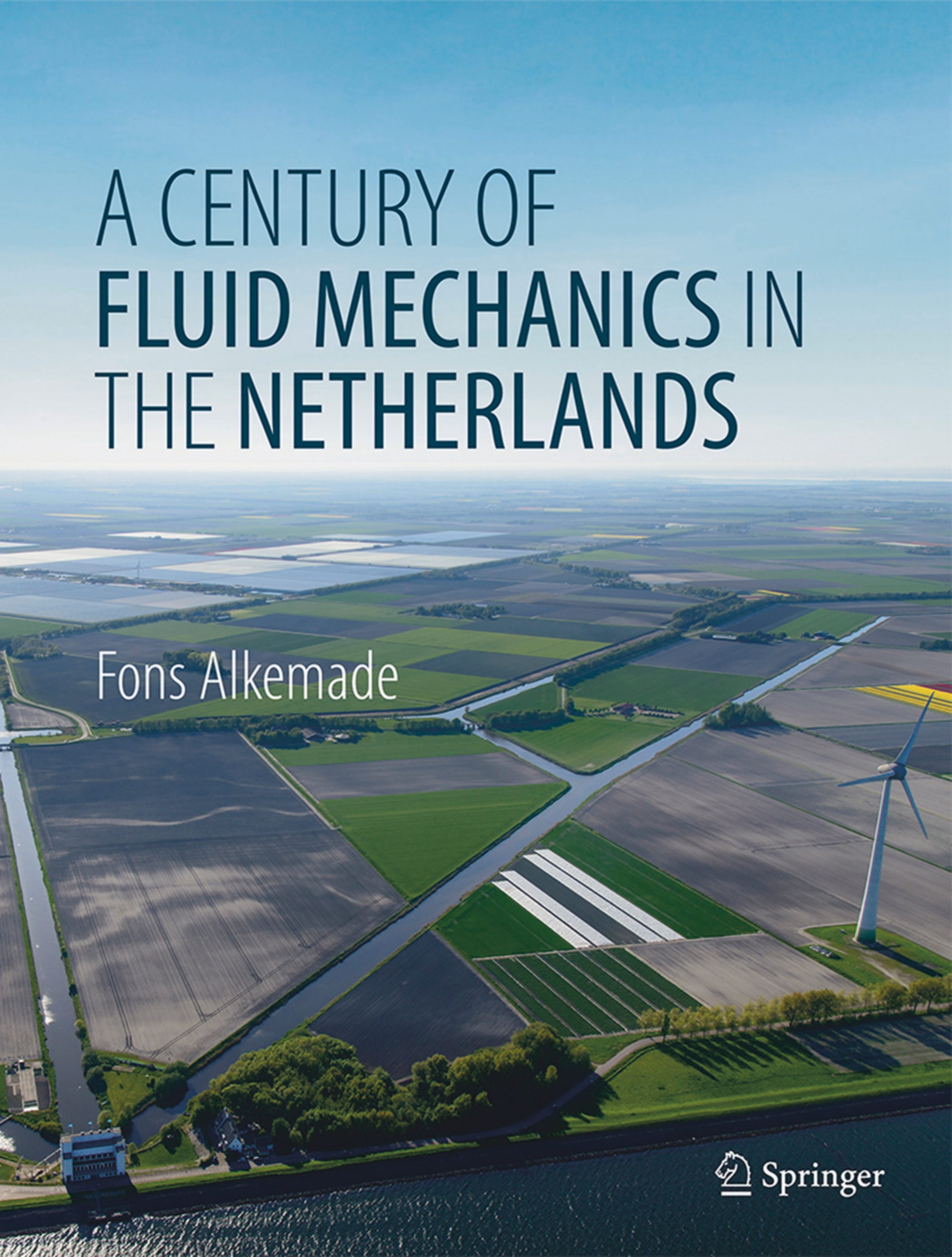
A CENTURY OF **FLUID MECHANICS** IN THE **NETHERLANDS**



Fons Alkemade

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PREFACE

The publication of this book marks the centenary of the appointment of the first professor in fluid mechanics in the Netherlands: this was Johannes (Jan) Martinus Burgers (1895–1981), who was appointed at the age of 23 (!) as professor at Delft University of Technology. This historical fact forms a good reason to look back on 100 years of fluid mechanics in the Netherlands. In particular, on developments in research in this area, both in academic settings and in industrial laboratories.
Fluid mechanics as an engineering activity has been practised in this country for much longer – just think of the development of wind mills for various purposes, the building of waterways and dikes for water management and coastal protection, land reclamation, ship building, and other engineering applications. Its broad societal relevance and its many direct applications have always been a primary driving force in the development of fluid mechanics as a branch of engineering. A century ago, it was realised that a more fundamental study of this field was also relevant and much needed, in order to lay a firm foundation under this fast-developing field. Research on fundamental issues would become of great importance for essential, deeper insights into the dynamics of the various flow phenomena encountered in daily life, be they in natural situations or in industrial configurations.
In this book, Fons Alkemade has collected interesting historical material that illustrates the activities of the various branches of fluid dynamics, thus providing a comprehensive overview of the development of the field since the appointment of J.M. Burgers. Many new areas have emerged within the field, and have led to essential, better understanding of the fundamental dynamics. Such important new developments were made possible by remarkable progress in experimental techniques and increasingly powerful computational resources.
This book project has received financial support from a number of industrial sponsors, and also from the JM Burgerscentrum (JMBC), the national research school for fluid mechanics in the Netherlands. This school is proud to be named after the first chair holder in fluid mechanics in this country. The JMBC acts as an umbrella organisation for many academic fluid dynamics research groups in different university departments, ranging from chemical, civil, and mechanical engineering to mathematics, physics, and zoology – illustrating the wide relevance of the field. With about 200 scientific staff and more than 350 PhD students and post-docs participating, it nicely shows that in the Netherlands fluid mechanics is a lively and very active branch of science and engineering.
It is my wish that reading this book will be as great a pleasure for you, as it has been for me.

GertJan van Heijst
scientific director JM Burgerscentrum

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- sharing with me all the names, dates, facts from his amazing memory: Leen van Wijngaarden, whose career, together with that of his father C.M. van Wijngaarden, professor in dredging engineering in Delft from 1922 onwards, covers almost the complete period treated in this volume

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And last but not least, many thanks to Henk Stoffels and Roy Wolfs of Curve (www.curve.nl) who have done an excellent job in giving this volume its lay-out and preparing it for publication.

CONTENTS

01

INTRODUCTORY REMARKS

Try to imagine: you have just been appointed as a professor in in a field of science of which you know little and of which you are the very first in your country. You have no laboratory, you have no international contacts and you are only 23 years old.

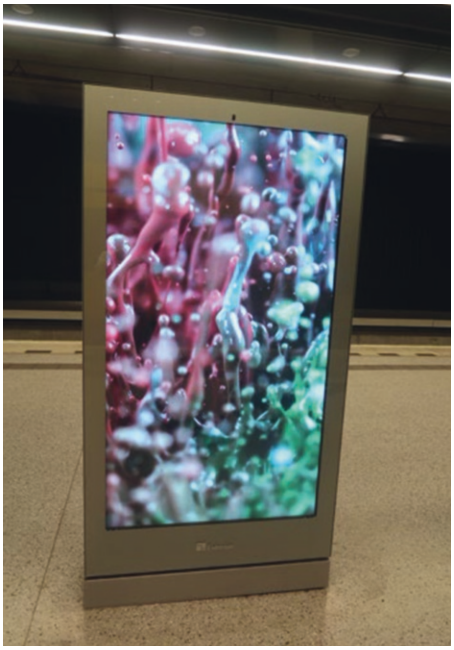
We do not know what Jan Burgers thought of his situation in his first years as professor in Delft, but we do know that he took his job very seriously and soon became well-known and respected in the world of mechanics. In 1975, contemplating on his years in Delft (1918–1955) in the *Annual Review of Fluid Mechanics*, he commented: “Looking back, I may even say that the major part of my scientific work has been directed towards interpretation, more than to finding new results, although interpretation often opens the mind for a new view.”

F. Alkemade, *A Century of Fluid Mechanics in The Netherlands*, https://doi.org/10.1007/978-3-030-03586-0_1

↑One of the few places in the Netherlands where the wonderful world of fluid flows is regularly presented to 'laymen' (and where they are invited to think about this world) is the column 'Alledaagse Wetenschap' (Everyday Science) written by science editor Karel Knip in the newspaper *NRC Handelsblad*. Knip started his weekly series in 1991 and the number of issues in which fluid mechanics is involved must by now have passed one hundred. Topics range from the waves generated by ducks or raindrops, to the rising smoke of cigarettes, to the 'tea cup effect'.

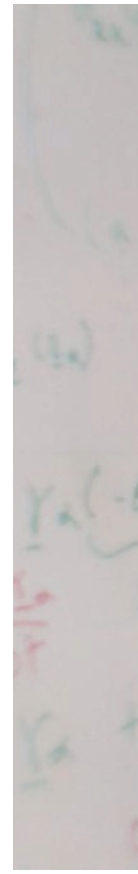
In this book we look back on developments in fluid mechanics in the Netherlands. Burgers' observation, quoted above, raises at least one intriguing question: did Burgers set a trend and can one say that most fluid mechanicists in this country have been 'interpreters' rather than 'discoverers'? It is up to the reader to try to formulate an answer. The topic of this book also leads, naturally, to a related question: has there ever been, or is there today, some aspect of this field of science and engineering which could with some convincing arguments be called 'typically Dutch'? The front cover of this monograph may be seen as a hint toward the author's answer to this question. Although it is an exaggeration, it makes sense to assert that the Dutch were, to a large extent, responsible for the shaping of their country. To achieve their goals, they had to find clever solutions with regard to the inherent threat posed by all the water flowing through and around their country, and they also had to understand its behaviour.

At the Burgers Symposium in June 2018 (the annual event where many of those working in Dutch fluid mechanics come together) the author put up an almost blank poster on which the participants could write down the achievements in Dutch fluid mechanics which they thought have been really unique or important. Among the results were the 'Delta Works' and the making of artificial islands near the coast of Dubai by Dutch contractors, proving that the pride about the Dutch 'fight against the water' is still there. Other achievements written on the poster had to do with "transport phenomena for chemical engineering", "up-scaling", "digitizing PIV", "immersed boundary methods", "convergence CFD non-Newtonian flows", and a few other topics.

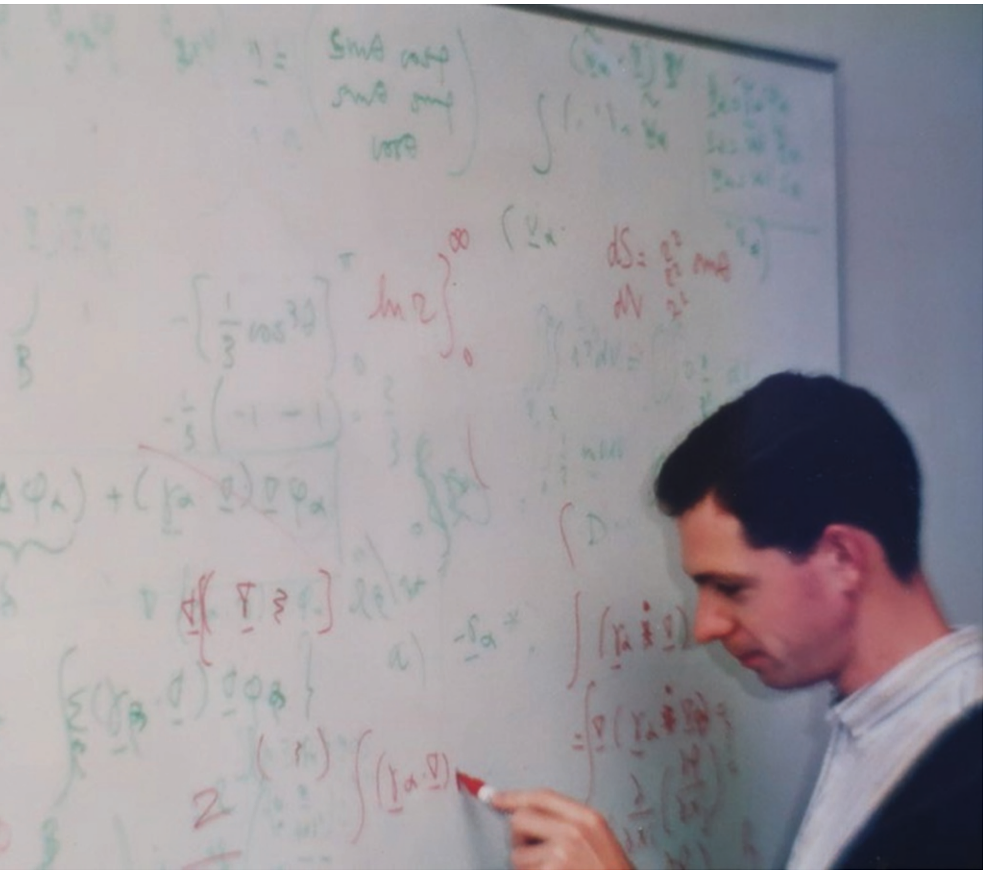


↑Flow phenomena for the entertainment of waiting train passengers. During his trips to Delft for consultation in the Library of the TU and the Burgers Archives, the author not only discovered that modern billboards can show moving images but that they also show non-commercial images related to fluid mechanics.

↑Fluid mechanics on Dutch television anno 2018. In March the 'NOS Journaal', the oldest news program of Dutch public broadcasting, reported on simulations which had been carried out by MARIN with a model of the South Korean ferry Sewol. In 2014 this ship had capsized, leading to the dramatic death of more than 300 people. In April 2018 a Dutch daily educational program for children reported on the unique research facilities in a swimming pool in Eindhoven (see chapter 7). During the hot summer of 2018 several broadcasters reported on the 'bubble screen' which Rijkswaterstaat had installed in the Canal between Amsterdam and the river Rhine to prevent salinization (see § 5.3.2). Also in July the Van Heck company, a specialist in pumps since 1964, got international attention by offering its services to save twelve boys from a flooded cave in Thailand. (courtesy of MARIN)



Fluid mechanics in the Netherlands has not really been different from fluid mechanics in other countries. But maybe one rather unique aspect could be mentioned: fluid mechanics has usually been called 'stromingsleer' (flow theory) in this country, so leaving aside the 'mechanics' character of the field. We should add that the term 'stromingsleer' was only used from the 1930s while in Germany 'Strömungslehre' was already fashionable in the 1920s.
Whereas the historiography of (fluid) mechanics has come of age during the last few decades, alas this cannot be said of fluid mechanics in the Netherlands. Fortunately, some of the institutes where flow phenomena have played important roles (like the Hydraulics Laboratory WL and the Aerospace Centre NLR) have initiated the publication of jubilee books in which the history of their activities have been described (more or less extensively). The history of some academic laboratories has also been written down, or the history of some particular fields within fluid mechanics like hydrology and hydraulics. But for most of the topics treated in this volume information could only be found in contemporary sources (of which several are mentioned in the list of references) or in the Burgers Archives in Delft.
The reader may find that a remarkably large part of this book treats researchers and facilities which are related to the University of Delft (THD, later TUD). The author can only admit that since he is a 'product of Delft' and is best known with the Delft archives and libraries it was tempting to put much 'Delft' into this book. But then, there are good reasons to defend this: Delft has been involved in fluid mechanics for much longer than any other university and it has been a source of many and very diverse examples of research, both theoretical and applied.
The author hopes that the content of this book will at least make two things clear to the reader: that many of the current topics in Dutch fluid mechanics have a long history in this country; and that despite the relatively small fluid mechanics community there has always been a large diversity in research and topics. It has not been the intention of the author to give a complete survey of Dutch research in all its aspects; the number of pages didn't allow this anyway. Selection of topics has been based on several criteria. One of them was that there had to be a real Dutch element. Another was: is it something of which Dutch scientists can be proud? Also important was whether enough information and a good image related to the topic could be found.
The author realizes that some readers will be disappointed about the absence of some topics. Some may also be disappointed about the fact that one can find hardly any graphs, tables, formulas, or simulations on these pages. Usually, these kinds of images are only meaningful to a large number of the readers when accompanied by (rather long) explanations. Besides, it would have led to many time-con-



←The author was a PhD student in fluid mechanics in the early 1990s. Here he is discussing some equations related to the so-called vorton method, a rather new 3D vortex method at that time, with which he and others hoped to be able to simulate the vortical coherent structures in turbulent boundary layers. Some 75 years after Burgers started in Delft, fluid mechanics had changed in many aspects, one of them being the use of computers. But in hindsight one can also conclude that the computational hardware and software were still quite primitive as compared to the situation 25 years later (the author was very happy at the time that he could use a '386 PC'). As for the theoretical approach, illustrated by this photo taken in the office of Burgers' 'academic great-grandson' Frans Nieuwstadt, things may not have changed much. This photo is also indirectly pointing to a 'problem' encountered by the author when doing research for this historical account of fluid mechanics: photos showing researchers 'in action' are hard to find.

suming considerations: which graphs, etc., should be used and which not? For the same reason, hardly any references are given to original papers which appeared in scientific or engineering journals.
The reader will also notice that in this book almost all names mentioned are those of professors. You will understand that mentioning all staff members from all groups involved in fluid mechanics would have led to long lists and would have cost a lot of research work. You will also notice that almost all the professors mentioned are not among us anymore. The author has chosen to hold back with the mention of researchers who are still active.

GUIDELINE FOR THE READER

The chapters 2–7 in this book can be divided into three segments.
Chapters 2, 3, and 4 present the history of Dutch fluid mechanics from the 16th century up till the early 1990s.
Chapter 2 describes some remarkable and sometimes characteristic achievements of the period leading up to 1918. The reader will notice that some kinds of research from the last century had some real pioneers (many) decades before 1918.
Chapter 3 starts in 1918, which is not only the year in which fluid mechanics got an 'official' status in the academic world (Jan Burgers in Delft) but two other important events for the development of Dutch fluid mechanics took place: the start of the work which would lead to the Afsluitdijk and several other important hydraulic works related to the Zuiderzee; and the start of the first Dutch aeronautical institute. This chapter ends around 1955, when Burgers emigrated to the US.
Chapter 4 describes how fluid mechanics developed in the Netherlands after 1955, in the academic world, in some of the institutes, and also in some branches of industry. The 1950s can be seen as the start of a new era. Several important events took place which had a major impact on the development of the field: the start of the Technical University (TU) in Eindhoven; the extension and modernization of the TU in Delft; a strong increase in the work done by Shell on flow phenomena, and the rise of industrial research elsewhere; the rise of numerical fluid mechanics; and the use of computers. This chapter ends with the foundation of the Burgers Centre for Fluid Mechanics in 1992 which meant the 'official' confirmation of the cooperation between the three 'worlds' (the academic, the institutional, and the industrial) and was the starting point for many new interactions.
Chapters 5 and 6 describe what types of flows have been studied during the last hundred years and how and with what facilities research in fluid mechanics has been done (and how this has changed).
In chapter 7 'capita selecta' are presented: some topics which deserve a place in this volume but did not get (enough) attention in the earlier chapters.

Courtesy of Haarlemmermeermuseum De Cruquius

F. Alkemade, *A Century of Fluid Mechanics in The Netherlands*, https://doi.org/10.1007/978-3-030-03586-0_2

02 COPING WITH AIR AND WATER IN THE NETHERLANDS BEFORE 1918

The Netherlands: the low countries. Where water easily flows in and is never far away. But also: the (mainly) flat countries. A country with a lot of air above it, with winds blowing and storms passing. It will come as no surprise to anyone that this country has been interested in the behaviour and the flowing of air and water for many ages.

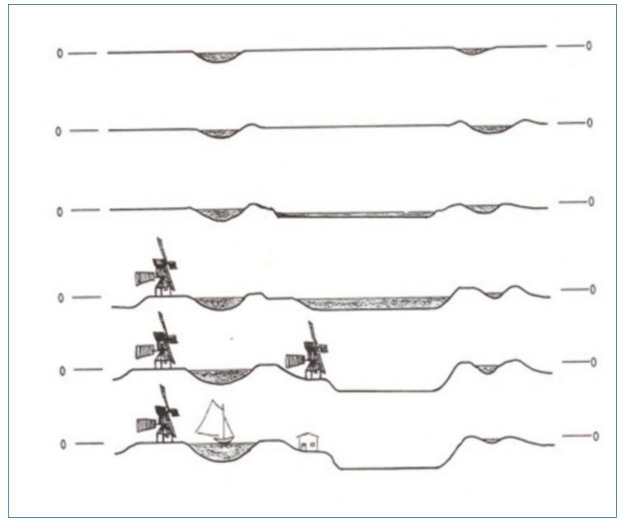
2.1 WATER WORKS

• 2.1.1 IMPOLDERING

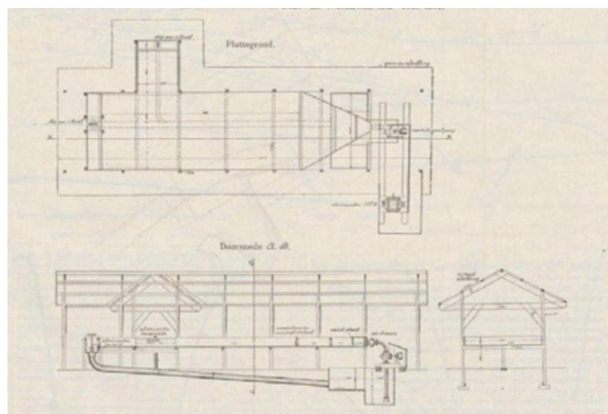
It is well known that over the centuries the Dutch have (more or less) constructed their own country by building dikes (or dykes), canals and locks, creating polders, pumping water, etc. One of the first Dutchmen who thought and wrote about the art of constructing dikes and locks was Andries Vierlingh, who died in 1579.

Even in the 19th century one could find several tempestuous lakes ('meren') near Amsterdam such as the Haarlemmermeer, where today one finds the national airport Schiphol. Plans for draining the Haarlemmermeer had already been made in the 18th century but the realization appeared unattainable using windmills alone. The Netherlands was slow in accepting and using steam engines. After the first Newcomen machine had been built and put into operation near Rotterdam in 1776, developments were few, particularly regarding drainage.

In 1847 the Royal Institute of Engineers (KIvI) was founded. Civil servants working for the Ministry (Waterstaat) played a prominent role in this society. The founders were determined to increase the innovative power of Dutch engineering, which had been lacking since the beginning of the 19th century. One of the main points of criticism was the fact that engineers in The Netherlands had failed to integrate the steam engine in their work. Furthermore, the building of dikes, ships, etc., had shown little innovation and a conservative attitude.
From around 1850 more and more people, decision makers and engineers, became convinced of the usefulness of steam pumping stations. The province of Holland, where the number of big steam engines had been low, now started to build the biggest engine in the world, for a draining station called Cruquius. The location was at the border of the Haarlemmermeer, between Amsterdam and Haarlem. From 1850 to 1852 the Cruquius station, together with two somewhat smaller steam-driven pumping stations, managed to drain the Haarlemmermeer completely and gave Holland about 175 square kilometres of new land. Since 1933 the Cruquius is a museum where one can admire the enormous engine with its piston of 3.66 metre diameter and its eight 'arms' which once brought 320,000 litres of water every minute from the lake to the canal around the lake (the Ringvaart). Today the museum shows an instructive and interactive 3D map of The Netherlands where real water is used to point out which parts of the Low Countries would be flooded if we didn't have the dikes, the dunes, and several other constructions which keep us safe.



↑The development of the western part of the Netherlands during the last thousand years in a nutshell. (courtesy of and © C.J.M. Tak/www.takarchitecten.nl)



↑Drawings of an 'installation' used to study the mouth of the Nieuwe Waterweg by an engineer of RWS in 1907 and published in the Dutch engineering journal *De Ingenieur.*

Models like these for scientific research didn't exist in the Netherlands during the 19th century. From around 1800 the French had done some primitive model experiments and by around 1880 these scale models had become more common in France, England, and especially in Germany. However, it was only in the 1890s that Dutch engineers performed the first – primitive - hydraulic model experiments in their own country; usually they had to travel to German laboratories. Among these engineers was the famous Cornelis Lely, a civil engineer who would later rise to become a Government minister.
In the early 1900s a fierce discussion arose about the best way to deepen the Nieuwe Waterweg, the connection between Rotterdam and the North Sea. One critic of the plans

↑Playing with water in the Cruquius museum: what would happen if the Dutch decided to break down their dikes and dunes?

↑One of the very first steam engines ('fire machines') in The Netherlands was built in Heemstede (near Haarlem) in 1781. It had to replace the windmill on the Groenendaal estate which had been unable to pump enough irrigation water. (courtesy of Noord-Hollands Archief)

→This statue of the Dutch hydraulic engineer Johannis de Rijke (1842-1913) can be found in Nagoya, Japan. In the period 1872-1903 a small group of Dutch experts in river improvement, harbour design, etc., were asked by the Japanese Government, which had only recently opened up the country, to come and help. The Dutch engineers had already become known for their skills in Asia from their achievements in Indonesia, then a colony of The Netherlands. (photo by Tawashi2006 / en.wikipedia.org/wiki/Johannis_de_Rijke / CC BY-SA 3.0)

which the Ministry (Rijkswaterstaat-RWS) had proposed, Brandsma, suggested starting a hydraulics laboratory (waterloopkundig laboratorium) at the TH in Delft. In 1907 one of the RWS engineers was ordered to do experiments in a model of the Nieuwe Waterweg that had been erected in the garden of his office. This model was used to gain a better understanding of the flows in the area; unripe cherries from the garden were used to visualize the flows!
But this kind of research was hardly taken seriously in the world of RWS and it lasted only for a year or two. The criticism around RWS increased. To do research in professional model laboratories, the Dutch engineers still had to visit Germany. In the Netherlands the first laboratory would only be put into operation in 1927, in Delft (see chapter 3).

The ultimate water works in The Netherlands were already in the minds of many engineers (and others) long before 1918 but its realisation would occur after 1930: the impoldering of the Zuiderzee, the inland sea that dominated and threatened many a village bordering it. The flooding of parts of Amsterdam in 1916 would be the triggering event.

↓A 'vijzelmolen', a typical Dutch windmill which drove an Archimedes screw (vijzel). This model can be admired inside the windmill called De Adriaan in Haarlem. Around the middle of the 18th century there was a great deal of discussion on the question whether in a drainage mill a water wheel or a screw was more efficient?

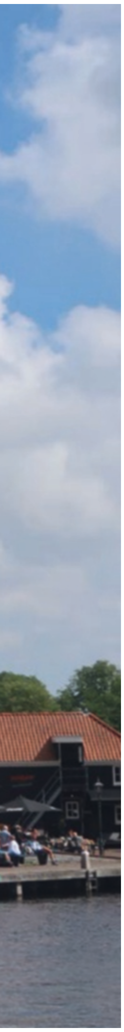
↑Windmill 'De Adriaan' in Haarlem was originally built in 1779 to produce cement, paint, and tanbark. It was converted into a tobacco mill some 25 years later. In 1932 it was destroyed by fire and in 2002 it was rebuilt. As is the case with many windmills in Dutch cities, De Adriaan has its sails at a considerable distance from the ground.

• 2.1.2 MILLING AND PUMPING

Watermills had been in general use from the 12th century. As far as we know, in The Netherlands the first windmills appeared at the beginning of the 13th century. From the beginning of the 15th century these mills were used for transferring water to a higher level. In 1612 fifty windmills had managed to drain an inland sea called the Beemster. The genius behind this huge project was Jan Leeghwater, a famous drainage expert (droogmaker). His plans to drain the Haarlemmermeer would only be realized two centuries later.

• 2.1.3 DREDGING

Keeping rivers accessible to all kinds of ships has always been important. Especially for The Netherlands: no shipping means no trading. And besides, rivers which are too shallow limit the flow of water from the East to the sea, which can lead to flooding. So, from about 1500 methods were invented and tried to remove mud, sand, gravel, and vegetation from the bottom of rivers and other waters. For the construction of canals in the 19th century, dredging machines also appeared to be indispensable.
Around 1500 dredging was still hard work, being done by hand and shovel (baggerbeugel). Even then the first dredg-



↑Pumping was also necessary in the new installations which arose during the 19th century to take care of water provision for the growing cities. Water towers were part of the water supply chain. This tower is in Dordrecht and was put into operation in 1883 as part of a 'high pressure water pipe' installation along the river Wantij. One of the towers (the original ones have disappeared) contained the chimney of the steam engine that drove the pumps. The river water was pumped to the round tank in the upper part of the tower which could contain 500,000 litres. Since 2007 this is a hotel and restaurant.

↑Dutch pumping inventions: (a) The painter and inventor Jan van der Heyden made important improvements on the fire pump around 1675. This picture shows a somewhat later model which can be admired in the Louwman Museum in The Hague. During the 19th century most of these manually operated machines were replaced by steam-driven versions. (b) The Eckhardt brothers patented this tilted paddle wheel in 1771. It was tested in Amsterdam for the refreshing of the dirty water from the famous city canals. The tests showed that the tilted wheel was not more efficient than the vertical wheel. (courtesy of Nationaal Archief, Den Haag)

ing vessels had appeared. Water ploughs (krabbelaars) were active as early as 1435 in Zeeland province. The harrow or plough loosened the bottom material of a harbour entrance while the tide was ebbing. The ship-like krabbelaar was also moved by the ebb, as it had wings under water which could be spread to catch the currents.

An important new development happened in 1575 when Joost Bilhamer built the first mud mill (moddermolen). Jan van der Heyden (the fire pump man) also invented a dredging mill, characterized by a vertical wheel with compartments. The Holland or Amsterdam moddermolen, which had to keep the river IJ and the harbours of the capital accessible, became well-known.

Thanks to dredging rivers could be made navigable again. Besides the silting of rivers, there was also the fact that the flow of water that entered the country through the upper rivers, was not distributed correctly among the rivers and canals which led to the sea: some got too much water to handle, others too little. During the 18th century it was realized that it would be very helpful if the (average) flow rate in rivers etc. could be measured. It was Christiaan Brunings, originally a German, who in the 1780s invented a flow meter which appeared to give reliable data.

An important new variant on the mud mill was the bucket dredger (emmerbaggermolen), which was used into the 20th century (first with steam engines, later with diesel