Survey of the history of the art of Navigation in The Netherlands

by C. KOEMAN

AT THE BEGINNING OF THIS CATALOGUE one might have inserted one or more chapters from Crone's book on Cornelis Douwes, which would have met the task of introducing this catalogue by a short history of the art of navigation in the Netherlands.

Before the publication of C.A. Davids' *Zeewezen en Wetenschap* in 1986, no one has given a better description of that history than Crone did in his book and in his many contributions to periodicals.

For someone who has not sailed the seas and intends to discuss this subject again it is very difficult to add fresh information. Only specialists among the historiographers like C.A. Davids could add more new elements. I should not be expected to make an original contribution to the historiography of the art of navigation. At most one may expect from me that I shall arrange and discuss the facts in such a way that a narrative will be composed from which the reader of this book may benefit. A narrative which sheds light on, amongst others, a number of interesting aspects of the instruction of the art of navigation.

My contribution may also be regarded as an account of the way in which the list of the books was drawn up. For this very list drawn up in chronological order naturally gives a history of the art of navigation. However, more from an international point of view than from a specifically Dutch angle.

To start with a few typically Dutch aspects: until the end of the 17th century contributions from the southern and northern Netherlands have substantially advanced the art of navigation. Gemma Frisius, Gerard Mercator, Willebrord Snellius, Christiaan Huygens, were scholars who played an important part in the developments in the field of position finding at sea. We will meet their names further on. In the 18th century it is not so much scholarship, but rather the skill of the English instrument makers that has advanced the art of navigation: John Hadley with his octant and John Harrison with his chronometer. The only Dutch contribution from that time is the method of determining ex-meridian latitudes according to Cornelis Douwes.

The most striking Dutch contribution is the abundant production of pilots and charts, but also of textbooks. That production was not limited to a short period but occurred both in the 16th and in the 17th and in the 18th century and surpassed all that was printed of this kind in foreign countries.

Two different aspects were therefore found: the scientific contributions from the early years and the cartographic contributions which manifested themselves somewhat longer. The scientific contributions were no commercial propositions, but this cannot be said of the cartographic contributions, for the printing of pilots, charts and textbooks was done for commercial reasons. However, this does not mean to say that this was the only reason.

Ensuring safe navigation and promotion of prosperity in the Netherlands were the background of the rutters, pilot guides,*) and textbooks for navigators that came from the press in the 16th and 17th centuries. Or, as many a preface puts it: 'for the prosperity of our praiseworthy maritime navigation', 'which the Almighty will bless ever more in honour of His name and for the bliss of all of us', as the Amsterdam ship-chandler Gerard van Keulen would add. The editions of pilots, which also included charts as from 1584, were not only intended for the sale to Dutch seafarers, but also for the sale to foreigners. This production of books for the international market, which also applied to land atlases, was characteristic of the Dutch typographical industry in the 16th and the 17th century. Textbooks were printed in many countries, in the vernacular, but pilots for the 'open sea', sailed by ships of many home ports, should also be printed in the English and French languages. Obviously, a translation was not necessary for Scandinavian navigators. Dutch was not only spoken along the German Bight, but also in the Baltic. We are now writing about the 16th century, the century when the practical and theoretical art of navigation were no longer exclusively taught in practice on board, but when the subject-matter also became available in printed form. First of all for the trade into the Baltic, at least if we restrict ourselves to the Dutch contributions to editions of books and rutters. From Venice a printed portolano of an earlier date can be mentioned:

Questa e una opera necessaria a tutti li naviganti. Venezia, 1490.

And the oldest known textook of the art of navigation, the anonymous *Regimento do Estrolabia e do Quadrante e Tractado da Sfera do Mundo*, was printed in Portugal in 1509.

Other early works that were of great importance to maritime navigation were those of Pedro Nunes of Coimbra: *De arte atque ratione navigandi*, first edition 1546 and the one of Francisco Faleiro of Sevilla: *Tratado del Esphera y del Arte de Marear*, first edition 1535. Of the very greatest importance for the development of the Dutch textbook for the art of navigation was, however, the work of the Spanish navigator Pedro de Medina: *Arte de nauegar*, which was printed for the first time at Valladolid in 1545. Via a French edition by Merten Everaert a Dutch edition saw the light in 1580.

But long before Italian, Portugese and Spanish pilots started writing down their knowledge for the benefit of those who could also write and read, generations of mates had to learn how to do their practical work exclusively on board. The knowledge of maritime navigation must however

*) Early pilotguides, when without maps are called rutters.

for that matter be gathered from experience in the first place; this has remained so until the present day. In a 'Survey of the history of the art of navigation in the Netherlands' attention will therefore have to be devoted to that period when oral transmission of knowledge from the master to the apprentice was the only teaching system.

Especially on the North Sea, in the English Channel and along the coasts of France and England an enormous quantity of information on tides, shoals and currents had to be collected. It certainly took as much as ten years before a man could be regarded as 'experienced' on a particular route, for example Antwerp-Copenhagen. Unlike the Mediterranean, where with the exception of the Straits of Messina, there are practically no currents, the North Sea is much more difficult to navigate. For these tidal movements the old sailing directions, the portolanos for the Western and Eastern Seas, (resp. the Atlantic coast plus the North Sea and the Baltic) distinguish themselves from the sailing directions for the Mediterranean.

On account of coastal navigation a navigator had firmly to commit to memory all the characteristic views. They served to assist him in his position finding. Out of sight of land navigation was only carried out by crossing from cape to cape, by crossing the North Sea or by crossing part of the Bay of Biscay. The order in which the characteristic views loomed up during the voyage had to be preserved in his memory. The primitive pictures in the sailing directions of the 16th and the 17th century were aids to his memory. Their resemblance was often so small that it must now be obvious to every one that recognition based on experience settled the matter. Sailing along the coast based on recognition is sometimes called 'pilotage' to distinguish it from 'navigation' which is understood as position finding from course and distance run.

During the period of West European maritime navigation, when position finding out of sight of the land was still out of the question, the compass was nevertheless still the most important aid. In fog, clouds and darkness the compass was the only device to find one's course. The apprentice was first of all made familiar with the points of the compass. The diagram of the points of the compass was universally applied, even for indicating the times of high and low tides. Medieval and 16th-century tide tables expressed the time of high and low tides in the 32 points of the compass, for example high tide moon southwest-northeast meant: high tide three hours after the meridian passage of the moon and low tide six hours before the meridian passage of the moon. Each point of the compass counted as 45 minutes.

The seafarers of the countries round the North Sea probably learnt the knowledge of the tides from the mariners of the Mediterranean. During the 13th to the 15th century Venetians, Mallorcans and others sailed several times a year to French, English and Flemish ports. Their nautical notes contain the oldest tide tables and on the famous Catalan map of the world by Abraham Cresques from approximately 1375 we see the oldest known diagram for determining high water full and change of 14 localities, including ports on the Channel.

Probably it has not been the seafarers of the countries round the North Sea themselves who have laid down the relation between high and low tides and the phase and age of the moon in rules. Naturally they were thoroughly familiar with this relation and the facts will have been transmitted orally but the aids to memory we probably owe to learned Italians, Spaniards and Portuguese. Rules for finding the age of the moon and those for the time at night are also based on memorizing, for which the fingers of the hand and rhymes were very useful. Only for those who could read and write there were graphic aids such as the almanac, the tide tables, the chart and the sailing directions. According to Professor E.R. Taylor, who has described the general history of the art of navigation very lucidly in *The Haven-finding Art*, the most remarkable contribution of the north-west European mariner to nautical science consists of the so-called Breton tidal charts. They date from the first half of the 15th century. Though they are real charts containing place-names, also those who cannot read can see at what time the various ports on the Channel and along the French coast have high tides. The knowledge of the relation between the age and phase of the moon and high water full and change naturally was not of such an extent before Isaac Newton's theories that there was a correct insight into the astronomical causes of high and low water. Apart from the knowledge of the 'falling of the waters' and the 'reckoning of the tides' the knowledge of depths and qualities of the bottom was of fundamental significance.

Again: in the period before the written and printed sailing directions and charts this was purely a matter of remembering them. But indeed more difficult to keep in mind than the matters of high and low tides, for which the moon and the time could serve as supports. To know where the shoals were and how to enter the ports between the shoals one needed auxiliary marks as well. These were the landmarks and the beacons and buoys established and moored for the benefit of shipping. Further there was the lead-line, but the art of sounding was of no use, if one did not preserve the pattern of depths and shoals in one's mind.

Because the coast of the Shallows of the Netherlands, Germany and Denmark is unique in Europe, the aids to shipping along this coast of Shoals and the Dutch coast are probably of Dutch origin. The beacons on the dunes are inventions of the seamen of this area. They are as old as the ship itself and have their origin in the self-evident necessity for a skipper to establish a mark on or near the shore, visible from seaward, in order to find his landing place again. In the course of the 14th and 15th centuries this system of marks developed into types of beacons and buoys which, provided with names, were later codified in the sailing directions. Finally the quality of the bottom made a contribution to position finding. Besides all the disadvantages the shallow water of the North Sea also yielded an advantage: practically everywhere soundings could be made, which were used to pick up samples of the bottom. The mate had to learn the local differences, but the sailing directions rendered him assistance. All the data which the sailing directions contained were successively mentioned in the above: course and distance run, current, high and low tides, the approach of ports, marks and beacons, qualities of the bottom, shoals and gullies. A mate who had sailed one and the same area for years could write down all its details. From such fragmentary notes, referring to special localities, the pilot for an extensive sea area arose probably during the 15th century. The great demand for it due to increasing shipping activity was the cause that it appeared in print.

The printed sailing directions or rutters

The world's oldest known printed rutter of West European coasts is the *Routier de la mer* by Pierre Garcie, Rouen, approx. 1502-1510, followed by *Le grant routtier* by the same, Poitiers, 1520. It contains sailing directions etc. for the area between Spain, France, England and the German Bight. The oldest translation into English appeared in London in 1528.

The oldest specific sailing directions for the Dutch coast and for the sea areas especially sailed by Dutch seamen we find in the rutters mentioned below:

Dit is die Kaert vander Zee ...
Printed by Jan Zeverssoon Cruepel, Amsterdam, 1532. – The only known copy is in the Koninklijke Bibliotheek, Brussels. – Later edition in 1540.

Die Caerte vandie Oosterse See ... by Cornelis Anthonisz.
Printed by Jan Ewoutzoon, Amsterdam, 1558.

Dit is die Caerte vander See...
Printed by Jan Ewoutzoon, Amsterdam, 1561.

The *Kaert vander Zee* from 1532 is a rutter which starts with the Dutch coast and continues as far as the Baltic. In the edition of 1540 a separate section on the Zuyder Zee has been included. A separate part on the Baltic has been included in the booklet by Cornelis Anthonisz. of 1558, which consists of two parts:

a) *Onderwijsinghe vander zee om stuurmanschap te leeren ...*

b) *Hier beghint die Caerte vandie Oosterse See ...* (see further under 'Textbooks')

Between 1561 and 1585 even more textbooks, some of which are provided with illustrations, appear in Antwerp and Amsterdam for the trade to the North-west European waters. These illustrations are views of the coast, profiles such as seen from seaward. In about 1510 Pierre Garcie already included some wood-cuts in his 'routier', but Cornelis Anthonisz. was probably the first to include better resembling, fairly long profiles of the coast in his oblong work.

The world's first printed pilot, in which charts are included, is the famous *Spieghel der Zeevaerdt* by Lucas Janszoon Waghenaer from 1584. Moreover this pilot covered a larger area than had ever before been included in a Dutch pilot: from the Canaries to the White Sea. The 23 beautifully engraved charts show the harbours, bays and capes with the profiles of the coasts side by side. The second part which appeared in 1585, contains 22 charts of the coasts of the Baltic and Scandinavia, the so-called Eastern Trade. The publication of Waghenaer's pilot by Christoffel Plantijn at Leiden immediately drew great attention at home and abroad and has been of great importance to the prestige of the Dutch art of navigation. In spite of all the imperfections where an exact representation of facts was concerned, Waghenaer's work was much used and was also translated into English and into French. The work meant a revolution in the composition of pilots which, from that time onwards, got a better presentation. Not only by the sublime cartography, but also by the description of the coasts outside the areas of the North Sea and the Baltic.

Lucas Janszoon Waghenaer of Enkhuizen 'common citizen and navigator at sea', as he styled himself, was one of those competent mates of the 16th century who recorded the coastal trade to Europe from his own observations. He also drew charts, but the text remained the main point. Because since the middle of the 16th century more and more voyages had been made to Portugal, the Canaries and the Cape Verde Islands, severer and different requirements were made on the knowledge of the Dutch mate. Waghenaer appears to have been one of the best educated men among his colleagues. He instructed them in the 'Konst der Zeevaert' (the art of navigation), amongst others by means of the introduction in his *Spieghel der Zeevaerdt.*

Textbooks

The oldest Dutch textbook for navigators is probably Cornelis Antonisz' *Onderwijsinghe vander zee om stuermanschap te leeren* ... (Amsterdam, 1558), preserved in the Harvard Library, Cambridge, Mass., U.S.A., which goes back to a first edition of 1544. Corn. Anthonisz may have borrowed from Spanish and Portuguese sources but does not mention them. He is obviously impressed by the wrong uses and obsolete navigation methods, for some chapters entirely consist of critical notes and rebukes. The knowledge of the seamen was evidently very imperfect, especially of those who sailed to Portugal and to the remoter islands in the Atlantic. In this unevenly composed booklet fresh subject-matter, such as determination of latitude from the altitudes of the stars and the sun, dead reckoning, determining time at night, is treated by the side of older subject-matter such as tidal prediction. Thanks to the original contributions from the Portugese centre of nautical sciences at Sagres (founded by prince Henry, 1394-1460, son of King John I), the Dutch navigator can also profit by this new knowledge. Both in the book by Cornelis Anthonisz and in the Dutch translation of Pedro de Medina's *Arte de nauegar*, but also in Waghenaer's *Spieghel der Zeevaerdt* we find the following new subjects discussed: the use of the cross staff, determination of latitude in the meridian by means of the altitudes of the stars and the sun; in this connection tables of the declination of the sun; determination of latitude by means of Polaris; finding time by means of the nocturnal; position finding from course and distance run; the estimated position; how many miles should one sail in a particular area to gain 1° in latitude; the use of the compass chart. Besides older subject-matter is discussed, such as determining the age of the moon and the times of high and low tides. A characteristic chapter is the 'Vermaninghe tot alle ionghe zeevarende luyden, yverich zijnde om yet te leeren' ('Exhortation to all young seafarers who are desirous of learning'). In this chapter they are instructed to make copies with the pen themselves of what they see when approaching a coast and to make written notes. Also to write down many soundings and depths and to determine the directions to the landmarks: towers, houses, mills, by means of the compass, 'for what a young man does and writes down himself he will keep in mind longer than what he learns from others'.

The Dutch textbook of De Medina was published by Hendrik Hendricksen at Antwerp in 1580. Later reprints were published in Amsterdam by the well-known publisher in the maritime field, Cornelis Claesz. The title was:

De Zeeuaert/ Oft Conste van ter Zee te varen, vanden Excelenten Pilote M.ter Peeter de Medina Spaignaert ...

Both to the first edition of 1580 and to the later Amsterdam editions a textbook has been added, written by Michiel Coignet of Antwerp:

Nieuwe Onderwijsinghe / op de principaelste Puncten der Zee-uaert...

The so-called *Leeskaartboek van Wisbuy* (Antwerp, 1566), also includes a chapter on the art of navigation. It is preceded by a reproach to those young seamen who do not take the trouble to learn how to read and write, for 'it would be very profitable for him if he could read and write to study the rutters of the sea, to see what has been written there on the tides, on courses...'.

In addition to the work by Pedro de Medina two more Spanish textbooks were highly valued in Western Europe:

1) Martin Cortes, *Breue Compendio de la Sphera y de la Arte de Nauegar.* Sevilla, 1551.

During the next twenty-five years it was printed nine times in England. In 1577 an English supplement by William Bourne appeared: *A Regiment for the Sea*, which was also translated into Dutch:

De Const der Zee-vaerdt / begrypende seer nootwendighe saecken voor allerhande Zee-vaerders / als Schippers / Stuerlieden / Piloten / Bootsvolck ende Coop-lieden. [door Willem Bourne], Amsterdam, Cornelis Claesz, 1594.

2) Rodrigo Zamorano, *Compendio Del Arte De Navegar* (Sevilla, 1581), translated into Dutch, bearing the title:

Cort Ondervviis Vande Conste der Seevaert beschreven deur den Licenciaet Rodrigo Zamorano ... Overgeset vvt den Spaenschen in ons Nederlantsche sprake: Deur Martin Everart. Amsterdam, Cornelis Claesz, 1598.

The above-mentioned books were relatively small: one hundred pages in quarto format. The purchase price was small in comparison with the sailing directions by Waghenaer. But the purchase of Waghenaers' pilot also included a textbook on the art of navigation. After the spectacular appearance of the first edition of the *Spieghel der Zeevaerdt* in 1584 and 1585 other editions followed in Latin (1586) and in French (1589, 1590). In London, in 1588, the work had been copied and translated, bearing the title: *Mariners Mirrour.*

In all these editions and also in the new pilot by Waghenaer: *Thresoor der Zeevaert,* which appeared in 1592, there is a substantial section on the 'konst der zeevaart' (the art of navigation). With the year 1592 we arrive at the period when Dutch mates started sailing the oceans on their voyages to East Asia. The requirements made on the art of navigation for this purpose were again considerably severer than the requirements for the trade to the Cape Verde Islands and the Azores. The pilot of 1592: *Thresoor der Zeevaert* is really a precursor to the pilot for the trade to Asiatic waters; it contains a report by Dirck Gerritsz (Pomp) alias 'Dirck China' on the trade and commerce to China together with a report by Jan Huyghen van Linschoten on the trade and commerce to India. In the pilots after 1608, when the first edition of Willem Janszoon Blaeu's *Licht der Zeevaert* appeared, the tradition of an introduction to the art of navigation is continued. In fact this has gone on till the 18th century. In Willem Janszoon Blaeu's *Licht der Zeevaert* 52 pages are devoted to a 'Corte ende clare Inleidinghe tot het verbant van de hemelsche Sphaera in zoo veele als tot de conste der Zee vaert van noode is'. ('Short and clear introduction to the relation of the celestial sphere as is necessary for the art of navigation'.) This emphasis on astronomy as a basis for the art of navigation is characteristic of the 17th century. The theories, however, were already formulated in the 16th century.

The great theoreticians of the art of navigation

In addition to the contributions from Sagres, nautical science owes much to the contributions by mathematicians of the 16th and the 17th century. During the first half of the 16th century Louvain flourished as a centre of theoretical mathematics and astronomy. The learned Gemma Frisius, to whom we owe the principles of triangulation (1533), published as early as 1522 his paper on the significance of chronometer transport for the solution of the problem of determining longitude. Among other objects Gemma Frisius also constructed the universal astrolabe: Astrolabium Catholicum, which also, propagandized by Plancius, was used during the long voyages at sea by the Dutch. At Louvain the world's greatest cosmographers met, including Gerhard Mercator. To Mercator maritime navigation owes the first application of the geographical grid with increasing latitude degrees (1569) and the representation of loxodromes on the terrestrial globe. The problem of determining longitude and navigation over great distances had been topical since the early part of the 16th century. According as the mates of the Netherlands got more involved in long distance navigation these subjects were also tackled by Dutch scientists.

First of all by Petrus Plancius, minister of the Reformed Church, who had gone into exile from Antwerp to Amsterdam in 1585 and had made an important contribution to the planning of the first Dutch voyages tot the East Indies. Both the cartographic and the nautical preparation largely rested with Plancius. For determining longitude at sea he placed great confidence in the observation of the magnetic variation of the compass for which a longitude finder designed by him was used. We know him as the instructor of mates and the well-known picture of the teacher in the pulpit no doubt refers to him.

Simon Stevin, too, was convinced of the possibility of 'finding East and West' from the variation of the compass. Simon Stevin (1548-1620), mathematician and tutor of Maurits van Nassau, wrote an interesting book on position finding at sea called *Havenvinding* in addition to his many publications on mathematics, weighing, architecture, hydraulic engineering and astronomy. It appeared in 1599, at the same time as the translations into Latin, French and English. The English translation is by Edward Wright, who is generally known as the author of *Certaine Errors in Navigation* in which amongst others the increasing latitude chart is preferred to a chart having equal degrees.

In 1605 another important work by Stevin was published: *Van de Seylstreken* ('The Bearings'). It is devoted to the two courses which a ship may follow: the great circle or the loxodrome. The nature of the course line which makes a constant angle with the meridian had already been found by Nunes in 1537 and Gerhard Mercator drew loxodromes on his terrestrial globe of 1541.

In his book on astronomy: *De Hemelloop,* Stevin shows that he is one of Europe's rare enlightened minds: he is convinced of the motion of the earth, moon and planets in accordance with the theory of Copernicus, which he explains to Prince Maurice. Maurice recognized the great importance which science could have for Dutch enterprise at sea. Among other things he gave orders to make stellar observations and to take azimuths at sea in order to determine the variation of the compass. The variation of the compass was already measured by Columbus. From the Portuguese textbooks we learn how the variation of the compass was already determined with a so-called azimuth compass.

In the method of position finding at sea, the measuring of the speed of the ship took an important place. The position was determined from the course set and the distance covered from the preceding position. Because the speed was estimated, an error could easily arise when, for example, the speed and the direction of the current were not known. From the movement of the water along the hull experienced seamen knew how to make a rather accurate estimate of how many miles the ship covered in 24 hours. There was not really a scientific method so that in the 16th and in the greater part of the 17 th century we had better speak of the 'art of navigation'. The learned Adriaan Metius published in 1632 a treatise on the calculation of speed on board: *Astronomische ende Geographische ondervvysinghe*, in which speed is calculated from a known covered distance.

As long as the length of the circumference of the earth was not known and one therefore did not know how many miles there were in one degree of latitude, position finding by course and distance rested on a weak basis. Professor Willebrord Snellius of Leiden was the first to measure a section of the meridian by means of triangulation between Alkmaar and Bergen op Zoom, the results of which he published in his book *Eratosthenes Batavus* in 1617. For the first time one could fairly accurately show how many Rhineland roods there were in one degree of latitude, through which the log, the line marked with knots which was paid out, got a mathematical basis.

Snellius describes the measuring of distance with the log in his book: *Tiphys Batavvs, Sive Histiodromice, De navium cursibus Et Re Navali* (Leiden, 1624). The use of the log was first mentioned by William Bourne in his book: *A Regiment for the Sea* (London, 1574), but Lucas Janszoon Waghenaer was the first to refer to it in a Dutch book: in the *Enchuyser Zee-Caert-Boeck* of 1598.

The first to introduce the use of a timepiece at sea (at least experimentally) was Christiaan Huyghens. Determination of longitude from lunar distances, from eclipses of the moon or from eclipses of the satellites of Jupiter remained limited to observations on land. Galilei's invention of the astronomical telescope offered the possibility to apply the latter method also at sea. The States General had offered a large reward for him who invented a method of determining longitude applicable at sea. Huyghens' experiments should therefore be seen in that light. His method was perfectly sound, but the pendulum clock invented by him in 1657 was not proof against the rolling of the ship. It was not before 1730 that the English watch-maker John Harrison constructed a timepiece that successfully stood the test at sea.

The pioneering work of the great theoreticians Gemma Frisius, Mercator, Plancius, Metius, Snellius benefited the art of navigation in the long run only. Throughout the 17th century and a great part of the 18th, the Dutch navigator kept using his plane chart, estimating his speed from the bow-wave and measuring his sun's altitude from the cross staff.

INSTRUMENTS

In the 16th century the cross staff, the astrolabe and the quadrant were the instruments with which the latitude was measured. The sea astrolabe, a heavy instrument, not affected by the rolling of the ship, was not generally used in the Netherlands as opposed to Portugal and Spain. The making of the cross staff we find discussed in the sailing directions as late as the latter part of the 17th century. At the time of the V.O.C. (the Dutch East India Company) the equipment lists of the ship mention what navigational instruments had to be on board. As early as in the first period (1602 – 1620) we meet the astrolabium catholicum dozens of times, but also the semi-circular astrolabe (circle of 180°), numerous globes, horizontal compasses (for determining the azimuth), sand glasses, and the cross staff, which is usually called 'Graedboogh'.

Only in the middle of the 18th century are modern instruments mentioned in the inventory lists. They were naturally the spy-glass (which already appeared on board in the middle of the 17th century for that matter) and the octant. In 1731 the Englishman John Hadley constructed the octant, an instrument for angular measurement by which the accuracy of latitude finding was considerably increased. In the introduction of this instrument on board Dutch ships the booklet by Cornelis Douwes: *Beschrijvinghe van het Octant,* 1749, will have played a part.

But in the well-known textbook by Gietermaker the octant is for the first time described in 1774 only. Especially for observations when the sun is at its zenith, Hadley's octant proves to be very useful. In 1779 the 'Heeren XVII' (the executive of the Dutch East India Company) decided 'to give the ships three octants instead of 2 octants and 4 cross staffs, because the cross staffs are very deficient instruments for taking the sun's altitude for which they actually serve'.

In the years after 1731, when Hadley's octant came to be used, the differences in the sun's altitude measured with it amounted to as much as 10'. Owing to the improvements of the octant these differences became smaller. From fixes obtained during the years from 1780 tot 1790 differences of 1' or 2' manifest themselves. With the introduction of the chronometer on Dutch trading ships the same thing will have happened as with the octant: it took dozens of years before everyone was convinced of its usefulness. However, on Dutch navy vessels, modern instruments were readily available, as Davids has demonstrated.

It should not be expected that the effect of improved clocks on navigation was immediately noticeable. In 1772 James Cook was the first shipmaster to raise navigation to a much higher level of accuracy. Maritime cartography owes its first reliable charts of the Pacific Ocean and of the vicinity of Newfoundland to Cook. Especially because position finding could be carried out so much more accurately after about 1780 all nautical charts had to be renewed. The process of the obsolescence of charts never went any quicker than at the turn of the century: around 1800. Thanks to the professional skill of an instrument maker who built a chronometer in 1765 which was only 15 seconds slow in 156 days at sea, the safety of navigation made enormous progress. Therefore one may rightly conclude that instrument making (octant and chronometer) have had a more direct effect on the art of navigation than mathematics and astronomy.

THE DUTCH TEXTBOOKS OF THE 17TH AND THE 18TH CENTURY

During more than two centuries one can observe the close relation between the subjects: textbooks, small schools of navigation and the examining of mates. As early as the 16th century we know the mathematical practitioners who provided instruction for inter alia land surveyors and navigators. They often taught from their own textbooks. As far as those textbooks are concerned: many larger and smaller works were published but in this survey we only mention the most important ones and will be guided by Crone's book on Cornelis Douwes. In addition to the chapters on the art of navigation in Willem Janszoon Blaeu's *Licht der Zeevaert,* of which about 25 editions were published between 1608 and 1637 and besides similar works by Colom and Jacobsz (later called Lootsman) the books stated below deserve mentioning:

Jan Hendrik Jarichs van der Ley, *Het Gulden Zeeghel des grooten Zeevaerts.* Leeuwarden, 1615.

[Idem,] *'t Gesicht des grooten Zeevaerts,* Franeker, 1619.

Ezechiel de Decker, *Practyck Vande Groote Zee-vaert.* Gouda, 1631 and Rotterdam, 1659. (Transcription from the edition of 1659.)

Cornelis Jansz. Lastman, *Kunst der Stuurlieden.* First edition. Amsterdam, 1642, followed by many new editions until after 1700. (Transcription uniformed.)

Abraham de Graaf, *De Seven Boecken Vande Groote Zeevaert.* First edition. Amsterdam, 1658.

[Idem,] *De Kleene Schatkamer of een korte beschrijving van de Konst der Stierlieden.* First edition. Amsterdam, 1680. (Transcription uniformed.)

Dirk Rembrandtsz. van Nierop, *Onderwys Der Zee-vaert, Inhoudende De voornaemste stucken der Stuer-luyden.* Amsterdam, 1661, with several reprints until 1680. (Transcription from the edition of 1667 (?).)

It may be said of the above-mentioned authors that they were proficient mathematicians, who, besides their books on navigation, also wrote works on astronomy and mathematics. They gained a living from the sale of their books and from the tuition fees they received from their pupils. Abraham de Graaf and Cornelis Lastman were moreover examiners of the mates of the Dutch East India Company. The subject-matter taught to the pupils did not always meet the requirements of the time but was more adapted to the traditional conceptions of the art of navigation. In many cases the mariner will only have been interested in earning double the wages as soon as he could show his certificate. The tutors, who were thoroughly conversant with the problems of determining longitude and latitude, accurate fixes, determining the error of the compass etc., competed with each other by means of provocative pamphlets and short essays. Contesting each other's theories was also a form of advertising to get more pupils. To such criticism and contestation even the most popular textbook has been subject: Claes Hendricksz Gietermaker, *'t Vergulde Licht Der Zee-vaert,* first edition (Amsterdam, 1660). Between 1660 and 1774 fourteen editions of this book were published, including a translation into French. Gietermaker was also examiner of the art of navigation and also kept school at his home. Besides the other very popular book by Klaas de Vries: *Schat-kamer Ofte Konst Der Stierlieden* (Amsterdam, 1702), his book was used for a long time. The book by Klaas de Vries was used as late as the first decades of the 19th century.

The subject matter in the books embraced more than the mate was really taught. By means of preserved 'exercice books' Crone showed that corrections for the determination of latitude were not required neither for the accurate determination of the error of the compass, time of sunrise, course reduction and course and distance run calculations. Further, 26 years after the invention of the octant Gietermaker has not yet inserted this instrument in the text of his book, but refers to descriptions in separate publications.

In order to illustrate the traditional drawing up of a textbook of the art of navigation we mention here the contents of Gietermaker's book, edition 1731.

First part: Moon calendar, calculation of the day of the full moon with the aid of the Golden Number and Epacta. Mode of reckoning time in the old style of the Julian calendar, although the new style of the Gregorian calendar had already been introduced in 1582. Tidal prediction. Calculation of high water full and change with the aid of a dial composed of the points of the compass (this method already dates from the 15th century; see earlier). Finding time at night. Determination of latitude. The astrolabe and the cross staff are mentioned. Construction of the cross staff. Tables of declination. The compass and the determination of the error of the compass.

Second part: Square and cubic tables. Planimetry. Oblique sailing. Goniometry. Calculation of course and distance run. Number of miles one sails to gain one degree of latitude. Compound courses. Constructing a chart having equal degrees. The deficiences of the chart having equal degrees: 'If one divides the measurements of latitude and longitude of a plane chart into equal degrees, the use of the chart cannot be faultless, because of the roundness of the globe and of the sea. As, although there are so many in use, there is a shortage because there are no others in sufficient numbers, and because of old custom and it is said that there is no matter stronger than custom and therefore I will describe how one should make and use the same.' Follows the construction of the grid. Table of increasing latitudes. The loxodrome: 'As the property of the progress of the ship, when sailing in accordance with the compass, is such that at sea she shapes a round or curved line which converges to either of the Poles; These curves are called equiangular spirals or rhumb lines.' Measuring the speed of the ship by means of estimating the speed. Mention is made of the method of the line having knots. Extent of the degree of latitude: 'According to the observation made by Willebrordus Snellius a degree of latitude or distance amounts to 285,000 Rhineland roods and a rood being reckoned at twelve Rhineland feet, a common German mile is 22,800 Rhineland feet.' (G. 1731, p. 138). Posting up the log book. Instruction: On the proporties of the Winds in the navigable waters between the Netherlands and Java.

Third part: This is entirely devoted to spherical trigonometry. The book ends with goniometric tables, Briggs' logarithms and the tables of increasing latitude. From a comparison with earlier editions of Gietermaker's book it appears that the greater part of the subject matter was still at the level of the textbooks from the years of about 1650. In a report produced by some naval officers in 1742 on the poor quality of the instruction in the art of navigation the authors state that 'the Citizens of the Republic have remained on that level of science as has been known in that matter for a hundred years and longer'.

To these arrears in nautical knowledge we must still add the arrears in cartography.

A comparison between Dutch and foreign charts from the middle of the eighteenth century shows that the contents of the Dutch charts were often more than half a century old. This notably applied to the printed charts in the sailing directions and the nautical atlases published by Messrs. van Keulen. In the neighbouring countries England and France, but also in Denmark and Sweden considerable renewals of the chart content had been carried out in the second half of the 17th century.

A somewhat planned hydrographic charting of the Dutch waters by a national fleet was as yet out of the question. For the trade to the East and West Indies the hydrographic office of the Dutch East India Company had the disposal of well posted up chart material and ditto sailing directions in the middle of the 18th century. But for this purpose they had a large staff of cartographers at their disposal and the instructions for the surveys of the waters in the East Indies were well carried out and regularly posted up.

The great changes in the 18th and 19th centuries

In February 1748 the Admiralty of Amsterdam appointed the 36-year old Cornelis Douwes, son of a Terschelling barge skipper trading to Bremen, as teacher in the Algemeen Zeemanscollege ('General Nautical College') of Amsterdam. His title became: Mathematician and Examiner of the National Naval Officers and Navigators. With Cornelis Douwes the period of what Professor Taylor would call the 'Mathematical Seaman' begins. Although very slowly, new methods, new instruments and improved tables were introduced, among other things because the angle-measuring instrument and the bearing compass had become more accurate, the corrections for dip of the horizon and refraction had to be calculated to the nearest minute. The most important innovation embraced more extensive instruction in mathematics and astronomy, without which basis no good instruction in the art of navigation can be given. In 1747 Cornelis Douwes had therefore suggested that the Admiralty, the municipal administration and the Board of the Dutch East India Company should establish a General Nautical College where these basic subjects, besides navigation, land surveying, artillery and the construction of fortresses would be taught by him. Fortunately his proposals were accepted, though, as the gentlemen of the Admiralty said: 'as yet not understanding fully how seafaring men could be induced to frequent such a school or college'.

Cornelis Douwes, an excellent mathematician and a very accomplished teacher trained numerous seamen until his death in 1773 and examined many naval officers in the field of navigation. The College founded by him became the predecessor of the 19th-century nautical colleges. Of the various learned treatises written by him his calculation of the determination of latitude from two measurements of the sun's altitude, neither being the meridian altitude, is the most important. Besides this navigation owes to him an improved bearing compass, a description of the use and the adjustment of the octant and a collection of *Zeemans-Tafelen* ('Seamen's Table'; transcription from the second edition of c. 1774), first edition 1761. This collection contains tables for dip of the horizon and refraction, for the sun's diameter, for the declination and the right ascension of the sun, for the goniometric relations and their logarithms, etc.

The principle of the determinations of latitude from two sun's altitudes which are some hours apart was already known to Pedro Nunes (see the latter's *De Arte Atqve Ratione Navigandi...* Coimbra, 1573). In the textbooks, among others in Gietermaker, it regularly occurs as a problem. But its theory is not given and the calculation was inaccurate, cumbrous and puzzling to the seaman of those days. It has been the great merit of Cornelis Douwes that he introduced a method of calculation (using approximate values for longitude and latitude) which, thanks to its simplicity, could be applied by the seaman.

In 1771, the tables by Douwes were inserted in the Nautical Almanac.

His computation method was internationally applied until far into the 19th century. After 1827 it was replaced by such a method of Lobatto and Hazewinkel which was replaced again by the method of the lines of position invented by Captain Sumner in 1843. Only in the second edition of Brouwer's standard work on *Theoretische en praktische zeevaartkunde* ('Theoretical and practical navigation'), 1880-1882, is Sumner's method for the first time inserted in a Dutch textbook.

As was to be expected after the renovations by Douwes, the textbooks of the last decades of the 18th century also got a different character, more directed towards mathematics. This successively appears from the editions of Pybo Steenstra's *Grond-beginzels Der Stuurmans-konst* ('Foundations of the Art of Navigation'), first edition, Amsterdam, 1766, last edition, Amsterdam, 1827.

We have now arrived in the 19th century and at this stage we wish to conclude our survey of the development of the art of navigation in the Netherlands. As a textbook the *Handleiding Voor De Praktische Zeevaartkunde* ('Handbook for Practical Navigation'; transcription from the first edition of 1845) by the great Jacob Swart has left its mark on the training during that century. The 19th century may further be looked upon as the century in which the problem of the determination of longitude at sea was definitely solved. Douwes, too, paid attention to this problem in his days, but all experiments with timepieces on board ships were bound to fail because of the still imperfect construction of those clocks. During the 18th century there was no lack of trial trips with chronometers on board in the Netherlands either, equal to those to which a great deal of attention was paid especially in England. We know of the attempts made by father and son Zumbach van Koesveld in 1750, two Leiden scholars who tested a self-made chronometer at sea in their endeavour to improve the determination of longitude. The mechanism could not meet the requirements made, however.

Only after approximately 1780 do seafarers in Holland get the disposal of reliable chronometers and, which is equally important, does the seaman learn how to use them. In the first few years of the 19th century the demand for marine chronometers became so large that the instrument makers could hardly meet the needs. The principles of the construction had been transferred from England to other centres of the watchmakers' art and now the navy could also concentrate on better hydrographic charting, both of the coasts of Europe and of the sea in America, Africa and Asia. The impulse for these improvements had already been given in 1787, when the government installed a committee: *De Commissie tot de Zaaken, het bepalen der lengte op zee en de verbetering der zeekaarten betreffende* ('Committee for the determination of longitude at sea and for the improvement of nautical charts'). At sea this organization made a contribution to the effect that the arrears which Dutch navigation had incurred, say with regard to England, were made up. In 1846 the task and the name were changed into: *Commissie tot het examineren der Zee-Officieren, Adelborsten en Stuurlieden, tevens belast met het opzicht over de uitgave van een Zeemansalmanak, der zeevaartkundige Berichten en Zeekaarten.* ('the Committee for examining Naval Officers, Naval Cadets and Mates, also charged with the supervision of the issue of a Nautical Almanac, of the nautical Reports and Nautical Charts'). In the meantime the Royal Netherlands Navy had already made a contribution to the accurate surveying of the Dutch waters. From 1820 to 1850 the sheets of the nautical chart of the Dutch waters successively appeared for the first time in a modern design satisfying the highest standards of accuracy. When the hydrographic department of the Ministry of the Navy was established in 1874, the continuity of the quality of hydrographic charting was ensured.

When we take a retrospective view of what has been written on the development of the art of navigation in Holland in the above lines, a thought on navigation suggests itself in a wider sense: By how many shipwrecks can this development be judged? For behind the story of astronomy, cartography, geodesy and the art of the instrument makers is the story of the thousands of disasters which hit the seaman and his relatives in the course of the last five centuries when we can speak of a scientific approach to the art of navigation. Meditating upon this we arrive at the conclusion that human genius had not really developed far enough to send ships overseas out of sight of land. The motives, which were behind shipping, however, were stronger than the consciousness that the human race was not really properly equipped for the great adventure.

Taking a retrospective view of the history of 'Five centuries of dead reckoning', we will let our thoughts linger on two fundamental contributions of human ability: the unveiling of celestial mechanics and the art of instrument making. The interplay of these two contributions has advanced the art of navigation so far that in our days one may say that the motives behind maritime navigation are in agreement with human ability.

The intellectual share of the Dutch in this development has been considerable. Their share in the techniques of instrument making was small, however. With this conclusion the historical survey in this book has not been brought to end, however. It is continued in the list of books on the art of navigation which also purports to be a historiography by its chronological arrangement.