofter noch plaets genoech ſou zijn om het ſant te leggen en de 50 toutreckers te gaen.

Ider ſanttrecker heeft achter hem een ſpatie van 5 voeten lanc, daer land, being high, sheltered the ships from the winds. It is true, they said, that the ships anchoring there were cast one end upwards the other downwards by the waves so that they seemed to be in extreme distress, but no danger was involved, because the strong winds did not affect the ship. This shows that the vessel near the buoys would not be endangered by storms because the wind cannot affect it, since it is very low and that the waves would not wash it.

It is also to be noted that the sand-drawing need not be performed in spring in order to have the advantage of much water flowing down then, for the depth remains the same, after the strong current, that it was before, or if there be any difference, it may happen that it becomes one or two inches deeper rather than shallower, as experience teaches. Therefore the calm of the summer might be chosen; then the days are longer too.

Thirdly, whether the vessel will support all the sand laid upon it.

By putting 25 lasts on the raft one would make it sink half a foot, and therefore if these were 50 men with sand-nets and each had drawn half a last of sand, which would be a heap of about 4 tons, the vessel with 25 lasts of sand would have sunk half a foot and would still be half a foot above the water. But if experience taught that it would be profitable to put more sand at a time on the vessel before it is carried away, one might take away some of the ballast until the vessel was half a foot more above the water. As to the danger of sinking that is feared, this cannot happen for even if the water reached the gunwales of the vessel, one might still put 25 lasts of sand on it before it could sink, for it would be one foot higher in the middle than on the gunwales, and this entire foot there amounts to half a foot for the total vessel, which supports 25 lasts.

Fourthly, whether on each side of the vessel 25 men with nets might stand and whether there would still be sufficient space for the sand to be deposited and for the 50 rope-drawers to walk.

Each sand-dredger has behind him a space five feet long, where he can put hy 4 tonnen ſants leggen mach;als dat ſant lage 3 voeten breet, en dat yder ſanttrecker voor hem behielde 3 voeten breede daer hy op ſtaet, ſo ſouder tuſſchen beyde de ſanthoopen noch 13 voeten langde zijn om de toutreckers op te gaen, en als ſy malcander tegen quamen ſo ſou elc hebben $2\frac{1}{2}$ voet ſpatie. Doch ſoo de ervaringe leerden dattet te luttel waer,men mocht de ſanttreckers wat wyder ſtellen en weyniger nemen.

Ten 5, Of het vat ſterc genoech can gemaect worden.

De Scheeptimmerlieden en twyffelen daer an niet, maer ſeggen dattet ſtercker can gemaect worden dan groote hooge ſchepen, want de leegde meerder vaſticheyt veroirſaect.

Angaende het wercvolc, dat can des nachts in een ſchip ſlapen daer toe veroirdent op ſyn anckers liggende, voorſien met ſpys en dranc, alſoo datſe niet en behoeven an lant te commen ſoo lange het werc geduert.

Gedachteniſſen op de nieuwe dyckage vande Neringe.

Ic ſal moeten ſien caertſche wyſe de nieuwe dyckage vande Neringe, want comtſe aldus  ſoo iſt wel, maer comtſe aldus  ſoo iſt qualic, want deſe manier maect wel meerder diepte inde Wyſſel nevens de nieuwe dyc, maer tſelve ſal meerder ondiepte veroirſaken ande tonnen. De oirſaec daer af can hier uyt lichtelic verſtaen worden : Doen over ettelicke jaren den dam van het cleen Weerder deurbrac, en dattet Weerder vande Wyſſel overloopen wiert, ſoo quam doen (gelijcmen ſegt) ter Munde een diepte wel van 9 ellen, loopende rechtuyt vande kiſten af. De reden daer af was als kennelic is,dat al twater dat int cleen Weerder liep, was als (by manier van ſpreken) gevangen over de Dantzicker zijde, daerom moeſtet daer na over de Dantzicker zijde ooc uytloopen, makende ſulcke ſchuyringe.

Maer doen daer na het cleen Weerder wederom toegedyct wiert, ſo verminderde wederom die groote diepte an de tonnen, want het water int cleen Weerder geen plaets crygende, liep na Thaf toe. Hier uyt is te verſtaen dat de Neringe aldus bedyct zijnde, dergelijcke ondiepte ooc veroirſaken ſal, want het water dat inde Neringe pleecht gevangen

te

4 tons of sand; if his sand lay over a width of 3 feet and each sand-dredger kept in front of him a width of 3 feet on which he stands, there would still remain between each set of sandheaps a stretch of 13 feet for the rope-drawers to walk, and if they met each other, they would have a space of 2½ feet. But if experience taught that this was too narrow, one might space the sand-dredgers wider apart and take fewer.

Fifthly, whether the vessel can be made strong enough.

The shipwrights do not doubt this, but say it can be made stronger than tall and large ships, because of its lowness makes for greater stability. As to the workmen, they might sleep at night on board a ship riding at anchor for this purpose, being supplied with food and drink, so that they need not go ashore as long as the work lasts.

Memorandum on the new embankment of the Nehrung.

I shall have to inspect on the map how the new embankment of the Nehrung is laid out, for if it is like this  it is alright but if it is like this , it would be unfavourable, for this method would indeed give greater depth to the Weichsel along the new dike, but it will cause greater shoals at the buoys. When several years ago the dam of Klein Werder burst and the Weichsel ran into the Werder, a depth of 9 ells (as they say) was then reached at Weichselmünde, walking straight from the cofferdams. The reason was obviously that all the water running into the Klein Werder was (in a manner of speaking) caught on the Danzig shore, and therefore it also had to run off on the Danzig shore, thus effecting such great scouring.

But when the Klein Werder was embanked again, the great depth at the buoys decreased again, for the water, having no room in the Klein Werder, ran off to the Haff. From this it is to be inferred that the Nehrung, being thus embanked, will also cause such shoals, for the water which is usually caught in the Nehrung and then has to run off on the Danzig shore will now no longer be caught there, but will flow into the Haff.

If the embankment is thus , it is not so unfavourable at the buoys, but still disadvantageous rather than advantageous, for it is useful to have the greatest volume at the buoys, in order that the water may fall more abundantly and from a greater height.

te zijn en daer na over de Dantzicker zijde te moeten uytloopen, dat en sal daer nu niet gevangen worden, maer na Thaf loopen.

Comt de dyckage aldus  soo en ist niet so seer schadelic an de tonnen, doch eer wat schadelic dan vordelic, want het is goet de menichte by de tonnen te hebben om overvloediger en van hooger te vallen.

VOOR ELBING.

Verclaringe van Simon Stevin anden E: Raet der Stadt Elbing, van syne inventien om in geduerige diepte te houden de versande Olde stroom : Ooc de gantsche Vaert van voor de Stadt tot buyten, de Kisten toe.

Welke inventien by Stevin metten E: Raedt overcommen is te verclaren, op sulke voorwaerde datse niet int werc gestelt en sullen worden int geheel noch ten deele, sonder dat den E: Raet an hem Stevin, of an syn Volmachtige, daer af eerst vernoegen sal.

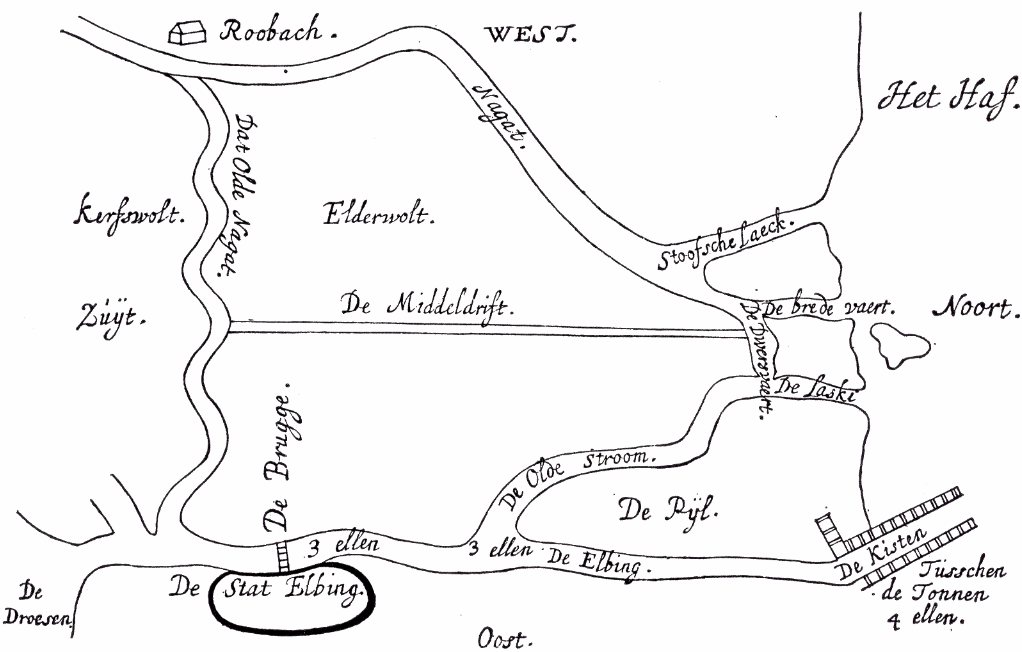
Voor al soo is te weten dat suyver water twelc met geen sant vermengt en is, gelijc ten tijde alst vriest ende in lang drooch weder, geen anwas van santplaten en maect, maer eer dieper schuyringe ende dat de anwassende santplaten alleenelic veroirsaect worden deur het dic sandich water des ysganx, snewaters en regenstrooms, welc het sant met grooter overvloet vande geberchte inde Wyssel brengt. Dit blyct metter daet ande tonnen die in verscheyden havens geleyt worden als te Dantzic, Melving, Coningsburch en meer ander, alwaer de veranderende santplaten gebrocht worden ten tijde des ysganx, ende van ander groote regenstromen, na welcke de tonnen somwylen moeten verleyt worden. Maer buyten dien tijt, te weten soo lange het Wysselwater suyver afcomt sonder sant, soo blyven de voorschreve santplaten ande tonnen onverandert. Ten anderen, soo blycket in ettelicke angewassen landen, dat sy haer anwas niet en crygen dan deur het voorschreve dic water des regenstrooms, snewaters en ysganx, wantmen an ettelicke canten der stroomen yder ysganx of hooge vloets anwas, d'een op d'an-

FOR ELBING

Declaration of Simon Stevin to the Noble Council of Elbing about his invention to keep constant depth in the silted-up river Olde, and also in the entire channel from the town beyond the cofferdams.

Which inventions he, Stevin, has agreed with the Noble Council to explain on condition that they will not be put into practice either in part or as a whole without the Noble Council first giving him, Stevin, or his deputy a renumeration.

First of all it is to be noted that pure water, not admixed with sand, as during frosts and in periods of drought, does not cause accretions to sandbanks, but rather tends to cause deeper scouring, and that growing sandbanks are only caused by the thick sandy water of ice-drifts, snow-water, and rain-water, which carries an excess of sand from the mountains into the Weichsel. This is evident in practice at the cofferdams placed in several harbours, such as Danzig, Melving, Königsberg and many others, where changing sandbanks are formed in times of ice-drifts and other strong currents due to rain, after which the cofferdams have sometimes been shifted. But beyond these periods, *i.e.* as long as the Weichsel water flowing along is pure and without sand, the above sandbanks at the cofferdams remain constant. Secondly, it is found in many such grown lands that they receive their accretions only from the abovementioned thick water of the rain, snow-water, and ice-drifts, for on many sides of rivers each ice-drift and high flood deposits accretions, one on top of the other, one



der fiet liggen een duym dic, somwylen meer, somwylen min, na dattet dic water overvloedich afgecomen heeft. De oirsaec waerom die anwassen also verscheyden op malcander leggen, is dattet gras ende cruyt wassende deur een tegenwoordige anwas, en daer op verdorrende, soo blyft dat selve gras en cruyt een onderscheyt tusschen dien anwas ende den toecommende. Uyt dese dingen blyct segge ic, dat niet dan dic water des ysganx, regenstrooms en snewaters, de ondiepte veroirsaect, en dat claer water niet dan meerder schuyringe en maect.

Dit verstaen wesende, soo sullen wy totte sake commen: Men sal leggen inde Dweervaert drie of vier roeden achter het hooft, een deure van form als hier onder geteyckent staet. Ende noch sulke een deure 18 of 20 roeden nederwaert, of soo veel roeden als oirboir sal verstaen worden. Voort salmen de Laski toe dammen, en alles sal gedaen zijn.

Siet de sluysdeuren voor Dantzic.

Met dese voorschreve twe deuren sullen te wege gebracht worden dese drie punten. Ten eersten, dat de Olde stroom niet meer versanden en sal. Ten anderen, datmen daer mede noch dieper schuyringe sal maken. Ten derden, dat de sluysen van Elderwolt veel beter haer water sullen loosen dan sy nu doen.

De canen, hout en schepen die van boven af na Elbing commen, sullen alhier meugen een corter wech varen dan deur de Olde stroom.

Tis ooc te weten dat de landen als Kerffwolt ende Elderwolt, geen perikel van hooch water noch ysganc en sullen lyden, meerder danse nu en doen, alsoo ooc en sal de brugge voor de Stadt Elbing, gemerct als voor geseyt is, datmen den ysganc en hoochwater daer buyten sal sluyten.

Somen noch veel meerder stroom wilde maken dan boven verclaert is, van voor de Stadt Elbing tot int Haf toe: Men sal leggen ant zuyteynde der Stadt vier of vijf optreckende sluysdeuren, neven malcander staende, ende meugen van form zijn als de bygevoechde figuer anwyst.

Siet die voor Dantzic.

Dese sluysdeuren toe zijnde, soo sal het suyver vvater int Olde Nagat, en ooc den heelen Droesen, op corter tijt so hooch verheven worden als de dammen verdragen connen; vvelc vvater ten hoochsten zijnde, soo salmen die sluysdeuren al tseffens optrecken, ende de heele verheven Droesen alsoo met grooter overvloet loosende ende valllende

inde

inch thick, sometimes more, sometimes less, according to the volume of thick water that has flown along. The cause why these alluvia form such distinct strata is that if the grass and weeds grow owing to a present accretion and wither thereon, the said weeds and grass form a division between this alluvion and the next. From these things it appears, I say, that nothing but the thick water of ice-drifts, rain-water, and snow-water causes the shoals and that clear water only causes great scouring.

This being understood, we will come to the point: In the Dweer canal three or four roods behind the pier a sluice-door should be built of the shape shown below. And another such door 18 or 20 roods downstream, or as many roods as is deemed suitable. Furthermore the Laske should be dammed, and this will be all. See the sluice-doors at Danzig.

With the above two doors the following three results will be achieved. Firstly the river Olde will no longer silt up. Secondly, the scouring will be even deeper with this method. Thirdly, the locks at Elderwolt will be able to drain their water much better than they do at present.

The boats, timber and ships coming from upstream to Elbing, will now be able to sail by a shorter route than through the river Olde.

It is also to be noted that lands like Kerswolt and Elderwolt will not be in danger of high floods or ice-drifts any more than they are now, and the same applies to the bridge in front of the town of Elbing, since as stated above, floods and ice-drifts will be excluded therefrom.

If it were desired to produce an even more powerful current than has been stated above, from the town of Elbing up to the Haff, at the south end of the town four or five vertical sluice-doors should be built side by side, and they might have the shape indicated in the annexed drawing. See those at Danzig.

These doors being closed, the clear water in the Olde Nagat and also the entire Drusen will be raised in a short time as high as the dikes will bear, and when this water is at the highest level, the doors should be raised simultaneously, and when the entire Drusen thus raised is drained very abundantly and falls into inde leege Elbing, ende dit al suyver vvater sonder sant, sal daer sulke schuyringe maken als dergelijcke stroomen elders doen.

VOOR BRAUSBERG.

Verclaringe van S. Stevin anden Eerbaren Raedt der Stadt Brausberch, van syne inventie, om de havenen in geduerige diepte te houden, vande Stadt af tot int Haf toe.

Welke inventie hy Stevin metten E: Raet overcommen is te verclaren, op sulke voorwaerde, datse niet int werc gestelt en sal worden int geheel noch ten deele, sonder dat den E: Raedt an hem Stevin of an syn Volmachtige, daer af eerst vernoegen sal.

Tis kennelic dat groote overvloedige stroom de eygen natuerlicke middel is die havens en rivieren in haer diepte hout. Dese versterckinge des strooms can alhier te Brausbergh seer geweldichlic vermeerdert worden, also datter een groote geduerige diepte uytvolgen sal van voor de Stadt tot int Haf toe, en dit door bequame middel van cleyne cost in deser vougen.

Neven de watermolens buyten de . . . poort ligt een dam die het water vande Passerge ophout: Inden selven dam salmen leggen drie of vier of so veel als oirboir sal verstaen worden optreckende sluysdeuren al neven malcander staende welke van sulke form meugen syn als de bygevouchde figuer anwijst: De selve deuren sullen so diep staen als de gemene gront der Passerge over de noortsyde des dams diep is, en sullen soo hooge commen datse het water soo hooge schutten alst lant boven verdragen can drie, vier, of vijf voeten (soot syn mach) hooger dan nu. Noch salmen voor de watermolens een schotdeur maken gelijc veel ander molens hebben, om als het water hoger comt, datmen daer mede niet meer waters en laet incommen danmen en behouft. Ende alles sal hier gedaen zijn.

Siet de sluys by de inventie voor Dantzic hier vooren.

T gebruyc hier af sal dusdanich wesen. Al de sluysdueren toe synde en door tbehulp der schotdeuren niet meer waters inde molens gelaten d'ander in en behouft, soo sal de Passerge over de zuytsyde der sluysen op corter tijt hooge connen verheven worden, voornamelic alst water over the low Elbing, and when all this is clear water without sand, this will cause the same scouring that is caused by rivers in other places.

FOR BRAUNSBERG

Declaration of S. Stevin to the Noble Council of the Town of Braunsberg about his new invention to keep the harbour at constant depth from the town down to the Haff.

Which invention he, Stevin, has agreed with the Noble Council to explain on condition that it will not be put into practice either partly or as a whole without the Noble Council first giving him, Stevin, or his deputy compensation.

It is obvious that a large strong current is the proper natural means of maintaining the depth of harbours and rivers. The current here at Braunsberg might be very greatly increased so that great constant depth will result from the town down to the Haff, and this by suitable means of little expense, in the following way.

By the side of the watermills beyond the ... gate there is a dam which holds back the water of the Passerge. In this dam there should be built three, or four (or as many as are deemed proper) vertical sluice-doors side by side which doors may have the shape shown in the annexed figure. See the doors of the invention for Danzig above.

The doors should reach as deep as the common bottom of the Passerge on the north side of the dam, and should be so high that they drain the water as high as the land will allow, three, four, or five feet (if possible) higher than at present. Furthermore in front of the watermills doors should be made as in many other mills, in order to let in no more water than is wanted if the water rises higher. And this will be all.

Its application will be thus. When all the doors are shut and by means of the mill-sluices no more water is admitted to the mills than is needed, the Passerge south of the sluices will rise high in a short time, especially if the overvloedich afcomt: Tselve water hooch genoech zijnde, so salmen de schotdeuren voor de watermolens gants toe doen, en laten de Passerge over de noortzyde der sluysdeuren drie of vier stonden lanc soo drooch afloopen als sy afloopen can. De Passerge aldus over d'een syde der sluysen ten hoochsten en over d'ander syde drooge ofte ten leegsten zijnde, so salmen al die sluysdeuren t'seffens op winden, ende het water vallende met sulcken menichte en sulcken hoochde, sal daer mede een schuyringe maken vande molens af voor by de Stadt tot int Haf toe, soo diep als de natuerlicke macht van sulke geweldigen stroom mede brengen sal.

Tis ooc te weten dat dese manier van schuyringe veel meerder diepte veroirsaect dan ofmen deur inbringinge van ander rivieren (soot meugelic waer) den stroom van so veel vermeerderde, uyt oirsaec dat vermeerderinge des strooms deur ander rivieren ooc meer sants van boven mede brengt twelc hem buyten de kisten legt. Maer na dese wijse wort groote geweldige stroom gecregen met een selve water dat niet meer sants buyten de kisten brengen en can dan het te vooren gedaen en heeft.

Het sal seer vorderlic syn dese schuyring dicvvils te doen ten tyde alst vriest, vvant soo de ervaringe van dergelijcke schuyringen in Hollant ende Zeelant leert, het ys telcken brekende ende sleypende langs den gront, maect groote diepte.

Wat de oncosten van dese sluysdeuren belangt, die en sullen so groot niet zijn, of ten wort bevonden dat in Hollant niet alleen Steden, maer ettelicke Dorpen, veel meerder oncosten doen om door sluysen en waterhouders diepten te maken, daer hun nochtans niet soo veel an gelegen en is als de Stadt Brausberch an dese diepte.

Angaende dat de Watermolens altemet een halven dach souden moeten stille staen te wyle dese schuyringē gedueren, dat waer een sake van cleen belanc, te meer dattet meugelic is de selve Watermolens alsо toe te maken datse op tvve dagen so veel souden doen als nu op drie.

VOOR DEVENTER EN ZUTPHEN.

Memorie vande middelen dieder zijn om het lant rontom Deventer tGraefschap Zutphen onder water te houden.

Ten eersten, datmen sal stoppen de Oude Yssel tot Duysborg, ende en laten de Mole aldaer niet malen. Daer nae de Berckel tot Zutphen sgelijx de Mole toehoudende sonder malen.

Daer

water flows off abundantly. When this water is high enough, the sluices of the water-mills should be completely closed and the Passerge should be allowed to drain north of the sluice-doors for three or four hours until it is as dry as possible. When the Passerge is thus at its highest on one side of the sluices and dry or at its lowest on the other side, all the doors should be raised simultaneously, and the water falling in such quantity from a great height will then cause scouring from the mills past the town down to the Haff, as deep as the natural power of such a powerful current will allow.

It is also to be noted that this method of scouring causes greater depth than if by letting in other rivers (if this were possible) the current were increased to this degree, because an increase of current through other rivers also brings along more sand from upstream which is deposited beyond the cofferdams. But by this method a large powerful current is obtained with the same water, which cannot bring more sand beyond the cofferdams than it did before.

It will be very profitable to perform this scouring frequently when it is freezing, for as experience with such scouring in Holland and Zeeland teaches, the ice, which breaks repeatedly and grinds along the bottom, causes greater depth. As to the expense of these sluice-doors, this will be not so large, for it is found that in Holland not only towns but many villages go to much greater expense to produce depths with locks and basins, though this is less important to them than is the depth to the town of Braunsberg.

As to the fact that the watermills would have to stop for half a day during the scouring, this is a matter of little importance, the more so as it is possible to construct these watermills in such a way that they could perform as much in two days as now in three.

FOR DEVENTER AND ZUTPHEN

Memorandum on the methods available for keeping the land around Deventer in the county of Zutphen inundated.

Firstly, the Old IJssel should be dammed at Doesburg, and the mill there should not work. Then the Berkel down to Zutphen should be dammed and

Daer na het beecxken beneden Zutphen, genaemt ſomen meent, het Bolixbeexken lopende onder de ſteene brugge deur. Op dat de bovegſchreven beken hooger gebrocht worden, ſoo ſalmen Stortebedden en ſchotdeuren verhoogen van twe of drie planccken, of ſoo veel alſmen oirboir bevint.

Ende gemerct hier mede de leege landen onder water gebrocht worden, ſo verſtaen wy dat de voornoemde ſtopping der beken tot Zutphen terſtont gedaen worden.

VOOR RYNBERC.

Voorſlach hoemen de gracht der Schans te Berc bequamelic ſou meugen diep houden ſonder verſanden, ooc ſonder beeren te leggen.

De beec die nu loopt vande watermolen A na B tot C, ſalmen an B ſtoppen, en doen loopen rechtuyt van B tot D, van daer overbeyden ſyden om de Schants deur de gracht, uytcommende in den Ryn an E. En de uytgegraven aerde ſalmen an beyde ſyē̃d ſo leggen, dattet hoog water inde beec niet en comme, voorſiende de twe hoecken by E wel met rijs.

Dit ſo zynde, daer ſou als dan noch meerder diepte inde beke commen dander nu is, om datſe vant hoogh water met ſant en cley niet vervult en ſou worden, en dattet water daer in ſoo wel ten tyde van hooch water als van leegh, altijt eenen wech ſou loopen uytcommende an E. Sulx dat daer geen rijnwater in loopen en ſal, en vervolgens geen ſant noch cley.

Maer ſomen de kille van B tot E noch veel dieper wilde hebben, dat can aldus toe gaen: Men ſal opt ſtortebedde der Watermolen by A, maken een of tvve optreckende ſluysdeuren vvaer me twater totten gronde toe wech can loopen, ſo leege als het water voor de molen diep is, en maken daer me ſchuyring ſoo dicwils alſmen oirboir verſtaet. Twelc grote diepte ſou maken, gelijcmen van ſulke ſchuyring in Hollant en Zeelant veel voorbeelden heeft.

Noch is te weten datmen de plaets goede verſekerheyt ſou connen geven, met een borſtweer te maken vande opgeworpen aerde der beke, en dat over de ſyde van D: Want tis daer voor te houden, dat ſoo lang de belegerde de ſchants hebben ſoo lang de vyant tuſſchen de Stadt the mill there also should stop working. Then the brook below Zutphen, presumably called the Boliksbeek, running below the stone bridge, should be dammed. In order that the brook may be raised higher, fascine-work and doors should be raised by two or three boards, or as much as is deemed suitable.

And since the low lands can thus be inundated, we hold that this damming of the brooks at Zutphen should be effected immediately.

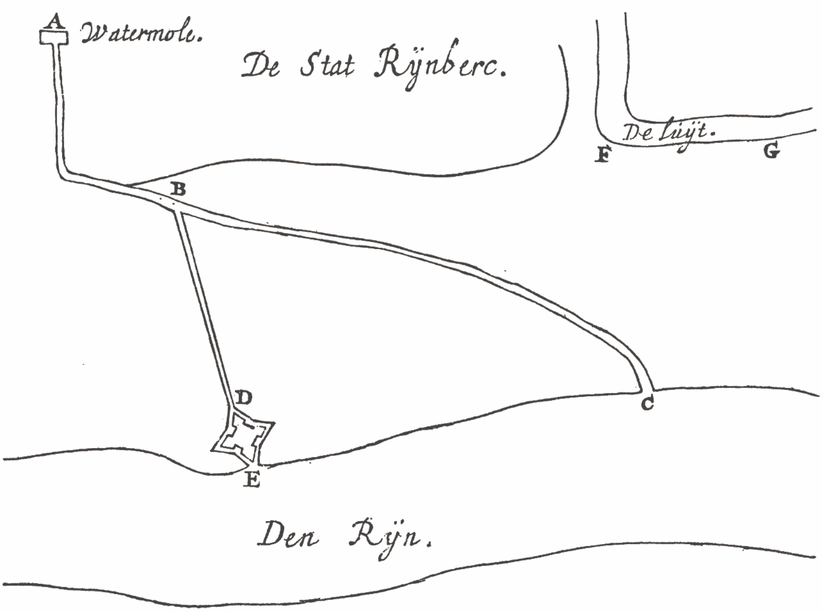
FOR RHEINBERG

Proposal as to how the ditch of the redoubt at Rheinberg can easily be kept deep without its silting up, even without dams being built.

The brook which now runs from the watermill *A via B* to *C* should be dammed at *B* and be made to run straight from *B* to *D*, then on both sides around the redoubt through the ditch, flowing into the Rhine at *E*. And the excavated earth should be cast on both sides, so that the high water will not enter the brook, the two corners at *E* being properly reinforced with fascine-work.

This being so, there would then arise greater depth in the brook than at present, because it would not be filled by flood waters with sand and clay and the water in it, at periods of high as well as low water would always follow the same course, ending at *E*. Thus no Rhine-water will enter and consequently no sand or clay.

But if one should want an even deeper channel from *B* to *E*, this might be obtained thus: On the fascine-work of the water-mill at *A* one or two vertical sluice-doors should be built, by means of which the water can be drained completely down to the bottom, as low as the depth of the water in front of the mill, and thus scouring should be effected as often as is deemed profitable. This would produce great depth, as many examples of such scouring in Holland and Zeeland show.



den Rijn geen leger te connen slaen , sulcx datmen achter dat borstweer vande Stadt totte Schants, sal meugen gaen en keeren om die te ontsetten.

Merct noch datmen met schepen sou connen commen uyt den Ryn tot ande Stadt by A : En ooc met groote schepen als het Rynwater wat hoochachtich waer.

Het sou ooc oirboir wesen gelijc syn Excell: voorwent, datmen de Luyt nu neerwaert lopende van F na G, dede keeren van F na B deur de gracht der buyte werken die nu drooch ligt , werpende de aerde daer uytcommende nade Rynsyde, so hooch datter het Rynwater uyt bleef. Waer deur de plaets met cleene cost seer sou versterken, het sou ooc dan van B tot E connen een goede haven worden tot groot gerief der Stadt.

VOOR SCHIEDAM.

Schiedamsche haven verslemt. Men souse connen helpen sonder ander spilsluysen te maken , leggende alleenlic ter plaets van A, B en C drie slechte deuren, en openende nu d'een dan d'ander, somwylen beyde tsamen, gelijc gesceyt is vande deurẽ des 13 forms vande voorgaende waterschuering; Maer de deure C altijt alsmen schuyrt gesloten blyvende.

VOOR LINGEN.

Voorslach hoemen de watermolen sou meugen leggen binnen de Stadt Lingen tegen't middel van een wal, blyvende nochtans het water des grachts in syn behoorlicke hoochde, en dat sonder beeren of dodanen.

Laet A en B twe bolwercken beteycken met een wal tusschen beyden, C het huys vande watermolen geleyt inde wals afdaking. Hier toe sal de waterloop veroirdent worden als volgt.

D E is een houte coker inde wal, diens bovencant so hoog mach commen als het leegste vvater des grachts. De gront van dien coker sal als een vvaterloop verlangt vvorden van E tot F, van F tot G, en van G tot H, al inde selve hoochde des gronts der coker D E. Maer van H voorvvaert tot den wal an I , sal sulken gront des vvaterloops veel dieper geleyt vvorden , te vveten ontrent een voet leger dan de beke an K.

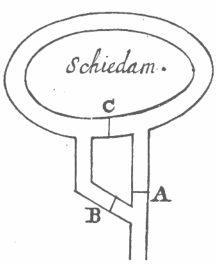
Daer

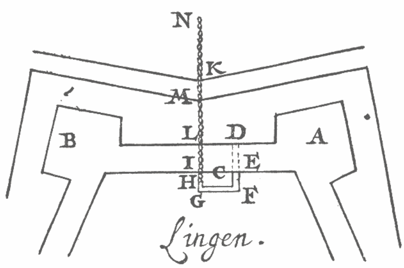
It is also to be noted that the site might be strongly fortified with a bulwark made with the excavated earth from the brook, and that on the side *D*: For it has to be assumed that as long as the besieged hold the redoubt, so long the enemy cannot camp between the town and the Rhine, so that it will be possible to go back and forth between the town and the redoubt behind the bulwark to relieve the town.

Note also that one would be able to sail with ships from the Rhine upto the town at *A*, and also with large ships when the Rhine water is rather high. It would also be profitable, as His Excell. proposes, if the Luyt, now running down from *F* to *G*, were diverted from *F* to *B* through the ditches of the outer works, which is now dry, the excavated earth being cast to the side of the Rhine, so high that the Rhine water was kept out. By this means the town would be considerably fortified at little expense; the part from *B* to *E* might then also form a good harbour, to the great convenience of the town.

FOR SCHIEDAM

The Schiedam harbour is silting up. One might remedy this without building other sluice-locks, only building at *A*, *B*, and *C* three simple sluice-doors and opening now one, now the other, sometimes two simultaneously, as has been stated in Figure 13 of the preceding Water-scouring, but the door *C* always remaining closed during scouring.





FOR LINGEN

Proposal as to how the watermill might be laid inside the town of Lingen against the middle of a wall, the water of the ditch nevertheless keeping its proper level, and that without dams or dodanes.

Let *A* and *B* represent two bulwarks with a wall in between, *C* the house of the watermill constructed in the slope of the wall. For this purpose the watercourse should be regulated as follows:

DE is a wooden pipe in the wall, the top of which may be as high as the lowest level of the ditch water. The bottom of the pipe should be extended as a watercourse from *E* to *F*, from *F* to *G*, and from *G* to *H*, all at the same level as the bottom of the pipe *DE*. But from *H* upto the wall at *I*, the bottom of the watercourse should be laid much deeper, *i.e.* one foot deeper than the

Daer na salder geleyt vvorden een ander coker rechtuyt van I tot K diens gront inde selve hoogde sy van H I, als van I deur de vval I L, en voort op de gront des gracht L M, (gelijcmen in Hollant de cokers legt om polders drooch te malen met vvatermolens die over d'ander syde vande vvatering liggen) en ooc deur de contrescharpe M K, commende daer inde beke K N. Dese vvaterloop aldus gemaect zijnde, soo sal het vvaterrat vande vvatermolen commen ter plaets van H I, en sal tvvater syn behoirlicke val hebben; Voort salmen de vvaterloop E F G H met plancken decken om vryelic daer over te meugen gaen.

Tis ooc te vveten datmen hier me versch loopende vvater inde Stadt sou hebben; En by aldienmen den loop langer begeerde dan van F tot G, tis kennelic datment doen mach na syn vville.

VOOR CALES.

Manier hoemen de Stadt Cales sou connen versterken na de meyning van Simon Stevin.

Angesien dese Stadt quade grachten heeft, ja tot sommige plaetsen geen, so schynet dat heur bolvverken, al synse sterc, geen heftige belegering en sou connen weerstaen. Wat belangt de ophouding des vvaters diemen sou connen doen om tegen sulc ongeval te voorsien, deur de haven ande rysbanck, 't schynt vvel dattet beloofde daer uyt sou volgen, maer tvverc sou seer besvvaerlic, ende de oncosten groot vallen.

En tschynt datment sou connen doen met een beec of gracht, en sluysen van minder cost en niet min voordeel, waer van de meyning deur dese nevengaende grontteyckening verclaert wort, als volcht:

Men sou een beec maken gelijc met A B C D E angewesen wort, diep 6 voet onder den leegsten vlacken gront, breet 100 voet inden bodem, int lege lant den bovecant breet 120 voeten, ende inde hooge plaetsen breder na den eysch.

In dese beec salmen drie sluysen stellen gelijc ter plaetsen van A, C, D, en noch drie an F, G, H, maer an I is de oude sluys.

De schuyring met dese sluysen sou aldus toe gaen: De grachten der Stadt en dese nieuwe gracht, mettet hooch water gevult wesende, men sou opt leech water de vier sluysen C, D, F, I, gesllooten laten, ende de twe A, G, open doen, schuerende daer me deur de ledige kreecke die brook at *K*. Thereafter another pipe should be laid straight from *I* to *K*, the bottom of which should be at the same level as *HI*, from *I* through the wall *IL*, and further on the bottom of the ditch *LM* (as in Holland they lay down pipes to drain the polders with watermills which are on the other side of the water) and also through the counterscarp *MK*, running there into the brook *KN*. This watercourse thus having been built, the waterwheel of the watermill should be placed at *HI*, and the water will have its proper fall. Furthermore the watercourse *EFGH* should be covered with boards in order that one may walk freely across. It is also be noted that the town would thus have fresh running water. And if the course were desired to be longer than from *F* to *G*, it is obvious that this may be done at will.

FOR CALAIS

Method of fortifying the town of Calais according to the opinion of Simon Stevin.

As this town has poor ditches, in some places even none, it seems that its bulwarks, though strong, will not be able to resist any violent siege. As to the damming-up of the water which might be effected to provide against this disadvantage by means of the harbour at the osiered dam, it may seem that the results aimed at might be thus obtained, but the work would be very difficult, and the expense would be great.

It seems that one might effect it with a brook or ditch and sluices, at lower cost and no less profit; the groundplan of the annexed drawing will explain this as follows: One should make a brook, as indicated by *ABCDE*, at a depth of 6 feet below the lowest level ground, 100 feet wide at the bottom, 120 feet wide at the top in the low country and in higher places wider according to demand. In this brook three sluices should be built at the points *A*, *C*, and *D* and another three at *F*, *G*, *H*, the old sluice being at *I*. The scouring with these sluices should take place thus. The ditches of the town and this new ditch being filled at high water, one should keep the four sluices *C*, *D*, *F*, and *I* closed at low water, and open the two *A* and *G*, thus scouring the empty creek na de have loopt. Maer om dergelijcke schuyring ooc an d'ander zijde der Stadt te doen, men mocht de vier sluysen A, G, C, I, sluyten, openende de twe D, F.

Dese schuyring soumen soo dicwils doen, ende an die zijde meer als an d'ander, als den oirboir vereyschte. De haven van Middelburch in Zeelant, wesende een halfuyr lanc, wort alleenlic (gelijc my ymant geseyt heeft) twemael ter weec geschuyrt.

Maer op dat de oude mueren der Stadt deur dese schuyring geen perikel en lyden, soo soudet oirboir zijn dit schuyrende water inde oude binnegrachten niet te laten commen, maer vier beeren te stellen ter plaetsen van K, L, M, N, soo hooch als noodich waer. An O en souder geen behoeven, om datter tegenwoordich een is.

Noch is te weten dat den voet voor de bolwercken, versorcht moest zijn met ryswerc of planckering, op datse niet wech en schuyrden, want daer muervalling uyt sou volgen.

Indien de ervarenheyt leerde dat de schuyring tegen de bolwercken te crachtich was, ende dattet onderhout van dien voet, meer sou costen dan oirboir waer daer aen te besteden, soo soumen de sluysen G,H,F,I, connen toe houden, want alsdan en sou in die gracht geen schuyring commen, maer alleenlic inde uyterste Nieuwe A B C D E.

De sluys H sou ooc tot desen eynde nut wesen: Den vyant gewonnen hebbende de buyten gracht, en gebroocken de sluysen A, D, men sou de sluys H mogen sluyten en daer aerde voorwerpen, vullende de gracht die om de bolwercken loopt met water, en dagelix schuyrende.

Noch soudet oirboir zijn tot seker lege plaets als an P, een houwer of boesen, groot 200 bunders, gelijc hier geteyckent is, te maken, of een ander grooter, want hoe grooter hoe beter.

Ter plaets van B, soumen voor eerst een scheepsbrug meugen leggen en de haven daer na diep genoech geschuyrt zijnde, een houten brugge.

Mette aerde uyt de gracht commende, soumen twe bedecte wegen connen maken, an elcke zijde eene, dienende soo wel voor dycken tot versekering des lants, als om sich daer mede als met bedecte wegen te behelpen.

De sluys by C, sou ooc dienen om in tijt van belegering het lant onder te doen loopen. Ende de sluys H, om volgens tgemeen gebruyc met schepen inde Stadt te commen.

which runs to the harbour. But to scour similarly on the other side of the town, the four sluices *A*, *G*, *C*, and *I* should be closed and the two *D* and *F* opened.

This scouring should be performed as often as deemed proper, and on one side more than on the other. The harbour of Middelburg, having a length of half an hour's walk, is only scoured twice a week (as somebody told me). But in order that the old walls of the city should not be endangered by this scouring, it would be profitable that this scouring water should not enter the old inner ditches, but that four dams should be placed at *K*, *L*, *M*, and *N*, as high as necessary. At *O* none would have to be built, since there is one already.

It should also be noted that the foot in front of the bulwarks should be protected with fascine-work or boards so that they may not be scoured away, for then the walls would collapse.

If experience taught that the scouring against the bulwarks is too strong and that the maintenance of the foot would cost more than would be proper to expend on it, the sluices at *G*, *H*, *F* and *I* might be kept closed for then there would be no scouring in the ditches, but only in the outer new brook *ABCDE*. The sluices *H* would also serve this purpose. If the enemy had conquered the outer ditch and broken the sluices *A* and *D*, the sluice *H* might be closed and earth cast in front of it, the ditch surrounding the bulwarks being filled with water and scoured daily.

It might also be profitable to build a basin or "*boezem*" in a given low place like *P*, 200 hectares large, as shown here, or a larger one, for the larger the better. At *B* first a pontoon-bridge might be made, and when the harbour has been scoured to a sufficient depth, a wooden bridge.

With the earth from the ditch two covered ways might be made, one on each side, serving both as dikes, to protect the land, and as covered ways.

The sluice at *C* might also serve in time of siege to inundate the country, and the sluice at *H* in order to enter the towns with ships, according to common practice.

Noch is te weten dat in dese sluysen twe ander deuren commen, welke alsmen wil, het water der Zee buyten de haven houden, twelc tot twe dingen dient: Ten eersten, datmen daer deur te wege can brengen, dattet binne water vant lant (alsmen niet en schuyrt) geduerich uyt het lant loopt, soo wel in tijt van hooch als leech water, twelc aldus toegaet: TZeewater ten leechsten zijnde, ende de grachten ledich, men sou de twe boveschreve deuren sluyten, keerende het toecommende hooch Zeewater; ende ondertusschen sou het soet water die grachten vullen: En de Zee daer na weder leger wordende alst binnewater, die deuren sullen haer selven openen, haer ontlastende vant op gehouden water; Daer na andermael als vooren gedaen, tbinnewater sal geduerich uyt het lant loopen. Ten tweden, de voorschreve deuren souden dienen om de grachten drooch te houden alsmen eenige wercken inde bodem wilde maken, of eenige hindernissen anden voet der mueren of dycken verbeteren.

Men sou voor dese sluysen bolwercken connen veroirdenen, gelijc an gewesen is mette form voor de sluys D.

Al en waert ten tijde van leech water inde kreecken tusschen de sluysen ende de Zee niet diep genoech, men sou (als den vyant daer deur wilde commen om te stormen) een of verscheyde deuren connen openen, sulx dattet water daer soo lange deur sou loopen, tot dat de Zee hooch genoech gewassen waer.

Gedachtenis op den Rijsbanc.

Angesien des bolwerx voorzijde na de Zee toe, niet gestreken en is, men sou een werc van rys connen maken gelijc met A angewesen wort.

Voor dit gebou is een grachtken met plancken becleet, int welc selden het water comt, gelijc hier met B angewesen wort, twelc so ondiep veroirdent wiert, op dat het sant onder de gronden niet wech en sou schuyren, en het bederf des gebous veroirsaken. Maer om daer een beter diepte, sonder gevaer voor te hebben, men mach voor het grachtken B een ander dieper van ryswerc maken, gelijc hier met C angewesen is; Maer somen dadelic bevont dat sulc grachtken geen hinder ande have en dede, men soudet daer na breeder en dieper connen maken, om alsoo tgebou in een Eylandeken te veranderen.

It is also to be noted that in these sluices there will be two other gates, which, if desired, keep the water of the sea out of the harbour, which will serve two purposes: Firstly, it can thus be ensured that the inner water (when not scouring) should drain continually from the land, both at high and at low tide, which takes place thus. The sea water being at it lowest level, and the ditches empty, the two above gates should be closed, thus stemming the oncoming sea-water; and in the meantime the fresh water should fill the ditches; and the sea-water then running down again below the level of the inner water, the gates will open themselves, draining off the confined water. If then the same process is repeated, the inner water will continually drain from the land. Secondly, the above gates might serve to keep the ditches dry, if certain works had to be executed on their bottom, or certain repairs had to be made at the foot of the walls or dikes. In front of these locks bulwarks might be built, as is shown in the figure in front of sluice *D*.

And even if at low tide the creeks between the locks and the sea were not deep enough, one or more sluices might be opened (if the enemy wanted to cross them in order to assault), so that the water would run through until the sea had risen to a sufficient level again.

Notes about the osiered dam

As the front of the bulwark towards the sea is not plastered, fascine-work might be made, as indicated at *A*. In front of this structure there is a small ditch timbered with boards, into which the water seldom enters, as shown at *B*, which is made so shallow in order that the sand beneath the foundations should not be scoured away and cause the decay of the masonry. But in order to have there greater depth, without danger, in front of the small ditch *B* another deeper one of fascine-work may be made, as indicated as *C*. But if it were found in practice that such a small ditch does not cause any trouble at the harbour, it might be made deeper and wider, so as to change the structure into a small island.

Gedachtenissen op de Brugge de Nielay.

Men sou een pilaer uyt de brugge wech connen nemen, ende van twe sluysen een maken, welke (gelijc in Hollant) sich selfs open en toe dede, de selve soo diep settende alsmen conde. Deur dit middel soumen het lant veel hooger uyt het water crygen als het nu is, streckende tot syn groote verbetering.

De bogen der voorseyde twe sluysen met een pilaer wech genomen wesende, en dan een valbrugge van hout daer op gemaect zijnde, het sou tot beter bewaring des lants strecken.

Wat de sterckte aldaer gebout belangt, men sou die connen verformen ende hermaken.

Tvoorgaende is oirdening mette minste cost, maer alsser genoech penningen waren, ic sou een dyc deur de have leggen, in manier als een ander grontteyckening hier neven gaende verthoont. Ende hier me soumen ooc de voordelen hebben diemen sich belooft door de ophouding des waters, te weten het hele lant an die zijde onder water houden.

Gedachtenissen op de versterckinge van Cales, an M. de Vic gesonden na syn vertrec.

Omtrent Q mochtmen een sluys stellen dienende tot schuyring der gracht voor de bolwercken; Ooc om de duynen wech te schuyren, tot welcken eynde men een Ezelsrugge sou stellen gelijc ontrent R, en van daer voort een graft graven na de duynen toe, gelijc mette tippelingen angewesen wort.

S beteyckent een Verlaet, om daer deur de schepen van Greveling inde boesem te commen, en van daer voor de Stadt.

De kreec voor de brugge de Nielay deelt hem in tween, commende het grootste deel langs de duynen des rysbanx, gelijc hier van A na B, en het cleenste deel van d'ander zijde, gelijc van A na C, loopende van daer langs het Casteel. Nu indienmen de groote kreec by A stoopte met ryswerc drie of vier voet hooch, of soo hooch alsmen oirboir bevant, men sou alsoo veel water inde kreecke A C doen loopen, die daerom ooc dieper sou worden; Waer toe noch sou connen helpen alsmen alsoo stopte alle cleene kreeckens uyt de kreecke A C nae den rysbanc uytloopende. Ende hier deur sou de kreecke langs het Casteel dieper worden

Notes about the Nielay Bridge

One might remove one of the pillars of the bridge and make the two sluices into one, which (as in Holland) opens and shuts itself, placing it as deep as possible. By this means the land would be raised much higher from the water than at present, which would result in a great improvement.

If one pillar were removed from the arches of the aforesaid two sluices and then a wooden draw-bridge were built on top, this would serve as a better protection of the land. As to the fortification built there, this might be rebuilt and reshaped.

The above is a method entailing minimum expense, but if there were sufficient money, I should lay a dike through the harbour, as indicated in another annexed ground-plan. And this would also yield the advantage aimed at in holding back the water, *i.e.* the inundation of the entire land on that side.

Memorandum about the fortification of Calais sent to M. de Vic after his departure.

Near *Q* one might build a sluice for the scouring of the ditch in front of the bulwarks, and also in order to scour away the dunes, for which purpose a dam should be built, e.g. at *R*, and thence a ditch should be excavated towards the dunes, as is shown by the dotted lines.

S indicates a navigation weir, through which the ships from Grevelingen may enter the basin and thus arrive in front of the city.

The creek in front of the Nielay Bridge divides itself in two, the larger part flowing along the slopes of the osiered dam, as here from *A* to *B*, and the smaller part on the other side, as from *A* to *C*, running from there past the castle. If the large creek at *A* were now dammed with osiers three or four feet high, or as high as was found suitable, one might cause much water to run into the creek *AC*, which accordingly would become much deeper.

To achieve this it might also be helpful to dam all the small creeks flowing from the creek *AC* towards the osiered dam. And thus the creek running past worden, maer tsou dan noodich zijn de muer vant Casteel met rysweroken te versorgen.

Soot beslooten waer dese wercken te maken, ic sou een ander gront-teyckening senden, int welcke op alles beter sou acht genomen wesen.

Ic versta seer noodich, borstweren met haer voetbanc op alle bolwercken en wallen te maken, want sonder die, de belegerden en durven alst noodich is, niet op de wallen commen. Angaende datmen segt die te sullen maken als de vyant voor de Stadt sou zijn, tis dan te laet, want dan zijnder veel ander wercken te maken; ende dat meer is, soumen alle dese borstvveren na behooren maken, tsou een vverc vvesen groot genoech in tijt van vree.

Overslach der oncosten soo naet oirdeel sommiger Werclien herwaerts over, als van dergelijcke werc elders gemaect.

De gracht lanc ontrent 1200 ellen, diep een elle, inde bodem breet 100 voet, boven vvyt 120 voet, begrypt 22000 ellen; Ende noch daerenboven het vierdepart vandien, bedragende 5500 ter oirsake vant hoge lant, maken tsamen 27200 ellen, tot 30 stuyv. de el, comt - - - - - -	*guld.* 41250
Den dyc vanden boesem 1588 ellen, beloopende 15 st. maect ontrent - - - - - -	1200
Voor de gracht die gemaect moet vvorden ande incomst des bosems, en lanc sal vvesen 100 ellen breet $18\frac{1}{3}$, bedragende 1833 tot 30 st. de el, maect - -	2750
De ses Sluysen genomen d'een deur d'ander, op 6000 guld. bedraecht - - - - - -	36000
Somen het rys haelt inden Hout vanden Coninc, gelijcmen seyt datment daer can crygen, vvesende op de cant vant vvater, tfatsoen daer van, de schreepsvragt en tgene vorder gelt soude moeten costen om int vverc te stellen, mach geschat vvorden op -	10000
Tvve houten brugge lanc 120 voet, mogen bedragen -	5000
De wercken anden rysbanc en brugge de Nielay, mogen gerekent worden op - -	6000

De

the castle would become deeper, but it would then be necessary to protect the wall of the castle with fascine-work.

If it were decided to make these works, I should submit another ground-plan taking everything better into account. I deem it highly necessary to make parapets with their bases on all the bulwarks and walls, for without these the besieged, if necessary, will not dare to appear on the walls. As to the statement that these would be made when the enemy is in front of the town, that would be too late, for then many other works would have to be made; and, which is more, if one were to make all these parapets properly, this would be a sufficiently large job in time of peace.

Estimate of the expense based on the opinion of some local craftsmen as well as on that of similar work made elsewhere.

	guilders
The ditch, 1,200 ells long, one ell deep, 100 feet wide at the bottom, 120 feet wide at the top, comprises 22,000 cubic ells; and another quarter of this amount being added, *i.e.* 5,500, because of the high land, this makes a total of 27,200 at 30 *stuyvers* an ell, which makes . .	41,250
The dike of the basin 1,588 ells at 15 *stuyvers*, makes about . .	1,200
For the ditch to be made at the inlet of the basin, which is to be 100 ells long, 18.1/3 ells wide, being 1,833 at 30 *stuyvers* an ell, this makes	2,750
The six sluices, taking on an average of 6,000 *guild.*, makes . . .	36,000
If the osiers are obtained from the King's Forest, as it is said that they can be got there, delivered on the bank, their shaping, the freight, and any further expense entailed by the work, may be estimated at . . .	10,000
Two wooden bridges, 120 feet long, may cost	5,000
The works at the osiered dam and the Nielay Bridge may be calculated at	6,000

De sterckte voor de sluys met syn gracht, mach commen te costen ontrent - - - - - -	18000
	4000
	6000
Somme -	130200

An Monſ. de Vic Gouverneur tot Calis.

MYn Heer, myns bedunckens en waert niet oirboir de duynen soo leech wech te nemen datter de hooge vloeden overliepen, wantse met grote storm commende, sy souden deur het slaen der baren wech genomen worden: Tis wel waer datmense sulx sou connen voorsien met ryswerc datse bleven, maer tschynt dat de oncosten van onderhout, hooger souden climmen als oirboir waer daer an te besteden. Ic sende u de teyckening vande deursnyding des rysbanx, waer in voorgenomen was twe borstweren te maken gelijcmen siet, en dunct my soo beter dan na de teyckening die gy my sent, &c.

An den selfden.

MYn Heer, ic heb u brief vanden 10 deser ontsangen int welke het ontworp van U Ed: angaende de schuyring mette sluys des bodems my oirboir schynt. Maer men sou connen over leggen oft niet soo goet en sou wesen daer een minder sluys te stellen om te blyven ende de duynen gedeurich voorwaert te schuyren; Ooc om het sant dat mettet tijt op de geleeghde plaetsen mocht wederom commen an te groyen, wech te schuyren. Voorts om voor de twe bolwercken diemen daer by sou mogen leggen een diepe gracht te behouden: Dese sluys sou ooc de schuyring der vloet vermeerderen daer van ic hier een teyckening sende.

Tschynt dat indient maken van die twe bolvvercken voorgenomen was dattet niet noodich sou syn daer me te vvachten tot dat dese schuyring der duynen volbracht waer.

Ic sende de manier der slachoirdening en d'oirdening der logiering van twe regimenten d'een van voetvolc d'ander van Ruyters. Belangende logiering van een heel leger, en d'opmerckingen angaende het Grofschut, dat sal tot een andermael zyn, vvant ic heb de gedachtenis hier niet.

Lopen-

The fortification in front of the locks with the ditch may cost about	18,000
	4,000
	6,000
Sum total	130,200

To Mons. de Vic. Governor of Calais

Sir, According to my opinion it would not be proper to dig the dunes so far away that the high floods would flow over them, for with large storms they might be washed away by the beating of the waves. It is true that this might be prevented by fascine-work, but it seems that the cost of upkeep would rise higher than seems proper to expend on this. I am sending you the drawing of the cross-section of the osiered dam, in which it was intended to make two parapets, as shown, and this seems to me better than according to the drawing you sent me, &c.

To the same

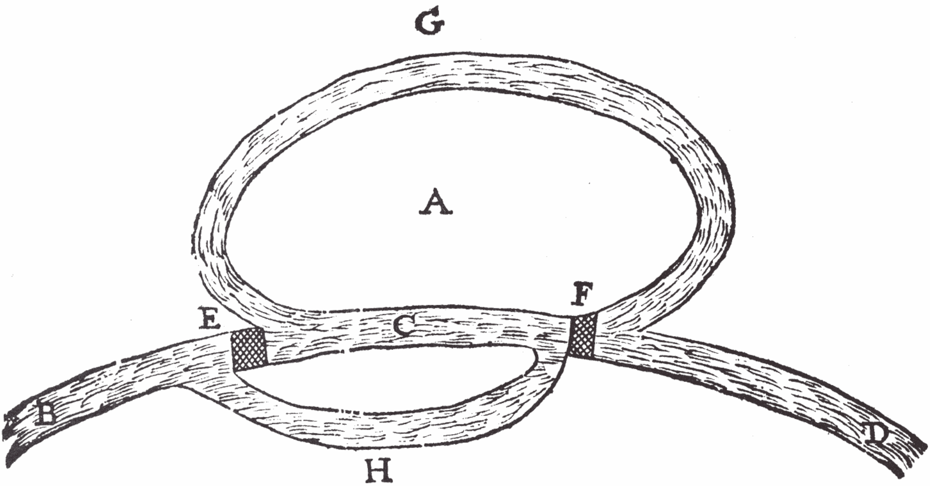
Sir, I have received your letter of the 10th inst., in which Your Hon.'s project of the scouring of the bottom with the sluices seems suitable to me. But one might consider whether it would not be as well to build there a small permanent sluice and to scour the dunes forward constantly, and to scour away any sand that should in time grow again in the lowered places. Furthermore to keep a deep ditch in front of the two bulwarks which one might build there. This sluice would also increase the scouring of the flood-tide, of which I am here sending a drawing.

It seems that, if the building of these two bulwarks should be resolved upon, it would not be necessary to wait until the scouring of the dunes is completed.

I am sending the method of the order of battle and the order of the quartering of two regiments, one of infantry, the other of cavalry. As to the quartering of a whole army, and the remarks on heavy artillery, that will be discussed another time, for I have not got the notes here.

LOPENDE LANGS EEN STADT EEN RECHTE Rivier ; Die rontsom de Stadt te leyden.

So een ſtadt als A lage an een rivier rechtuytlopende van B over C naer D ; Tis mogelic de rivier rontſom de Stadt te doen loopen, alleenlic de dicte van een dam geſtopt blyvende, twelc aldus toe ſoude gaen :



Men ſal graven van E over G naer F, en van E over H naer F, en leggen een dam aen de boveſyde der Stadt tot E , en een ande laege zyde als F; en ſo ſalt water lopen den wech B H F C E G F D. Hier en ſal ſonder twijſtel geen ſchuering gebreken , gemerct al het water daer deur moet.

Het is kennelic hoemen tot E en F in plaets van dammen ooc ſluyſen ſou connen leggen om ſich daer van naer gelegentheyt te dienen. Het ſy om in yſganc de ſtroom recht deur te laten lopen en de ſchepen inde gracht daer voor te bergen of anders.

Ooc ſal licht te verſtaen ſijn hoe het perc tuſſchen H en C beſonderlic geſterct of tot voorſtadt aen die zyde van A gebracht ſou connen worden.

A STRAIGHT RIVER RUNNING PAST A TOWN:

how to divert it round the town.

If a town like *A* were situated on a river with a straight course from *B via* C to D, it would be possible to divert the river round the town, being held back only by the width of a dam, which would be thus: From *E via G* to *F*, and from *E via H* to *F*, cuts should be made and a dam should be built above the town at *E* and one below it at *F*; then the water will run the course *BHFCEGED.* Here there will undoubtedly be no lack of scouring, since all the water has to run this course.

It is obvious that one might also build sluices instead of dams at *E* & *F* to use them according to need, either in order that in time of ice-drifts the current should be enabled to flow straight on and the ships might be protected in the ditches against it, or otherwise. It will also be easy to understand that the areas between *H* and *C* might be specially fortified or might serve as a suburb of *A* on this side.

VANDE HOOFDEN DER HAVENS.

Int 12 Voorstel van des Eertcloots stofroersel, is d'oirsaec verclaert waerom voor de mont der rivieren tot verhindernis vande incomst der schepen dorpels liggen: Om de selve te verdiepen leghtmen twe hoofden deur het strant verre genouch in zee, daer het water in een naeute tusschen deur lopende, diepte maect. De gemeene manier van het maecsel deser hoofden is int sant te heyen lange palen diemen met gordingen an malcander hecht, sulx datter viercante percken tusschen blyven, diemen kisten noemt, welcke met steen en rijs gevult zijnde, houden haer plaets sonder wechspoelen.

Het ongeval vande manier deser hoofden is, dat den gront wechspoelende, de palen om vallen, de kisten daer tusschen breken en het steen wech drijft. Maer om dien gront te verstyven, men sinct daer in groote menichte van steen d'een op d'ander, sulx dattet eyntlic wort als een steenclippe dieper onder water dan de palen lanc zijn, waer in het heyen een beswaerlic lancsaem costelic werc valt, want de palen onder elc beset synde met een yser schoe, om deur het steen te geraken, en boven met een yser beugel, om int heyen niet te splyten, worden dicwils int heyen gebroken, en dieder in commen staen tusschen de steen sonder den sandigen gront te geraken.

Een ander manier die my veel beter bevalt heb ic gesien tot Dantsic, diens gedaente mette navolgende form A B C D E F angewesen wort, wesende een vlot van boomen op en an malcander gewrogt, sulx datter tusschen commen de viercante perken diemen met steen vult, en syn die boomen ande doorcruysingen so ingekipt, dat e inde langde deurgaens malcander geraken, sonder openheden tusschen beyden te wesen: Onder is een houten bodem daer de steenen op rusten sonder int sant te vallen Dit vlot wort gemaect inde rivier tot een bequame plaets en gereet zijnde, men brenget aldryvende met een stil weer ter plaets van het hooft, en liggende daer het syn moet, men worpt de kisten vol steenen en sinct daer me tot op den gront. Daer na slaetmen de yspalen daer voor.

De voordelen diemen met dese kisten heeft syn dusdanig: Ten eersten, den gront onder de kisten wechspoelen het vlot volgt den gront sonder van malcander te gaen of steen te verliesen, en tgene dan inde

hoochde

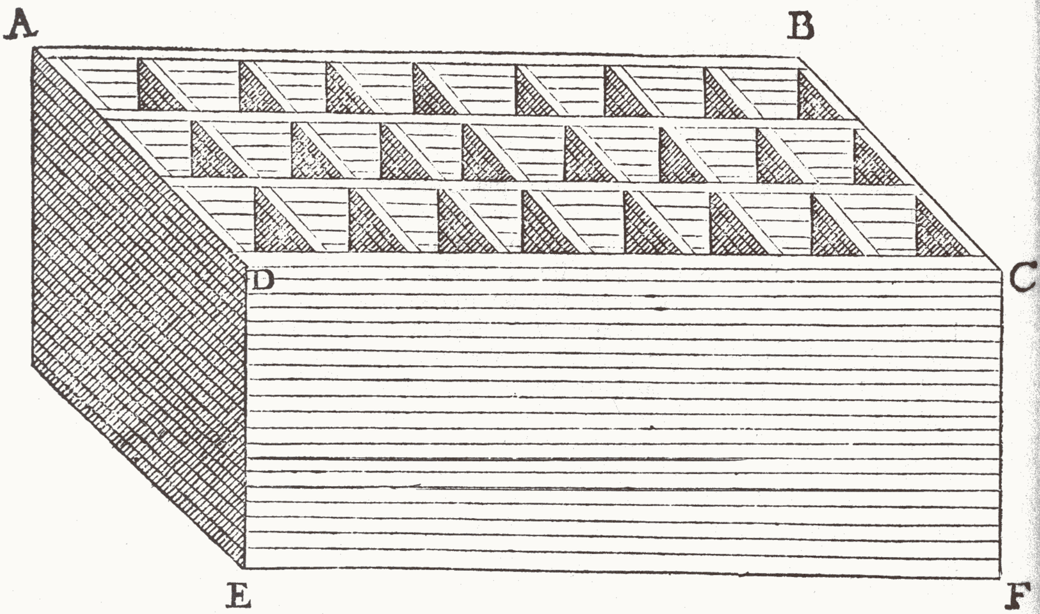
OF THE PIERS OF HARBOURS.

In Proposition 12 of the *Eertcloots Stofroersel,* the cause had been explained why bars are present in the mouths of rivers, forming an obstacle to the entry of ships. In order to lower them, two piers are built from the beach far enough into the sea, between which the water flows in a narrow channel, thus scouring deeply. The common method of building such piers consists in driving long piles into the sand and linking them with girders, in such a way that square areas remain between them, which are called casings, and when filled with osiers and stones, will keep in their place without being washed away.

The drawback of this method of building piers is that when the soil is washed away, the piles will collapse, the casings in between will break, and the stones will be washed away. But in order to stabilize this soil, a large number of stones are sunk there, one on top of the other, so that at last it becomes like a rock deeper below water-level than the length of the piles, this making the pile-driving a difficult, slow and expensive job, for the piles, each ending in an iron shoe, for them to penetrate through the stone, and with an iron sheath at the top, so that they should not split during the pile-driving, are often broken during the operation, and those which finally penetrate, stand between the stones, without coming into contact with the sandy soil.

Another method, which I like much better, I have seen at Danzig; it is shown in the following figure by *ABCDEF*, being a raft of logs fastened on and to each other in such a way that square areas are formed in between, which are filled with stone, and where the logs meet they are so notched that they are in contact over their full length, without openings forming in between. At the bottom there is a wooden floor, on which the stones rest without falling into the sand. This raft is made in the river in a suitable place and, when complete, is carried floating during calm wheather to the site of the pier and when it lies where it ought to be, the boxes (caissons) are filled with stones and with them sink to the bottom. Then the ice-posts are driven in front.

The advantages derived from such caissons are these. Firstly, if the soil below the caissons is washed away, the raft follows the soil without disintegrating



hoochde gebreɫt, wort daer boven op gewrocht nade manier gelijɫt voorgaende werc.

Ten anderen, hier en valt geen heyige deur ſteen, alſoder buyten de kiſten geen ſteen en leght.

Ten derden, eenige yſpalen brekende, men heyt ander inde plaets, ſonder als geſeyt is van ſteen hindernis te hebben Hoofden veroirſaken een rinc. Anders, groote rivieren lopende deur verſcheyden killen, maken elc wel ſyn manier van rinc, die in malcander commen, maer en ſyn ſoo merckelic niet als wanneert al deur een kille loopt.

DAT GRACHTEN INT SANT DIEPER CONNEN gegraven worden deur ſanttrecking onder water, dant in droge te graven deurt behulp van hoſing.

Alſmen int graven der grachten of putten ſoo diep comt, datmen twater crijcht, ſo iſt int gebruyc, twater uyt te hooſen of malen om int

 drooor losing stones, and what is then lacking in height, can be added on top by a method similar to the preceding procedure.

Secondly, no piles have to be driven through stones, since outside the caissons there is no stone.

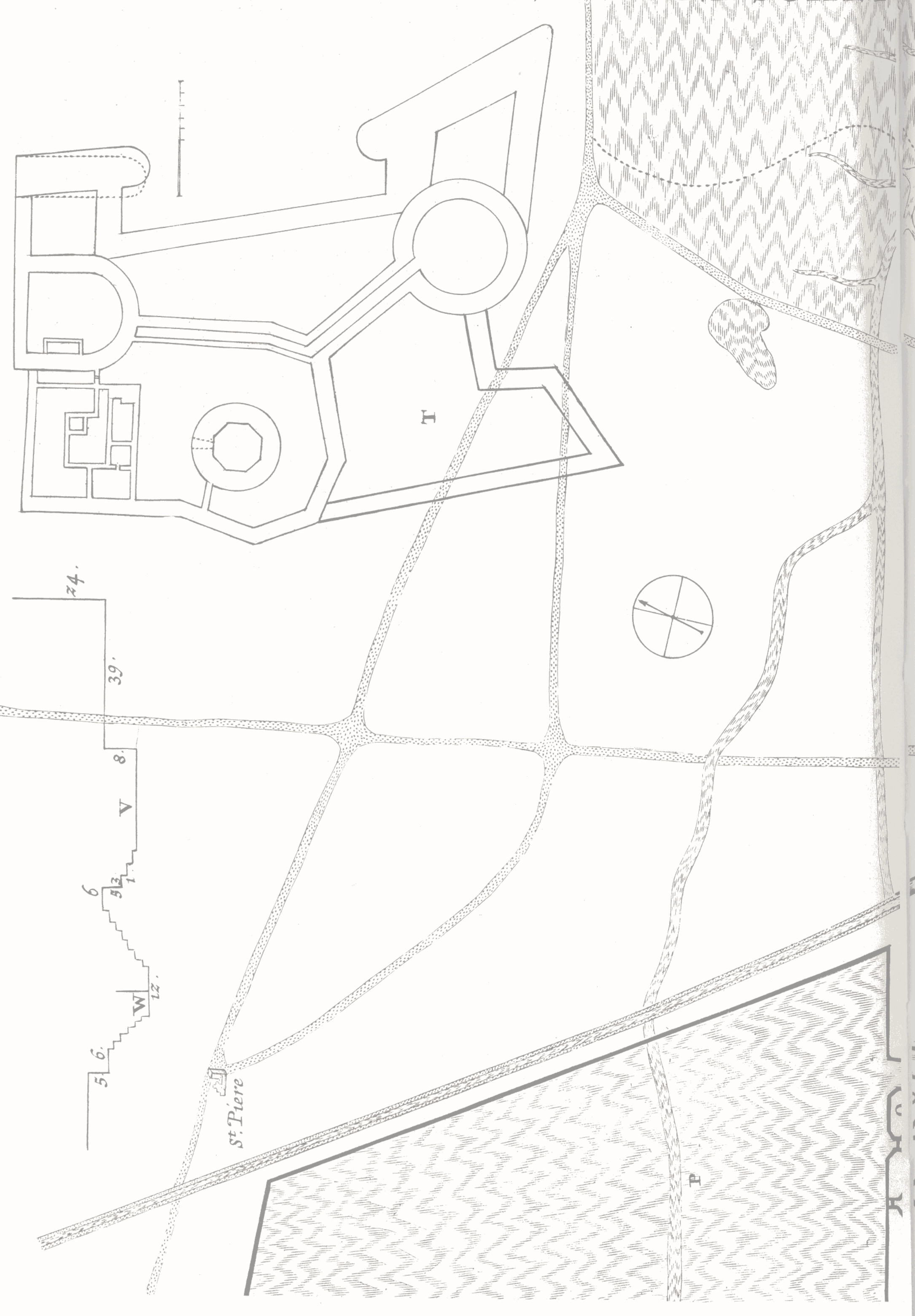
Thirdly, if some ice-posts break, others are driven in instead, without (as said) any impediment caused by stones. Piers produce a ring. Expressed in a different way, large rivers running through different channels, each form their own manner of ring, running into one another, but they are not so noticeable as they are if the river runs completely through a channel.

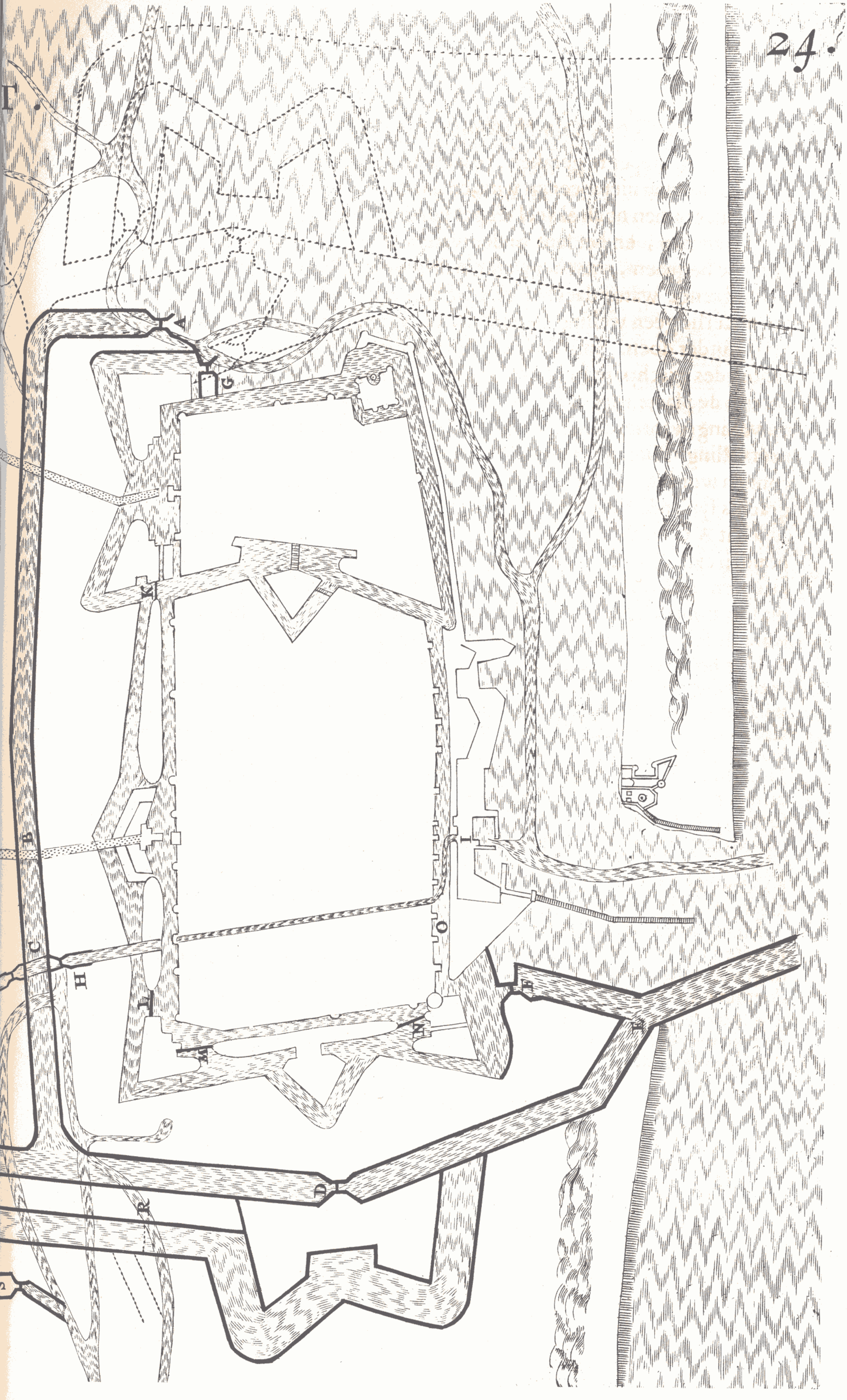
THAT DITCHES CAN BE MADE DEEPER IN THE SAND

by sand-dredging under water, instead of by excavation in dry soil by bailing.

If, when excavating ditches or wells, one reaches a depth such that water appears, it is usual to bail out the water or to remove it with a mill in order

XI BOEC. 2 ONDERSCHEY




A
G
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drooge noch dieper te geraken, te weten so diep, tot dattet sant so seer opwelt, datmen niet meer en wint, en dan houtmen op: Maer die de saec verstaen, connen noch al veel dieper geraken, mits het water daer in te laten commen, en het sant onder water uyt te trecken, met reetschap daer toe bequaem, want het water in de gracht so hooch zijnde, als het nevenstaende water daer het eertrijc af deurdroncken is, soo en cander openbaerlic geen welling geschien, en vervolgens en cander welling geen hinder doen. Sulx datmen dan soo diep graven mach tot dat de canten des grachts te steyl wordende, het neervallende sant weerom vervult de plaets vant uyt getrocken sant: Twelc niet en geschiet deur opwelling (wantter als geseyt is geen syn en can) maer heel verkeert deur neervalling. Hier uyt is te verstaen, dat de breetste grachten also diepst connen worden: Laet tot opentlicker verclaring A B de breede eens grachts syn ande bovecant vant sant, C tmiddelste des selven grachts, sulx dat A C en B C syn de schoensche afdakingen die het sant int water houden can. Laet nu andermael de gracht boven twemael so breet syn alsvoren A B was, ic neem van A tot D, en E tmiddelste des grachts, dit soo zijnde, 't kiel sal nu an E twemael soo diep connen sijn als an C, want de schoensheyt van C tot E is al de selve gelijc van A tot C.

Uyt het voorgaende is kennelic dat een gracht int sant gegraven, haer meeste diepte int middel can hebben. Ende die dit deur dadelicke ervaring wil sien, macht versoecken in een tobbe of ander vat gevult met sant, en claer water; daermen 't sant deur sien can; want makende daer in metter hant diepten, hy sal dadelic sien de breetste te connen de diepste worden. Daerom Stadtgrachten diemen in sandige gront diep begeert, de selve diepte can int middel kielsche wijse diepst gecregen worden: waer deur de dieping soo wel int gedeurich onderhout als in deerste opmaking behoort int middel gedaen te worden; Want de gront daer leegst wordende, het sant schict hem selven op beyden syden totte natuerlicke schoensheyt diet een tijt lanc behouden can. Maer ande canten sant te trecken, en brengt geen behoorlicke diepte noch daer noch inde middel vant kiel.

Merct noch een swaricheyt die sulke grachten connen onderworpen zijn; te weten alse by rivieren liggen die haestelic veel hoger wassen als twater van de gracht. Sulke rivieren connen het sant doen opwellen dat niet en welde doement met een leegh rivierwater uyt groef. Sgelijx can ooc weervaren an grachten die haestelijc leege afloopen eer dan 't water daer het omstaende eertrijc me deurdroncken is. Daerom alsmen sulx bevint te gebeuren, men mach dencken dattet om bekende oirsaken geschiet.

Eynt vant 11 Boec.

to get deeper into dry soil, *i.e.* until the sand rises so much that nothing more is gained, and then the work is stopped. But those who know their job may attain much greater depth still by letting the water enter and dredging the sand under water, with the proper instruments, for when the water in the ditch is as high as the adjacent water, with which the earth is permeated, obviously no rising can take place, consequently this rising cannot form an obstacle. Thus one can dig until the sides of the ditch becoming too steep, the sand falling down replaces the excavated sand. This is not caused by rising-up (for, as stated, this cannot occur), but on the contrary by falling down. From this it will be understood that the widest ditches can thus become the deepest. For a better explanation let *AB* be the width of a ditch at the top of the sand, *C* its middle, so that *AC* and *BC* are the gradients which the sand can have in the water. Now again let the ditch at the top be twice as wide as the above *AB*, say from *A* to *D*, and let *E* be the middle of this ditch; this being so, the channel at *E* can now be twice as deep as at *C*, for the gradient from *C* to *E* is identical with that from *A* to *C*.

From the above it is obvious that a ditch cut in sand may have its greatest depth in the middle. And he who wishes to observe this by practical experience, may try it in a tub or other vessel filled with sand and clear water, through which the sand can be seen; for when he makes a cavity there with his hand, he will see in practice that the widest will become the deepest. Therefore town-ditches being desired to be deep in sandy soil, this depth can be obtained greatest in the middle, in the manner of a channel; in view of which the dredging should be performed in the middle at the start as well as during constant maintenance. For the soil becoming lowest there, the sand will settle on both sides to the natural gradient which it can keep for some time. But dredging sand at the sides will not give proper depth, neither there nor in the middle of the channel.

Note yet another difficulty to which such ditches may be subject, *i.e.* if they are near rivers which rapidly rise to a much higher level than the water of the ditch. Such rivers may cause the sand to rise which did not rise when dredging took place at low river level. This may also happen with ditches which run off quickly before the water that has permeated the surrounding earth. Therefore, if this is found to be the case, one should bear in mind that this is due to known causes.

End of Book 11.

CHAPTER VII

THE DRAINAGE MILLS

1. INTRODUCTION

It is still an open question as to when the windmill came to Western Europe. Our first definite data go back to the latter part of the twelfth century in England, France and Flanders. During the thirteenth century the windmill penetrated to the Low Countries. The legal right to tax the use of wind was then debated and many a lawsuit of this period deals with the quarrels between millers and their masters as to the right to insist on official permission to erect such mills. By the thirteenth century these matters were more or less settled and many a monastery or lord of the manor derived some income from windmills, as the documents go to show. By the end of the thirteenth century the windmill was a fairly common prime mover in the Netherlands for the Count Floris V signed a document laying down the tariff for windmills and watermills in general for the town of Haarlem (1274) [1]).

These windmills were at first corn mills, but gradually they became real prime movers, being applied to all kinds of tasks, even for hoists in certain mining districts. Their home was, however, the flat coastal region along the North Sea. Here the drainage of higher swamps and moors had proceeded rapidly and by the turn of the fiftheenth century areas that lay below ebb-tide and therefore could not be drained by natural flow, were embanked and drained. The windmills found a new task and they were applied to the drainage of the polders in the fourteenth century. And though treadmills and horse-gins still pumped the larger part of the water from the district of Rijnland in 1570, by 1600 the drainage-mill led, and remained the leading drainage pump until quite modern times. The Archimedean screw or tun-mill was already displacing the scoop wheel in the seventeenth century.

We hear about a drainage(?) mill in Brielle [2]) in 1394 (which was more probably a tide-mill turning the mill-stones) and the dike-reeves of Delfland went to Alkmaar (between March 1, 1406 and June 16, 1408) in order to inspect "the water, which Florents van Alkemade and Jan Grietenzn throw out with the mill". The first drainage mill must therefore have been built before that date, but a good deal of thought had to be expended on its construction before it could really be considered efficient.

It would seem from recently discovered documents that the first drainage mills were tower mills. Such a tower drainage mill was built in the polder Oud-Reijerwaard in 1438, an octagonal mill usually called the "Old Mill" in these documents.

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[1]) G. Doorman, *Octrooien voor Uitvindingen in de Nederlanden in de 16e—18e eeuw,* 's-Gravenhage, 1940, 61—64.
G. Doorman, *Techniek en Octrooiwezen in hun aanvang,* 's-Gravenhage, 1953, 32—37.
K. Boonenburg, *De Windmolens,* Amsterdam, 1949.
F. Stokhuyzen, *The Dutch Windmill,* Bussum, 1962.

[2]) Van Mieris' *Groot Charterboek,* 3rd vol., 610.

XXIII

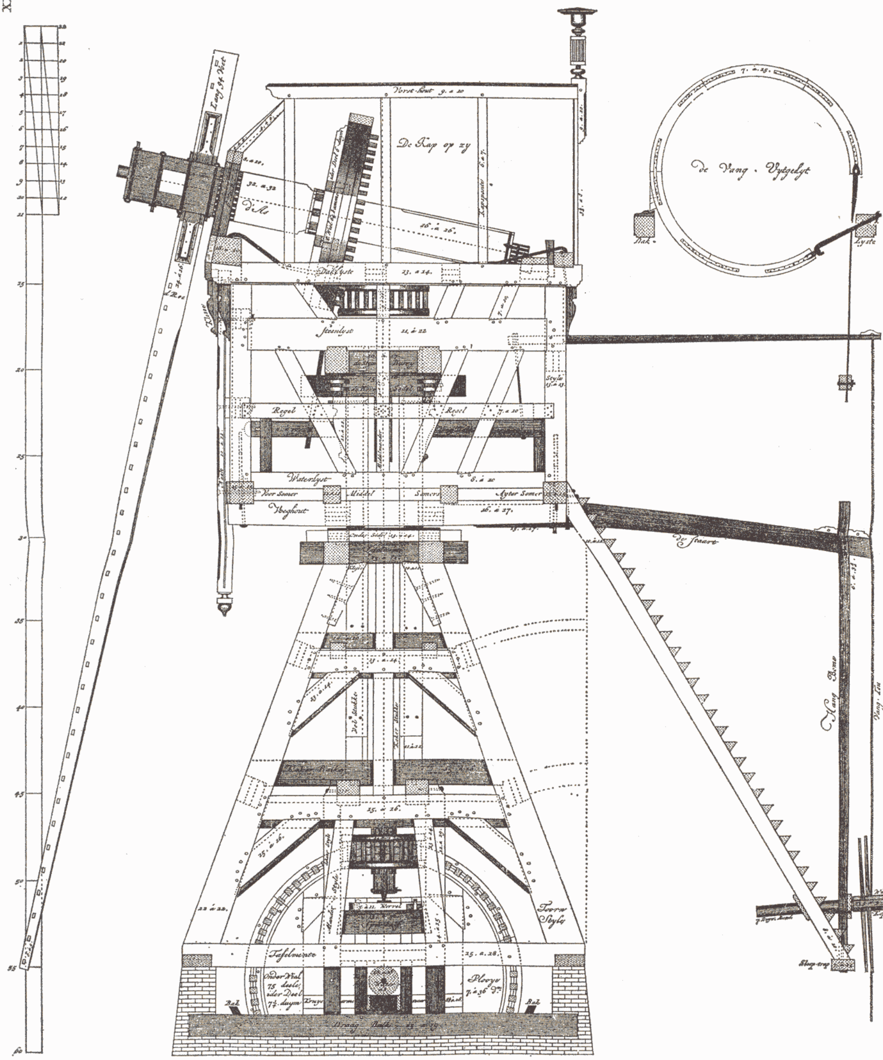

Fig. 20. Cross-section of a typical wipwatermolen of the 18th century (Van Zijl, Molenboek, 1761)

Between 1438 and 1453 the "New Mill", a windmill of the *wipmolen* type was added to it to drain the region southeast of Ridderkerk.

It is usually maintained that the first drainage mill of the *wipmolen* type was built in 1430 for the Bonrepas polder naer Schoonhoven. A careful study of the documents in the State Archives revealed that on May 13, 1430 Jacoba van Beieren and Philip of Burgundy issued a charter to the Krimperwaard, which allowed that district to put its drainage problems in order. This was no easy task for on March 14, 1550 the emperor Charles V commanded the bailiwick of Schoonhoven (which embraced the villages of Bergambacht, Stolkwijk, Haastrecht, Vlist, Bonrepas, etc.) to take the necessary steps to remove such high trees, etc. which imperilled the proper functioning of drainage mills about which the inhabitants had already frequently complained "during the last hundred years". This indicates that these drainage mills were built between 1430 and 1450. The Bonrepas mill was built in 1449 [3]) and served the polder well for over a century. By the end of the fifteenth century the wipmolen had proved its mettle, there were no less than 17 of them in the region of the Vlist. New drainage mills were going up in many other parts of the country too in this period.[4])

The sixteenth century saw many new applications of the windmill. Cornelis Dircksz Muys invented a drainage mill driving an inclined shaft (1589), on which was an Archimedean screw. The *tjasker,* for many centuries popular in the province of Friesland, is probably derived from this invention. Cornelis Cornelisz. of Uitgeest invented the wind-driven saw-mill (1593) and the edge-runner mill for crushing oil seeds (1597) and thus by 1600 windmills were used in the Low Countries for the sawing of timber, the hulling of rice, fulling, the crushing of oil seeds, the grinding of pigments, snuff and mustard, and the manufacture of paper.

Certain districts were favoured by nature. The banks of the river Zaan, west of Amsterdam, formed a flat country with favourable strong winds and an easy approach via the Zuyderzee and from Amsterdam; and it was here that the main industrial district of Holland arose. By the end of the seventeenth century it contained no fewer than 900 windmills (all drainage mills included); other industrial districts deriving their power from windmills were to be found around the towns of Amsterdam, Leiden, Rotterdam and Dordrecht. Many towns had windmills built on their city-ramparts and fortifications so as to provide the necessary power for raising water in times of war.[5]) Altogether the United Provinces must have had some 8000 windmills, 2000 of which survived in 1900. Only 991 were still in existance in 1960, 397 drainage mills and 594 industrial and corn mills, and many of them in a damaged condition.

The oldest form of the windmill was the *post mill,* a box-like timber body, carrying the sails and containing the machinery. This body was mounted on a massive oaken upright *post* on which it could turn. Its weight was taken by

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[3]) *Archief der heerlijkheden Cabauw en Zevender, inv. no. 109,* State Archives for the province of Utrecht.

[4]) G. Doorman, *Octrooien voor Uitvindingen in de Nederlanden uit de 16e—18e eeuw,* 's-Gravenhage, 1940, 61—62.
G. Doorman, *Techniek en Octrooiwezen in hun aanvang,* 's-Gravenhage, 1953, 30—31.

[5]) A. F. de Graaff, *Leidse windmolens vóór 1600,* Kroniek van de Vriendenkring van het Rembrandthuis, Vol. 17, 1962, 3—12.

diagonal *quarter bars* mortised into it about half-way up. The mill could be turned to the wind by means of a *tail pole* fastened to the sheers below the lower floor and passing downwards through the ladder, but the effort required to turn it round was considerable. It seems that the post mill was an adaptation of the watermill to circumstances where wind was available and water-power was not.[6])

In the Low Countries a new type of post mill, the *wipmolen* (see Fig. 20), was developed in which the post was no longer solid but hollow, thus accommodating the upright shaft by which the energy derived from the wind was transmitted to machinery below in the fixed body of the mill. This was the most popular drainage mill in the days of Stevin and long after, though it was also used for industrial purposes such as paper, oil seeds, timber and paint. The "tower mill" had a fixed tower of timber or brickwork which enabled more floor space to be devoted to machinery and grain storage. The top or "cap", carrying the sails, windshaft and brake wheel only, was turned to face the sails into the eye of the wind. Timber-built tower mills were usually octagonal but sometimes hexagonal; masonry towers were either circular, ten-sided or twelve-sided.

In the Netherlands this type of windmill is mentioned in a deed of October 5, 1451 by William, Lord of Bergh, who set apart a percentage of the profit of each of his mills for a hospital. One of these mills is still in existence at Zeddam (A. P. van Schilfgaarde, *Het archief van het Huis Bergh*). Two tower mills for draining the Polder Oud-Reijerwaard were built in 1438 and the accounts of the deputy for this polder for 1513/1514 prove that circular tower mills were in use there.

These then were the three types of mills in common use in the days of Simon Stevin. The industrial mill was not invented by Lief Jansz Andries van Moerbeek, a Fleming, as usually claimed, but he was the first to process oil seeds in a "square mill", probably a *wipmolen* though local tradition has it that this was a post mill. Tower mills became more frequent in the latter half of the sixteenth century.

When adapted to the pumping of water and to drainage or scouring, the machinery was designed to transmit the revolution of the sails to a vertical scoop wheel. In principle this machinery would consist (Fig. 21 and Plate III) of the following parts:

B is the windshaft (*molenas, bovenas, wiecas* (Stevin)) which is turned by the sails. These sails may already have had the "double curvature" or *zeeg,* which is shown in the patent of Cornelis Dirckz Muys of October 31, 1589 as well as in an etching by J. v. d. Velde of 1617[7]); it was also prescribed for the Beemster mills, and became common practice by the eighteenth century. We have, however, no idea just how frequently this new type of sail was used by Stevin's contemporaries. In his calculations Stevin correlates the wind pressure with the width of the sails which holds only for flat sails. The windshaft rests with its neck journal on the neck bearing *H* (*halssteen*) which is borne by the breast beam *P*

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6) Rex Wailes, *Windmills in England,* London, 1948.
7) See H. Martin and G. J. Veenstra, *Het Huis Oud en Nieuw,* 1918, 283.

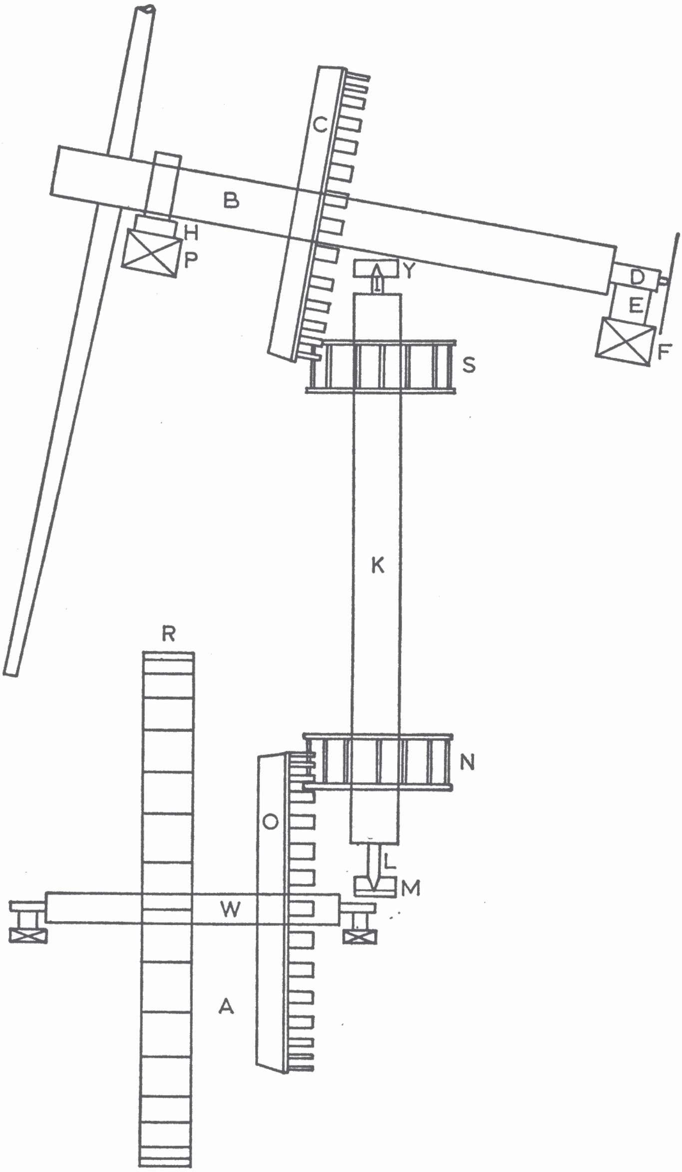

Fig. 21. The machinery of a drainage mill (simplified)

(*windpeluw*) and with the tail journal *D* (*prop*) on the tail bearing *E* (*pensteen*) which is supported in its turn by the tail balk *F* (*penbalk*). On the windshaft is the brake wheel (*bovenwiel, aswiel, kamwiel*) *C*, a toothed wheel, the cogs of which engage the staves of the wallower *S* (*bovenschijfloop, lantarenwiel, bovenbonkelaar*) which is attached to the upright shaft *K* (*koningsspil, molenspil*). The shaft *K* revolves on a top journal *I* (*bovenijzer*) in the centre beam *IJ* (*ijzerbalk*) and on a thrust journal or pintle *L* (*onderijzer*) in the *rode balk* at the bottom *M* (*pot*). The wallower *S* driven by the brake wheel turns the upright shaft which turns the crown wheel *N* (*benedenschijfloop, benedenbonkelaar*) and thus the pit wheel *O* (*onderwiel, spoorwiel*). This is connected with the scoop wheel (*scheprad, waterwiel*) *R* through the horizontal scoop wheel shaft (*wateras*) *W*. In order to keep the pit wheel dry it is enclosed by a timber-lined pit *A* not detailed in the drawing.

The scoop wheel turns between the two closely fitting vertical walls (*krimpwanden*) of the wheel pit, in which the curved bottom or wheel race (*opleider*) closely follows the circumference of the scoop wheel. When the mill turns the water of the inner level is raised and the water gate (*schoep* or *wachtdeur*) is opened which gives into the high water. As the supply of water stops this gate is closed by the pressure of the water on the other side. This vertical scoop wheel was the principal means of raising water with wind mills in the days of Simon Stevin. They usually had 16-24 floats, sometimes inclining slightly backwards, but more often radial. The water was usually raised 4-6 feet only and greater heights could only be achieved by a series (*gang*) of drainage mills, each receiving the water from the preceding one and raising it to the next.

Simon Stevin's inventions are largely concerned with the design of a scoop wheel revolving slowly and having a smaller number of much wider floats, raising the water but a few feet, like the conventional scoop wheel, as we shall see. He tried to make his scoop wheel fit closely between the walls of the wheel pit by attaching flaps of leather to the rim of the wheel, which were to prevent the water from flowing back between the wheel and the vertical walls.

The introduction of the Archimedean screw, either the screw and its cylinder revolving (Hendrik Stevin's *tonnewentel*) or the screw alone (Hendrik Stevin's *gootwentel*) gradually ousted the scoop wheel from many drainage mills and this may be one reason why Simon Stevin's invention did not have the success hoped for, apart from his apparent inability to translate some of his constructional ideas into reality. Still the very large scoop wheel he advocated made it necessary to house it in an extra large pyramidal lower part of the wipmolen, the upper part of which then became larger but lower, as he was loth to change either the span of his sails or the slope of the wind shaft.

2. STEVIN'S CALCULATIONS OF WINDMILLS

Stevin would not be Stevin if he did not illustrate his ideas on windmills with calculations (*wercking met ghetalen*) and if he did not link them with his ideas of mechanics and hydrostatics. This makes his calculations of windmills unique in the sixteenth century.

Let us take his first example, the Zuyt Nootdorp mill "arranged according to the old manner", on which he gives the following data, using throughout all his calculations the "Rhineland foot" of 314 mm.:

Length of the sails	l_2	$40\,^1/_2$	feet
Width of the sails	b_2	$8\,^1/_4$	feet
Number of cogs of the brake wheel		44	feet
Number of staves of the wallower		13	feet
Number of staves of the spur wheel		10	feet
Number of cogs of the driven wheel		52	feet
Radius of the scoop wheel	l_1	$^{31}/_4$	feet
Width of the floats	b_1	$^{29}/_{24}$	feet
Immersion of the floats	h_1	$^4/_3$	feet
Difference between the high water and the low water level	h_2-h_1	4	feet

The first problem Stevin now wants to solve is: what is the total weight of the water acting on the scoop wheel in the centre of gravity of the low-water side of the wheel?

Stevin imagines a float, vertically immersed in the water, which on the low-water side reaches $^4/_3$ feet from the bottom of the float (*BC*) and on the high-water side 4 feet higher (*BG*).[1] For the low-water level the centre of gravity of the pressure is in *D* ($BD = {}^1/_3BC$), for the high-water level in *H* ($BH = {}^1/_3\ BG$). As the width of the float is $^{29}/_{24}$ feet, according to the propositions 11 and 18 of the *Hydrostatics*[2]) the force in *D* is equal to a weight of $^{29}/_{24} \times {}^4/_3 \times {}^2/_3 = {}^{29}/_{27}$ cubic feet of water and the force in *H*, equal to the weight of $^{29}/_{24} \times {}^{16}/_3 \times {}^8/_3 = {}^{464}/_{27}$ cubic feet.

He now asks himself what further force should act in *D* in order to equilibrate the scoop. He first transforms the force of the high-level water acting in *H* into one acting in *D* which would have the same effect on the scoop wheel. As $AH = {}^{31}/_4 - {}^{16}/_9 = {}^{215}/_{36}$ feet and $AD = {}^{31}/_4 - {}^4/_9 = {}^{263}/_{36}$ feet, this force according to Proposition 1 of *The Art of Weighing* is equal to the weight of $^{215}/_{263} \times {}^{464}/_2 = {}^{3\,034}/_{216}$ cubic feet of water. Taking the weight of one cubic foot of water to be equal to 65 lbs, the result is expressed as 913 lbs. As the pressure exerted by the low-level water on the float is $^{29}/_{27} \times 65 = 69$ lbs, the force required, acting in *D*, turns out to be 844 lbs.

In modern terminology Stevin first calculates the moments of the forces with which the high-level and the low-level water act on the shaft of the scoop wheel. The difference is formed by the moment of the force which the drainage mill should exert on the float. If we take the length of the float to be l_1, its width b_1, the specific gravity of the water s, the depth of immersion of the float in the low-level water h_1 and in the high-level water h_2, the resultant moment relating to the shaft of the scoop wheel is:

$$M_1 = {}^1/_2\, b_1 s\, (h_2^2 d_2 - h_1^2 d_1) \;\ldots\ldots\; (1) \text{ in which formula}$$
$$d_1 = l_1 - {}^1/_3\, h_1 \text{ and } d_2 = l_1 - {}^1/_3\, h_2.$$

Stevin now calculates a force acting in *D* and having a moment M_1 related to the shaft, which is therefore M_1/d_1.

Now before he can calculate what pressure per square foot of sail will yield this force wanted at *D* he has to go into the problem of how many revolutions

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[1]) See the figure in the text, p. 1.

[2]) Cf. Vol. I of this edition, p. 420 and p. 465. Proposition 11 gives the pressure on a rectangular bottom plane, whose highest side is in the water's upper surface.. Proposition 18 shows where the centre of pressure is located.

the sails have to make for one revolution of the scoop wheel (Proposition 2). Considering the number of cogs and staves on the different wheels he finds $^{52}/_{10} \times {}^{13}/_{44} = {}^{676}/_{440}$ revolutions. He expresses this in the words "patients shall be multiplied by patients (the number of staves of the wallover with the number of cogs of the driven wheel) and agents with agents" (the number of cogs of the brake wheel by the number of staves of the spur wheel) and then take the ratio of the two.

This result will then allow him to calculate the pressure on each square foot of sail (Proposition 3). If sails and scoop wheel revolved at the same rate, the total pressure of the wind on the sails would be equal to a force acting on the float at a distance of half the length of a sail from the shaft of the scoop wheel. The force of 844 lbs acting at $^{263}/_{36}$ feet from the scoop wheel shaft is equal to one of 304 lbs at 20 $^{1}/_{4}$ feet distance from the same shaft. But as the sails revolve $^{676}/_{440}$ times as often as the scoop wheel in a given period, the force on the sails need only be $^{440}/_{676} \times 304$: 197 lbs. As the total surface of the floats is 1 136 $^{1}/_{2}$ square feet this amounts to about 2.3 ounce per square foot of sail.

In a generalised form we get the following formula: If K_1 and K_2 be the number of cogs of the driven wheel and the brake wheel and s_1 and s_2 the number of staves of the spur wheel and the wallower the ratio of the revolutions of the sails and the scoop wheel shaft is $n = K_1 s_2/K_2 s_1$. If the sails have a length l_2 and a width b_2 and if the pressure of the wind is W, then the moment of the force of the wind on the sails relative to the windshaft will be:

$$M_2 = 4\ l_2 b_2 W \times {}^{1}/_{2} l_2 = 2\ l_2^2\ b_2 W$$

As we want M_1 to be equal to nM_2 we find

$$W = {}^{1}/_{n} \times M_1/2 l_2^2 b_2 \qquad (2)$$

the formula expresses the value of the force of the wind counterbalancing the pressure exerted on a scoop immersed vertically in the water.

Stevin now calculates (Proposition 4) with what force the cogs press on the staves and he finds the amount of water displaced by one revolution of the sails (later called *waterkrul* to distinguish it from the amount displaced by one turn of the scoop wheel) (Proposition 5).

His reasoning is as follows:
A float during one revolution of the scoop wheel completes a volume equalling $\pi\ l_1^2\ b_1$, the part that emerges from the water a volume $\pi\ (l_1\text{-}h_1)^2 b_1$. During one revolution of the scoop wheel, therefore, a volume equal to $\pi\ b_1 h_1\ (2\ l_1\text{-}h_1)$ is ejected, hence during the revolution of the sails $^{1}/_{n}\ \pi\ b_1 b_1\ (2 l_1\text{-}h_1)$. Stevin here neglects the volume of the floats themselves and the water that flows back between the scoop wheel and the wall of the race.

When calculating the volume of water displaced by one revolution of the scoop wheel Stevin proves that he is familiar with the so-called "*hydrostatic formula*" which is still used today in investigating the efficiency of a scoop wheel. It is based on the consideration that the flow and turbulence caused by a scoop wheel is negligible and that therefore the calculation can be based on hydrostatic laws. Stevin's result is identical with the formula, used for many centuries:

$V_0 = \pi\ [(l^2_1 - (l_1\text{-}h_1)^2]\ b_1$ in which
V_0 = Total volume of water ejected
l_1 = Radius of the scoop wheel
h_1 = Depth of immersion of the scoops
b_1 = Width of the scoops

This formula usually gives values which are too high. On the other hand the values adopted by Stevin for the depth of immersion of the floats (generally 16″) seem very low.

This practical formula would no longer hold if there were a strong flow near the scoop wheel and if at high velocities of this wheel large amounts of air were enclosed in the compartments of the wheel. These two as well as other factors limit the output of scoop wheels, which does not increase, as modern tests[8]) have shown, when the circumferential velocity exceeds $6\sqrt{h_1}$ ft/sec (h_1 expressed in feet). This was, however, often the case in the period we are discussing. The velocity of the scoop wheel was usually measured indirectly by the millers of those days by counting the number of sails or *enden* passing a certain point per minute, just as modern millers are wont to do. From the number of revolutions of the wind shaft they could deduce the number of revolutions of the scoop wheel.

We are now able to calculate various data on ancient drainage mills provided we know sufficient details of their construction. If we refer to the specifications of the drainage mills contracted in 1607 to drain the *Beemster* polder (province of North Holland)[9]) we find that their brake wheels had 52 cogs, their wallowers 18 staves, the crown wheel 16 staves and the driven wheel 66 cogs. The ratio of the radial velocities of scoop-wheel shaft and windshaft must have been 0.70 : 1. The scoop wheel was 17′ high and 1′ wide, the depth of immersion of the floats was to be 2′, the difference between the water levels was about 3′. Theoretically some 77.7 cubic feet of water were ejected per revolution of the scoop wheel. The maximum capacity of the scoop wheel would have been reached at a circumferential velocity of 500 ft/min of this wheel, i.e. at 9.4 revolutions per minute of the scoop-wheel shaft and 13.5 of the windshaft. The miller would have expressed this velocity in the terms "54 *enden*/minute". At such a speed the capacity would have been 700 cubic feet of water per minute, the energy needed would have been 10 HP on the scoop wheel shaft.

Probably the depth of immersion of the floats will have exceeded 2′ quite frequently. If we take this to have been 2′6″ in wet periods, the maximum capacity of the scoop wheel running at "60 *enden*/minute" must have been 950 cubic feet of water per minute. Hence the statement made by Leeghwater[10]), that octagonal tower mills had a capacity of 1900 cubic feet per minute, which figure he based on rather crude water-gauge readings, must be considered over-optimistic, the more so as his pamphlet was designed to interest bankers and to raise money for his project.

Stevin tried to calculate the minimum wind pressure needed to move his scoop wheel, but he failed to relate the wind velocity to the energy available on the

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[8]) Ir. A. Havinga, *Proefnemingen met een schepradmodel* (Kon. Instit. v. Ing., 's-Gravenhage, 1935, 31 pp.).

[9]) J. Bouman, *Bedijking, opkomst en bloei van de Beemster,* Purmerend, 1857.

[10]) J. A. Leeghwater, *Haarlemmer-Meer-Boek,* 1641, par. 80—82.

scoop-wheel shaft, for in his day there were no means of measuring the speed of the wind.

Strangely enough the standard works of the Dutch millwrights of that century [11]) contain nothing but structural details. Possibly corn millers were not so interested in the maximum output of their mills since they could organize their work, and the only early attempts at the calculation of windmill capacities concern drainage mills. We have plenty of eighteenth century publications which claim to be "mathematical and mechanical calculations on drainage mills" [12]), but none were based on actual practical tests. Apart from the rough estimate made by Leeghwater and mentioned above, more exact data are few and far between.

Measurements comparing a drainage mill turning a scoop wheel and one turning three Archimedean screws were made near Leiden in 1763 [13]); we have a report on the output in cubic feet of water of four drainage mills near Rotterdam measured in the years 1774-1776 [14]) and another comparing the efficiency of scoop wheels and Archimedean screws in the years 1821-1824.[15]) They all suffered from the fact that accurate measurements of wind velocities were still beyond the engineers of those days.

On May 31 and June 14, 1759, John Smeaton [16]) read a most important paper to the Royal Society when, continuing his report of the water wheels he discussed experiments on windmills and different forms of sails. He made them on laboratory scale with windmill-models having a span of about 3 1/2 feet. "In trying experiments on windmill-sails, the wind itself is too uncertain to answer the purpose, we must therefore have recourse to an artificial wind." He thus avoided taking the irregularities of the flow of the wind into account, though he published a table which gave a rough scale of winds expressed in feet per second. His experiments certainly established the changes of the brake shaft capacity of a known mill with the velocity of the sails and the shape of the mill but said little on the actual windshaft capacity of windmills. For this Smeaton lacked the proper instruments and even units to express this energy, though he may have used some type of wind-gauge, which he standardized on his whirling table.

However, Smeaton took Stevin's primitive testing method a step further and he made an attempt to evaluate the energy output of a windmill in this way: "Desaguliers makes the utmost power of a man, when working so as to be able to hold it for some hours, to be equal to that of raising a hogshead (63 ale gallons) of water ten feet high in a minute. When working at a mean rate, the 30′ (enlarged) sail will be equal to the power of 18.3 men, or of 3.66 horses; reckoning 5 men to a horse; whereas the effect of the common Dutch sails, of the same length, will scarce be equal to the power of 10 men, or two horses.

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[11]) P. Linperch, *Moole-boek* (1727).
J. van Zijl, *Groot Algemeen Molenboek* (1776).
Van Natris, C. van Vuuren and J. Polly, *Groot Volkomen Moolenboek* (1734/6).

[12]) F. W. Conrad, *Omtrent eenige werktuigen tot het opbrengen van Water,* Verspreide Bijdragen, Amsterdam, 1849, 165—178.

[13]) J. Noppen, *Rapport van Proeven gedaan op de werking van een Vijselmolen en een Scheprad-Molen staende aan de Westvaart onder Haserswoude* (Leiden, 1765).

[14]) B. J. Douwes, *Verhandeling over de proporties tusschen de vermogens der gewone watermolens werkende met een staand scheprad en de nieuwelings door Gebr. Eckhardt uitgevonden hellende schepradmolens* ('s-Gravenhage, 1779).

[15]) Nieuwe Verhandelingen Bat. Genootschap vol. IX, Rotterdam 1844, 1—80.

[16]) John Smeaton, Phil. Trans. Royal Society, 1759, vol. LI, 138—174.

That these computations are not merely speculative, but will hold good when applied to works in large, I have had an opportunity of verifying; for in a mill with the enlarged sails of 30 feet, applied to the crushing of rape seed, by means of two runners upon the edge, for making oil, I observed that when the sails made 11 turns per minute, in which case the velocity of the wind was about 13 feet in a second, the runners then made 7 turns in a minute; whereas 2 horses, applied to the same two runners, scarcely worked at the rate of 3 1/2 turns in the same time."

Bernoulli and Euler continued such calculations.[17]) Smeaton says that the common Dutch windmill of the eigthteenth century had a span of 100 feet (i.e. sails of 50 feet) and a windshaft some 45-50 feet above the ground but this holds true for the larger mills only. He may have been unaware of the fact that the Dutch millwrights used the *houtvoet* of 283 mm. But even then, mills with a span of 90 English feet were rare at that early date.

According to Smeaton's calculations it would have an energy output of some 10 HP, a figure which does not agree with modern measurements. The smaller Dutch windmills with 24-foot sails were found to give 4.5 HP in a 20-mile wind. An interesting set of data was obtained with an old drainage mill of the larger type, built in 1648.[18]) When pumping 1250 cubic feet of water per minute against a head of 6 feet and an average wind velocity (constant over a reasonable period of time) of 18-20.1 miles per hour, measured at a height of 79 feet, it proved to produce 40 HP on the windshaft, the actual output being only 15.6 (water) HP (39%). Therefore 61% of the energy on the windshaft was lost in transmission and hydraulic turbulence, and this hydraulic factor certainly outweighed the losses in transmission by the primitive machinery.

Data obtained from other Dutch drainage mills in the Alblasserwaard (Waterschap *De Overwaard*) again point to the fact that the old eighteenth century windmill needed a wind of 18-20 miles per hour (measured at a height of 66 feet) to displace an amount of water equivalent to 10-12 (water) HP and 15 (water) HP at the utmost. The energy available at the scoop-wheel shaft was nearly double this amount and that at the windshaft some 12% higher.

Nor were drainage mills in the days of Stevin exceptionally low in energy output. If we take a post mill with one set of stones such as that specified by Beyer[19]) which is very similar to the corn mills depicted by the Dutch painters of the sixteenth century we find that the brake wheel had some 72 cogs, the wallower only 9 staves, the span of the sails was 64 feet. Taking the millstones (5 feet in diameter) to revolve 120 times per minute (the usual speed) we find that the brake energy of this mill must have been 6-10 HP, an output which agrees with that we found for the drainage mills of Stevin's day. This low energy output is intimately linked with the primitive gearing of these ancient mills and the hydraulic energy losses in the scoop wheel pit.

As to the first factor, we do not understand why the ancient millwrights of the seventeenth century restricted the number of staves on their wallowers, which was often as low as 9 or 10, so that they were unable to transmit more than 10 HP,

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[17]) See also Johan Lulofs, *Wiskundige en Werktuigkundige beschouwingen der Windmolens,* Verh. Holl. Maatsch. d. Wetenschappen II, 1755, 525—621.

[18]) *Prinsemolenboek*, Wageningen, 1942.

[19]) J. M. Beyer, *Theatrum machinarum molarium,* Leipzig, 1735, Taf. 25.

or at utmost 12 HP. The transmission must have been irregular and rough and the linear velocities of the cogs and staves had to be restricted and high tooth pressure avoided. More efficient gearing was gradually developed by the Dutch millwrights in the course of the 17th and 18th centuries. Stronger materials for gear wheels, such as box wood, were introduced. Cast iron was still frowned upon, its quality remained doubtful for a long time; though Smeaton introduced the use of cast-iron in mill-work, its use in windmills spread slowly. Wooden cogged wheels and pinions had, however, the advantage of damping vibrations much better than the later cast-iron parts did, and there was no stringent reason to depart from their use as their design improved.

In fact, the windmill remained essentially a timber structure, which was limited by its size to a capacity of 50-60 HP on the windshaft when charged to the utmost, and 30-40 HP under normal circumstances.

As to the main energy loss, this was due to the strong turbulence of the water in the scoopwheel pit and the foam formation. When the rather small scoop wheels of Stevin's day "beat" and "threw out" the water (Dutch engineers use the words *uitslaan* and *uitwerpen* for such raising of water) at great velocities (soon exceeding the fatal limit of $6 \sqrt{h_1}$ feet per second, this was unavoidable. Stevin though only applying hydrostatic theories, must have realized the resulting waste of energy, and this realization may be at the bottom of his application of scoop wheels (with leather flaps) wide enough to fill the entire width of the pit but revolving more slowly at a given number of revolutions of the sails per minute. Why he was inclined to diminish the number of floats is not very clear.

In reading Stevin's essay on drainage mills we should remember these limitations and judge his proposals accordingly.

3. STEVIN'S IMPROVEMENT OF WINDMILLS

When reading this essay, we should also remember that it is a mere draft, which was found amongst the notes and unfinished manuscripts of the author. Taking into account the contents of the patents granted to Stevin, his notes on cogs and staves, and the correspondence on the mills he built, we feel that the ultimate essay Stevin wanted to publish was one in which he was going to prove that these inventions were most efficient. The careful indication in the case of

	Old design		New design	
	Zuyt Nootdorp (1)	Sarlois (10)	Escamp (14)	Stolwijck (15)
Length of sails l_2	$40\,^1/_2$	$33\,^1/_2$	$33\,^1/_2$	40
Width of sails b_2	$8\,^1/_4$	$7\,^1/_2$	10	$9\,^1/_2$
Radius of scoop wheel l_1	$^{31}/_4$	$7\,^1/_3$	8	$10\,^1/_6$
Width of float b_1	$^{29}/_{24}$	$1\,^1/_4$	$3\,^1/_2$	$3\,^1/_2$
Immersion of float h_1	$^4/_3$	$1\,^1/_2$	$2\,^2/_3$	$4\,^1/_6$
Difference of water level h_2-h_1	4	$4\,^1/_3$	$3\,^5/_6$	4
Momentum M_1	6161	6825	22 282	39 142
Ratio revolutions sails/floats n	$^{676}/_{440}$	$^{882}/_{510}$	$^{1\,330}/_{251}$	$^{1\,957}/_{308}$
Wind pressure W	2.4	3.7	3	3.25

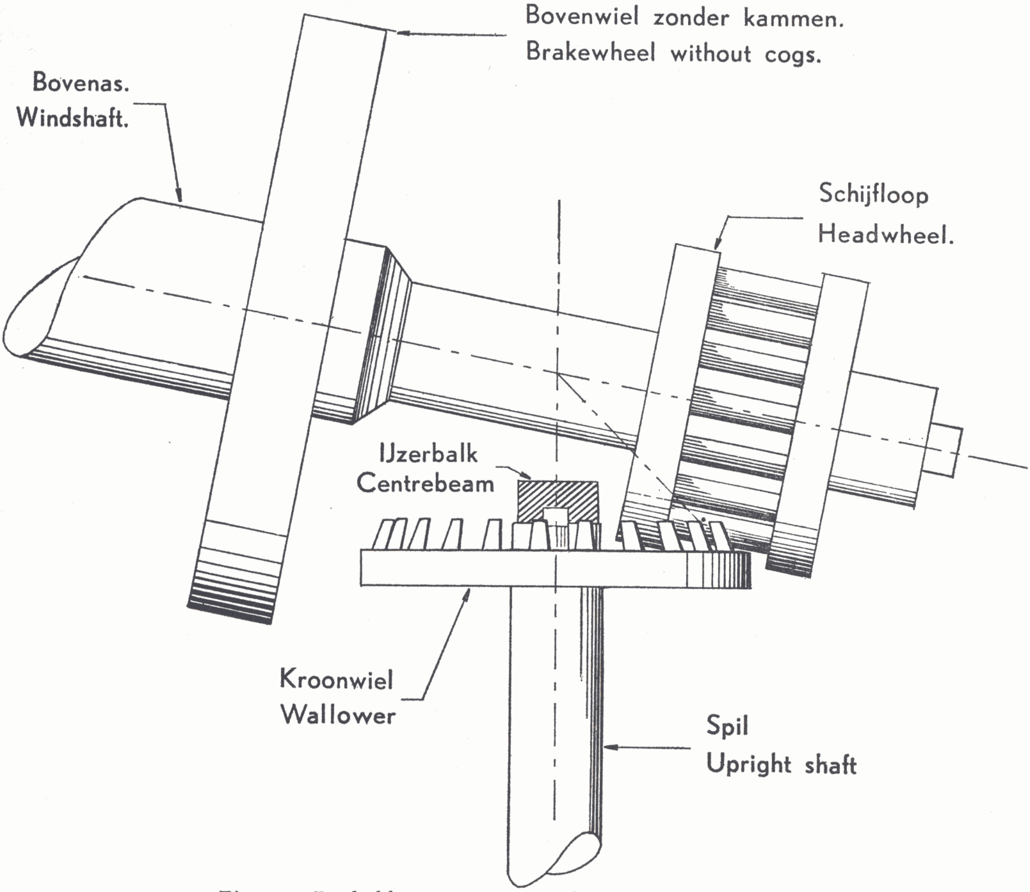

Fig. 22. Probable arrangement of Stevin's windmills.

each mill whether it was or was not constructed "according to the new design" shows the ultimate purpose of the essay. Let us, therefore, tabulate a few of the data given by Stevin on this point.

Stevin does not bother much in his calculations as to whether the dimensions are correct. He uses "feet" for real length, but also for areas and foot-pounds (M_1) and ounces for pressure like W (ounces per square feet). When comparing the data we find that equal lengths of sails show a slightly greater width of sails according to the "new design", but the floats of the "new design" are both significantly wider and also dip much deeper, this is repeatedly claimed by Stevin.

Also the ratio between the revolutions of the sails and the scoop wheels has greatly increased, i.e. for an equal number of revolutions of the sails the scoop wheel now turns much more slowly.

In his calculations Stevin constantly takes a certain predetermined wind pressure W and then calculates the ratio n. He then finds the number of cogs and staves for the different gearwheels of his drainage mills. Thus for the Escamp Mill (our no. 14) taking $K_1 = 47$, $s_1 = 12$ and $s_2 = 16$ he finds the value 21 for K_2. This does not fit in with the formula $n = K_1 s_2 / K_2 s_1$ which held for the old system. but with $n = K_1 K_2 / s_1 s_2$.

This goes to show that Stevin puts a lantern wheel on the windshaft (*schijfloop aan de wiecas*) which we have termed "head wheel" (Fig. 22). Hence he regularly speaks of the "lantern wheel on the windshaft" instead of the "wallower" (*bovenschijfloop*), which expression he reserves only for the lantern wheel on top of the upright shaft in the old design mills. The probable arrangement is shown in Fig. 22. It is doubtful whether he could have found conical lantern-wheels as illustrated in his patent of 1589 (Fig. 12) strong enough to transmit the energy from windshaft to upright shaft. We find all the characteristics of his inventions in the figures given by Stevin for the new mills.

What we do not learn are the reasons which prompted Stevin to design this new form of transmission. In his essay he does not stress the fact that the new mills would be able to throw out more water in a given period of time than did the old ones, though this is said in some of the testimonials he had laid down (Appendix II). Perhaps he believed that the ratio M_1/W would speak for itself, it is much larger in the "new" mills. Stevin's efforts had few practical results. His scoop wheel was forgotten in the general struggle between the scoop wheel and the Archimedean screw, though later millwrights certainly made larger scoop wheels which may be due to Stevin's propaganda. The conical form of the wallower was also soon forgotten. None of the important handbooks for millwrights written in the Netherlands in the eighteenth century such as Linperch, Van Zijl, or Van Vuuren and Polly mention Stevin's construction of a conical lantern wheel on the windshaft and a cog wheel on the upright shaft, nor did his design of the floats of the scoop wheel have any success, but this does not diminish his merits in drawing on hydrodynamics, hydrostatics and mechanics to establish and defend his inventions and in trying to give a mathematical foundation to his calculations. We should not forget that even in the days of Galileo and Descartes, applied mechanics was still concerned only in treating the classical devices which the Greek authors had already discussed and the attempt to calculate so complicated a mechanism as that of a drainage mill, fruitless though it may have been, deserves high praise.

4. HIS CONTEMPORARIES' REACTIONS

Stevin was not always fortunate in his new experiments. This is illustrated by the history of the new mill he built near IJsselstein, a story which is given by two files (nos. 512 and 513) still in the archives of IJsselstein. On April 8, 1589 De Groot had signed a contract with the representatives of the polder Leege Biesen, Achtersloot, Meerloo, and "het Brouck" in the land of IJsselstein [20]) for the delivery of "a good new drainage mill made of timber and iron ... for the sum of 630 carolus florins and an extra gift at discretion" guaranteeing that "the drainage mill would draw as much water as two of the best mills of thereabouts could do."

The mill should have been delivered before Matthewday 1589 but delivery did not take place until June 1590. According to the contract the payment was to take place in four instalments, the first within eight days after the signing of

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[20]) The present "waterschap" Broek en Lage Biesen en Neder Oudland, cut in two by the Achterslootsche Weg.
W. F. J. Den Uyl, *De Molen van de Polder Broek onder IJsselstein, gebouwd in 1589 ...*, Oud-Utrecht, vol. 33, 1960, 137—140.

the contract by the representatives of the polder, the second on the day of delivery, the third and the fourth after the lapse of a year. The note for the third payment bears the date of June 24, 1591, so that the mill must have been finished by June 24, 1590. Other papers show that the timberwork was inspected and accepted on February 8, 1590, and that the mill has worked on February 16, 1590. Hence the mill did not according to contract work in the autumn of 1589 to the distress of the farmers. The mill does not seem to have satisfied the authorities; it did not work for considerable periods and hence caused inundations of the land and anger of the inhabitants of the polder. The dike-reeves, therefore, after having paid the sum due in June 1591, refused to pay the fourth term a year later.

De Groot then lodged a complaint with Princess Maria of Nassau (usually called My Lady of Orange) who since the death of William the Silent managed the barony of IJsselstein for her brother Philips William, then held captive in Spain.

Now began a long series of letters between the Princess and her Council and the Bailiff of IJsselstein (Nicholas von Helmont), which are still kept in the IJsselstein files. Stevin, in order to safeguard his reputation and to prove that his designs worked well in other parts of the country, now set out to obtain the series of testimonials (Appendix II), which we have discussed. He also visited the mill personally on several occasions and concluded that the bad functioning was entirely due to sabotage, neglect and bad management. This was laid down in an official document drawn up by Paulus Viruly, notary public, on August 26, 1593 in which document two millwrights report on an inspection, which they carried out in the presence of Simon Stevin. The dike-reeves, however, stuck to their point, that faulty construction was the cause of the trouble, they stated that Stevin's witnesses were "disciples of Mr. Stevin and therefore they buttered him up", they were too young and their own experts made quite contrary statements.

This correspondence went on and on. The main point seems to have been that the upright shaft was made of too soft a timber and thus the thrust journal (*onderijzer*) penetrated into the timber and the smooth turning in the thrust bearing was endangered. Stevin in increasing the size of the scoop wheel caused a heavier load on the pit wheel (the diameter of which remained the same) and thus greater stresses in the cogs and staves of this wheel and the crown wheel. He was not able to solve this difficulty mechanically nor to cope with the greater stresses in other parts of the machinery.

It was not until after the Princess had exerted fairly strong pressure on the Bailiff of IJsselstein that the dike-reeves and the inhabitants were ready to accept arbitration. On August 6, 1594 at a meeting at IJsselstein, which was also attended by Stevin and a number of councillors of the Princess, it was decided that the parties would agree to accept the conclusion of a committee of four impartial lawyers, two of them to be nominated by each party, who would then appoint a super-arbitrator.

The files are full of suggestions about the fresh repairs, but the complaints did not stop and the dispute became so heated that De Groot had to complain to the Princess that the persons he had sent to inspect the mill did not dare to approach it because of the threatening attitude of the population.

The decision of the committee has not reached us, but we have a *Deductie van gerechticheyt* (Conclusion of justice), in which the dike-reeves again recapitulate the whole affair and expatiate on all the complaints, a demand by De Groot for the fourth payment together with 10% interest and the gift promised in the contract, and also a draft conclusion stating that the money should be paid to De Groot, the sums spent on repairs and advanced to him to be deducted. The decision must have fallen between November 3, 1594 and January 25, 1595, for the dike-reeves accepted the decision on March 16, 1595, but the Princess and her husband, Philip of Hohenlohe, still had to send several dunning-letters to the bailiff to obtain his actual payment of the sums due.

We reproduce (Fig. 23) part of a personal letter from Stevin found in these files, addressed to the bailiff of IJsselstein. From this letter we read that on November 3, 1594 no decision had yet been reached and the "compromise" mentioned probably refers to the decision to accept arbitration.

Stevin encountered similar trouble in the case of the Kralingen mills. Our information stems from three sources:

1. his own calculations of the two drainage mills in the "Ambacht Kralingen" (See his (6), (7), (17) and (17a));
2. documents of the Ambacht Kralingen now in the archives of the Hoogheemschapschap Schieland at Rotterdam,
3. two testimonials on the efficiency of these mills after they had been rebuilt (See Appendix II, sub 5 & 6).

The Ambacht (manor) of Kralingen disposed at that time of two drainage mills, both on the Slaak, north-east of Rotterdam, one octagonal mill and one square *wipwatermolen.* As late as 1587 rather large sums had been spent on repairs for the octagonal mill. The square mill seems to have been beyond repair, at least in 1589 it was completely restored according to an estimate which closely resembles that made by Stevin for a drainage mill for Duiveland (Appendix III). The only important difference consists in the fact the Kralingen mill (our no. 17) was to have a brake wheel with cogs. Probably this is a mistake. The estimate for the Duiveland mill mentions a break wheel without cogs, but having on the same windshaft a lantern wheel, a typical feature of Stevin's constructions.

The new Kralingen Mill was built by Master Joost Govertsz. and it was delivered in December 1589 (Plate I). According to a note on the orginal document it was wholly according to specifications on delivery, but the authorities were rather doubtful about the upright shaft. Possibly rumours about the IJsselstein difficulties had penetrated to Rotterdam.

Jan De Groot (who had cooperated with Master Joost Govertsz. in rebuilding this mill) had guaranteed that the new mill would "throw out as much water as two of the best octagonal mills in Schieland". The fear of the Council that the upright shaft (16" square!) would collapse under torsion points to heavy loads on the scoop wheel. This heavy load is confirmed by the double cogs of the pit wheel (also a feature of the Duiveland mill) and the width of the mill at the foot plates. Here again Stevin's new design must have seemed rather too bold to the Council of the Manor of Kralingen.

After this success Stevin planned to get the octagonal Kralingen mill rebuilt according to his views. In his calculations (our no. 17a) figures a scoop wheel $3\,^1/_2'$ wide, the floats of which were to dip about $3\,^1/_2'$ into the inner polder water. However, this estimate was not accepted by the Council of Kralingen Manor. Not until May 21, 1593 did this Council enter into a contract with Master Joost Spelt, according to which the latter was to build in the octagonal mill a scoop wheel

$3\,{}^{1}/_{4}'$ wide and dipping 2'10" into the inner water. According to the contract the number of floats was to be twelve, which looks like another concession on the part of Stevin.

In this contract of 1593 Master Joost pledged himself to cure the defects of the re-construction of 1589, and especially to rebuild and strengthen the pit wheel. Certain parts of this pit wheel, which had been found to be defective, were allowed to be used for the new machinery of the old octagonal mill. Between the lines of this contract we can read that the negotiations between the Council and Master Joost did not always run very smoothly. At the end of the contract there is a curious clause that the Manor was to give Master Joost's wife pin-money in the form of a *Rozenobel* to the value of seven guilders. The testimonial accorded to Stevin in June 1594 should be regarded as another conciliatory gesture.

We should mention here the costs of these two reconstructions. Those of the square Kralingen mill cannot be established precisely, the contract mentions four instalments, the first two of which were *f* 600.— each. The rebuilding of the scoop wheel, the water course and the machinery of the octagonal mill were estimated at *f* 1 100.—, to be paid in two instalments.

THE MANUSCRIPTS OF "ON MILLS"

It will be clear from the foregoing pages that Stevin never finished this manuscript and that the only thing we have are draft notes in a more or less final condition. The essay was first published in 1884 by Bierens de Haan [21]), who writes as follows on its origin:

"When undertaking another piece of research I had the good fortune to find certain unpublished works of Simon Stevin. They were amongst some papers of Constantijn Huygens, now in the library of our Academy of Sciences at Amsterdam, in the file *Handschriften* XLVII."

Since then they were sent to the Royal Library at The Hague, where they are now kept. He continued:

"There remains the latter work, which contains the calculations on 19 windmills (which I have numbered 1-19 in order to be able to refer to them) both of the old design and of the new design invented by Stevin himself. The essay discusses the geared wheels, cogs and staves needed to satisfy certain given conditions.

This is one of these essays which do not appear in the usual editions of the Works of Simon Stevin. But his son Hendrik Stevin used these notes partly in his work (XVI B, Book X), where one finds the mills numbered by me 1, 10, 14, 15, 16, 17, 18 and 19. There is therefore no doubt as to the authenticity of this work. The reproduction of a work or so famous a man will interest historians of science".

De Waard, when editing the Journal of Isaac Beeckman, who also used the notes left by Stevin, discussed them and compared the editions of Hendrik Stevin and Bierens de Haan in the following table [22]):

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[21]) J. Bierens de Haan, Simon Stevin, *"Van de Spiegheling der Singconst" et "Van de Molens", deux traités inédits,* Amsterdam, 1884.

[22]) C. de Waard, *Journal tenu par Isaac Beeckman, de 1604 à 1634,* Vol. II, 1619—1627, The Hague, 1942, Avertissement.

Title	Extract by *Beeckman*	Edition *B. de Haan* 1884	*H. Stevin* Wisc. Fil. Bedrijf 1667
Overslach der Suyt Noordorpsche molen	Fol. 204 *recto*, *l.* 1-205 *recto*, *l.* 21	p. 101, *l.* 1-p. 104, *l.* 27	X Boec, p. 10, *l.* 28-p. 13, *l.* 21
1e Voorstel. Te vinden met wat ghewicht waters het scheprat verladen is ende	Fol. 204 *recto*, *l.* 14-204 *recto*, *l.* 12	p. 101, *l.* 14-p. 102, *l.* 25	p. 11, *ll.* 1-34
2e Voorstel. Te vinden wat reden de keeren der wiecken teghen de keeren des schepprats hebben	Fol. 204 *verso*, *ll.* 13-22	p. 102, *l.* 26-p. 103, *l.* 8	Boec X, p. 12, *ll.* 1-11
3e Voorstel. De ghewelt van yder voet te vinden	Fol. 204 *verso*, *ll.* 23-28	p. 103, *ll.* 9-28	p. 12, *ll.* 12-27
4e Voorstel te vinden hoe styf de staven teghen de cammen persen	Fol. 205 *recto*, *ll.* 1-11	p. 104, *ll.* 1-14	p. 12, *l.* 28-p. 13, *l.* 10
5e Voorstel te vinden hoeveel waters datter met elcken keer der wiecken deurgaet, als 't binnewater op syn somerpeyl is	Fol. 205 *recto*, *ll.* 12-22	p. 104, *ll.* 15-27	p. 13, *ll.* 11-21
Overslach der molen tot Escamp na de nieu manier te veroirdenen reden der keeren deser wiecken tot het scheprat also dat yder voet seyls doe de gewelt van 3 oncen	Fol. 205 *recto*, *l.* 23-205, *l.* 17 Fol. 205 *verso*, *ll.* 1-14	p. 114, *l.* 25-p. 117, *l.* 29 p. 114, *l.* 25-p. 116, *l.* 6	Boec X, p. 15, *l.* 16-p. 18, *l.* 23 p. 16, *ll.* 1-15
Te veroirdenen de menichte der cammen en staven om te cryghen ten naestenby de bovenschreven reden der keeren van 1330 tot 251	Fol. 205 *verso*, *l.* 15-Fol. 206 *recto*, *l.* 17	p. 116. *l.* 7-p. 117, *l.* 29	p. 16, *l.* 16-p. 17, *l.* 28

Our edition is based on that of Bierens de Haan (1884) supplemented with such data and such passages as can be found in Henric Stevin's pious publication of his father's notes in his own book, but omitting the introductory passages and interjections by Henric Stevin.

6. THE LOCATION OF STEVIN'S DRAINAGE MILLS

If we try to locate the drainage mills mentioned by Stevin in his essay, we can find most of them on contemporary maps such as the maps drawn by Floris Balthazars (1611) of the *hoogheemraadschappen* (drainage provinces) of Delfland and Schieland. In a few cases the location is uncertain, but their approximate location is indicated on our map (Fig. 24). None of these mills have survived. Only in a few cases do we have any idea what they looked like. Thus Fig. 25 may illustrate the mill at the bridge near Pijnakker (Stevin's no. 4) as it was in 1900, for we have no indication that it was rebuilt or destroyed by fire before that date. We also have pictures of the mills near IJsselstein (Stevin's nos. 8 & 9), which were both closed in January 1925 and which are the lower and the upper mill of a set of two, draining the polder called *Het Broek* (Fig. 26). Upto 1844 when the lower mill was rebuilt, the drainage mill of Stevin's days probably stood there with very few changes except the usual repairs.

The earliest West-Escamp mill was built in 1465 and worked for over 100 years. In 1598 it was decided to replace it by an entirely new *wipwatermolen* and this plan was executed during the following year. The calculations given under no. 3 in Stevin's Essay on the Mills probably refer to this oldest mill of 1465 and his calculations of the Escamp mill "according to the new design" probably go back to 1598. Possibly Stevin submitted to the authorities a proposal on the new mill in which he stressed his ideas on a larger but slowly revolving scoop wheel. We do not know wether this invention was really applied at Escamp in 1599. The new mill of 1599 was repeatedly rebuilt in the course of the centuries; in 1858 it was definitely demolished. But this time the West-Escamp polder had been merged with the Oost-Escamp polder, and this new complex of polders received a new pumping-installation consisting of a circular stone mill and a steam-driven pumping station. They were built on the site of the old Oost-Escamp mill. The West-Escamp mill, on which Stevin based his calculations, vanished. We still possess a photograph of the Robbenoort mill (Stevin's no. 18) as it was in 1900, probably unchanged since the days of Stevin at least as far as the body of the mill is concerned.

7. STEVIN'S ESTIMATE OF A DRAINAGE MILL

In addition to the testimonials which Simon Stevin had drawn up and the documents on his IJsselstein lawsuit we have also reproduced an interesting document (Appendix III), in which Simon Stevin gives an estimate for a "square mill", a drainage mill (*vierkante wipwatermolen*) which is to be built in "Duvelandt". This document is one of the earliest detailed specifications we have in the Netherlands, the oldest drawing being that of Leeghwater (Fig. 27) designed for the draining of the Beemster Lake in the province of North Holland. The original drawing by Leeghwater is in the State Archives at Haarlem and is dated 1633. The "Duvelandt" mentioned in this document is undoubtedly the part of Zeeland near Zierikzee called Duiveland. It formed part of the polders embanked in the 14th century, like many others nearby belonging to the province of Zuid-Holland. As in the latter regions tax for drainage mills (*molengeld*) was paid throughout the 16th century, there is hardly any doubt that the deep Vierbannen polder of Duiveland had at least one drainage mill about 1590 when this document was drawn up, though we have no official records of it.

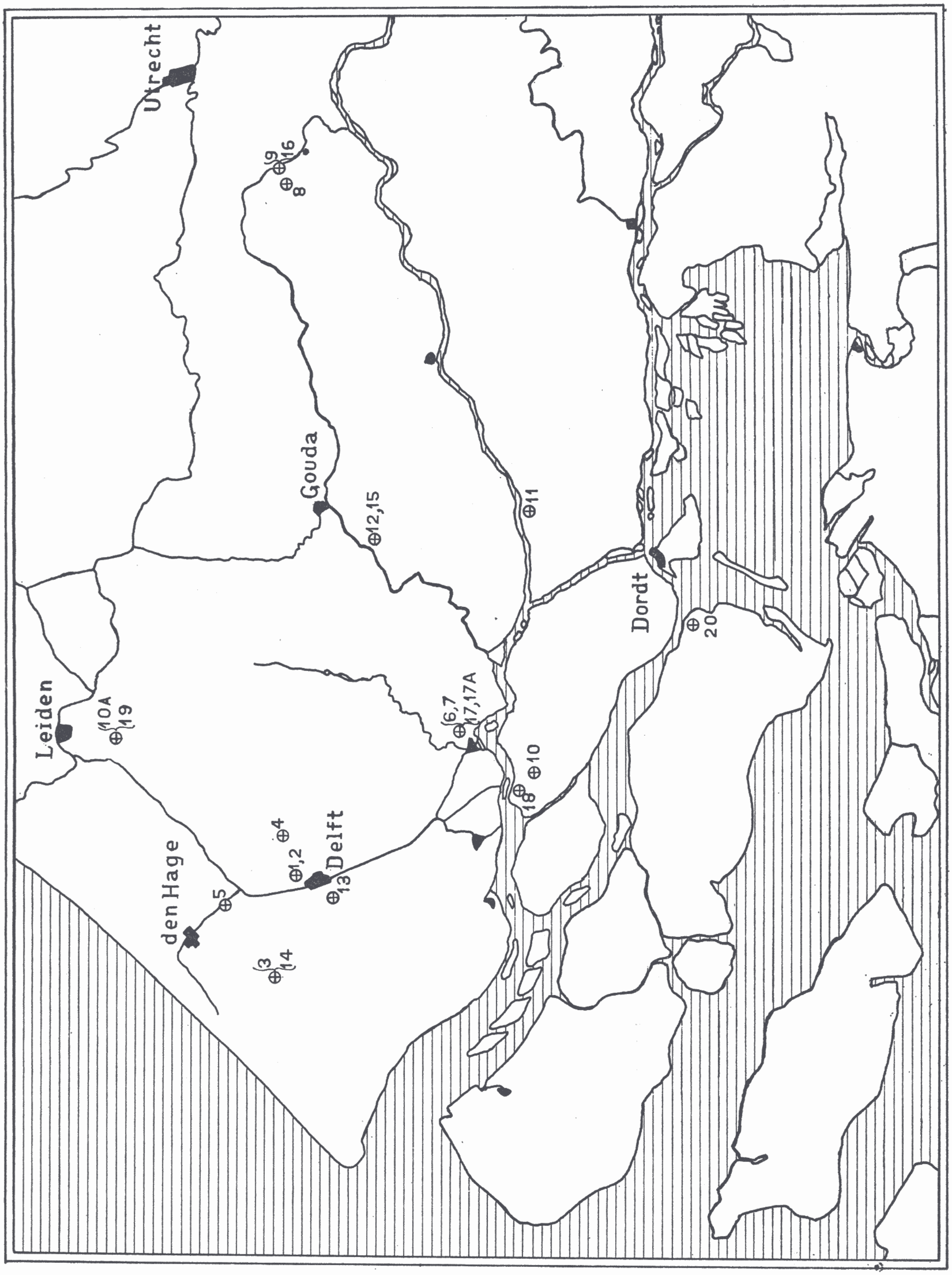

Fig. 24. Map of the Draining Mills, discussed by Stevin.

The document which Beeckman gives in detail (De Waard, vol. II, 413-416) was taken from Stevin's unpublished manuscripts, it was not reproduced by Stevin's son.

Unfortunately Stevin's estimate is very loosely composed. It seems that he copied the specifications of drainage mills or post mills in general available to him in contemporary documents quite correctly giving full details, and paid only slight attention to such details where he had a new construction to offer. Maybe like every inventor he did not wish to spill the secrets he had, or he had but a vague idea how to solve their practical application. Thus the estimate shows serious gaps, notably there is no clear specification of the scoop wheel and the gate in its water course, which were essential and even very important to Stevin, for here he had something new to offer. The cap of the mill as described by Stevin has a pointed shape. The hollow post struts specified by Stevin are $5\,^1/_2'' \times 19''$ only as compared with the usual $10'' \times 21''$, and hence his construction does not seem very solid. However, the mill was designed to run with furled sails in heavy winds, the windshaft being designed for moderate loads.

There is little difference generally between the construction of Stevin's mill, the earlier drainage mill and that of the famous millwrights of the eighteenth century (compare the plates XXII and XXI given by Van Natris and our plates I-III). In this specification we again observe the very primitive gearing which is a characteristic of windmills until well into the eighteenth century.

It should also be noted that Stevin was looking well after his own interests, for from the very first payment on this mill he wants his full patent rights deducted and paid to himself! However, incomplete as this estimate may be it is valuable not only for its information on the construction of early seventeenth-century mills but also for the cost of such mills, a figure on which we do not have many data as early as this one.

Even more interesting is the contract for the "square mill" at Kralingen, rebuild in 1589 by Jan Govertz. van der Spelt according to Stevin's design (Appendix IV). This document gives also the details of the water course and of the scoop wheel, so often lacking in other estimates. An attempt has been made to reconstruct the general aspect of this mill in a drawing and to represent its mechanism on scale (Plate I). This is the same mill about which we have testimonials of the miller and of local authorities, drawn up in 1590 and later in 1594 (Appendix III, nrs. 5 and 6).

The detailed estimate with which we can compare Stevin's figures is that of the 10 HP drainage mills built to drain the Beemster Lake in 1608 (Fig. 27 and plate III). However, improvements were already introduced in the 1607 estimate before these mills were actually built. We should never forget that Stevin is but the most prominent respesentative of a generation which stands out in the history of Dutch engineering as extremely active and inventive.

The characteristics of Stevin's constructions can best be demonstrated by comparing drawings of his drainage mill with the common drainage mills of his time. Data on the latter have been taken from the mills used to drain the Beemster Lake (Plate III), of which detailed estimates dating from 1607 are known.[23]) Therefore, we should compare the cross-section of a Beemster mill (according to

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[23]) J. Bouman, *Bedijking, opkomst en bloei van de Beemster* (Purmerend, 1857).

the 1607 estimate) with that of Stevin's Kralingen mill (Plate I). Plate II gives the common scoop wheel (and its water course) of those days to be compared with that of Stevin's Kralingen mill (Plate I).

Both the Dutch and the English contemporary terms for parts of the windmills and their water-pumping machinery have been given on these plates, the figures refer to the bilingual list of mill terms appended to this introduction. These will enable the reader to appreciate all details of the work of Stevin showing him to be a daring and ingenious engineer besides being one of the foremost scientists of his times.

CONTEMPORARY TERMS FOR PARTS OF THE WINDMILLS [24])

The figures refer to plate II

DUTCH		ENGLISH
Vorst Naald	1	Ridge Pole
Kap	2	Cap
As, wiekas, bovenas, molenas	3	Windshaft
Windpeluw	4	Pillow block
Blokkeel	5	Rode balk, breast beam
Daklijst	6	Upper side girt
Steenlijst	7	Side girt
Vangstok	8	Brake lever
Schoor	9	Brace
Steenbur	10	Crown tree
Boven zetel	11	Upper collar
Regel	12	Stretcher
Vangbalk	13	Brake beam
Waterlijst	14	Lower side girt
Voor somer	15	Front tie beam
Achter somer	16	Rear tie beam
Voeghout	17	Sheer
Staartbalk	18	Tailpole
Onder zetel	19	Lower collar
Boven tafelment	20	Upper cill
Koker balk (looze)	21	Hollow post beam
Bovenbalk	22	Upper beam
Kokerbalk	23	Cross tree
Onderbalk	24	Lower beam
Schijfloop (beneden), beneden- -bonkelaar	25	Crown wheel
Bovenschijfloop, lantarenwiel, bovenbonkelaar	26	Wallower
Scheprad	27	Scoop wheel
Spilkalf	28	Thrust bearing
Schoorstijl	29	Sprattle
Ondertafelment	30	Lower cill
Wateras	31	(Scoop)wheel shaft
Vleugel, waterdeur	32	Sluice door, slacker
Draagbalk	33	Foundation balk, bearer
Onderwiel, spoorwiel, waterwiel	34	Pit wheel
Bak	35	Pit
Dorpel	36	Sill
Roede	37	Stock
Wiek	38	Sail
Borstnaald	39	?
Stijl	40	Corner post

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[24]) Cf. also the description on p. 314 and the list of Appendix V.

Bovenwiel, aswiel, kamwiel	41	Brake wheel
Kokerstuk, kokerstick	42	Hollow post strut
Spil, molenspil	43	Upright shaft
Manderstijl	44	Raking stud
Krombeel	45	Cogged brace
Stoel	46	Break beam guide
Trapboom	47	Stringer
Leuning	48	Handrail
Hangboom	49	Winch support
Vangtouw	50	Brake rope
Midden spant	51	Centre span
Vlaamsche vang	52	Wooden brake
Sabelijzer	53	Sword iron
Klos	54	Console
Volstuk, rollingstuk	55	Hollow post stiffeners
Zetelstuk	56	Collar beam
Tafelmentstuk	57	Upper cill beam
Baartplanken	58	Wartherboarding
Kalver	59	Binding beam
Middelsomer	60	Intermediate tie beam
Achterste waaispant	61	Tail span
Achter balk	62	Outer tail beam
Penbalk	63	Inner tail beam
Deur	64	Door
Klos, hondsoor	65	Knee
Wervel	66	Thrust block
Spilkalf	67	Sprattle
Torenstijl	68	Quarterbar
Plooy	69	Cant
Kruisarm	70	Clasp arm
Kapspant	71	Cap spar
Wintkoppel	72	Winch
Sleeptrap	73	Ladder cill
Schoorstijl	74	Stud
Schoor	75	Brace
Gording	76	Brace
Swaart, Kalf	77	Brace
Schoep, lepel	78	Paddle, start, float
Achterwaterloop	79	Water course or intake
Rijsingstuk, opleider	80	Water guide
Voorwaterloop	81	Outgoing water course, outlet, discharge
Slagbint	82	Bearer, jamb
Tasting	83	Immersion
Kam	84	Cog
Staaf	85	Stave

VAN DE MOLENS

GEREVICEERT DOOR DEN PROFESSOR GOLIUS
1634

ON MILLS

REVISED BY PROFESSOR GOLIUS
1634

VAN DE MOLENS
GEREVICEERT DOOR DEN PROFESSOR GOLIUS
1634

[1] OVERSLACH der
Zuyt Nootdorpsche molen

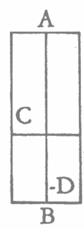
Langde der wiecke	$40\,^{1}/_{2}$	voet
Breede	$8\,^{1}/_{4}$	voet
Camrat boven	44	cammen
Schijfloop boven	13	staven
Schijfloop beneen	10	staven
Camrat beneen	52	cammen
Camrats halfmiddellijn tot opt middel der cammen	$^{31}/_{6}$	voet
Scheprats half middellijn	$^{31}/_{4}$	voet
Breede der lepels	$^{29}/_{24}$	voet
Commen onder tpeijl	$^{4}/_{3}$	voet
Verschil des hoochsten en leeghsten waters	4	voet

Hier uyt worden de volghende voorstellen beschreven.

1e VOORSTEL.

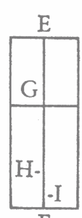
Te vinden met wat gewicht waters het scheprat verladen is, ende dat op eenich seker punt. Ick neem opt swaerheytsmiddelpunt des gheprangbs van het leeghste water.

De somme des wercx is dese, men sal vinden tghewicht tegen de lepel van achter persende, opt swaerheijts middelpunt des geprangs: daer na tghewicht datter van vooren perst, op een punt soo verre vanden as, als het swaerheijts middelpunt des gheprangs van tleegste water daer af is.



AB	$^{31}/_{4}$
Breet	$^{29}/_{24}$
BC	$^{4}/_{3}$
BD	$^{4}/_{9}$
AD	$^{263}/_{36}$

Daer na ghetrocken tcleenste ghewicht vant grootste, de rest is tbegeerde. *Tghegheuen.* Laet AB d'een sijde des lepels beteeckenen, lanck alsboven $^{31}/_{4}$, breet $^{29}/_{24}$, ende BC sij de hooghde des binnewaters van $^{4}/_{3}$ ende BD $^{4}/_{9}$ sij het derdendeel van BC ende D sal swaerheijtsmiddelpunt sijn des geprangs, deur het 18e voorstel der beghinselen des waterwichts, ende ghetrocken die $^{4}/_{9}$ van AB $^{31}/_{4}$, blijft voor AD $^{263}/_{36}$.
Laet nu EF dander sijde des lepels beteeckenen en FG sij de hoogde des buytewaters van $^{16}/_{3}$, want na luijt der beschriving hier voor, tbinnewater staet tegen de lepel hooch $^{4}/_{3}$ ende het buytewater noch 4 voet hoogher, maken tsamen als vooren $^{16}/_{3}$: Ende HF $^{16}/_{9}$ sij het derdendeel van FG, ende H sal swaerheijts middelpunt sijn des geprangs.



FG	$^{16}/_{3}$
HF	$^{16}/_{9}$
EH	$^{215}/_{36}$
EI	$^{263}/_{36}$

Ende ghetrocken HF $^{16}/_{9}$ van EF $^{31}/_{4}$, blijft voor EH $^{215}/_{36}$.
Laet nu ghestelt worden het punt I, also dat EI even sij an AD doende $^{263}/_{36}$. *Tbegheerde.* Wij moeten vinden hoe veel gewichts de lepel vooren meer heeft dan achter, ende dat op D, ofte, welck tselve is, op 't punt I. *Twerck.* Ick vinde deur het 15e voorstel der beghinselen des waterwichts, dat teghen

ON MILLS
REVISED BY PROFESSOR GOLIUS *
1634

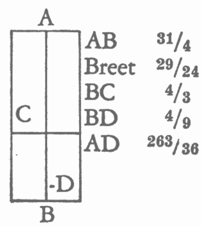
(1) CALCULATION of the *South Nootdorp Mill*

Length of the sails	$40\,^{1}/_{2}$	feet
Width	$8\,^{1}/_{4}$	feet
Brake wheel	44	cams
Wallower	13	staves
Crown wheel	10	staves
Pit wheel	52	cogs
Radius of pit wheel up to the pitch line	$^{31}/_{6}$	feet
Radius of the scoop wheel	$^{31}/_{4}$	feet
Width of the floats	$^{29}/_{24}$	feet
Immersion of floats	$^{4}/_{3}$	feet
Difference between the high-water and the low-water level	4	feet

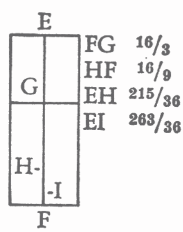
With these data the following propositions are calculated:

FIRST PROPOSITION

How to find the weight of the water bearing on the scoop wheel and that at any given point. I take for this the centre of gravity of the low-water level.



The essential task is to find the weight bearing from behind on the float in the centre of pressure[1]): then the weight bearing in front at a point as far from the wheel shaft as the centre of pressure of the low-water level. Then subtracting the smaller weight from the greater one, we find what is wanted. If *AB* be one side of a float, $^{31}/_{4}$ long (as given above) $^{29}/_{24}$ wide and *BC* be the inner level of the water of $^{4}/_{3}$, and *BD* $^{4}/_{9}$ be one third of *BC* and *D* is the centre of pressure according to the 18th proposition of the *Elements of Hydrostatics,* then subtraction of these $^{4}/_{9}$ from *AB* $^{31}/_{4}$ leaves for *AD* $^{263}/_{36}$.[2])
If now *EF* be the other side of the float and *FG* be the outer level of the water of $^{16}/_{3}$, (for according to the description the inner level of the water rises $^{4}/_{3}$ against the float and the outer level another 4 feet, which adds to the $^{16}/_{3}$ mentioned) and *HF* $^{16}/_{9}$ be one third of *FG,* then *H* shall be the centre of pressure.



Then subtraction of *HF* $^{16}/_{9}$ from *EF* $^{31}/_{4}$, leaves for *EH* $^{215}/_{36}$. Let us take a point *I* such that *EI* is equal to *AD* that is $^{263}/_{36}$. *Required.* We have to find how much more weight the float has in front than behind, and that at a point *D,* or what is the same at the point *I.*

Procedure. With the aid of the 15th proposition of the *Elements of Hydrostatics*[3]) I find that against the part of the float *BC* bear $^{29}/_{27}$ feet, the centre of pressure of which is *D.* Against

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*) Jacobus Golius, The Hague 1596—The Hague 1667, professor of Arabian literature at the University of Leyden, later also professor of mathematics.

1) Throughout this essay Stevin speaks of the "centre of gravity of the pressure".

2) See the note in the Introduction, p. 317.

3) See Vol. I of this edition, p. 449.

het lepeldeel BC, perst $^{29}/_{27}$ voet, wiens swaerheijts middelpunt des geprangs is D. Teghen het lepeldeel FG perst $^{3712}/_{216}$ voet, ende dat opt swaerheijts middelpunt H, de selve doen an I $^{3034}/_{216}$, want ick segh EI $^{263}/_{36}$ gheven $^{3712}/_{216}$, wat EH $^{216}/_{36}$? comt alsvoren $^{3034}/_{216}$ voet, die weghen (rekenende 65 £ voor de voet) 913 £, daer af ghetrocken de bovengeschreven $^{29}/_{27}$ voet, wegende 69 £, blijft voor tbegeerde 844 £, dieder perssen opt punt I inde selfde hoogde van tswaerheijts middelpunt D, des geprangs van tleegste water.

2e VOORSTEL

Te vinden wat reden de keeren der wiecken, teghen de keeren des scheprats hebben.

Ick menichvuldighe doenders met doenders, als 44 cammen van boven, met 10 staven van beneen, comt 440, daer na lijders met lijders, als 13 staven van boven, met 52 cammen van beneen (want sulck is de meenichte der cammen en staven deur de voorgaende beschrivingh van dien) comt 676, ende de reden den uytbrenghs der lijders als 676, totten uytbrengh der doenders als 440, is de begeerde reden vande keeren der wieken tottet scheprat, dat is, de wiecken $^{676}/_{440}$ mael, ofte 1 $^{59}/_{110}$ tegen tscheprat eens.

3e VOORSTEL

De ghewelt van yder voet seijls te vinden.

Tmiddel vande wieck is 20 $^{1}/_{4}$ voet vant middel vanden as, daerom sullen wij vinden tghewicht daer tscheprat mede verladen is, oock op 20 $^{1}/_{4}$ voet van tmiddel vande wateras, segghende 20 $^{1}/_{4}$ voet vande halve wieck, gheeft 844 £ persinghe, wat AD $^{263}/_{36}$? comt 304 £; Nu soo de wiecken even soo dickwils draeijden als tscheprat, soo soude de macht der wiecken sijn van 304 £, maer sij draeijen $^{676}/_{440}$ maer [1]) soo rasch, deur het 2e voorstel, daerom gedeelt 304 £ deur die reden der keeren als $^{676}/_{440}$, comt voor de macht der wiecken evestaltwichtich teghen de last des scheprats 197 £. Nu moet ick hebben de vlacke grootheijt der vier wiecken, daerom menichvuldighe ick haer langde deur breede, dats 40 $^{1}/_{2}$ voet deur 8 $^{1}/_{4}$ (soo langch ende breet sijnse deur de voorgaende beschrijvinghe) – maect $^{2673}/_{8}$ voet, voor een wieck, de selve vier mael, comt voor de vier wiecken 1336 $^{1}/_{2}$ voet, der selver ghewelt is van 197 £. daerom gerekent 16 oncen opt pont, soo comt yder voet seyls te doen de gewelt van 2 $^{480}/_{1\,336}$ oncen.

4e VOORSTEL

Te vinden hoe stijf de stauen teghen de cammen perssen.

Aengesien dat opt swaerheyts middelpunt des leeghsten waters, dats op $^{263}/_{36}$ voeten van tmiddel vanden as, perst 844 £ deur het je voorstel ende dat het middel vande cammen na de voorgaen beschrijvinghe $^{31}/_{6}$ voet van tmiddel van den as is, soo segh ick, $^{31}/_{6}$ geeft 844 £, wat $^{263}/_{36}$ voet van AD? comt 1193 £, ende soo stijf perssen de staven teghen de cammen des ondersten camrats opt middel der cammen berekent.

Om voort te vinden hoe stijf de bovenste staven tegen de cammen perssen, jck segh: ghelijck de middellijn des schijfloops beneden, tot de middellijn des schijfloops boven, alsoo de perssinge boven, tot de persinge beneden.

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1) XVI B has correctly "mael".

the part of the scoop *FG* bear $^{3\,712}/_{216}$ feet, and that in the centre of gravity *H*, which therefore bears in *I* $^{3\,034}/_{216}$, for I say: *EL* $^{263}/_{36}$ gives $^{3\,712}/_{216}$, what does *ER* $^{215}/_{36}$ give? This is $^{3\,034}/_{216}$ feet as given above, which weigh (taking 65 lbs to a foot of water) 913 lbs, subtraction of the above $^{29}/_{27}$ feet, weighing 69 lbs, yields what is wanted, 844 lbs, which bear on the point *I* at the same level as the centre of gravity *D* of the low-water level.

SECOND PROPOSITION

To find the ratio of the revolutions of the sails to the revolutions of the scoop wheel.

I multiply agents by agent, *i.e.* 44 cogs above by 10 staves below, which makes 440, then patients by patients, *i.e.* 13 staves above by 52 cogs below (for these are the number of cogs and staves as given in the above specification) which makes 676. Then the ratio between the product of the agents (676) and the product of patients (440) is the required ratio between the number of revolutions of the sails and those of the scoop wheel, *i.e.* the sails $^{676}/_{440}$ times, or 1 $^{59}/_{440}$, against the scoop wheel once.

THIRD PROPOSITION

To find the pressure on each (square) foot of sail.

The centre of the sail is at a distance of 20 $^{1}/_{4}$ feet from the centre of the wind shaft, therefore we have to calculate the weight bearing on the scoop wheel also at 20 $^{1}/_{4}$ feet distance from the scoop wheel shaft, saying 20 $^{1}/_{4}$ feet of half the sails gives a pressure of 844 lbs, what if *AD* is $^{263}/_{36}$? This gives 304 lbs. Now if the sails turned as often as the scoop wheel, the pressure on the sails Now if the sails turned as often as the scoop wheel, the pressure on the sails would be 304 lbs, but they turn $^{676}/_{440}$ times as fast (see proposition 2), hence 304 lbs divided by the ratio of the revolutions, *viz.* $^{676}/_{440}$ gives for the pressure on the sails equivalent to that on the scoop wheel 197 lbs. Now I must have the area of the four sails, therefore I multiply their length and width, *i.e.* 40 $^{1}/_{2}$ feet by 8 $^{1}/_{4}$ feet (so long and wide they are according to the specification) which makes $^{2\,673}/_{8}$ feet for one sail, four times this amount for the four sails makes 1 336 $^{1}/_{2}$ feet, the pressure of which is 197 lbs. Taking 16 ounces in the pound, this makes a pressure of 2 $^{480}/_{1\,336}$ ounces per (square) foot of sail.

FOURTH PROPOSITION

To find what pressure the staves exert on the cogs.

As in the centre of gravity of the low water level, *i.e.* at $^{263}/_{36}$ feet from the centre of the wheel shaft, bear 844 lbs according to the first proposition, and according to the specification the centre of the cogs is at $^{31}/_{6}$ feet from the centre of the wheel shaft, I say that $^{31}/_{6}$ gives 844 lbs, what will $^{263}/_{36}$ feet give for *AD*? This gives 1193 lbs, and this is the pressure of the staves against the cogs of the driven wheel calculated on the centre of the cogs.

To find what pressure the upper staves exert against the cogs, I say: as the radius of the driven wheel against the radius of the wallower, so the pressure above to that below.

5e VOORSTEL

Te vinden hoe veel waters datter met elcken keer der wiecken deurgaet, als tbinnenwater op sijn somerpeyl is.

Want des scheprats half middellijn doet $^{31}/_{4}$, ende de breede der lepels $^{29}/_{24}$, soo is tgeheel lichaem (te weten den ronden pilaer beschreven deur een keer der lepels) groot 228 voet. Hier af moet ghetrocken sijn het middeldeel des scheprats datter buyten het binnewater gaet, tselve deel is een ronde pilaer diens gront halfmiddellijn AC doet $^{77}/_{12}$, tselve lichaem is groot 156 voeten, die getrocken vande voorsz. 228 voet blijft 72 voet. Dit gaet eens om in $^{676}/_{440}$ keeren der wiecken; daerom ghedeelt 72 deur $^{676}/_{440}$, comt met elcken keer der wiecken 46 voeten waters.

[2] OVERSLACH der
Noort Nootdorpsche molen

Langde der wiecke	40 $^{1}/_{2}$	voet
Breede	8 $^{1}/_{4}$	voet
Camrat boven	48	cammen
Schijfloop boven	13	staven
Schijfloop beneen	9	staven
Camrat beneen	53	cammen
Camrats halfmiddellijn tot opt middel der cammen		
Scheprats half middellijn	7 $^{11}/_{12}$	voet
Breede der lepels	1 $^{1}/_{6}$	voet
Commen onder tpeijl	$^{4}/_{3}$	voet
Verschil des hoochsten en leeghsten waters	4	voet

Hier uyt volght het nabeschreuen.

[3] OVERSLACH der
Westescamp molen

33	voet	Langde der wiecke . . . .
8 $^{10}/_{12}$	voet	Breede . . . .
52	cammen	Camrat boven . . . .
		Schijfloop boven . . . .
		Schijfloop beneen . . . .
		Camrat beneen . . . .
		Camrats halfmiddellijn tot opt middel der cammen . . . .
6 $^{1}/_{6}$	voet	Scheprats half middellijn . . . .
		Breede der lepels . . . .
1 $^{7}/_{12}$	voet	Commen onder tpeijl . . . .
3 $^{10}/_{12}$	voet	Verschil des hoochsten en leeghsten waters . . . . . .

Hier uyt volght het nabeschreuen.

FIFTH PROPOSITION

To find how much water is raised by each revolution of the sails, if the inner waters are at the summer level.

As the radius of the scoop wheel is $^{31}/_{4}$ and the width of the floats $^{29}/_{24}$, the entire volume (*i.e.* of the cylinder described by one revolution of the scoop wheel) is 228 feet. From this we must subtract the centre part of the scoop wheel which does not enter the water of the wheel race which is a cylinder with a radius *AC* $^{77}/_{12}$, the volume of which is 156 feet, which, subtracted from the 228 feet already mentioned gives 72 feet. These are raised once in $^{676}/_{440}$ revolutions of the sails, therefore 72 divided by $^{676}/_{440}$ makes 46 feet of water for each revolution of the sails.

(2) CALCULATION of the *North Nootdorp Mill*

Length of the sails	$40\,^1/_2$	feet
Width	$8\,^1/_4$	feet
Brake wheel	48	cogs
Wallower	13	staves
Crown wheel	9	staves
Pit wheel	53	cogs
Radius of the pot wheel to the pitch line		
Radius of the scoop wheel	$7\,^{11}/_{12}$	feet
Width of the floats	$1\,^1/_6$	feet
Immersion of the floats	$^4/_3$	feet
Difference between the high-water and the low-water level	4	feet

These data lead to the following calculations.[1]

(3) CALCULATION of the *West-Escamp Mill*

Length of the sails	33	feet
Width	$8\,^{10}/_{12}$	feet
Brake wheel	52	cogs
Wallower		
Crown wheel		
Pit wheel		
Radius of the pot wheel to the pitch line		
Radius of the scoop wheel	$6\,^1/_6$	feet
Width of the floats		
Immersion of the floats	$1\,^7/_{12}$	feet
Difference between the high-water and the low-water level	$3\,^{10}/_{12}$	feet

These data lead to the following calculations.[2]

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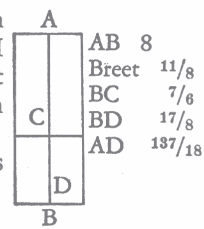
1) No further calculation is given, probably because one of the data is missing.
2) No calculation follows, because certain data are lacking in the list above.

[4] OVERSLACH der
Pynackersche molen aen de brugghe

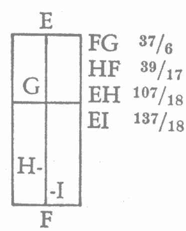
Langde der wiecke	41	voet
Breede	$7\,^{1}/_{2}$	voet
Camrat boven	50	cammen
Schijfloop boven	13	staven
Schijfloop beneen	10	staven
Camrat beneen	53	cammen
Camrats halfmiddellijn tot opt middel der cammen		
Scheprats half middellijn	8	voet
Breede der lepels	$^{11}/_{8}$	voet
Commen onder tpeijl	$^{7}/_{6}$	voet
Verschil des hoochsten en leeghsten waters	5	voet

Hier uyt volght het nabeschreuen.



Teghen BC perst $^{539}/_{576}$ voet ende dat op D. Teghen FG perst $^{15\,059}/_{576}$ voet ende dat op H, die doen an I $^{29\,003\,634}/_{1\,420\,476}$ want ick segh EI $^{137}/_{18}$ gheven $^{15\,059}/_{576}$ wat EH $^{107}/_{18}$? comt als vooren $^{19\,003\,634}/_{1\,420\,416}$ voet die weghen 1327 £ daer af getrocken de $^{539}/_{576}$ voet, weghende 60 £ blijft 1267 £ daer tscheprat mede verladen opt swaerheyts middelpunt des leeghsten waters als D.

De ghewelt van yder voet seyls te vinden.



$20\,^{1}/_{2}$ voet halve wieck gheeft 1267 £ persinge wat AD $^{187}/_{18}$? comt 470 £ die gedeelt deur reden der keeren $^{689}/_{500}$ comt 341 £ die ghedeelt deur 1230 voet der vier seylen comt yder voet seyls te doen de ghewelt van $4\,^{536}/_{1\,230}$ oncen.

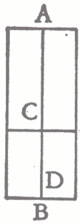
[5] OVERSLACH der
Nieu achtcante molen byden Hage

Langde der wiecke	$38\,^{1}/_{3}$	voet
Breede	$8\,^{1}/_{4}$	voet
Camrat boven	51	cammen
Schijfloop boven	12	staven
Schijfloop beneen	10	staven
Camrat beneen	53	cammen
Camrats halfmiddellijn tot opt middel der cammen		
Scheprats half middellijn	$6\,^{1}/_{3}$	voet
Breede der lepels	$^{17}/_{12}$	voet
Commen onder tpeijl	$^{7}/_{4}$	voet
Verschil des hoochsten en leeghsten waters	3	voet

(4) CALCULATION of the
Pynacker Mill at the bridge

Length of the sails	41	feet
Width	$7\,^{1}/_{2}$	feet
Brake wheel	50	cogs
Wallower	13	staves
Crown wheel	10	staves
Pit wheel	53	cogs
Radius of the pit wheel to the pitch line		
Radius of the scoop wheel	8	feet
Width of the floats	$^{11}/_{8}$	feet
Immersion of the floats	$^{7}/_{6}$	feet
Difference between the high-water and the low-water level . .	5	feet

These data lead to the following calculations:



AB 8
Breet $^{11}/_{8}$
BC $^{7}/_{6}$
BD $^{17}/_{8}$
AD $^{137}/_{18}$

Against *BC* bear $^{539}/_{576}$ feet, and that in *D*. Against *FG* bear $^{15\,059}/_{576}$ feet and that in *H*, which bear at *I* $^{29\,003\,634}/_{1\,420\,416}$ for I say *EI* $^{137}/_{18}$ gives $^{15\,059}/_{576}$, what does *EH* $^{107}/_{18}$ give? this gives $^{19\,003\,634}/_{1\,420\,416}$ feet as indicated which weigh 1327 lbs after subtraction of the $^{539}/_{576}$ feet weighing 60 lbs, gives 1267 lbs, which bear on the scoop wheel in the centre of gravity of the low-water level *D*.

To find the pressure on each (square) foot of sail.

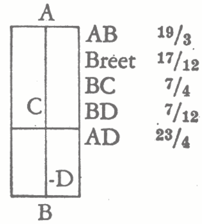
FG $^{37}/_{6}$
HF $^{39}/_{17}$
EH $^{107}/_{18}$
EI $^{137}/_{18}$

$20\,^{1}/_{2}$ feet in the centre of the sail give a pressure of 1267 lbs what if *AD* is $^{137}/_{18}$? This gives 470 lbs, which divided by the ratio between the revolutions $^{689}/_{500}$, gives 341 lbs, which divided by 1230 feet of the four sails, gives the pressure on each foot of sail of $4\,^{536}/_{1\,230}$ ounces.

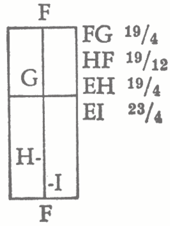
(5) CALCULATION of the
New octagonal mill near The Hague

Length of the sails	$38\,^{1}/_{3}$	feet
Width	$8\,^{1}/_{4}$	feet
Brake wheel	51	cogs
Wallower	12	staves
Crown wheel		
Pit wheel	53	cogs
Radius of the pit wheel to the pitch line		
Radius of the scoop wheel	$6\,^{1}/_{3}$	feet
Width of the floats	$^{17}/_{12}$	feet
Immersion of the floats	$^{7}/_{4}$	feet
Difference between the high-water and the low-water level . .	3	feet

Hier uyt volght het nabeschreuen.



Teghen BC perst $^{833}/_{384}$ voet ende dat op D. Teghen FG perst $6\,^{137}/_{384}$ voet ende dat op H die doen an I $466\,^{412}/_{35\,328}$ want ick segh EI $^{23}/_{4}$ gheven $6\,^{187}/_{384}$ voet, wat EH $^{19}/_{4}$? comt alsvooren $466\,^{412}/_{35\,329}$ voet die weghen 858 £ daer af getrocken de $^{833}/_{384}$ voet weghende 141 £ blijft 717 £ daer tscheprat mede verladen is opt swaerheyts middelpunt des leeghsten waters als D.



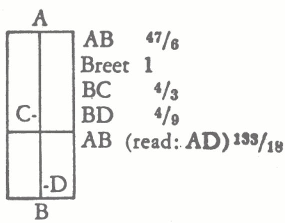
De ghewelt van yder voet seyls te vinden.

$19\,^{1}/_{6}$ voet halve wieck gheeft 717 £ persinge wat AD $^{23}/_{4}$? comt 215 £, die ghedeelt deur reden der keeren $^{636}/_{510}$ comt 172 £ die gedeelt deur 1265 der vier seylen comt yder voet seyls te doen de geweld van $2\,^{222}/_{1\,265}$ oncen.

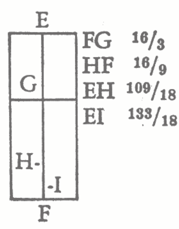
[6] OVERSLACH der
Craylinger achtcante molen

Langde der wiecke	$35\,^{1}/_{2}$ voet
Breede	$7\,^{1}/_{2}$ voet
Camrat boven	53 cammen
Schijfloop boven	12 staven
Schijfloop beneen	9 staven
Camrat beneen	52 cammen
Camrats halfmiddellijn tot opt middel der cammen	4 voet
Scheprats half middellijn	$7\,^{5}/_{6}$ voet
Breede der lepels	1 voet
Commen onder tpeijl	$1\,^{1}/_{3}$ voet
Verschil des hoochsten en leeghsten waters	4 voet

Hier uyt volght het nabeschreuen.



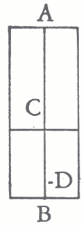
Teghen BC perst $^{8}/_{9}$ voet ende dat op D. Teghen FG perst $^{128}/_{9}$ voet ende dat op H die doen an I $251\,^{136}/_{21\,456}$ [read: 21546] want ick segh EI $^{133}/_{18}$ gheven $^{128}/_{9}$ wat EH $^{109}/_{18}$ comt alsvooren $251\,^{136}/_{21\,546}$ voet die weghen 757 £ daer af getrocken de $^{8}/_{9}$ £ [*read:* voet] weghende 57 £ blijft 700 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leegsten waters als D.



De ghewelt van yder voet seijls te vinden.

$17\,^{3}/_{4}$ voet, halve wieck, geeft 700 £ persinge wat AD $^{133}/_{18}$? comt 291 £ die ghedeelt deur reden der keeren $^{208}/_{159}$ comt 222 £ die ghedeelt deur 1065 voeten der vier seijlen, comt yder voet seijls te doen de ghewelt van $3\,^{357}/_{1\,065}$ oncen.

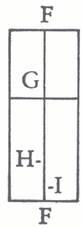
These data lead to the following calculations:



AB $^{19}/_{3}$
Breet $^{17}/_{12}$
BC $^{7}/_{4}$
BD $^{7}/_{12}$
AD $^{23}/_{4}$

Against *BC* bear $^{833}/_{384}$ feet, and that in *D*. Against *FG* bear $6\,^{137}/_{384}$ feet, and that in *H*, which bear in *I* $466\,^{412}/_{35\,328}$, for I say *EI* $^{23}/_{4}$ gives $6\,^{137}/_{384}$ feet what does *EH* $^{19}/_{4}$ give? This gives as indicated $466\,^{412}/_{35\,328}$ feet, which weigh 585 lbs, subtraction of the $^{833}/_{384}$ feet, weighing 141 lbs, gives 717 lbs with which the scoop wheel is loaded in the centre of gravity of the low-water level in *D*.

To find the pressure on each (square) foot of sail.



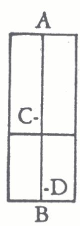
FG $^{19}/_{4}$
HF $^{19}/_{12}$
EH $^{19}/_{4}$
EI $^{23}/_{4}$

$19\,^{1}/_{6}$ feet in the centre of the sail gives a pressure of 717 lbs what at *AD* $^{23}/_{4}$? This gives 215 lbs, which, divided by the ratio between the revolutions $^{636}/_{510}$ gives 172 lbs, which, divided by 1265 of the four sails, gives a pressure on each foot of sail of $2\,^{222}/_{1\,265}$ ounces.

(6) CALCULATION of the
Cralingen octagonal Mill

Length of the sails	$35\,^{1}/_{2}$	feet
Width	$7\,^{1}/_{2}$	feet
Brake wheel	53	cogs
Wallower	12	staves
Crown wheel	9	staves
Pit wheel	52	cogs
Radius of the pit wheel to the pitch line	4	feet
Radius of the scoop wheel	$7\,^{5}/_{6}$	feet
Width of the floats	1	feet
Immersion of the floats	$1\,^{1}/_{3}$	feet
Difference between the high-water and the low-water level	4	feet

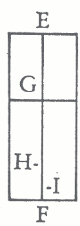
These data lead to the following calculations:



AB $^{47}/_{6}$
Breet 1
BC $^{4}/_{3}$
BD $^{4}/_{9}$
AB (read: AD) $^{133}/_{18}$

Against *BC* bear $^{8}/_{9}$ feet, and that in *D*. Against *FG* bear $^{128}/_{9}$ feet, and that in *H*, which would amount to $251\,^{136}/_{21\,456}$ [*read:* 21546] in *I*, for I say *EI* $^{133}/_{18}$ gives $^{128}/_{9}$; and, if *EH* is $^{109}/_{18}$, this gives, as above $251\,^{136}/_{21\,546}$ feet, which weigh 757 lbs, subtraction of the $^{8}/_{9}$ lbs [*read:* feet] weighing 57 lbs gives 700 lbs which bear on the scoop wheel in the centre of gravity of the low-water level at *D*.

To find the pressure on each foot of sail.



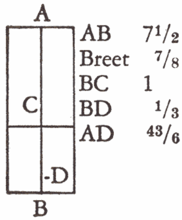
FG $^{16}/_{3}$
HF $^{16}/_{9}$
EH $^{109}/_{18}$
EI $^{133}/_{18}$

$17\,^{3}/_{4}$ feet in the centre of the sail give a pressure of 700 lbs what does *AD* $^{133}/_{18}$ give? This gives 291 lbs, which, divided by the ratio between the revolutions $^{208}/_{159}$ gives 222 lbs which divided by 1065 feet of the four sails gives a pressure on each foot of sail of $3\,^{357}/_{1\,065}$ ounces.

[7] OVERSLACH der *Craylingher Wipmolen*

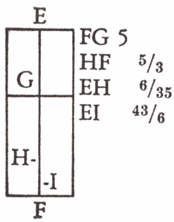
Langde der wiecke	34	voet
Breede	$7\frac{1}{2}$	voet
Camrat boven	47	cammen
Schijfloop boven	12	staven
Schijfloop beneen		
Camrat beneen	56	cammen
Camrats halfmiddellijn tot opt middel der cammen	$5\frac{1}{4}$	voet
Scheprats half middellijn	$7\frac{1}{2}$	voet
Breede der lepels	$1\frac{1}{6}$	voet
Commen onder tpeijl	1	voet
Verschil des hoochsten en leeghsten waters	4	voet

Hier uyt volght het nabeschreuen.



Teghen BC perst $^7/_{12}$ voet ende dat op D. Tegen FG perst $^{175}/_{12}$ voet ende dat op H, die doen an I $^{36\,750}/_{3\,096}$ want ick segh EI $^{43}/_6$ gheven $^{175}/_{12}$ wat EH $^{35}/_6$? comt alsvooren $^{36\,750}/_{3\,096}$ voet die weghen 771 £ daer af getrocken de $^7/_{12}$ voet weghende 38 £, blijft 733 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leeghsten waters als D.

De ghewelt van yder voet seyls te vinden.



17 voet halve wieck gheeft 733 £ persinge wat AD $^{43}/_6$? comt 309 £ die ghedeelt deur $^{672}/_{423}$ reden der keeren komt 194 £, die ghedeelt deur 1020 voet der vier seijlen comt yder voet seijls te doen de ghewelt van $3\,^{44}/_{1\,020}$ oncen.

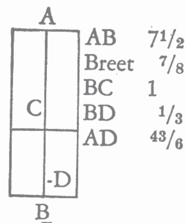
[8] OVERSLACH der *Leeghste staende Brouckscher molen by Ysselsteyn*

Langde der wiecke	37	voet
Breede	$7\frac{1}{4}$	voet
Camrat boven	44	cammen
Schijfloop boven	13	staven
Schijfloop beneen	10	staven
Camrat beneen	48	cammen
Camrats halfmiddellijn tot opt middel der cammen	$4\frac{2}{3}$	voet
Scheprats half middellijn	$7\frac{1}{3}$	voet
Breede der lepels	$1\frac{1}{3}$	voet
Commen onder tpeijl	$2\frac{5}{12}$	voet
Verschil des hoochsten en leeghsten waters	$1\frac{10}{12}$	voet

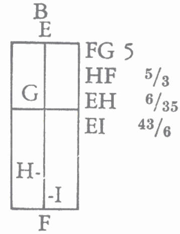
(7) CALCULATION of the *Cralingen Marshmill* ("Wipmolen")

Length of the sails	34	feet
Width	$7\frac{1}{2}$	feet
Brake wheel	47	cogs
Wallower	12	staves
Crown wheel		
Pit wheel	56	cogs
Radius of the pit wheel to the pitch line	$5\frac{1}{4}$	feet
Radius of the scoop wheel	$7\frac{1}{2}$	feet
Width of the floats	$1\frac{1}{6}$	feet
Immersion of the floats	1	feet
Difference between the high-water and the low-water level	4	feet

These data lead to the following calculations:



Against *BC* bear $^7/_{12}$ feet and that in *D*. Against FG bear $^{175}/_{12}$ feet and that in *H*, which bear in *I* $^{36\,750}/_{3\,096}$, for I say: *EI* $^{43}/_6$ gives $^{175}/_{12}$, what does *EH* $^{35}/_6$ give? As described above, this gives $^{36\,750}/_{3\,096}$ feet, which weigh 771 lbs; subtraction of the $^7/_{12}$ feet weighing 38 lbs, gives 733 which bear on the scoop wheel in the centre of gravity of the low-water level in *D*.



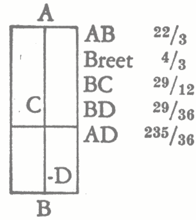
To find the pressure on each foot of sail.

17 feet in the centre of each sail give a pressure of 733 lbs what does *AD* $^{43}/_6$ give? This gives 309 lbs, which, divided by $^{672}/_{423}$, the ratio between the revolutions, gives 194 lbs, which, divided by 1020 feet of the four sails, gives a pressure on each foot of sail of $3\,^{44}/_{1\,020}$ ounces.

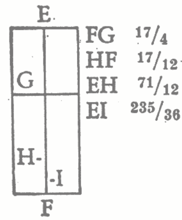
(8) CALCULATION of the *Lowest Mill at Broek near IJsselstein*

Difference between the high-water and the low-water level	37	feet
Length of the sails	$7\frac{1}{4}$	feet
Width	44	cogs
Brake wheel	13	staves
Wallower	10	staves
Crown wheel	48	cogs
Pit wheel	$4\frac{2}{3}$	feet
Radius of the pit wheel to the pitch line	$1\frac{1}{3}$	feet
Radius of the scoop wheel	$2\frac{1}{3}$	feet
Width of the floats	$2\frac{5}{12}$	feet
Immersion of the floats	$1\frac{10}{12}$	feet

Hier uyt volght het nabeschreuen.



Teghen BC perst $^{1\,682}/_{432}$ voet ende dat op D. Teghen FG perst $^{289}/_{24}$ voet ende dat op H die doen an I $^{738\,684}/_{67\,680}$ want ick segh EI $^{235}/_{36}$ gheven $^{289}/_{24}$ wat EH $^{71}/_{12}$? comt alsvooren $^{738\,684}/_{67\,680}$ voet die weghen 709 £ daer af getrocken de $^{1\,682}/_{483}$ voet weghende 253 £ blijft 456 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des waters als D.



De ghewelt van yder voet seijls te vinden.

18 $^1/_2$ voet halve wieck gheeft persinghe 456 £ wat AD $^{235}/_{36}$? comt 160 £ die ghedeelt deur reden der keeren $^{624}/_{440}$ comt 112 £, die ghedeelt deur 1073 voet der vier seijlen comt yder voet seijls te doen de ghewelt van $1\,^{719}/_{1\,073}$ oncen.

[9] OVERSLACH der
Hoochst staende Brouckscbe molen by Ysselsteijn

Langde der wiecke	36	voet
Breede	7 $^1/_4$	voet
Camrat boven	45	cammen
Schijfloop boven	12	staven
Schijfloop beneen	9	staven
Camrat beneen	5[0]	cammen
Camrats halfmiddellijn tot opt middel der cammen	4 $^7/_{12}$	voet
Scheprats half middellijn	6 $^{11}/_{12}$	voet
Breede der lepels	1 $^1/_2$	voet
Commen onder tpeijl	1 $^3/_4$	voet
Verschil des hoochsten en leeghsten waters	2 $^2/_3$	voet

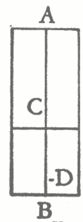
[10] OVERSLACH der
Ghinste molen in Sarlois [1])

Langde der wiecke	33 $^1/_2$	voet
Breede	7 $^1/_2$	voet
Camrat boven	51	cammen
Schijfloop boven	14	staven
Schijfloop beneen	10	staven
Camrat beneen	63	cammen
Scheprats half middellijn	7 $^1/_8$	voet
Breede der lepels	1 $^1/_4$	voet
Commen onder tpeijl	1 $^1/_2$	voet
Verschil des hoochsten en leeghsten waters	4 $^1/_3$	voet

1) Text identical with XVI B, Book X, 13—14.

These data lead to the following calculations:

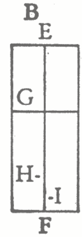
Against *BC* bear $^{1\,682}/_{432}$ feet, and that in *D*. Against *FG* bear $^{289}/_{24}$ feet, and that in *H*, which bear in *I* $^{738\,684}/_{67\,680}$, for I say: *EI* $^{235}/_{36}$ give $^{289}/_{24}$, what does *EH* $^{71}/_{12}$ give? This gives as above $^{738\,684}/_{67\,680}$ feet, which weigh 709 lbs; subtraction of the $^{1\,682}/_{432}$ feet, weighing 253 lbs, gives 456 lbs, which bear on the scoop wheel in the centre of gravity of the low-water level in *D*.



AB	$^{22}/_{3}$
Breet	$^{4}/_{3}$
BC	$^{29}/_{12}$
BD	$^{29}/_{36}$
AD	$^{235}/_{36}$

To find the pressure on each foot of sail.

$18\,^{1}/_{2}$ feet in the centre of the sail gives a pressure of 456 lbs; what does *AD* $^{235}/_{36}$ give? This gives 160 lbs, which divided by the ratio of revolutions $^{624}/_{440}$, gives 112 lbs which, divided by 1073 feet of the four sails, gives on each foot of sail a pressure of $1\,^{719}/_{1\,073}$ ounces.



FG	$^{17}/_{4}$
HF	$^{17}/_{12}$
EH	$^{71}/_{12}$
EI	$^{235}/_{36}$

(9) CALCULATION of the *Highest Mill at Broek near IJsselstein*

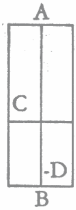
Length of the sails	36	feet
Width	$7\,^{1}/_{4}$	feet
Brake wheel	45	cogs
Wallower	12	staves
Crown wheel	9	staves
Pit wheel	5 (o)	cogs
Radius of the pit wheel to the pitch line	$4\,^{7}/_{12}$	feet
Radius of the scoop wheel	$6\,^{11}/_{12}$	feet
Width of the floats	$1\,^{1}/_{2}$	feet
Immersion of the floats	$1\,^{3}/_{4}$	feet
Difference between the high-water and the low-water level	$2\,^{2}/_{3}$	feet

(10) CALCULATION of the *Ghinst Mill at Charlois*

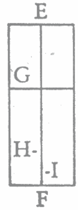
Length of the sails	$33\,^{1}/_{2}$	feet
Width	$7\,^{1}/_{2}$	feet
Brake wheel	51	cogs
Wallower	14	staves
Crown wheel	10	staves
Pit wheel	63	cogs
Radius of the pit wheel to the pitch line		
Radius of the scoop wheel	$7\,^{1}/_{3}$	feet
Width of the floats	$1\,^{1}/_{4}$	feet
Immersion of the floats	$1\,^{1}/_{2}$	feet
Difference between the high-water and the low-water level	$4\,^{1}/_{3}$	feet

Hier uyt volght het nabeschreuen.

Teghen BC perst $^{45}/_{32}$ voet ende dat op D. Teghen FG perst $6\,^{125}/_{288}$ voet ende dat op H die doen an I $^{3\,564\,750}/_{212\,544}$ want ick segh EI $^{41}/_{6}$ gheven $6\,^{125}/_{288}$ wat EH $^{97}/_{18}$? comt alsvooren $^{3\,564\,750}/_{212\,544}$ voet die weghen 1090 £ daer af getrocken de $^{45}/_{32}$ voet weghende 91 £ blijft 999 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leechsten waters als D.



AB $^{22}/_{3}$
Breet $^{5}/_{4}$
BC $^{3}/_{2}$
BD $^{1}/_{2}$
AD $^{41}/_{6}$



FG $^{35}/_{6}$
HF $^{35}/_{18}$
EH $^{97}/_{18}$
EI $^{41}/_{6}$

De ghewelt van yder voet seyls te vinden.

16 $^{3}/_{4}$ halve wieck gheeft 999 £ persinge wat AD $^{41}/_{6}$? comt 407 £ die ghedeelt deur reden der keeren $^{882}/_{510}$ comt 235 £ die ghedeelt deur 1005 voet der vier wiecken comt yder voet seijls te doen de ghewelt van 3 $^{745}/_{1\,005}$ oncen.

Menichte des waters dat met elcken keer der wiecken voort gedreven wort.[1])

Want des scheprats halfmiddellyn doet $^{22}/_{3}$ dats 7 $^{7}/_{2}$ voet, ende de breede der lepels $^{5}/_{4}$ dats 1 $^{1}/_{4}$ voet, so its geheel lichhaem (te weten de ronde pilaer beschreven deur een keer der lepels) groot 211 voeten, hier af moet getrocken zijn het middeldeel des scheprats datter buyten het binnewater gaet, tselve deel is een ronde pilaer, diens gronts halfmiddellyn AC doet $^{35}/_{6}$ tselve lichhaem is groot 133 voet, die getrocken vande voorschreve 211 voet, blijft 78 voet, dit gaet eens om in $^{882}/_{510}$, comt met elcken keer der wiecken 45 voeten waters.

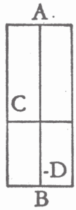
[10a] OVERSLACH

Van de Theens Molen tSoeterwoude na de oude manier

Langde der wiecke	15 $^{1}/_{2}$	voet
Breede	5	voet
Camrat boven	28	cammen
Schijfloop boven	10	staven
Schijfloop beneen	8	staven
Camrat beneen	28	cammen
Camrats halfmiddellijn tot opt middel der cammen		
Scheprats half middellijn	$^{15}/_{4}$	voet
Breede der lepels	$^{5}/_{12}$	voet
Commen onder tpeijl	$^{5}/_{4}$	voet
Verschil des hoochsten en leeghsten waters	2	voet

1) This passage up to [11] occurs in XVI B, Book X, 14—15 only.

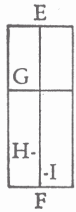
These data lead to the following calculations:



AB $^{22}/_{3}$
Breet $^{5}/_{4}$
BC $^{3}/_{2}$
BD $^{1}/_{2}$
AD $^{41}/_{6}$

Against *BC* bear $^{45}/_{32}$ feet, and that in *D*. Against *FB* bear $6\ ^{125}/_{288}$ feet, and that at *H*, which bear in *I* $3\ ^{564\ 750}/_{212\ 544}$; for I say: *EI* $^{41}/_{6}$ gives $6\ ^{125}/_{288}$, what does *EH* $^{97}/_{18}$ give? This gives, as indicated, $3\ ^{564\ 750}/_{212\ 544}$ feet, weighing 1090 lbs, subtract the $^{45}/_{32}$ feet, weighing 91 lbs, then 999 lbs remain, bearing on the scoop wheel in the centre of gravity of the low-water level in *D*.

To find the pressure on each foot of sail.



FG $^{35}/_{6}$
HF $^{35}/_{18}$
EH $^{97}/_{18}$
EI $^{41}/_{6}$

$16\ ^{3}/_{4}$ feet in the centre of the sails give 999 lbs presure; what does *AD* $^{41}/_{6}$ give? This gives 407 lbs which divided by the ratio between the revolutions $^{882}/_{510}$ gives 235 lbs, which, divided by 1005 feet of the four sails, gives on each foot of sail a pressure of $3\ ^{745}/_{1\ 005}$ ounces.

Volume of water raised by each revolution of the sails.

The radius of the scoop wheel is $^{22}/_{3}$, *i.e.* $7\ ^{1}/_{2}$ feet, and the width of the scoop $^{5}/_{4}$, *i.e.* $1\ ^{1}/_{4}$ feet; therefore the entire volume (of the cylinder described by one revolution of the scoop wheel) is 211 feet. Then subtract the centre part of the scoop wheel, which does not touch the water; this part forms a cylinder the radius of the bottom of which AC is $^{35}/_{6}$, while the volume is 133 feet. This subtracted from the above 211 feet, gives 78 feet; this is raised in $^{882}/_{510}$ revolutions of the sails, therefore 78, divided by $^{882}/_{510}$, gives 45 feet of water with each revolution of the scoop wheel.

(10a) CALCULATION of the *Theens Mill at Soeterwoude of the old design*

Length of the sails	$15\ ^{1}/_{2}$	feet
Width	5	feet
Brake wheel	28	cogs
Wallower	10	staves
Crown wheel	8	staves
Pit wheel	28	cogs
Radius of the pit wheel to the pitch line		
Radius of the scoop wheel	$^{15}/_{4}$	feet
Width of the floats	$^{5}/_{12}$	feet
Immersion of the floats	$^{5}/_{4}$	feet
Difference between the high-water and the low-water level	2	feet

Hier uyt volgt het nabeschreven.

Tegen BC perst $^{125}/_{384}$ voet, ende dat op D. Tegen FG perst $^{845}/_{384}$ voet ende dat op H, die doen an $1\,^{20\,280}/_{11\,520}$, want ic segh EI $^{10}/_{3}$, geven $^{845}/_{384}$ wat EH $^{8}/_{3}$? comt alsvooren $^{20\,280}/_{11\,520}$ voet, die wegen 114 £, daer afgetrocken de $^{125}/_{384}$ voet, wegende 21 £, blyft 93 lbs, daer tscheprat mede verladen is opt swaerheyts middelpunt des leegsten waters als D.

De gewelt van yder voet zeyls te vinden.

$3^{1}/_{4}$ Voet halve wiec geeft 93 £ persinge wat AD $^{12}/_{3}$? comt 40 £, die gedeelt deur reden der keeren $^{5}/_{4}$? comt 32 £, die gedeelte deur 310 voet der vier zeylen, comt yder voet zeyls te doen de gewelt van $1\,^{202}/_{310}$ oncen.

Hier achter volgen noch veel meer sulke overslagen van wesentlicke Molens diens tijts naer de oude manier, welcke wy niet nodig en achten alle hier by te voegen; Als connende hy, dieder lust toe hebben mocht, diergelijcke overslagen maken van wesentlicke schepratmolens deses tijts, naer de oude wyse; Ende daer me sal hy met enen ervaren wat veranderingen tsedert daer in gevallen zijn.

[11] OVERSLACH der
Streefkercksche middel molen

Langde der wiecke	38	voet
Breede	7 1/2	voet
Camrat boven		
Schijfloop boven		
Schijfloop beneen		
Camrat beneen		
Scheprats half middellijn	7 1/2	voet
Breede der lepels		
Commen onder tpeijl	2 3/4	voet
Verschil des hoochsten en leeghsten waters	2 1/2	voet

[12] OVERSLACH der
Beyersche molen te Stolck

Langde der wiecke		
Breede		
Camrat boven	47	cammen
Schijfloop boven	13	staven
Schijfloop beneen	9	staven
Camrat beneen	47	cammen
Scheprats half middellijn	6 1/2	voet
Breede der lepels	1 1/3	voet
Commen onder tpeijl	11/6	voet
Verschil des hoochsten en leeghsten waters	3	voet

These data lead to the following calculations:

Against *BC* bear $^{125}/_{384}$ feet, and that in D.

Against *FG* bear $^{845}/_{384}$ feet, and that in *H,* which bear in *I* $^{20\,280}/_{11\,520}$, for I say: *EI* $^{20}/_{3}$ gives $^{845}/_{384}$, what does *EH* $^{8}/_{3}$ give? This gives, as above $^{20\,280}/_{11\,520}$ feet, weighing 114 lbs, subtract $^{125}/_{384}$ feet, weighing 21 lbs, this gives 93 lbs bearing on the scoop wheel in the centre of gravity of the low-water level in *D.*

To find the pressure on each foot of sail.

$^{31}/_{4}$ feet in the centre of the sail give a pressure of 93 lbs what does AD $^{10}/_{3}$ give? This gives 40 lbs which divided by the ratio of revolutions $^{5}/_{4}$ gives 32 lbs which divided by 310 feet for the four sails gives on each foot of sail a pressure of $1\,^{202}/_{310}$ ounces.

Here follow many more data of real mills built at the time according to the old design, which we do not all consider worth while mentioning here (says Hendrik Stevin!); for anyone, who wishes to can make such calculations of the raising of drainage mills of today built according to the old design. And he will then at once perceive what changes have since been wrought in the design.

(11) CALCULATION of the
Middle Mill at Streefkerk

Length of the sails	38	feet
Width	$7\,^{1}/_{2}$	feet
Brake wheel		
Wallower		
Crown wheel		
Pit wheel		
Radius of the scoop wheel	$7\,^{1}/_{2}$	feet
Immersion of the floats	$2\,^{3}/_{4}$	feet
Difference between the high-water and the low-water level	$2\,^{1}/_{2}$	feet

(12) CALCULATION of the
Beyer Mill at Stolwijk

Length of the sails		
Width		
Brake wheel	47	cogs
Wallower	13	staves
Crown wheel	9	staves
Pit wheel	47	cogs
Radius of the scoop wheel	$6\,^{1}/_{2}$	feet
Width of the floats	$1\,^{1}/_{3}$	feet
Immersion of the floats	$^{11}/_{6}$	feet
Difference between the high-water and the low-water level	3	feet

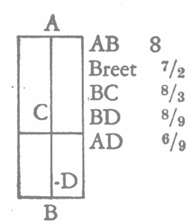
[13] OVERSLACH der
Molen opt hof van Delf

Langde der wiecke	35	voet
Breede	8	voet
Camrat boven	48	cammen
Schijfloop boven	13	staven
Schijfloop beneen	9	staven
Camrat beneen	56	cammen
Scheprats half middellijn	7	voet
Breede der lepels	$1\,{}^{1}/_{6}$	voet
Commen onder tpeijl	${}^{13}/_{12}$	voet
Verschil des hoochsten en leeghsten waters	$4\,{}^{1}/_{2}$	voet

[14] OVERSLACH der
Molen tot Escamp na de nieu manier

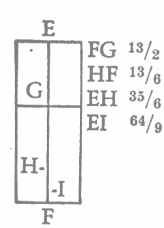
Langde der wiecke	$33\,{}^{1}/_{2}$	voet
Breede	10	voet
Scheprats half middellijn	8	voet
Breede der lepels	$3\,{}^{1}/_{2}$	voet
Commen onder tpeijl	$2\,{}^{2}/_{3}$	voet
Verschil des hoochsten en leeghsten waters	$3\,{}^{5}/_{6}$	voet

Hier uyt volght het nabeschreuen.



Teghen BC perst ${}^{112}/_{9}$ voet ende dat op D. Teghen FG perst $1\,{}^{183}/_{16}$ [voet] ende datop H die doen [an] I ${}^{372\,645}/_{6\,144}$ want ick segh EI ${}^{64}/_{9}$ gheven $1\,{}^{183}/_{16}$ wat EH ${}^{35}/_{6}$? comt alsvooren ${}^{372\,645}/_{6\,144}$ voet die weghen 3943 [£] daer af getrocken de ${}^{112}/_{9}$ voet weghende 809 £ blijft 3133 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leeghsten waters als D.

Te veroirdenen reden der keeren deser wiecken tot het scheprat alsoo dat yder voet seyls doe de ghewelt van 3 oncen.



Ick vinde eerst de platte grootheijt der vier wiecken meenichvuldighende de langde $33\,{}^{1}/_{2}$ deur de breede 10 maect voor den wieck 335 die viermael comt voor de wiecken 1340 voeten, de selve menichvuldighe ick met de 3 oncen, comt voor de ghewelt der vier wiecken 251 £ ende dit opt middelpunt der wiecke dats op $16\,{}^{3}/_{4}$ voet van tmiddel vanden as. Nu soo tpunt D des gheprangs der 3133 £ oock waer $16\,{}^{3}/_{4}$ voet van tmiddel vande wateras soo soudemen segghen de reden der keeren te moeten wesen van 3133 £ tot 251, maer dat gheprang op D

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[1]) Text identical with XVI B, Book X, 15—17.
In Hendric Stevin's version this title is preceded by a caption "Van Poldermolens nae de nieuwe manier ons Vaders" (On Drainage mills according to our father's design).

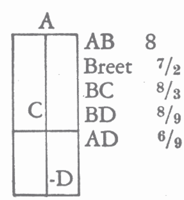
(13) CALCULATION of the
Mill in the court (?) of Delft

Length of the sails	35	feet
Width	8	feet
Brake wheel	48	cogs
Wallower	13	staves
Crown wheel	9	staves
Pit wheel	56	cogs
Radius of the scoop wheel	7	feet
Width of the floats	$1\,^{1}/_{6}$	feet
Immersion of the floats	$^{13}/_{12}$	feet
Difference between the high-water and the low-water level	$4\,^{1}/_{2}$	feet

(14) CALCULATION of the
Escamp Mill, new design [1])

Length of the sails	$33\,^{1}/_{2}$	feet
Width	10	feet
Radius of the scoop wheel	8	feet
Width of the floats	$3\,^{1}/_{2}$	feet
Immersion of the floats	$2\,^{2}/_{3}$	feet
Difference between the high-water and the low-water level	$3\,^{5}/_{6}$	feet

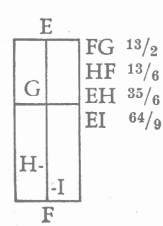
These data lead to the following calculations:



Against *BC* bear $^{112}/_{9}$ feet and that in *D*.

Against *FG* bear $1\,^{183}/_{16}$ (feet) and that at *H*, which would bear (in) *I* $^{372\,645}/_{6\,144}$, for I say *EI* $^{64}/_{9}$ gives $1\,^{183}/_{16}$ what does *EH* $^{35}/_{6}$ give? This gives as above, $^{372\,645}/_{6\,144}$ feet, weighing 3942 (lbs); subtract the $^{112}/_{9}$ feet weighing 809 lbs, this gives 3133 lbs which bear on the scoop wheel in the centre of gravity of the low-water level in D.

To establish the ratio between the revolutions of sails and scoop wheel if the pressure on each foot of sail be 3 ounces.



I first find the area of the four sails by multiplying the length $33\,^{1}/_{2}$ by the width 10 which gives per sail 335, four times this amount for the four sails gives 1340 feet. These I multiply by the three ounces, which makes a pressure on the four sails of 251 lbs and that in the centre of the sails, *i.e.* at a distance of $16\,^{3}/_{4}$ feet from the centre of the windshaft. If then point *D* of the pressure of the 3133 lbs were also at a distance of $16\,^{3}/_{4}$ feet from the centre of the scoop-wheel shaft one would have to say that the ratio between the revolutions must

1) Probably never built.

alleenlick wesende $^{64}/_{9}$ voet van middel vanden as, soo moeten wij dat vinden op $16\,^{3}/_{4}$ voet seggende $16\,^{3}/_{4}$ gheven 3133 wat $^{64}/_{9}$? comt 1330. Ic segh dan dat de reden der keeren moet sijn van 1330 tot 251, daerom ghedeelt 1330 deur 251 comt $5\,^{75}/_{251}$ ende soo menichmael sullen de wiecken moeten ommegaen teghen tscheprat eens.

Te veroirdenen de menichte van cammen en staven om te cryghen ten naesten by de boueschreuen reden der keeren van 1330 *tot* 251.

Ghenomen dat ick aensiende de grootheijt des camrats ende de behoirlicke dickte der cammen ende der staven die daer tussen commen moeten, soo veroirden ick het camrat beneen met 47 cammen, het schijfloop daertoe met 12 staven ende het schijfloop aende wieckas met 16 staven. Vrage hoe veel cammen het croonradt sal moeten hebben om de begheerde reden der keeren te crijghen. Ick stelle de voornomde [sic] 16. 12 en 47 in oirden ende *O* ter plaets daer tgetal der begheerde cammen moet staen als hier onder segghende 16 mael 12 is 192, die stel ick daer neven aldus:

16.	12.	192
O.	47.	

Nu ist kennelick dat ter plaets van *O* een getal moet staen soodanich dattet selve ghemenichvuldicht met 47 gheve den uytbrengh die sulcken reden hebben tot 192 als 1330 tot 251. Om tselve te vinden ick segghe 251 gheeft 1330 wat 192? comt 1017 die stel ick onder de 192. Nu aenghesien tgetal ter plaets van *O* ghemenichvuldight met 47 moet maken 1017, soo deel ick 1017 deur de 47 comt ten naesten bij 21 ende soo veel cammen sal het croonrat hebben. Ende de ghestalt der werckinghe sal sijn als hier onder

16.	12.	192
21.	47.	1017.

Doch alsoo 21 mael 47 maer uytenbrenghen 987, soo en salder eijghentlicke reden der keeren int ghemaeckte werck maer sijn van 987 tot 192 als hieronder

16.	12.	192
21.	47.	987.

Ick segghe dan datted schijfloop aende wieckas sal hebben . .	16	staven
het croonrat	21	cammen
het schijfloop beneen	12	staven
het camrat beneen	47	cammen
Ende tselve camrat ghemaect wesende soo is sijn half middellijn tot opt middel der cammen	$5\,^{1}/_{2}$	voet

Proef.

Somen nu den proef wil doen ende sien of yder voet wiecks hier mede de begheerde ghewelt uytbrenght ten naesten bij van 3 oncen men doe na de leeringhe des 3^{en} Voorstels int j^{e} overslach aldus.

$16\,^{3}/_{4}$ voet halve wieck gheeft 3133 £ persinge, wat AD $^{64}/_{9}$? comt 1330 £ die ghedeelt deur reden der keeren $^{987}/_{192}$ comt 258 £ die ghedeelt deur 1340 voet der vier wiecken comt yder voet wieck te doen de ghewelt van $3\,^{108}/_{1\,840}$ oncen.

be as 3133 lbs to 251, but the pressure in *D* is only at $^{64}/_{9}$ feet from the centre of the shaft so we have to find this at $16\,^{3}/_{4}$ feet, saying: $16\,^{3}/_{4}$ give 3133, what does $^{64}/_{9}$ give? This gives 1330. I therefore say that the ratio between the revolutions must be as 1330 to 251; therefore divide 1330 by 251, this gives $5\,^{75}/_{251}$, and so often the sails will revolve against one revolution of the scoop wheel.

To establish the number of cogs and staves in order to obtain approximately the above-mentioned ratio of 1330 to 251.

Suppose that in view of the size of the brake wheel and the necessary dimensions of the cogs and staves which should interact I make a pit wheel with 47 cogs, the crown wheel with 12 staves and the wallover with 16 staves. The question is now how many cogs should the brake wheel have in order to get the indicated ratio between the revolutions? I put the above-mentioned 16, 12 and 47 in a row and *O* at the place where the desired number of the cogs should be and saying that 16 times twelve make 192 I add this number in the way shown below:

16.	12.	192.
O.	47.	

It is obvious that in the place of *O* there should be a number which if multiplied by 47 will give a result which is to 192 in the same ratio as 1330 to 251. In order to find it I say 251 gives 1330, what does 192 give? This gives 1017, this I place under the 192. As the number in the place of the *O*, multiplied by 47 must give 1017, I divide 1017 by 47 which gives approximately 21 and so many cogs the brake wheel must have.

And the form of the calculation must become as below:

16.	12.	192.
21.	47.	1017.

But as 21 times 47 gives only 987, the actual ratio in the mechanism constructed must be only as 987 to 192, as shown below

16.	12.	192.
21.	47.	987.

I say then that the wallower should have . . . . 16 staves
the brake wheel . . . . 21 cogs
the crown wheel . . . . 12 staves
the pit wheel . . . . 47 cogs
and the pit wheel thus made should have a radius up to the centre of the cogs of $5\,^{1}/_{2}$ feet.

Proof.

Should one now seek a proof to see whether each foot of the sails has a pressure of nearly three ounces as desired, calculate according to the instruction in the third proposition of the first calculation, thus: $16\,^{3}/_{4}$ feet in the centre of the sail give a pressure of 3133 lbs, what does *AD* $^{64}/_{9}$ give? This gives 1330 lbs, which divided by the ratio between the revolutions $^{987}/_{192}$, gives 258 lbs, which divided by 1340 feet of the four sails gives a pressure on each foot of the sails of $3\,^{108}/_{1\,340}$ ounces.

Het is wel waer datter maer begheert en was 3 oncen doch dit verschil is soo cleen dat bij aldienmen int croonrat maeckt een cam meer en stelde als 22 cammen, soo soudet dan min vallen als 3 oncen, te weten $2\,{}^{1256}/_{1840}$ oncen.

Te vinden hoe stijf de Staven tegen de cammen perssen. 1)

Angesien opt swaertheytsmidpunt des leegsten waters, dat is op $^{64}/_{9}$ voeten vant middel vanden as perst 3133 £ deurt 1 lit deses gevolgs; En dat het middel vande cammen $5\,{}^{1}/_{2}$ voet vant middel der as is, deur het 3 lit deses gevolgs: Soo seg ic $5\,{}^{1}/_{2}$ voet, geeft $^{64}/_{9}$, voet wat 3133 £? comt $4050\,{}^{74}/_{99}$ £: En so stijf persen de staven tegen de cammen des ondersten camrats opt middel gerekent.

Om nu te vinden hoe stijf de bovenste staven tegen de cammen persen. Ic seg gelijc de midlini des schyfloops beneen, totte midlini des schyfloops boven, also perssing boven tot perssinge beneen.

De dracht des Molens tot Escamp, en wort vant middel der wiecas aldus berekent.

De tafelmenten elck dick 1 voet tsamen 2 voet, daer afgetroken moet syn haer inkipping elc drie duym, ende d'inkipping des ondersten tafelments en de 2) slove ooc elc drie duym tsamen

1 voet, blijft	1	— —	0
De tooren tusschen borsten	17	— —	0
De zetel	0	— —	11
De vouchouten 3)	1	— —	0
De somers	0	— —	9
De waterlysten	0	— —	7
De houckstylen tusschen borsten	8	— —	0
De dacklysten	0	— —	10
De steenlysten	1	— —	5
De steen	1	— —	0
Den halve as	1	— —	0
Somma	33	— —	6

Laet de hoogde van $33\,{}^{11}/_{3}$ voet AB zijn, ende BC sy deel der slove, en de AB is vijfvoudich tot BC, daerom sal BC doen $^{67}/_{10}$, ende AC $\sqrt{1167\,{}^{7}/_{50}}$, maer CD doet 7, daerom de roe AD doet $\sqrt{1118\,{}^{7}/_{50}}$ dats by 33-5.

[15] OVERSLACH der
Stolwyckschc molen na de nieu manier 4)

Langde der wiecke	40	voet
Breede	$9\,{}^{1}/_{2}$	voet
Scheprats half middellijn	$10\,{}^{1}/_{6}$	voet
Breede der lepels	$3\,{}^{1}/_{2}$	voet
Commen onder tpeijl	$4\,{}^{1}/_{6}$	voet
Verschil des hoochsten en leeghsten waters	4	voet

1) The following passages up to [15] occur only in XVI B, Book X, 17—18.
2) For "*in* de slove". à
3) For "vouch-houten".
4) Text identical with XVI B, Book X, 18—19.

It is true that only three ounces were desired, but this difference is so small that if one should add one cog to the brake wheel and give it 22 cogs one would get less than three ounces, to wit $2\,{}^{1\,256}/_{1\,340}$ ounces.

To find the pressure of the staves against the cogs:

As in the centre of gravity of the low water level, *i.e.* at $^{64}/_{9}$ feet from the centre of the wheel shaft bear 3133 lbs according to the first chapter of this calculation and the pitch line of the cogs is $5\,^{1}/_{2}$ feet from the centre of the wheel shaft according to the third chapter: I say $5\,^{1}/_{2}$ feet gives $^{64}/_{9}$ feet what does 3133 lbs give? This gives $4050\,^{74}/_{99}$ lbs. And so strongly do the staves press against the cogs of the driven wheel calculated for their pitch line.
In order to find the pressure of the staves (of the wallower) against the cogs (of the brake wheel) I say as the radius of the crown wheel to the radius of the wallower, so is the pressure above to that below.

The sweep of the Escamp mills calculated from the centre of the wind shaft.

The cills each one foot thick make 2 feet, subtract their indentation of three inches each and the indentation of the lower cill and the groove also three inches each together

1 foot, this gives	1—0
The tower between the breasts	17—0
The collar	0—11
The sheers	1—0
The tie beams	0—9
The lower side girt	0—7
The corner uprights between the breasts	8—0
The upper side girt	0—10
The side girts	1—5
The crown tree	1—0
Half the shaft	1—0
Together	33—6

If the height of $33\,^{11}/_{2}$ feet be *AB* and *BC* be part of the "groove" and AB be five times *BC*, *BC* will be $^{67}/_{10}$ and AC $\sqrt{1167\,^{7}/_{50}}$ but *CD* is 7 therefore the whip AD is $\sqrt{1118\,^{7}/_{50}}$, *i.e.* about 33.5.

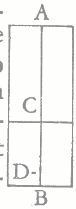
(15) CALCULATION of the *Stolwijk Mill, new design* [1])

Length of the sails	40	feet
Width	$9\,^{1}/_{2}$	feet
Radius of the scoop wheel	$10\,^{1}/_{6}$	feet
Width of the floats	$3\,^{1}/_{2}$	feet
Immersion of the floats	$4\,^{1}/_{6}$	feet
Difference between the high-water and the low-water level	4	feet

[1]) Situated close by No. 12.

Hier uyt volght het nabeschreuen.

Teghen BC perst $^{4\,375}/_{144}$ voet ende dat op D. Teghen FG perst $^{16\,807}/_{144}$ voet ende dat op H die doen aen I $^{10\,134\,621}/_{102\,384}$ want ick segh EI $^{79}/_{9}$ gheven $^{16\,807}/_{144}$ wat EH $^{67}/_{9}$? comt alsvooren $^{10\,134\,621}/_{102\,384}$ voet die weghen 6434 £ daer af getrocken de $^{4\,375}/_{144}$ voet weghende 1974 £ blijft 4460 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leeghsten waters als D.



AB $^{61}/_{6}$
Breet $^{7}/_{2}$
BC $^{25}/_{16}$ (read: $^{25}/_{6}$)
BD $^{25}/_{18}$
AD $7^{8}/_{9}$ (read: $^{79}/_{9}$)

Te veroirdenen reden der keeren deser wiecken tottet scheprat alsoo dat yder voet seyls doe de ghewelt van $3\,^{1}/_{4}$ *oncen.*

1520 voet der vier seijlen gemenichvuldicht met $3\,^{1}/_{4}$ oncen comt 308 £. Voort 20 voet halve wieck gheeft 4460 £ des gheprangs wat AD $^{79}/_{8}$ [*read:* $^{79}/_{9}$]? comt 1957 daerom segh ick dat de reden der keeren sal sijn van 1957 tot 308.

FG $^{49}/_{6}$
HF $^{49}/_{18}$
EH $^{67}/_{9}$
EI $^{79}/_{9}$

Te veroirdenen de menichte van cammen en stauen om te cryghen ten naesten by de boueschreuen reden der keeren van 1957 *tot* 308.

Ghenomen voor tschijfloop aende wieckas 12 staven, voor tschijfloop beneen 8 staven, voor tcamrat beneen 43 cammen.

Vraghe hoe veel cammen het croonrat sal moeten hebben om de begeerde reden der keeren te crijghen?

Ick segh 12 mael 8 is 96. Voort 308 minste pael gheeft 1957 meeste pael wat 96? comt 609 die ghedeelt deur de 43 cammen comt voort croonrat 14 cammen.

Deze 12 staven boven 14 cammen int croonradt, 8 staven beneen ende 43 cammen int camrat brenghen uyt reden der keeren van 301 tot 48.

Prouf.

Om nu te sien of yder voet seijls hiermede de begheerde ghewelt uyt brenght ten naesten bij van $3\,^{1}/_{4}$ oncen, ick segh 20 voet halve wieck gheeft 4460 £ persinge wat AD $^{79}/_{9}$? comt 1957 £ die ghedeelt deur reden der keeren $^{301}/_{48}$ comt 312 £ die ghedeelt deur de 1520 voeten der vier seijlen comt yder voet seijls te doen de ghewelt van $3\,^{432}/_{1\,520}$ oncen.

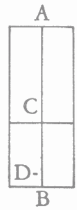
[16] OVERSLACH der
Brouckschе molen by Yselsteyn na de nieu manier 1)

Langde der wiecke	39	voet
Breede	10	voet
Scheprats half middellijn	$10\,^{11}/_{24}$	voet
Breede der lepels	$3\,^{3}/_{4}$	voet
Commen onder tpeijl	3	voet
Verschil des hoochsten en leeghsten waters	$4\,^{1}/_{2}$	voet

1) Text identical with XVI B, Book X, 19—21.

These data lead to the following calculations:

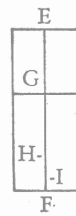
Against BC bear $^{4\,375}/_{144}$ feet, and that in *D*. Against *FG* bear $^{16\,807}/_{144}$ feet, and that in *H*, which bear in *I* $^{10\,134\,621}/_{102\,384}$, for I say: *EI* $^{79}/_{9}$ gives $^{16\,807}/_{144}$ what does *EH* $^{67}/_{9}$? This gives, as above, $^{10\,134\,621}/_{102\,384}$ feet weighing 6434 lbs; subtract the $^{4\,375}/_{144}$ feet, weighing 1974 lbs, there remain 4460 lbs, bearing on the scoop wheel in the centre of gravity of the low-water in *D*.



AB $^{61}/_{6}$
Breet $^{7}/_{2}$
BC $^{25}/_{16}$ (read: $^{25}/_{6}$)
BD $^{25}/_{18}$
AD $7^{8}/_{9}$ (read: $^{79}/_{9}$)

To establish the ratio between the revolutions of sails and scoop wheel so that the pressure on each foot of sail be $3\,^{1}/_{4}$ ounces.

1520 feet of the four sails multiplied by $3\,^{1}/_{4}$ ounces, makes 308 lbs. Further 208 feet at the centre of the sail gives 4460 lbs of pressure what does *AD* $^{79}/_{9}$ give? This gives 1957, therefore I say that the ratio between the revolutions must be as 1957 to 308.



FG $^{49}/_{6}$
HF $^{49}/_{18}$
EH $^{67}/_{9}$
EI $^{79}/_{9}$

To establish the number of cogs and staves to obtain approximately the above ratio between the revolutions as 1975 to 308.

Taking 12 staves for the wallower, 8 staves for the crown wheel and 43 cogs for the pit wheel, the question is how many cogs should the brake wheel have in order to obtain the desired ratio between the revolutions?
I say 12 times 8 is 96. Further 308 for the smaller term gives 1957 for the greater term, what does 96 give? This gives 609, which divided by the 43 cogs, gives for the brake wheel 14 cogs.
These 12 staves above, 14 cogs in the brakewheel, 8 staves below, and 43 cogs in the pit wheel yield the ratio between the revolutions as 301 to 48.

Proof.

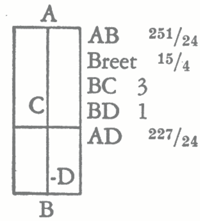
In order to find whether each foot of sail now has the desired pressure of about $3\,^{1}/_{4}$ ounces, I say 20 feet for the centre of the sails give 4460 lbs pressure, what does AD $^{79}/_{9}$ give? This gives 1957 lbs, which, divided by the ratio between the revolutions $^{301}/_{48}$, makes 312 lbs, which, divided by the 1520 feet of the four sails, makes the pressure on each foot of sail $3\,^{432}/_{1\,520}$ ounces.

(16) CALCULATION of the
Broek Mill near IJsselstein, new design [1])

Length of the sails	39	feet
Width	10	feet
Radius of the scoop wheel	$10\,^{11}/_{24}$	feet
Width of the floats	$3\,^{3}/_{4}$	feet
Immersion of the floats	3	feet
Difference between the high-water and the low-water level . .	$4\,^{1}/_{2}$	feet

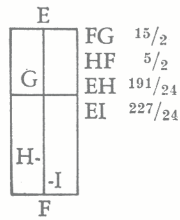
1) Replaced No. 8 or No. 9.

Hier uyt volght het nabeschreuen.



Teghen BC perst $^{135}/_{8}$ voet ende dat op D. Teghen FG perst $^{3\,375}/_{32}$ voet ende dat op H die doen aen I $^{15\,471\,000}/_{174\,336}$ want ick segh EI $^{227}/_{24}$ gheven $^{3\,375}/_{32}$ wat EH $^{191}/_{24}$? comt alsvooren $^{15\,471\,000}/_{174\,336}$ voet die weghen 5768 £ daer af getrocken de $^{135}/_{8}$ voet weghende 1096 £ blijft 4672 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leegchsten waters als D.

Te veroirdenen reden der keeren deser wiecken tottet scheprat alsoo dat yder voet seyls doe de ghewelt van $3\,^{3}/_{4}$ *oncen.*



1560 voet der vier seijlen gemenichvuldicht met $3\,^{3}/_{4}$ oncen comt 365 £ voort $19\,^{1}/_{2}$ voet halve wieck gheeft 4672 £ des gheprangs wat AD $^{227}/_{24}$ comt 2266, daerom segh ick dat de reden der keeren sal sijn van 2266 tot 365.

Te veroirdenen de menichte van cammen en stauen om te crijghen ten naesten bij de boueschreuen reden van 2266 tot 365.

Ghenomen aende wieckas 16 staven, voor tschijfloop beneen 8 staven, voor tcamrat beneen 45 cammen. Vraghe hoe veel cammen het croonrat zal moeten hebben om de begheerde reden der keeren te krijghen?

Ick segh 16 mael 8 is 128. Voort 365 minste pael gheeft 2266 meeste pael wat 128? comt 794 die ghedeelt deur de 45 cammen comt voor tcroonrat $17\,^{29}/_{45}$ daer ick voor neem 18 cammen.

Dese 16 staven boven, 18 cammen int croonrat, 8 staven beneen ende 45 cammen int camrat brengen uyt reden der keeren van 810 tot 128.

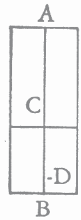
Prouf.

Om nu te sien of yder voet seijls hier mede de begheerde ghewelt uytbrenght ten naesten bij van $3\,^{3}/_{4}$ oncen ick segh $19\,^{1}/_{2}$ voet halve wieck gheeft 4672 £ persinge, wat AD $^{227}/_{24}$? comt 2266 £ die ghedeelt deur reden der keeren $^{810}/_{128}$ comt 362 £ die ghedeelt deur de 1560 voeten der vier seijlen comt yder voet seijls te doen de ghewelt van $3\,^{1\,112}/_{1\,560}$ oncen.

[17] OVERSLACH der
Craeylingher molen na de nieu manier

Langde der wiecke	39	voet
Breede	10	voet
Scheprats half middellijn	$10\,^{11}/_{24}$	voet
Breede der lepels	$3\,^{3}/_{4}$	voet
Commen onder tpeijl	$3\,^{1}/_{2}$	voet
Verschil des hoochsten en leeghsten waters	4	voet

These data lead to the following calculations:



AB ${}^{251}/_{24}$
Breet ${}^{15}/_{4}$
BC 3
BD 1
AD ${}^{227}/_{24}$

Against *BC* bear ${}^{135}/_{8}$ feet, and that in *D*. Against *FG* bear ${}^{3\,375}/_{32}$ feet and that in *H*, which bear in *I* ${}^{15\,471\,000}/_{174\,336}$, for I say: *EI* ${}^{227}/_{24}$ gives ${}^{3\,375}/_{32}$ what does *EH* ${}^{191}/_{24}$ give? This gives as above ${}^{15\,471\,000}/_{174\,336}$ weighing 5768 lbs, subtract the ${}^{135}/_{8}$ feet weighing 1096, this gives 4672 lbs bearing on the scoop wheel in the centre of gravity of the low-water level in *D*.

To establish the ratio between the revolutions of sails and scoop wheel so that the pressure on each foot of sail be 3 ³/₄ ounces.

FG ${}^{15}/_{2}$
HF ${}^{5}/_{2}$
EH ${}^{191}/_{24}$
EI ${}^{227}/_{24}$

1560 feet of the four sails, multiplied by $3\,{}^{3}/_{4}$ ounces makes 365 lbs, further $19\,{}^{1}/_{2}$ feet in the centre of the sail gives 4672 lbs of pressure, what does *AD* ${}^{227}/_{24}$ give? This gives 2266, therefore I say that the ratio between the revolutions must be as 2266 to 365.

To establish the number of cogs and staves in order to obtain approximately the above-mentioned ratio of 2266 to 365. If we take 16 staves for the wallower, 8 staves for the crown wheel and 45 cogs for the pit wheel, the question is how many cogs should the brake wheel have in order to obtain the desired ratio between the revolutions? I say 16 times 8 is 128. Further 365 for the smaller term gives 2266 for the greater term, what to 128? This gives 794, which divided by the 45 cogs, gives $17\,{}^{29}/_{45}$ for the cams of the brake wheel for which number I take 18 cogs.
These 16 staves above, 18 cogs in the brake wheel, 8 staves below, and 45 cogs in the pit wheel give the ratio between the revolutions as 810 to 128.

Proof.

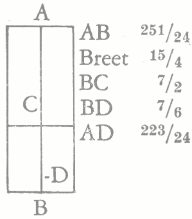
In order to establish whether each foot of sail thus gets the desired pressure of approximately $3\,{}^{3}/_{4}$ ounces I say $19\,{}^{1}/_{2}$ feet in the centre of the sail give 4672 lbs pressure, what does *AD* ${}^{227}/_{24}$ give? This gives 2266 lbs, which divided by the ratio between the revolutions ${}^{810}/_{128}$ gives 362 lbs, which divided by the 1560 feet of the four sails, gives on each foot of sail a pressure of $3\,{}^{1\,112}/_{1\,560}$ ounces.

(17) CALCULATION of the *Cralingen Mill, new design*[1])

Length of the sails	39	feet
Width	10	feet
Radius of the scoop wheel	$10\,{}^{11}/_{24}$	feet
Width of the floats	$3\,{}^{3}/_{4}$	feet
Immersion of the floats	$3\,{}^{1}/_{2}$	feet
Difference between the high-water and the low-water level	4	feet

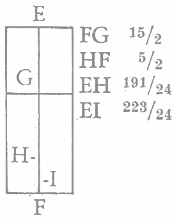
1) The same as No. 6.

Hier uyt volght het nabeschreuen.



Teghen BC perst $^{735}/_{32}$ voet ende dat op D. Teghen FG perst $^{3\,375}/_{32}$ voet ende dat op H die doen aen I $^{15\,471\,000}/_{171\,264}$ want ick segh EI $^{223}/_{24}$ gheven $^{3\,375}/_{32}$ wat EH $^{191}/_{24}$? commt alsvooren $^{15\,471\,000}/_{171\,264}$ die weghen 5871 £ daer af getrocken de $^{735}/_{32}$ voet weghende 1492 £ blijft 4379 £ daer het schep-rat mede verladen is opt swaerheijts middelpunt des leeghsten waters als D.

Te veroirdenen reden der keeren deser wiecken tottet scheprat alsoo dat yder voet seyls doe de ghewelt van[1])



[17a] *Van de Cralinger achtcante Molen verandert na de nieuwe manier*

Langde der wiecke	35 $^1/_2$	voet
Breede	9	voet
Scheprats half middellijn	10	voet
Breede der lepels	3 $^1/_2$	voet
Commen onder tpeijl	3 $^1/_2$	voet
Verschil des hoochsten en leeghsten waters	4	voet

Hier uyt volcht het na beschreven.

Tegen CB perst $^{847}/_{36}$ voet, en dat op D. Tegen GF perst $^{3\,703}/_{36}$, en dat op H, die doen an I $^{2\,232\,909}/_{25\,596}$ want ick segh, EI $^{79}/_{9}$ geven $^{3\,703}/_{36}$, wat EH $^{67}/_{9}$? comt als vooren $^{2\,232\,909}/_{25\,596}$ voet, die wegen 5670 £, daer afgetrocken, de $^{843}/_{63}$, wegende 1529 £, blijft 4141 £, daer het scheprat mede verladen is, opt swaerheyt middelpunt des leegsten waters, als D.

Te verordenen de reden der keeren deser wiecken tottet Scheprat, alsoo dat yder voet zeijls doe de gewelt van 4 $^1/_2$ *oncen.*

1278 Voet der vier zeylen, gemenichvuldicht met 4 $^1/_2$ oncen, comt 359 £: Voort 17 $^3/_4$ voet halve wieck, geeft 4141 £ des geprangs, wat AD $^{79}/_{9}$? comt 2047, daerom segh ic dat de reden der keeren sal zijn, van 2047 tot 359.

Te veroirdenen de menichte van cammen en staven om te crijgen ten naesten by de boveschreve reden van 2047 *tot* 359.

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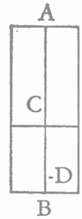
[1]) Calculation not given; XVI B, Book X, 21—22 gives the passage up to [18].

These data lead to the following calculations:

Against *BC* bear ${}^{735}/_{32}$ feet, and that in *D*. Against *FB* bear ${}^{3\,375}/_{32}$ feet, and that in *H*, which bear in *I* ${}^{15\,471\,000}/_{171\,264}$, for I say: *EI* ${}^{223}/_{24}$ gives ${}^{3\,375}/_{32}$ what does *EH* ${}^{191}/_{24}$ give? This gives as above ${}^{15\,471\,000}/_{171\,264}$ feet, weighing 5871 lbs, subtract the ${}^{735}/_{32}$ feet, weighing 1492 lbs, gives 4379 lbs, being the pressure on the scoop wheel bearing in the centre of gravity of the low-water level in *D*.



AB ${}^{251}/_{24}$
Breet ${}^{15}/_{4}$
BC ${}^{7}/_{2}$
BD ${}^{7}/_{6}$
AD ${}^{223}/_{24}$

To establish the ratio between the revolutions of the sails and the scoop wheel in order to obtain a pressure on each foot of sail of . . .

FG ${}^{15}/_{2}$
HF ${}^{5}/_{2}$
EH ${}^{191}/_{24}$
EI ${}^{223}/_{24}$

(17a) CALCULATION of the *Cralingen octagonal Mill, new design* [2])

Length of the sails	35 1/2	feet
Width	9	feet
Radius of the scoop wheel	10	feet
Width of the floats	3 1/2	feet
Immersion of the floats	3 1/2	feet
Difference between the high-water and the low-water level . .	4	feet

These data lead to the following calculations:

Against *CB* bear ${}^{847}/_{36}$ feet, and that in *D*.
Against *GF* bear ${}^{3\,703}/_{36}$ feet, and that in *H*, which bear in *I* ${}^{2\,232\,909}/_{25\,596}$, for I say: *EI* ${}^{79}/_{9}$ gives ${}^{3\,703}/_{36}$, what does *EH* ${}^{67}/_{9}$ give? This gives as above, ${}^{2\,232\,909}/_{255\,596}$ feet, weighing 5670 lbs, subtract the ${}^{847}/_{63}$, weighing 1529 lbs, gives 4141 lbs, bearing on the scoop wheel in the centre of gravity of the low-water level in *D*.

To establish the ratio between the revolutions of the sails and of the scoop wheel in order to obtain a pressure on each foot of sail of 4 1/2 ounces.

1278 feet for four sails, multiplied by 4 1/2 ounces, gives 359 lbs. Further 17 3/4 feet in the centre of the sail gives 4141 lbs of pressure, what does *AD* ${}^{79}/_{9}$ give? This gives 2047, therefore I say that the ratio between the revolutions must be as 2047 to 359.

To establish the number of cams and staves in order to obtain approximately the above-mentioned ratio of 2047 to 359.

[2]) The same as No. 6a.

Genomen voort schijfloop ande wiecas 12 staven, voor het schijfloop beneen 8 staven, voor het camrat beneen 43 cammen, vrage hoe veel cammen het croonrat sal moeten hebben, om de begeerde reden der keeren te crijgen?

Ick segh 12 mael 8 is 96: Voort 359 minste pael, geeft 2047 meeste pael, wat 96? comt 544, die gedeelt deur de 43 cammen, comt voor het croonrat 13 cammen.

Dese 12 staven boven, 13 cammen int croonradt, 8 staven beneden, en 43 cammen int camrat, brengen uyt reden der keeren van 559 tot 96.

Prouf.

Om nu te sien of yder voet zeyls, hier mede de begeerde gewelt uytbrengt, ten naesten by van 4 $^1/_2$ once; Ic seg 17 $^3/_4$ voet halve wiec, geeft 4141 £ persinge, wat AD $^{79}/_9$? comt 2047, die gedeelt deur reden der keeren $^{559}/_{96}$, comt 315 £, die gedeelt deur 1278 voeten der vier zeylen, comt yder voet zeyls te doen de gewelt van ten naesten by 4 oncen.

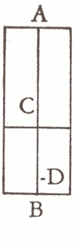
Dicte der staven boven op haer middel	5	duym
Dicte der schyven	5 $^1/_2$	duym
De steec	10 $^1/_2$	duym
De cammen dic int gat	5	duym
De cammen dic op de cruyn		
De ployen dic	5 $^1/_2$	duym
De schyven beneen dic	6	duym
De staven dic	5	duym
De cammen dic op de cruyn		
De ployen	6	duym

[18] OVERSLACH der
Robbenoirtsche molen na de nieu manier

Langde der wiecke	19	voet
Breede	$10^1/_2$	voet
Scheprats half middellijn	$6^1/_2$	voet
Breede der lepels	$2^3/_4$	voet
Commen onder tpeijl	$2^1/_2$	voet
Verschil des hoochsten en leeghsten waters	$2^1/_2$	voet

Hier uyt volght het nabeschreuen.

Teghen BC perst $^{275}/_{32}$ voet ende dat op D. Teghen FG perst $^{275}/_8$ ende dat op H die doen aen I $^{23\,925}/_{816}$ want ick segh EI $^{17}/_3$ gheven $^{275}/_8$ wat EH $^{29}/_6$? comt alsvooren $^{23\,925}/_{816}$ voet die weghen 1905 £ daer af getrocken de $^{275}/_{32}$ voet weghende 558 £ blijft 1347 £ daer tscheprat mede verladen is opt swaerheijts middelpunt des leeghsten waters, als D.



AB	$^{13}/_2$
Breet	$^{11}/_4$
BC	$^5/_2$
BD	$^5/_6$
AD	$^{17}/_3$

Taking 12 staves for the wallower, 8 staves for the crown wheel, and 43 cogs for the pit wheel, the question is now how many cogs should the brake wheel have in order to obtain the desired ratio between the revolutions?
I say 12 times 8 makes 96. Further 359 for the smaller term gives 2047 for the greater term, what does 96 give? This gives 544, which divided by the 43 cams, makes for the brake wheel 13 cogs. These 12 staves above, 13 cogs in the brake wheel, 8 staves below, and 43 cogs of the driven wheel give the ratio between the revolutions as 559 to 96.

Proof.

In order to establish whether each foot of sail has approximately the desired pressure of $4\,{}^{1}/_{2}$ ounces, I say: $17\,{}^{3}/_{4}$ feet in the centre of the sail gives 4141 lbs of pressure, what does *AD* ${}^{79}/_{9}$ give? This gives 2047, which divided by the ratio between the revolutions ${}^{559}/_{96}$, gives 315 lbs; divided by 1278 feet for the four sails, it makes a pressure on each foot of sail of about 4 ounces.

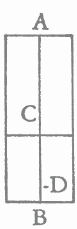
Width of the staves at their centre	5	inches
Width of the flanges	$5\,{}^{1}/_{2}$	inches
The pitch	$10\,{}^{1}/_{2}$	inches
Width of the cogs in the hole	5	inches
Width of top of the cogs		
Width of cants	$5\,{}^{1}/_{2}$	inches
Width of the flanges below	6	inches
The width of the staves	5	inches
Cogs at the top		
The cats	6	inches

(18) CALCULATION of the *Robbernoirt Mill, new design*

Length of the sails	19	feet
Width	$10\,{}^{1}/_{2}$	feet
Radius of the scoop wheel	$6\,{}^{1}/_{2}$	feet
Width of the floats	$2\,{}^{3}/_{4}$	feet
Immersion of the floats	$2\,{}^{1}/_{2}$	feet
Difference between the high-water and the low-water level	$2\,{}^{1}/_{2}$	feet

These data lead to the following calculations:

Against *BC* bear ${}^{275}/_{32}$ feet, and that in *D*. Against *FG* bear ${}^{275}/_{8}$, and that in *H*, which bear at *I* $23\,{}^{925}/_{816}$, for I say *EI* ${}^{17}/_{3}$ gives ${}^{275}/_{8}$, what does *EH* ${}^{29}/_{6}$ give? This gives, as above, $23\,{}^{925}/_{816}$ feet, weighing 1905 lbs, subtract the ${}^{275}/_{32}$ feet weighing 558 lbs, this gives 1347 lbs, bearing on the scoop wheel in the centre of gravity of the low-water level at *D*.



AB	${}^{13}/_{2}$
Breet	${}^{11}/_{4}$
BC	${}^{5}/_{2}$
BD	${}^{5}/_{6}$
AD	${}^{17}/_{3}$

Te veroirdenen reden der keeren deser wiecken tottet schep-rat alsoo dat yder voet seyls doe de ghewelt van $2\,^3/_4$ *oncen.*

798 voet der vier seijlen ghemenichvuldicht met $2\,^3/_4$ oncen comt 137 [£]. Voort $9\,^1/_2$ voet der halve wieck gheeft 1347 £ des gepranghs wat AD $^{17}/_3$? comt 803 [£], daerom segh ick dat de reden der keeren sal sijn van 803 tot 137.

FG 5
HF $^5/_3$
EH $^{29}/_6$
EI $^{17}/_3$

Te veroirdenen de menichte van cammen en staven om te cryghen ten naesten by de boveschreven reden van 803 *tot* 137.

Zij ghenomen voor tschijfloop aende wieckas 12 staven, voor tschijfloop beneen 8 staven, voor tcamrat 35 cammen. Vraghe hoe veel cammen het croonradt sal moeten hebben om de begheerde reden der keeren te crijghen?

Ick segh 12 mael 8 is 96, voort 137 minste pael gheeft 803 meeste pael wat 96? comt 562 die ghedeelt deur 35 cammen, comt voor tcroonradt 16 cammen.

Dese 12 staven boven, 16 cammen int croonradt 8 staven beneen en 35 cammen int camrat brenghen uyt reden der keeren van 560 tot 96.

Prouf.

Om nu te sien of yder voet seijls hiermede de begeerde gewelt uytbrengt ten naesten bij van $2\,^3/_4$ oncen. Ick segh $9\,^1/_2$ voet der halve wieck gheeft 1347 £ persinge wat AD $^{17}/_3$? comt 803 £ die ghedeelt deur reden der keeren $^{560}/_{96}$ comt 137 £ die ghedeelt deur de 798 voet der vier seylen comt yder voet seyls te doen de ghewelt van $2\,^{596}/_{798}$ oncen.

Menichte des waters met elcken keer der wiecken.[1])

Want des scheprats halfmiddellyn doet $6\,^1/_2$ voet, en de breede der lepels $2\,^3/_4$ dats $^{11}/_4$, so ist geheel lichhaem (te weten den ronden pilaer beschreven deur een keer der lepels) groot 365 voet, hier af moet getrocken zijn het middeldeel des scheprats datter buyten het binnewater gaet, tselve deel is een ronde pilaer diens gronts halfmiddellyn AC doet 4 voet, tselve lichhaem is groot 138 voet, die getrocken vande voorschreve 365 voet, blijft 227; Dit gaet eens om in $^{560}/_{96}$ keeren der wiecken, daerom gedeelt 365 deur $^{560}/_{96}$, comt met elcken keer der wiecken 62 voeten.

[19] OVERSLACH der
Molen tsoeterwoude na de nieu manier [2])

Langde der wiecke	16	voet
Breede	$5\,^1/_2$	voet
Scheprats half middellijn	$5\,^3/_8$	voet
Breede der lepels	$2\,^5/_6$	voet
Commen onder tpeijl	3	voet
Verschil des hoochsten en leeghsten waters	2	voet

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1) This passage occurs in XVI B, Book X, page 24.
2) Text identical with XVI B, Book X, 24—25.

To establish the ratio between the revolutions of sails and scoop wheel in order to obtain a pressure on each foot of sail of $2\,{}^{3}/_{4}$ ounces.

FG 5
HF ${}^{5}/_{3}$
EH ${}^{29}/_{6}$
EI ${}^{17}/_{3}$

798 feet of four sails multiplied by $2\,{}^{3}/_{4}$ ounces give 137 (lbs). Further $9\,{}^{1}/_{2}$ feet in the centre of the sail give 1347 lbs pressure, what does AD ${}^{17}/_{3}$ give? This gives 803 (lbs), therefore I say that the ratio of the revolutions should be as 803 to 137.

To establish the number of cogs and staves in order to obtain approximately the above mentioned ratio of 803 to 137.

Taking 12 staves for the wallower, 8 staves for the crown wheel and 35 cogs for the pit wheel, the question remains how many cogs the brake wheel should have in order to obtain the desired ratio between the revolutions?

I say 12 times 8 make 96. Further 137 for the smaller term gives 803 for the greater term, what does 96 give? This gives 562, which divided by 35 cogs, gives 16 cogs for the brake wheel. These 12 staves above, 16 cogs of the brake wheel, 8 staves below and 35 cogs of the pit wheel give the ratio between the revolutions as 560 to 96.

Proof.

In order to see whether the pressure on each foot of sail is approximately the desired $2\,{}^{3}/_{4}$ ounces, I say $9\,{}^{1}/_{2}$ feet in the centre of the sail give a pressure of 1347 lbs, what does *AD* ${}^{17}/_{3}$ give? This gives 803, which divided by the ratio of revolutions ${}^{560}/_{96}$ gives 137 lbs, which divided by the 798 feet of the four sails, it gives a pressure on each foot of sail of $2\,{}^{596}/_{798}$ ounces.

The volume of water with each revolution of the sails.

As the radius of the scoop wheel is $6\,{}^{1}/_{2}$ feet and the width of the floats $2\,{}^{3}/_{4}$, *i.e.* ${}^{11}/_{4}$, the entire volume (the cylinder described by one revolution of the floats) is 365 feet, subtract the centre part of the scoop wheel which does not dip into the water, *i.e.* a cylinder with a bottom radius *AC* of 4 feet, this volume is 138 feet, which subtracted from the above 365 feet, gives 227. This is raised in ${}^{560}/_{96}$ revolutions of the sails, therefore 365 (sic!) divided by ${}^{560}/_{96}$, *i.e.* 62 feet are raised with each revolution of the sails.

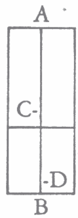
(19) CALCULATION of the *Soeterwoude Mill, new design* [1])

Length of the sails	16	feet
Width	$5\,{}^{1}/_{2}$	feet
Radius of the scoop wheel	$5\,{}^{3}/_{8}$	feet
Width of the floats	$2\,{}^{5}/_{6}$	feet
Immersion of the floats	3	feet
Difference between the high-water and the low-water level	2	feet

1) If ever built, probably replaced No. 10a.

Hier uyt volght het nabeschreven

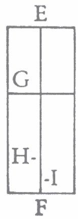
Teghen BC perst $^{153}/_{12}$ voet ende dat op D. Teghen FG perst $^{524}/_{12}$ voet ende dat op H, die doen aen I $^{30\,260}/_{1\,008}$ want ick segh EJ $^{35}/_{8}$ gheven $^{425}/_{12}$ wat EH $^{89}/_{24}$? comt alsvooren $^{30\,260}/_{1\,008}$ voet die weghen 1951 £ daer af getrocken de $^{153}/_{12}$ voet weghende 828 £ blijft 1123 £ daer tscheprat mede verladen is opt swaerheyts middelpunt des leechsten waters als D.



AB $^{43}/_{8}$
Breet $^{17}/_{6}$
BC 3
BD 1
AD $^{35}/_{8}$

Te veroirdenen reden der keeren deser wiecken tottet scheprat alsoo dat yder voet seyls doe de ghewelt van 2 $^{2}/_{3}$ oncen.

325 voet der vier seylen ghemenichvuldight met 2 $^{2}/_{3}$ oncen comt 58 £, voort 8 voet der halve wieck gheeft 1123 £ des gheprangs wat AD $^{35}/_{8}$? comt 614 daerom segh ick dat de reden der keeren sijn sal van 614 tot 58.

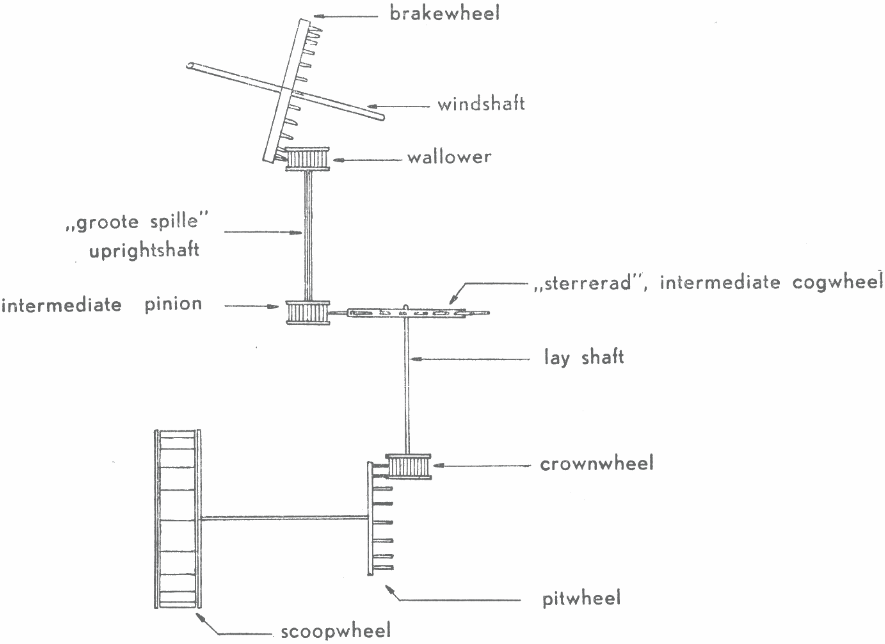


FG 5
HF $^{5}/_{3}$
EH $^{89}/_{24}$
EI $^{35}/_{8}$

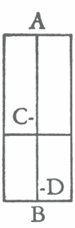
Te veroirdenen de menichte van cammen en staven om te cryghen ten naesten by de boveschreven reden der keeren van 614 *tot* 58.

Fig 28.

The mechanism of the Soeterwoude mill (19)



These data lead to the following calculations:

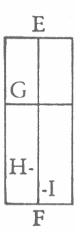


AB	$^{43}/_{8}$
Breet	$^{17}/_{6}$
BC	3
BD	1
AD	$^{35}/_{8}$

Against *BC* bear $^{153}/_{12}$ feet, and that in *D*. Against *FG* bear $^{425}/_{12}$ feet, and that in *H*, which in *I* bear $^{30\,260}/_{1\,008}$; for I say: *EI* $^{35}/_{8}$ gives $^{425}/_{12}$ what does *EH* $^{89}/_{24}$ give? This gives, as above, $^{30\,260}/_{1\,008}$ feet, weighing 1951 lbs, subtract the $^{153}/_{12}$ feet, weighing 828 lbs, this gives 1123 lbs, which bear on the scoop wheel at the centre of gravity of the low-water level at *D* .

To establish the ratio between the revolutions of sails and scoop wheel in order to obtain a pressure on each foot of sail of 2 ²/₃ ounces.

325 feet of the four sails multiplied by $2\,^{2}/_{3}$ ounces, give 58 lbs, further 8 feet at the centre of the sail give 1123 lbs of pressure, what does *AD* $^{35}/_{8}$ give? This gives 614 lbs, therefore I say that the ratio between the revolutions is as 614 to 58.



FG	5
HF	$^{5}/_{3}$
EH	$^{89}/_{24}$
EI	$^{35}/_{8}$

To establish the number of cogs and staves in order to obtain approximately the above mentioned ratio between the revolutions as 614 to 58.

Ghenomen voor tcamrat aende wieckas 25 cammen het schijfloop onder aende groote spille 6 staven het sterrerat daer in draeyende 20 cammen, het schijfloop beneden 8 staven, het camrat beneden 40 cammen. Vraghe hoe veel staven het schijfloop boven aende spille sal moeten hebben om de begheerde reden der keeren te cryghen.

Ick segh 25 mael 6 is 150 de selve deur 8 maeckt 1200. Voort 58 minste pael gheeft 614 meeste pael wat 1200? comt 12703, die gedeelt deur 20 mael 40 dats deur 800 comt voor tschijfloop boven $15\,^{703}/_{800}$, daer voor ghenomen syn 16 staven.

Dese 25 cammen aende wieckas 16 staven int schijfloop boven, 6 staven onder int schijfloop aende groote spille, 20 cammen inde sterre acht staven int schijfloop beneen, 40 cammen int camrat beneen brenghen uyt reden der keeren van 32 tot 3.

Prouf.

Om nu te sien of yder voet seyls hiermede de begeerde gewelt uytbrenght ten naesten by van $2\,^{2}/_{3}$ oncen ick segh 8 voet der halve wieck gheeft 1123 £ persinge wat AD $^{35}/_{8}$? comt 614 £, die ghedeelt deur reden der keeren $^{32}/_{3}$ comt 57 £, die ghedeelt deur 352 voeten der vier seylen comt yder voet seyls te doen de ghewelt van $2\,^{208}/_{352}$ oncen.[1])

[20] *Vande Altenasche Bonavonteursche Molen na de nieu manier*

Langde der wiecke	$43\,^{1}/_{2}$	voet
Breede	9	voet
Scheprats half middellijn	10	v. $7\,^{1}/_{2}$ d.
Breede der lepels	3	v. 1 d.
Commen onder tpeijl	3	voet
Verschil des hoochsten en leeghsten waters	$4\,^{1}/_{2}$	voet

Hier uyt volght het nabeschreven.

Tegen CB perst $^{11}/_{8}$ voet, en dat op D. Tegen GF perst $2\,^{775}/_{32}$ voet en dat op H, die doen an I $2\,^{342}/_{32}$, want ic seg EI $^{77}/_{8}$ geven $2\,^{775}/_{32}$, wat EH $^{65}/_{8}$? comt alsvoren $2\,^{342}/_{32}$ voet, die wegen 4757 £, daer het scheprat mede verladen is, op swaerheyts middelpunt des leegsten waters als D.

Te veroirdenen reden der keren deser wiecken tot het scheprat, also dat yder voet zeyls doe de gewelt van $4\,^{1}/_{2}$ *oncen.*

1566 voet der vier zeylen, gemenigvuldigt met $4\,^{1}/_{4}$ oncen, comt 428 £; Voort $21\,^{3}/_{4}$ voet halve wiec, geeft 4757 des geprangs, wat AD $^{77}/_{8}$? comt 2105; daerom seg ic dat de reden der keeren sal zijn van 2105 tot 428.

Te veroirdenen de menichte van cammen en staven, om te crygen ten naesten by de voorschreve reden van 2105 *tot* 428.

Genomen voort schyfloop ande wiecas 20 staven, voor het schyfloop ande spilbeneden 9 staven, voor het camrat beneden 44 cammen; Vrage hoeveel cammen het croonrat sal moeten hebben, om de begeerde reden der keeren te crygen.

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[1]) The text in XV, 125—130 now gives different mathematical proofs of the length of the path described by a point on a rotating circle, demonstrations which seem out of place in this essay.
We continue with further calculations and notes given by Stevin's son (XVI B, Book X, 25—29) and dealing with windmills.

If we take 25 cogs for the brake wheel, 6 staves for the intermediate pinion [1]) at the bottom of the upright shaft and 20 cams for the intermediate cogwheel turning within it, 8 staves for the crown wheel, and 40 cams for the pit wheel, the question is how many staves the wallower should have in order to obtain the desired ratio between the revolutions.

I say 25 times 6 is 150, which multiplied by 8 makes 1200. Further 58 for the smaller term gives 614 for the greater term, what does 1200 give? This gives 12703, which divided by 20 times 40, *i.e.* 800, this gives for the wallower 15 $^{703}/_{800}$, for which I take 16 staves. These 25 cams at the brake wheel, 16 staves of the wallower, 6 staves in the intermediate pinion at the upright shaft, 20 cams of the cog wheel, 8 staves of the crown wheel, and 40 cams of the pit wheel give the ratio between the revolutions of 32 to 3.

Proof.

In order to see whether the desired pressure on each foot of sail is approximately 2 $^{2}/_{3}$ ounces, I say 8 feet in the centre of the sail give a pressure of 1123 lbs, what does *AD* $^{35}/_{9}$ give? This makes 614 lbs, which divided by the ratio between the revolutions $^{32}/_{3}$, make 57 lbs, which, divided by the 352 feet of the four sails, makes 2 $^{208}/_{352}$ ounces on each foot of sail.

(20) CALCULATION of the
Bonaventura Mill near Altena, new design

Length of the sails	43½	feet		
Width	9	feet		
Radius of the scoop wheel	10	feet	7½	inches
Width of the floats	3	feet	1	inch
Immersion of the floats	3	feet		
Difference between the high-water and the low-water level	4½	feet		

These data lead to the following calculations:

Against *CB* bear $^{111}/_{8}$ feet, and that in *D*. Against *GF* bear $^{2\,775}/_{32}$ feet, and that in *H*, which bear at *I* $^{2\,342}/_{32}$; for I say: *EI* $^{77}/_{8}$ gives $^{2\,775}/_{32}$, what does *EH* $^{65}/_{8}$ give? This gives, as above, $^{2\,342}/_{32}$ feet, weighing 4757 lbs, which bear on the scoop wheel in the centre of gravity of the low-water level in D.

To establish the ratio between the revolutions of sails and scoop wheel so that the pressure on each foot of sail be 4 $^{1}/_{2}$ ounces.

1566 feet of the four sails multiplied by 4 $^{1}/_{2}$ ounces gives 428 lbs. Further 21 $^{3}/_{4}$ feet in the centre of the sails give 4757 lbs of pressure, what does *AD* $^{77}/_{8}$ give? This gives 2105, therfore I say that the ratio between the revolutions shall be as 2105 to 428.

To establish the number of cams and staves in order to obtain approximately the above mentioned ratio of 2105 to 428.

Taking 20 staves for the wallower, 9 staves for the crown wheel and 44 cogs for the pit wheel, the question is now how many cogs should the brake wheel have in order to obtain the desired ratio between the revolutions?

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[1]) Stevin here discusses an unusual mechanism involving both an upright shaft and a lay shaft, see figure 28.

Ic seg 20 mael 9 is 180; Voort 428 minste pael, geeft 2105 meeste pael, wat 180? comt 909, die gedeelt deur de 44 cammen, comt voor het croonrat 20 cammen.

Tvolgende overslach ist selve dattet naest voorgaende is, doch wort deur thiende talen berekent, doende elcke voet ⊙ en ooc een pont ⊙.

[21] *Men wil maken twee Molens tot Altena van deser gedaente*

1	Langde der wiec	435 ① voet
2	Breede	9 ⊙ voet
3	Scheprats halfmiddellyn	106 ① voet
4	Breede der lepels	32 ① voet
5	Commen onder tSomer peyl	3 ⊙ voet
6	Verschil des hoochsten en leegsten waters dat is meeste opdracht	45 ① voet
7	Ider voets zeyls sal doen	28 ② pont
8	Het schyfloop ande wiecas	20 staven
9	Het schyfloop beneen ande spil	9 staven
10	Het camrat ande wateras	44 cammen

Nu is de vraeg hoeveel cammen het croonrat sal moeten hebben om deurt voorgaende gestelde te doen tgene int 7 *des oirdens geseyt is, te weten met yder voet zeyls* 28 ② £? *Tot desen eynde seg ic aldus:*

11	Tvijfde des oirdens is 3 ⊙; sijn derdendeel 1 ⊙ getrokken vant derde des oirdens 106 ①, blyft	81 ①
12	Tvijfde en seste des oirdens maken tsamen	75 ①
13	Diens derdendeel	25 ①
14	Getrocken van 106 ① derde des oirdens, blyft	96 ①
15	Gemenichvuldicht het derde des oirdens 106 ① deurt vierde 31 ① maekt 3286 ②, tselve deur 53 ② helft vant derde des oirdens, comt	17415 ②
16	Gemenichvuldicht het twaelfde des oirdens 75 ① deurt vierde 31 ①, maekt 2325 ②; tselve deur 375 ② helft vant twaelfde des oirdens, comt	8719 ②
17	Het elfde des oirdens 96 ①, geeft het sestiende 8719 ②, wat het veertiende 81 ①? comt	7357 ②
18	Die gemenichvuldicht met 65 altijt, comt	478205 ②
19	Gemenichvuldicht het eerste des oirdens door het tweede, comt 3915 ①, tselve viermael altijt, comt	1566 ⊙
20	Die gemenichvuldicht deurt sevende des oirdens 28 ②, comt . .	43848 ②
21	Den helft vant eerste des oirdens 2175 ②, geeft 478205 ② achtiende des oirdens, wat het elfde des oirdens 96? comt	21106 ①
22	Gemenichvuldicht het achste des oirdens 20, mettet negende 9, comt	180
23	Het twintichste des oirdens 43848 ②, geeft het eenentwintichste 21106 ①, wat het tweentichsten 180? comt	866
24	Die gedeelt deur het thiende des oirdens 44, comt voor de begeerde cammen des croonrats in heelgetal	19

I say 20 times 9 is 180. Further 428 for the smaller term gives 2105 for the greater term; what does 180 give? This gives 909, which divided by the 44 cogs, gives 20 cogs for the brake wheel.
The following calculation is the same as the preceding one but it is made by means of "tenths", each foot being ⊙, and also each lb ⊙.[1])

(21) *Two mills shall be built at Altena according to this design:*

1.	Length of the sails	435 ① feet
2.	Width	9 ⊙ feet
3.	Radius of the scoop wheel	106 ① feet
4.	Width of the floats	31 ① feet
5.	Immersion of the floats	3 ⊙ feet
6.	Difference between the high-water and the low-water level	45 ① feet
7.	Each foot of sail will have	28 ② lbs.
8.	The wallower will have	20 staves
9.	The spur wheel will have	9 staves
10.	The driven wheel will have	44 cogs

Now the question is how many cogs should the brake wheel have in order to make what has been said in the preceding supposition sub 7, to wit a pressure on each foot of sail of 28 ② lbs? In order to calculate this I proceed as follows:

11.	The fifth number is 3 ⊙; one third of this is 1 ⊙ subtraction from the third number 106 ①, leaves	96 ①
12.	Numbers 5 and 6 add up to	75 ①
13.	One third of this amount is	25 ①
14.	Subtracted from number 3, 106 ①, this leaves	81 ①
15.	The third number 106 ① multiplied with the fourth number 31 ① makes 3286 ②, this being multiplied by 53 ②, one half of the third number, makes	17415 ②
16.	Multiply number 12. 75 ① by number 4, 31 ①, this makes 2325 ②, multiply by one half of number 12. 375 ②, this makes	8719 ②
17.	The eleventh number is 96 ①, gives the sixteenth 8719 ②, what does the fourteenth number 81 ① give? This makes	7357
18.	This, multiplied by 65, gives	478205 ②
19.	Multiply the first number by the second; this makes 3915 ①, this taken four times makes	1566 ⊙
20.	This, multiplied by the seventh number, 28 ② makes	43848 ②
21.	One half of the first number 2175 ②, and the eighteenth number being 478205 ②, what does the eleventh number 96 give? This makes	21106 ①
22.	Multiply the eighth number 20 by the ninth 9, this makes	180
23.	The twentieth number is 43848 ②, and the twentyfirst 21106 ①; what does the twenty second 180 give? This makes	866
24.	This, divided by the tenth number 44, gives the desired number of cams of the brake wheel in a whole number	19

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1) The symbols used on this and the next pages indicate units, tenths, hundreths, respectively. Cf. vol. II A of this edition, pp. 376 and 405.

[22] *Verlycking vande nieuwe Mole des 7 Overslachs deses;*[1] *met Theens Molen*[2] *die vant 3 Overslach des 2 Onderscheyts is; welke twe ontrent evegroot zijn.*

Des schepsrats middelini vande nieuwe Mole is elf voeten, de breede 2 voet 11 duym; tlichhaem van dat rat beschreven (genomen des ronts gemeen reden van 22 tot 7) is groot 277 $^{7}/_{24}$ voeten. Maer gaende yder lepel 4 voeten diep int leegste water, so isser 2 $^{1}/_{2}$ voet buyten twater, daeromsulken lichhaem, beschreven uyt die 1 $^{1}/_{2}$ voet als halfmiddellini, is groot 20 $^{5}/_{8}$ voeten, die getrocken vande 277 $^{7}/_{24}$, blyft 256 $^{2}/_{3}$ voet; daer af, noch de grootheyt des houtwerx vant rat int water gaende doende 9 $^{1}/_{2}$ voet (want het wageschot der lepels is dic bycans $^{1}/_{2}$ duym, breet byde 3 voet, lanc 4 voet, die doen $^{1}/_{2}$ voet, twelc 6 mael maekt 3 voeten; Voort 12 eynden der spruyten elc lanc 4 voet, breet 4 duym, dic 3 duym, doen 4 voet: Noch 12 stocken dic 2 duym, breet 3 duym, lanc 5 voeten, maken 2 $^{1}/_{2}$ voet, welke 3 voet, 4 voet ende 2 $^{1}/_{2}$ voet, maken tsamen de voornoemde 9 $^{1}/_{2}$ voeten) blyft 247 $^{1}/_{6}$ voeten, ende so veel waters dryft dit scheprat voort met elcke 8 keeren der zeylen.

Des cleynen scheprats middellini is van 7 voeten, ende breet 5 duym, tlichhaem van dat rat beschreven, is groot 16 $^{1}/_{24}$ voeten, nu gaende van yder lepel 2 voet int leegste water, so isser (als boven ooc dede) 1 $^{1}/_{2}$ voet buyten water, daerom sulken lichhaem beschreven uyt die 1 $^{1}/_{2}$ voet, als halfmiddellini, is groot 2 $^{53}/_{56}$ voeten, die getrocken vande 16 $^{1}/_{24}$, blyft 13 $^{2}/_{21}$. Daer af de grootheyt des houtwerx int water gaende doende 2 $^{1}/_{12}$ (te weten van 20 eynden, der lepels lanc 2 voet, breet 5 duym, dic 1 $^{1}/_{2}$ duym) blyft 11 $^{1}/_{84}$ voeten, en so veel waters, by aldien het deur ginge, sou dit scheprat voort dryven met elk $^{5}/_{4}$ keeren der zeylen, Ic seg $^{5}/_{4}$ keeren (want twiel boven heeft 28 cammen, de schijfloop boven 10 staven, de schijfloop beneden 8 staven, twiel beneden 28 cammen) daerom seg ic $^{5}/_{4}$ keeren geven 11 $^{1}/_{48}$, wat 8 keeren? comt 70 $^{8}/_{15}$ voeten, daerder de ander Meule met 8 keren 247 $^{1}/_{6}$ voeten doet, daerom so als het bevangen water tusschen de cleene lepels deur gejaegt wierde, twelc verre van daer is, so doet dese nieuwe Mole voor al 3 $^{2\,201}/_{6\,510}$ mael meer als de ander.

Maer somen nam de lepelen vant cleen scheprat maer een voet diep int leegste water te gaen, gelijkt wel gebeurt, en tgroot scheprat 3 voeten, men sal bevinden na de oirden alsboven, dat het groot scheprat by de sesmael meer doet dant cleen.

Desgelijx genomen tcleene maer $^{1}/_{2}$ voet diep te gaen, en tgroote 2 $^{1}/_{2}$ voet, dit sal dan byde thien mael meer doen als dat.

Bovendien so is noch tanmerken, dat al twater begrepen tusschen de lepelen van dese nieuwe Mole, voortgedreven wort sonder datter weder water te rugge can keren als in d'ander, twelc daer an blykt dat de Mole gemalen hebbende en daer na stil staende, de waterdeur en valt niet weder toe, of immers met langer tijt, seer traeglic, want de lepels self twater schutten; Inder voegen dattet daer voor te houden is, so wy geseyt hebben, dat al twater begrepen tusschen twe lepels, voort moet; maer niet also inde ander, alwaer altijd een grooten deel weder nootsakelic te rugge keert, want het gebeurt dicwils, dat sy met een tamelicke wint de waterdeur niet openen en connen, alwaer nootsakelic uytvolcht, dat al twater begrepen tusschen twe lepels, altemael weder te rugge keert deur de garren tusschen de lepels en de krimp; Ooc al gaet de waterdeur open met een wint die niet heel

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1) Our number [19].
2) Our number [10a].

(22) *Comparison of the new mill* (19) *and Theens Mill* (10a) *which two are about the same size.*

The diameter of the scoop wheel of the new mill is eleven feet, the width 2 feet 11 inches, the volume described by it (taking the ratio of the circle to be 22 to 7) is 277 $^7/_{24}$ feet. But each float dips 4 feet into the low-water level, which makes 2 $^1/_2$ feet above the water, therefore this volume described by the radius of 1 $^1/_2$ feet, is 20 $^5/_8$ feet, which, subtracted from the 277 $^7/_{24}$ gives 256 $^2/_3$ feet, from this we should subtract the volume of the timber of the wheel in the water, which is 9 $^1/_2$ feet (for the boards of the floats are nearly $^1/_2$ inch, nearly 3 feet wide, 4 feet long, *i.e.* $^1/_2$ foot, which, taken six times makes 3 feet. Then there are 12 ends of the starts, each 4 feet long, 4 inches wide, 3 inches thick, which makes 4 feet. Also 12 spokes of 2 inches thick, 3 inches wide, 5 feet long, making 2 $^1/_2$ feet; these 3 feet, 4 feet and 2 $^1/_2$ feet make together the above 9 $^1/_2$ feet, which leaves 247 $^1/_6$ feet and so much water this scoop wheel raises with each 8 turns of the sails.

The diameter of the small scoop wheel is 7 feet, it is 5 inches wide, the volume described by the wheel is 16 $^1/_{24}$ feet; now each float dips 2 feet into the lowest water level, which makes (as above) 1 $^1/_2$ feet above the water. Therefore this volume described by the radius of 1 $^1/_2$ feet is 2 $^{53}/_{56}$ feet which subtracted from the 16 $^1/_{24}$ leaves 13 $^2/_{21}$. From this we should subtract the volume of the timber circulating in the water which is 2 $^1/_{12}$ (to wit 20 ends of the floats, 2 feet long, 5 inches wide, 1 $^1/_2$ inches thick) which leaves 11 $^1/_{84}$ feet and so much water this scoop wheel would raise with every $^5/_4$ turns of the sails. I say $^5/_4$ revolutions, for the brake wheel has 28 cams, the wallower 10 staves, the sper wheel 8 staves, the driven wheel 28 cogs; hence I say $^5/_4$ turns yield 11 $^1/_{48}$, what do 8 turns yield? This gives 70 $^8/_{15}$ feet. Whilst the other mill raises 247 $^1/_6$ feet with 8 revolutions; therefore if the small floats (of the old-design mill) indeed raised this amount of water which is doubtful, this new mill does 3 $^{2\,201}/_{6\,348}$ times as much as the other.

But if we assume the floats on the small scoop wheel to dip only 1 foot into the low-water level, which is fairly common, and the large scoop wheel 3 feet, then a calculation as above will show that the large scoop wheel will do about six times as much as the small one. Likewise if we assume that the small one dips only $^1/_2$ foot and the large one 2 $^1/_2$ feet, the latter will do ten times the amount of the former.

Furthermore it is to be noted that the water contained between the floats of the new mill is raised without water being able to flow back like in the other mill, which appears from the fact that when the new mill has worked and then comes to a standstill, the gate (*waterdoor*) does not close, or only after a long time and very slowly, for the floats themselves shutt off the water. Therefore we may assume, as we maintained, that all the water contained between two floats has to rise; but not so in the other mill where always a large amount of water must flow back, for it often happens that with a reasonable wind it can not open the gate, from which it follows logically that the water between the two floats must all return through the slits between the floats and the walls of the wheel race. Again the gate does open when there is a wind that is not very sterc genoech en is, so blykt altemet so slappe schoten des waters, dattet nau de pyn weert en is van malen, waer af de oirsaec is datter so veel water weder te rugge keert; Inder voegen dat sommige achten de helft des waters begrepen tusschen de lepels nau voort te comen, twelc so genomen dese Mole verleken by de andere, sou wel noch een mael so veel meer doen dan boven geseyt is.

Wyder is tanmercken datse deur een schyfloop te versteken, met seer cleene wint malen can als dander hun waterdeur niet openen en connen, want drajende slechts de wiecken metter hant (ic laet de wint varen) twater ryst, de water deur gaet open, en twater wort voort gedreven; maer want het dicwils gebeurt datter binnen twe of drie weken geen so sterke wint en waeyt dat dander malen connen, so sal dese daerentussen haer Polder drooch hebben twelc angemerkt zy, sal by dander verleken, meer doen dan ic seggen wil, want het genoech wordt metter daet te blycken.

Meer sulke verlijckingen can hy diet lust, overleggen; Nemende uyt elc der voorgaende twe Overslagen een Mole met ontrent eve lange wiecken: Als de Zuytnootdorpsche Mole des 1 Overslachs vant 2 Onderscheyt; hebbende langde der wiecken 40 $^{1}/_{2}$ voet; Ende de Stolwycsche Mole des 2 Overslachs deses 3 Onderscheyts, hebbende de langde der wiecken 40 voet: Of dergelijke andere twe.

strong, and therefore it is very clear that the water comes in such weak laps that it is hardly worthwile to "mill" at all, the cause of which is that so much water flows back, so that some are of the opinion that hardly half the water contained between two floats is raised at a time, this would make the amount raised by the new mill, as compared with the other, to be another hundred per cent more than stated above.

It is also to be noted that this one (the new mill) because of proper pinions can turn at a lower velocity of the wind when the others cannot yet open their gates, for if we turn the sails by hand only (and I neglect even the wind), the water rises, the gate opens and the water is driven forth; but because it often happens that in two or three weeks there is no wind strong enough to enable the others to pump, but this one will meanwhile have drained its polder properly. It should therefore be noted that, if comparing it with the other one, it will do more than I prefer to say for the proof of the pudding is in the eating.

More such comparisons can be made by whomsoever wishes to do so, by taking from these two series of calculations mills with sails of approximately equal length, such as the South Nootdorp Mill (our number (1)), which has sails 40 1/2 feet long, and the Stolwijk Mill (our number (15)), with sails 40 feet long, or other pairs.

APPENDIX I

Aende E:Heeren, Schoutet en Burgmeesters der Stadt Delft

Hebbende Simon Stevin onlanx uytgegeven een bouck, geseyt de *beginselen des waterwichts,* en van wille sijnde de Daet of *praktique* van sulcx nu int werc te stellen, Soo is hem onder anderen voorgecommen de schuering ofte deurleyt des waters die mijn Heeren met overvloet deur de Stadt begeeren. Maer want de voornoemde *Beginselen der waterwichts* seker kennis geven om de voorschreve scheuring met kleyne cost en arbeyt te maken, alsoo datter een groote menichte waters loope, ongelijc al veel overvloediger dant nu doet; Soo heeft hem goet gedocht sulcx mijn Heeren an te dienen, bethoonende deur seker redenen de oirsaken, waerom dese manier dat doen can, ende d'ander niet. Maer by aldien mijn Heeren daer an twijfelen, so presenteert de voornoemde Simon sulcx tsynen laste te doen, en so teynde niet goed en viele, dat alle verlooren cost, tsyner schade sal wesen.

Men sal maken een reetschap gelijck hier van houte bygevoucht is, te weten een schepradt met ses lepelen, elcke lepel van seven voeten lanc, en soo breet als de sloot daerment in stellen wil, ick neem 16 voeten ofte noch breder, soot de plaets of sloot toeliet, want hoe breder hoe meerder voordeel; 'tselve radt sal gestelt worden op een vloer van binnen ront, welcke soo lanc sal zijn, datter int draeyen altyd een lepel binnent ront sy. Tvoornoemde radt sal deur een peert inden ganck gehouden worden, en dat so snel als tot den behoirlicken arbeyt eens peerts genouch is, twelck geschien sal, niet met een groot camradt als van een rosmeulen, twelck te groote snellicheyt by soude brengen, maer met minder cost, deur een cleen schyfloop, die hy S. Stevin na de grootheyt des rats en omganc des peerts, daer toe veroirden soude.

Tot hier toe hebben wy tmaecsel der reetschap verclaert; Maer want nu ymant twyffelen mocht, hoe dit radt soude connen beweeght worden, om 't groot gewicht waters voor elcke lepel liggende, soo sullen wy dat bethonen, niet alleen deur gelijckenis, maer bycans metter daet sonder onse cost, te weten in een groote deur van een sluys, ic neem 16 voeten breet en 7 voeten diep als de voornoemde lepel, welcke deur van een mensch alleen ('t water over beyde syden evenhoch synde) lichtelick omgedraeyt wort als kennelick is. Nu genomen dattet water voor de lepels niet en rese, daer volcht uyt dat een mensch met sulcken arbeyt twater van een sloot breet synde 16 voeten en 7 voet diep, soo seer soude doen voortloopen als die lepel voortgaet, ofte om eygentlicker der af te spreken (overmits t'eynde des lepels naest den as meest verroert) soo seer als haer middelpunt voortgaet.

Reeden dat een ront even is anden rechthouck begrepen onder syn half middellini. en een rechte linie even aan eens ronts omtrec, beschreven uyt het vierendeel van syn middellini.

Daer rest nu noch bethoont te worden d'orsaeck, waerom de jegenwoordige watermeulen soo weynich waters (int ansien van dit) voortdrijft; Welcke oirsaeck int gemeen geseyt, de snelle drajing is, des rats dat het water voortdryft, waer uyt twe merckelicke ongevallen spruyten; Het een dattet water voren onnodelick rijst, Tander dattet volgende water van achter tegen de lepelen niet seer en perst, maer eer als voortgetrocken synde daer agter loopt;Maer om van dese twe ongevallen breeder reden te geven, soo laet ons nemen een deure van een sluys, 10 voeten breet, en twater over d'een zyde 10 voeten hooch, en over d'ander syde 9 voeten hooch, Dit hoochste water (hoe wel het maer een voet hooger en is alst ander) sal

APPENDIX I[1])

To the Hon. Bailiff and Burgomasters of the Town of Delft

When Simon Stevin, having recently published a book, called *The Elements of Hydrostatics,* and intending to write the *Daet* or practical application of it, he amongst other things pondered on the scouring or flow of water which you, dear Sirs, desire in great quantity through your town of Delft. But because the above *Elements of Hydrostatics* give sure instruction how to achieve such scouring with little cost and labour in order that a large flow of water may be achieved, much more plentiful than is now the case, he still thought it wise to point this out to you, Gentlemen, in order to show with sure reason the cause why it can be done in this manner and not by another. But in case you, Gentlemen, should doubt this, then the above-mentioned Stevin offers to do this at his owns cost and if it should be unsuccessful in the end, all money lost shall be his own loss.

An instrument should be made like the wooden model attached, i.e. a scoop wheel with six floats, each float seven feet long, and as wide as the ditch in which it is to be mounted, I take 16 feet or even wider, if the site or canal will allow of it, for the wider the greater the profit; this wheel should be mounted on a floor, round on the inside, which should be so long that as the wheel turns there will always be a float in the quadrant. This wheel shall be turned by a horse and as quickly as is sufficient to keep the horse well employed, which will not be done with a large cogwheel as of a horse-mill, which would give too great a velocity, but at lower cost with the help of a small lantern wheel which he, S. Stevin, will calculate according to the size of the wheel and the circular path of the horse.

Up to now we have explained the construction of the apparatus, but because anyone might doubt how this wheel could be moved because of the great weight of the water in front of each scoop, we will demonstrate this not only by analogy but also practically by experiment but not at our own cost, *i.e.* with a large door of a lock, I take 16 feet wide and 7 feet deep like the above-mentioned float, which door (the water being equally high on both sides) is easily moved by one man alone as everybody knows. Now assuming that the water in front of the float would not rise, it follows that one man with such a machine would make the water of a canal 16 feet wide and seven feet deep move as quickly as the float moves, or more exactly (as the end of the float that is nearest to the axle moves most quickly) as quickly as its centre.

A circle is equal to a rectangle formed by its radius and a straight line as long as the circumference of a circle described by a quarter of its diameter.

It remains to show the cause why the present-day drainage mills raise so little water (in comparison with this one), the general reason of which is the rapid revolution of the scoop wheel, from which result two remarkable difficulties: the first is that the water in front is raised too high, the second is that the water behind does not bear strongly on the floats but rather flows behind them as if it were drawn along. But in order to discuss these two difficulties in more detail let us take a gate of a lock 10 feet wide and the water 10 feet in front and 9 feet behind. This highest water (though it be only one foot higher than the

[1]) This memorandum *On the scouring drainage mills according to my father's new design* is given in Work XVI B, Book X, 30—33; we do not know whether it was ever dispatched to the Delft authorities to which it is addressed.

soo veel styver tegen die deure drucken dan tleegste water, als 6175 ponden gewichts op eenige tafel leggende, want deurt eerste Voorbeeldt des vijftiende Voorstels vande *Beginselen des Waterwichts*) tegen d'een zyde sal rusten tgewicht van 500 voeten water, tegen d'ander zijde 405 voeten, welcke getrocken van de 500, rest 95 voeten, dese 65 mael (want elc voet waters weegt 65 £) comt alsvooren 6175 £ dieder over d'een zijde meer tegen rusten als over d'ander; Twelck ymant inde *Beginselen des Waterwichts* onervaren, naulic gelooven en sou, te weten dat om een voet die twater op d'een zijde maer hooger en is als op d'ander, so veel swaerder perssing sou veroirsaect worden, te meer dat die overschietende voet, hebbende inde breede 10 voeten op haer selven angesien, niet meer drucking tegen de deure en doet, dan van vijf voeten waters wegende 325 £, doch het is also nootsakelic in de natuer, waer af de ervaring ooc betuycht, daer in, dat men sulke deuren niet open trecken en can. Uyt het welck kennelic is, hoe seer dattet scheprat des Watermolens beswaert can worden, deur een cleene verhooging des waters uyt syn snelle loop spruytende.

Maer om nu tander ongeval breeder te verclaren, namelic dattet volgende water tegen de lepel van achter niet en perst, so waer ons noodich te weten hoe snel de natuerlicken loop is langs het *Orizon* van eenich water bekender hoochde. Hier af hebben wy een voorbeelt deur het keerende getye in sommige rivieren, als die voor Londen ende meer ander; alwaer het voornoemde getye met een bare comt, myns bedunckens, hooch ontrent twee voeten, d'eenmael meer d'ander mael min; Waer uyt kennelick is, dat een schepradt van een Watermolen so diep, ende even so snel drajende als dien loopt, sulc rat en wort vande perssing des volgende waters niet geholpen, maer blijft onnodelic beswaert mettet gantsche gewicht des waters voor de lepel zijnde, welc gewicht tegen een lepel lanc ses voeten, en een voet breet, bedraecht (deurt voornoemde 15 Voorstel) 1170 £, daer het scheprat sonder noot, geduerlic mede beswaert blijft. Maer so den loop des scheprats so snel niet en waer, het sal van de perssing des volgende waters eenige hulpe crygen: Maer so den loop des scheprats noch snelder waer, dan sulken natuerlicke loop des waters, het sal noch meerder onnodigen arbeydt doen dan die voornoemde 1170 ponden, overmits het dan tvolgende water na hem suycht ofte trekt.

Alle dese tsamen maken, datmen met grooten arbeyt cleene schuering des waters crycht, maer een groot seer breedt scheprat als boven beschreven is, traechlick omgaende, en lyt de voornoemde twe ongevallen niet; want gelijc een Waech over beyde zijden eveswaer zijnde, (jae al hadse in elcke schael 3000 pont) lichtelic met een vinger beweecht wordt, alsoo ooc dit groot scheprat traechlic gedraeyt, overmits de groote druckende gewichten over beyde zijden bycans evegroot blyven. Maer soo myn Heeren aent boveschreve twyffelden, so wil den voornoemde Stevin, als vooren geseyt is, sulx tsynen lasten annemen. Twelck tgene is datter voorgenomen was te verclaren.

Bewys dattet nieu werck ande Watermolen binnen Delft viermael meer waters voortdryft dant toude werck dede.

De diameter des ouden schepradts was 13 voeten, de breede der lepels 16 duym, daerom is tlichaem van dat scheprat beschreven groot $177\,{}^{1}/_{21}$ voeten (hier af getrocken $31\,{}^{16}/_{21}$ voeten voor het deel des scheprats dat buyten twater gaet, met de grootheyt des houtwerx (want ic neem tmiddel vanden as te leggen twe voeten boven twater, daerom is dat lichhaem groot $16\,{}^{16}/_{21}$ voeten met 15 voeten voort hout) blyft $145\,{}^{2}/_{7}$ voeten, ende soo veel waters gater voort met elcken other) will bear on the door as much more than the lowest water as 6175 lbs bearing on a table. Because according to the first example of the fifteenth proposition of the *Hydrostatics* against the one side bear 500 feet of water against 405 on the other, which subtracted from the 500 gives 95 feet, this, taken 65 times (for each foot of water weighs 65 lbs), give, as above, 6175 lbs more on the one side than on the other). One not versed in the *Elements of Hydrostatics* would hardly believe this, i.e. that a difference of one foot of water between the two sides would cause such a pressure since this one foot over a width of ten feet does not bear against the gate more than five feet of water, weighing 325 lbs, but it is well-known in practice that one cannot open such gates. From which it will be clear how much pressure can be exerted on the scoop wheel of the drainage mill by a small rise of the water owing to its rapid flow.

In order to explain the second difficulty in more detail (*i.e.* that the water behind no longer bears on the floats), we have to know how quickly water flows along the horizon at a given level. Of this we have an example in the tides of certain rivers, such as in London and other places; where the tide comes in with a wave, I believe two feet high, now more now less. Which goes to show that a scoop wheel runs as fast and as deep but is not helped by the pressure of the water behind and the full weight of the water in front necessarily bears on it, which weight (according to the afore-mentioned 15th proposition) for a float six feet long and one foot wide amounts to 1170 lbs, with which weight the float is constantly loaded without need. But if the velocity of the wheel be not so great it will get some support from the water behind, and if the wheel turns even more quickly than the natural flow of the water it will have to do even more unnecessary work than the said 1170 lbs, since it then draws or sucks the water behind it.

All this together is the cause why much energy produces but little scouring of the water, but a large wide scoop wheel as described above turning slowly does not suffer from the said two defects, for just as a balance that is equally heavy on both sides (yes, even if there were 3000 lbs in each scale) is moved easily with one finger, so the large scoop wheel is also turned with ease as the weights bearing on it from both sides are nearly equal. But if you, Gentlemen, were to doubt what has been said above, the said Stevin will, as stated, have it built at his own cost. This was what we set out to explain.

Proof that the new machinery of the drainage mill in the town of Delft moves four times as much water as the old one did.

The diameter of the old scoop wheel was 13 feet, the width of the floats 16 inches, therefore the volume described by the floats is $177\,^{1}/_{21}$ feet ($31\,^{16}/_{21}$ being subtracted for the part of the wheel remaining above the water and the size of the timber, for I take the centre of the shaft to be two feet above the water, and therefore the volume is $16\,^{16}/_{21}$ feet and 15 feet for the timber), there remains $145\,^{2}/_{7}$ feet and so much water is raised with each turn of the wheel. But then keer des scheprats; Maer drajende het scheprats eens om, so keeren de wiecken 1 $^{142}/_{441}$ mael om, daerom met elcken keer der wiecken so gater voort min dan 110 voeten waters.

Tot hier toe hebben wy 't oude werck berekent, ende inder selver voegen sullen wy nu 'tnieuwe berekenen.

De Diameter des nieuwe scheprats is 17 voeten, de brede der lepels 6 voet 7 duym, daerom is 'tlichhaem van dat schepradt beschreven groot 1494 voeten. Hier aftrocken 107 $^{16}/_{21}$ voeten voor het deel der scheprats dat buyten twater gaet, met de grootheyt des houtwercx, (want ic neem 't middel vanden as te liggen 2 voeten boven twater gelijc vant oude werck; daerom is dat lichaem groot 82 $^{16}/_{21}$ voeten, met 25 voeten voort t'hout) blijft 1386 $^{5}/_{21}$ voeten; Ende soo veel waters gater voort met elcken keer des scheprats; maer drajende het scheprat eens om, so keeren de wiecken 4 $^{324}/_{343}$ mael om; daerom met elc keer der wiecken so gater voort 280 voeten waters.

Nu seg ick met 1 $^{142}/_{441}$ keren vant out werc, gaet voort 110 voeten water; hoeveel met 4 $^{324}/_{343}$ keeren? comt in als geen 416 voeten; Maer 't nieuwe werc dryft met elcke 4 $^{324}/_{343}$ keeren 1386 voeten, so boven bethoont is; daerom so de wiecken van d'een en d'ander Mole eve ras omgingen, so sou de reden vant nieuwe werck tottet oude zijn als van 1386 tot 416, dat ist nieuwe $^{1\,386}/_{416}$ mael, dat is 3 $^{75}/_{208}$ mael meer te doen dan 't oude; maer de wiecken vant nieuwe werc gaen rasser, en so deur d'ervaring tot veel verscheyden mael ondersocht is tegen de ander Mole, die noch lichter draeyt dan de oude Mole (stellende op een selve tijt de keeren van d'een en d'ander) so wort bevonden de wiecken vant nieuwe werc over de ses mael te keeren, terwyl d'ander maer vijf mael en keeren daerom seg ic 5 geeft 6, wat $^{1\,386}/_{416}$? comt 4 $^{11}/_{476}$, dat is het nieuwe werc doet 4 $^{11}/_{416}$ mael meer dan het oude, als voorgenomen was te bethonen.

Hier toe sou men noch meugen nemen het voordeel datter comt uyt de nausluyting der lepels inde crimp, want hebbende 16 duym breede, der oude lepels 1 duym openheyt, so souden 6 voet 7 duym der nieuwe lepels, meugen hebben bycans een halve voet openheyt, ende haer redens sou gelijc zijn, daer sy maer een vieren deel duyms openheyt en hebben.

Hier by sou men noch meugen voegen, dat de wiecken van dese vernieude Mole, swaerder van gang zijn als van d'ander Mole.

GEDACHTENIS

Wesende 't scheprat breet 14 voet, so sal 't vangrat hebben 18 staven, dic op de steeck 6 duym, ende 't croonrat 16 cammen, dic op de steeck 4 duym, achterwaert hellende op van 3 een, de steeck vandien sal zijn 11 duym.

't Schijfloop beneen sal hebben 8 staven, dick op de steeck 4 $^{3}/_{4}$ duym, het camrat 54 cammen, breet 20 duym, dick op de steeck 3 duym, achterwaert hellende op van 4 een.

Wesende 't scheprat breet 10 voet, soo sal 't vangrat hebben 18 staven, 't croon 17, 't schyfloop 11, 't camrat 54.

Wesende 't schepradt breet 6 voet, soo sal 't vangradt hebben 18 staven, 't croonrat 16, 't schijfloop 14, tcamrat 54.

the sails have turned $1\,^{142}/_{441}$ times, therefore with each revolution of the sails 110 feet of water is moved. Up to now we have calculated the old mill and now we turn to the new one.

The diameter of the new scoop wheel is 17 feet, the width of the floats 6 feet 7 inches, therefore the volume described by the scoops is 1494 feet, subtract $107\,^{16}/_{21}$ feet for the part of the wheel that does not enter the water and the volume of the timber (for I take the axis of the shaft to be two feet above the water, as in the old mill, therefore the volume is $82\,^{16}/_{21}$ feet, and 25 feet for the timber), there remains $1386\,^{5}/_{21}$ feet. So much water is moved by one turn of the scoop wheel, but as one turn corresponds with $4\,^{34}/_{343}$ turns of the sails, therefore one revolution of the sails moves 280 feet of water. Now I say $1\,^{142}/_{441}$ revolutions of the old machinery move 110 feet of water, what do $4\,^{324}/_{343}$ turns move? This gives nearly 416 feet. But the new machinery moves in $4\,^{324}/_{343}$ turns 1386 feet, as proved above, therefore as the sails of the old mill and the new mill turn with the same speed, the ratio of the old to the new machinery would be as 1386 to 416, *i.e.*, the new one will do $^{1\,386}/_{416}$ times, or $3\,^{75}/_{208}$ times as much as the old one, but the sails of the new one turn more quickly, as has been proved by experience several times against an other mill which turns even more easily than the old one (taking the revolutions in a set period of time), it is found that the sails of the new mill turn more than six times against five of the old mill. Therefore I say 5 gives 6, what does $^{1\,386}/_{416}$ give? This gives $4\,^{11}/_{416}$, *i.e.* the new machinery will do $4\,^{11}/_{416}$ times as much as the old one, and this we wanted to calculate. We might add the advantage of the tight fit of the floats in the wheel race, for whereas the old floats of 16 inches width have a gap of 1 inch, the new floats 6 foot 7 inches wide might have a gap of nearly half a foot and their output would still be the same, but they have a gap of only one quarter of an inch. One might also add that the sails of the new mill turn somewhat more heavily than those of the old mill.

NOTES

If the scoop wheel is 14 feet wide, the wallower should have 18 staves, 6 inches thick on the pitch, and the brake wheel 16 cogs 4 inches thick, with a slope of 1 : 3 and the pitch should be 11 inches.

The crown wheel should have 8 staves, $4\,^{3}/_{4}$ inches thick on the pitch (*steek*) the pit wheel 54 cams, 20 inches wide, 3 inches on the pitch (*steek*) and sloping 1 : 4.

If the scoop wheel is 10 feet wide, the wallower should have 18 staves, the brake wheel 17, the crown wheel 11 and the pit wheel 54.

If the scoop wheel is 6 feet wide the wallower should have 18 staves, the brake wheel 16, the crown wheel 14 and the pit wheel 54.

APPENDIX II

1. *Verclaringe der inventie van Simon Stevin, die by voegen sal totte Watermolens vant welc mijn Heeren de Staaten hem Octroy verlenen.*

Simon Stevin sal maken een Watermolen vande groote daermen nu gemeenlic anstelt een schepradt diens lepelen lanc 3 ½ voeten ende breet ontrent 5 duymen, maer inde plaets van sulken schepradt sal hy setten een radt van ander form, twelc inde plaets der 20 of 24 lepelen hebben sal ses groote vierhouckige houten planckeren lanc 6 voeten ende breet 3 voeten; de selve sullen aen haer uytersten, hangende houten regelen hebben aengehecht met vet leer, welke regelen (drajende de Meulen) strijcken sullen tegen den vloer, en tegen de zijden daer dat radt indraeyt, inder vougen dat hoewel sulken radt lancsamelic omgaet, so en salder geen water weder te rugge keeren deur de garren of openheyt tussen sodanige planckeren ende den vloer ende de zijden daer tradt indraeyt. De voornoemde grootheyt der planckeren des radts dient tot een cleen Molen van grootheyt als boven geseyt is, tot grooter Meulens sal hy na gelegentheyt grooter gebruycken; Wyder soudemen meugen seggen van de rest, maer so veel tvoornemen belangt, namentlic tgene tottet Octroy nodich valt, dae rtoe is int boveschreven genouch verclaert, te weten, dat niemant en sal meugen maken, doen maken of gebruycken, sulken groot radt met de voornoemde planckeren, besloten met sodanigen houten regelen met leer aengehecht, noch van eenige ander stof, in die plaets dan den voornoemde Stevin, en dat voor den tijt ende op de verbeurte int Octroy breeder verclaert. Onder stond, Hier achter volchde een Figuer vande inventie, hier onnodich te stellen: Leger stont, Gecollationeert jegens tprincipael Octroy, met de verclaring daer deur getranstixeert wesende d'Octroy in perquemente geschreven, met een uythangende groote zegel der voorschreve Generale Staten in dobbelen staet, ende onderteeckent d'Octroy als voorschreve, syn dese daer me van woorde tot woorde bevonden taccorderen op ten 25 Iuly 1591, was onderteeckent by my P. VIRVLY *Not. admi.* Op de rugge stont: Volcht hier dat op ten rugge vande voorschreve Octroy stond geschreven, luydende aldus: Naer dat dese opene brieven van Octroy ter bureel vande Camer vande reeckening in Hollant zijn gepresenteert geweest, so zijn de selve aldaer ter ordonnantie vande Luyden der selve rekeningen geregistreetrt int witte register met die rode rose Fol. 51. Actum ten burele voorschreve desen 15 Septemb. anno 1588, onderwaerts stond, my jegenwoordich ende onderteeckent, *C. vander Goes.* Onder stont, Gecollationeert tegen tgene op ten rugge vande voorschreve Octroy geschreven stont, is tselve van woort tot woort bevonden taccorderen op den 26 Iuly 1591, Was onderteeckent by my *P. Veruly Not. admit.*

2. COPYE 1591

De Ridderschap Edelen en Steden van Hollant ende Westvrieslant representerende de Staten vanden selven Lande. Doen te weten: Also wy bevonden hebben, dat Simon Stevin binnen den voornoemde Lande op onse voorgaende Brieven van Octroy tot dienste der selver Lande, sijne conste van nieuwe maniere van Watermolenen sulx heeft doen oprechten ende effectueren, dat daer afby de Ingesetenen der selver Lande kennisse daer afhebbende, seer goede getuygenisse zijn gegeven vanden uytmalen ende losinge vande wateren die daer deur boven alle voorgaende Watermolenen, met minder costen, zijn genoten: So hebben wy de voornoemde Symon Stevin wel willen houden voor gerecommandeert, so wel binnen sLants als in andere omleggende Rijcken ende Provincien, ten eynde aldaer sijne geexprimenteerde conste mede besocht ende gebruyct mach worden als naer behooren.

Gedaen inden Hage onder tZegel vanden Staten voornoemt hier opgedruct den 13 Martii anno 1591, Onder stont, ter ordonnantie vande Staten &c.

3. COPYE 1590

Wy Schout, Burgemeesters, Schepenen ende Regeerders der Stadt Delft, Oirconden ende certificeren voor de gerechte waerheyt ten versoecke van Mr. Simon Stevin Mathematicijen, wonende binnen de Stadt Leyden, dat de selve Stevin tot onsen versoecke inden Iare 1588 voorleden, volgende sijne const en inventie, vermaket heeft de oude Watermolen staende aent Duyvelsgat opte vesten teijnde de Geerwech binnen deser Stadt, ende dat de selve Molen nu twe jaren gemalen hebbende int roeren vande wateren en tochten te maken tot ververschinge van dien, seer omtrent driemael so veel wercx gedaen heeft en alsnoch doende is, als de oude Molen van te vooren plach te doen, sulx dat Wy omme de Stadt met verversinge van water noch meerder te gerieven, in dese jegenwoordige Iare 1590 de Watermolen staende op de Vesten teynde de nieuwe lange Dijc, by den selve Stevin, mede volgende sijne const ende inventie, hebben doen vermaken, waer deur de wateren binnen deser Stadt deur de gestadige werckinge der selver twe Molens so beroert worden ende sulken stroom maken als of het een stadige loopende revier ware; Ende bevinden by experiente ende metett gesichte der oogen, dat de selve twe Molens, sulx volgende de const van den voornoemde Stevin hermaect zijnde, ten minsten wel driemael so veel schuyringe maecken ende beroeringe van water, als de twee voorgaende Molens plegen te doen. Ende wantmen schuldich is der waerheyt getuygenisse te geven, besonder van des versocht zijnde, als wy nu zijn, So hebben wy Schout, Burgemeesters, Schepenen ende Rade voornoemt, tZegel ten saecke der voorschreve Stadt hier onder op gedrukt. Gedaen den 29 dach in Augusto inden Iare 1590. Was onderteeckent *I. Groenhout.*

4. COPYE 1590

Op huyden compareerde voor my Ian Reyniersz van Woerden Notaris by den Hove van Hollant tot d'exercitie van dien geadmitteert ende den Getuygen onderschreven, d'Eersame Harmen Dircksz oudt 60 Iaren, ende Floris Claesz Cnick out 37 Iaren, beyde jegenwoordich Schepenen der Stede vander Goude, mitsgaders Claes Dirck Dammesz out 66 Iare, ende Pieter Cornelisz out 63 Iaren, of elck daer omtrent, beyde Inwoonders tot Haestrecht, attesterende ende verclarende ten versoecke van Mr. Simon Stevin, ende de Schout, ende Heemraden tot Stolck respektive, by hare conscientie ende ziele zalicheyt, in plaetse van Eede waerachtich te zijn, dat Sylieden attestanten ende getuygen, te weten de voornoemde Harman Dircksz en Floris Claesz Cnick, van wegen de voornoemde Mr. Simon Stevin, ende de voorschreve Claes Dirck Dammesz ende Pieter Cornelisz by de voornoemde Schout ende Heemraden van Stolwijck respektive op huyden geeligeert ende vercoren zijn geweest, omme kennisse te dragen vande prouf die de Stolwijcksche Molen, by M. Joost Govertsz Timmerman, op de nieuwe maniere vande voorschreve Mr. Simon Stevin vermaekt ende geerigeert, doen soude tegens de Beeyersche Molen, daer beneffens staende, in heure gemeene bosem, sulx dat Sylieden Attestanten, ter plaetse ende omtrent de voorschreven bosem haer gevonden, ende met de voorsz Requirant seeckere peyl neffens twater hebbe gestelt, inder voegen dat dien volgende de Beeyrsche Molen in den bosem, een tijt van drie uyren aen malcanderen eerst heeft gemalen, sulx Sylieden Attestanten, by een Santloper gemerkt ende onthouden hebben, twelck gedaen zijnde, dat alsdoen by hen Attestanten ende getuygen, ter presentie vande voorschreve Requirant een peyl daer afgenomen is geweest. Attesteerden ende verclaerden voorts, dat de voorschreve Stolwijcksche Molen op de maniere vande voorschreve Mr. Simon Stevin als vooren geerigeert, daer nae in de voorschreve bosem, den tijt van een uyre alleenlick heeft gemalen, nae het Santloper teycken voorsz, ende dat Sylieden alsdoen insgelijcx een peylteycken daer van genomen, ende jegens voorschreve peylteycken vant water by de Beeyersche Molen, inden voorschreven bosem eerst gemalen hebben overgeleyt ende geconfereert, verclarende de voorschreve Harman Dircksz ende Floris Claesz Cnick, dat Sylieden by de selve conferentie bevonden hebben, dat de voorschreve Stolwijcksche Molen in een uyre so veel water inden voorschreve bosem heeft gemalen als de Beeyersche Molen in drie uyren, ende de voornoemde Claes Dirck Dammesz ende Pieter Cornelisz, verclaren by de voorschreve conferentie nae haer beste wetenschap te bevinden, dat de nieuwe Stolwijcksche Molen voorschreve, in een uyr so veel waters als de Beeyersche Molen in drie uyren in den voorschreve bosem heeft gemalen, doch dat het verscheelde, maer heel weynich. Attesteerden de voornoemde Attestanten, voorts tsamentlick ende gelijckelicken, dat de Beeyersche Molen het voormalen heeft gehadt; Presenterende tgene voorschreve is, solemnelicke by Eede te stercken. Aldus gedaen int Souderak opte Stolwijcksche Sluys, ten huyse van Dirck Cornelisz den Dubbelden den 26 Martii 1590. Ter presentie vande voorschreve Dirck Corneliz ende Cornelis Thysz Poorter ter Gouda, als getuygen waerdich van geloof, met my Notario hier over geroepen ende sonderlinge gebeden. Onder stont, In kennisse vant gene voorschreve staet, hebbe ick Notarius voornoemt dese Akte selfs getrouwelick geschreven en ten oirconde onderteeckent, ende was onderteeckent *R. Woerden Notar.*

5. COPYE 1590

Op heden den 25 dach der Maent van April 1590 compareerde voor my Balthasar van Baerle Openbaer Notaris by den Rade van Hollant geadmitteert ende de Getuygen na genoemt, de Eersame Pieter Aertsz woonende aen den ouden Dyck by deser Stede van Rotterdam out 48 jaren ofte daer omtrent, ende heeft ten versoecke van Ian de Groote woonende tot Delft, verclaert, getuycht en gecertificeert, verclaert, tuycht en certificeert mits desen op syne manne waerheyt in plaetse van Eede die hy altijt, des versocht zijnde, rechtelicke presenteert te doen, waerachtich te zijn dat hy Deponent tsedert December anno negenentachtich, gemalen heeft de nieuwe Molen in Cralingen Polder, gestelt by Mr. Joost Govertsz vander Spelt woonende ter Gouwe, ende dat sedert dien tijdt inde selfde Molen noyt cam ofte staf verandert is, ende de selfde cammen ende staven geen rugge van een mes gesleten zijn, ende na sijn goetduncken de selfde cammen ende staven in twintich jaren niet sullen behoeven vernieut te werden, ten ware hier ofte daer een stuck van een cam quam te springen ofte deur eenich ongeluck yet quame te borsten. Verclaerde voort, dat hy Deponent tot menichmael seker peyl gestelt heeft om te sien hoeveel waters hy in een ofte twee of meer etmalen mochte slyten, en heeft bevonden als het lant gelijck de water was, ofte het water boven an de wal was, ende het eene lant een weynich boven het ander onder water lach, dat hy in twee etmalen also veel meerder moel als de Ruychbroeksche Molen dede, die nochtans niet meer dan derdalfhondert morgen onder hem hadde, daer de voorschreve nieuwe Molen in Cralingen staende, ontrent de vijftienhondert morgen onder haer heeft. Dat hy Deponent voort tot menichmael gesien heeft dat hy in een etmaal, een duym meerder moel, en in vier dagen en vier nachten een hantbreet, en dat hy dit afgepeylt, gemerct, ende bevonden heeft, als het water weder angesact was, ende eenen nacht ende dach stille gestaen hadde. Verclaerde voorder, dat hy Deponent van alle de voorleden Winter ende Lente niet half so veel tijts gemalen alsde Ruychbroeksche Molen gedaen heeft, ende nochtans even drooch geworden is, ende oversulx dickwils heeft moeten ophouden van malen omdat de Huyslieden het water niet wilde so ras quyt wesen om dat sy haer vullens moesten op het lant brengen ende wilde meerder vlot hebben; ende dat hem by Schout ende Ambachtsbewaerders van Cralingen verboden is geweest meer te malen, Seggende: dat sy vocht wilde wesen, ende dat hy over sulx heeft opgehouden. Verclaerde noch, dat hy Deponent tsedert dat Leyden ontset worden, gemalen heeft een achtcante Molen, staende by dese nieuwe Cralingsche Molen, ende dat hy nu met dese nieuwe Molen over de selve Polder, op even veel tijdts ende even hooch water ende even windt, soo veel ende meerder water gemalen heeft als sy te vooren met haer drie Molens plegen te doen. Verclaerde vorder, dat hy Deponent bevonden heeft het verschil vant water voor ende achter de Molen, over de vier voeten, sulx dat het water stond boven aen de cade, ende dattet boven een duym niet en scheelde of den bosem was vol. Alle d'welcke de voorschreven Deponent verclaert waerachtich te zijn, presenterende tallen tijden, des noot ende versocht zijnde, bij Eede tselve te bevestigen; waer van de voorschreve Requirante versochte Akte, om hem de selve te dienen ende valideren daer ende also hy tsynen radesal vinden te behooren. Aldus gedaen ende gepasseert binnen der voorschreve Stede van Rotterdam, in den Iare ende ten dage als boven, ter presentien vande Ersamen personen Pieter Karsamont schoenmaker, Adriaen vande Sande ende Merten vander Cammen, alle Borgers ende Ingesetenen deser Stede als getuygen hier over geroepen ende gebeden, ende my Notario genomineert, tgene voorschreve is met myn gewoonlicke hantteecken Notariael confirmeren, ende was onderteeckent *B. Baerle Not. Publ.*

Daer na den vierden dach van Augusto in den selven Iare negentich is voor my Notario ende den getuygen nae genoemt, gecompareert Ioncker Jan van Assendelft Heere van Cralingen, residerende binnen dese Stadt van Rotterdam, ende heeft ten versoecke vande voorgemelde Ian de Groote verclaert, getuycht, ende gedeponeert, verclaert, tuycht ende deponeert mits desen waerachtich, ende hem Deponent kennelick te zijn, dat alle het gene hier vooren by den persoon van Pieter Aertsz woonende aen den ouden Dyck, nopende den nieuwe Molen in Cralinger Polder, gestelt by Mr. Joost Govertsz vander Spelt woonende ter Gouwe, is gedeponeert op den 25 Aprilis lestleden, dat tselve also waerachtich is in alle de poincten inde selve Certificatie verhaelt, jae dat den selve Molen eer meer als min is malende, dan by den selven Pieter Aertsz is gedeponeert, allegerende de voorschreve Deponents redenen van wetenschap, dat hy selfs aldaer dickwils by, aen, en present is geweest ende het selve al selfs heeft geobserveert en gade geslagen; Van alle het welke de voorschreve Requirant versochte Akte. Aldus gedaen binnen dese Stede van Rotterdam ten dage als boven, ter presentien van Ian Clemmetsz Waert int Sint Joris, en Ian Ruttesz Wijnverlater, als getuygen hier mee geroepen en gebede. Onderstont, Oirconde mijn signiture, ende was onder teeckent, B. Baerle, Not. Publ.

6. COPYE 1594

Ic Adriaen de Wit Cornelis Soon, Schout inden Ambachte van Cralingen out ontrent een en veertich jaren, Pieter Wiggeren Soon Ambachtsbewaerder out ontrent veertig jaren, Egbert Pietersz Soon mede Ambachtbewaerder van den Ambachte voorschreve out ontrent ses en dertich jaren, Huych Pieters Soon Schepen out ontrent vier en vijftich jaren, Symon Feys Soon Schepen out ontrent ses en veertich jaren, Jan Frans Soon Schepen out ontrent vijf en vijftich jaren, Pieter Willems Soon Keyser Schepen out ontrent een en veertich jaren, Cornelis Cornelis Soon Jongen Borger Schepen out ontrent twee en dertigh jaeren, ende Meester Christiaen Vincentius Secretaris tot Cralingen out ontrent een en sestich jaren, ende ick Pieter Aerts Soon Molenaer out ontrent veertich jaren; Altesamen rechtelicke verdaegt zijnde om getuygenis der gerechticheyt te geven ter versoucke van *Symon Stevin;* So verklaren wy Schout Ambachtbewaerders Schepens ende Secretarius voornoemt by den Eet in stuck van ons elcx Officie die wy int accepteren vandien gedaen hebben, en ick Pieter Aertsz. Molenaer van de nieuwe Watermolen op de nieuwe manier gemaect, hebbe met opgerechte cingeren verclaert ten versouck als vooren 'tgunt hier navolgt voor de gerechte waerheyt te zijn: Soo ist ons genoegsaem kennelic, datter inden jare negen en tachtich eenen nieuwe Watermolen in onse Ambachte voorschreve gestelt is opte nieuwe maniere der geoctroyeerde van dien, welcke Molen alsoo vier jaren lanc gemalen heeft, soo hebben wy metter daet bevonden datse meerwaters alleen geloost heeft als d'ander drie Molens nade oude manier gemaect tsamen plegen te doen, want onse Polder die later pleech drooch te wesen als ander omleggende Polders, heeft sedert dien tijt vanden eersten drooch geweest, vant welke wy metter daet wel verseeckert zijnde, ende dat deur de ervaringen van so veel jaren als boven, hebben den voorleden Somer int jaer drie en negentich om ons land noch meer te geriven, also ooc doen veranderen onsen ouden achtcanten Molen; Sulx dat ons lant daer mede op dit jegenwoordige jaer so seer nat geweest hebben als kennelic is, tot ons vernougen vroech drooch is geweest eer dan onse naburen die ons op alsucke natte jaerscharen plegen te helpen, niet tegenstaende datmen het Verlaet daer neven staende, heel vryelick gebruykt heeft door het selve dickwils open te doen groot water int landt comt, dat welc men soo heel vryelic gedoocht, omdat de Molens water genoech loosen connen. Verclaren oock dat by aldien onsen Polder den overleden winter hadde moeten gedient zijn met de drie voorgaende Molens nae d'oude manier gemaekt, dat wy dit tegenwoordige jaer niet veel genuts van ons Landt gecregen soude hebben; Twelk ons genoechsaem kennelick is door de ervaringe van ander natte jaeren; Sulcx dat wy ons vanden voorschreven geoctroyeerden niet alleen en houden voor voldaen, maer voor meer als voldaen, alles sonder arch ofte list, ende wantmen schuldich is van alle rechtveerdige saken getuygenisse der waerheyt te geven, soo verclaren wy Deposanten voornoemt ten versoucke als vooren 'tgunt voorsz is, alsoo waerachtich te zijn, soo waerlick moet ons Godt Almachtich helpen en sijn Heylich VVoort; T'oirconden so hebbe ic Adriaen de Wit Schout door Bede en begeerte van ons Ambachtbewaerders ende Schepens voornoemt, mijn open Zegel over de Deposanten als over mijn selven, op spacium van dese Certificatie gedrukt. Actum dese 24 Juy anno 1594. in kennisse van mijn; Was onderteeckent *C. Vincenti*[49]) 1594.

APPENDIX II
TESTIMONIALS

These series of testimonials deal with the merits of the marshmills which Stevin invented. They are given in full by his son Hendrik (XVI B, Book X, pp. 3 - 10) who regrets that they have not come into common use before his father's death, as no one seems to have been able to make such excellent cogs and staves as he, and hence his drainage mills are little used, notwithstanding the testimonies of such high authorities as here reproduced.

1. The first document was drawn up by the notary-public P. Viruly on July 25, 1591. It deals with the new type of marshmill patented by Stevin in 1588 (see our Patent No. IV). Stevin here proclaims that he is going to "replace the usual water wheel with floats 3 1/2 feet long and 5 inches wide by another one of a new type which instead of the usual 20 or 24 floats will have only six big rectangular planks of 6 feet by 3, the ends of which will have wooden strips joined with greased leather, which wooden strips will slide over the floor and along the sides of the scoop wheel when the mill turns slowly, in such a way that no water will flow back through gaps or slits between the floats and the floor or the sides. Planks as indicated above serve for a small mill only, for larger mills they will grow larger in proportion". Nobody may imitate this patented construction.

2. In this second document representatives of the States of Holland and West-Friesland state that they have had excellent reports on the new drainage mills built by Simon Stevin, both for drainage and for scouring. They recommend the use of such mills to all concerned (March 13, 1591).

3. On August 29, 1590 the bailiff, burgomaster and town representatives of the town of Delft state that in 1588 Stevin replaced the old mill on the fortifications at the "Duyvelsgat" at the end of the "Geerweg" (a street in Delft) and that this mill "has served well in scouring the canals and replacing the water during the past two years, accomplishing about three times the amount of work of the old mill". They have now asked Stevin to rebuild the old mill on the fortifications at the end of the Nieuwe Langendijk (another street of Delft) in order to perfect the scouring of the water of the canals in the town and this second mill has again performed three times as much work as the old one. The testimonial was drawn up at the request of Stevin.

4. This fourth document was drawn up by Jan Reyniersz. van Woerden on March 26, 1590 on the Stolkwijksche Sluis (locks) at Souderak where an experiment was carried out in the presence of Stevin and the bailiff and dike-reeves of Stolwijk. Stevin had rebuilt the Stolwijk Mill (our no. 15) with the assistence of the carpenter and millwright Joost Govertsz. and this rebuilt mill now had to compete with the old type Beyer Mill. With the help of an hourglass and accurate water-gauge it was found that the "above-mentioned Stolwijk Mill in one hour pumped as much water from the polder as the said Beyer Mill in three hours".

5. The fifth document is a testimonial drawn up by Mr. Balthazar van Baerle, notary public of Rotterdam on April 25, 1590 at the request of Jan de Groot, Stevin's friend. Together with Joost Govertsz. van der Spelt he rebuilt the Kralingen Mill (our no. 17) in December 1589 and though it has been in use ever since, the cogs and staves "have not worn down the thickness of a knife and are good for another twenty years". This mill drains a district with an area of 1500

morgen and it performs as much work (even if the polder were just under water or the water risen to the brink of the canaldykes) as the Ruychbroek Mill which has to drain only 350 *morgen*. Several times it was found that in one day's pumping the water fell one inch and in four days and four nights the breadth of a hand. In general the new mill had to work about half the time of the Ruychbroek mill to keep the land dry.
It was also stated that an octagonal mill nearby rebuilt according to the new desigen (our No. 17a) now performed three times as much as it used to, though the water in front of this mill were four feet high and nearly overflowed its dykes. Jonkheer Jan van Assendelft, Lord of Kralingen, declares in the same document that he can vouch for the truth of these statements.

6. This document is complementary to the preceding one, as it contains a testimonial drawn up by C. Vincenti on June 24, 1594 of the information given by the bailiff of Kralingen, local authorities and the miller (Pieter Aertsz.) living in the new mill of Kralingen, rebuilt *) according to the new design in 1589. Four years of experience have shown that the new mill pumped as much as three old ones and even more, for formerly this polder was always in a "wet" condition even if the neighbouring polders were dry. But now they have ordered the old octagonal mill to be rebuilt (1593) according to the new design too and they declare that they have been more than satisfied and have now easily drained their land.

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* See Appendix IV.

APPENDIX III
BESTECK VAN EEN VIERCANTE WATERMOLENS IN DUVELANDT

DEN TOOREN

Dese molen sal onder wijdt sijn buytenwerckx 24 1/2 voeten.
De hooghte van den toren tusschen borsten 24 voeten.
De voetplaten 16 en 18 duymen.
De vier hoeckstijlen onder 19 ende boven 14 duym.
De acht ondermander stijlen 14 en 12 duym.
De vier ondermander balcken 14 en 13 duym.
De vier bovenmander balcken 12 en 10 duym.
De vier middelmander stijlen 12 en 10 duym.
De vier bovenmander stijlen 10 duym viercant.
De acht onderste corbeels 15 en 13 duym.
De hontsooren 10 en 8 duym.
Het tafelment op de houckstijlen 16 en 13 duym.
De setel daerop 15 en 12 duym.
De vier cokerbalcken 14 en 12 duym.
De vier kokersticken 19 en 7 duym.
De vier volsticken na den eysch.
De setel boven om de coker 17 en 14 duym.
De vier clampen daer-onder na den eisch.
De acht middelste corbeels 13 en 11 duym.
De toren sal gedeckt worden met goede noo(r)tsche delen over malkander gespijckert, soot behoort.

HET HUYS

Het huys sal lanck sijn 17 voeten buytenwerckx.
De vier hoeckstijlen tusschen borsten hoogh 10 voet ende 10 duym vierkant.
De voughhouten 15 en 13 duym.
De calvers 15 en 13 duym.
De voorsomer 13 en 12 duym.
De drij ondersomers 12 duym viercant
Hier op een eycken solder van 7 uyt de voet.
De twee waterlijst(en) 10 en 8 duym.
De twee steenlijsten 18 en 10 duym.
De twee dacklijsten 13 en 11 duym.
De vier cruyssen 9 en 6 duym.
De steenbalcken onder de steenlijsten 15 en 13 duym.
De calvers na den eysch.
Dit huys sal wijt sijn buytenwerckx 11 voet.
Ende sal gedect sijn met goet wagenschot van een duym dick met saghen.
De (s)tempelbalck 13 en 11 duym.
De middelbalck 11 en 10 duym.
De naelde int sturmeijnde 8 en 9 duym, daerboven aengewrocht een blockeel met een cloot, daer de wintpeluw op rust.
De wintpeluw 20 en 16 duym.
De cruyssen int stormeijnde na den eysch.

APPENDIX III
SPECIFICATION OF A SQUARE DRAINAGE MILL IN DUIVELAND[1])

THE TOWER

This mill at the bottom shall be wide 24½ feet outside measurement.
The height of the tower between the breasts 24 feet.
The footplates 16 by 18 inches.
The four corner-posts below 19 and above 14 inches.
The eight lower raking studs 14 and 12 inches.
The four lower raking beams 14 and 13 inches.
The four upper raking beams 12 and 10 inches.
The four middle raking studs 12 and 10 inches.
The four upper raking studs 10 inches square.
The eight lower corbels 15 and 13 inches.
The knees 10 and 18 inches.
The cill on the corner posts 16 and 13 inches.
The lower collar on top of it 15 and 12 inches.
The four post beams 14 and 12 inches.
The four hollow post struts 19 and 17 inches.
The four post struts as required.
The upper collar round the top of the hollow post 17 and 14 inches.
The four clamps underneath them as required.
The eight middle corbels 13 and 11 inches.
The tower shall be roofed with good Norse deals properly nailed over each other.
other.

THE BUCK

The buck shall be long 17 feet outside measurement. The four corner posts between the breasts 10 feet high and 10 inches square.

The sheers	15 and 13 inches
The binding beams	15 and 13 inches
The front tiebeam (or summer)	13 and 12 inches
The three lower summers	12 inches square

On them an oak floor (boards wide) seven in the foot.

Two lower side girts	10 and 8 inches
The two side girts	18 and 10 inches
The two upper side girts	13 and 11 inches
The four clasp arms	9 and 6 inches
The crown trees under the side girts	15 and 13 inches
The binding beams	as required

This buck shall be wide 11 feet outside measurement and shall be covered with good sawn one-inch warther-boarding.

The thrust beam	13 and 11 inches
The intermediate beam	11 and 10 inches

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1) Some of the terms in this estimate have no English equivalent, the Dutch word is then given as far as possible in English in parentheses or italicized.

De ijserbalck 12 en 10 duym.
De penbalck 17 en 15 duym.
De balck over de deur 12 en 10 duym.
De wolfbalck 9 en 8 duym.
De stijlen van de deure 8 en 6 duym.
Al de corbeels boven int huys na den eysch.
De capspanten, regels, keuvelsbalck, keerstijl, casijn met het vorsthout, met de knick ende manderstijlkens altsamen na den eysch.
De vier naeldens tusschen de waterlijsten ende dacklijsten 10 en 8 duym.
De trapbooms 9 en 8 duym boven ende onder 7 en 6 duym.
De trappen na den eysch.
De durpel an de trappen 9 en 4 duym.
De hanghereels van dobbelde barcoenen.
De jacht-schooren 7 duym viercant.
De loopstaken, speetken en windas na den eysch.
De steert (staartbalk) onder de molen 14 duym vierkant afloopende na den eysch.

HET WATERLOOP

Ten eersten sal men legghen onder de berristes, slijckhouten lanck 8 voet breet 5 duym dick 4 duym.
Op desen slijckhouten sal geleydt sijn een bodem van boken planken van 7 uyt de voet.
Hier op sullen gewrocht worden twee berrichouten van 9 en 8 duym waerin gewrocht sullen worden elf swalpen van 9 en 8 duym.
Ende over dese swalpen een bodem van goede eycken planccken van seven uyt de voet om den opleider daerop sijn gront te geven.
Op deze berrichouten sullen staen over elcke sijde elf stijlen welck vier buytenstijlen dick sullen sijn 15 duym viercant, de binnenste 8 en 7 duym.
Hierop twee slooven breet 20 duym dick elf duym.
De sijden vant waterloop sullen van binnen becleydt worden met eycken plancken van 7 uyt de voet ende van buyten met eycken plancken van 8 uyt de voet.
Noch sullen daer sijn vier palingplancken on elck buytenstijl een, breet 20 duym dick 2 duym.
De back van goede eycken plancken dick 3 duym dicht opmalkander gestreken gemost, geteert ende getingelt in elck naet met een pastende langhde en diepte voort camrat ende datmen daer bequaemlick in mach komen om schoon te maken.
De brugghevleugels 10 en 8 duym vier voeten langhe dan de steert van de molen met palen daer in de middel op twee voet dick 5 en 4 duym.
Deze gescho(e)yt met eycken plancken van 9 uit de voet dicht op malkander.
De brugghe van eycke plancken van 7 uyt de voet.

The ridge pole at the breast 8 and 9 inches, fixed on top of it a beam with a bracket, on which the pillow block rests.

The pillow block	20 and 16 inches
The crosses at the breast	as required
The outer tail beam	12 and 10 inches
The inner tail beam	17 and 15 inches
The beam over the door	12 and 10 inches
The beam over the inner tail beam	9 and 8 inches
The posts of the door	8 and 6 inches
All the beams in the buck above	as required

The cap spars, laths, "hood-post" (*keuvelbalk*), *keerstijl,* window frame and the ridgepole, with the bent studs and raking studs altogether as required.

The four poles between the lower side girts and upper side girts	10 and 8 inches
The stringers 9 and 8 inches above and 7 and 6 inches below.	
The stairs	as required
The sill at the stairs	9 and 4 inches
The winch supports of double beams	
The "hunting" braces	7 inches square
The rails, *speetken,* and windshaft	as required
The tail pole under the mill 14 inches tapering as required.	

THE WATER-COURSE

Firstly under the floor-boards "mud-boards" should be laid, 8 feet long, 5 inches wide, 4 inches thick. On these "mud-boards" a floor of beach boards will be laid of seven in a foot.

On this shall be erected two sills of 9 and 8 inches into which shall be fastened eleven hood supports of 9 and 8 inches and over these hood supports a floor of good oak boards of seven in a foot in order to give the wheelguide its proper foundation. On these sills shall stand on each side eleven posts, the four outer posts to be 15 inches square, the inner ones 8 and 7 inches. On top of these two upper sills or bearers 20 inches wide and 11 inches thick. The inner sides of the water-course shall be timbered with oak boards of seven in a foot and on the outside with oak boards of eight in a foot. Further there shall be four *sheath-boards* around each outer post one, 20 inches wide, 2 inches thick. The pit of good oak boards 3 inches thick, fixed tightly together, "mossed" [1]), tarred and battened in each seam with a fitting length and depth for the scoop wheel and in such a way that one can enter it easily in order to clean it.

The bridge wings 10 and 8 inches, four feet longer than the tail of the mill, with piles 5 and 4 inches thick, at the centre at two feet.

These timbered with oak planks of nine in a foot closely together. The bridge of oak planks of seven in a foot.

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[1]) The seams in timberwork were often caulked with Irish moss, which made a water-tight seal. "Moss-paper" is still used in Holland for this purpose.

T GAENDE WERCK

De molenas 30 duym.
De royen 14 en 13 duym.
De spille 16 duym.
De wateras 22 duymen.
Het camrat sal sijn diameter hebben van 12 voet met dubbel eycke cammen elck breet 8 duym tsamen 16 duym.
De ployen 6 duym dick, breet 30 duym, de corbeels na den eysch.
De cruysermen 12 en 8 duym.
De velgen na den eysch.
Het schijfloop beneden met 8 staven van doorne, de schijven dick 6 duym.
Het vangrat sonder cammen mette vang daertoe na het behooren.
Het schijfloop boven 12 staven van doorne, de schijven dick 6 duym.
De diameter vant scheprat aanden as 21 voeten.
Het spruyten vant scheprat anden as 9 en 7 duym, voor 7 en 4 duym.
Ende becleet met wageschot op een duym dick met de saghe.
Het croonrat boven aen de spille na het behooren.
Ende dit alles van goet wesels houdt sonder onredelich spint, faillecant rootolm vier ofte onredelick quasten.

Is aengenomen voor 3800 gull.

Stevijn ende Mr. Joos hebben gelooft datse 24 d hogher sal connen maken als de teghenwoordighe doet ende datse so veel op een uyre ende een nachtmael sal doen als dander op twee uyre ende twee nachtmael malen. Ende sullen de aennemers voor dese molen ontfanghen 750 guld metter kermisse a°. 90 naest kommende ander 750 gul. mettet opgaen van den werck (Nota: van dese 750 gl. moet meester Joos ons betalen de 500 gull. vant octroy welverstaende dat hij daer af sijn sestendel behouden sal) ende half Maerte a° 92 noch 1150 gul. ende half Maerte 93 de restende 1150 gull. De aennemers sullen de voors. molen onderhouden van staven ende cammen voor den tijt van drij aenstaende jaren. Sij sullen den 14^en^ November moeten verklaren of sij se begeeren te setten of niet, setten sijse niet sullen ons vacatum betalen.

THE MACHINERY

The windshaft	30 inches
The stocks	14 and 13 inches
The upright shaft	16 inches
The scoop wheel shaft	22 inches

The pit wheel should have a diameter of 12 feet with double oak cogs, each 8 inches wide, together 16 inches.
The cants 6 inches thick, 30 inches wide, the corbels as required.

The slap-arms	12 and 8 inches
The felloes	as required

The lower lantern pinion with 8 ashen staves, the discs 6 inches thick.
The brakewheel without cams and with a brake as required.
The upper lantern pinion with 12 ashen staves, the discs 6 inches thick.
The diameter of the scoop wheel on the shaft 21 feet.
The sprigs of the scoop wheel 9 and 7 inches at the shaft, 7 and 4 inches at the tip.
And timbered with sawn one-inch wartherboarding.
The trundle-wheel on top of the upright shaft as required and all this of good Wesel timber without an unreasonable amount of sapwood, bad red elm, dry rot or knots.

Has been contracted at 3800 florins.

Stevin and master Joos have promised that it will pump 24 inches higher than the present one does, and that it will draw as much in an hour and a nightwatch as the other will pump in two hours and two nightwatches. And the contractors will receive for this mill 750 fl. at the next fair of the year (90); another 750 fl. on the completion of the work (Note: Out of these 750 fl. Master Joos shall pay to us the 500 fl. of the patent, on the understanding that he will keep of this his sixth part), and about the middle of March of the year 92 another 1150 fl., and about the middle of March 93 the remaining 1150 fl. The contractors shall supply the aforementioned mill with staves and cams during a period of three subsequent years. They will have to declare on November 14 whether they wish to built it or not: if they do not build it, they shall pay to us a fee.

APPENDIX IV

(Archief van het Hoogheemraadschap van Schieland te Rotterdam:
Stukken betreffende het Ambacht van Kralingen, inventaris L. 8)

Besteck conditien ende voorwaerden daerop meester Joost Timmerman woonende te goude beloeft ende aengenomen heeft te maecken een nijeuwe viercante molen dien hij sal stellen int Ambocht van cralingen
Ten ersten den toeren zal wijt sijn onder op die voet plaeten 24 voet end die hoec(h)te van den toeren thussen boersten 24 voet.
Item die voet plaeten suaer 18 en 16 duijm lanck 26 voet.
Item die hoeck stillen onder suaer 18 duijm ende boven suaer 15 (duijm).
Item boeven op dese stijlen een taeflement suaer 16 en 15 duijm.
Item 4 mander baelken suaer 12 en 14 duijm.
Item 8 onder maender stielen suaer 12 en 14 duijm.
Item 4 mijedel maender stijlen suaer 10 en 11 duijm.
Item 4 mijedel maender baelken suaer 12 en 13 duijm.
Item (die) boeven maender stielen suaer 10 duijm vijerkant.
Item die 8 onderste kerbels suaer 12 en 16 duijm lanck naeden eijs.
Item dije 8 mijedelste kerbels suaer 10 en 13 duijm lanck naeden eijs.
Item die 8 honsoeren suaer eijs lanck doe dat behoert.
Item op die taefelment een setel suaer 13 duijm.

HET HUIJS

Ten ersten het huijs sal lanck sijn 17 voet ende wijt 10 voet ende hoech tussen boersten 9 voet.
Item dije hoeckstijlen suaer 10 duijm vijerkant.
Item 2 voechlouten suaer 13 duijm vierkant met 2 kaelvers daer in suaer 17 en 13 duijm.
Item boeven op deze voech(h)outen 4 soemers ende die 2 bijten soemers 12 en 14 ende dije mijedelste suaer 12 duijm viercant.
Item boeven op dese soemers 2 waeter lijsten suaer 8 en 9 duijm.
Item 2 sten lijsten suaer 9 en 18 duijm.
Item 2 dacklijsten suaer 10 en 12 duijm.
Item 4 opghaende manders 2 in dije waeter lijsten ende 2 in die dacklijesten suaer 9 en 8 duijm lanck naden eijs.
Item all die wint banden an weder sijeden suaer 4 en 6 duijm lanck nae den eijs.
Item twee steen baelcken suaer 14 duijm vijerckant met 2 kalvers suaer 15 en 14 duijm.
Item boeven op dese soemers een eijcken soelder die plancken dick anderhalven duijm.
Item een wijnt poelu suaer 19 en 21 duijm.
Item een tempelbaelck suaer 12 en 11 duijm.
Item een mijedel baelck suaer 10 en 11 duijm.
Item een krus in stoerment suaer 9 en 7 duijm.
Item (e)en naelde suaer 8 duijm vierkant lanck naeden eijs end boeven op die naelde een blockel met een kloet daer die wijnt poelu op rust.
Item ant trapeent een balck over die doer suaer 10 en 11 duijm.
Item in dese baelck 2 kerbels suaer 10 en 11 duijm lanck naeden eijs.

APPENDIX IV

SPECIFICATION OF A SQUARE DRAINAGE MILL IN KRALINGEN (1589). *Cf. Plate I.*

(Archives of the Hoogheemraadschap of Schieland, Rotterdam: Documents concerning the Ambacht of Kralingen, inventory No. L. 81)

Specifications, terms and conditions on which Master Joost, carpenter, resident of Gouda, promised and accepted to make a new square mill which he will build in the Ambacht of Kralingen.

Firstly the body at the bottom on the footplates shall be wide 24′ and the height of the body between the breasts 24′.
Ditto the footplates heavy 18″ and 16″, length 26′.
Ditto the corner-posts below 18″ and 16″, length 26′.
Ditto on top of these posts an upper cill of 16″ by 15″.
Ditto four raking beams heavy 12″ by 14″.
Ditto eight lower raking studs heavy 12″ by 14″.
Ditto four middle raking studs heavy 10″ by 11″.
Ditto four middle raking beams heavy 12″ by 13″.
Ditto (the) upper raking beams heavy 10″ square.
Ditto the eight lower cogged braces 12″ and 16″, length as required.
Ditto the eight middle cogged beams heavy 10″ and 13″, length as required.
Ditto the eight knees as heavy as required, as long as they should be.
Ditto on the upper cill a lower collar heavy, 13″.

THE BUCK

Firstly the buck shall be 17′ long and 10′ wide and 9′ high between the breasts.
Ditto the corner posts heavy 10″ square.
Ditto two sheers 13″ square with two binding beams therein heavy 17″ and 13″.
Ditto on top of these sheers four summers and the two outer summers 12″ and 14″ and the two middle summers heavy 12″ square.
Ditto on top of these summers two lower side girts heavy 8″ and 9″.
Ditto two side girts heavy 9″ and 18″.
Ditto two upper side girts heavy 10″ and 12″.
Ditto four vertical raking studs two in the lower side girts and two in the upper side girts heavy 9″ and 8″, length as required.
Ditto all the crossbeams on both sides heavy 4″ and 6″, length as required.
Ditto two crown trees heavy 14″ square and two binding beams heavy 15″ and 14″.
Ditto on top of these summers an oak floor with boards heavy 1½″.
Ditto a pillow block heavy 19″ and 21″.
Ditto a thrust beam heavy 12″ and 11″.
Ditto an intermediate beam heavy 10″ and 11″.
Ditto a cross at the breast heavy 9″ and 7″.
Ditto a ridge pole heavy 8″ square, length as required and on top of this pole a breast beam with a bracket on which the pillow block rests.
Ditto at the side of the staircase a beam over the door heavy 10″ and 11″.
Ditto in this beam two corbels heavy 10″ and 11″, length as required.

Item 2 doerstijlen 7 en 6 duijm lanck naeden eijs.
Item een woellefbalck suaer 7 duijm vijerkant lanck soe dat behoort.
Item dije regels suaer naeden es.
Item een Isser baelck suaer 12 en 13 duijm lanck naeden eijs.
Item een penbaelck suaer 14 en 14 duijm.
Item een koesijn om den as die stijelen suaer 6 en 7 duijm vijerkant met een knije naeden es met een koevelens baelck suaer 7 en 6 duijm.
Item dije spaenten suaer 4 duijm viercant met alle die reghels daer toe soe dat behoert.
Item het voerst hout suaer 7 en 5 duijm met alle die maender(s) daer toe ende met die baelkens daer toe soe dat behoert.
Item dijt huijs ende kaep gedecht ende beschoeten met goede waegeschoet van (e)en duijm dijck alsaemen wel gewrocht soe dat behoort.
Item den toeren gedecht met goede denemerckse delen over malkander gespijckert soe dat behoert.
Item een moelen as suaer 29 duijm vijerkant met 2 roden suaer 13 ende 14 duijm inden aes lanck soe dat behoert met 2 lassen daer aen naeden eijs ende gheheckt soe dat behoert.
Item een staert lanck 20 of 21 voet dick 12 en 14 duijm onder die moelen ende afloepende naeden eijs.
Item twee trapboems suaer 7 en 9 duijm boven onder naeden eijs met die trappen daer toe ende wijntd taes daer toe met die loepstaecken ende hangereels al saemen nae den eijs.
Item die spille suaer 16 duijm viercant.
Item die waeter As suaer 22 duym viercant.

HET GHAENDE WERCK

Ten eersten het groete camraet die krusen suaer 8 en 12 duijm dije ploijen suaer 7 duijm dick ende breet 28 duijm ende die velligen breet 17 duijm ende doebelde kammen elck bret 7 duijm macht saemen 14 duijm met die kerbels daer in naeden eijs.
Item het schijfloep daer toe die schieven dijck 7 duijm met die staeven daer in naeden eijs.
Item het boevenste Caemrat dije 4 kruijsaermen suaer 6 en 8 duijm die ploijen suaer 5 duijm dick ende breet 18 duijm die veligen daer op met die kammen daer in alsaemen naden eijs.
Item het schepraet die spruyten suaer bijden As 9 duijm viercant ende an die enden suaer 5 en 7 duijm met die goerdi(n)gen suaer 7 duijm viercant alsaemen ghewrocht met pennen ende gaeten ende suavelstaerten soe dat behoert dijt schepraet salmen met goede waegeschot van een duijm dijck becleen.
Item den back soe ru(ij)m dat het kamraet daer bequamen in gaen mach ende onder soe wijt datmen die bequaemen schoen mach maecken die plancken dick 4 duijm met die saech desen baeck alsaemen wel dicht op malcande gevoecht ende gebast ende getijnkhe(l)t al soe dat behoer(t).

WATERLOEP

Ten eersten 8 slickhouten lanck 8 voet bret 9 duijm dijck 4 duijm.
Item op dese slickhouten een boedem van boecken plancken van 7 uut die voet.

Ditto two door-posts 7″ and 6″, length as required.
Ditto an outer tail beam heavy 7″ square, length as required.
Ditto the laths heavy as required.
Ditto a spindle beam heavy 12″ and 13″, length as required.
Ditto an inner tail beam heavy 14″ and 15″.
Ditto a hollow post (frame) around the post, its struts heavy 6″ and 7″ square with a bent stud as required and a hood post heavy 7″ and 6″.
Ditto the spars heavy 4″ square and all the laths required.
Ditto the ridge pole heavy 7″ and 5″ with all the studs needed and all the beams needed as it should be.
Ditto this body and cap thatched and panelled with good wainscot 1″ thick all properly wrought as it should be.
Ditto the tower covered with good Danish deals nailed overlapping as they should be.
Ditto a windshaft heavy 29″ square and two stocks heavy 13″ and 14″ in the shaft length as they should be with two clamps as required and screened as it should be.
Ditto a tail pole 20′ or 21′ long, 12″ and 14″ thick under the mill and tapering as required.
Ditto two stringers heavy 7″ and 9″ above and below as required with the stairs belonging to them and the winch belonging to them and the handrails and the winch supports alltogether as required.
Ditto the upright shaft heavy 16″ square.
Ditto the scoop-wheel shaft heavy 22″ square.

THE MACHINERY

Firstly the large pit wheel, its clasp arms heavy 8″ and 12″, its cants heavy 7″ thick and 28″ wide and the felloes 17″ wide and double cams each 7″ across makes together 14″ with the corbels therein as required.
Ditto the crown wheel, its discs 7″ thick and their staves as required.
Ditto the wallower, its 4 clasp arms heavy 6″ and 8″, its cants heavy 5″ thick and 18″ across, its felloes and the cams in it alltogether as required.
Ditto the scoop wheel, its starts heavy near the shaft 9″ square and at their ends heavy 5″ and 7″ and the girders heavy 7″ square, all joined together with pegs and holes and dovetails as they should be; this scoop wheel shall be panelled with good wainscot 1″ thick.
Ditto the pit so large that the pit wheel shall turn in it with ease and so wide at the bottom that it can be cleaned easily, its boards 4″ thick, with the saw this pit will be fitted together so tightly and basted and battened as it should be.

THE WATER-COURSE

Firstly 8 mud-boards 8′ long, 9″ large, 4″ thick.
Ditto on these mudboards a floor of beach boards of 7 in the foot.

Item op dese slijckhouten aen weder sijeden een baerhout suaer 10 en 7 duijm lanck 24 voet.
Item op dese baerhouten 12 suaelpen suaer 7 en 5 duijm lanck nae den eijs.
Item op dese sualpen een boedem van eijcken planeken van 7 uut die voet soe dat men den opleijder daer sijn gront op geven mach doe dat behoort.
Item op dese baerhouten aan weder sijeden sullen staen 12 stijlen waer van dije 4 buijten staen(de) sullen suaer sijn 14 en 16 duijm ende die bijnnen stijelen suaer 7 en 9 duijm.
Item op dese stijelen 2 sloeven suaer 16 duijm vijercant lanck 25 voet.
Item dese stijelen sullen bekl(e)et sijn van binnen met eijken planeken van 7 uut die voet ende van buijten met eijcken planeken van 8 uut dije voet alsaemen wel dicht op melkandere gestrecken ende gemost ende getijnghelt soe dat behoert.
Item 4 paelijn planeken breet 22 duijm dick 2 duijm lanck 9 voet.
Item aen weder sijde een baert bret 22 duijm dijck 2 duijm lanck naeden eijs.
Item aen weder sijeden van waeterloep een brughe soe lanck datmen daer de moelen bequaemelijck over kruijen mach.
Item 4 koeker baelken suaer 12 en 14 duijm lanck naeden eijs.
Item een koeker die koekerstuijken suaer 7 duijm ende bret 15 duijm met die voelstuijken daer toe soe suaer ende lanck als het behoert met een setel daer boven en suaer 14 en 15 duijm met 4 kloeten daer onder an so dat behoert.

(Here the handwriting changes)

Item oft ijet hier inne vergeten mochte wesen ende nootel(ick) tot die werck behor(ende) dat sal den aennemer leveren tot sijn cost ende buijten cost van t ambocht.
Alle dit hout sal wesen goet deventer off wesels hout sonder onredel(ick) spint off onredelick falicant sonder rodolingen oft viere oft onredel(icke) quaede quasten.
Den aennemer sal gehou(den) weesen tot acht steeden dese moelen te bewaren met heijen ende dat met masten ofte sware elsse paelen te verheijen xl paelen off masten.
Den aennemer sal die schijffloepen ende kamraden den tijt van drie jaren lanck ten zijnen costen onderhouden.
Den aennemer sal het ambocht cave(ren) dat dese moelen zoe veel waters sal maelen ende vuijt werpen als twee vande beste achtcante moelens in scielant doen waervoer ick Jan de groot constituere mijn selven als borch ende belove tambocht brieven te passeren voor die van delft tot c(on)tentement van tselve ambocht (is geteekend Jan de Groot).
Den aennemer sal ontf(anghen) vj^{c} gulden bin(en) twee maenden noch vj^{c} g(ulden) op renten j(ege)ns den pe(nning) xvj die ingaen sullen soe wanneer die moelen volgens dit besteck gemaect ende opgenomen sal wesen ende die rest op twee termijnen te weten den helft als die molen ganckbaer is ende die verder reste als toecom(ende) winter water vuijtgemalen is. T resterende binnen den tijt van vier toec(omende) jaeren.
Tambocht sal den aennemenr bijsetten int heijen vande molenwerff acht man ende int rechten vande moelen vier man.
Den aennemer sal desen moelen volgende dit besteck gemaect hebben Sint Jelis nu toec(omende) acht dagen daer aenv(olgende) onbegrepen weer ende wint vuijtgesondert tot discretie van mijne heeren dhooge heemraden Ende is die moelen

Ditto on these mudboards on both sides a warther-beam heavy 10″ and 7″, long 25′.
Ditto on these warther-beams 12 hood-supports heavy 7″ and 5″, length as required.
Ditto on these hood-supports a floor of oak boards of seven in the foot so that the water guide can be made to rest upon it as it should.
Ditto on these warther-beams on both sides shall stand 12 posts, the outer ones heavy 14″ and 16″, the inner ones heavy 7″ and 9″.
Ditto on these posts two upper sills heavy 16″ square, 25′ long.
Ditto these posts shall be panelled on the inside with oak boards of seven in a foot and on the outside of 8 in a foot, fitted closely and mossed and battened as they should be.
Ditto 4 sheating boards 22″ large, 2″ thick, 9′ long.
Ditto on both sides a board 22″ wide, 2″ thick, length as required.
Ditto on both side of the water-course a bridge sufficiently long to turn the mill over them easily.
Ditto four postbeams heavy 12″ and 14″, length as required.
Ditto a hollow post, its hollow post struts 7″ thick and 15″ wide with its post struts as heavy and long as required with a collar beam on top heavy 14″ and 15″ with four brackets underneath as required.

(the ms. is continued by another hand).

Ditto should anything have been omitted from the above and yet be required for this work the builder shall deliver it at his expense and without cost to the Ambacht.
All the timber shall be good Deventer or Wesel timber without unreasonable sap-wood or unreasonable twisted grain, without dry rot or unreasonable knots.
The builder is bound to safeguard this mill by driving piles down at eight points using fir or alder piles, to be driven in 40 piles or spars.
The builder will bear the upkeep of the lantern wheels and cog wheels during a period of three years.
The builder will guarantee the Ambacht that this mill will pump and throw out as much as two of the best octagonal mills in Schieland for which I, Jan de Groot, will stand bail personally and promise to furnish the Ambacht letters for the gentlemen of Delft to the satisfaction of the Ambacht (signed Jan de Groot).
The builder will receive 600 guilders, within two months another 600 guilders (at an interest of 16%) from the time the mill has been finished according to this estimate and has been accepted, the remainder in two installments, *i.e.* half when the mill runs and the remainder when next winter the water has been thrown out, the remainder within a period of the next four years.
The Ambacht will furnish the building for the driving the piles for the foundation of the mill eight men, and for the erection of the mill four men.
The builder shall have finished this mill according to this estimate next St. Giles' day (or within the following eight days) wind and weather permitting at the discretion of the honourable hoogheemraden and if the mill is not ready he

dan nijet gemaect zoe sal hij all dagen verbeuren twee guldens diemen hem an sijne p(enningen) corten sal.
Aennemer opt besteck ende conditien als voeren Josst govertsz' vander goude voordie somme van ze en twintig hondert ende vijff ende twintich gulden Des sal den aennemer hier en buijten tot zijn proffijt genijeten ende naer hem tmoeleken dat opte plaetse staat daer dese nijeuwe moelen geset sal word(en) met alle het hout ijser ende zeijl soet rijt ende staet.
Aldus gedaen bijden heere van cralingen Willem van melissant hoog(e) heemraet van schielant den schout ende ambochtsbewaerders van cralingen jegenwoordich in officien sijnde ende zekere ingeerffden vanden lande van cralingen ten huijse van Johan clemens ende inde Sint Joris tot Rotte(rdam) den vj^{en} aprilis lxxxix
(volgend de handteekeningen: Johan van Assendelff, G. Melissant, Joost govertsz', C. Vincenten, Huich Spelt, Adriaen Jansz' ende Leendert Pietersz'.)

will forfeit two guilders per day which will be deducted from his pay. The builder of the above estimate and conditions is Joost Govertsz' of Gouda for the sum of twenty-six hundred twenty-five guilders. Apart from this the contractor shall also have the profit and the command of the small mill on the site of which new mill will be built including all the timber, iron and sails as it stands.
Thus done in the presence of the lord of Cralingen, Willem van Melisaant, hoogheemraad of Schieland, the bailiff and office-bearers of Cralingen at present sitting and certain householders of the land of Cralingen in the house of Jan Clemens and in the Saint George at Rotterdam April 6, '89.
(Follow the signatures: Johan van Assendelft, G. Melissant, Joost Govertsz', C. Vincenten, Hugo Spelt, Adriaan Jansz' and Leendert Pietersz'.)

APPENDIX V
LIST OF TERMS

used by Simon Stevin in his estimate of 1589
and other documents, with the equivalent English terms
(The numbers refer to Plate I and App. IV)

Dutch		*English*
TOREN		*TOWER* (Body)
Heipalen	1	piles
Voetplaat (onder-tafelment)	2	foot plate, lower cill
Hoekstijl (v. d. toren)	3	quarter bar
Boven-tafelmentstukken	4	upper cills
Onder-manderbalken	5	lower raking beams
Middel-manderbalken	6	middle raking beams
Onder-manderstijlen	7	lower raking studs
Midden-manderstijlen	8	middle raking studs
Boven-manderstijlen	9	upper raking studs
Onderste korbeels	10	lower corbels
Middelste korbeels	11	middle corbels
Hondsoren	12	knees
Kokerbalken	13	crosstree, postbeam
Kokerstukken	14	hollow-post struts
Vulstukken (tussenkokerstukken)	15	(padding) struts (between hollow post struts)
Onderzetel	16	lower collar
Bovenzetel (met de vier klampen)	17	upper collar (with four clamps)
HUIS		*BUCK* (Cap)
Voeghouten	18	sheers
Kalvers (tusschen voeghouten)	19	binding beams (between sheers)
Sommers, somers	20	tie beams
Hoekstijlen	21	corner posts
Waterlijsten	22	lower side girts
Steenlijsten	23	side girts
Daklijsten	24	upper side girts
Opgaande manders	25	vertical raking studs
Wind(verband), kruissen	26	cross beams
Steenbalken	27	crown trees (under side girts)
Kalvers	28	binding beams
Kruis in het stormeinde	29	crosses at the breast
Middelbalk	30	intermediate beam
Tempelbalk	31	thrust beam
Naald	32	prick post
Blokkeel met klamp	33	beam and clamp
Windpeluw	34	breast beam, pillow block
IJzerbalk	35	spindle beam
Penbalk	36	inner tail beam
Wolfbalk	37	outer tail beam

Kozijnstijlen	38	neck studs
Knie	39	bent stud
Kovelensbalk	40	hood post
Kapspanten (met regels)	41	cap spars
Vorsthout	42	ridge pole
Balkje aan het vorsthout	43	beam on ridge pole
Balk over de deur (in het trapeinde)	44	beam over the door
Korbeels	45	corbels
Deurstijlen	46	doorposts, door styles
Regels in de deurstijlen	47	laths in the doorposts
Staart, staartbalk	48	tail pole
Hangereels	49	winch support
Dorpel aan de trap	50	ladder cill
Trapboomen	51	ladders, stringers
Traptreden	52	stairs
Leuningen	53	handrails
Schoren	54	braces
Windas met spaken	55	winch with spokes
GAANDE WERK		*MACHINERY*
Bovenas, groote as	56	windshaft, mainshaft
Spil	57	upright shaft
Wateras	58	scoop-wheel shaft
Groote kamrad, onderwiel	59	pit wheel
a. kruisarmen		a. clasp arms (slap arms)
b. plooien		b. cants
c. velgen		c. felloes
d. korbeels		d. corbels
e. kammen		e. cams
f. schijven		f. discs
g. staven		g. staves
Beneden schijfloop	60	crown wheel
Kroonrad, bovenwiel	61	wallower
Schijfloop aan de bovenas	62	lantern-pinion on the mainshaft
Vangrad zonder kammen	63	brake wheel (without cams)
Roeden	64	stocks
Lassen aan de roeden	65	clamps at the stocks
Scheprad	66	scoop wheel
Spruiten	67	starts (sprigs)
Gordingen	68	girders
WATERLOOP		*WATERCOURSE*
Slijkhouten	69	mud boards
Bodem van beuken planken	70	floor of beach boards
Baarhout, berkhout	71	sill, warther beam
Zwalpen	72	hood supports
Bodem van eiken planken	73	floor of oak boards
Stijlen (in de berkhouten)	74	posts
Sloven	75	upper sills, bearers

Opleider	76	water guide
Palijn(paling)-planken	77	sheating boards
Baardplank	78	board
Bruggevleugels (beschoeiing)	79	bridge wings
Wielbak	80	pit

LIST OF TERMS, REFERRING TO THE BEEMSTER MILL, PLATE III.

See also the general description, p. 314.

A. Wielbak	Pit
B. Bovenas	Windshaft
C. Bovenwiel	Brake wheel
D. Prop	Tail journal
E. Pensteen	Tail bearing
F. Penbalk	Inner tail beam
G. Wolfbalk	Outer tail beam
H. Halssteen	Neck bearing
I. Bovenijzer	Top journal
J. Roede	Stock
K. Spil	Vertical shaft
L. Onderwijzer	Thrust journal
M. Pot	Bottom
N. Benedenschijfloop	Crown wheel
O. Onderwiel	Pit wheel
P. Windpeluw	Breast beam
R. Scheprad	Scoop wheel
S. Bovenschijfloop	Wallower
T. Ondertafelmenten	Lower cills
U. Buitenwaterloop	Outgoing water course
V. Binnenwaterloop	Intake
W. Wateras	Scoop wheel shaft
X. Hoekstijl	Corner post
IJ. IJzerbalk	Centre beam

VANDE SPIEGHELING DER SINGCONST

ON THE THEORY OF THE ART OF SINGING

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INTRODUCTION
SIMON STEVIN'S VIEWS ON MUSIC

Simon Stevin for some time seems to have contemplated writing a treatise on music. If ever he accomplished this design, the work must obviously have been lost. Only some fragments were discovered in 1884 by D. Bierens de Haan in a collection of miscellaneous manuscripts, which belonged to Constantijn Huygens (1596-1687), the well-known secretary to the Princes of Orange, who, at the same time, was a gifted poet and musician. (*Cf.* this edition, Vol. I, p. 33, work XV). This collection, now in the possession of the Koninklijke Nederlandse Akademie van Wetenschappen at Amsterdam, is preserved at the Koninklijke Bibliotheek at The Hague, The Netherlands.

Stevin often divided his books into a main part, containing the established doctrine, and an appendix dealing with controversial matters, in order "not to obscure the instruction by dispute", as he says. Accordingly we find two main parts, or sketches thereof, and two appendices. Neither of these treatises is complete, and in the plan they show an appreciable difference in the stress laid on certain points. One draft is in Stevin's own handwriting. It dwells rather more upon discussions than the other. This part will be reproduced hereafter. The other draft, which has been copied as if in preparation for print, indulges rather more in elementary definitions. It shows some gaps, presumably to be filled up later.
Stevin used to open his books with a summary. In one of the drafts the main part and the appendix contain pages bearing the title *cort begrijp* (*i.e.* summary), but one of these pages is blank, and the other contains a dedication to the "singing masters" of his time and the statement that he will give his critical remarks in an appendix.
Nowhere does Stevin use the word *music.* He always writes *singing.* Composers are called makers of singing. The stave is called singing ladder. Perhaps the word *singconst,* the art of singing, was the best translation into Dutch he could think of for *musica.* As is well known, Stevin was extremely keen in inventing and propagating vernacular translations of Latin words (see Vol. I, p. 6 and p. 58). It is to the semantic power of the Dutch language in making a word express its meaning properly by means of its components, and to the lack of this power of the Greek language, that he ascribes the fact that the clever Greeks failed to find the correct solution of how properly to divide the string to suit the true musical scale, whereas he himself was able to offer this solution.

For his reflections and conclusions Stevin based himself on "natural singing" (*natuerlicke sanck*), taking for granted that natural singing is an empirical fact liable to be observed with an amount of reasonable exactitude sufficient for all kinds of practical purposes. That, of course, is not rigid mathematical precision. The scale of natural singing shows five major steps and two minor steps. Stevin maintains that all major steps must be equal. So are the minor steps, each being one half of a major step. Thus, the sum of all steps in a "round" (*ommeganck;* we call it octave) amounts to six major steps. The major steps are whole tones, the minor steps are semitones.

With this statement Stevin took sides in the controversy on the problem of how to place frets on the fingerboard of a stringed instrument in order to ensure the correct intervals. The problem arises from the recognition that two fundamental intervals are equally important, but at the same time clash owing to their mutual incommensurability. These concordant intervals are commonly called the perfect fifth and the perfect major third. Though a certain amount of musical training will be helpful in understanding the nature of the difficulty, the general reader might grasp the point at issue as follows, if he does not mind being confronted with figures.

It is quite natural to divide a string of a lute, between neck and bridge, into two equal parts, and to listen to the sounds produced. Again, it is natural to divide the halves into two. It is also natural to divide the string into three equal parts, and again each third part into two, and into three. Thus, taking the whole length to have 144 parts, we get a division at the numbers

144 128 120 112 108 96 80 72 64 48 36 32 24 16

For shorter parts of the string we get higher notes.

We place frets on the fingerboard according to this division. By pressing down the string on these frets, we can easily produce the notes required.

We may use the numbers given to designate the notes thus produced. Actually, however, people have agreed to call them by letters, *e.g.* the following

A *B* *c* . *d* *e* *g* *a* *b* *e′* *a′* *b′* *e″* *b″*

The note 112 was not included in the ancient lettered system. For our purpose we may ignore it.

The most important relation is the interval between the notes corresponding to a certain length of string and its half. Such notes are designated by the same letters, as *A* and *a* (144 : 72), or *a* and *a′* (72 : 36); as *B* and *b* (128 : 64), or *b* and *b′* (64 : 32) and *b′* and *b″* (32 : 16); again *e* and *e′* (96 : 48), or *e′* and *e″* (48 : 24). Their relation, their interval (2 : 1), is called an octave.

Next comes the so-called interval of the perfect fifth, 3 : 2, as between *A* and *e*, *e* and *b*, *c* and *g*, *d* and *a*, *a* and *e′*. Then follows the interval of the perfect fourth, 4 : 3, as between *A* and *d*, *d* and *g*, *B* and *e*, *e* and *a*, *b* and *e′*, *e′* and *a′*, *b′* and *e″*. There are the intervals of the major third, 5 : 4, as between *c* and *e*, *g* and *b*.

For the technique of playing it is desirable that the fingers should not have to reach out far from the neck to the smaller numbers. For that reason a second string will be provided, with the same length as the first, a lighter one which at full length produces the note 108, which we called *d*. The second string at full length producing the note 108, the frets will produce notes corresponding to numbers proportionally reduced in the ratio $^3/_4$. Here they are.

108 96 90 81 72 60 54 48 36 27 24 18 12

The names by letters will be

d *e* *f* *g* *a* *c′* *d′* *e′* *a′* *d″* *e″* *a″* *e‴*

There is a gain. A new note represented by a new letter, *f*. But there is a clash also. The fret number 108, producing by the first string a note *d*, is now producing a note $g = 81$, which cannot be the same note as $g = 80$ played on the first string.

Using a third string, which at full length produces the note 81 = *g*, again there appears a new note, but we find more clashes, as is seen from the table below of the notes given by numbers and by letters.

Table

144	128	120	108	96	80	72	64	48	36	32	24	16
108	96	90	81	72	60	54	48	36	27	24	18	12
81	72	$67^1/_2$	$60^3/_4$	54	45	$40^1/_2$	36	27	$20^1/_4$	18	$13^1/_2$	9
A	*B*	*c*	*d*	*e*	*g*	*a*	*b*	*e'*	*a'*	*b'*	*e''*	*b''*
d	*e*	*f*	*g*	*a*	*c'*	*d'*	*e'*	*a'*	*d''*	*e''*	*a''*	*e'''*
g	*a*	*b-flat*	*c'*	*d'*	*f'*	*g'*	*a'*	*d''*	*g''*	*a''*	*d'''*	*a'''*

There is a note $c' = 60\,^3/_4$ clashing with $c' = 60$ and $c = 120$ on the second and first strings. There are notes $g' = 40\,^1/_2$ and $g'' = 20\,^1/_4$ on the third string clashing with $g = 80$ on the first string.

These clashes constitute a very serious difficulty in playing on a lute tuned in this way. The error 81 : 80 is called a "comma".

J. Murray Barbour, in his book on *Tuning and Temperament* (Michigan State College Press, 1953), presents a historical survey of the attempts to find a satisfactory solution for the problem how to improve the placing of the frets. His book contains an ancient explanatory picture of a lute, by Gassani, indicating the places of the frets.

It shows a division equivalent to the division given above, making in numbers

72 64 60 54 48 40 36

Gassani adds some more, filling up gaps

72 68 64 60 57 54 51 48 45 40 36

We can fill up the whole tones 45 : 40 : 36 in this way:

45 42 40 38 36

We now see three series of semitones

72 : 68 : 64 : 60 = 18 : 17 : 16 : 15

60 : 57 : 54 : 51 : 48 : 45 : 42 = 20 : 19 : 18 : 17 : 16 : 15 : 14

42 : 40 : 38 : 36 (: 34 : 32 : 30) = 21 : 20 : 19 : 18 (: 17 : 16 : 15)

I continued the last series beyond 36 as a repetition of the first, lower series. There is a continuous range of semitones with the values 14 : 15 : 16 : 17 : 18 : 19 : 20 : 21, from major semitones 14 : 15 to minor semitones 20 : 21.

Vincenzo Galilei (*Dialogo della musica antica e moderna,* Firenze, 1581) disclaimed such a variety of semitones. Before Stevin, he wanted them all to be equal, and he chose the value 17 : 18, which happens to be midway. For the fifth, seven such semitones added would make $18^7 : 17^7$, about 6.12 : 4.10 (canceling 10^8), a rather good approximation to 6.15 : 4.10 = 3 : 2. The defect is 3 in 615, or 1 in 205.

For the major third, four such semitones would make $18^4 : 17^4$ = about 10.50 : 8.35 (canceling 10^4). This is a poorer approximation to the accepted value 5 : 4 = 10.50 : 8.40. The excess is about 5 in 840, or 1 in 168.

Now the octave, when taken to consist of twelve such semitones, turns out to be $18^{12} : 17^{12}$, approximately 11.57 : 5.83 instead of 11.66 : 5.83 = 2 : 1. The defect is 9 in nearly 1170, all but 1 in 130. It is three fifths (and in the opposite sense) of the comma excess of 1 in 80 in the values 81 and 80, $60\,^3/_4$ and 60, noted earlier.

The equal temperament by semitones 17 : 18 distributes the error of the comma over the octave ($-^3/_5$ c), the fifth ($-^2/_5$ c) and the major third ($+^1/_2$ c).
Vincenzo Galilei's rule seems to have been commonly accepted at the end of the sixteenth century, as it is to this day, but only for the lute, the viol, and similar instruments.

For organs and for harpsichords no attempt was made to divide the octave into twelve equal steps. Organists tried to have pure octaves and perfect major thirds by a slight adjustment of the fifth. They corrected the sequence of four fifths

$$486 : 324 : 216 : 144 : 96$$

so as to have perfect consonance between 480 and 96, because

$$480 : 96 = 5 : 1.$$

The comma excess 486 : 480 = 81 : 80 is distributed over the four steps, each step losing one fourth of a comma, *i.e.* 1 in 320, as follows (approximately):

$$480 : 321 : 214^2/_3 : 143^5/_9 : 96.$$

In order to have perfect major thirds (as between $480 = 5 \times 96$ and $384 = 4 \times 96$), a small infringement is thereby made of the perfect fifths.
Barbour (*l.c.,* p. 26) gives the credit for the first description of this method of tuning to Pietro Aron (*Toscanello in musica,* Venice, 1523). It is the mean-tone temperament, strongly advocated by Gioseffo Zarlino (1517-1590; Stevin occasionally calls him *Meester Sarlijn*) and by Francesco Salinas (1577), two great early legislators of music. It has been in use for three centuries.

Stevin boldly did away with all these subtleties. In his view, all semitones had to be equal. In this he agreed with Vincenzo Galilei, that dissenting pupil of Zarlino.
He rejects any relationship between concordant intervals and ratios of integer numbers. For him the numbers resulting from the division of the ratio 2 : 1 into twelve equal ratios, twelve times the twelfth root of 2, are the *true* numbers. Barbour's remark is very appropriate (*l.o.*, p. 7): "In his days only a mathematician (and perhaps only a mathematician not fully cognizant of contemporary musical practice) could have made such a statement." Barbour adds: "It is refreshingly modern, agreeing completely with the views of advanced theorists and composers of our day." [1]) It is Stevin's outstanding achievement that he produced the exact proportional numbers, between 10 000 and 5 000, in four figures, representing the steps of twelve semitones in the octave leading from 1 to $^1/_2$. He was able to do so, referring to his French work on arithmetic (1585, this ed. Vol. II. B) where he had shown that the requirement of twelve equal ratios leading from 2 to 1 involves the twelfth root of 2. By combining the operations of computing two square roots and subsequently a cube root, he finds for the twelfth root of 2 the ratio 10 000 : 9 438 = 1.0595 : 1. The more exact figure is 1.059463 . . . . .
Stevin never mentions the approximate value $^{18}/_{17}$, familiar to makers of lutes, who used it in fixing frets on the fingerboards.
He had no bump for the plain simplicity of small integer numbers. In his treatise on arithmetic (Work V) he had explained that there are "no absurd, irrational,

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[1]) The present editor believes that Stevin's duodecimal division of the octave is now going to be superseded by the division into 31 steps, advocated by Nicola Vicentino (1588) and Christiaan Huygens (1691).

irregular, inexplicable, or surd numbers" (see this edition, Vol. II B, p. 532, also Vol. I, p. 23).

For him a number like $2^{7/12}$ is as good as any other, say $^3/_2$. If anybody should doubt that the sweet consonance of the fifth could be compatible with so complicated a number, then, says Stevin, rather haughtily and aggressively, he is not going to take pains to correct the inexplicable irrationality and absurdity of such a misapprehension. He repudiates the Pythagorean values for the intervals ($^3/_2$ for the fifth, $^9/_8$ for the second, $^{81}/_{64}$ for the major third, $^4/_3$ for the fourth) on the ground that they lead up to the ratio $^{256}/_{243}$ for a semitone (the minor limma). This, when subtracted from a whole tone ($^9/_8$), leaves another semitone with a ratio very close to $^{256}/_{240}$. Stevin remarks that this major semitone is all but a quarter larger than the previous minor semitone (the differences of 243 and 240 from 256 being 13 and 16 respectively). All semitones having to be equal, the initial assumption of $^3/_2$ for the ratio of the fifth must be wrong. For Stevin the equality of the twelve semitones follows from the fact that in tuning a harpsichord one obtains a closed cycle of fifths and fourths. Strictly speaking, the excess of twelve fifths over seven octaves should be 1 part in 73 (comma of Pythagoras). Stevin, however, ascribes any small deviations from the perfect cycle to unavoidable experimental errors.

Joseph Needham, in Vol. 4, Part 1, of his *Science and Civilisation in China,* refers to the duodecimal equal temperament as "the princely gift of Chu Tsai-Yü". He points out that at the end of the 16th century there was a great flow of Chinese information into Europe. He urges the probability of some idea of Chu Tsai-Yü's solution having floated towards Stevin's mind. Stevin himself refers to Prop. 45 in his book on arithmetic as the source of his method for finding the 12 equal semitones, ascribing his success to the wonderful semantic power of his Dutch language. He could not have said so, if he had to admit that a Chinese had been able to find the formula without Dutch words. The book of Chu Tsai-Yü quoted by Needham is dated 1584. Stevin's book on arithmetic appeared in 1585. We can agree with Needham saying "the name of the inventor is of less importance than the fact of invention." As far as we know Stevin, we can apply to him the very same words of praise which Needham gives to Chu Tsai-Yü: "Stevin himself would certainly have been the first to give another investigator his due, and the last to quarrel over claims of precedence".

There is the ancient problem, come down from the Greeks, as to whatsoever sounds may have to do with numbers. In Stevin's time people had no clear consciousness of the frequency of vibrations. He speaks of "coarseness" or "fineness" determining pitch, and postulates a proportionality of this coarseness to the length of the sound-producing part of a string. By way of example, he refers to the half, to the quarter, and to the eighth part of a string only. He does not mention other aliquot parts, or $^2/_3$, or $^3/_4$ of a string as examples. In this he shows a bias against integer numbers. Two is the only integer admitted by him in music. One would not have expected such a bias in a mind which knew quite well that the regular solids exhibit only selected integers in the number of their faces, edges, and angular points. Perhaps he would have admitted that consonant intervals, and their beauty, primarily have to do with integer numbers if he could have seen Lissajous' delightful figures of interfering oscillations. He never mentions the phenomenon of beats, so essential for tuning perfect concords. Stevin never verified whether on a harpsichord tuned with a closed cycle of fifths and fourths the thirds and sixths would turn out to be concords. They certainly would not! Nevertheless he takes the consonance of these intervals for granted as an empirical fact. He decides rather by definition which intervals are good and which are bad.

As a practical rule, the "singing masters" condemned the interval of the fourth in polyphonic singing. This interdiction is not recognized by Stevin. He argues that very often, when one hears two instruments, *a* and *b,* playing in unison, it is very difficult to know whether they are playing at the same pitch or one octave apart. If a third instrument, *c,* plays in consonance with both, then of course it is in consonance with each of them. In case the concord seems to be that of a fifth, it is difficult for the ear to decide whether *c* makes a fifth with both *a* and *b,* or with one of them only, making a fourth with the other. But, this being so, the fourth must be a good concord too.

Stevin refuses to recognize a difference in singing with a flat on the stave or without (*mollaris* and *duralis*). He says that by transposition every tune can be written on the stave without a flat. In this he is right. Of course this has nothing to do with the difference in mode, with minor and major scales. There is no chapter on this subject of modes, but we have collected some scattered data.

Sometimes, in the scale the note *si* is flattened by a semitone to *sa.* Stevin seems to have seen a reason for giving *sa* a place on the stave without the sign for a flat. It is curious to see that in certain diagrams he assigns the vocables

ut re mi fa sol la sa ut

to the letters

g a b c d e f g

If he had assimilated *ut* to *c,* as we do, of course *sa* would have meant *b*-flat, and *si* would have to be *b*-natural (the Germans would say *b* and *h,* respectively). In one place Stevin promises to return to this question of *sa* and *si,* but no chapter on this question is included. In the manuscript there is no consistent notation of *sa* and *si* on the stave.

We do not know whether Stevin ever considered his work to have been brought to a satisfactory conclusion, and whether he intended to publish it. It might well be that discussions with musicians made him change his mind in some respect. Among the manuscripts of Constantijn Huygens mentioned above, published as an appendix to Stevin's *Singconst* (listed as Work XV in Vol. I of this edition, p. 33), there is a letter to Stevin from Abraham Verheyen, organist at Nijmegen (Gelderland), who urges that experiment, in tuning a harpsichord, shows that the three major thirds, *i.e.* six whole tones, do *not* make an octave. He explains to Stevin the merits of the current mean-tone temperament, and how to compute the ratios involved. Verheyen also produces an example of a song in two parts, clearly showing the difference of major and minor semitones. We know that Isaac Beekman (1588-1637, *Journal,* ed. C. De Waard, The Hague, 1942, Vol. 4, p. 157) at first very much admired Stevin's proportional division of the octave. Later he rejected it.

Maybe the criticisms of very able friends shook Stevin's sturdy conviction a little, so that he abandoned the idea of making a full size treatise based on his mathematical axiom.

VANDE SPIEGHELING DER SINGCONST

BEPALINGHEN

1e *Bepaling*

Trap is de naeste vervolghende climming diemen inde nateurlicke sanck rijst wiens minste stemming cleentrap geheeten wort de meeste groote trap.

2e *Bepaling*

Nateurlicke sanck is, die deur oirdentlicke climming aldus gheschiet: Twee groote trappen een cleene drie groote een cleene twee groote een cleene drie groote een cleene. Ende soo overhandt oirdentlick voort.

Verclaring

Anghesien dat de leeck luijden sonder kennis vant onderscheyt tusschen halve ende heele trappen door nateurlicke gheneghenheijt sulcken voortganck ghebruyken soo wortse met goede reden nateurlicke sanck ghenoemt want 2 of 3 halve trappen ofte 4 of 5 heele trappen vervolghens achter malcander te singhen en is niet alleen moeyelick om doen maer oock int anhooren onbehaghelick ende als onnateurlick.

3e *Bepaling*

Dese seven trappen na de nateurlick gesanck oirdentlick climmende maken des ghesanckx een ommeganck.

Verclaring

Wanneer men boven een ghestelde toon seven trappen rijst met oirdentlick climming soo heeft het laetste gheluijt sulcken ghelyckheijt mettet eerste dattet schijnt al ofmen een ommeganck ghedaen hadde ende wederom quaem daermen begosten: Inder voughen datmen sulcx van weghen die ghelyckheyt ommeganck heet: Welck ghenouchsaem toegaet als inde Sterreconst met de slangkeeren, die de Maen duer haer daghelicx roersel daghelicx beschryft welcke eyghentlick gheen evewijdighe ronden sijnde nochtans om de ghelijckheyts wille alsoo ghenoemt worden.

4e *Bepaling*

Die seven trappen worden elck aldus ghenoemt, *ut, re, mi, fa, sol, la, si*, wiens trappen van *mi* tot *fa* ende van *si* tot *ut* cleen sijn dander al groot.

5e *Bepaling*

Twee gheluyden even hooch sijnde hun verlycking wert selftoon ghenoemt. Maer een cleen trap verschillende half toon. Een groote trap verschillende toon: Een groote met een cleene verschillende anderhalftoon: Twee groote verschillende tweetoon. Ende soo oirdentlick voort.

ON THE THEORY OF THE ART OF SINGING[1])

DEFINITIONS

1st *Definition*

Step is the next subsequent ascent which one rises in natural singing, of which the smaller variety is called minor step, the larger, major step.

2nd *Definition* [2])

Natural singing is that which by an orderly ascent takes place as follows: two major steps, one minor, three major steps, one minor, two major steps, one minor, three major steps, one minor, and so on gradually, in orderly sequence.

Explanation

Since lay people, not knowing the difference between half steps and whole steps, use this progression by natural inclination, it is with good reason called natural singing, because singing two or three half steps, or four or five whole steps in succession not only is difficult to accomplish, but also is unpleasant to hear as well as unnatural.

3rd *Definition*

These seven steps, ascending in an orderly way according to natural singing, make one round of singing.

Explanation

When one rises seven steps above a given note in an orderly ascent, the last sound is so similar to the first that it seems as if one had made a round and arrived again at where one began, so that, because of that similarity, this is called a round. This is rather similar to what happens in astronomy with the helices described daily by the moon owing to its daily motion, which, though not being properly parallel circles, are so called because of this similarity.

4th *Definition*

Those seven steps are called as follows: *ut, re, mi, fa, sol, la, si,* among them the steps from *mi* to *fa* and from *si* to *ut* are [3]) minor steps and all the others major steps.

5th *Definition*

Two sounds having the same pitch, their relation is called selftone. But differing by a minor step, semitone. Differing by a major step, a whole tone. Differing by one major and one minor step, one-tone-and-half. Differing by two major steps, ditone. And so forth in an orderly way.

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[1]) The selected pages which follow have been taken from the part that is in Stevin's own handwriting, with the exception of the chapter on the modes.

[2]) The second definition corresponds to the scale, sung to the vocables *ut, re, mi, fa, sol, la, si, ut, re,* etc.

[3]) The fourth definition was in contradiction to the second definition, in that the step *la* : *si* was here called a minor step, which does not fit in with the sequence major - major - minor - major - major - major - minor - major - etc. We therefore put: *si* to *ut*. If *si* is flattened by a semitone, the resulting note is called *sa*. Thus *la* to *sa* and *si* to *ut* are semitones; *la* to *si* and *sa* to *ut* whole tones.

6e *Bepaling*

Twee gheluyden even hooch sijnde haer verlycking wert oock eerste ghenoemt maer een trap verschillende tweede welcke trap cleyner sijnde heet eyghentlick cleene tweede groot wesende groote tweede: Ghelijcx twee trappen verschillende wort derde gheheijten welcke een cleene sijnde heet cleene derde maer van twee grooter, groote derde endesoovoort tot de sevende wiens volghende trappen dobbeleerst dobbeltweede heeten ende soo oirdentlick voort met de eenvoudiche eerste tweede ende haer volghende.

Verclaring

De singhelicke gheluijden ontfanghen twee verscheyden manieren van namen ghelyckse inde voorgaende 5e ende 6e bepalinghen beschreven sijn die elck haer besonder ghebruijck hebben. Want wesende de redens der gheluijden te vergaren ofte van malcander te trecken men noemtse bequamelicker duer de namen der toonen overmidts dat totten tweethoon vergaert den drietoon haer somme is den vyftoon; treckende den tweetoon vanden drie enhalftoon blyft de onderhalftoon inder voughen dat sommen en resten namen der ghetalen cryghen lijckformich an heur sij sijn. De namen van eersten tweeden derden ens. sijn bequamer om int dadelick *) maecksel des sancx te ghebruycken. Want lichter ende bequamelicker telt men tverschil van twee gheluyden deur trappen na de nateurlicke ghesanck climmende of dalende dan deur toonen en halftoonen overmits de menichte der trappen met de menichte der toonen niet en overcomt.

Begheerte

Wij begheeren toeghelaten te werden dat ghelijck snaersdeel tot snaersdeel also haerder gheluyden grofheyt tot grofheyt.

Verclaring

Wanneer twee persoonen tsamen een dobbel eerste singhen de grover stem des leegsten heeft een ghelaet van dobbelheijt teghen de fine stem des hoochsten: dat is ghelijck 2 ellen dobbel sijn teghen 1 elle alsoo schijnt dese leegste stem in grofheijt dobbel te wesen ande hoochste: Tis wel waer dat de selve dobbelheijt ons int gheluijt niet soo heel claer ende verstaenlick en ontmoet als in grootheijt ghetal ghewicht tijt roersel, ende meer ander: nochtans soo beweeght ons de ghespannen snaer selve toe te laten overmits haer deelen in dobbel reden der grootheijt sijnde de selve gheluyden clijncken die wij segghen van dobbel reden der grofheijt te wesen. Want de heel snaer teghen haer helft clincken tsamen de voorschreven dobbel eerste. Voort ghelyck hier gheseyt is, dat de heele snaer tot haer helft in dobbel reden der grootheijt sijnde, haer gheluyt in dobbel reden der grofheijt heeft, alsoo is oock te verstaen dat de heele snaer tot haer vierendeel in verhoudinghe reden der grootheijt wesende haer gheluijt in verhoudinghe reden der grofheyt heeft ende alsoo voort met allen anderen soo wel deelen teghen malcander als deelen teghen de heele snaer.

Nu alsoo ymant mocht willen ontkennen den helft der snaer teghen de heele een dobbel eerste te clijncken, daer uyt oock niet toestaende der gheluyden grofheijt te wesen inde reden van haer snaersdeelen soo wort hier boven beschreven welcke toeghelaten te worden overmidts sulcx als beghinsel gheen ander bewijs en verreyscht. Want ghelijck de ervaring leert, soo en ghebeurt de contrari niet dan deur valsche snaren oft ander ongheval.

*) *Compositione cantus.*

6th *Definition*

Two sounds having the same pitch, their relation is also called a first (or prime), but when differing by one step, it is called a second, and when this step is a minor step, it is properly called a minor second, when it is a major step, a major second. Likewise, when the sounds differ by two steps, their relation is called a third, and when one of them is a minor step, it is called a minor third, but when both are major steps, it is called a major third, and so on to the seventh, the steps following it being called double-first, double-second, and so on in a regular way like the simple first, second, and the following.

Explanation

Singable sounds receive names of two different kinds, as described in the foregoing 5th and 6th definitions, each of which has its special use. For when the ratios of sounds have to be added or subtracted, they are more conveniently referred to by the names of the tones, since, the tritone added to a ditone, their sum is a five-tone; the ditone being substracted from the three-tone-and-half, the remainder is the one-tone-and-half, in such a way that sums and remainders receive names in conformity with the numbers to which they correspond.

The names of firsts, seconds, thirds, etc. are more convenient for practical use in the composition *) of songs. For it is easier and more convenient to count the difference between two sounds by steps ascending or descending according to natural singing than by whole tones and semitones, since the number of the steps does not agree with the number of tones.

Postulate

We postulate that as one part of a string is to another, so is the coarseness of the sound of the one to that of the other.

Explanation

When two persons sing together a double-first, the coarser voice of the lower has an appearance of doubleness with respect to the sharp voice of the higher, i.e. as 2 yards are double to 1 yard, so this lower voice in coarseness seems to be double to the higher. It is true that this doubleness does not present itself quite so clearly and intelligibly in sound as it does in size, number, weight, time, motion, and otherwise; yet the stretched string itself induces us to grant this, since if its parts are in the double ratio as to size, the same sounds ring that we say to be in the double ratio as to coarseness. For the whole string, when played against its half, together make us hear the aforesaid double-first. Further, as it has here been said that, the whole string being to its half in double ratio as to size, its sound is in double ratio as to coarseness, so also it is to be understood that, the whole string being to its quarter in a certain ratio as to size, its sound has the same ratio as to coarseness, and so on for all other cases, parts of the string against each other as well as parts against the whole string.

Now if anyone should wish to deny one half of the string to sound against the whole string as a double-first, and on this account should not admit the coarseness of sounds to be in the ratio of the parts of the string, what is described above has been put as a postulate, since such a postulate in principle does not require any proof. Anyhow, as experience teaches, the contrary does not happen unless owing to false strings or some other mishap.

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* *Compositione cantus.*

2e *Begheerte*

Heele toonen al even groot te wesen, dat sgelijcx oock halve toonen al even groot sijn.

Verclaring

De sin is dese datmen van *ut* tot *re* even soo veel ryst als van *re* tot *mij* ende als van *fa* tot *sol*, van *sol* tot *la* ende van *sa* tot *ut*. Datmen desgelijcx eerst van *mi* tot *fa* even soo hooch rijst als van *la* tot *sa*.

	Vertooch			Voorstel
Ghelyck 1 tot	1	Alsoo den eenen toon tot den anderen	Selftoon	Eerste
	$\sqrt[12]{1/2}$		Halftoon	Cleen tweede
	$\sqrt[6]{1/2}$		Toon	Groote tweede
	$\sqrt[4]{1/2}$		Onderhalftoon	Cleen derde
	$\sqrt[3]{1/2}$		Tweetoon	Groote derde
	$\sqrt[12]{1/32}$		Twee en halftoon	Vierde
	$\sqrt{1/2}$		Drietoon	Qua groote vierde of qua cleene vijfde
	$\sqrt[12]{1/128}$		Drie en halftoon	Vijfde
	$\sqrt[3]{1/4}$		Viertoon	Cleen seste
	$\sqrt[4]{1/8}$		Vier en halftoon	Groote seste
	$\sqrt[6]{1/32}$		Vijftoon	Cleen sevende
	$\sqrt[12]{1/2048}$		Vijf en halftoon	Groote sevende
	$1/2$		Sestoon	Dobbeleerste.

Bewijs

[abest]

Vande Reden int ghemeen

Want de redens inde stof des gheluijdts niet soo opentlick bekent en sijn als in ander stoffen daer sij ons ontmoeten, sullen om meerder claerheyt eerst segghen vande Redens ende Everedenheyt int ghemeen; daer nae vande ghedaente des redens der Singconst duer haer verlijcking met de bekende reden der meetconst. Ende ten laetsten van d'eijghen redens der singhelicke gheluyden.

Reden dan int ghemeen bepaelt, is tselver stoffen verlyckingh na de menichvuldenheyt. Als in ghetalen grootheyt, ghewichten, tijt; 6, 6 voeten, 6 pont, 6 uijren, sijn in dobbel reden tot 3, 3 voeten, 3 pont, 3 uijren. D'Everedenheyt is de verlyckinge van twee even redens als 6 tot 3 is een dobbel reden, alsoo oock is 8 tot 4, daerom de reden van 6 tot 3 is even ander reden van 8 tot 4. tsijn dan even redens ende haer verlycking segghende ghelyck 6 tot 3 alsoo 8 tot 4, is everedenheijt ofte 6, 3, 8, 4, sijn everednighe palen.

Siet hier duytsche woorden licht om verstaen ende van slecht ghelaet maer eyghentlick van oneindelick vermueghen. Want soomen ansiet het bepaelde te weten Everedenheijt tis als bepaling sijns grondts, wiens gheluijt alleen, int eerste anhooren ons vermaent ende anwijst dattet recht grontlick verstandt der Evere-

2nd *Postulate*

All whole tones to be equal and likewise all semitones to be equal.

Explanation

The meaning is this: that one rises as much from *ut* to *re* as from *re* to *mi,* and also from *fa* to *sol,* from *sol* to *la,* and from *sa* [1]) to *ut.* That likewise one rises as much from *mi* to *fa* as from *la* to *sa.*

As 1 is to — *Theorem.* [2])	So one tone to the other	*Proposition*
1	Selftone	First (prime)
$\surd^{(12)}\,1/2$	Semitone	Minor second
$\surd^{(6)}\,1/2$	Whole tone	Major second
$\surd^{(4)}\,1/2$	One-tone-and-half	Minor third
$\surd^{(3)}\,1/2$	Ditone	Major third
$\surd^{(12)}\,1/32$	Two-tone-and-half	Fourth
$\surd\,1/2$	Tritone	Bad major fourth or bad minor fifth
$\surd^{(12)}\,1/128$	Three-tone-and-half	Fifth
$\surd^{(3)}\,1/4$	Four-tone	Minor sixth
$\surd^{(4)}\,1/8$	Four-tone-and-half	Major sixth
$\surd^{(6)}\,1/32$	Five-tone	Minor seventh
$\surd^{(12)}\,1/2048$	Five-tone-and-half	Major seventh
$1/2$	Six-tone	Double-first (octave)

Proof

(abest)

On Ratio in General

Because ratios in the field of sound are not as manifestly known as in other fields where we meet with them, for the sake of greater clarity we shall first speak about ratios and equirationality [3]) in general; subsequently about the aspect of ratio in singing by comparison with the familiar ratio in geometry. And finally of the ratios proper to musical sounds.

Ratio as defined generally is the relation according to quantity between things of the same nature. As in number, size, weight, time: 6, 6 feet, 6 pounds, 6 hours are in the double ratio to 3, 3 feet, 3 pounds, 3 hours. Equirationality is the relation of two equal ratios. For instance, 6 to 3 is a double ratio, so also is 8 to 4, therefore the ratio of 6 to 3 is equal to the ratio of 8 to 4. They are thus equal ratios, and their relation, *i.e.* saying that as 6 is to 3, so is 8 to 4, is an equirationality, or 6, 3, 8, 4 are terms of an equirationality.

Look here: Dutch words, easy to understand and modest in appearance, but in reality of an infinite power. For if one conciders the thing defined, *viz.* equirationality, it is like a definition of its substance, the mere ring of which, at first hearing, brings home to us and shows us that the very thorough understanding of equira-

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[1]) In the manuscript, erroneously, *si.* This same error has been pointed out in note 3 p. 423. Sometimes Stevin writes the scale as *fa sol la sa ut re mi fa.* Cf. figure 1, p. 436.

[2]) The notation $\surd^{(n)}a$ is currently used bij Stevin for $\sqrt[n]{a}$. (See volume II B of this edition, p. 524).

[3]) In Stevin's Dutch: *everedenheijt.*

denheyt byde Griecken ende hun navolghers niet gheweest en heeft. Want (veel ander ghelaten die elders te pas sullen comen) te segghen dat 6, 4, 3 van drie ghelycke singconstighe everedenheyt maken daer oneindelicke ydelheden uijt volghen ende besloten worden; Men antwoort duer beweghing van tvoornoemde gheluijt, hier van sijn gheen even redens, daerom oock gheen Everedenheyt. Doirsaeck dier dwalinghen is dat hun spraeck dit woort medtsgaders al d'ander Wisconstighe namen niet soo eyghentlick beteeckenen en conden als dese daerom soomen met goet onderscheyt van der talen nutbaerheijt wilde spreken; men mocht segghen de wetenschap van Griecx oirboir te wesen van veel verscheijden vonden der Griecken die thaerder tyt de voornaemste waren int licht te brenghen, duer oversetting uyt het Griecx in ander talen: sgelijckx daeghelicx ghebeurt; Tlatijn om daer mede (als bij ghevalle des werrelts ghemeen tael gheworden synde) in alle landen verstaen te worden, oock om alle konsten te mueghen besien, die van alle stoffen bij verscheijden geslachten van volcken daerin beschreven worden; Tfranszois Italiaens Spaens Pools, etz om sijn handel daer deur te dryven yder nae sijn ghelegenheyt. Maer het DUYTSCH om de vrie consten daer in te leeren, om de natuerens verborghentheden daer in duergronden ende te bewysen dat wonder gheen wonder en is. Daerom hij die van meyningh waer na de groote Wysheyt te trachten daer der Caldeen ende Egyptenaeren wetenschappen eertijts overblijfselen af waeren, hem soude nut sijn tot desen born oft eerste oirspronck te gaen van daer sijse gekreghen hadden vlietelick in Duytsch leerende onder anderen wat de voornoemde Everedenheyt is. Want dit gheluyt beeldet wesen van dese groote saeck eyghentlick uijt andre woorden als *Proportio Analogia,* synder onbequaem toe ghelyck de daet tot verscheyden plaatsen claerlick betuycht.

Verlijcking der Meetconstighe Reden met de Sinconstighe

Tot hier toe is vande Redens int ghemeen gheseyt maer om nu nae tvoornemen duer verlijcking der meetconstighe Reden die der Singconst te verclaren soo is te weten dat ghelyck de Meetconstighe Reden bestaet in der formen grootheyt ende cleenheyt welcke afghemeten wort duer langhde, alsoo de Singconstens Reden in der gheluyden grofheyt en fynheyt, die afghemeten wort duer hoochde of leechde: Als twee singhende een dobbeleerste, men seght uyt sulck verschil der leechde die deen onder dander is de grofste stem dobbel onder finste. Ende sulcke stof der dobbelheyt als dit is vande selve sijn al d'ander meerder ende minder singconstighe Redens. Wederom ghelyckmen alle Redens van twee voorghestelde rechtlinighe platten of lichamen duer tghesicht niet bekennen en can, maer hun meetconstighe reghels hebben, leerende hoemen die vinden sal, alsoo en sijn alle Redens van twee voorghestelde gheluyden uyt het ghehoor niet te oirdeelen, maer sij worden openbaer duer haer Sinconstighe reghels daer wij nu af segghen moeten.

tionality was not found among the Greeks and their successors. For (leaving aside many other things, to be discussed elsewhere) from saying that 6, 4, 3 of three sounds make a musical equirationality endless vanities follow and are concluded. [1]) The answer, called forth by such a saying is: these form no equal ratios, and consequently there is no equirationality either. The cause of these errors is that the language of the Greeks could not interpret this term together with all other mathematical terms as properly as the Dutch language does. Therefore, if one wished to speak with good discrimination of the suitability of languages, one might say that knowledge of Greek is useful in order to bring to light various discoveries of the Greek, which in their days were the most important, by translation from the Greek into other languages; as is done daily. Latin (because it has happened to become the common language of the world) serves to be understood in all countries, and also to study all sciences about all subjects, which have been described in it by various kinds of people. French, Italian, Spanish, Polish, etc. serve to carry on trade, everybody according to his situation. But DUTCH serves to teach the liberal arts, to fathom the hidden secrets of nature, and to prove that miracle is no miracle.[2]) Therefore, whoso should be minded to seek after the great Wisdom, of which the knowledge of the Chaldees and the Egyptians formerly was a remnant, would find it useful to go to this source or first origin from which they had got it, learning diligently in Dutch, among other things, what is the aforesaid equirationality. For this word depicts the character of this great matter properly. Other words, such as *Proportio, Analogia,* are unable to do so, as is clearly shown by practice in several places.

Comparison of Geometrical Ratio with Musical Ratio

So far we have spoken of ratios in general, but in order to explain now, as intended, ratio in singing by comparison with geometrical ratio, we are to know that, as the geometrical ratio consists in the largeness and smallness of figures, which is measured by length, so ratio in singing consists in the coarseness and sharpness of sounds, which is measured by height or lowness. Thus when two persons sing a double-first, it is said, in view of this difference in lowness of one below the other, that the coarser voice is double below the sharper one. And all the other greater or smaller singing ratios are made of the same stuff as the stuff this doubleness is made of. Again, just as all the ratios of two given rectilinear plane figures or solids cannot be recognized by sight, but obey geometrical rules teaching us how to find them, so all the ratios of two given sounds cannot be judged by hearing, but they are revealed by means of the musical rules governing them, which we now have to discuss.

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[1]) Between two numbers p and q one can have an arithmetic mean (a), a harmonic mean (h), and a geometric mean (g). These are defined by $p - a = a - q$; $1/p - 1/h = 1/h - 1/q$, and $p : g = g : q$. Obviously the numbers 6, 4, and 3 quoted by Stevin show the harmonic mean 4 of the outer terms 6 and 3, 4 being $1/3$ more than 3 and $1/3$ less than 6 so that $1/3 - 1/4 = 1/4 - 1/6$. Accordingly the note, given by a length of string 4, is the harmonic mean of the notes given by the lengths 6 and 3. The latter make an octave. The harmonic mean gives a fifth against the lower, a fourth against the higher note. Stevin has in mind geometrical ratio only, and he objects to equating two musical (*singconstighe*) ratios to be construed from the three numbers in question. Obviously he refuses to admit the harmonic ratio to be called a ratio.

[2]) *"Wonder en is gheen wonder"* was the motto on the frontispiece of Stevin's treatise on statics, *De beghinselen der Weeghconst;* see this edition, vol. I, p. 47.

Vande Redens der singchelicke gheluyden na der Griecken meining

D'ervaring betuycht dat de gespannen snaer op eenich reetschap als luyt cyter viool of derghelycke teghen haer helft een gheluyt maeckt daer mede soo seer ghelyck dattet in hem een ghelaet van selfheyt heeft diens Reden der grofheyt wij duer eenighe natuerlicke gheneghentheyt dobbel verstaen maer niet soo wesentlick als de dobbelheyt die ons in ander stoffen ontmoet, ghelyck vooren gheseyt is, doch soo wort sulcx merckelicker bevesticht duer de lichamen dese gheluijden uijtende als der heelsnaer ende haer helft, welcke oock in dobbel reden sijn. Tselve heeft hem alsoo met de halfsnaer tot huer vierendeel, achtendeel, sesttiendendeel ende d'ander in die voortganck. Want alsulcke gheluyden al tvoornoemde ghelaet der selfheyt hebben, met begrijpelicke ghedaente der viervoudighe achtvoudighe, sesthienvoudighe Reden der grofheijt. Desgelycs is oock openbaer in al dander redens buyten den boveschreven voortganck. Want nemende een deel des snaers wiens Reden tot de heele den helft sij des Redens vande dobbelden haer gheluyt sal oock tot halfweghe duer oirdeelick leeghde ghedaelt sijn: Maer want dese bekende daling de maet der grofheyt is ghelyck wij vooren gheseyt hebben, soo is ons de Reden der grofheijt hier bekent, ende alsoo met anderen dier ghelycken waer uijt besloten wordt dat ghelyck dit snaersdeel tot dat snaersdeel, alsoo desens gheluyt tot diesens gheluyt, dat is de snaersdeelen brenghen gheluyden voort inde Reden haerder grootheden. Dit eertijts bemerckt sijnde, soo was de drangh na de ware deeling des snaers alsoo datse de eijghentlicke toonen begrepen die wij duer natuerlick ghesanck synghen. twelck de Griecken tot onderscheyt van tgheen sy *Chromaticum* ende *Harmonicum* heeten, *Diatonicum genus* noemen, op dat alsoo tnatuerlick ghesanck inde singconstighe reetschappen volcomelick ghetroffen wierden. Om hier toe te commen soo en behouftmen maer eenich toon den halftoon vervatende als onderhalftoon, tweeenhalftoon, drieenhalftoon enz. wantmen daer uijt om der Redens vergaring ende aftrecking wil, al de rest gewislick vinden can sonder meer gheluyden te hooren. Sij hebben daer toe ghenomen de vyfde, dat is den drieenhalftoon ende vinden de ware Reden der langde des snaers ende haers deels desen drieenhalftoon clijnckende seer naer in de Reden van 3 tot 2 hebben gheschat Reden $^3/_2$ de warachtiche te wesen. daermede voortgaende als of syt waer treckense van Reden $^2/_1$ des sestoons blyft Reden $^4/_3$ des tweeenhalftoons, de selve van Reden $^3/_2$ des drieenhalftoons blijft reden $^9/_8$ voor den toon, daer toe vergaert noch een reden $^9/_8$ comt Reden $^{81}/_{64}$ des tweetoons de selve getrocken van Reden $^4/_3$ des tweeenhalftoons blyft voor den halftoon Reden $^{256}/_{243}$, etz. Maer alsmen de sanglijn ofte om werckelicker te spreken, den hals van een luyt of cyter deelt na de boveschreven Redens d'ervaring betuycht opentlick duer tghehoir sulcx den halftoon niet te wesen want sij veel te cleen is. Indervoughe dat de natuerlicke toonen duer sulcke deeling niet recht ghetroffen en sijn. Ende hoewel d'ouden dit ghenomen merckten hebben nochtans dese deeling voor goedt ende volmaeckt ghehouden ende liever tghebreck

On the Ratios of Singable Sounds According to the Opinion of the Greeks

Experience shows that a stretched string on some instrument, such as a lute, a cither, a violin, or the like, produces against its half a sound so similar to it that it has a semblance of identity, the coarseness ratio of which, by some natural inclination, we understand to be double, but not with the same evidence as the doubleness with which we meet in other matters, as has been said before; but this is confirmed more perceptibly by the bodies producing these sounds, such as the whole string and its half, which are also in the double ratio. The same also applies to half the string and its quarter, its eighth, its sixteenth part, etc. in this sequence, for all these sounds have the aforesaid semblance of identity, with the understandable form of the fourfold, eightfold, sixteenfold ratio of coarseness. The same is also obvious in all the ratios besides the above-mentioned sequence. For if we take a part of the string whose ratio to the whole string is one half of the ratio of the double part,[1]) its sound will also have dropped halfway by properly estimated lowness. But because this known dropping is the measure of the coarseness, as we have stated above, here the ratio of coarseness is known to us, and the same also applies to other similar sounds, from which it is concluded that as this part of the string is to that part of the string, so also is the sound of this to the sound of that, *i.e.* the parts of the string produce sounds in the ratio of their sizes.

This being noted in former times, the impulse to the true division of the string was such that it should comprise the notes proper which we sing in natural singing. Which the Greeks, to distinguish it from what they called *Chromaticum* and *Enharmonicum genus,*[2]) called *Diatonicum genus,* in order that thus natural singing might be hit off flawlessly on musical instruments.

To effect this, one merely requires some interval[3]) containing a semitone, such as a one-tone-and-half, a two-tone-and-half, a three-tone-and-half, etc., because from these, by way of addition and subtraction of the ratios, one can accurately find all the rest without hearing any further sounds. For this purpose they took the fifth, *i.e.* the three-tone-and-half, and found the true ratio of the length of the string and its part producing this three-tone-and-half to be very close to the ratio of 3 to 2; they estimated that the ratio $3:2$ was the true one. Proceeding therewith as if it were the true ratio, they subtracted it from the ratio $2:1$ of the six-tone, the remainder being the ratio $4:3$ of the two-tone-and-half; the latter being subtracted from the ratio $3:2$ of the three-tone-and-half, the remainder is the ratio $9:8$ for the whole tone. When another ratio $9:8$ is added thereto, this gives the ratio $81:64$ of the ditone. When this is subtracted from the ratio $4:3$ of the two-tone-and-half, the remainder for the semitone is $256:243$, etc. But if the melodic line, or to speak more concretely: the neck of a lute or cither, is divided according to the above-mentioned ratios, experience shows patently by hearing that this is not the semitone, because it is much too small. Therefore the natural notes are not correctly hit off by such a division. And although the Ancients perceived this fact, nevertheless they took this division to be correct and perfect, and preferred to think that the defect was in our singing

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[1]) Stevin means the square root of $\frac{1}{2}$.
[2]) The manuscript, erroneously, has *harmonicum.*
[3]) Stevin writes: *toon.*

(ghelyck oftmen seyde de Son mach lieghen maer tuijrwerck niet) in ons ghesanck gheacht; ja hebben hierom de soete ende lieflicke gheluijden der cleene ende groote derde en sesten, welcke in haer misdeelde sanglijn mishaeghlick clancken voor quaet ghehouden, te meer dat een sinlicheijt van oneyghen ghetalen hun hier toe drang. Maer willende Ptolemeus daer naer dese onvolmaectheijt verbeteren heeft tvoornoemde *genus diatonicum* op een ander wyse ghedeelt makende onderscheijt tusschen groote toon in Reden $^9/_8$ ende cleene toon in Reden $^{10}/_9$ welck verschil inde natuer niet en bestaet wantet openbaer is alle heele toonen evegroot ghesonghen te worden. Deze onghetroffen toonen van Pitagoras en Ptolemeus an Zarlinus niet ghevallende heeft noch een ander deeling ghemaeckt verspreydende seker *comma* (in Ptolemeus deeling overschietende) op deen en dander toon daert hem goet docht maer al tastende. Alle dese dwalinghen syn daer uyt ghesproten dat den aert der everedenheijt niet grontlick ghenomen begrepen en heeft gheweest twelck niet en quam duer ghebreck des verstants want hun naeghelaten daden ghenouch betuyghen datse van d'alder scherpsinnichsten waren die de natuer voortbrenght maer tlooch hun an goede reetschap naemlick de duytsche tael sonder welcke men inde diepsinnichste saecken soo weijnich doen can als een ervaren timmerman sonder goede verstaelde reetschappen sijn ambacht want ghelyck men duer een ongheschickt cromlinighe form de meetconstighe eygenschappen des viercants niet soo duergronden en can als met een eyghen viercante form na den vyften des 4 voorstels wiens gheduerich opsicht gheduerich tghedacht versterckt alsoo en condemen de diepsinnichste natuerens verborghentheden duer dongheschickte (bij Duytsch verleken) Gryecksche spraeck niet soo grontlick begrypen als duer dese aldergheschickste ende aldervolmaeckste tael der talen wiens eijghentlicke beteeckening ons tbeteeckende soo claerlick inbeelt dat de saeck self daer duer gheduerich voor ooghen schijnt welcke in dander talen onbegrijpelicke duysterheden blijven soo dervaring onder anderen in dese stof overvloedelick betuijcht. Want Reden $^3/_2$ voor de vyfde te stellen, daer mede na den vyften voortgaende ende eintlick niet wel uijtcommende noch te meijnen dat Reden $^3/_2$ de waerachtighe sij, voorwaer de grontlicke aert der vergaring ende aftrecking vande Redens isster onbekent. Maer op dat wij dit misverstant in d'onverstaen aert der Redens duer verlijcking van verstaenlicken gheluiden ghetalen openbaer maken: laet ons nemen eenich ghetal als 110 inde plaets der dobbeleerste of des sesthoons, ende vyf persoonen, A, B, C, D, E, oirdentlick beteeckenende den drienhalftoon tweeenhalftoon, toon, tweetoon ende halftoon, daer mede den eysch stellende lyckformich ande voorgaende Pitagorische wercking des Redens aldus: *Van 110 ghetrocken tghene A hebben moet de rest is voor B, ende ghetrocken B van A t'overschot is voor C, daer toe noch soo veel ghedaen de somme is voor D, die ghetrocken van B toverblyfsel moet 35 syn voor E.* Ymant om tot besluyt van desen te commen, neemt een ghetal voor A dat hem soo veel tuyterlick ghevoel belanght na ghenouch dunckt als 60, hier mede voortgaende als oftet twaerachtich waer, trecket van 110 blyft 50 voor B, die ghetrocken vande (as if one should say: the sun may lie, but the clock cannot). They even considered the sweet and lovely sounds of the minor and the major third and sixth, which sounded unpleasant in their misdivided melodic line, to be wrong, the more so because a dislike for inappropriate numbers moved them to do so. But when Ptolemy afterwards wanted to amend this imperfection, he divided the aforesaid *genus diatonicum* in a different way, making a distinction between a major whole tone in the ratio 9 : 8 and a minor whole tone in the ratio 10 : 9, a difference that does not exist in nature, for it is obvious that all whole tones are sung equal. Since these tones of Pythagoras and of Ptolemy displeased Zarlino, he made yet another division, distributing a certain *comma* (which remained in Ptolemy's division) over one tone and another, where it seemed appropriate to him, but tentatively.[1])

All these misconceptions have originated from the fact that fundamentally the nature of equirationality was not understood, which was not due to a lack of brains, for their acts as have come down to us show sufficiently that the Greek were of the most intelligent that Nature produces, but they lacked a good tool, *viz.* the Dutch language, without which in the most profound matters one can accomplish as little as a skilled carpenter without good tempered tools can carry out his trade. For just as one cannot grasp the geometrical properties of a square by means of an unsuitable curvilinear figure so well as by means of a proper square figure according to Proposition 4, sub 5,[2]) the continual sight of which continually strengthens one's insight, so it was not possible to penetrate into the most profound secrets of Nature as thoroughly by means of the unsuitable Greek language (unsuitable as compared to Dutch) as by means of this eminently suitable and most perfect language of languages, whose characteristic designation pictures the matter designated so clearly for us that the matter itself thus seems to be continually before our eyes, whilst in other languages it remains incomprehensible and obscure, as experience amply proves, among other things in the present matter. For whoso puts the ratio 3 : 2 for the fifth, proceeding therewith five times, and in the end not coming out right, still holds that the ratio 3 : 2 is the actual one, he in truth ignores the essential character of addition and subtraction of ratios.

But in order to show up this misapprehension as to the misunderstood character of ratios by means of an example in intelligible words with numbers, let us take some number, such as 110, as representing the double-first, or the six-tone, and five persons A, B, C, D, E, representing in this order the three-tone-and-half, the two-tone-and-half, the whole tone, the ditone, and the semitone, putting therewith the requirement similar to the preceding Pythagorean operation with the ratio, as follows: *Subtract from* 110 *what A should have, the remainder is for B; subtract B from A, the remainder is for C; add to this the same amount, then the sum is for D; after subtraction of the latter from B, the remainder should be* 35 *for E.* To arrive at this result, somebody takes for A a number which as a superficial guess appears to him close enough, for instance 60. Proceeding with this as if it were the true number, he subtracts it from 110, there remains 50 for B; this

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[1]) For this question, see note A, page 460.

[2]) Reference to an item of Stevin's treatise *De Meetdaet,* Work XI, this edition vol. IIB.

60 rest 10 voor C, daer toe ghedaen noch 10 vint 20 voor D, die ghetrocken van 50 der B blyft 30 voor E, maer E moest 35 hebben hij siet dan opentlick dat E tsijne niet en heeft; doch sonder te mercken dat sulcx comt uijt het eerste ghetal voor A dats 60 onrecht ghestelt te wesen acht dat laetste ongheval de naturens verborchenheijt houdende sijn boveschreven besluyt voor goet. Maer wat sal den ervaren Telder hier toe segghen? seker met goede reden dat soodanighen deyghenschappen der Telconst niet ghenough bekent en sijn, wetende dattet recht deel voor A 59 is, twelck van 110 ghetrocken blyft 51 voor B, welcke van 59 rest 8 voor C, daer toe noch 8 comt 16 voor D, die ghetrocken van 51 der B blyft 35 voor E naer tbegheerde. Even eens ist inde berekening vande Redens der gheluyden toegeghaen, want wesende voor de vyfde een Redens te stellen, die na seecker reghel af te trecken ende te vergaren was, alsoo datter eintlick de ware Reden des halftoons overschiete welcke men duert stellen van Reden $^3/_2$ daetlick bevandt daer niet uijt te commen, ende bevandt noch gheduerlick te blyven meijnen dat die Reden $^3/_2$ de waerachtighe is; Voorwaer soo opentlick als den Telder hier boven sach dat den stelder van 60 voor A de Telconst niet ghenouch en verstont naestelick ghevoelende doirsaeck sijnder dwaling; even soo claerlick siet den ervaren der Everedenheijt dese stelders van Reden $^3/_2$ voor de vyfde den grontlicken aert der Redens end Everedenheyts niet innerlick ghenomen begrepen te hebben spruijtende daer uijt als voor gheseyt is dat sij gheen woorden en hadden die de Wisconstighe saken soo eyghentlick beteeckenen conden als het DUYTSCH.

Vande ware redens der natuerlicke toonen

Maer om tot de saeck te commen ende deyghen Redens der natuerlicke toonen te beschryven, soo segh ick dat de ware reden der vyfden ofte des drieenhalftoons is van 1 tot $\sqrt{(12)}\ ^1/_{128}$, dat is van 1 tot syde der twelfde grootheyt van $^1/_{128}$, de selve ghetrocken van Reden $^2/_1$ des sestoons blyft Reden van 1 tot $\sqrt{(12)}\ ^1/_{32}$ voor den tweeenhalftoon, die wederom ghetrocken vande voornoemde Reden des drieenhalftoons blijft Reden van 1 tot $\sqrt{(6)}\ ^1/_2$ voor den toon, daer toe ghedaen noch alsulcken reden comt Reden van 1 tot $\sqrt{(3)}\ ^1/_2$ voor den tweetoon, de selve ghetrocken vande boveschreven Reden des tweeenhalftoons blyft reden van 1 tot $\sqrt{(12)}\ ^1/_2$ voor den halftoon. Om twelck te bewysen soo laet A, B, C, D, E, F, G, *a, b, c, d, e, f, g,* beteeckenen de clawieren van een orgel ofte clavesingel ende H I K L M N O P Q R de tusschen toonen diese fenten noemen. Want ons dit reetschap tottet voornemen bequamer is, dan de sanglijn, tselve laet ghestelt worden met de volmaeckte natuerlicke toonen in deser voughen

Boven F de dobbeleerste f met de vijfde *c* tusschen beyden
Onder *c* de dobbeleerste C met de vijfde G tusschen beyden
Boven G de dobbeleerste *g* met de vijfde *d* tusschen beyden
Onder *d* de dobbeleerste D met de vijfde *a* tusschen beyden
Onder *a* de dobbeleerste A met de vijfde E tusschen beyden
Boven E de dobbeleerste *e* met de vijfde *b* tusschen beyden
Onder *b* de dobbeleerste B met de vijfde L tusschen beyden
Boven L de dobbeleerste Q met de vijfde O tusschen beyden

being subtracted from 60, there remains 10 for C; adding 10 again to this, he finds 20 for D; this being subtracted from the 50 of B, there remains 30 for E. But E was to have 35, so he sees patently that E has not received his due. But not perceiving that this follows from the fact that the first number for A, *i.e.* 60, had not been put right, he considers the last mishap to be the secret of Nature and looks upon his former supposition as correct. But what will the experienced arithmetician say to this? Certainly, and with good reason, that such a person is insufficiently acquainted with the properties of arithmetic, for he knows that the correct portion for A is 59; when this is subtracted from 110, there remains 51 for B; this from 59, there remains 8 for C; adding another 8, that makes 16 for D; this subtracted from 51 of B, there remains 35 for E, as required.

The same thing happened in the calculation of the ratios of sounds, for a ratio had to be put for the fifth and this had to be subtracted and added according to a given rule, in such a way that finally the true ratio of the semitone should remain. In fact this was found not to come right if the ratio was put to be 3 : 2, and people continually went on maintaining this ratio 3 : 2 to be the true one. Truly, as patently as the arithmetician above saw that the man who put 60 for A did not sufficiently understand arithmetic, feeling at once the cause of his error, so clearly the expert in equirationality sees that the supporters of the ratio 3 : 2 for the fifth have not essentially understood the fundamental character of ratios and equirationalities, which was due, as said above, to the fact that they had no words which could designate mathematical matters as adequately as DUTCH.

Of the True Ratios of Natural Tones

But, to come to the point and to describe the proper ratios of natural intervals[1]), I say that the true ratio of the fifth or the three-tone-and-half is 1 to $\sqrt{(12)}\,{}^1/_{128}$, *i.e.* 1 to the twelfth root of $^1/_{128}$. When this is subtracted from the ratio 2 : 1 of the sixtone, there remains the ratio of 1 to $\sqrt{(12)}\,{}^1/_{32}$ for the two-tone-and-half. When this again is subtracted from the aforesaid ratio of the three-tone-and-half, there remains the ratio of 1 to $\sqrt{(6)}\,{}^1/_2$ for the whole tone. Addition to this of the same ratio makes the ratio of 1 to $\sqrt{(3)}\,{}^1/_2$ for the ditone. This being subtracted from the above-mentioned ratio of the two-tone-and-half, there remains the ratio of 1 to $\sqrt{(12)}\,{}^1/_2$ for the semitone. To prove this, let A, B, C, D, E, F, G, *a, b, c, d, e, f, g* designate the keys of an organ or a harpsichord, and H, I, K, L, M, N, O, P, Q, R the intermediate keys, which are called slit keys. Because this instrument is more convenient for the present purpose than the monochord, let it be tuned with the perfect natural tones, as follows:

Above F the double-first *f* with the fifth *c* between them
Below *c* the double-first C with the fifth G between them
Above G the double-first *g* with the fifth *d* between them
Below *d* the double-first D with the fifth *a* between them
Below *a* the double-first A with the fifth E between them
Above E the double-first *e* with the fifth *b* between them
Below *b* the double-first B with the fifth L between them
Above L the double-first Q with the fifth O between them

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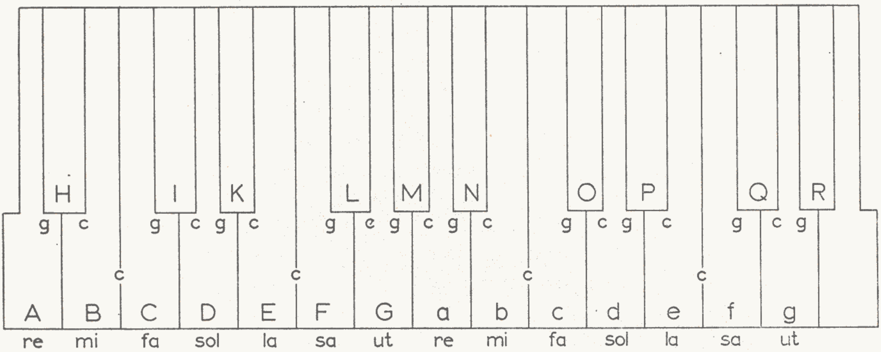
[1]) Stevin writes: toonen *(= tones)*.

Onder O de dobbeleerste I met de vijfde M tusschen beyden
Boven M de dobbeleerste R met de vijfde P tusschen beyden
Onder P de dobbeleerste K met de vijfde N tusschen beyden
Onder N de dobbeleerste H



Dit soo wesende dervaring betuycht dat HF een volmaeckte vyfde maken, ende hoewel sulcx voor ghemeen ende ghewisse Reghel gehouden wort van al de ghene hun dies verstaende, heb nochtans tot meerder versekering voor de ghene die daer an twijfelen mocht de Loofweerdicheyt willen ghebruijcken van . . .

Wesende dan HF een volmaeckte vijfde, soo syn alle halftoonen nootsaecklick evegroot ende den rechten helft des toons twelck aldus bewesen wort: Laet den halftoon van B tot C ende van E tot F cleynder oft grooter syn, waert mueghelick dan den rechten helft des toons; ick neem na de Pitagorische meining cleender, twelck wij daerom (metgaders *bc* ende *ef*) teyckenen met *c* clein bediende, duer tletttercken *g* salmen groot halftoon verstaen: Om dan voort te gaen LB is duer de stelling een vijfde bestaende uijt drie toonen ende een cleen halftoon, ofte dattet selve is uyt twee toonen, twee cleene halftoonen met een groot halftoon; Dit soo synde van F tot L is een groot halftoon twelck aldus bewesen wort. BC is een cleen halftoon CD ende DE elck een toon, EF een cleen halftoon maken tsamen twee toonen ende twee cleene halftoonen, soo moet dan FL tot voldoening der vyfde BL een groot halftoon sijn, ende vervolghens van L tot G is een cleen halftoon want van F tot G is een toon daer af ghetrocken de groot halftoon van F tot L soo moet dan L tot G een clein halftoon sijn. Maer *fQg* sijn dobbeleersten met FLG daerom oock ist van *f* tot Q een groot halftoon ende van Q tot

Below O the double-first I with the fifth M between them
Above M the double-first R with the fifth P between them
Below P the double-first K with the fifth N between them
Below N the double-first H

Figure 1. Plan of a harpsichord's keybord. Between the keys, semitones supposed minor have been marked c by Stevin (from cleen = small); major semitones by g (from groot = large). Starting the scale with ut on G, Stevin in f has sa, on a white key.

This being so, experience shows that H and F make a perfect fifth, and although this is considered a common and certain rule by all those who are skilled in this matter, yet to convince those who should doubt it I thought fit to use the authority of . . . . . [1])

Thus from H to F being a perfect fifth, all semitones must needs be equal and an exact half of a whole tone, which is proved as follows.

Let the semitone from B to C and from E to F be smaller or larger, if possible, than a right half tone; I assume, according to the Pythagorean view, that it is smaller, which we therefore (as also *b : c,* and *e : f*) designate by *c* [2]), meaning small; the letter *g* must be taken to stand for a major semitone. To proceed, L to B, by tuning, is a fifth, consisting of three whole tones and a minor semitone or, which is the same, of two whole tones, two minor semitones, and one major semitone. This being so, from F to L is a major semitone, which is proved as follows. BC is a minor semitone, CD and DE each a whole tone, EF a minor semitone, making together two whole tones and two minor semitones; therefore FL, to make up the fifth BL, must be a major semitone, and consequently from L to G is a minor semitone, for from F to G is a whole tone; subtracting from this the major semitone from F to L, from L to G must be a minor semitone. But *f,* Q, *g* make double-firsts with F, L, G, therefore from *f* to Q is a major semitone

[1]) The same diagram, and the method of tuning, in which Stevin uses the expressions *doctaaf* (the octave) and *de quinte* (the fifth) was shown on a separate leaflet. A foot-note also was on a separate slip of paper. In the note Stevin supposes that in the tuning experiment one has started from E-flat (the keys K and P in the diagram). In that case the last step leads to G-sharp (*gis,* the keys M and R). Stevin argued that the people quoted by him proclaim that they find the starting note P to be identical with the perfect fifth (d-sharp or *dis*) above M. Hence, he says, F too is a perfect fifth above H.

[2]) *c,* taken from Dutch *cleen* = small. The letter *r* in earlier publications seems to be corrupt. The letter *g* is taken from Dutch *groot* = large.

g een cleen halftoon. Voort soo is O een vyfde op L. duer de stelling daerom oock ist van *c* tot O een groot halftoon twelck aldus bethoont wort: LG is een cleen halftoon, G*b* twee toonen, *bc* een cleen halftoon, maken tsamen twee toonen ende twee cleene halftoonen soo moet dan *c*O tot voldoening der vijfde LO een groote halftoon sijn, ende vervolghens soo is O*d* een cleen halftoon. Maer CID sijn dobbeleersten met *c*O*d* daerom oock ist van C tot I een groot halftoon ende van I tot D een cleen halftoon. Voort soo is M een vyfde op I duer de stelling, daerom oock ist van G tot M een groot halftoon want ID is een cleen halftoon ende DE een toon, EF een cleen halftoon, FG een toon maken tsamen twee toonen ende twee cleene halftoonen indervoughen dat GM tot voldoening der vyfde MI een groot halftoon maken ende vervolghens soo is M*a* een cleen halftoon. Maer *gR* sijn dobbeleersten met GM, daerom oock is *gR* een groot halftoon.

Wyder soo is P een vyfde op M duer de stelling daerom oock ist van *d* tot P een groot halftoon want van M tot *a* is een cleen halftoon van *a* tot *b* een toon, van *b* tot *c* een cleen halftoon, van *c* tot *d* een toon, maken tsamen twee toonen ende twee cleene halftoonen waer duer *d*P tot voldoening der vyfde PL nootsaeckelick een groot halftoon is, ende vervolghens soo moet P*e* een cleen halftoon sijn. Maer DKE sijn dobbeleersten met *d*P*e* daerom oock is DK een groote halftoon ende KE een cleen halftoon. Voort soo is N den vijfde op K duer de stelling daerom ist oock van *a* tot N een groot halftoon. Want van K tot E is een cleen halftoon ende van E tot F oock een cleen halftoon ende van F tot *a* twee toonen, maken tsamen twee toonen ende twee cleene halftoonen waer duer *a*N tot voldoening der vyfde NK een groot halftoon maeckt, ende vervolghens N*b* een cleen halftoon, maer AHB sijn dobbeleersten inde *a*N*b*, daerom oock is AH een groote halftoon ende HB een cleen halftoon. Dit dus wesende HF bestaet uyt twee toonen ende drie cleyn halftoonen. Want HB is een cleen halftoon, alsoo oock is BC, ende CE sijn twee toonen ende EF een cleen halftoon maken tsamen als vooren gheseijt is, twee toonen ende drie cleene halftoonen. HF dan en is gheen vyfde twelck teghen dervaring teghen loofweerdicheyt teghen tghemeen ghevoelen ende ontkenning der beginselen soude sijn; merckt wijder dat soo veel BC cleender waer dan een recht halftoon soo veel soude AH nootsaeckelick grooter moeten wesen ende vervolghens haer verschil tot malcander tweemael soo veel twelck teghen tghemeen ghevoelen is. Want ghelyck int ghesanck de climming van *mi* tot *fa* evensoo hooch is als van *la* tot *sa*, alsoo istter van B tot C evensoo veel rysing als van A tot H. BC dan en is niet minder dan den rechten helft eens toons; sghelycx salmense oock bewysen niet meerder te wesen, sij is dan nootsakelick den rechten helft, alsoo oock sijn al dander ghelyck van A tot H, van H tot B, enz. Dit soo wesende de dobbeleerste bestaet nootsaecklick in ses toonen al even groot ofte in twelf evegroote halftoonen daerom heeft men tbegheerde alsder tusschen de palen der dobbeleersten 1 ende $1/2$ gheteyckent hier onder met AB ghevonden sijn. elf middeleverednighe ghetalen C, D, E, F, G, H, J, K, L, M, N, aldus and from Q to *g* a minor semitone. Further, O is a fifth above L, by tuning, therefore from *c* to O is a major semitone, which is proved as follows: LG is a minor semitone, G*b* two whole tones, *bc* a minor semitone, making together two whole tones and two minor semitones. Therefore *c*O, to make up the fifth LO, must be a major semitone, and consequently O*d* is a minor semitone. But *c,* O, *d* make double-firsts with C, I, D, therefore from C to I is a major semitone and from I to D a minor semitone. Again, M is a fifth above I, by tuning; therefore from G to M is a major semitone, for ID is a minor semitone and DE a whole tone, EF a minor semitone, FG a whole tone, making together two whole tones and two minor semitones, so that GM, to make up the fifth IM, is a major semitone, and consequently M*a* is a minor semitone. But *g,* R make double-firsts with G, M, therefore *g*R is a major semitone.

Further, P is a fifth above M, by tuning, therefore from *d* to P is a major semitone also, for from M to *a* is a minor semitone, from *a* to *b* a whole tone, from *b* to *c* a minor semitone, from *c* to *d* a whole tone, making together two whole tones and two minor semitones, in consequence of which *d*P, to make up the fifth LP, must needs be a major semitone, and consequently P*e* must be a minor semitone.

But *d,* P, *e* make double-firsts with D, K, E; therefore DK too is a major semitone and KE a minor semitone. Further N is a fifth above K, by tuning, therefore from *a* to N is a major semitone. Because from K to E is a minor semitone and from E to F also a minor semitone, and from F to *a* two whole tones, this makes together two whole tones and two minor semitones, in consequense of which *a*N, to make up the fifth KN, makes a major semitone, and consequently N*b* is a minor semitone; but *a,* N, *b* make double-firsts with A, H, B, therefore AH is a major semitone and HB a minor semitone. This being so, HF consists of two whole tones and three minor semitones. For HB is a minor semitone; such is BC too, and CE are two whole tones and EF is a minor semitone; these make together, as said above, two whole tones and three minor semitones. HF therefore is no fifth, which would be contrary to experience, contrary to authority, contrary to common opinion, and a denial of the principles. Note further that so much smaller as BC would be than a right semitone, so much larger AH must needs be, and consequently the difference between them twice as much, which is contrary to the common opinion. For just as in singing the ascent from *mi* to *fa* is equal to that from *la* to *sa,* so the ascent from B to C is equal to that from A to H. BC therefore is not less than the right half of a whole tone; likewise one will also show it not to be more. Therefore it must needs be the right half, and thus all the others, from A to H, from H to B, etc., are also equal. This being so, the double-first must needs consist of six whole tones which are all equal, or of twelve equal semitones; therefore the requirement will be satistied if, between the bounds of the double-first 1 and $^1/_2$, designated below by A and B, there have been found eleven mean proportional numbers C, D, E, F, G, H, I, K, L, M, N [1]), as follows:

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[1]) Mean proportionals, forming a geometric progression.

A.	1	Selftoon	Eerste
C.	$\sqrt{(12)}\ {}^1/_2$ . . .	Halftoon	Cleen tweede
D.	$\sqrt{(6)}\ {}^1/_2$ . . .	Toon	Groote tweede
E.	$\sqrt{(4)}\ {}^1/_2$ . . .	Onderhalftoon . . .	Cleen derde
F.	$\sqrt{(3)}\ {}^1/_2$ . . .	Tweetoon	Groote derde
G.	$\sqrt{(12)}\ {}^1/_{32}$ . . .	Tweeenhalftoon . .	Vierde
H.	$\sqrt{}\ {}^1/_2$	Drietoon	Qua groote vierde of qua cleene vijfde
I.	$\sqrt{(12)}\ {}^1/_{128}$ . .	Drieenhalftoon . .	Vijfde
K.	$\sqrt{(3)}\ {}^1/_4$ . . .	Viertoon	Cleen seste
L.	$\sqrt{(4)}\ {}^1/_8$ . . .	Vierenhalftoon . . .	Groote seste
M.	$\sqrt{(6)}\ {}^1/_{32}$ . . .	Vijftoon	Cleen sevende
N.	$\sqrt{(12)}\ {}^1/_{2\,048}$ . .	Vijfenhalftoon . . .	Groote sevende
B.	${}^1/_2$	Sestoon	Dobbeleerste, achtste.

Inder voughen dat A, 1 tot A, 1 de reden des selftoons ofte der eerste is, maer A, 1 tot C, $\sqrt{(12)}\ {}^1/_2$ de reden des halftoons ofte der cleen tweede ende A, 1 tot D, $\sqrt{(6)}\ {}^1/_2$ de reden des toons ofte der groote tweede ende soo voort met de rest, waer uijt blyckt dat de vyfde en dander in sulcke redens zijn als wij voorghenomen hadden te bewysen.

Ymant mocht nu achten na doude meyning hoe dattet soet gheluydt der vyfde in soo *) onuijtsprekelick, onredelick, ongeschickt ghetal bestonde, daer op wij int breede souden connen antwoorden maer want ons voornemen niet en is an donuytsprekelicke onredelicheyt ende ongeschicktheyt van sulcken misverstant hier te leeren duytsprekelicheyt redelicheyt geschicktheijt ende natuerlicke constighe volmaecktheyt deser ghetalen, sullent, als elders bewesen hebbende, daer bij laten.

Maer soomen de boveschreven redens al wilde beteeckenen met syden en twelfde grootheden inde selve weerde men soude den voortganck des noemers vande ghebroken in oirdentlicke voortganck vinden waeruyt, duer lichticheyt bekent worden al de redens boven den sestoon ofte dobbeleerste ghelyck dit voorbeelt opentlick ghenouch aenwyst:

---

*) *Inexplicabili irrationali absurdo numero.*

A.	1	Selftone	First
C.	$\sqrt[(12)]{1/2}$	Semitone	Minor second
D.	$\sqrt[(6)]{1/2}$	Whole tone	Major second
E.	$\sqrt[(4)]{1/2}$	One-tone-and-half	Minor third
F.	$\sqrt[(3)]{1/2}$	Ditone	Major third
G.	$\sqrt[(12)]{1/32}$	Two-tone-and-half	Fourth
H.	$\sqrt{1/2}$	Tritone	Bad major fourth or bad minor fifth
I.	$\sqrt[(12)]{1/128}$	Three-tone-and-half	Fifth
K.	$\sqrt[(3)]{1/4}$	Four-tone	Minor sixth
L.	$\sqrt[(4)]{1/8}$	Four-tone-and-half	Major sixth
M.	$\sqrt[(6)]{1/32}$	Five-tone	Minor seventh
N.	$\sqrt[(12)]{1/2\,048}$	Five-tone-and-half	Major seventh
B.	$1/2$	Six-tone	Double-first, eighth

Thus, A,1 to A,1 is the ratio of the selftone or first, but A,1 to C,$\sqrt[(12)]{1/2}$ the ratio of the semitone or minor second, and A,1 to D,$\sqrt[(6)]{1/2}$ the ratio of the whole tone or the major second, and so on with the remaining ratios, from which it appears that the fifth and the others are in such ratios as we had proposed to prove.

Now, someone might wonder, according to the ancient view, how the sweet sound of the fifth could consist in so *) unspeakable, irrational, and inappropriate a number [1]). To this we might give a detailed answer. However, since it is not our intention to teach to the unspeakable irrationality and inappropriateness of such a misunderstanding the speakability, rationality, appropriateness, and natural wonderful perfection of these numbers, we shall leave it at that because we have proved it elsewhere.

But if one wished to express all the above mentioned ratios by twelfth roots, one would find the progression of the denominators of the fractions in a regular sequence, from which all the ratios above the six-tone or double-first become easily known, as the following example shows sufficiently clearly:

*) *Inexplicabili irrationali absurdo numero.*

[1]) Referring to his work on arithmetic, (Work V, Vol. II B of this edition, p. 532; Vol. I, p. 23), Stevin in advance ridicules objections concerning the irrationality of his numbers.

A tot A	A	$\sqrt[(12)]{1}$	Selftoon	Eerste
A » H	C	$\sqrt[(12)]{^1/_2}$	Halftoon	Cleen tweede
A » B	D	$\sqrt[(12)]{^1/_4}$	Toon	Groote tweede
A » C	E	$\sqrt[(12)]{^1/_8}$	Onderhalftoon	Cleen derde
A » I	F	$\sqrt[(12)]{^1/_{16}}$	Tweetoon	Groote derde
A » D	G	$\sqrt[(12)]{^1/_{32}}$	Tweeenhalftoon	Vierde
A » K	H	$\sqrt[(12)]{^1/_{64}}$	Drietoon	Qua groote vierde of qua cleen vyfde
A » E	I	$\sqrt[(12)]{^1/_{128}}$	Drieenhalftoon	Vyfde
A » F	K	$\sqrt[(12)]{^1/_{256}}$	Viertoon	Cleen seste
A » L	L	$\sqrt[(12)]{^1/_{512}}$	Vierenhalftoon	Groote seste
A » G	M	$\sqrt[(12)]{^1/_{1\,024}}$	Vijftoon	Cleen sevende
A » M	N	$\sqrt[(12)]{^1/_{2\,048}}$	Vijvenhalftoon	Groote sevende
A » *a*	B	$\sqrt[(12)]{^1/_{4\,096}}$	Sestoon	Dobbeleerste, achste
		$\sqrt[(12)]{^1/_{8\,192}}$	Sessenhalftoon	Dobbel cleen tweede
		$\sqrt[(12)]{^1/_{16\,384}}$	Sevetoon	Dobbel groote tweede
		$\sqrt[(12)]{^1/_{32\,768}}$	Sevenenhalftoon	Dobbel cleen derde.

*Meetconstighe deeling der *) sanglini*

Om nu de sanglijn meetconstlick te deelen alsoo datmen daer in hebbe de ware volcommen gheluyden des natuerlicken ghesancks dat is inde boveschreven redens so laet AB de sanglijn beteeckenen wiens middelpunt C is, de selve salmen deelen in D, E, F, G, H, I, K, L, M, N, O, alsoo dat GB ende LB. twee middeleverednighe lynen sijn tusschen AB ende CB die op verscheyden wyse, werckelick (want de wisconstighe is alsnoch onbekent) ghevonden wort doch bequamelicst mijns bedunckens na de manier van . . . . Voort alsoo dat IB middeleveredniche sij tusschen AB ende CB, diemen vindt duer het . . . . Voor-

stel des . . . . boucs van Euclides. Sghelycx EB tusschen AB en GB. Wederom DB tusschen AB en EB. Voort FB tusschen AB en IB. Sghelycx HB tusschen GB en IB; Ende KB tusschen EB en CB. Wederom MB tusschen IB en CB ende NB tusschen LB en CB. Ten laetsten OB tusschen NB en CB.

Maer soomen dese deelinghen van C naer B noch voorder begheerde dat can met lichticheyt geschien in deser voughen: Men sal teeckenen P int middel van DB ende Q int middel van EB ende soo voort want PB sal teghen AB den sesenhalftoon ofte dobbel cleentweede maken ende QB teghen AB den sevetoon ofte dobbelgroote tweede.

*) *Regula harmonices seu monocordus.*

A to A	A	$\sqrt[(12)]{1}$	Selftone	First [1]
A to H	C	$\sqrt[(12)]{1/2}$	Semitone	Minor second
A to B	D	$\sqrt[(12)]{1/4}$	Whole tone	Major second
A to C	E	$\sqrt[(12)]{1/8}$	One-tone-and-half	Minor third
A to I	F	$\sqrt[(12)]{1/16}$	Ditone	Major third
A to D	G	$\sqrt[(12)]{1/32}$	Two-tone-and-half	Fourth
A to K	H	$\sqrt[(12)]{1/64}$	Tritone	Bad major fourth or bad minor fifth
A to E	I	$\sqrt[(12)]{1/128}$	Three-tone-and-half	Fifth
A to F	K	$\sqrt[(12)]{1/256}$	Four-tone	Minor sixth
A to L	L	$\sqrt[(12)]{1/512}$	Four-tone-and-half	Major sixth
A to G	M	$\sqrt[(12)]{1/1\,024}$	Five-tone	Minor seventh
A to M	N	$\sqrt[(12)]{1/2\,048}$	Five-tone-and-half	Major seventh
A to *a*	B	$\sqrt[(12)]{1/4\,096}$	Six-tone	Double-first eighth (octave)
		$\sqrt[(12)]{1/8\,192}$	Six-tone-and-half	Double minor second
		$\sqrt[(12)]{1/16\,384}$	Seven-tone	Double major second
		$\sqrt[(12)]{1/32\,768}$	Seven-tone-and-half	Double minor third

*Geometrical Division of the * Monochord*

Now in order to divide the monochord geometrically in such a way that we have the true perfect sounds of natural singing, *i.e.* in the above mentioned ratios, let AB designate the monochord, whose centre is C. Divide this in D, E, F, G, H, I, K, L, M, N, O in such a way that GB and LB are two mean proportional lines between AB and CB [2]), which may be found in practice (for the mathematical method is still unknown) by different methods, but in my opinion most conveniently in the manner of . . . .

Figure 2. Division of the monochord in equal tones and semitones.

Further in such a way that IB be the mean proportional between AB and CB, which is found by the . . th Proposition of the . . th Book of Euclid. Likewise EB between AB and GB. Again DB between AB and EB. Further FB between AB and IB. Likewise HB between GB and IB; and KB between EB and CB. Again MB between IB and CB, and NB between LB and CB. Finally OB between NB and CB.

But if these divisions from C to B are required to be continued, this can easily be done as follows. Mark P in the middle of DB and Q in the middle of EB, and so on, because PB will make against AB the six-tone-and-half or double minor second, and QB against AB the seven-tone or double major second.

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1) The letters in the first column of the following table correspond to the diagram, fig. I, p. 436. In the second column they refer to the preceding table on p. 441.

2) AB : GB = GB : LB = LB : CB.

*) *Regula harmonices seu monocordus.*

Telconstighe deeling der sanglijn

Tot hier toe is vande Meetconstighe deeling gheseyt; int volghende sullen wij de telconstighe verclaren dat is duer slechte ghetalen inde daet ghenouch doende, aldus: Ic deel de lijn AB in 10 000 even deelen; nu om te weten hoeveel der selver tot yder toon behooren ist beghin anden drieenhalftoon segghende 1 gheeft $\sqrt{}^{(12)}\ {}^{1}/_{128}$ wat 10 000? comt
$\sqrt{}^{(12)}$7 812 500 000 000 000 000 000 000 000 000 000 000 000 000 000 000
die doet zeer bij ende in heel ghetal ten naesten 6 674. Want 6 675 te veel is soo duer de twelfde grootheyt van deen en dander blijcken can. Maer om eyghentlicke bewys te doen in yder deel der wercking vande vinding deser syden soo is te weten dat de syde der tweede grootheyt ofte viercants syde des boveschreven vierde paels is bina $\sqrt{}^{(6)}$88 388 347 648 318 440 550 105 (die de gront hier af begheert mach dit ghetal in sich self menichvuldighen daer bij doende 96 389 809 968 824 984 488 975 dieder overschoten; tblyckt oock duer tvoornomde overschot dat de ware syde van gheen eenheyt meerder en is maer alleenlick van ontrent $\frac{96\,389\,809\,968\,824\,984\,488\,975}{176\,776\,695\,296\,636\,881\,100\,211}$).
Vande voornomde $\sqrt{}^{(6)}$ 88 388 347 648 318 440 550 105 wederom ghetrocken viercants syde die doet $\sqrt{}^{(3)}$ 297 301 778 750 (de prouf is openbaer duer menichvuldighing deses ghetals in sich daer toe doende doverschietende 404 488 987 605, tblyckt oock duer tvoornomde overschot dat de ware syde van gheen eenheyt meerder en is maer alleenlick van ontrent $\frac{404\,488\,987\,605}{594\,603\,557\,501}$ *). Hier uyt ten laetsten ghetrocken syde der derde grootheyt ofte teerlinxsyde comt 6 674, de prouf van desen is dat 6 674 teerlincwijs ghemenichvuldicht ende daer toe ghedaen doverschietende 26 628 726 maken haer eerste teerlincstal, tblyckt oock duer tvoornomde overschot datde ware teerlincxsyde van gheen eenheyt meerder en is maer alleenlick van ontrent $\frac{26\,628\,726}{133\,646\,851}$. Inder voughen dat 6 674 de voornomde syde in heeltal ten naesten is. De Reden die des drieenhalftoons is in slechttal te nemen als van 10 000 tot 6 674, daervan ghetrocken Reden ${}^{10\,000}/_{6\,674}$ des drieenhalftoons van Reden ${}^{2}/_{1}$ des sestoons blyft Reden ${}^{13\,348}/_{10\,000}$ des tweeenhalftoons. Maer de telder en is gheen 10 000, om die dan daer toe te brenghen ick seg 13 348 gheeft 10 000 wat 10 000? comt 7 491. Inder voughen dat de tweeenhalftoon is van Reden ${}^{10\,000}/_{7\,491}$, de selve ghetrocken van Reden ${}^{10\,000}/_{6\,674}$ des drieenhalftoons blyft (na verandereing in ghemeen telder 10 000) Reden ${}^{10\,000}/_{8\,909}$ des toons tot de selve ghedaen noch alsulck Reden comt Reden ${}^{10\,000}/_{7\,937}$ des tweetoons, de selve van Reden ${}^{10\,000}/_{7\,491}$ des tweeenhalftoons blyft Reden ${}^{10\,000}/_{9\,438}$ des halftoons. Dese toonen bekent wesende, al dander worden openbaer duer verscheyden manieren van wercking want om te hebben de Reden des onderhalftoons men mach trecken den toon vanden tweeenhalftoon ofte den tweetoon vanden 3 ${}^{1}/_{2}$ toon ofte vergaren den toon tot den halftoon, ende alsoo met al d'ander.

*) Dese ghetalen moeten noch eens overzien wesen teghen den oirspronck.

Arithmetical Division of the Monochord

So far we have spoken of the geometrical division; in the following we shall explain the arithmetical division, *i.e.* by simple numbers, which in practice suffice, as follows. I divide the line AB into 10 000 equal parts. Now in order to know how many of these parts pertain to each tone [1]), we begin with the three-tone-and-half, saying: 1 gives $\sqrt{(12)}\ ^1/_{128}$, what does 10 000 give? This makes $\sqrt{(12)}$ 7 812 500 000 000 000 000 000 000 000 000 000 000 000 000 000,
which comes very near to the integer 6 674. For 6 675 is too much, which may appear from the twelfth power of the one and of the other. But to furnish a proper test in each part of the operation of finding these roots, it is to be noted that the square root of the above written fourth power [2]) is nearly $\sqrt{(6)}$ 88 388 347 648 318 440 550 105. Those who wish to check this may multiply this number by itself and add thereto the defect [3]) 96 389 809 968 824 984 488 975. It also appears from the aforesaid defect that the true root exceeds the number by less than one unit, only by about $\frac{96\ 389\ 809\ 968\ 824\ 984\ 488\ 975}{176\ 776\ 695\ 296\ 636\ 881\ 100\ 211}$. When from the aforesaid $\sqrt{(6)}$ 88 388 347 648 318 440 550 105 the square root is again extracted, this makes $\sqrt{(3)}$ 297 301 778 750. The proof is evident by multiplication of this number by itself and addition of the defect 404 488 987 605; it also appears from the aforesaid defect that the true root exceeds the number found by less than one unit, the excess being only about $\frac{404\ 488\ 987\ 605}{594\ 603\ 557\ 501}$ *). From this finally extracting the cube root, we get 6 674, the proof of this being that when 6 674 is raised to the third power and the defect 26 628 726 is added thereto, this makes the first cube number. It also appears from the aforesaid defect that the true cube root exceeds the number found by less than one unit, only by about $\frac{26\ 628\ 726}{133\ 646\ 851}$, so that 6 674 is the nearest integer number to the aforesaid root. The ratio of the three-tone-and-half has to be taken in simple numbers, as from 10 000 to 6 674. Then, this ratio 10 000 : 6 674 of the three-tone-and-half being subtracted from the ratio 2 : 1 of the six-tone, there remains the ratio $^{13\,348}/_{10\,000}$ of the two-tone-and-half. But the numerator is not 10 000. In order to bring it to this value, I say: 13 348 gives 10 000, what does 10 000 give? This makes 7 491. Thus the two-tone-and-half has the ratio $^{10\,000}/_{7\,491}$. This being subtracted from the ratio $^{10\,000}/_{6\,674}$ of the three-tone-and-half, there remains (after conversion to the common numerator 10 000) the ratio $^{10\,000}/_{8\,909}$ of the whole tone. Adding to this the same again makes the ratio $^{10\,000}/_{7\,937}$ of the ditone. This same subtracted from ratio $^{10\,000}/_{7\,491}$ of the two-tone-and-half, there remains the ratio $^{10\,000}/_{9\,438}$ of the semitone. These tones being known, all the others are revealed by various methods of operation, for in order to have the ratio of the one-tone-and-half, one may subtract the whole tone from the two-tone-and-half, or the ditone from the three-tone-and-half, or add the whole tone to the semitone, and thus with all others.

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1) Read: interval.

2) The twelfth root of a number is the sixth root of the square root of that number. Stevin is computing the twelfth root, R, of $(10^4)^{12}/2^7 = ((R^3)^2)^2$. First he takes this to be a fourth power ("the above written fourth power"), and he draws a square root, which makes $8.8 \ldots . \times 10^{22}$. He again draws a square root, to find $R^3 = 2.97 \ldots \times 10^{11}$. The last step is drawing the third root. Stevin gets 6674.

3) Stevin writes: remainder. In the actual operation of extracting the root this is in fact the remainder after one stops the calculation.

*) These numbers should be compared once more with the original computation.

Men soude de voornoemde deeling oock muegghen aldus doen: Ghevonden hebbende de Reden des drieenhalftoons als boven ick krijgh die des drietoons segghende 1 gheeft $\sqrt{1/2}$ wat 10 000? comt 7 071 inder voughen dat Reden $^{10\,000}/_{7\,071}$ die des drietoons is, de selve ghetrocken van Reden $^{10\,000}/_{6\,674}$ des drieenhalftoons blyft (na verandering in ghemeen telder 10 000) Reden $^{10\,000}/_{9\,438}$ voor den halftoon, daertoe vergaert noch alsulcken reden comt voor den toon Reden $^{10\,000}/_{8\,908}$ daer wij na deerste manier creghen Reden $^{10\,000}/_{8\,909}$ doirsaeck van welck verschilken openbaer is. Wij sullen ons inde onderschreven tafel om oirdentlicker vervolghs wil an 8 909 houden ende om der ghelycke oirsake inden tweetoon an 7 936. De ghetalen boven den sestoon worden lichtelick ghevonden duer halving der voorgaende, als om te hebben tghetal des sessenhalftoons, ick neem den helft van 9 438 die doet 4 719 ende voor den sevetoon den helft van 8 908 enz. Een sanglijn dan aldus ghedeelt synde, in 10 000 even deelen voor yder toon sullen soo veel deelen commen rekenende van B naer A als de volghende beschryving van dies uytwyst.

10 000.	Selftoon	Eerste
9 438.	Halftoon	Cleen tweede
8 908.	Toon	Groote tweede
8 409.	Onderhalftoon	Cleen derde
7 936.	Tweetoon	Groote derde
7 491.	Tweeenhalftoon	Goe vierde
7 071.	Drietoon	Qua vierde
6 674.	Drieenhalftoon	Vyfde
6 298.	Viertoon	Cleen seste
5 944.	Vierenhalftoon	Groote seste
5 611.	Vyftoon	Cleen sevende
5 296.	Vyfenhalftoon	Groote sevende
5 000.	Sestoon	Dobbeleerste
4 719.	Sessenhalftoon	Dobbelcleen tweede
4 454.	Sevetoon	Dobbelgroot tweede

Soomen nu wilde sien hoe verre de ghedwaelde deelinghen van Pitagoras, Ptolemeus, Bootus ende Zarlinus buyten den wegh waren, men can daer lichtelick toe commen ende haer redens grootste ghetal oock op 10 000 te stellen. Ic neem de Pitagorische diens tafel tot den drieenhalftoon wert beschreven, soodanich is

One might also perform the aforesaid division as follows. Having found the ratio of the three-tone-and-half as above, I get that of the tritone by saying: 1 gives $\sqrt{1/2}$, what does 10 000 give? This makes 7 071, so that the ratio $^{10\,000}/_{7\,071}$ is that of the tritone. This being subtracted from the ratio $^{10\,000}/_{6\,674}$ of the three-tone-and-half, there remains (after conversion to the common numerator 10 000) the ratio $^{10\,000}/_{9\,438}$ for the semitone. Adding the same ratio makes for the whole tone the ratio $^{10\,000}/_{8\,908}$, whereas by the first method we got $^{10\,000}/_{8\,909}$, the cause of which small difference is evident. In the table below, for the sake of a more regular sequence, we shall stick to 8 909, and for the same reason to 7 936 for the ditone. The numbers above the six-tone are easily found by halving the preceding number; thus, to get the number of the six-tone-and-half, I take one half of 9 438, which makes 4 719, and for the seven-tone one half of 8 908 etc. A monochord, therefore, thus being divided into 10 000 equal parts, for every whole tone there will be so many parts, reckoning from B in the direction to A, as the following description shows.

10 000	Selftone	First
9 438	Semitone	Minor second
8 909	Whole tone	Major second
8 409[1]	One-tone-and-half . . .	Minor third
7 936	Ditone	Major third
7 491	Two-tone-and-half . . .	Good fourth
7 071	Tritone	Bad fourth
6 674	Three-tone-and-half . . .	Fifth
6 298	Four-tone	Minor sixth
5 944	Four-tone-and-half . . .	Major sixth
5 611	Five-tone	Minor seventh
5 296	Five-tone-and-half . . .	Major seventh
5 000	Six-tone	Double-first
4 719	Six-tone-and-half	Double minor second
4 454	Seven-tone	Double major second

If one now wants to see how far amiss were the erroneous divisions of Pythagoras, Boëthius, and Zarlino, this is readily possible by putting the largest number of their ratio also 10 000. I take the Pythagorean division, whose table being described up to the three-tone-and-half, runs as follows:

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1) In the table a mistake, 8404, has been corrected to 8409. The correct numbers should read:

10 000.0		
9 438.7	7.491.5	5 946.0
8 909.0	7 071.1	5 612.3
8 409.0	6 674.2	5 297.2
7 937.0	6 299.0	5 000.0

10 000	Eerste
9 492	Minste tweede
9 364	Meeste tweede
8 888	Groote tweede
8 437	Cleen derde
7 901	Groote derde
7 500	Goe vierde
7 023	Qua vierde
6 666	Vyfde

Alwaer blyckt dat de cleynste pael des drieenhalftoons van 8 deelen te cort is. Want ghetrocken 6 666 van 6 674 blyft 8 maer den halftoon van 54 deelen te lanck. Ymandt mocht nu dencken waerom dit verschil inden halftoon soo veel grooter is dan inden drieenhalftoon? Daer af seg ick doirsaeck openbaer te wesen int voorbeelt hier boven ghegheven met slechter talen daer wij 110 inde plaets des sestoons stelden ende vyf persoonen A, ... E oirdentlick beteeckenende den drieenhalftoon tweeenhalftoon, toon, tweetoon, ende halftoon, alwaer A inde quad wercking maer een te veel en creegh ende B een te weijnich, C twee te veel D vier te veel maer E vyf te weynich. Inder voughen dat E vyfmael meer te weynich had dan A te veel; Ende even eens uyt de ghelycke oirsaecke cryght hier den halftoon vyfmael meer te weynich (int ansien der Redens vande grofheyt) dan den drieenhalftoon te veel heeft. Uyt desen is oock openbaer dattet verschil des cleen halftoons ende groothalftoons thienmael meerder is dan de Reden des drieenhalftoons te groot ghestelt was, twelck doirsaeck is dat dese dwaling inden halftoon soo veel merckelicker blyckt als in dander toonen.

MERKT

Tis teghedencken dat de namen van de dobbelheyt drievoudicheyt viervoudicheyt der eersten tweeden derden enz. niet en sijn int ansien vande grofheyt der gheluyden maer vande omganghen (nemende acht vervolghende trappen voor een omganck) want ghelyckmen twee drie of vier keeren der slanghens dobbel, drievoudich oft viervoudich mach segghen an een omtrec niet int ansien vande oneven lengden der lynen waer in sulcke Reden niet en bestaet maer opsicht hebbende tot de menichte der keeren: Alsoo heetmen dese eersten tweeden enz. dobbel drievoudich viervoudich int ansien der omganghen sonder te letten opde grofheyt der gheluyden na welck de palen der drievoudicheerste in viervoudighe Reden sijn ende die der viervoudighe eerste in achtvoudighe reden. Inde dobbel eersten overcommet bij ghevalle om wat anders. Want een eersten ofte selftoon te weten Reden $^1/_1$ ghedobbelt dat is daer toe vergaert noch een Reden $^1/_1$ en maeckt al maer Reden $^1/_1$ men heeftse dan alleenlick opsicht tot de omganghen des gheluydts.

10 000	First
9 492	Lesser minor second
9 364	Greater minor second
8 888	Major second
8 437	Minor third
7 901	Major third
7 500	Good fourth
7 023	Bad fourth
6 666	Fifth

From this it appears that the smallest term, of the three-tone-and-half, is 8 parts too short, for when 6 666 is subtracted from 6 674, there remains 8, but the semitone is 54 parts too long. Now one might think: why is this difference so much greater in the semitone than in the three-tone-and-half [1]? I would say that the cause of this is obvious in the example given above in simple language, where we put 110 instead of the six-tone and where five persons, A . . . . E in due order stood for the three-tone-and-half, the two-tone-and-half, the whole tone, the ditone, and the semitone, where A in the wrong operation received only one too many and B one too few, C two too many, D four too many, but E five too few, so that E had too few five times more than A had too many. And likewise from the same cause the semitone here gets too few, five times more (with respect to the ratio of coarseness) than the three-tone-and-half has too many. From this it is also obvious that the difference between the lesser and the greater semitone is sixteen times [2] greater than the excess in the ratio of the three-tone-and-half, which is the cause of this error becoming so much more perceptible in the semitone than in the other tones.

NOTE

One must remember that the names of doubleness [3], triplicity, quadruplicity of firsts, seconds, thirds, etc. do not refer to the coarseness of the sounds, but to the rounds (taking eight [4] successive steps for a round), for just as one may say that two, three, or four turns of a helix are the double, triple, or quadruple of one circumference, not with respect to the unequal lengths of the lines, in which such a ratio does not consist, but with reference to the number of the turns, so these firsts, seconds, etc. are called double, triple, quadruple with respect to the rounds, without minding the coarseness of the sounds, according to which the constituent notes of the triple first are in the fourfold ratio, and those of the quadruple first in the eightfold ratio. With the double-first the matter happens to be different. For a first or selftone is a ratio 1 : 1. Doubling it means adding another ratio 1 : 1 to it; this makes the ratio 1 : 1 again. Therefore the name double-first refers to the rounds of sound only.

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1) Stevin explains why the deviation between his scale and the Pythagorean scale is so much larger for the (minor) semitone (9492 — 9438) than for the fifth (6666 — 6674).

2) The Dutch text has: "ten times", obviously by mistake.

3) By definition Stevin defined his double-first, our octave. In a double-first (according to the 6th definition) the two notes are in the twofold ratio. This is different from the double of, *i.e.* twice the ratio of the first.

4) This should be: "seven". See the 3rd Definition.

ANHANG

Voorreden / Vande Vierde / Van *la si ut* / Vande twelf toonen / De natuer en wort inde compositie niet ghevolcht als in Rhetorica / Der sesten en derden ghelycke daling en climming is wettelick als sij overhandt nu een cleen dan een groote comt / Waerom niet cijferletters inde langhe noten / Bemollaris cantus is onnut onderscheijt. / Tis een ghemeen woordt dat die wel onderscheyt die leert vaec, maer daerbenevens is te weten dat die qualick onderscheyt leert qualick / Species perfecta ende imperfecta sijn al quaet onderscheyt.

Hier vooren beschreven hebbende de spiegheling der Singconst soo heeft mij ghoedt ghedocht daer bij te voughen met corte woorden de verclaring van sommighe duysterheden ende valscheden inde Singdaet deses tydts inghewortelt.

Hooftstick vande vierde

De *) vierde wort vande ghesanckmakers deses tijts voor quaetluydich ghehouden, alsoo datse in ghesanck met drie of meer stemmen teghen de leeghste niet ghehoort en mach worden ja onder twee stemmen en wilmense gantschelick niet lyden. Maer soomen vraeght waerom? sij antwoorden overmidts datse in ons ghehoir mishaeghlick is: Twelck ick ontken: sal oock de contrari bewijsen eerst met reden daer na, dat meer is, mitterdaet. De reden is dusdanich: Twee gheluyden der dobbeleerste hebben soo grooten ghelijcheyt dat singhende twee persoonen, eenen liedt, ick neem een oudt mensch met een kindt, dese een dobbeleerste hoogher als die doch sonder kennis der dobbeleersten sij en weten ghemeenlick anders niet dan datse beyde in een selfde toon synghen. Ja wij sullen hieroock bewysen dat sulcx dalder ervarendste somtyts ghebeurt. Soo groot dan is dese ghelyckheyt dattet in hen een ghelaet der selfheyt heeft, daerom bij de twee boveschreven stemmen der dobbeleersten ghestelt eenighe derde stem alsulcken aert van soetluidichheyt ofte quaetluijdichheyt als die derde met deene maeckt soodanighe maektse oock met dander. Als neem ick die derde stem een toon boven de leegste wesende, sij maekt daer mee de qualuydighe tweede ende teghen de bovenste de qualuydighe sevende van ghelycke ghedaente: Maer soo de derde stem twee toonen boven de leechste waer, maken de soetluydighe derde ende met de bovenste gheen qualuydighe toon maer de soetluydighe sesten van ghelycke gedaente: Ende vervolghens de derde stem met de bovenste een behaeglick vyfde makende, sij en can met donderste stem niet mishaeghlick wesen, maer maeckt daer teghen een behaeghlicke soetluydighe vierde. Want dit is een ghemeen reghel dat een selfde tot eveneen selfde reden 1 heeft. Hier toe mochtmen noch brenghen de loofweerdiche der Grieken met hun navolghers diet soo mede verstaen hebben, maer die verlatende sullen ant daetlich bewijs commen. Ymandt de vierde quaetluydich achtende segghende die in sijn ghehoir mishaeghlick te wesen, de contrari ende sijn onghelyck wort hun aldus bethoont, men sal nemen eenighe twee verscheyden gheluijden als van een snaer met een menschestem ofte een fluyte met een snaer oft een stem met een fluyte daer mede makende alsnu een vierde alsdan een vyfde ende dat tot verscheydemael ende

*) *De Diatesseron*

APPENDIX [1])

Preface / On the fourth / On *la, si, ut* / On the twelve modes [2]) / In musical composition nature is not followed as it is in Rhetoric / The joint descent and ascent of sixths and thirds is allowed if minor ones alternate with major ones/Why not numerals in the long notes? / *Bemollaris cantus* is a useless distinction. / It is a common saying that whoso distinguishes well teaches well, but besides it must be known that whoso distinguishes improperly, teaches improperly. *Species perfecta* and *imperfecta* is an evil distinction.

Having above described the theory of music, I thought it useful to add, in brief words, an explanation of some obscurities and errors rooted in present-day musical practice.

Chapter on the Fourth *)

The fourth is considered a discord by present-day composers, so that in singing with three or more voices it must not be heard against the lowest part; nay, below two voices it is not suffered at all. But when one asks: why?, they answer: because it displeases our ears. Which I deny, and I shall also prove the contrary, first by argument, next – which is more – in practice. [3])

The argument is as follows. Two sounds making a double-first have so great a similitude that, two persons singing a song – I take an old person and a child, the latter singing a double-first higher than the former, but without knowing about double-firsts – usually for all they know they are singing the same note. Nay, we shall also prove here that this will sometimes happen even to the most experienced people. So great is this similitude, that it has an appearance of identity; therefore, when to the two above-mentioned voices producing the double-first is added a third voice, the same concord or discord that this third voice makes with one of them is also made with the other. If then, for instance, this third voice is a whole tone above the lowest voice, it produces therewith the discordant second and with the higher voice the discordant seventh of a similar character. But if the third voice is two whole tones above the lowest voice, it produces therewith the concord third, and with the highest voice not a discordant tone, but the concordant sixth of a similar character. And consequently, if the third voice produces with the highest voice a pleasant fifth, it cannot be unpleasant with the lowest voice, but produces therewith a pleasant concordant fourth. For this is a common rule that an identical tone is to the same in the ratio 1. To this might also be added the authority of the Greeks and their successors, who also regarded it in this way, but, leaving them alone, we shall come to the empirical proof.

If anyone considers the fourth a discord, saying that it is unpleasant to his hearing, the contrary and his error are proved to him as follows. Take any two different sounds, such as those of a string and a human voice, or a flute and a string, or a voice and a flute, producing therewith now a fourth, now a fifth, and

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[1]) Only some of the announced items will be discussed in the following pages.

[2]) A mode consists in the manner in which tones and semitones are distributed within the compass of an octave.

*) The *diatessaron.*

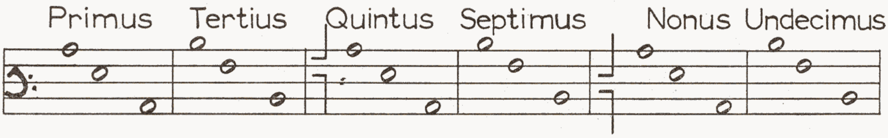
[3]) In a similar argument contained in the other draft Stevin quotes in his favour a treatise of Andreas Papius (1547—1581): *De consonantiis, seu pro diatesseron libri duo,* Antverp, 1581, Chrstph. Plantinus.

oock verscheyden vierden en vyfden hoogher en leegher, vraghende telck an syn partie wat het is dat hij sinct ende sullen daetlick bevinden dat hij sonder sekerheyt daer af oirdeelende sijn selven dickwils teghen sal spreken dicmael een vyfde achtende tgene hij te vooren een vierde seyde te wesen ende weder ter contrarie een vierde oirdeelende tgene hij te vooren een vyfde gheseyt had: Twelck soo daetlick blyckende wat behouven wij meer woorden? Wie isser soo onredelick die hem met sijn selfs woorden beschamen sal? segghende de vierde mishaeght mij ende de vyfde bevalt mij seer wel. Maer om deser dynghen oirsake wat breeder te verclaren soo is te weten dat als sulcke twee gheluyden tsamen een eerste ofte dobbel eerste maken dalderscherpste ghehoiren en connen niet sekerlick oirdeelen welck van tween het is. Om hier af by voorbeelt noch opentlicker te spreken ick neem datter twee sijn deen op de fluyte spelende dander synghende, elck sijn partie van eenich liedt ghesonghen ghelyckmen achten soude dattet behoort te wesen. Dit liedt daer naer noch eens overgaen maer alsoo dat den sangher een dobbeleerste hoogher ga dan te vooren, yder (om de reden als vooren te weten datter op een dobbeleerste na gheen sekerheyt en is) hooret voor goedt an, nochtans die toon daer den singher eerst een vyfde onder den fluter was daer sal hij nu nootsaecklick een vierde boven wesen. Inder voughen dat ghenomen het deerste mael een vyfde was soo salmen hier de vierde voor vyfde anhooren. Daerom de ghene die noch segghen dat de vierde in hun ooren mishaeghelick luyt, maer de vyfde seer bevallick, ick en siender niet beter af te besluyten dan dat de ghewoonte uyt de leest eeu ghesproten een weeckheyt in hemlien ghewortelt heeft.

Van de twaelf toonen

Alsoo ick van meijninge was met Meester Davidt te spreken van Sarlijns twaelf thoonen, soo verschreef ick de noten na mijn manier, om hem te bethoonen dattet twaelf waren. Maer alsoo ick vorder meende te bewijsen datter niet meer sijn en conden, bevant ter contrarie datter veertien waren: welck bewijs ick u hier sende. Dus wilt mij uijt den droom helpen, of u selven daer in brengen.

Sarlijns ses thoonen (die met haer contrarie twaelf souden maken) sijn, soo ghijse mij sendt, dusdanich.



this several times and also several fourths and fifths higher and lower, each asking his partner what it is that he is singing or playing, then we shall find in practice that, judging thereof without certainty, he will frequently contradict himself, often regarding as a fifth what he previously stated to be a fourth, and again conversely judging that to be a fourth which he had previously stated to be a fifth. This being found in practice, what more words do we need? Who is so unreasonable as to disgrace himself by his own words, saying: the fourth displeases me and the fifth pleases me very well? But to set forth the cause of these things somewhat more amply, it must be known that when two such sounds produce together a first or a double-first, the very keenest hearing cannot tell for certain which of the two it is. To speak of this even more clearly by way of example, I suppose that there are two persons, one playing the flute and the other singing, each having sung his part of a given song as one would consider it should be. If this song is thereafter repeated again, but in such a way that the singer goes a double-first higher than before, everyone (for the aforesaid reason, to wit that but for a double-first there is no certainty) thinks it is all right. Nevertheless, at the note where the singer first was a fifth below the flutist, he now inevitably will be a fourth above him, in such a manner that, taking that the first time it was a fifth, one now will hear the fourth as a fifth. Therefore, as to those who still say that the fourth sounds unpleasant in their ears, but the fifth very pleasant, I cannot but conclude that the habit grown during the last century has bred a certain effeminacy in them.

On the twelve modes[1]

As I intended to speak with Master David about the twelve modes of Zarlino, I copied the notes in my own way, to show him that there were twelve. But though I further meant to prove that there could not be more, I found on the contrary that there were fourteen, the proof of which I am sending you herewith. Therefore, please undeceive me, or be deceived yourself.

Zarlino's six modes (which would make twelve with their contraries[2]), as you send them to me, are as follows:

Figure 3. The principal notes of the odd numbers of the modes in the Dodekachordon of Glareanus, given to Stevin by a friend who took them from Zarlino.

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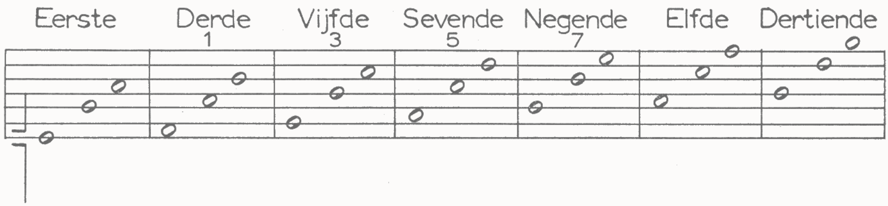
1) In the manuscript a chapter on the twelve modes, as given by Zarlino, is missing. We insert, as a substitute, a copy of a letter from Stevin to an unnamed person, preserved by his son Hendrick. Cf. Note B on p. 461.

2) Stevin refers to the *plagal modes* as contrary to the *authentic* modes. By the middle joint note the octave of the mode is divided into a fifth and a fourth. In the authentic modes the fifth is below the fourth, in the plagal modes the fourth is below the fifth. A pair of conjugated authentic and plagal modes, Stevin's *contrary modes*, share their fifths.

Dese stel ick na mijn manier (daer bij voughende de sevende anders de dertiende) aldus



Nu ist kennelick dat uijt de verscheijden plaetsen der halftoonen, onderscheijt wort de verscheijden aert van gesanc diemen verscheijden thoonen noemt. Daerom make ick seven gelijcke fugen in elcken toon een, als hier onder: Mette getippelte trappen beteecken ick tot meerder claerheijt, de plaetsen die op haer voorgaende note halfthoonen maken.

De selve segh ick altemael verscheijden te wezen: twelck ick aldus bewijse:

$4^{e}.8^{e}$. Deerste toon haar vierde en achste heeft halfthoonen.

$3^{e}.7^{e}$. T'verschil vande derde toon met d'eerste is, dat die haer derde en sevende note halfthoonen heeft dese heeltoonen.

$2^{e}.6^{e}$. T'verschil vande vijfde toon met de twee voorgaende is, dat die haer tweede en seste noten halftoonen heeft dese heelthoonen.

$5^{e}.8^{e}$. T'verschil vande sevende mette drie voorgaende is, dat die haer vijfde note halfthoon heeft dese heelthoonen; Voorts dat die haer achste note halfthoon heeft, maer de derde en vijfde hebbense heeltoonen.

$4^{e}.7^{e}$. T'verschil vande negende toon met de derde vijfde en sevende is, dat die haer vierde note halftoon heeft, maer dese hebbense heeltoonen; Voort dat die haer sevende note halftoon heeft, maer d'eerste vijfde en sevende hebbense heeltoonen.

$3^{e}.6^{e}$. T'verschil vande elfde toon met d'eerste, vyfde, sevende en negende is, dat die haer derde note halftoon heeft, dese heeltoonen; Voort dat die haer seste note halftoon heeft, maer de voorgaende eerste, derde, sevende, en negende, hebbense heeltoonen.

$2^{e}.5^{e}$. T'verschil vande dertiende toon met d'eerste, derde, sevende, negende en elfde is, dat die haer tweede note halftoon heeft, dese heeltoon: Voort dat die haer vijfde note halftoon heeft, maer d'eerste, derde, vijfde, negende en elfde hebbense heeltoon.

I arrange them in my own way (adding thereto in the seventh place the thirteenth mode), as follows:

Primus	Tertius	Quintus	Septimus	Nonus	Undecimus	
First	Third	Fifth	Seventh	Ninth	Eleventh	Thirteenth

Figure 4. The principal notes of the odd numbers of the modes, supplemented by a thirteenth of Stevin's invention. The small figures indicate the numbers of the ecclesiastical modes.

Now it is evident that it is by the different places of the semitones that the various kinds of music called different modes are distinguished. Therefore I make seven equal scales, one in each mode, as shown below. By the dotted steps I indicate, for greater clarity, the places which make semitones with their preceding notes.

Figure 5. Places of semitones in the various modes, indicated by the dotted lines.

I say that these are all different, which I prove as follows.

4th, 8th. The first mode has its fourth and eighth note making semitones.

3rd, 7th. The difference between the third mode and the first is that the former has its third and seventh notes making semitones, the latter has them making whole tones.

2nd, 6th. The difference between the fifth mode and the two preceding ones is that the former has its second and sixth notes making semitones, in the latter they make whole tones.

5th, 8th. The difference between the seventh mode and the three preceding ones is that the former has its fifth note making a semitone, the latter have it making a whole tone; further that the former has its eighth note making a semitone, but the third and fifth modes have it making a whole tone.

4th, 7th. The difference between the ninth mode and the third, fifth and seventh modes is that the former has its fourth note making a semitone, but the latter have it making a whole tone; further that the former has its seventh note making a semitone, but those of the first, fifth, and seventh modes make whole tones.

3rd, 6th. The difference between the eleventh mode and the first, fifth, seventh, and ninth modes is that the former has its third note making a semitone, the latter have it making a whole tone; further that the former has its sixth note making a semitone, but in the preceding first, third, seventh, and ninth modes it makes a whole tone.

2nd, 5th. The difference between the thirteenth mode and the first, third, seventh, ninth, and eleventh modes is that the former has its second note making a semitone, the other have it making a whole tone; further that the fifth note of the former makes a semitone, but the first, third, fifth, ninth, and eleventh modes have it making a whole tone.

Dese toonen met haer contrarien (welcke contrarien ick om cortheyt achter laet) maecken veerthien toonen, en niet meer en cander wesen, want d'eerstvolgende, twelcke in d'oirden de vijftiende waer, soude sijn als d'eerste, twelck ick bewijsen wilde.

Doirsaeck waerom Zarlin syn eerste toon niet en stelde als dander heeft goede reden overmidts daer duer verdorven soude sijn doirdentlicke voorganck der climming van deen toon tot dander dats van trap tot trap.

Want had hij deerste toon der ouden voor sijn eerste ghenomen soo en soude sijn elfde toon gheen trap hoogher gaen dan sijn voorgaende neghende maer vyf trappen leegher. Ende om de selve reden moet sijn tweede toon oock tot die selve plaets wesen.

Merckt dat ons 1e toon overcomt met haer 10e want sij beyden in *fa* sijn, alleenlick verschillense daer in dat dese hun middelste tsaemval een trap hoogher maeckt dan die. Sgelycx overcomt de 2e met de 11e, de 3e mette 12e, de 5e mette 7e, de 6e mette 8e. Wat de vierde en de 9e belanghen, sij en overcommen noch met malcander noch met eeniche van al dander.

Vant gemeen onderscheijt tusschen de gesanck diemen noemt Bemollaris ende Beduralis

Tgemeen onderscheijt datmen maeckt tusschen de gesanck diemen noemt *Bemollaris* end *Beduralis* is onnut, ende eijgentlick geen onderscheijt, maer al deselfde: Want geeft de C *sol fa ut* sleutel Bemol, den naem van G *sol re ut,* beduyer daer singende, ghij hebt al de selfde gesanck die in Bemol was. Tselve heeft hem alzoo gevende de sleutel van F *fa ut* Bemol, den naem van C *sol fa ut* Bedeur; Sgelijcx de sleutel G *sol re ut* Bemol den naem van D *la sol re* beduijer: Ofte geeft ter contrarie alle dese den naem van die, ende hebt al t'selfde. Ten is dan geen ander aert van gesanck als d'ander en vervolgens soo ist een onut onderscheijt.

Hoofstick waer in doirsaeck verclaert wort vande onvolmaecktheyt dieder int stellen der orghels ende clavesimbels ghebuert

Tgheen wij int voorgaende hooftstick vande vyfde MP gheseyt ende besloten hebben is ghenomen de selfde vyfde MP goet te wesen*) maer tghebuert in

*) Om twelck te bewijsen, soo is te weten dat alsmen syngt (soot derghelicken noemen) *gis* teghen *dis* opwaert als onder anderen Orlando en etc., tzelfde hooren wij een goede vijfde te wesen.

These modes with their contraries (which contraries I leave aside for the sake of brevity) make fourteen modes, and there can be no more, for the next, which would be the fifteenth in the series, would be identical with the first, which I intended to prove.

The motive why Zarlino did not locate his first mode like the others has good reason, since the regular progress of the ascent from one mode to the other, *i.e.* from step to step would have been disturbed by this. For if he had taken the first mode of the Ancients [1]) as his first, his eleventh mode [2]) would not be one step higher than his preceding ninth [3]), but five steps lower. And for the same reason his second tone must also be in the same place.

Note that our first mode corresponds to their tenth, because both are in *fa*.[4]) They only differ in that the latter makes its middle joint note one step lower than the former. Likewise the second corresponds to the eleventh, the third to the twelfth, the fifth to the seventh, the sixth to the eighth. As to the fourth and the ninth they correspond neither to one another nor to any of all the others.

On the Usual Distinction between the Singing that is called Bemollaris and Beduralis.[5])

The usual distinction that is made between the music that is called *Bemollaris* and *Beduralis* is quite useless and is no real distinction, but they are the same thing. For if you give the C *sol fa ut* key, where B is flattened (Bemollaris), the name of G *sol re ut,* singing B natural thereto (Beduralis), you have entirely the same music that was written with B-flat. The same is found when the F *fa ut* key with flattened B is given the name of C *sol fa ut* with B natural, and likewise when the G *sol re ut* key with flattened B is given the name of D *la sol re* with B natural. Or if conversely you give all the latter the name of the former, you will have the same. It is thus no other kind of music than the other, and consequently it is a useless distinction.

Chapter in which is explained the Cause of the Imperfection that arises when Organs and Harpsichords are tuned

What we have said and concluded in a former chapter [6]) about the fifth MP is the finding that this same fifth MP is good,*) but it happens in different in-

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[1]) on *d.*
[2]) on *c.*
[3]) on *a.*
[4]) Stevin here writes *fa* for *c.* This agrees with his nomenclature in figure 1 (p. 436).
[5]) Cf. Note C on p. 463.
[6]) See note [1]) on p. 437. - Cf. Note D on p. 464.
*) To prove this, it is to be noted that if one sings (as people sometimes call it) *g*-sharp against *d*-sharp upwards, as Orlando, among others, etc., we hear this to be a good fifth.

verscheyden reetschappen soo dervaringh betuycht datse deenmael een weynich te groot valt dandermael een weynich te cleen, somtijts oock goet, maer wantse int spelen niet, oft maer seer weynich ghebruyckt wort, soo latent veel meesters diese stellen, blyven by tgheen tgheval uytbrenght overmidts al de rest diemen besicht sooveel tghehoir belanght, goet ghenouch is. Maer om te verclaren donverclaerden oirsaeck waerom dese vijfde . . . inde voorsz. reetschappen niet soo recht te treffen en is als de natuerlicke ghesanck der menschelicke stemmen die betuijcht te moeten wesen, soo dient verstaen te worden de ghemeene onvolmaecktheijt des werckelicken handels in alle stoffen, welcke niet soo volcommentlick ghelyck de wisconstighe te treffen en is. Als by voorbeelt een stuck lywaet van 50 ellen duer verscheyden persoonen voorsichtelick ghemeten d'een sal een stroobreet ofte duijm meer vinden als dander, Doch soose teenemael ende gants effen uyt commen sonder een haer te verschillen, sulcx ghebuert selden ende by ghevalle, sgelycx heeft hem alsoo int meten der vlacken, lichaemen ende ander stoffen als tijt, roersel, swaerheijten; Oock mede inde stof des gheluyts daer ons verschil af is. Want men can gheen twee gheluyden als der vierde, vyfde of seste etc. alsoo passen dat sijt in duyterste volcommenheyt sijn, ten waer bij ghevalle; daer af oock gheen bewys en can ghedaen worden. Maer om dese werckelicke onvolmaecktheyt duetlick te bethoonen, soo leght den bandt van een luyt ter plaets daer u dunckt haer snaer teghen een ander snaer de volmaeckte vyfde te maken, verschuyf daer naer dien bandt alleenlick soo veel als de dickte van een haer opwaert of neerwaert ende sult bevinden datter gheen merckelicke verandering duer en ghebuert niet teghenstaende datter voor seker eenighe verandering gheschiet. Doch soo ghij vermoedet ende u selven toegaeft die valsheijt der vyfde te bemercken soo laet die verschuijving des bandts duer een ander persoon ghedaen worden, alsoo dat ghij niet en weet of hyse de breede van een haerken opwaert of neerwaer schuyft, ofte op de selve plaets laet; hij u alsoo tot verscheydenmael vraghende na de goetheyt der vyfde sult daetlick u oirdeel onseker bevinden, dicwils de goede quaet segghende ende de quade goet. Tis dan openbaer dattet gheen menschelick ghehoir mueghelick en is hoe scherp het sij twee toonen in haer uyterste volcommenheyt heel seker te passen. Waer uyt volght dat veel sulcke feylen die elck int besonder onbemerckelick sijn, nochtans tsamen een merckelicke dwaling maken; Want ghelyck in tvoorseyde stuck lywaet duer verscheyden persoonen ghemeten veel cleyne verschillekens op yder elle tsamen opt einde eenich merckelick verschil maken, alsoo hier ook inde gheluyden. Want overmidts dese vijfde... seer selden ghebruyckt wort soo laetmen die cleyne onbemercklicke feylkens daer op al ancommen welcke ten einde altsamen bemercklick connen sijn, somtijts oock onbemerckelick na tgheval. Daerom en ist gheen wonder dat de bovenste meesters sulcke reetschappen voorsichtelick stellende int laetste nochtans quade toonen ontmoeten die goet behooren te wesen, maer tis natuerlick. Ende diet niet en verstaet hem ghebreeckt de kennis des onderscheyts tusschen werckelicke ende wisconstighen handel, twelck wij bewysen moesten.

struments, as experience shows, that at one time it turns out slightly too large, at another time slightly too small, sometimes also good; but because in playing it is used very little, if at all, many masters who tune the instruments leave it to chance, since all the rest that is used is good enough as regards the ear. But to explain the unexplained cause why this fifth on the aforesaid instruments cannot be hit off as right as the natural singing of human voices testifies it should be, the common imperfection should be understood of practical operation in all matters, which cannot be performed as perfectly as mathematical operations. Thus, for instance, when a piece of linen of 50 yards is carefully measured by different people, one will find a strawbreadth, or an inch more than another. But it seldom happens, and then accidentally, that they all arrive altogether and quite alike at the same result. The same also applies in the measurement of surfaces, solids, and other things, such as time, motion, weight, and again in the matter of sound, which is our point in question. For one cannot match two sounds, such as make a fourth, a fifth or a sixth, etc. in such a way that these intervals are quite perfect, unless by chance; nor can they be proved to be so. But to show this practical imperfection clearly, place the fret of a lute in the place where you think its string will make a perfect fifth against another string. After this, shift this fret over the thickness of a hair only, upwards or downwards, and you will find that no appreciable change takes place, although, to be sure, some change does take place. But if you surmise and concede to yourself that you perceive this falseness of the fifth, let the fret be shifted by someone else, in such a way that you do not know whether he shifts it a hair's breadth upwards or downwards, or leaves it in the same place; when he several times thus inquires of you after the goodness of the fifth, in practice you will find your judgment uncertain, often saying that the good fifth is bad and that the bad fifth is good. It is therefore obvious that no human hearing, however keen it may be, is able to fit two tones quite surely in their perfection. From this it follows that many such mistakes, each of which in itself is inappreciable, yet in combination produce an appreciable error. For as in the aforesaid piece of linen measured by various people many small differences in every single yard, added together, finally make an appreciable difference, so here in the case of sounds too. For since this fifth MP is very rarely used, one let these tiny inappreciable errors drift, which together may finally be appreciable, sometimes also inappreciable, as the case may be. Therefore it is not astonishing that superior masters, tuning these instruments carefully, nevertheless in the end find bad notes which ought to be good; this is but natural. And whoso does not understand this, lacks discrimination between practical and mathematical operations, which we had to prove.

NOTE A, referring to pp. 431/432

In his loose reference to Zarlino, tainted with some derision, Stevin does not do justice to the problem Zarlino was trying to solve. Representing the pitches of the common scale by

$$c \quad d \quad e \quad f \quad g \quad a \quad b \quad c' \quad d' \quad e' \quad .. \quad etc.,$$

according to the theory of Ptolemy adopted by Zarlino, in the triad *c, e, g* the note *e* was the harmonic mean between *c* and *g*. The latter making a perfect fifth, *c* and *e* make a perfect major third. The triads *f, a, c'* and *g, b, d'* were transpositions of the same triad. Thus the numbers assigned to these major chords are $24:30:36 = 32:40:48 = 36:45:54$ ($= 4:5:6$) respectively. This procedure entails a difference of one comma in the whole tones $(d:c)$ and $(e:d)$, with the ratios $^9/_8$ and $^{10}/_9$ respectively; likewise in the whole tones $(g:f)$ and $(a:g)$. It follows that $(a:d)$ is one comma short of a fifth (ratio $^3/_2$). For a transposition of a melody from $c:d:e$ to the initial note *g*, one therefore needs a note α, one comma sharper than *a*. This note can be readily produced in singing, but once an organ pipe or a harpsichord string has been tuned to *a*, it cannot suddenly be brought to α. Zarlino sought for a compromise, by which he might make slight alterations in the pitches that would not disturb the harmonies too much. Suppose we strain the fifth a little bit, by an amount *x*, and the major third by *y*, then the pitches of the common scale will become c, $(d + 2x)$, $(e + y)$, $(f - x)$, $(g + x)$, $(a - x + y)$, $(b + x + y)$, c', $(d' + 2x)$.

We want the new fifths to be equal, therefore

$$(g + x) - c = (a - x + y) - (d + 2x)$$
$$(g - c) - (a - d) = -4x + y = \text{comma.}$$

Likewise there is equality of the new seconds

$$(d + 2x) - c = (e + y) - (d + 2x), \text{ and again}$$
$$(d - c) - (e - d) = y - 4x = \text{comma.}$$

Now, if by a kind of equipartition, the fifth being nearly double the third, one chooses for the strains a relation $x = 2y$, then the solution is $x = -^2/_7$ comma, $y = -^1/_7$ comma. This is the solution which Zarlino offered in his *Institutioni* 1558, Parte II, cap. 43) and to which Stevin refers. Obviously less damage is done to the fundamental intervals if one puts $y = 0$, hence $x = -^1/_4$ comma. This solution was put forward by Zarlino in his *Dimostrationi harmoniche* in 1571 (Ragionamento quinto). Full credit for the first description of this solution is given by Barbour to Pietro Aron (Venice, 1523). Stevin does not mention it. For him the problem does not exist, or rather: he puts $x = -^1/_{12}$ comma, this being the difference between his fifth and the Pythagorean fifth of $^3/_2$.

Therefore the damage done by his equal temperament to the perfect third of $^5/_4$ amounts to $y = ^2/_3$ comma. That solution of the tuning problem was discussed by Zarlino in 1588, in his *Sopplementi musicali* (Libro quarto, cap. 28). Stevin does not mention this at all.

NOTE B, referring to pp. 452/453

In this letter, which is not preserved in his own handwriting, Stevin tentatively enumerates two more, *i.e.* fourteen different modes. In the diagram he indicates by minims (half notes) the principal notes of the odd modes, the so-called authentic modes. These notes are the points of convergence for melodic lines in singing. We believe that Stevin calls *tseamval* (coincidence) the principal note in the middle which joins the fourth and the fifth that constitute the octave. The fact that, against his usual method, he nowhere gives a definition of this term, shows that his work is not complete. The final and initial note of an authentic, odd mode becomes the principle note in the middle of the following even mode, which is called a plagal mode. It turns out that the first and the eighth mode have the same division of the octave, but the difference lies in the positions of the principal notes. In the third diagram[1]), by the added numbers Stevin indicates

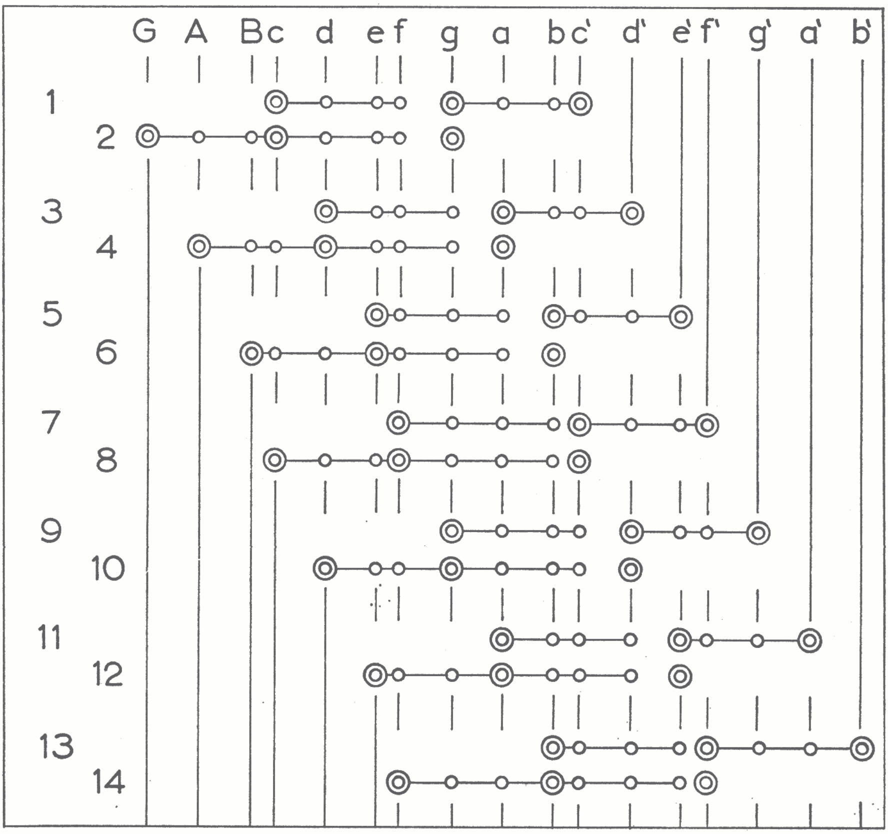

Figure 6. The twelve modes of Zarlino, supplemented with numbers 13 and 14 by Stevin. The latter contain in f : b and in b : f' an augmented fourth and a diminished fifth respectively.

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1) Fig. 5 on p. 454.

the similar octaves. For the even mode in question the minim must be put one note lower than for the odd mode. Stevin's thirteenth and fourteenth modes show between the principal notes the discord of a diminished fifth or an augmented fourth. For this reason they had been rejected by Zarlino.
The numbers 1, 3, 5, 7 in Stevin's second diagram refer to the ecclesiastical modes.

In the accompanying diagram the editor gives a full exposition of all these modes (*met haer contrariën*). The editor has also added the title of the chapter and the line beginning with 4e.8e on p. 454.

The last two paragraphs are in Stevin's own handwriting again. He compares his own and Zarlino's numbering of the modes with the numbering of the ecclesiastical modes first. It is not clear what numbering the manuscript refers to in the last paragraph. I keep the numbers as written by Stevin. The correlation between pairs of modes as pointed out by him is found in the pairs (1,8), (2,9), (3,10), (4,11), (5,12), with 6 and 7 solitary.

NOTE C, referring to pp. 456/457

Stevin remarks that one might do without a sign for flat at the beginning of the stave. By a simple transposition, choosing an appropriate clef, a tune can be written without such a flat. He says that if you prescribe a *b*-flat, having *c* on a certain line of the stave, then, by changing the clef you can place *g* on this line. By the same notes on the same lines, without a flat, the same melody comes out as before, written with a *b*-flat.

In a similar way, in figure 1, p. 436, placing *ut* on the key for *g*, *sa* came out on the key for *f*, and there was no need for a black key.

In Stevin's days no importance was attached to absolute pitch. That is the gist of his remark.

The same change of clef transforms the stave line for *f* into a line for *c*, and the line for *g* into a line for *d*.
An example is shown in figure 7.

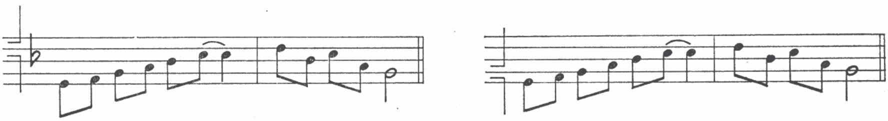

Figure 7. A simple melody: re mi fa sol la sa – ut la sa sol fa –, where sa has been written as b-flat and as f, respectively.

NOTE D, referring to pp. 458/459

This discussion more or less completes the argument in the former chapter on the true ratios of natural tones, pp. 434-435, where the tuning was described of a harpsichord. There the tuning started from F and resulted in a tone H (our A-sharp or B flat) that by ear was to be judged a perfect fifth below F.

The present argument presumes that the tuning has started from K or P (see figure 1, our E-flat), and led to M (our G-sharp). Stevin's contention here is that M and P (G-sharp and *e*-flat) make a perfect fifth. In the note where he refers to other people's meaning, M and P are called *g*-sharp and *d*-sharp. This is the only place where Stevin writes sharps.

It is quite remarkable that Stevin, discussing the possibility of perfect tuning, nowhere mentions that listening to beats of simultaneous sounds offers a powerful means for judging the accuracy of tuning.

CIVIC LIFE

BY

SIMON STEVIN

EDITED BY

DR. ANNIE ROMEIN—VERSCHOOR

INTRODUCTION[1])

The work of Simon Stevin of Bruges shows the versatility of the practical genius in a time when science did not yet pride itself on its specialization. At first Stevin was a bookkeeper and tax official; then, having probably fled his native city from fear of Alva, after ten years of wandering through half Europe he became a student and soon also a lecturer at Leiden University, the teacher, counsellor, engineer, fortification expert, estate steward, and commissariat officer of Prince Maurice, as well as a writer of pioneering works on mathematics, mechanics, and bookkeeping, and of a number of curious essays on architecture, on the theory of music, on the use of language, and on what he called political subject-matter ("burgherlicke stoffen") — we should now say: on political science and law. The following work *Het Burgherlick Leven* is an example both of the latter kind of essay and of his advocacy of the pure use of the vernacular in scientific work.

Anyone who considers this activity too variegated to believe in its high level should bear in mind: 1. that, as stated, in Stevin's day the intellect knew hardly any division of labour as yet; 2. that all this work, both that chosen by himself and that entrusted to him, reveals *the* one guiding central idea which has sometimes been regarded as the hallmark of genius. For Stevin this is invariably the idea of order and law, to be searched for in nature, with the negation of the miraculous, and to be established in human relations, with the rejection of all that is unlawful and savours of disturbances.

Too little is known about Stevin's youth to enable us to decide whether this preference may partly have been due to the fact that, as has been discovered by the official of the Bruges Record Office, Mr. Schoutteet, he was an illegitimate child. When Catharina van der Poort, a girl from a distinguished Bruges middle-class family, who seems to have been rather unconventional, married Joost Sayon, she already had two "bastards" with Noeël Caron and a "natural son" Symoen with Antheunis Stevin.

But there were more serious motives for Stevin's sense of order than the accident of his birth. He grew up amidst the turmoil of civil war and was forced by it to give up his quiet existence and to become an exile; but it was also a period in which science was thrown out of its speculative isolation by the questions which practice asked of it, turned to the reality of experiment and investigation, and reduced one wonder of nature after another to a process taking place according to fixed laws. To the grand work of Copernicus, Tycho Brahe, Galileo, Kepler, and others, the worthy counterpart of the discoveries of Columbus and Vasco da Gama, Stevin made valuable contributions in the domain of mechanics: his *Beghinselen des waterwichts* (The Elements of Hydrostatics) and *Beghinselen der weeghconst* (The Elements of the Art of Weighing), and what he himself called the "rule of rules", algebra, for which he developed the first efficient system of notation.

Fate decreed that his very desire to make his work accessible to as wide a circle of readers as possible led to its not being incorporated in European thought, and that, when his restless active life was at an end, he himself was

[1]) By kind permission of the author, this Introduction has been translated from the Dutch edition of 1939 (Amsterdam, Wereldbibliotheek).

practically forgotten and most of his discoveries were made again by later scientists. Stevin himself had entered science from the practice of applied arithmetic. He had found how great was the need of a manageable mathematical apparatus felt by merchants, architects, surveyors, and the like. And although he proceeded with great scientific rigour in his writings — at least according to the standards of his time —, serving science for its own sake was to him pure nonsense: "Just as it would be useless expense to lay large and strong foundations which can support a heavy edifice without ultimately wishing to erect any building thereon, thus in the elements of the arts theory is labour lost when the end does not tend to practice", he wrote in the introduction to *The Practice of Weighing* [1]). Making science subservient to practice, this meant renouncing the solemn Latin of scholars — which was undoubtedly no hardship to Stevin, since he had received no university education — and addressing his audience in the vernacular. He did so in the lessons which he himself gave at Leiden, he prescribed it in the instructions which in 1600 at the request of Prince Maurice, who was in great need of trained forticification experts, he drew up for Simon van de Werven and Ludolph van Keulen to teach "in good Dutch language arithmetic and surveying, principally for the benefit of those who would wish to become engineers" [2]).

The extent to which Stevin's personal preference for his native language coincided with the demands of practice on this point appears from a list of the "students" who attended these courses: they included "sworn surveyors" and one teacher, but also "stone-cutters, carpenter's mates, and masons" [3]).

In writing too, Stevin considered it his duty to express himself in the vernacular, and to supply the deficiency of the vocabulary required for this task by the formation of series of new words. In consequence of this, some of his innovations, such as the introduction of decimal fractions, undoubtedly were accepted more readily in practice, but on the other hand he thus also cut himself off irrevocably from the small circle of European scientists who possessed in Latin a means of intercourse with each other, making it impossible for others to develop his ideas. One may regret this, but this loss, which in itself is already difficult to evaluate, becomes altogether uncertain if we set over against it the considerable, but unapparent and diffuse effect of Stevin's directly transmitted knowledge. The fact that his writings are of a lucidity that is quite unusual for his time makes it probable that he must have been an excellent teacher, and by this not only his Leiden pupils and Prince Maurice, but also all those whom he directed in his numerous organizing functions will have benefited. A teacher and a man who cannot help influencing his people with his ideas, which — this is evident from his whole argumentation — he himself finds so obvious and convincing, as such he again presents himself in the following essay, which falls slightly outside his usual sphere of action.

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1) "Ghelijck onnutte cost waer een groote, stercke grondt te legghen, die een swaer gesticht dragen can, sonder eintlick eenich ghebau daerop te willen brenghen, also is de spiegheling in de beghinselen der consten verloren arbeydt, daer 't einde totte daet niet en streck."

2) "... in goeder duytscer tale die telconste ende landmeten principalycken tot bevordering van de geenen, die hem souden willen begeven totten ingenieurscap."

3) "... ghesworen landmeters... steenhouwers, timmergesellen en metselaers."

Het Burgherlick Leven dates from 1590, and the references to "onse binnen-Landse verschillen" (our internal discord) corroborate the supposition that this small handbook for the good citizen is the result of speculations inspired by the disturbances during the period of Leicester's governorship. It is a striking feature that the essay itself avoids practically all allusion to contemporary reality: Athens, Rome, and Switzerland are mentioned as examples of a republic, but the Republic of the United Netherlands is not referred to, and where the right to revolt against a tyrant is discussed, one vainly looks for the names of King Philip II of Spain and the Prince of Orange. All this demonstrates a certain scientific as well as practical caution as well as that peculiar and apparently inconsistent blend of theoretical straightforwardness and flexible — even extremely opportunist — adaptation to practice which characterized his whole activity.

Straightforward is his predominant demand of order and law, a demand typical of a post-revolutionary period. The sixteenth century with its victory of the modern unitary state over feudalism, of central authority over civil war and lawlessness, on the whole greatly venerated a strong, central authority protecting the quiet citizen in his trade and occupation. Stevin fully shares this veneration, and is therefore prepared to recognize the central government as the supreme authority also in the Republic — this is one of the few passages in which the Republic is mentioned by name — and to subordinate to it the old privileges of the cities and provinces, for whose defence against King Philip's central authority the Union had been formed.

It appears to us typical of a post-revolutionary period, this extreme upholding of authority, which does not permit infringement of the law on the ground of any imperative ethical or religious conviction, but solely on the ground of tradition or the fact that the infringement is becoming general: thus, for instance, when general valuation begins to depart from the value of the currency as established by the authorities.

Post-revolutionary are also his views of religion and religious liberty, and this is all the more striking because the revolt of the Netherlands had had a strongly religious character. Anyone who should expect that here, where Stevin clearly expresses his views of the value of religion and the rules of ecclesiastical policy, will be found the solution of the mystery of his own creed, on which all biographical data leave us in the dark, will be disappointed. The usefulness of religion as an element making for order comes first with him, apart from any creed, and the image of God emerging from this essay is literally that of the bogey.

The atheist or libertine — thus Stevin argues — commits a social sin when in front of others, and especially in front of his children, he robs this bogey of its authority. And what about the religious liberty of the various creeds among themselves? Here again the rules are simple according to Stevin's straightforward views. Again: the law decides. To him the case where it should prescribe universal liberty appears hypothetical; for the rest, anyone not adhering to the prevalent church should either conform or leave the country. If he considers it his duty to propagate his creed, let him go to the savage heathens, where, as Stevin thinks, he will not come into conflict with any divine and human laws in his missionary work. It will be obvious that Stevin was equally alien from Loyola and from Calvin or Luther. However rationalistic the doctrine of the former two in particular may be in many respects, such a complete utilization of religion for "reasons of state" would only have roused their horror.

What gives these "reasons of state" their peculiar character is that in Stevin's political conception the "Gottesgnadentum", royalty as a divine institution, which usually was the factor determining those reasons, is practically absent. He does distinguish different forms of government with and without an "absolute monarch", but it is evident that the state essentially to him is the symbol of the community of the citizens. A community, indeed, which is mathematically organized on the principle of "the most votes carry the day" or "the most important votes carry the day", and from which anything departing from the straightforward system is automatically banished and has to draw the consequences from this. A symbol, indeed, which has become an independent thing and has taken over the rights of the community, as the shadow in Andersen's fairy tale did that of his master.

It is striking how in this conception of the political and national community Stevin, who advocated one of the binding elements of the national community to which he himself belonged, the Dutch language, with such fervour, denied any organic cohesion to this community. This is plain from his last chapter, in which he summarizes his views. It is not to a family that he there compares his ideal national community, but to a boarding house. If you take lodging there, you will have to conform to the rules of the house; if you do not like them, choose other lodgings which suit you better.

Is it merely the spirit of the age speaking here, the spirit which after the bloody discord of the late Middle Ages and of wars of religion made stability and order its predominant ideal, the sober spirit of the merchant, who had no other desire except safe roads and secure markets for his goods? Or is it also the spirit of the fatherless child, of the exile, a word the bitterness of which is felt again in our day by so many people who, uprooted from their native soil, have as their only directive *ubi bene ibi patria?*

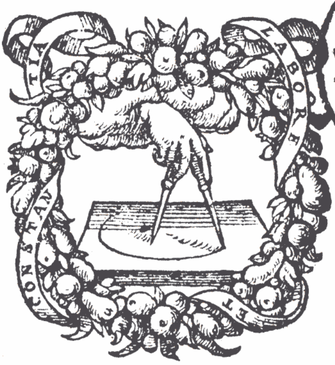
The present-day reader of Stevin's *Burgherlick Leven* should read it primarily as a monument of the Dutch language, as a specimen not only of exceptional personal style qualities, but also of the way in which a young nation created a civilization of its own and in its scientific language produced an individual instrument of civilization. But it is insufficient as a means of becoming acquainted with Stevin the man and the scholar, and it would be unfair to use it for this purpose. Anyone who wants to become familiar with *him* should study his mathematical works as well as his life, so rich in action and useful to the nation.

VITA POLITICA.

HET Burgherlick leuen,

Beſchreuen deur

SIMON STEVIN.



TOT LEYDEN,
By Franchoys van Ravelenghien.
CIↃ. IↃ. XC.

Goetwillighe Leser.

T'waer wel te wenschen / dattet de ghewoonte daer toe ghebrocht hadde / dat ettelicke Duytsche woorden gheen verclaringhe en behoufden duer Griecksche ende Latijnsche / maer dat dese overlanck haer verclaringhe ghenomen hadden uyt die / want sulcx van het menschelick gheslachte soude gheweert hebben veel onwetentheyt / leeckheyt / ende misverstant / daert langhe in gheswermt heeft / duer ghebreck van tale / die de sake eyghentlick mochte uytbeelden. Doch also dit niet ghebeurt en is / wy sullen ons gheboughen na tghebal des teghenwoordighen tijts / stellende inde canten der volghende bladeren / neven sommighe ghoede Duytsche woorden / haer ergher ghewonelicke Griecksche ende Latijnsche.

DEAR READER.

It were to be wished that custom had caused many Dutch words to need no explanation by means of Greek and Latin words, but that the latter had long been explained by the former, for this would have prevented among mankind a good deal of ignorance, inexpertness, and misconception, in which it has abounded for a long time, through lack of a language capable of expressing the matter properly. But because this has not taken place, we shall conform to present-day usage, placing in the margin of the following pages, by the side of certain good Dutch words, their inferior customary Greek and Latin equivalents.

Simon Steuin wenscht
DHEER
GOVERT BRASSER
BVRGHMEESTER
DER STAT DELF
veel ghelucx.

DEN dien datter tot veel verscheyden plaetsen groote veranderingen inde regieringhe vallen/alwaer deen dese/dander die sijde anhangt/ ende elck het sijne voor tbeste drijft, soo rijst daer uyt tusschen de menschen groot verschil inde * ancleuinghen der Burgherlicheyt, te Adiunctis politiæ. meer datter veel tot verscheyden fortuynen gheraken, deen tot hooghen staet dander tot een schricklick einde, alwaer ghemeenelick de vraghe is, wie hem * Bur- Politicè.

SIMON STEVIN WISHES MR. GOVERT BRASSER, BURGOMASTER OF THE CITY OF DELFT, MUCH HAPPINESS.

Because in many different places great changes take place in the government, with one adhering to this and another to that side and each considering his own party best, this gives rise to great difference of opinion among people on what belongs to good citizenship, the more so because many people meet with different fortunes, one reaching a high position and another coming to a dreadful end, in connection with which it is commonly asked which of them behaved as a good gherlick ofte onburgherlick ghedraghen heeft. Maer want het oirdeel van velen hier in gantsch onbescheyden is, streckende niet alleen tot haer eyghen schande, maer oock tot ontstichtinghe der gantsche ghemeente, soo is mijn voornemen haer misverstant te ontmoeten, met sulcke redenen als my

Materia. van die * stof nu te voren commen,

Vitam politicam. ende tot een recht * Burgherlick leven bequaemst duncken. Hier toe heeft my noch vlietigher ghe-

Opinio. maect, ons ernstich * vermoeden (wie en worter van het sijne niet gheregiert?) vande wonderlicke verborghen eyghenschappen der Duytsche sprake, om inde welcke my met besonder wellust te oeffenen, hebbe daer toe vercoren dese

Materiam politicam. * Burgherlicke stof, ende die ghe-

brocht

or a bad citizen. But because the judgment of many people in this matter is quite inconsiderate, tending not only to their own disgrace, but also to the perversion of the whole community, I intend to counter their misconception with such arguments as now occur to me with respect to this subject-matter and appear most suitable for a righteous civic life.

I have been induced to do so all the more diligently by my serious conviction (and who is not governed by his own conviction?) about the wonderful hidden properties of the Dutch language, and in order to practise myself in this with particular relish, I have selected for it this political subject-matter and cast brocht tot sulcke form, ghelijckse uwe Eerweerdicheyt hier toegheeyghent wort. Ende welcke een recht ghevoelen van dien seer angenaem wesende (also dat betuycht de gheduerighe vliet ende neersticheyt, die ghy tot voorderinghe ende bescherminghe der * Ghemeensake ghewillichlick anneemt, met grooter onrust sonder eyghen prouffijt) en twijffel niet, of ghy en sult onse goede meyninghe, al waer inde reste ghebreck, ten besten duyden. Angaende de cleenheyt deses wercx, twelck yemant niet sonder eenighe reden straffen mochte, om de oneindelicke voorbeelden, ende verscheyden * ghevallen, daerment mede soude hebben connen verbreyden: Hier af sal my ontschuldighen, eensdeels onse gheneghentheyt tot

Reipublicæ.

Casus.

 cortheyt,

it in the form in which it is here dedicated to Your Honour. Since a correct view of this is very pleasing to you (as is testified by the constant diligence and zeal which you willingly apply in order to further and protect the commonwealth, with great discomfort and without profit to yourself), I do not doubt but you will appreciate my good intentions, even if the rest be deficient. As to the shortness of this work, which might be reproved with some reason in view of the endless examples and different cases with which it might have been amplified, the cortheyt, ten anderen teghenwoordighe oeffeninghe in * Wisconstighe daet, daer mede wy hopen te doen nutten dienst an tghemeene landt, ende vervolghens behaeghelicke wercken an uwe Eerweerdicheyt; die ick met een Burgherlick ghemoet, in sijn Burgherlicke regieringhe, wensche een lanck gheluckich Burgherlick leven.

* Praxi Mathematica.

CORTexcuse for this must be on the one hand my love of briefness and on the other hand my present mathematical work, with which I hope to perform a useful service to the whole country and consequently works pleasing to Your Honour, whom with a civic mind I wish a long and happy civic life in your civil government.

CORTBEGRIP.

Argumentum.

ALSOO ons voornemen niet en is, dese * stof des Burgherlicx levens, int langhe ende breede te beschrijven, noch de sake voorvoets op * van ghestacht tot afcomsten te vervolgen, waer toe ons tijdt en wille ghebreect, sullen alleenlick roeren de voornaemste ende nootelickste twijfelachtighe punten, van welcke tusschen de menschen daghelicx de heftichste * verschillen vallen: Te weten, Eerst * bepalende het Burgherlick leven, sullen daer na segghen welcke eens * Burgherlicx persoons rechte overheyt sy: Voorts hoemen hem * Burgherlick draghen sal inde * binnelantsche twisten: Inde regieringhe:

Materiam vitæ politicæ.

A genere ad species.

Quæstiones.

Definiēdo.

Politici.

Politice.

Intestinis bellis.

ARGUMENT

Because it is not our intention to describe this subject-matter of civic life at length or to pursue it step by step from genus to species, for which we lack time and inclination, we shall only touch upon the principal and most essential doubtful points, on which there are daily the most violent differences of opinion among people. Therefore, first defining civic life, we shall subsequently say what is the rightful authority governing a citizen; next, how one is

Inde wetten die wy achten ons niet te verbinden, die twyfelachtich sijn, ende teghen malcander strijden: Inde Religie: Ende ten laetsten van het Burgherlick leven int ghemeen, alles vervatende onder acht * hooftsticken.

* Capitibus.

to behave as a good citizen in internal discord: in government; in the laws which we regard as not binding us, those which are dubious, and those which contradict each other; in religion; and finally of civic life in general, the whole to be contained in eight chapters.

HET BVRGHERLICK LEVEN,

Beschreuen deur

SIMON STEVIN.

Eerste Hoofstick vande bepalinghe des Burgherlicx leuens.

Primum caput de definitione.

De ghemeenten om bevrijt te sijn voor allen anstoot haerder nabueren, en der vreede volcken, hebben hun stercke plaetsen ghemaect, diese int ghemeen Burghen hieten, ghelijcker noch veel van dien den naem behouden, als Middelburch, Oudenburch, Straetsburch, ende meer ander. De inghesetens dier burghen noemden sy Burghers, ghelijckmen de inghebooren van Haerlem, Haerlemmers heet. Dese Burghers, om vreedsamelick met malcander te connen leuen, hebben seker rechten, wetten, insettinghen, keuren, oude ghebruycken, ende int ghemeen ghesept, reghelen, daer sy na leven. De

selve

CIVIC LIFE,

described by
SIMON STEVIN

1ST CHAPTER
of the definition of civic life.

In order to be protected from any attacks of their neighbours and of foreign peoples, communities have made their strongholds, which they generally called "boroughs", many of which still preserve the name, like Middelburg, Oudenburg, Straatsburg (Strasbourg), and many others. The inhabitants of those boroughs were called burghers, just as the natives of Haarlem are called Haarlemmers. In order that they may live together in peace, these burghers have certain rights, laws, institutions, privileges, old customs, and, stated generally, rules according to which they live. These are of three kinds, *viz.* civil, natural, Ciuiles. selve sijn driederhande/ te weten * Steetsche / Natuerlicke / ende Goddelicke. Steetsche * bepaeltmen die tot onderhout van Steden / of menschelicke versamelinghen / na den eysch der plaetsen/ persoonen/ ende tijden beroirdent worden. Natuerlicke noemtmen/die overal eeuwelick blyven/ende yeder duer ghemeene wetenschap / ende ingheboren gheneghentheyt bekent sijn. Goddelicke reghele heetmen die de Goddelicke saken angaen/ als oirdeninghe der Godsdiensten/ende dies anclevende/ welckmen anders gemeenelick deur een uytheens woort Religie noemt. De bovenschreven wetten ende ghemeene reghelen/also de staet der Burggerie daer uyt haer form crijcht/ worden * Burgherlicheyt gheheeten. En die hem inde selve so draecht/ datter in dit leven/ de gemeentens grootste ruste en welvare uyt volght/ een * Burgherlick persoon. Ende sulcke rechte oeffeninghe / een * Burgherlick leven/van twelcke wy voorghenomen hebben de volghende beschrijvinghe te doen.

definiuntur.

Policia.

Politicus.

Vita politica.

2^e Hooftstick welcke eens Burgherlicx persoons rechre ouerheyt sy.

WAnneer eenighe der voornomde wetten of reghelen / met yemants ghevoelen gantsch overcommen / sonder

dat

and divine rules. Civil rules are defined as rules which are ordained for the maintenance of cities or human assemblies according to the requirements of places, persons, and times. Natural rules are those which are permanent everywhere and which are known to all by common knowledge and innate inclination. Divine rules are those which relate to divine matters, such as ordinances of religions and what belongs thereto, which otherwise are usually called, by a foreign word, *"religie"*. Because the organization of the citizens receives its form from the above-mentioned laws and common rules, they are called good citizenship. And a man who so behaves himself in it that the greatest stability and welfare of the community results from it in this life is called a civic person. And such proper practice is called a civic life, of which we propose to give the following description.

2ND CHAPTER

as to which is the rightful authority governing a citizen.

If more of the aforesaid laws or rules agree completely with a man's views, without one kind being in contradiction with another, it is easy in such a case

dat deen * afcomst teghen dander strijt/ Species.
soo is hem de * Burgherlicheyt in dien Politia.
ghevalle licht om treffen/ ja soo open-
baer/ datter gheen onderwys en behouft:
want volghende Rechts sijn eyghen ghe-
moet/ hy doet daer in * Burgherlick; in- Politic i.
der voughen dat daer af hier niet te seg-
ghen en valt. Maer wetten ende costuy-
men/ die na sijn oirdeel onrecht syn/ of
datse teghen malcander strijden/ also dat-
tet volbrenghen van deen/ overtredinghe
van dander is/ die hebben meerder swa-
richeyt/ ende dieper andacht noodich/om
hem altijt Burgherlick daer in te connen
draghen. Dit is de * stof/ die wy duer Materia.
sommighe voorbeelden breeder verclaren
moeten/ende eerst vande rechte overheyt
eens * Burgherlick persoons als volght: Politici.

Tis wel openbaer ghenouch/ dat ye-
ghelick alle ghetrouheyt ende onderda-
nicheyt an sijn overheyt schuldich is/ als
duer de * Statwetten daer aen verplich- Leges ciui-
tet sijnde/ maer wie datmen daer voor be- les.
kennen moet/ staet tusschen de ondersaten
dickwils in twyfel: Ende overmits veel
eenvoudighe menschen/ onervaren inde
* Burgherlicheyt/ hemlien duer misver- Politia.
stant hier in seer misgaen/ lasterende haer
rechte wettelicke overheyt/ ende verhef-
fendende een diet niet en is/ alsoo dat der
landen groote benautheden ende onghe-
vallen

for him to be a good citizen; it is even so evident that no instruction is needed, for if he only follows his own inclination, he behaves as a good citizen, so that nothing need be said about this here. But laws and customs which in his view are wrong or contradict each other, so that performance of the one is transgression of the other, involve greater difficulty and call for deeper attention if he is always to behave as a good citizen. This is the subject-matter which we must explain more fully by means of some examples, and firstly we must deal with the proper authority governing a citizen, as follows:

It is sufficiently evident that everyone has to be a faithful and loyal subject of his authorities, as being obliged by the civil laws, but it is often a matter of doubt among subjects who is to be acknowledged as such. And since many simple people without civic experience misbehave greatly therein through misconception, slandering their truly legitimate authorities and praising one which is not legitimate, so that great distress and misfortune of countries frequently vallen daer dickmael uyt spruyten/ ten sal hier niet buyten weghen sijn / daer af dese seker ghemeene reghel te beschrijven : Yeghelick moet voor sijn rechte overheyt altijt houden, deghene die teghenvvoordelick metter daet regieré, over de plaetse daer hy sijn vvoninghe verkiest, sonder hem te becommeren, of sy ofte haer voorganghers, met recht of onrecht daer an ghecommen sijn: De reden is dese: Soo de ondersaten opde voorgaende tijden mosten letten / men soude / om de onrechte veranderinghen die de landen tot verscheyden mael ghebeurt sijn/ nauwelick eenighe seker overheyt inde weerelt connen setten/ overmidts datse deen uyt de laetste veranderinghe soude begheeren / dander uyt de voorgaende / de derde uyt noch een ouder/ yder na de gheneghentheden die hem beweeghden : ende dit elck met evenveel ghelijcx; want mach yemant de teghenwoordighe verworpen/ ende in die plaetse de voorgaende stellen/ met de selve reden sal een ander die voorgaende mueghen weeren / ende in haer plaetse noch een ouder brenghen / waer uyt openbaerlick oneindelicke twisten souden volgen/ende een onsekerheyt voor de ghemeente/ an wien sy haer sal moeten houden. Want soomen hem niet en moste ghevoughen nae den teghenwoordighen

Burgherlicke reghel.

result therefrom, it will not be amiss here to describe the following indubitable general rule thereof:

Everyone must always consider as his rightful authority those who at the present are actually governing the place where he chooses his dwelling, without concerning himself about the question of whether they or their predecessors have reached their position justly or unjustly.

The reason is this: If the subjects had to pay regard to former times, in view of the unlawful changes that have repeatedly befallen the countries we could hardly assume any indubitable authority in the world, since one would desire that resulting from the last change, another that resulting from the previous one, a third that resulting from an even older one, everyone according to his own inclination, and each with equal right. For if a man can refuse the present authorities and put the preceding in their place, with the same reason another may reject those preceding ones and put yet older ones in their place, from which evidently endless quarrels would result and uncertainty for the community on the question to whom it should adhere. For if one must not conform to the

ghen ſtaet/ wat voordeel can / by natuer-
licke redenen / deen der voorgaende on-
rechte veranderingen boven dander heb-
ben ? Om hier af by voorbeelt noch claer-
der te ſpreken / ghenomen dat v voorne-
men ſy in Vranckrijck te gaen wonen /
eyſcht niet de reden dattet gheſchiede/met
meyninghe ende wille / van v te ghebou-
ghen onder de regieringhe die ghy daer
vinden ſult ? ſy eyſſchet ſonder twyffel :
Sult ghy u daer becommeren / met de
onrechte veranderinghe van Philips de
Valois/ willende inde plaetſe van ſijn na-
commelinghen/gheſtelt hebben de afcom-
ſte van Eduart dē derden/ Keuninck van
Enghelandt/ wiens erfghenamen uyt die
oirſake (alſoo dat out bloedich verſchil
noch ongheſliſt ſtaet) de Franſche wapen
voeren/ eñ ſich Keuninghen van Vranck-
rijck noemen en ſchrijven ? Gheenſins /
want/ſegdi/ een ander ſoude met de ſelve
reden Eduwaert mueghen verworpen /
om het miſbruyck van ſijn voorgangher
Hughe Capet / ende daerom in diens
plaetſe verkieſen de nacommelingen van
Pepin / ande welcke de croone doen toe-
quam : Ende om dergheliicke redenen
ſal een derde den ſchalcken Pepin afwy-
ſen / ende in ſijn plaetſe begheeren de af-
comſte van Merovee / deur hem liſtelick
afgheſtelt : Een vierde ſal den gheweldi-
ghen

present situation, what advantage can one of the preceding unjust changes have over another by natural reasons? To speak of this even more clearly by means of an example, let us assume that you intend to live in France. Does not reason demand that this should be done with the intention and the will to conform to the government which you will find there? The latter will no doubt demand this. Must you concern yourself there with the unjust change of Philip of Valois, wishing to have his descendants replaced by the offspring of Edward III, King of England, whose heirs owing to that cause (because this old bloody feud is still undecided) bear the French arms and call and sign themselves Kings of France? By no means, for — you say — another might reject Edward with equal reason because of the abuse of his predecessor Hugh Capet, and on that account prefer instead of him the descendants of Pippin, who was then entitled to the crown. And for similar reasons a third will reject the scoundrel Pippin and desire instead of him the descendants of Meroveus, cunningly deposed by him. A fourth will reject the mighty Meroveus and will want to substitute ghen Merovee versteken/ ende voor hem de Romeynen willen invoeren / die van Merovee onwettelick verdruct wierden: Een vyfde sal de Romeynen ontsegghen/ ende voor haer verkiesen de ghene die van hemlieden t'onrecht versteken was / als Ariovistus; ende so int oneindelick voort/ twelcmen soude connen vertellen / waer slechts den oneindelicken voorleden tijt bekent. Ghy antwoort seer wel: Maer tghene van dies an u betaemt/die daer in Vranckrijck als vreemdelinck comt/ sonder verbitterde verblindende ghenegentheden / om tghene datter voorleden is; tselve betaemt oock voor al de ghene die daer wonen / ende vervolghens an yder in sijn landtschap waer het sy/ inder vougheu dat de reghel seker ende overal ghemeen is.

Yemant mochte nu segghen / Sal dan een ondersaet / sijn verdreuen ofte veronghelijckte Vorst/ ofte overheyt / die hy in sijn*ghewissen ghevoelt alle eere ghetrouheyt eñ dienst schuldich te sijn/ niet mueghen helpen ande landen/ plaetsen/ of saken/ die hy verstaet hem gherechtelick toe te commen? Ja hy: maer het moet deur behoirlicke middelen gheschien / treckende voor al uyt de heerschappie/vande ghene die hy wil teghen staen/ totten ghenen/ die hy voor hem neemt te helpen / of tot sulcke

conscientia.

for him the Romans, who were illegitimately oppressed by Meroveus. A fifth will denounce the Romans, and instead of them will prefer the man who had been rejected unjustly by them, *viz.* Ariovistus. And so on *ad infinitum*, which might be related if only the infinite past were known. You answer very rightly, but what in this respect it behoves you to do, you who come to France as a foreigner, without bitter and blinding predilections because of what happened formerly, the same also behoves all those living there, and consequently everyone in his country, wherever it may be, so that the rule is indubitable and everywhere general.

Now a man might say: Will not then a subject be allowed to aid his dispossessed or wronged prince or authority, to whom in his conscience he feels he owes all homage, loyalty, and service, to be reinstated in the countries, places, or things which he regards as his rightful due? Yes, he may, but it must be done by proper means; he should first of all go from the dominion of the person he wishes to oppose to that of the person he intends to help, or to sulcke plaetse / daer de teghenwoordighe regieringhe hem sijn voornemen toelaet/ alsoo van buyten incommende als verclaert viandt: Want andersuis hem ondersaet der teghenwoordighe regieringhe te veinsen / ende die achter rugghe niet woorden te lasteren / of metter daet heymelick te beschadighen / het is verraet. Julius Cesar hadde vande ghene die hem duer sulcke middel prouffijtelicken dienst deden/ dit ghemeen spreecwoort: Ick beminne het verraet, maer niet de verraders. Het selue verstont sijn navolgher den * Burgherlicken Keyser Augustus oock grondelick wel / in wiens teghenwoordicheyt de smeeckende Strabo eens willende Cato verachten / om dat hy den Senaet teghen Julius Cesar seer voorghestaen hadde/antwoorde hem: Die des Stats teghenvvoordighen staet niet en vvil verandert hebben, dat is een Burgher ende man met eeren: Tselve sijn oock al de ghene die der ghelijcke doen / haer woninghe nerghens verkiesende noch houdende / dan daerse de teghenwoordige regieringhe in wesen laten/ die sulcke eere ende onderdanicheyt bewysende als haer rechte overheyt toestaet / twelck wy in dit * hoofstick voorghenomen hadden te bethoonen.

Iulius Cæsars spreec woort.

Politicus.

Macrob. Satur. lib. 2 cap. 4.

Capite.

3e Hooft-a place where the present government allows him to carry out his intention, thus entering from outside as a professed enemy. For to feign to be a subject of the present government and to slander it behind its back or actually to harm it secretly is treason. With respect to those who served him in a profitable way by such means Julius Caesar had this general adage: *I love treason, but not the traitors.* This was also understood very well by his successor, the civic-minded Emperor Augustus, who, when one day in his presence the supplicating Strabo wanted to despise Cato because he had greatly supported the Senate against Julius Caesar, answered him: *He who does not want the present condition of the state to be changed is a good citizen and an honourable man.* Such are also all those who act similarly, choosing or keeping their residence nowhere but where they accept the present government, rendering it such homage and obedience as is due to their rightful authorities; which we intended to show in this chapter.

Intestinis bellis.

3e Hoofststick hoemen inde binnelantsche twisten de eerlickste sijde sal kennen ende kiesen.

Hoe wel de binnelantsche oorloghen verscheyden oirsaken hebben/ doch soo is de voornaemste / daer de ghemeene reghel duer mach verstaen worden / twist tusschen de regierders / spruytende ghemeenelick daer uyt/dat yemant van hemlieden sijn * bepaelde macht souct te vermeerderen / ende eens anders te verminderen. Maer wantmen om in sulcke beroerten hem * Burgherlick te draghen / ende de eerlickste sijde te anveerden / de kennis behouft vande form der regieringhe daer hem yder na gheboughen moet/ so sullen wy eerst int corte de vier besonderste * bepalen / te weten van * Eenichvorstheyt / * Ghemeenheyt / Staetvorstheyt / ende Voornamelickheyt. Eenichvorstheyt is wãneer de gantsche regieringhe teenemael staet in handen van een Vorst alleen/diemẽ daerom ooc * Eenichvorst noemt/alsins bevelende ende doende wat hy wil / sonder dat yemandt anders daer yet teghen mach/ ghelijck nu ter tijt den Turck/ den Grootvorst van Moscovia/ende voormael Moyses/Tamerlaen/ ende dierghelijcke. * Ghemeenheyt is die onder

Limitatã.

Politicè.

Definiemus.

Monarchia.

Democratia.

Aristocratia.

Monarcha

Democratia.

3RD CHAPTER

on how one is to know and choose the right side in internal discord.

Although intestine wars have different causes, yet the principal cause, by which the common rule can be understood, is dissension among the rulers, usually arising from the fact that one of them seeks to increase his limited power and to diminish that of another. But because, in order to behave as a good citizen in such disturbances and to choose the right side, one has to be acquainted with the form of the government to which everyone has to conform, we shall first briefly define the four most important, to wit absolute monarchy, democracy, constitutional monarchy, and aristocracy. Absolute monarchy is when the entire government is in the hands of a sole monarch, who for this reason is also called an absolute monarch, who commands and does in every respect as he wishes, without anyone else being able to do anything against it, as at the present time the Turk, the Grand Duke of Moscovia, and formerly Moses, Tamerlane, and the like. Democracy is that which is subject to the community, according to whose

onder de ghemeente staet/naer wiens oir-
deninghe verscheyden persoonen diemen
Staten noemt/ tot de regieringhe ghero-
ren sijn / doch sonder in regieringhe erf-
achtich te wesen/maer mueghen dickwils
verandert worden: Als voormael de Ghe-
meenheyt van Athenen/van Roome/ nu
ter tijt van Switserlant / eñ meer ander.
De Vorsten die niet alleen en regieren als
Eenichvorsten / maer met Staten bene-
vens haer / noemen wy Staetvorsten;
oock sulcke form van regieringhe Staet-
vorstheyt/ ende soodanich sijn nu ter tijdt
de meestendeel der regieringhen van Eu-
ropa; als Brabant heeft een Hertoch met
Staten / Vranckrijck een Kueninck met
een Parlement/Venegie een Hertoch met
een Senaet/Spaeigne een Kueninck met
een Inquisitie; alwaer Parlement / Se-
naet/ Inquisitie / het ghene beteeckenen
dat wy op Duytsch int ghemeen/ Staten
noemẽ/oft immers sijn tvoornaemste deel
van dien : Merckt oock dat de Griecken
met haer navolghers/soodanighe Staet-
vorsten den naem van * Eenichvorst ghe- Monaicha
ven/twelck wy om de ghewoonte wel soo
mede souden ghedaen hebben/ ghebruyc-
kende * lijckspreuck voor eyghen/maer la- Metapho-
tent om tvervolgh/welck is/dat die oney- ra.
ghen naem / oock mede ghebrocht heeft
oneyghen verstant des saecx/ te weten der

 Burgher-ordinances different persons, who are called parliament, have come to the government, but without their function being hereditary, for they can frequently be replaced. As formerly the democracy of Athens, of Rome; at the present time of Switzerland, and others. Princes who do not govern alone as absolute monarchs, but have a parliament at their side, we call constitutional monarchs, and this form of government we also call constitutional monarchy, and of this kind are at the present time most of the governments of Europe. Thus, Brabant has a Duke with a parliament, France a King with a Parliament, Venice a Duke with a Senate, Spain a King with an Inquisition, in which cases Parliament, Senate, Inquisition stand for that which we in Dutch generally call parliament, or are at any rate the principal part thereof. Note also that the Greeks and their successors give such constitutional monarch the name of "monarch", which because of the custom we should also have done, using the conventional term instead of the proper name, but we do not do so on account of the consequence, which is that this improper name has also involved an improper conception of the matter, to wit of good citizenship, as we might explain more fully with arguments, if it were not for

Politiæ. * Burgherlickheyt / ghelijck wy dat met
redenen breeder soudē muegen verclaren/
ten waer ons voornemē met en is de Bur-
gherlicheyt selfs / maer alleen het Bur-
gherlick leven te beschrijven. Ten laet-
sten / als de regieringhe bestaet onder de
gheschickste/ achtbaerste/ ofte voornaem-
Aristocratia. ste/ des landts; so ist * Voornamelicheyts
Species. form. Angaende alle ander/ alsoo sy * af-
comsten der boveschreven sijn/of daer uyt
versaemt worden / ende dat dese tot ons
voornemen ghenouch doen / sullen die la-
ten. Dus dan bepaelt hebbende wat
form van regieringhe sy : soo is te weten/
Politico. dattet yder * Burgherlick persoon betaẽt/
hem te gheboughen na de teghenwoordi-
ghe form die de fortuyne over sijn woon-
plaetse ghebrocht heeft : Ist volcommen
Monarchia. * Eenichvorstheyt/soo isser alleenelick een
Vorst onderdanich te wesen / ende van
Democratia. gheen Staten te roeren : Ist * Ghemeen-
heyt/soo sijnder alleenelick Staten te vol-
gen/ sonder Vorst: Inde Staetvorstheyt/
Limitata. is de Vorst in sijn * bepaelde gherechtic-
heyt voor te staen/ eñ de Staten inde ha-
re/ alwaer te ghedencken valt/ dattet on-
recht versaken van deen/ soo schandelick
is als van dander / eñ het recht voorstaen
van dese/ soo eerlick als van die : Tis wel
waer dat de Vorst by velen in meerder an-
sien is dan de Staten / ende daerom int

onrecht

the fact that it is not our intention to describe good citizenship itself, but only civic life. Lastly, when the government consists of the most suitable, most honourable, or most distinguished persons of the country, it has the form of an aristocracy. As to all the others, because they are species of those described above or a combination thereof and the latter are sufficient for our purpose, we shall ignore the former. Having thus defined what is the form of government, it is to be noted that it behoves every citizen to conform to the present form of government which Fortune has set over his dwelling-place. If this is an absolute monarchy, one only has to obey a prince and not to speak of a parliament. If it is a democracy, one only has to follow parliament, without a prince. In a constitutional monarchy it is necessary to stand up for the prince and his conditioned rights and for parliament in theirs, in which connection it should be born in mind that it is as disgraceful to neglect the injustice of the one as of the other, and that it is as honourable to stand up for the authority of the latter as of the former. It is true that with many people the prince is more highly esteemed than the parliament, and for that reason is sooner onrecht eer gheholpen wort / spruytende daer uyt/dat de ghemeente selden de form haerder eyghen regieringhe kent/ ten anderen dat ghiften/ gaven/en ampten/ van dien lichtelicker te becommē sijn dan van dese/ maer de * Burgherlicke en worden duer dit noch duer dat beweeght. Politici.

Om dan tot de sake te commen/wy sullen daer af eerst int ghemeen spreken: Wesende eenighe binnelandtsche twist voor handen/ ende datmen ghenootsaect wort deen of dander sijde te kiesen / soo valter voor al te ansien hoedanich de twistende partien sijn: By aldien deen de ghemeente waer/ sonder dat eenighe der wettelicke regierende persoonē haer voorstonde / als inden oproer te Munster deur Jan van Leyden / der Adamisten tot Amsterdam/ en dierghelijcke / die sijde te volghen is voor ghemeene reghel openbaer onburgherlick/ want ghelijck int ij^e Hooftstick bewesen is / de ondersaet die hem teghen sijn overheyt stelt/ en can dat/ onder sijn ghebiedt sittende/ niet * Burgherlick beghinnen/ dan moet van buyten in commen. Maer by aldien beyde de twistende partien wettelicke regierders tot hoofden hadden/ soo salmen de form der regieringhe met yders bepaelde macht anmercken/ daerbeneven de sake daer sy om twisten / van twelck goet bescheyt wetende/ Politicè.

helped in injustice, which results from the fact that a community seldom knows the form of its own government, and secondly that gifts and offices are to be obtained more easily from the former than from the latter, but the good citizens are moved neither by this nor by that.

To come to the point, we shall first speak of it in general. If there is some internal discord and one is forced to take sides, it should first of all be considered which are the dissenting parties. If one of the two is the community, without any of the legitimate governing persons standing up for it, as in Jan van Leyden's revolt at Munster, that of the Adamists at Amsterdam, and the like, as a general rule it is evidently bad citizenship to follow that side, for, as has been proved in the second Chapter, the subject that revolts against his authorities cannot do so as a good citizen while he is living in their territory, but must enter it from outside. But if both contesting parties are headed by legitimate rulers, one should consider the form of the government with the limited powers of each of them, and besides this the

soo salmen den ghenen teghenstaen / die
teghen sijn eedt / de goede wetten / vryhe-
Materia. den/ampten(want sulcke *stof is ghemee-
nelick de oirsake van soodanighe beroer-
ten) wil veranderen/ oft gheheel wechne-
men / ende die regierders toevallen / die
sulcx/ volghende haer eedt / beschermen.
Om van twelck by ghelijckenis te spre-
ken/ ghenomen dat den Hertoch van Ve-
negie de form der regieringhe wilde ver-
anderen/ voor hem nemende sijn Senaet
af te setten / teghens haer wille / ende in
hunlieder plaetse gheestelicke regieringhe
te brenghen / diemen Inquisitie noemt:
Nu deen willende aldus dander weeren/
en dander van deen niet willende geweert
sijn/tgheraect/neem ick/ tot een openbare
binnelantsche twist tusschen den Hertoch
ende den Senaet: Vraghe hoemen sich
(ghenootsaect sijnde deen of dander sijde
te kiesen) hier in dragen sal? Voor al/men
siet dat de form der regieringhe Staet-
Reipublicæ. vorstheyt is/ alwaer het beleyt der *Ghe-
meensake / ghestelt is in handen van een
Hertoch/met een Senaet benevens hem/
daerom welcke sijde van beydē de onder-
saet teghenstaet/ hy staet sijn overheyt te-
ghen / die hy ter contrarie alle eere ende
onderdanicheyt schuldich is / nochtans
van sulcke twee quaden het minste te vol-
politica ghen / is de * Burgherlicke wech: Om
welcke

matter in dispute, and if one knows this well, one should oppose the one who against his oath wants to change the good laws, privileges, offices (for this matter is usually the cause of such disturbances) or abolish them altogether, and support those rulers who, according to their oath, protect them. In order to speak of this by comparison: let us assume that the Duke of Venice wished to change the form of the government, intending to depose his Senate against their will and to replace it by a clerical government, which is called Inquisition. Now the one thus wanting to expel the other, and the other not wishing to be expelled by the one, I suppose this leads to public internal discord between the Duke and the Senate. The question is how one is to behave in this case (if one is forced to take sides)? First of all it is seen that the form of this government is a constitutional monarchy, in which the conduct of the commonwealth is placed in the hands of a Duke, with a Senate by his side. Therefore, whichever of the two sides the subject may oppose, he opposes his government, which on the contrary he owes all homage and obedience. Nevertheless, it is the way of a good citizen welcke te wandelen / men sal de redenen van beyden sijden overweghen in deser voughen: Ghenonien dat de Senaet aldus seght: Doenmen u inhulde / ghy hebt gheswozen / onder anderen / de teghenwoordige fozm der regieringhe niet alleen onverandert te laten / maer die met alle vliet voor veranderinghe te beschermen. Waer op den Hertoch antwoozt: Jck hebbe oock gheswoozen ende ghylieder met my / de Roomsche kercke onderdanich te wesen / de selve beveelt ons nu soodanige veranderinge te makē / daerom het waer teghen onsen eedt dat sulcx niet en ghescchiede: Dander segghen hier op / datmen int sweeren niet soo seer en moet letten op de bloote woorden (diemen ghemeenelick tot verscheyden beteeckeninghen draeyen can) als opden eenvoudighen sin van dien / welcke tot sulcke onderdanicheyt niet en strecte / want dat wy ons souden moeten gheboughen na hun bevel / inhoudende te scheyden uyt onsen staet / vryheyt / eere ende goet / ende hemlieden tselve altemael over te gheuen / het strijt teghen tghemeen ghevoelen. Want hoewel de Staten van Spaigne sulcx toeghelaten hebben / tis nu met groot berou vande onvoorsichtighe afghestelde / die int beghin soodanich einde niet en verwachten / waermede sy oock an allē regierders to follow the least of these two evils, and to do so, one should consider the arguments of both sides, as follows. Let us assume that the Senate says thus:

When you were invested, you swore among other things that you would leave the present form of the government not only unchanged, but that you would protect it zealously against change. To which the Duke answers: I have also sworn, and so have you, to obey the Roman Catholic Church. The latter now orders us to make this change, and therefore it would be against our oath if this were not done. The others say to this that in an oath one should not heed so much the bare words (which can usually be distorted into different senses), but rather their simple meaning, which did not imply such obedience, for it is contrary to the general feeling that we should have to conform to their command, to the effect that we should eliminate from our state: liberty, honour, and property, and surrender it all to them. For although the parliament of Spain has consented to it, it is now greatly regretted by the imprudent deposed body, which in the beginning did not expect such an end, and thus they hold such

sulcken spieghel ghewo[r]den sijn / dat gheen Staten van landen nergens tot so-danighe veranderinghe en verstaen; daer-om so wy ghesegt hebben / den sin vanden eedt onser onderdanicheyt en was niet tot sulcx: Den Hertoch wil ter contrarie. An-
Argumenta. ghenomen dit de * strijtredens van weder sijden te wesen / tis openbaer dat de onder-
Politicè. saet / om * Burgherlick te doen / hem by den Senaet soude moeten voughen.

Neemt ander voorbeelt ande binnelant-sche twist tusschen den Staetvorst Nero / ende sijn mederegierders de Statē of Se-naet van Roome / alwaer den handel soo verre quam / dat de Senaet Nero voor viant verclaerde / ende hem veroirdeelde / soo hy ghecreghen wierde / totter doot toe ghegheesselt te worden: Nu also de regie-ringhe onder dese twee gherocht was / het betaemde de ondersaten / die ghenoodicht waren een sijde te kiesen / de sake van deen en dander te overwegen / welcke was / dat Nero buyten sijn palen tredende / den Se-naet sijn mederegierders verdructe / alles doende na sijn quaet gheballen / sonder op wetten te schaffen / die dander als rechte voorstaenders beschermden; Daerom de ondersaten die haer bydē Senaet vouch-den / ende teghen Nero stelden / worden
Politicis. vande ervaren * Burgherlicke / gheacht de rechte sijde ghecoren te hebben.

4e Hooft-a mirror to all rulers that no parliament of any country consents to such a change. Therefore, as we have said, the meaning of our oath of allegiance did not tend that way. The Duke holds the contrary. Now assuming these to be the arguments on either side, it is evident that the subject, in order to behave as a good citizen, would have to take the side of the Senate.

Take another example from the internal discord between the constitutional monarch Nero and his co-rulers, the parliament or Senate of Rome, in which case the matter reached the point where the Senate declared Nero to be an enemy and condemned him, if he were caught, to be flogged to death. Now because the government had been established under these two, it behoved the subjects, who were obliged to choose one of the sides, to consider the case of one as well as the other, which was that Nero, exceeding his powers, oppressed the Senate, his co-rulers, doing everything according to his evil pleasure, without concerning himself about laws which the others, as righteous defenders, upheld. Therefore the subjects who took the side of the Senate and opposed Nero are considered by experienced citizens to have chosen the right side.

4^e^ Hooftstick hoemen hem inde regieringhe Burgherlick dragen sal.

DE gheleerde erbaren * Burgerlicke/ houdent daervoor/ dat een die hem tot de regieringhe begheeft/ of laet ghebruycken/ behoort/om hem Burgherlick te connen draghen/ voor al te weten/ ende ghedurerelick te ghedencken/ dat de ghemeente bestaet/ uyt menschen soo wel regierende/ als gheregierde/ van verscheyden sinnen ende gheneghentheden/ deen contrarie dander/ welcke altsamen te behaghen/ ende alles van passe te doen/ onmuegelick is. Want int stuck vande Religie/ tghene den eenen voor heylichdom eert/ ende als Godt vreest/ daer drijft den anderen sijn schimpelickste spot mede; In * Steetsche saken/ deen verstaet tot oorloghe/ dander tot paeys/ die acht noodich schattinghen ende ghemeene oncosten te doen/ dese isser teghen: Inder voughen dat met wien het de regierder houdt/ hy behaelt den ondanck ende haet van een groote menichte; Ja niet teghenstaende hy Godvreesende/ ghetrou/ ende rechtveerdich waer/sullen hem nochtans schelden voor een Godslasteraer/lantverrader/ ende dief der ghemeene middelen/ welcke ongheballen teenemael ontvliedelick sijnde/ soo moet hyse van te voren verwachten/

Politici.

Ciuilibus.

4TH CHAPTER

on how one should behave as a good citizen in government.

Learned and experienced citizens consider that, in order to behave as a good citizen, a man who is to take part in or to be employed in the government should know first of all and constantly bear in mind that the community consists of people, rulers as well as ruled, of different views and inclinations, one contrary to the other, and that it is impossible to please and satisfy them all at the same time. For in the matter of religion, what one venerates as sacred and fears as God, another flouts at in the most scandalous way. In civil matters one will decide in favour of war, another of peace; one considers it necessary to exact tributes and general payments, another is against this, so that, whomever the ruler sides with, he incurs the ingratitude and the hatred of a great multitude. Indeed, notwithstanding his being righteous, loyal, and just they will yet brand him as a blasphemer, a traitor, and a thief of the national finances, and since these misfortunes are altogether inevitable, he must expect them beforehand, ten / op datse soo dickwils sy commen / hem inde bedieninghe sijns ampts niet en beroeren / noch sijn tijt en doen verliesen met kijven / kermen / ende hem te beclaghen over de onbillicheyt des ghemeene volcx / maer dat hy in die plaetse / wetende sulcx sijns staets * onscheydelicke anclevinghe te wesen / met een gheruste gheest overdencken mach alle onghevallen te voorcommen / ende sijn ampt / so veel hem mueghelick is / recht te bedienen. Dits int gemeen gheseyt; maer om van dies besonderlicker te spreken / so is te weten / dat de regierders sijn Vorsten / of Staten / of leden van dien. De Vorsten regieren met Staten / als inde Staetvorstheyt; ofte alleen / als inde * Eenichvorstheyt; ende gheraken daer toe / of deur verkiesinghe met voorgaende verdrach / of deur erfachticheyt of deur ghewelt. Nu om van deerste soorte eerst te segghen / yemant tot Staetvorst ghecoren sijnde / sal / eer hy hem laet bevestigen / goede kennis vereyschen vanden teghenwoordighen staet des landts / eñ int verdrach gheen ander punten toelaten / dan die hy niet alleen mette monde / maer oock van gantscher hertē voor hem neemt te onderhouden; Ja lieuer den staet der regieringhe te laten / dan int minste daer teghen dencken te doen / want hoewel gheveinstheyt somtijts haer plaetse heeft /

Inseparabile accidens.

Monarchia.

in order that, whenever they come, they may neither disturb him in the discharge of his function nor cause him to lose his time in wrangling, groaning, and complaining about the unfairness of the common people, and that instead, knowing that this is inseparably connected with this office, he may with a tranquil mind reflect on how to avoid all misfortunes and to discharge his function to the best of his ability. This is a general statement, but to speak of it more in particular, it is to be noted that the rulers are princes or parliaments or members of the latter. Princes govern with a parliament, as in a constitutional monarchy; or alone, as in an absolute monarchy. And they come into power through election preceded by a treaty, through inheritance, or through force. Now to speak first of the first kind: when a man has been chosen as a constitutional monarch, before his inauguration he will require good knowledge of the present condition of the country and in the treaty will not permit the inclusion of any points beyond those which he intends to maintain not only ostensibly, but also wholeheartedly. Indeed, he will abstain from government rather than propose to do anything against it, for although dissimulation is sometimes in place, in this case heeft/ doch isse in desen ghevalle gantsch onnut / ende niet alleen openbaer onburgherlick/ maer oock onbequame middel/ om te gheraken tottet ghene daer hy na tracht ; te weten / tot vermeerderinghe sijns goets eñ ghebiets. De reden is dese: Al can hy de ghemeente deur bedrieghelick ghelaet / een ander vermoeden van hem doen hebben / dan sijn inwendighe meyninghe is/ doch soo sijnder onder de Staten altijt eenighe / welcke met hem daghelicx verkeerende / ende lettende op al sijn woorden ende wercken/sien terstont sijn innerlick ghemoet / twelck sy bekennende/ende merckende dattet strect tot eyghenbaete / ende vermeerderinghe sijns *bepaeldē machts/twelck sonder verminderinge vande hare niet gheschien en can/ het isser mede ghedaen ; sy en ontsegghen hem niet alleenelick sijn begheerten/maer verhinderen sijn voornemen waer sy connen/ vermaken hem na hun uyterste vermeughen/ by dander regierders / eñ voor de gantsche ghemeente/ inder vougen dat alle sijn anslaghen daer na onoirdentlick toegaen/ crijcht hy yet met list ofte ghewelt/ hy besittet onversekert met vreese eñ onruste. Maer een die ter contrarie met een onbeweghelick voornemen / altijdt tracht in sijn *palen te blijven / die niet kintschelick latende vercorten / noch met

Limitatæ.

Limitibus.

it is entirely useless, and not only evidently uncivic, but also an unsuitable means to the end he is aiming at: to wit, increase of his property and territory. The reason is this: Although by a deceitful face he may cause the community to assume him to be different from his inward intention, in the parliament there are always some people who, daily associating with him and observing all his words and deeds, see at once his inner mind, and when they recognize this and perceive that it aims at his own profit and at the increase of his limited power, which is not possible without a decrease of theirs, he is done for. They not only deny him that which he desires, but prevent his intentions wherever they can and slander him to their utmost before the other rulers and before the whole community, in such a way that all his enterprises accordingly fail; when he gains something by guile or force, his possession of it is insecure and involves fear and unrest. But when a man, on the contrary, with a firm intention always tries to keep within his limits, neither weakly allowing them to be shortened nor wanting to broaden them by force, holding that without this no proper

ghewelt willende verbreeden / achtende sonder sulcx gheen rechte ghemeene welvaert te connen beneersticht worden/daer vinden hun de Staten an een versekert Vorst gherocht te wesen/ sy vermeerderen dickwils sijn macht eñ ghebiedt uyt haer eygen wille/betrouwen ende gheven hem sonder sijn versouck/sonder sijn moeyte/ tghene ander deur begheerten/ende grooten arbeyt niet crijghen en connen; ghelijckmen dat deur veel oude voorbeelden mochte bewysen / ten waer de nieuwe eñ heel versche/ self in dese landen/ sulcx ghenouch betuycht hadden. Het gaet hier mede ghelijck met onse schaduwe/ welcke haer navolgende lichamen ontvliet/ ende haer ontvliedẽde navolght. Maer om dat der Vorsten schadelicke pluymstrijckers dese sake anders verstaen / soo laet ons mercken wat hemlien tot haer oorblaserie ghemeenelick beweeght: Sy sien des Vorsts groote staet / sijn groot naghevolgh/ende de uyterlicke eere diemen hem andoet: maer weder ter contrarie/ dat hy onderdanich moet sijn het besluyt sijnder Staten / twelck somtijts persoonen sijn
Qualitate. van cleender * ghedaente/ als cooplieden/ ambachtslieden / of sulcke allser deur de Fortuyne tot regierders des landts gherocht sijn: Dit verleken by het ander / dunct hun te gantsch onbillich te sijn/ dit en con-

general welfare can be furthered, the parliament finds that he is a reliable prince. It often increases his power and territory of its own free will, entrusts and gives to him without his request, without his effort, what others cannot obtain by claims and great insistence, as might be proved by many old examples if it were not for the fact that the new and quite recent ones in these countries had shown this sufficiently. It is with this as with our shadow, which flees from bodies following it and follows such as flee from it. But since mischievous toadies flattering the princes view this matter differently, let us note what it is that usually prompts their flatteries. They see the great state in which the prince lives, his great retinue, and the outward homage paid to him, but on the other hand observe that he must submit to the decision of his parliament, which sometimes consists of persons of lower quality, such as merchants, crafstmen, or such as owing to Fortune have come to rule the country. This in comparison with the other things appears to them quite unfair, they cannot stand it, and en connen sy niet lijden / ende even al oft sy niet en wisten / sulcx de eygenschap van Staetvorstheyts form te wesen / ende al oft hun onbekent waer / dattet onderhout sijns staets vande ghemeente quame / segghen tot hem: V Ghenade laet haer selven te groote cleenicheyt andoen / wat is sy anders dan een dienaer van dese slechte lieden? tghene deur * versoeckbrieven an V Ghenade self dickwils begheert wort / daer laet ghy hemlieden op raetslaghen / besluyten / ende handelen / na hun ghelieven: Soo sy tot V Ghenade segghen reyst hier / treet daer / doet dit / laet dat / sy ghebouchter haer toe als hemlieden knecht; Seker ick waer liever een slecht vry edelman / niet bevel over mijn page / dan een Vorst / in sulck schijnsel van vryheyt / eyghentlicker slavernie sijnde; Cyrus / Alexander / Cesar / ende haers ghelijcke / hebbent al anders ghedaen / niet sonder groot lof / voorspoet / ende welvaren / sulcke soude u Ghenade navolghen.

Libellos supplices of Requesten.

Siet doch hoe dese menschen sich selfs behaghen / in haer onburgherlick misverstant / ende dat beclaghelicker is / hoe de Vorsten daer deur dickwils verleyt worden / niet alleen tot haren grooten achterdeele / maer oock tot onrust ende ellende der gantsche ghemeente. Met sulcke redenen segtmen den Hertoch van Alenson / deur as if they did not know that this is the characteristic property of the form of constitutional monarchy and as if it were unknown to them that the maintenance of his state was due to the community, they say to him: Your Honour lets herself be humiliated too much; what else is she but a servant of these simple people? What is often asked for by means of requests addressed to Your Honour herself, you leave to them to deliberate, decide, and act upon as they choose. If they say to Your Honour: travel to this, go to that place, do this, do not do that, you conform to this as if you were their servant. Truly, I had rather be a simple free nobleman commanding my page than a prince with such semblance of liberty, which is more properly slavery. Cyrus, Alexander, Caesar, and their equals have all done this differently, not without attaining to great praise, prosperity, and welfare; *them* Your Honour should imitate.

See how self-satisfied these people are in their uncivic misconception and, what is a greater pity, how princes are often seduced thereby, which results not only in their great disadvantage, but also in the unrest and misery of the whole community. With such arguments the Duke of Alençon is said to have

deur sijn quaden raet beweecht gheweest te sijne/ tot de onburgherlicke overvallinghe der Stat van Antwerpen: Sghelijcx den Graef van Leycester / tot de overtre-
Limitum. dinghe sijnder * palen in Hollandt; maer wat vervolgh daer uyt deen en dander wedervoer / is voor yder openbaer ghenouch/ eñ al haddet ter cõtrarie tot haren
Hoc per accidẽs, illud per se. grooten voordeele beter gheluckt (*twelck by ghevalle soude sijn/ het ander is deur sich selfs) soo ist openbaer/ onburgherlick ende oneerlick te wesen. Maer wat soude een ervaren Vorst an sulcke oorblasers meughen antwoorden? Dit: Ghy verheughdet u met my / doen ick eerst gherochte an dese staet/ welcke ghy nu slavernie noemt/ ghy hebt u dan verblijt in mijn ongheval. Ten anderen/ de form der regieringhe deses landts / ende de puncten by ons onderteyckent ende beswooren/ sijn
Dilemma op Duyts strickreden. u bekent of onbekent: Soo sy u bekent sijn/ ghy sondicht teghen God eñ de menschen / willende ende radende dat ick de selve overtrede teghen recht / reden / ende trouwe: Maer sijnse u onbekent / soo ist van u dwase vermetentheyt / een Vorst te raden in dinghen die ghy niet en verstaet. Met dese ende der ghelijcke redenen den pluymstrijckers beschèydende/ eñ beschamende/ en sal sich self niet alleen ontlasten ende bevrijden van haer verdrietige bleyn-
mghen/

been induced by the bad advice he received to undertake the uncivic assault on the city of Antwerp, and similarly the Earl of Leicester to exceed his limited powers in Holland. But what consequences this had for each of them is sufficiently evident to everyone, and even if, on the contrary, they had, to their great advantage, been more successful (which would be an exception, the natural course of events is the reverse), it is clear that it would have been uncivic and dishonourable. But what might an experienced prince answer such flatterers? This: You rejoiced with me when first I attained to this state, which you now call slavery; you then rejoiced in my misfortune. Secondly, the form of the government of this country and the points subscribed and sworn to by us are either known or unknown to you. If they are known to you, you are sinning against God and men when you wish and advise me to transgress them against right, reason, and loyalty. But if they are unknown to you, it is foolish audacity in you to advise a prince in things which you do not understand. By answering and shaming the arguments of the toadies with these and similar arguments he will not only rid and free himself of their annoying inghen/ maer oock een goede wech bereyden/ om te gheraken ter faem ende * daet/ die een ghecoren Staetvorst betaemt. Effectum,

Tghene tot hier toe gheseyt is vanden ghecoren Staetvorst/ sal hem oock alsoo verstaen vanden erfachtigen: Want ghelijck hem die moet gheboughen na de beswooren punten des verdrachs uyt verkiesinghe cōmende/ alsoo dese na de besworen punten uyt sijn erfachticheyt spruytende.

Angaende regieringhen deur ghewelt vercreghen/ alsoo sy gheraken tot eenighe form der * afcomsten daer hier af ghehandelt wort/ wy verstaen de reghelen der selve voor soodanighe te verstrecken. Specierum

Nu om vanden * Eenichvorst te segghen/ soo is te weten/ dat hoewel uytbrekende gramschap/ voor yeghelick een seer schadelick ghebreck is/ doch isse inden Eenichvorst alderschadelicxt/ overmidts des gramschaps * daden/ uyt desen lichtelicker volghen connen dan uyt die; de oirsake is/ dat al dander yemant vreesen/ als den Staetvorst sijn Staten/ ende elck der Staten tgheheel lichaem/ twelck hemlieden belet/ de daden haerder gramschap int werck te durven stellen; maer sulcke verhinderinghe inden Eenichvorst niet wesende/ om dat hy boven al is/ daerbeneven alsoo de gramschap te recht * bepaelt wort/ een corte uytsinnicheyt/ soo volgen- Monarcha Effecta, Definitur.

der

flatteries, but will also pave the road to acquiring the fame and the real merit which becomes a chosen constitutional monarch.

What has so far been said of the chosen constitutional monarch must be understood to apply also to the hereditary monarch. For just as the former must conform to the sworn points of the treaty resulting from his election, so the latter must conform to the sworn points resulting from his hereditary rights.

As to governments acquired by force, because they develop into any one of the species here dealt with, we take the rules of the latter to apply to such cases.

Now if we are to speak of the absolute monarch, it is to be noted that although wrath is a very harmful vice in anyone, it is most harmful in an absolute monarch, since the effects of wrath follow more readily from the latter than from the former. The reason is that all those others fear some one, *e.g.* the constitutional monarch his parliament, and each member of the parliament the whole body, which prevents them from daring to realize the effects of their wrath. But since an absolute monarch is not thus prevented, because he has supreme power, and since moreover wrath is rightly defined as a "brief madness", the acts

der uytsinnighens ende dulleliens wercken uyt / welcke somwylen op een uyre tijts soo schrickelick sijn/datmen niet al de weldaden sijns levens die niet boeten en can/ maer inder eewicheyt voor een wreet tyrant vermaert blijft : Daerom moet hy niet een besloten voornemen/ deur sijn eyghen cracht en deucht/sijn gramschap bedwinghen/ andersins tis onmueghelick/ ja oock de vroomste (om de onredelicheyt veler menschen daer hy gheduerlick mede handelen moet/ als vooren geseyt is) hem
Politicè. in soodanighen staet altijt * Burgherlick te connen draghen : Twelck keyser Augustus deur de ervaringhe wel gheweten heeft/ want alsoo Athenodorus oirlof nemende van hem scheyden soude / hy begheerde van Athenodoro een ghedenckenis; welcke hem dese spreucke schanck : Als ghy u gramschap ghevoelt te rijsen/ verhaelt inwendich al de letteren van het A/ B/ C/ eer ghy antwoort ofte yet doet/ twelck Augustus soo wel beviel / ende in sulcken danck naem / dat hy Athenodorum noch een jaer by hem dede blyven : Siet / hy kende sijn eyghen ghebreck / ende de ongheballen die hem deur onbedwonghen gramschap gebeurt waren : Twelck yder Eenichvorst tot voorbeelt soude meughen dienen/ om hem te
Monarchiæ. connen wachten voor de * Eenichvorstheyts

of madmen follow therefrom, which are sometimes in one hour's time so dreadful that one cannot atone for them by all the good acts of one's life, but retains for ever the reputation of being a cruel tyrant. Therefore he must with firm resolution bridle his wrath by his own effort and virtue, otherwise it is impossible even for the most righteous (because of the unreasonableness of many of the people with whom he must constantly deal, as said before) always to behave as a good citizen in such a situation. A fact which the Emperor Augustus knew by experience, for when Athenodorus, taking leave, was going to part with him, he wanted a memento from Athenodorus, who presented him with this saying: When you feel your wrath arising, recite to yourself all the letters of the ABC before you answer or do anything. This pleased Augustus so much and he was so grateful for it that he made Athenodorus stay another year with him. You see, he knew his own fault and the misfortunes that had befallen him through uncontrolled wrath. This might be an example to any absolute monarch,

heyts quade eyghenschap/te weten wree-
de tyrannie / welcke niet alleen onbur-
gherlick en is/ ende tot verdriet der ghe-
meente streckt/ maer hem selven een drou-
vich ellendich leven doet leyden / deur
dien dat de ghene die van veelen gevreest
wort/ moeter oock veel vreesen. Voort al-
soo de wetten om de ghemeente sijn/ van-
de welcke hy een lidtmaet is/ soo sal hy(ja
al waer hy schoon boven de wetten) die
onderdanich wesen ghelijck de geringste:
Want hoe souden de ondersatẽ de wetten
recht onderhouden / als den beschermer
ende voorgangher die self overtreet? An-
gaende de saken der regieringhe die onder
gheen wetten en staen/ dat hy daer in be-
neerstighe des landts welvaert / ghedenc-
kende/ ende als voor eeuwighe wet hou-
dende/ dat de ghemeente niet om sijnent
wille/ maer dat hy om de ghemeentens
wille is. Voort soo hy beneven sijn staet
van Eenichvorstheyt; noch eenighe ander
formen van regieringhe onder hem had-
de/ghelijckt soodanighe Vorsten ghemee-
nelick ghebeurt/ als van eenighe plaetsen
beschermheer / ofte Staetvorst te wesen/
daer sal hy regieren als Beschermheer /
als Staetvorst/ ende alleenelick als * Ee- Monarcha
nichvorst / ter plaetse daer hy wettelick
Eenichvorst is; want hoewel dickwils ter
contrarie ghebeurt/ soo gheschiedet meer
deur

so that he might beware of the bad quality of an absolute monarch, to wit cruel tyranny, which is not only uncivic and causes unhappiness of the community, but also makes his own life sad and miserable, because the man who is feared by many must also fear many. Furthermore, because the laws are for the sake of the community of which he is a member, he must (even if he were above the law) obey them like the least [of his subjects], for how are the subjects properly to observe the laws if their protector and leader offends against them? As to the affairs of government which are not subject to laws, in those he should seek to promote the prosperity of the country, bearing in mind and considering it as an eternal law that the community does not exist for his sake, but that he exists for the sake of the community. Furthermore, if besides his state of an absolute monarch he should also have been invested with some other forms of government, as commonly happens with such princes, such as being the patron or constitutional monarch of certain places, he must govern there as a patron, as a constitutional monarch, and only as an absolute monarch in the place where he is the absolute monarch by the law. For although the contrary often happens, this takes place through uncivic force rather than reason, for deur onburgherlicke ghewelt/dan met reden/wantet even so veel is/als oft yemãt/ om dat hy eenighe slaven heeft / alle vrye menschen voor slaven wilde houden.

Angaende Staten of leden van dien/als regierders van Steden ofte plaetsen/ tis een ghemeen ghebreck/ dat sommige welwetens ongherechticht sijnde/ de vryheden van hun naburen onredelick verdrucken/ twelck alst slechts gheschiet tot vermeerderinghe des ghebiets ende machts/ der Stede ofte plaetse diese dienen ofte regieren / sy achtent al voor eerlick / voor Burgherlick/ haer eedt wel ghequeten te sijne/ eñ cloucke bedienders haers ampts te wesen : maer de sake wel inghesien/ het isser anders mede ghestelt want ghelijck een voocht / die sijn weesen rijck maeckt met geroofde goeden / de selve weesen niet voor en staet/ noch sijn eedt te recht en betracht/ maer heel ter contrarie doet/ overmidts hy hemlieden bereyt een quade oneerlicke name/ als te wesen besitters van gheroofde goeden/ ten anderen manden/ welcke haer slach wachten / om ghewelt met ghewelt / of bedroch met bedroch te vergheldén: Alsoo oock sulcke regierders/ sy begaderen haer Steden schandelicke hoocheyt/ ende viandelicke nabueren/ diese verhinderen daerse connen/ ja dickwils tot onderganck brenghen: Inder vougen dat this is equivalent to the case where a man, because he has some slaves, would be inclined to regard all free men as slaves.

As to parliaments or members thereof, such as rulers of cities or places, it is a common defect that some, being knowingly unjust, unreasonably trample the privileges of their neighbours, and provided this is done to increase the territory and power of the city or place which they serve or rule, they consider that it is all honourable and civic, that their oath has been properly fulfilled, and that they discharge their office efficiently. But when the matter is properly viewed, it is different, for just as a guardian who enriches his orphans with stolen goods does not stand up for those orphans and does not rightly perform his oath, but acts contrarily, since he causes them to get a bad and dishonourable reputation as being owners of stolen goods, and on the other hand brings them enemies, who await their chance to render force for force or fraud for fraud, thus also such rulers: they cause their cities to gain infamous greatness and hostile neighbours, who thwart them wherever they can and even frequently dat soodanighe (ick spreke vande ghene die welwetens ongherechticht sijn) haer eedt niet en quiten / noch haer Steden voor en staen / maer sijn onburgherlicke meyneedighe verderbers van dien / ende dickwils schadelicke oirsaken / van meerder ongheballen die daer uyt spruyten / eñ deur de gantsche ghemeente strecken. Tselve is oock soo te verstaen met de regierders / die hun Stat bevrijden / van op te brenghen haer behoorlick deel der ghemeene middelen / daer sy nochtans na hun eyghen ghevoelen in ghehouden sijn / alles affettende met woorden sonder reden; denckende; het mach mettet gheheel gaen