HANDBOOK WATERMILLER

The Guild of Millers

COLOPHON
HANDBOOK WATER MILLER

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Het Gilde van
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Foreword

Our slogan 'Become a miller' calls for action. The route to becoming a miller at a watermill has a clear approach and will indeed require a lot of action from you over the next few years.

During the training, you will learn how to work with the watermill. The training approach is a practical one; above all, it involves a lot of doing. But theoretical knowledge is also required. The topics you need to have knowledge about include: water management around the mill, the driving gear and the standing parts, working safely, and the different types of watermills and their functions.

The theoretical knowledge is contained in this instruction book. In addition, you can attend theory evenings organised by the Guild. Many books that will give you a deeper understanding of a particular topic are also mentioned. If you want to explore the subject in depth, then you should obtain these books for reference. And you can, of course, ask an instructor for an explanation.

You complete the water miller course with a national exam administered by the examination committee of *Vereniging De Hollandsche Molen* (The Dutch Mill Society). The training takes two years on average.

The instruction book for the course to become a water miller was completely revised in 2020. Some chapters had to be completely rewritten. And the course material has been brought more in line with the exam requirements. As a result of the improvements, the instruction book can be considered to be an important reference work not only for trainee millers, but also for water millers who have long practised this craft. Taken as a whole, the instruction book forms part of the Guild's history.

This new edition describes what the craft of a water miller entails, which gives it a cultural and historical value. With its combination of practice and theory, the revised publication is unique within the mill world. No other publication pulls together all that information so compactly.

All that remains for me to do is to wish you much pleasure and success as you pursue your training to become a water miller. Don't be put off by all the new things that will come your way. Above all, enjoy a working watermill and remember that, after obtaining the certificate for water miller, you may work in a watermill yourself. How fun and challenging is that! In doing this, you will be helping to preserve this part of our intangible cultural heritage for future generations. That is something you can be very proud of!

Erik Kopp,
President of the Guild of Millers

Responsibility

At the request of the board of the Guild of Millers, we have undertaken the revision of this Handbook: the teaching material for water millers. Being a miller is a craft — primarily practical, in other words — and so several visits were made to water mills to see how things work in practice and to share in the knowledge and experiences of water millers. Deepening our theoretical knowledge was necessary for selecting and organising the material to be taught and for representing it correctly and intelligibly on paper.
It was an engaging and educational experience that greatly strengthened our connection to the world of watermills.

Watermills are found in fairly scattered areas in the Netherlands. From region to region, we see very different developments in the standing parts and driving gear in addition to similarities. Regional differences are also seen in the names and terms used and in common practices. Doing justice to these local differences is very important from a cultural and historical point of view.
At the same time, we have found that putting together teaching materials that will be widely used can be at odds with wanting to stay faithful to local differences. If we were to include all the common regional terms throughout the text, we would end up with a document that is not easy to read. For this reason, we chose to mention the various terms here and there, but not to continuously repeat them. Therefore, using a term that is common in one region does not mean that it is preferable to the term used in another region.
We call on all instructors and millers to be vigilant in preserving the regional heritage.

We would like to mention another aspect that plays a role in this teaching material. The content includes much more than is strictly necessary for a miller-in-training to prepare for the exam (see the exam requirements for that). We see this document not only as teaching material but also as a record of our contemporary knowledge and experience regarding (milling with) watermills. Our hope is that this may also be a source of information for future generations.

Fortunately, when it came to revising this teaching material, we did not have to reinvent the mill wheel ourselves. The teaching material used up to now was taken as a starting point. In addition, new or revised texts were provided for a number of chapters. Grateful use was made of these.
Intensive consultations also took place with several millers, who always proved willing to answer our questions or provide additional information. Much of those discussions has also been incorporated into the text.
As for the design, it was determined from the start that it should be identical to the teaching materials for wind millers. The organisation of the chapters and topics also correspond with each other as far as possible.
Through this continuity in design, we underscore our common goal: Whether it's water or wind, mills must turn!

We hereby wish to express our sincere thanks and appreciation in particular to everyone who contributed to this review. By supplying texts, photos or illustrations, gathering information, providing explanations or advice on questions, or by critically reviewing and commenting on prepared texts.
We would like to mention the following individuals: Jan ten Böhmer, Annemie Driessen, Mark Dwarswaard, Hans Gijsbers, Klaas de Jonge, Hans Kalkhoven, Ron Keizer, Jo Meessen, Gerrit Olink, Wilfred Scholten and Jan Wieffer.
Their enthusiasm, knowledge, experience and willingness to contribute their thoughts and to participate over and over again was very stimulating! For this edition, we were also allowed to use the work of P.W.E.A. van Bussel, former grain miller D.J. Abelskamp, and former sawmiller Joseph Derkman as well as a contribution on the watermill landscape by Hans de Mars. That forms an important addition to this teaching material.
Last but not least we thank Alisa Crawford for her contribution to this English translation as a co-reader.

For millers (-in-training) who take up this book: we have a wonderful hobby in which the past and present are connected. It is more than worth all our efforts!
Our wish is that this Handbook Water Miller can contribute to that.

The compilers

We cordially invite users of this Handbook to communicate any additions or improvements to us.
Please send any responses to: gvmhandboek@gmail.com

Chapter 2 Introduction

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Fig. 2.0.1
Den Haller – Diepenheim
Grain mill with undershot wheel.
Year of construction: 1169

NOTES

2.1 WHY VOLUNTEER MILLERS?

As early as 1923, the preservation of mills in the Netherlands was coordinated by the establishment of *Vereniging De Hollandsche Molen.* (The Dutch Mill Society) Years of hard work have passed since then, sometimes with scant success due to a lack of understanding but ultimately with a wonderful result of more than 1,000 mills having been preserved in the Netherlands. Hundreds of mills have been restored over the years and have come under the management of associations, foundations and municipalities that oversee mill preservation.
But restoration and management alone, however necessary and useful, are not enough. For few other historic landmarks does the saying 'standing still is going backwards' apply so aptly. Exposed to wind and weather, this decline happens incredibly quick with mills. Practical experience has shown that a restored mill that never runs will need another restoration after only ten to fifteen years. In other words, mills are best preserved by keeping them running regularly. And that requires properly trained millers.

Fig. 2.1
A watermill, ca. 1664

Meindert Hobbema Collection, Rijksmuseum, Amsterdam

2.2 BECAUSE MILLS MUST TURN!

A mill is exposed to all types of weather because of its function. When not in use, there is usually little or no supervision. Minor defects such as loose hatches, leaks, rust, parts of the thatched roof in poor condition and the like are then not noticed in time. Once these become clearly visible, the damage is usually already extensive. When mills are operated regularly, these defects are more likely to be noticed and can then often be fixed at little expense, often by the miller him or herself. Periodic maintenance also tends to be more timely in that case, which obviously has a strong cost-saving effect. In addition, a turning mill enlivens the landscape much more than a stationary one. Mills in working condition also better display the ingenuity of our ancestors who used these tools to initiate industrialization, contribute to food supplies and drain large areas of our land.

That's why mills must turn!
The government of the Netherlands also recognizes the importance of working mills and skilled millers: since 2014, the craft of the miller has been on the Netherlands' National Inventory of Intangible Cultural Heritage. And, since 2017, it has also been on UNESCO's list of Intangible Cultural Heritage.

2.3 THE GUILD OF MILLERS

In 1967, a number of mill enthusiasts came together who had a clear guiding principle in common as far as mill preservation was concerned: namely, to keep mills working. The only proper use of a mill that is consistent with its preservation as a living historic building is one in which the mill as a machine remains untouched. This means that the original function of the mill (grain milling, wood sawing, polder drainage, etc.) must be preserved.
Increasingly, however, there arose the problem of professional millers growing old or stopping altogether. In our current society, mills — whether industrial mills, polder mills or watermills — are hardly "economic" and cannot manage without government subsidies or other financial support. Many skilled millers had to close the mill door behind them for good for that very reason. The number of mills with a professional miller was already extremely limited, and it continued to decline further.
This meant that people capable of making the mill perform its function were needed. In the first place, these were primarily the remaining skilled millers, of course. But in addition to them, volunteer millers had to be trained.
For that reason, the aforementioned group of mill enthusiasts decided to establish the Guild of Volunteer Millers in 1972.

Fig. 2.3.1
The Franse Molen [The French Mill] – Valkenburg

Grain mill with improved undershot wheel.

That their arguments proved valid and did not stem only from idealism is evidenced by the fact that the government allocates substantial subsidies towards the cost of annual mill maintenance, on the condition that they run regularly!

The Guild's articles state that its objective is to serve the interests of mills in the Netherlands. To this end, the Guild provides miller training for its members and looks after the interests of all members who are undergoing or have already completed this training and are operating mills or working at mills. Furthermore, knowledge and experience about the production processes of windmills and watermills is collected, documented, maintained and disseminated.

The Guild seeks to achieve its objective by:

- Organising both practical and theoretical instructional meetings for knowledge transfer by instructors and other experts.
- Recruiting, appointing and supporting instructors and trainee millers.
- Supervising members who follow the training and assisting them in making the necessary contacts for this purpose.
- Acquiring existing informational material and preparing or arranging for the preparation of new information material related to milling with mills and making it available to members.
- Organising the proof examinations and guiding its members through the national examination, conducted by a committee of experts under the auspices of De Hollandsche Molen. (The Dutch Mill Society)
- Advising on and setting examination requirements in consultation with De Hollandsche Molen. (The Dutch Mill Society)
- Liaising and cooperating with other national and regional mill societies to achieve the best possible outcome for all activities associated with mills. (See also Articles of Association of the Guild of Millers.)

Fig. 2.3.2
Opwetten watermill – Nuenen
Grain mill with undershot wheel.

2.4 WHAT DOES IT TAKE TO BECOME A MILLER?

As described above, what is required above all is genuine interest and enthusiasm. To successfully complete the training, you will not only have to attend instructor's classes on a regular basis but you must also visit working mills. This means not just watching but rolling up your sleeves; even when it's raining or blowing a gale, and, of course, not in your best clothes. A miller must gain experience under all weather and other conditions.
Initially, the plan was that apprentices would seek out a skilled miller on their own initiative and learn the trade from him or her, after which they could take the exam on that miller's recommendation, subject to having the necessary theoretical knowledge. However, the diminishing number of skilled millers led to the compilation of a list of volunteer instructors willing to instruct members-in-training.
Since there are not enough operating mills to be found in all regions of the country, some students will have to travel for this.
While it is certainly recommended to learn the practice from a miller-expert instructor or volunteer instructor, it is not, however, mandatory. This can also be done with another experienced certified miller who is willing to help. Departmental boards of the Guild can offer advice in this regard.

Fig. 2.4.1
De Witte Molen [The White Mill] – Arnhem
Grain mill with overshot wheel.

The minimum age for starting the training is 14 years.
The duration of the training depends greatly on the student's own commitment and the frequency with which he or she attends the instructional meetings. Those whose interest in mills developed later in life should count on the training taking a good two years.
Aspiring millers must learn to work with a mill in all seasons and to gain sufficient experience under all weather conditions.
To be trained as a water miller, students must have worked at a mill for a minimum of 100 hours, of which 30 hours must have been at mills other than

the instruction mill. Practical hours should be recorded in a logbook and signed off by the miller with whom the hours were spent.
For the wind miller training, the minimum quota of practical hours is 150 and 30 hours, respectively.
For certified wind millers who are going to take the water miller course, the following applies: a minimum of 70 hours of mill work, of which 20 are at mills other than the instruction mill. These hours must be spent in the autumn or the spring, as well as in the winter.
Finally, all members-in-training are required to be physically able to operate the mill safely and responsibly under all conditions.

Upon successful completion of the exam administered by *De Hollandsche Molen* (The Dutch Mill Society) examination committee, the candidate will receive the 'Miller Certificate'. Most of those who pass will then go on to work as a miller themselves. The Guild can still continue to be helpful, such as with finding a suitable mill or with further expanding your knowledge of mills. Virtually all graduates also remain members of the Guild after obtaining their certificate. In this way, lively and instructive contact is maintained between independently operating millers and members-in-training. Successful members can also continue to make use of the Guild's insurance.

Fig. 2.4.2
De Volmolen [The Fulling Mill] – Epen (L)
Grain mill with breastshot wheel.

2.5 THE TRAINING

Most mills in the Netherlands are no longer operated by professional millers. Volunteers take their place, even at industrial or other mills that are still or again in full or partial operation. They work with a precious machine and are engaged in a very ancient craft. So it is not surprising that a great deal of knowledge must be learned and experience gained before one gets to the point where one can take responsibility for running a mill.

The training to become a water miller is not just limited to being able to run the mill unloaded, but, for the exam, he/she must also be able to put the machine into operation. This is because, during their training or afterwards, many millers work at a mill that is still operational. And also so they can act as host and explain the operation of the mill to interested visitors.

Fig. 2.5.1
The Oelemeulle – Hengelo
Grain mill with undershot wheel.

There are very few professional millers left to learn the trade from but fortunately enthusiastic volunteers have acquired a lot of knowledge of the craft from them. The instructors and other certified millers of the Guild are the appropriate people to teach the students the practice and theory. It is recommended that most of the time during the initial training period be spent at a designated instruction mill.
There aspiring millers will learn how to lubricate the mill and how to operate and stop it by opening/closing a gate. Also covered is knowledge of the various driving wheels, turbines, lubricants, minor maintenance and safe working practices, among other subjects.
The weather is also important, especially with heavy precipitation, hard frosts and thaw. But students will also need to be able to operate the mill when the water supply is high or too low.

Once the basic skills are mastered, it's a good idea to visit other mills as well or even spend a day watching them in operation. In this way students get practical training and gain experience in operating mills.

The requirement to have 100 hours of practice at a mill should be considered a minimum. It goes without saying that aspiring millers must have experienced all kinds of weather situations in all seasons once, and therefore should spread the practical hours throughout the year before applying for the proof exam. This proof exam for water millers is administered by the Examination Committee of the Guild.
After passing the proof exam, participation in the national exam follows. That exam is administered by the Examination Committee of *De Hollandse Molen.* (The Dutch Mill Society)

Fig. 2.5.2
De Collse Molen [The Coll Mill] – Eindhoven
Oil mill on the left, grain mill on the right, each with its own undershot wheel.

In recent years, volunteers have also learned from skilled millers how to mill or hull grain, saw wood, press oil or make paper.

And they, too, pass on their craft knowledge and skill to the next generation. this development led to the formation of the Artisan Grain Millers Guild (AKG), which established its own training program for grain millers. (in 1976) Wood sawyers and oil pressers also exchange their knowledge and experiences.
Although being able to work with mills in operation is not the Guild's goal, that development is nevertheless welcomed.
It goes without saying that some theoretical knowledge of various mills and components is also necessary. A volunteer miller lacks the knowledge and innate feel for the mill that used to be passed down from father to son. The need for theoretical knowledge has been recognized by the Guild from the beginning.
One of the first steps was to find mill experts willing to put the much-needed theory on paper.
In addition, over the years since the establishment of the Guild in 1972, there have been professional millers and volunteer millers who have further expanded the knowledge they acquired and documented it. Some of this was published by the Guild as 'Information' and provided great support for the instruction.
Much available knowledge and experience have been brought together in the compilation of this Handbook for the Water Miller. Furthermore, the Guild is helpful in providing practical and theoretical information.

The many efforts of the Guild of Millers have certainly helped put an end to the trend of mills laying idle and decaying. Lots of mills are turning and/or milling away again on a regular basis! Because mills must turn; that is their strength and that is what they were built for!

Fig. 2.5.3
The water mills of Singraven – Denekamp
On the right the grain mill (front) and sawmill (behind), the former oil mill is on the left. Each mill has its own undershot wheel.

2.6 THE MILL AS A HISTORIC BUILDING

Millers should not only have practical skills and some theoretical knowledge but should also be aware that, in many cases, they are working with a protected historic building. What does that mean?

A protected historic building
There are more than 60,000 nationally listed buildings in the Netherlands, including about 1,150 mills. These are protected by the government because of their heritage or cultural and historical value, for example because of rarity or typology or because they are located in a water management or urban development structure. To prevent these values from being lost, these mills are recorded in the Listed Buildings Register.
The administrator of the Listed Buildings Register is the Netherlands Cultural Heritage Agency (RCE), an implementing agency of the Ministry of Education, Culture and Science. The RCE connects heritage policy, science and practice. It implements laws and regulations, advises municipalities in permit procedures, handles grant applications and makes knowledge available. For these tasks, the RCE employs two mill specialists.

Dealing with mills
The starting point for the national government in dealing with mills and the remains of mills is their heritage value, their place in the landscape, and their function in society. It is an objective appreciation of what is currently there, tailored to the individual mill.
Keeping the mill working, preferably as if it were still in full economic operation, is not the only goal of the policy. The national government is in favour of keeping mills turning and milling as long as the protection of heritage values is observed in the process.
The publication 'A Future for Mills' formulates a number of points of reference for dealing with mills, consisting of, for example, the location, the building and any driving gear, the building's history, and the history of the location. This publication is available digitally or for free at www.cultureelerfgoed.nl

Listed building: more than just the mill
The term 'listed building' is not limited to the mill itself, but also includes the interior, individual mill components, the landscape around the mill, and stories about the mill. A bedstead, tools, kitchen garden, old crown wheel, sack stencil, flour shovel, fish trap or electric motor are parts that sometimes still date back to the construction period, represent a high historical value and are therefore irreplaceable.
Every miller should be aware of this value; walk around the mill and survey the mill's collection.

Archaeology
Digging a trench in the mill yard for drainage or excavating old foundations also reveals information about the mill.
But what does the miller do with that archaeological information? In the case of such activity, he or she must always first ask themself whether it's a good idea to do this on any random Saturday.

Practical considerations
Mills are precious and expensive so people try to keep the mill running with as few resources as possible. Sometimes this has unintended negative consequences for the historic building and its value. Repairs, interventions or changes are often made without being aware of what this actually signifies for the mill. Examples of this are installing heating in the mill, installing new machinery, changing functions, replacing parts or cleaning the stone mill body. All the changes made to the interior or exterior of a mill removes traces of its history but also leaves them behind. Mills are structures with many building traces that have a story to tell. The challenge, then, is to add one's own chapter without throwing away old stories. Replacing floors or repainting an interior wall so that the mill looks neat again can have many implications for the heritage value. When carrying out an intervention, evaluate and document the current heritage values and add something in a sustainable way without throwing away historical layers in the process.
Consult with the owner if, in your role as a miller, you want to change anything about the mill. The mill's owner can contact the municipality or the government department to see to what extent a permit is needed and to obtain knowledge.

The role of the miller
The miller is indisputably part of the chain. Running the mill regularly or carrying out minor maintenance work keeps it in good condition. Running the mill safely and especially responsibly, as well as preventing unsafe situations, is very important for its continued existence.
While fulfilling your role as a miller, a variety of issues may come your way. It is important to recognize these and ask yourself how to deal with them without negatively affecting the mill's heritage. Every mill owner must realize that a mill is a wonderful historical machine on loan from those who come after us.

Fig. 2.6.1
The Wenum Mill – Wenum
A sawmill and grain mill with overshot wheel.

2.7 THE MILLER AS HOST AND AMBASSADOR

The miller is also the host and ambassador for visitors. He or she fulfils this role either alone or with fellow millers and/or mill guides. And it is no small role. The impression visitors get of the mill depends largely on the people they meet there and the hospitality they experience. That makes hospitality an extremely important aspect. What does that mean exactly? And as a miller, how do you fulfil your role as host and ambassador?

Hospitality: what does it entail?
Hospitality (also called customer friendliness or guest orientation) means: being focused on and keeping in mind the wants and needs of your guest, the visitor. If you ask a visitor what he or she thinks of when they think of hospitality, the following things come to mind: receiving personal attention, feeling at ease, being treated as one wishes to be treated, and experiencing warmth, atmosphere and conviviality.
But hospitality encompasses more. Hospitality plays a role in all aspects of the visit. It starts with searching for information about the mill on the Internet: can visitors quickly and easily find what they need? Several factors influence how welcome a visitor feels. These include: information (information is provided), hygiene (toilets are clean), safety (free from obstacles), attention (the visitor's presence is noticed), friendliness (the visitor is received by a person who shows engagement), and price (the price corresponds to what the visitor gets in return).

The visitor
Who actually are the visitors who come to the mill? There is a wide variety of visitors and they have very diverse backgrounds. They may come individually or in a group. They come from the Netherlands or from other countries. They may be tourists or business customers. However, consciously or unconsciously, every visitor comes with certain expectations that can be very different. You can categorize these as follows:

- Expectations about content: what topics the visitor wants to see or learn more about.
- Expectations regarding the 'institution', such as the mill: most people will think of a mill as an operating mill, where a miller works who keeps it running.
- Expectations regarding their own well-being: visitors expect a warm welcome from a friendly staff member, a toilet and perhaps a cup of coffee.

If these expectations are not met, a visit is not necessarily less successful. But visitors do need time to adjust their expectations. In any case, it is good to be aware that every visitor to the mill has expectations (and wishes!).

Role and duties of the host and ambassador
Millers and mill guides who look after visitors are the mill's calling card. Their appearance and actions determine the success of the visit. For good service, you at least need to have sufficient knowledge and information on several levels:

a. Content and tourist information for the visitor

First and foremost, this concerns information about the history and operation of the mill and its own activities. In addition, knowledge is needed about the organization that owns the mill, such as the mill foundation. This is where the role of ambassador comes in. As an ambassador, the miller is the representative and promoter of both the mill and the managing organization/owner. For example, is the mill foundation engaged in a fund-raising campaign? Are special activities being organized? Include this information in your contact with the visitor. Finally, it is important to be aware of what there is to do in your town, village or region, where to have lunch, where the bus stop is and what the bus departure times are.

b. House rules for employees and for visitors

By house rules is meant: what employees may or may not do, what visitors may or may not do. Many organizations have house rules for staff, such as about the (company) clothing or badge to be worn. House rules can also relate to adherence to agreements or safety rules. An organization can also establish house rules for visitors. By placing or hanging these house rules (or visiting conditions) at the entrance, visitors will immediately know what is or is not allowed.

c. Own duties and authority

As a miller, you need to know what your duties and authority are. In addition, it is important to know their scope, for example, where does your job end.

d. Security and safety

As a miller, you are aware of the various safety issues and everyone's duties in case of an emergency. This is discussed in detail in chapter 10, Safety.
To ensure that fellow millers know the state of things, a good handover is necessary (what happened today: in terms of the mill, visitors, millers, other things).

Listening and non-verbal communication
Listening is an important skill for the host. There are different ways of listening. For example, you can hear what is being said but not do anything with the words. However, you can also actively listen and ask a question every now and then to check your understanding of what has been said. With active listening, you also pay attention to the visitor's non-verbal communication. What is perhaps meant or asked between the lines?
Another skill is empathy: you put yourself in the visitor's position to understand their wants and needs. What does this visitor want? A detailed story or a few highlights? As a miller, you have a lot of knowledge and you are happy to share it. But the visitor may only want to know a few things. So you should enquire as to what the visitor's wishes are for this visit. Non-verbal behaviour can also tell you a lot, by the way. For example, a visitor loses attention and looks at the next staircase. Perhaps they have heard enough and want to move on?

Chapter 3 Literature list

For a broadening of the required knowledge, it is recommended that, in addition to the information in this Handbook Water Miller, you read other books that contain a great deal of information about watermills. Do keep in mind, though, that not all the information in these books is part of the exam requirement.
Books whose titles are in bold are especially recommended as supplements to this Handbook. Therefore, we recommend that you obtain these books to look through or, if still available, purchase them. Books are also regularly offered second-hand through The Guild Newsletter (De Gildebrief) or at millers' meetings.
If a library does not have a book itself, in many cases it can be requested from the central library service. Please inquire at the lending desk.
The following is a selection from the many books on watermills and other mills that have been published (in Dutch only).

Title	Author or publisher
De Brabantse Molens	S.H.A.M. Zoetmulder
De Molens van Limburg	**P.W.E.A. van Bussel**
De Nieuwe Stokhuyzen	**Reissue of 'Molens'**
De Veluwse Papiermolen	**C.Th. Kokke**
De werking van de pelmolen *	P.H. Havik
De wind- en watermolens in Overijssel	F.D. Zeiler, G.J. Perfors
Een toekomst voor molens	Rijksdienst v.h. Cultureel Erfgoed (RCE)
Gelders Molenboek (1968)	Walburg Pers
Getijmolens	B. Boonman
Het Nederlands malend korenmol. boek	J. Gunneweg e.a.
Hout voor de Molenbouw	G.J. Pouw
In en om de Grutterij	A.J. Bernet Kempers
In de ban van Ceres / Klein- en grootmaalderijen in Vlaanderen	Frank Becuwe
Kijk op Molens	J.Th. Balk
Korenmolens	**P.W.E.A. van Bussel**
Kracht van Wind en Water	P. Bauters
Molens	F. Stokhuyzen
Molens in Nederland	W.A. Roose
Molenwielen	A. Sipman
Mulders, Molens en Meesters	H. Hagens
Oliemolens	A.J. Bernet Kempers
Oliemolens	P.W.E.A van Bussel
Op kracht van stromend water	H. Hagens
Rond zingende stenen *	D.J. Abelskamp
Rosmolens Westvlaamse kuststreek	L. de Vliegher
Spieren, water, wind	J.J. Kamphuis
Van Zadelsteen tot Zetelkruiers, 3 delen	P. Bauters
Watermolens in Nederland	**P. Nijhof**
Veiligheid op Wind- en Watermolens	**Vereniging De Hollandsche Molen**
Watermolens in Twente	Boekhandel Broekhuis
Watermolens in Noord-Brabant	**Ir. P.H. van Halder**
Watermolens in Noord-Brabant	**Wiro en Wim van Heugten**
Zingende Stenen *	D.J. Abelskamp

Publications in bold constitute recommended literature.
Books marked with * are still available and can be ordered through the webshop or downloaded from the website: www.gildevanmolenaars.nl

Some websites (some in multiple languages):

Information about mills	www.molendatabase.nl
Information about mills	www.allemolens.nl
Guild of Millers	www.gildevanmolenaars.nl
Information about vanished mills	www.molendatabase.org/
The Dutch Mill Society	www.molens.nl
The Artisan Grain Millers Guild	www.molenaarsgilde.nl
The Oil Pressers Guild	www.olieslagersgilde.nl
The Woodcutters Guild	www.houtzaagmolen.nl/platformhoutzagers.php
Sawmills: a practical manual	https://nl.wikibooks.org/wiki/Houtzaagmolens_praktijkhandboek
The mill biotope	www.molenbiotoop.nl
Netherlands Cultural Heritage Agency (RCE)	www.cultureelerfgoed.nl
De Bekenstichting (The Streams Foundation)	www.sprengenbeken.nl
Water mills in the Netherlands	www.waterradmolens.nl

Many mills also have their own website. These can usually be found in the Mills Database via a link at the information about that mill.

Chapter 4 What are the different types of watermills?

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NOTES

4.1 WATERMILLS

4.1.1 Introduction

watermill, waterwheel mill
water-powered mill

Watermills, sometimes referred to as waterwheel mills or water-powered mills, are much older than windmills.
The reason for developing the watermill was the total change in mankind's way of life. It involved moving on from a nomadic/hunting existence to the life of an agricultural population. As long as people lived on whatever was edible and whatever they happened to come across, there was no need for any tool to break down or crush all kinds of food.
However, humans as crop farmers have long used rubbing stones, pestles, mortars, so-called querns and various other manual crushing tools to grind hard seeds. Humans — often slaves — as well as animals were used as motive power. It is not known when mankind moved on to applying water power. The oldest records are from ancient Greece and relate to watermills in the kingdom of Mithridates. This kingdom was located in the far north of Turkey.

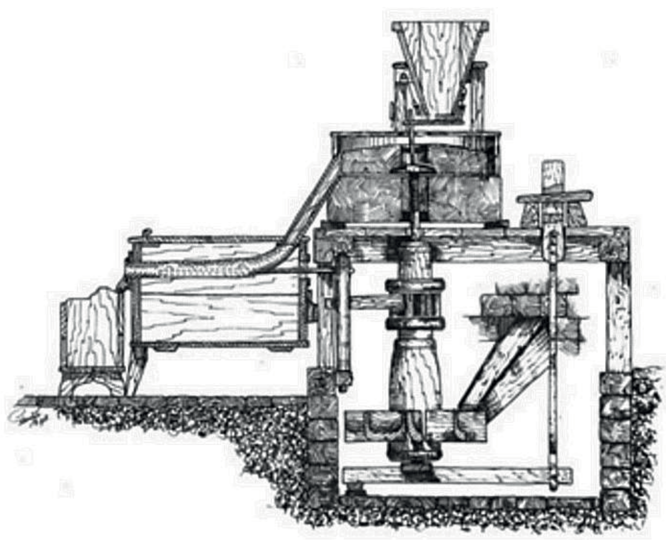

Fig. 4.1.2
An example of a complete 'Stockmühle' [stock mill].

4.1.2 Watermills with a horizontally placed waterwheel

horizontal waterwheel

These water mills had a horizontal waterwheel. The shaft on which the paddle wheel is placed has its bearing there at the bottom on a bridge tree beam (see Fig. 4.1.2). The runner stone also rests on the top of that same shaft.
According to the amount of water available to drive the mill, the paddles are constructed in various ways.
This type of mill has never been used in the Netherlands due to the lack of height differences. Its distribution area is around the Mediterranean, in Alpine regions and in Norway.
We will not consider it further within the scope of this handbook.

4.1.3 Watermills with a vertically placed waterwheel

vertical waterwheel

Around 40 AD, we come across more and clearer mentions of watermills with a vertical waterwheel.
Based on these records, it was even possible to reconstruct the probable design of such a wheel (see Fig. 4.1.3). The first tangible evidence for the existence of watermills at the beginning of the Current Era was found at Venafio, in the Italian province of Compobasso. The waterwheel found was dated to around 300 A.D. and had a diameter of 1.85m. The further development of the watermill was broadly completed around the year 1000.

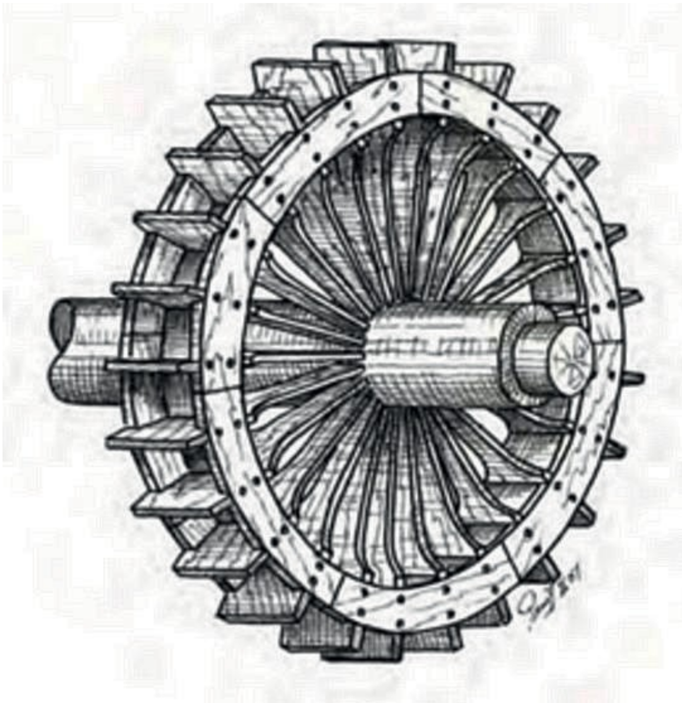

Fig. 4.1.3
Reconstruction of a waterwheel from Roman times.

4.1.4 Current watermills in the Netherlands

In 2020, the Netherlands still had about 100 working watermills. Many of them are also still capable of milling. They can be found wherever there is running water with a sufficient fall, that is, in the regions of Limburg, Eastern Brabant, Gelderland — with the main concentration in the region between the Veluwe plateau and the IJssel river — and Overijssel. They are driven by a vertical waterwheel or a turbine.
Just like windmills, watermills can have various functions. The most important are milling grain, hulling barley, sawing wood, pressing oil and making paper. Some mills have multiple functions. Sometimes the mill also generates electricity.

What is interesting is the variety of watermills in the Netherlands. Not only can most of the watermills still be found in Limburg, that is also where various developments that are absent or infrequent elsewhere in the Netherlands are located.
We mention some developments that have been applied since the beginning of the 19th century:
- the use of cast iron for mill gears and hurst frames;
- the use of turbines instead of waterwheels;

- designing and installing improved, more efficient waterwheels;
- the use of an apron and guideways for the water.

Breastshot watermills are found only in Limburg. All remaining Brabant mills are undershot watermills, many of which have a distinctive and large iron waterwheel.

The remaining watermills provide a fascinating picture of their development over the centuries. They are closely related to industrial and economic developments in a region, which have given rise to huge diversity.
There are still mills that take you back several centuries, as it were, but also mills that have grown into imposing factories from a more recent past. Watermills without water are doomed. Thus, the battle for water that often had to be fought over the centuries is also inseparable from the history of many watermills. Those stories, too, are worth telling and preserving. Traces of the past can still be found in many mills.

Therefore, those wishing to gain a broad view of the history, development, construction and operation of watermills will certainly want to visit watermills in other regions.

Fig. 4.1.4
The Weverlose Volmolen [The Weverlo Fuller Mill] – Weverlo

A fuller mill with undershot wheel.
Year of construction 2020.

4.2 WATERWHEELS AND TURBINES

4.2.1 Introduction

waterwheel, turbine

undershot watermill
breastshot watermill
overshot watermill
turbine watermill

watermill complex
double mill

Watermills are driven by a waterwheel or by a turbine. If the mill is driven by a waterwheel, it is characterized according to the design of the waterwheel, namely undershot, breastshot or overshot watermill.
If the watermill is powered by a water turbine, then it is called a turbine mill.
Watermills can also form a complex: then there are several mills with different functions near each other — for example, a sawmill and a grain mill in a single building. Each mill then has its own waterwheel.
Sometimes the complex also consists of two mills located on either side of the mill stream. That is called a double mill. There are also complexes of three mills: two mills in one building, the third in another. Consequently, there are (or were) three waterwheels.
If there are two buildings, then we refer to the right or left mill when looking downstream.

4.2.2 Undershot watermill

undershot wheel, mill race
water channel

In undershot mills, water flows at great speed into and through the mill race or water channel in which the wheel rotates, colliding with the lower floats. These floats are flat or slightly curved and made of wood or iron.

Fig. 4.2.2.1
Mill with undershot wheel.

Watermill – Laag-Keppel

4.2.3 Breastshot watermill

breastshot wheel

low or high breastshot wheel

In a breastshot watermill, the water arrives at the floats of the waterwheel approximately at shaft height.
If the water flows in at a slightly lower or higher position, such as in the case of a small or large fall, then it is a low breastshot wheel or a high breastshot wheel.
In a breastshot wheel, the floats are curved or have raised edges.

4.2.4 Overshot watermill

trough, flume
shuttle, bottom hatch

In overshot watermills, a trough or flume carries the water to above the wheel after which it flows into the buckets through a bottom hatch (shuttle) that can be opened.

overshot wheel, buckets

Overshot wheels have buckets instead of floats: the weight of the water in the buckets sets the wheel in motion.
In an overshot watermill, the waterwheel — with a few exceptions — turns in the opposite direction to the wheel of a breastshot or undershot mill.

Fig. 4.2.4.1
Mill with overshot wheel and long flume.

Cannenburg Mill – Vaassen

4.2.5 Turbine mill

turbine

turbine chamber

In a turbine mill, the waterwheel is replaced by a turbine. Turbines are usually placed in a concrete basin made in a separate extension to the mill, the turbine chamber.
A vertical turbine may be installed on the floor of the basin with the outflow opening through the floor. However, the turbine may also be mounted horizontally with the turbine shaft passing through the wall of the mill.

Fig. 4.2.5.1
A turbine mill.
The basin for the turbine is visible to the right of the mill.

Nordbecksmühle (Nordbecks Mill) – Halle (Germany) *mill pond*

mill pool

The approximately 3-metre-deep basin is fed from a stream or a mill pond. The outflow from the turbine passes via a pipe through the basin bottom to a mill pool or flows back into a stream. The fall between the mill pond and the mill pool is about 5 metres.
The lack of a waterwheel generally makes a turbine mill less recognisable as a watermill.

Fig. 4.2.5.2
The turbine chamber (centre), an extension for the turbine.

The Old or Ban Mill [Soke Mill] – Valkenburg

4.2.6 Mill water

mill race
mill pond

Many watermills were built directly on a stream or on a branch of it, called the mill race. That is where undershot, breastshot or turbine mills are generally found. At overshot mills, there is often a mill pond which has been dug out and fed by a stream.

mill water

The water passing the mill, known as mill water, must be free of entrained floating and/or suspended debris or other coarse pollutants. Especially in the case of undershot or breastshot wheels or a turbine, floating debris can easily block the waterwheel or destroy floats. In overshot mills where water is fed through a flume, floating debris does not reach the waterwheel as easily.

flume, lade, sluiceway

blocking of waterwheel or turbine

Blocking of the waterwheel may also cause damage to the drive mechanism due to blocking of the mill shaft.
Due to the narrow passageways in the turbine housing, water turbines have more stringent requirements for the removal of floating debris. After all, small objects trapped between the turbine wheel and the guide vanes or the turbine housing are difficult to remove and only after disassembly of the often hard-to-reach turbine.

Noria

For the sake of completeness, we mention here another type of waterwheel mill that, however, is not found in the Netherlands: the Noria. This is an undershot wheel with jars or pots on the outside of the rim. As the wheel turned, the jars filled up with the underwater and they were emptied into a trough at the top. The water was used for irrigation.
The wheel was simply suspended in the river. A mill building was not needed and neither were weirs or locks.
This type of watermill is still found occasionally in parts of the Middle East and Far East.

4.3 BOAT MILLS

4.3.1 Introduction

boat mills

Boat mills have been around since the siege of Rome in the sixth century. The Netherlands also used boat mills on a modest scale. For example, in the Maas river near Maastricht, there was a small island on the left bank. The flow of the Maas river at that location was such that it was an ideal place for anchoring boat mills. There were also boat mills in the Waal and IJssel rivers.
Boat mills were preferably located in the middle of a river — and if possible on a bend — because that is where the flow velocity is highest. In favourable places, there were sometimes several together.
The possibility of harnessing currents for hydropower had long been known.

waterwheels

The waterwheels required for this purpose had considerable dimensions, especially in width in order to best utilise the energy of the flowing water.
The number of boat mills in the Netherlands varied over the centuries. The largest number was ten in 1439. In Maastricht, the last boat mills were demolished in 1705.
During very high water levels and especially as a result of heavy ice, the cumbersome and unwieldy boat mills sometimes became detached from their anchorages, drifted off and could not be retrieved. Military activity also destroyed some. Around the 18th and 19th centuries, European law banned boat mills in many places because they severely hindered maritime traffic.

4.3.2 The structure of a boat mill

The word 'ship' is actually too grand a word for the plump barges on which the mill itself was usually placed. The part of a boat mill that provided buoyancy was a rectangular wooden barge that had a sloping bow on the upstream side that in some cases also had a slightly pointed shape. The downstream side was simply straight.

boat-shaped barge

On this boat-shaped barge stood the mill house, which was simple in design. All fairly straightforward and covered by a pitched roof. Several windows were installed for light.

mooring lines
windlasses

The boat mill was held in place in the river with several mooring lines that could be hauled in or winched using windlasses on the foredeck and afterdeck in connection with the rise and fall of the water level in the river.

4.3.3 The design of a boat mill

The layout was extremely simple, both in terms of the waterwheel and internally. The substantial waterwheels were all undershot wheels.

waterwheel shaft

Boat mills as used on the Maas river near Maastricht had two wheels, one on each side of the boat, both mounted on a common, heavy waterwheel shaft. Each wheel typically had six large blades or floats. The position of the floats of the two wheels on the shaft differed from each other, so that at least one float was always in the flow, limiting rotation at uneven speeds. The slow rotation *lay shaft*

of the mill shaft was transferred by a large cog wheel to a lantern wheel of a lay shaft. A crown wheel on this lay shaft drove the stone nut on the stone spindle. Boat mills usually had one pair of millstones laid on a hurst frame next to or above the continuous main shaft.
The gear ratio between main shaft and runner stone was between 1:10 and 1:12. This was due to the slow motion of the water wheel.
The power from a boat mill's waterwheel is considerably lower than that of a waterwheel at a fixed watermill due to the great resistance of the water.

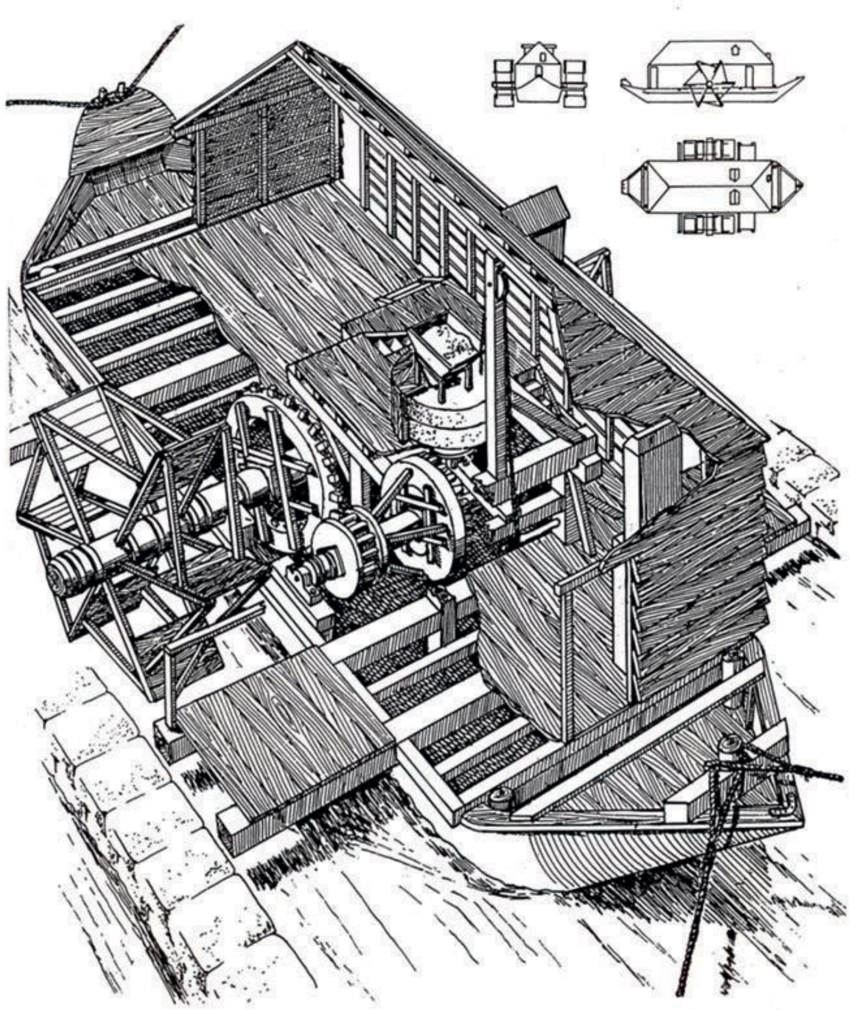

Fig. 4.3.3.1
A boat mill.

In addition to the arrangement outlined above, there existed boat mills with a single wheel that rotated between a larger vessel containing the mill and a smaller vessel on which the outboard bearing of the mill shaft rested.
A fine replica of this type of boat mill can still be found in Germany in the Weser river, near Minden.

4.4 TIDE MILLS

4.4.1 Introduction

Just as we find watermills only in the eastern part of the Netherlands, so were the tide mills found only in the provinces adjacent to the North Sea coast. These were mainly South Holland and Zeeland, the latter province in particular. This is due to the fact that the tide difference becomes smaller the further north you go. The English Channel — between England and France — acts as a weir, increasing the tidal range there.
Another notable difference from ordinary watermills was that the tide mill was powered by seawater flowing in and out of the rivers and deep inlets of the Dutch coast, under the influence of the tidal ebb and flow. So it was not a continuous process.

tidal ebb and flow

Tide mills are recorded existing in both South Holland and Zeeland but only in the latter province did they play any significant role. Thus, they could be found along the borders of the Oosterschelde (Eastern Scheldt) estuary in Bergen op Zoom, Goes, Reimerswaal, Tholen, Veere and Zierikzee. In the Western Scheldt area, these special mills were located at Biezelinge, Hulst, Middelburg, Ossenisse, Sas van Gent and Vlissingen.
We know what these Dutch mills looked like thanks to a number of specifications from the 18th century that have been preserved in the city archives of the municipality of Goes. These specifications were for alterations and improvements carried out in the period between 1735 and 1747.

Fig. 4.4.1.1
Old engraving from 1865 depicting the Bergen op Zoom tide mill.

4.4.2 Tidal movement

Sea level rise and fall is caused by a combination of two forces acting on sea water.
On the one hand, the moon's attraction to the earth; this influence varies as the moon's position changes. On the other hand, the centrifugal force due to the earth's rotation.

Both forces create the tidal movement, the twice-daily rising and falling sea levels that are as high as 15 to 20 metres in some places on Earth. The difference between low tide and high tide measured at Vlissingen is an average of 3.74 metres.

flow rate

Another factor involved in tide mills is the flow rate of the water. On average for the North Sea, this is 1.5 to 2 m/s.

However, due to constrictions in the channel, this rate can increase sharply, such as at the Nauw van Bath (Bend of Bath) in the Western Scheldt. Here the speed increases to 4 m/s and above.

4.4.3 The water works

In order to operate a tide mill, a considerable difference between low tide and high tide is needed at the site. The tidal range, according to the old data, should be at least 2.50 m. This is the minimum height needed to raise enough water to power the mill for a profitable length of time each 24-hour period. Given that the mill always had to be built close to the sea and at as low a point as possible, it was very vulnerable to extremely high water levels and increased sea levels during storms.

reservoir
basin

Before building a tide mill, a suitable site had to be chosen so that an adequate, not too expensive reservoir could be built or a stream channel, river or estuary could be easily dammed. A pre-existing harbour basin, whether or not expanded by any city canals, was sometimes used for this purpose. This specially dug or dammed section then acted as the reservoir or basin as it was called.

flow sluice

The dam thus created was fitted with a sluice gate. This sluice gate was opened on the rising tide, allowing seawater to flow into the basin.

inlet sluice

As soon as the tide turned — or just a little sooner — the sluice gate was closed and the incoming water was held for operating the mill. The inlet sluice was opened for this purpose. However, before this could be done it was necessary to wait for some time until the difference between the level of the basin and the outside water had become sufficiently large, at least 1 metre. Thus, the water works basically consisted of the basin, the inlet and outlet to and from the mill, and the associated sluice works.

4.4.4 The structure of a tide mill

The mills themselves were somewhat similar in construction to an ordinary watermill except that the sluice complex was much larger and more elaborate.

inlet sluice, sluice gates

single-acting mill

Looking at the layout of the mill itself, what is immediately noticeable are the large waterwheel placed in the inlet sluice and the sluice gates placed in front and behind it for the purpose of controlling the flow of water through the inlet sluice. This is the version as applied to a single-acting mill.

ebb mill, flood mill

The shape of the sluice complex already immediately indicated whether it was an ebb mill or a flood mill. An ebb mill milled during the falling tide, and a flood mill milled during rising tide; in other words, the ebb mill was powered by the water from the basin, while the flood mill was powered by the inflowing flood water.

double-acting mill

A combination of an ebb and flood mill also occurred. Milling was then possible during both rising and falling tides. These were referred to as double-acting mills.

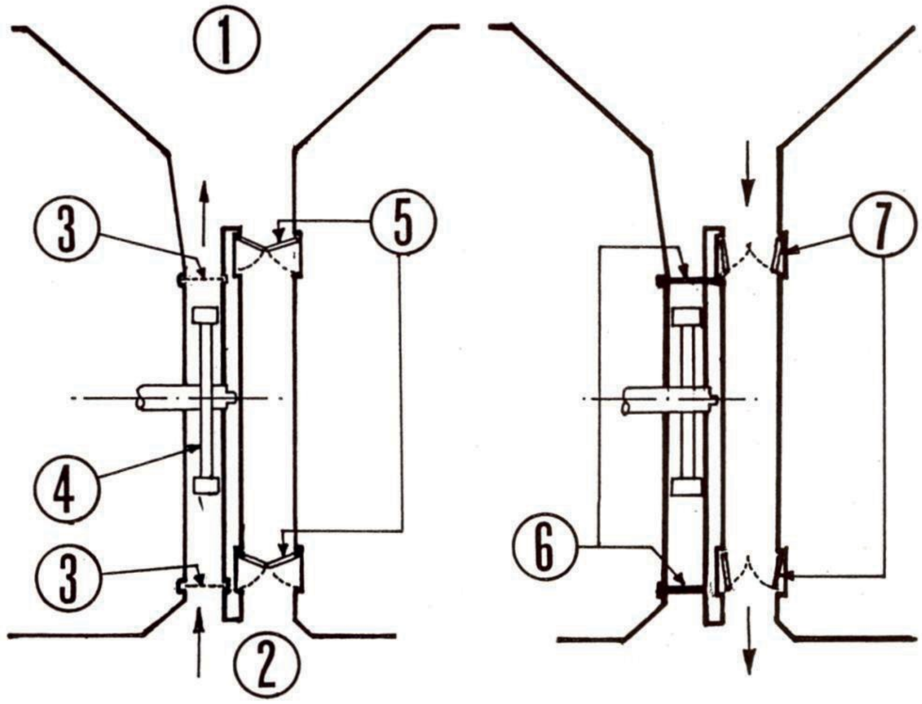

Fig. 4.4.4.1
The single-acting tide mill (here an ebb mill).

Left on falling tide: sluice closed, inlet sluice open.

Right on rising tide: sluice opened, inlet sluice closed.

1. *sea or outside water*
2. *reservoir or inland water*
3. *raised sluice gates*
4. *waterwheel*
5. *closed sluice*
6. *lowered sluice gates*
7. *opened sluice*

bypass sluice

The sluice complex of a double-acting mill was equipped with a bypass sluice. By opening the inlet sluice on the seaward side, the incoming flood water flowed against the undershot wheel. This enabled the mill to drive one or two pairs of millstones. Behind the waterwheel, water collected in the basin. When the ebb set in, water from the basin flowed past the waterwheel back into the outside water. As a result, a double-acting mill had (on average) four milling periods per day (twice at low tide, twice at high tide).

But double-acting mills also experienced periods of rest. As with an ebb mill, you could only start milling from the reservoir when the outside water had lowered sufficiently.

A disadvantage of milling on the tidal flow was that the waterwheel worked less efficiently. The water level of the rising tide keeps increasing so that when the tide starts to come in there is insufficient water to drive the wheel properly. At the end of the flood tide, the wheel becomes increasingly affected by tail water that is too high because the reservoir has become fuller. Only during part of the tidal flow period does the water level have the optimum height to obtain the highest efficiency from the waterwheel.

The waterwheel was fixed to the waterwheel shaft that was mounted in the mill and above the bypass sluice. The mill wheels that drove the stone spindle via a lay shaft or directly was also mounted on this shaft. Despite its simple design, the tide mill was still a costly arrangement because of the extensive hydraulic construction and high maintenance costs given its location on open saltwater. As a result, soon this type of mill was no longer used.
Portions of some tide mills in the Netherlands are still preserved, including in Goes, Middelburg and Bergen op Zoom.

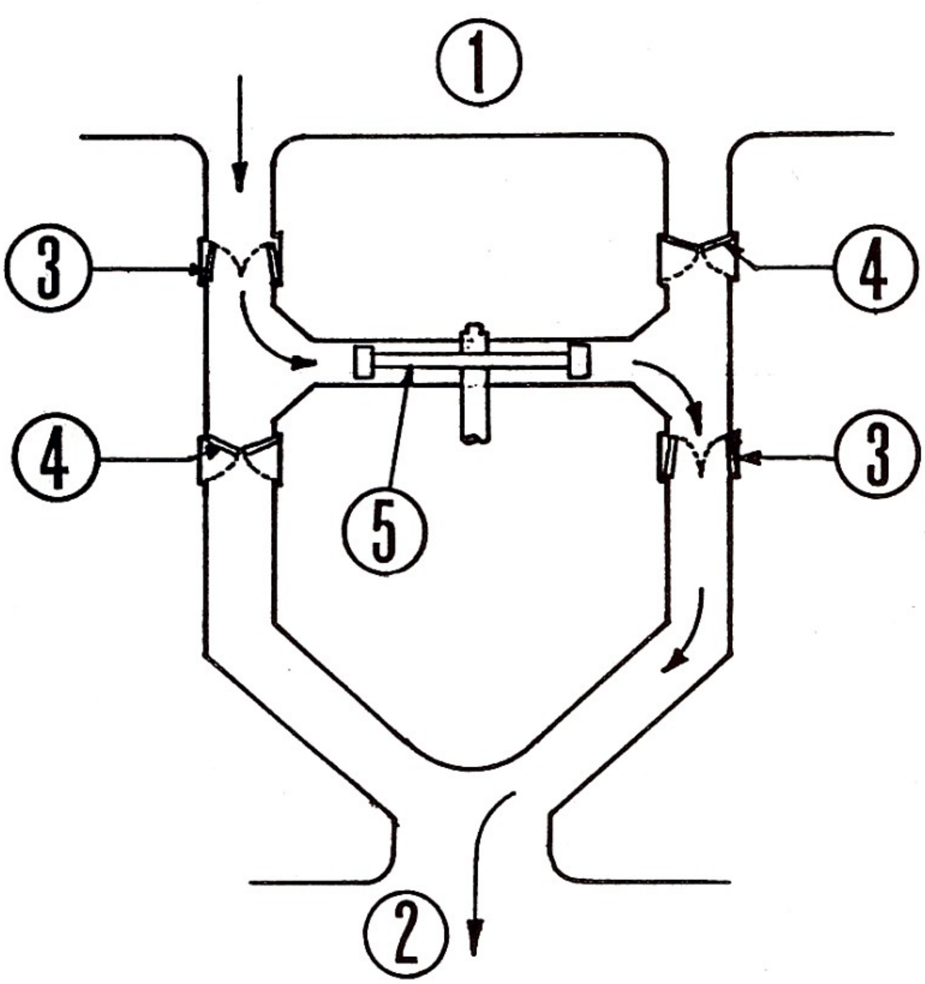

Fig. 4.4.4.2
Schematic of a double-acting tide mill.
The situation depicted is at high tide.

1. *sea or outside water*
2. *reservoir or inland water*
3. *opened inlet sluice / flow sluice*
4. *closed inlet sluice / flow sluice*
5. *waterwheel in the bypass sluice*

(At low tide sluices 3 are closed and sluices 4 are opened)

4.5 COMBINED WATER AND WINDMILL

As its name implies, this is a combination of a watermill and a windmill. The machinery can be powered by either wind or water.
Up until 2008, no water and windmill combinations remained in the Netherlands. However, the Kilsdonk grain and oil mill was restored in that year and, since November 25, 2008, the mill has been operational again.
The combination of wind and water power makes the complex unique, even on an international scale.

Fig. 4.5.1
A combined wind and watermill. The oil mill is on the right, the grain mill is on the left.

The Kilsdonk Mill – Heeswijk-Dinther

oil works

The oil mill is a water mill. The oil works are driven by a waterwheel. This oil mill has a front and rear beater, making it the only remaining water-powered oil mill in the Netherlands with a rear beater. An oil mill with front and rear beaters is called a double-works mill.

front and rear beaters
double-works mill

The grain mill can be powered by either water or wind. This mill has a second waterwheel. The central upright spindle is equipped with a clutch that disengages the wind drive gear when the mill is driven by water. When the wind drive gear is in operation, the waterwheel shaft is decoupled.
The mill shafts of both wheels can also be coupled if necessary so that together they drive either the oil mill or the grain mill.
The driving gear of the non-working mill can then be disengaged by a clutch on the shaft.

Across the border in the Emsland district of Germany at Hüven, there is also a working combined water and windmill, the Hüvener Mühle, which is a grain mill. At this mill, the windmill is positioned on the mill house.

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Chapter 5 Standing parts

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NOTES

5.1 STANDING PARTS

5.1.1 Introduction

standing parts
driving gear

By the standing parts of a watermill we mean, in short, the building and the structures. This is in contrast to the driving gear (power train): that is the entire system of wheels and shafts that transmits the motion of the water wheel or turbine to machinery.
This distinction between standing parts and driving gear is not just of theoretical importance, it has also had significance in practice. Old leases often stipulated that the cost and maintenance of the standing parts were the responsibility of the owner and costs for the driving gear were to be borne by the lessee or miller.
If the miller wanted to change or expand the equipment of the mill, they usually had to pay for it themselves.

5.1.2 The location

For centuries, watermills have been connected to flowing water that winds its way down through a gently rolling landscape.
People looked for favourable locations to build a watermill along those streams. They were found throughout the countryside, sometimes in the most remote places. Together with the beautiful scenery and the meandering stream, they often form a uniquely picturesque sight.

streams (artificial / man-made)

In the eastern Veluwe area of the Netherlands, these artificial streams were created before the construction of a mill. The water came from wells that were dug. However, watermills were also common in towns and villages, especially if the mill operation needed more personnel to function properly.
And town or village residents also provided a good outlet for certain products, such as flour, oil or pearl barley (hulled barley).

right-hand mill
left-hand mill

For power transmission purposes, watermills were built on the banks of rivers, brooks, or artificial streams. This happened on both the right and left banks. Looking in the direction of the flow, we then speak of a right-hand mill or a left-hand mill.

flow rate
fall

The choice of location was determined first of all by the presence of sufficient water (flow rate) and sufficient fall. These provide power to the waterwheel. The fall also determines which type of waterwheel is suitable.
But the location will be determined in part by the availability of land and its accessibility by road. And the preference was to locate the waterwheel on the south side of the mill so that in winter the sun could thaw a frozen wheel.

It was very common to build several mills on one stream, sometimes facing each other, often behind each other. For example, at one time as many as 15 watermills could be counted on the three branches of the Jeker river through Maastricht over a distance of about two kilometres. This regularly produced disagreements about too much or too little water at a mill as a supposed result of too much damming from the upstream or downstream mills. This issue gave rise to many legal actions!

upper mill, lower mill
front mill, rear mill

If there are two mills on the same stream at some distance from each other, they are called upper mill and lower mill. The terms front and rear mill were also used.

middle mill

If there were three mils, then there was also a middle mill. These terms say something about their position relative to each other: upstream or downstream. Sometimes this designation was also reflected in the name of the mill; such as the 'Middelste Molen' (Middle Mill) in Loenen or the 'Onderste Molen' and the 'Bovenste Molen' (Lower and Upper Mills) in Mechelen. Such a name persisted even if the other mill or mills had since disappeared.

double mill

If there are two watermills facing each other on either side of the stream, we call this a double mill.
A frequently occurring double mill consisted of a grain mill and an oil mill. The grain mill then usually had the larger premises because of the mill carts for transporting grain and flour. The grain mill was preferably located such that you did not have to cross the bridge with a horse and cart.
The oil mill was then across the bridge because the transport of seeds, oil and cake was less bulky.

mill complex

Watermills can also form a complex: a single building then houses several mills with two or even three different functions.
Each mill originally had its own waterwheel. These wheels were sometimes straight, sometimes at an angle, sometimes even behind the same inlet sluice. The oil mill was then located behind the grain mill because pressing oil required less power and the lower waterwheel sometimes received less water.
Later, a single waterwheel was increasingly used for several functions.

A complex can also consist of three mills: two mills in one building on one bank, the third on the other bank. Consequently, there are — or were — two or three waterwheels. In such a complex, the oil mill was usually on the other side of the bridge as less transportation was involved.

A mill complex could be in the hands of one owner or several. One complex is also known to have been located on either side of the Netherlands national border. It regularly happened that upon the death of the owner, each of the children inherited a part of the mill complex. Later, the parts were then sold to others.

mill pond
mill race, cut-off branch, weir

The appearance of a watermill can range from a modest little building to an imposing factory. Sometimes a mill is difficult to distinguish from other buildings, especially if the waterwheel is covered or enclosed (e.g., the Wittemer Mill in Limburg, the Netherlands) or if a turbine is present. Especially in the south of the Netherlands, a mill is often part of a larger building or farm that includes barns and a dwelling house. And sometimes a mill is hidden in a castle (such as the Castle Mill at Elsloo, the Netherlands). The watercourse usually puts us on the right track for recognizing a mill or former mill. For example, we see brick flumes, or mill pond. Or a brook that splits into a mill race and a cut-off branch. Usually there is a weir with a bridge and sluices or there are other hydraulic facilities.

5.1.3 Developments

By comparing the occurrence and development of the watermill in the Netherlands in different regions over time, we can sketch some broad outlines.
- The vast Limburg hill country with its many streams offered numerous suitable locations for building watermills. Good locations were far fewer in other regions, so the mills there were less scattered.

- Industrial-scale application of watermills occurred most often in Limburg, especially in the southern part of the province. The increasing prosperity of mill owners and competition among them led to greater investments than elsewhere in the Netherlands.
This is readily apparent from the size of some mill buildings.
This large-scale development is not seen or hardly seen in other regions of the Netherlands. Some larger paper mills did develop in the province of Gelderland on account of the ample supply of clean water that was needed not just for driving the mill but also for making paper.

The Old or Ban Mill – Valkenburg (L)

Watermill grown into a flour mill.

Tiled roof, marlstone, ashlar window surrounds, multiple floors.

cast iron

- We see the application of new developments more in Limburg than in other regions of the Netherlands: e.g., the use of cast iron and steel for waterwheels, gearwheels and hurst frames.
The proximity of Belgian and German iron foundries and machine shops will have certainly contributed to this.
But use of iron or cast iron also required specific knowledge, as artisan millwrights traditionally worked only with wood. The making and fitting of cast iron hurst frames and gearwheels was work for machine builders.

turbines

- Turbines were used on a large scale especially in the province of Limburg, but in a very limited way elsewhere in the Netherlands. However, there are also drawbacks to the use of turbines (see section 6.4.4), so in various mills the turbine was later replaced by an improved waterwheel.

improved waterwheel

- Improved waterwheels were developed with higher efficiency, mainly made of iron (see section 6.3). These replaced wooden waterwheels on a large scale in Limburg.
This development almost completely bypassed the provinces of Overijssel and Gelderland. The wheels in those regions, with few exceptions, are still made of wood and with crossed arms.
Iron spokes were used in the province of North Brabant, but almost all of those wheels still have wooden floats.
- At some watermills, the waterwheels were covered. This made them less susceptible to icing up and — in the summer period — to imbalance because the floats above the water dried out less.

5.2 CONSTRUCTION AND BUILDING MATERIALS

Formerly, transportation was a limiting factor in daily life. Horse and wagon had a limited range and water for navigation was not available everywhere. Transportation over longer distances was complex and expensive.
Consequently, locally available materials were widely used for construction. This included the construction of houses and farms as well as watermills. Examples are wood and brick (clay) or a combination of them. Natural stone that can be readily supplied from nearby (foreign) quarries was also used.
This also applied to roofing materials: straw, thatch, tile, slate, etc.
Sandstone is more water-resistant than brick and is less likely to break into pieces when frozen. For this reason, sandstone was applied in foundations and walls or sub-walls on the side of the waterwheel and lower watercourse (the tail water), and also in the apron walls and head stock on which the outboard bearing of the mill shaft rests.

apron wall, wing wall

Local craftsmen built using traditional methods, in mostly local ways. Such features can still be found in many mills, such as half-timber construction, characteristic brickwork patterns, window frames and so on.
Over the years, we gradually see the emergence of new materials and techniques, including in construction (cast iron, concrete, tropical hardwood and the like). With improved means of transportation and communication, areas gradually became less isolated, and outside influences began to be seen in construction methods.

Below we draw general attention to some characteristic aspects of the construction of mills that still exist in four provinces of the Netherlands.

5.2.1 Limburg

Limburg is the province with the most watermills: it has over fifty watermills, or more than half of the number of watermills that still exist in the Netherlands. There are also many recognizable remnants of mills that now serve as homes, restaurants or business premises.
Fortunately, there are also several major restoration projects in which the driving gear is being restored, a waterwheel is being replaced, and the mill ponds are also being re-established.

A classification of the types of watermills in the region reveals 13 undershot mills, 19 breastshot mills, 7 overshot mills and 14 turbine mills.
In addition, there are another three combinations: undershot + overshot (Wymarsche Mill), breastshot/neckshot (Plas Mill), undershot + turbine (Grathemer Mill). (Data as per the Netherlands Mill Database, 2019.)

neckshot wheel, pitchback wheel

In this area, locally quarried building materials, such as Kunrader stone, Nievelder sandstone and marlstone, were used early on for walls and foundations.
The mills in North Limburg and Central Limburg are all built almost entirely of brick. In South Limburg, marlstone was used in addition to brick. And ashlar was also used occasionally.

marlstone, ashlar

It is easy to see that in the past people sometimes carried out repairs or renovations using materials other than the original ones.
Around windows and doors, several mills have a distinctive framing of granite.
Mills made of wood are no longer found in Limburg. The familiar half-timbered construction is only to be found at one mill (Oil mill in Heerlen). Most of the mill buildings are covered with roof tiles — sometimes with straw dollies (straw bundles) — but a few mills have slate as roof cladding. Only one mill, the horse-driven mill in Oostrum, is thatched.

straw dollies, straw bundles

Several mills in South Limburg are whitewashed.
Turbine mills often have a distinctive attached turbine room.

Fig. 5.2.1.1
The Eper or Wingberger Mill – Epen

Brick, slate roof, turbine room.

Watermills are sometimes part of a farm, both the typical Limburg castle farmstead with an (enclosed) courtyard and long-fronted farmhouses, which also include a dwelling house and barns. The large size of some of the mill buildings, sometimes as many as three or four storeys, points to the mill's industrial past. At the end of the 18thcentury and in the early 19thcentury, there were many industrial mills, especially in South Limburg. These included paper mills, needle grinding mills, artificial wool mills, and mills for the woollen fabric industry: spinning, dyeing, fulling (of sheet cloth) and woollen blankets.

weed rack
grille
rack-and-pinion, pull, winch

Both brick and concrete mill races are common, usually with an iron weed rack or grille in front of it. The operation of the sluices gives a varied picture: we see rack-and-pinions, pulls and winch. But also electric controls.
Most mills still in existence are listed as grain mills (one of which also has a working oil mill in the same space). Some mills are used to generate electricity.

5.2.2 North Brabant

Twelve watermills remain in North Brabant. All are undershot mills with, in many cases, a characteristically large waterwheel. Eight of these mills are located on the Dommel and Kleine Dommel rivers.

These eight feature wooden construction and wooden walls.
The remaining four mills were built from brick.
Half-timbered construction does not occur in North Brabant, nor does the use of marlstone or natural stone.

apron, weed rack
spars
rack-and-pinions
winch drum, pull
combined water and windmill

The roof cladding almost always consists of tiles with the exception of a wooden watermill that has a thatched roof. (Hooydonk Mill in Nuenen). Both the brick and the concrete mill race appear with an iron weed screen or spars in front.
The sluices are generally operated by rack-and-pinion or (wooden) winch drums with a lever. A pull is seen in a few mills.
The Kilsdonk Mill is a combined water and windmill powered by both water and wind.
Of the Brabant watermills, seven are set up as grain mills, two as grain/oil mills, one generates electricity, and two no longer have a function.

Fig. 5.2.2.1
The Coll Mill – Eindhoven

A double mill: the grain mill is in front, the oil mill is behind, with the weir between them.

Timber construction, tiled roof with straw bundles; the grain mill is before the bridge.

5.2.3 Gelderland

There are still 25 watermills in Gelderland. These are 16 overshot mills — all of which can be found on the sloping eastern edges of the Veluwe region, west of the IJssel river — and seven undershot mills found east of the IJssel, in the Achterhoek region. This two-way split came about due to the available fall in those areas.
Especially on the eastern edge of the Veluwe, the somewhat larger buildings of industrial watermills can be found.
Two of the existing mills have been rebuild (Heerde, 2018) or restored (Renkum, 2021) recently.

wing walls, apron wall

All but two watermills in Gelderland were built of brick. Two of them have plasterwork. One mill is part brick, part Bentheimer sandstone. One mill has wooden walls, a brick façade and an apron wall built of brick. Two mills have wooden apron walls instead of made of concrete.
Natural stone has been used at some mills.
The roof claddings consist of tiles, except for one mill that has a flat roof and one mill with part thatch, part tile.

undercutting

The wooden foundations and mill races were in most cases replaced by stone or concrete ones to prevent undercutting.

pull
wooden lever

At seven overshot mills, the flume gate is operated with a pull.
At all undershot wheels, the inlet sluices are opened with a wooden lever.

The mills remaining in Gelderland consist of 13 grain mills, two paper mills, one oil mill, one grain / sawmill, one grain / hulling mill, and five mills that generate electricity. Two mills no longer have a function.

Fig.5.2.3.1
The Mallum Mill – Eibergen

Tiled roof, waterwheel side of Bentheimer sandstone with wall anchors, remaining façades of brick, concrete apron.

5.2.4 Overijssel

Overijssel still has nine watermills. Of these, six are undershot mills and three are overshot mills. Again, the landscape determines the mill type: the three overshot mills are located in the eastern, hilliest part of the Twente landscape and the six undershot mills are found in the somewhat flatter part of Overijssel. There are two double mills with three waterwheels. The remaining seven mills are relatively small, simple structures.

Fig. 5.2.4.1
The Mast Mill – Vasse (Overijssel province)

Tiled roof, half-timbering, brick, wooden cladding of the gables. On the façades is a façade sign.

In Overijssel, a lot of Bentheimer sandstone was used for construction. We see this reflected in the mills: eight mills have foundations of Bentheimer sandstone, one stands on wooden posts and has wooden walls (Den Haller at Diepenveen).

half-timbered construction

At five mills we find half-timbered work.

straw bundles, straw dollies

All nine mills have a roof consisting of Old Dutch tiles, eight of which have straw bundles (straw dollies) and one has roof boarding. One mill has wooden cladding at the gables and three mills have it at the wall behind the waterwheel.

The aprons are made of concrete.

sluice gate

bottom hatch, shuttle

The overshot mills have a hand-operated flume gate for the water supply. The water supply from the flume to the wheel is operated from inside one mill with a pull. In the other two, the bottom hatch (shuttle) outside is operated manually.

inlet sluice, inlet gate
wooden lever
pull

At the six mills with undershot wheels, the inlet sluice (inlet gate) is opened with a wooden lever.
For the grain mill, 1 mill controls the inlet sluice with a pull.

Fig. 5.2.4.2
Oostendorper Mill – Haaksbergen

A double mill, grain mill on the left, oil mill on the right.

Tiled roofs, lower walls of Bentheimer sandstone, half-timbering in both buildings, concrete apron.
Straw bundles or straw dollies under the tiles as a seal against the wind.

The watermills in Overijssel have the following functions: there are six grain mills, an oil mill, a grain / oil mill, and a grain / sawmill.

5.3 FACILITIES FOR FISH AND FISHING

5.3.1 The eel basket or fish trap

eel basket, fish trap
fish tank

For catching fish, mills were sometimes equipped with an eel basket (fish trap, fish tank) in the weir.
This is a slatted basket with narrow openings between the slats, and at the end of the basket there should be a slatted gate as a closure. When the gate in the weir is opened, water from the stream flows into the eel basket and flows out through the open slatted bottom. This bottom works like a sieve.
During the period when the eels migrate to the Sargasso Sea to spawn, the gate was opened and the eels which were carried by the water were left on the bottom for collection. Small (juvenile) eels slip through the openings in the bottom.

Fig. 5.3.1.1
The eel basket

Oostendorper Mill – Haaksbergen

fish trap

St. Ursula Mill and the Schaloen Mill in Limburg also feature a similar construction. Because it can be used to catch other fish, it is called 'the fish trap' there.
At the Opwetten Watermill in North Brabant, there is also an eel basket. This is made of iron and installed in the concrete apron of the spillway. A horizontal lattice frame work leads the eel to the vertical lattice frame, which can be lowered with a winch drum that closes off the way back for the eel. Through a hole in the apron's concrete wall, the eel automatically enters the basket. Again, the construction of the lattice frame is such that young eels are not caught.

5.3.2 Fish ladder and fish passage

fish ladder

fish passage

Whereas the miller used to like to catch fish from the water streaming past and sometimes had an eel basket for it or placed nets in the mill race, today we see a more fish-friendly policy. Fish ladders that allow fish to swim upstream past the mill have been constructed at several watermills. In Natura 2000 areas, the construction of a fish ladder or fish passage is even prescribed to the water authorities.
The disadvantage of a fish ladder along a mill is that it usually means a lot of water for milling is lost. Fish ladders are usually open year-round, even during periods when the fish hardly migrate, if at all.
Weirs for the mill are therefore limited or ruled out.

Fig. 5.3.2.1
A fish ladder

Leeuwen Mill – Maastricht

But we are also seeing solutions to that problem these days that can be found at the St. Ursula Mill and the Elisabeth Mill, among others.

fish passage

There is a fish passage at the St. Ursula Mill: a branch of the mill stream that runs around the mill. The millers may — within the applicable rules —regulate the distribution of water between the mill race and the fish passage on their own initiative.
There is a fish ladder at the Elisabeth Mill. The miller may fill the reservoir but a sensor controls an electrically driven spillway when the water level is too high. With planking on the spillways and at the fish ladder weir, the supply of water can be divided between the mill race and the fish ladder.

Chapter 6 Driving gear

Contents Page

NOTES

6.1 SHAFTS AND SPINDLES

6.1.1 Introduction

driving gear, running gear

By the driving gear we mean the whole assembly of shafts, spindles and wheels that transmits the rotary motion of the waterwheel or turbine — both horizontally and vertically — to the machinery.
The shafts in mills are made of wood or iron. Horizontal shafts are called shafts, vertical shafts are spindles.
Wheels are used both horizontally and vertically.

shafts, spindles

mill shaft
turbine shaft

In mills with a waterwheel, that wheel is attached to a horizontal mill shaft.
Turbine-driven mills have a turbine shaft. Depending on the placement of the turbine, the turbine shaft runs vertically or horizontally.
Sometimes there is a line shaft used to drive machinery items.

central spindle,
vertical shaft

A second important shaft is the central spindle, although it is not found in all mills. This one is vertical.
Some other shafts and spindles:

spherical spindle
sack hoist shaft
camshaft, tumbler shaft

- Grain mills are equipped with one or more quant spindles and/or spherical spindles that belong to the set of millstones. In addition, there is usually a sack hoist shaft for hoisting sacks of grain (see chapter 12, The grain mill).
- Oil mills have a camshaft, also called a tumbler shaft (see chapter 14, The oil mill).
- In watermills there are also — mostly iron —horizontal drive shafts, with which other machinery can be driven, such as an elevator. These are usually belt or rope drives.

The chapters covering the various mill functions will discuss these specific shafts and spindles in more detail.

6.1.2 Mill shaft or waterwheel shaft

mill shaft

The mill shaft transfers the movement of the waterwheel outside the mill to the driving gear inside the mill.
Note: In practice but also in the literature, both the terms "mill shaft" and "waterwheel shaft" are used. It is recommended that regional names always be used.

waterwheel shaft

6.1.2.a Wooden mill shaft

Originally, all watermills were equipped with a wooden mill shaft, generally made of oak, with a thickness of 80 to 90 cm. These wooden shafts suffer greatly from the water dripping from the waterwheel. The lifespan of a wooden mill shaft in daily use was 25 to 30 years.
Today, tropical hardwoods such as Azobé or Bilinga are used for mill shafts.

6.1.2.b Cast iron mill shaft

Cast iron has been in use since the Middle Ages. People casted relatively small objects, such as round (cannon) balls and household utensils. When the Industrial Revolution took off in the early 19th century, people, especially in England, learned to cast large iron objects and structural parts.

Consequently, the first cast iron windshafts for windmills originated from England.
But in the mid-19th century, Dutch iron foundries were also casting mill shafts.

collar

To prevent water ingress, the shaft is sometimes fitted with a collar, a disc around the shaft that seals the opening in the water wall.

Fig. 6.1.2.1
A wooden mill shaft. (The wheel has been removed due to replacement). On the left is the wing gudgeon with two clamp irons around the shaft. The gudgeon rests in a covered bearing.
Under the shaft there is an eel basket.

Oostendorper Mill – Haaksbergen

6.1.2.c Bearing

bluestone

bronze shell

Mill shafts are bearing-mounted at both ends. These bearings usually consist of a stone made of bluestone, which is a hard type of limestone. However, other materials were also used, such as pockwood or a cast iron or wooden bearing block with a bronze bearing seat (see Fig. 6.1.2.2).

Fig. 6.1.2.2
Iron wing gudgeon in a bronze bearing seat. Double clamp irons around the shaft.

Outboard bearings are usually closed or covered to protect against weather conditions, and inner bearings are usually closed or covered to protect them from debris.

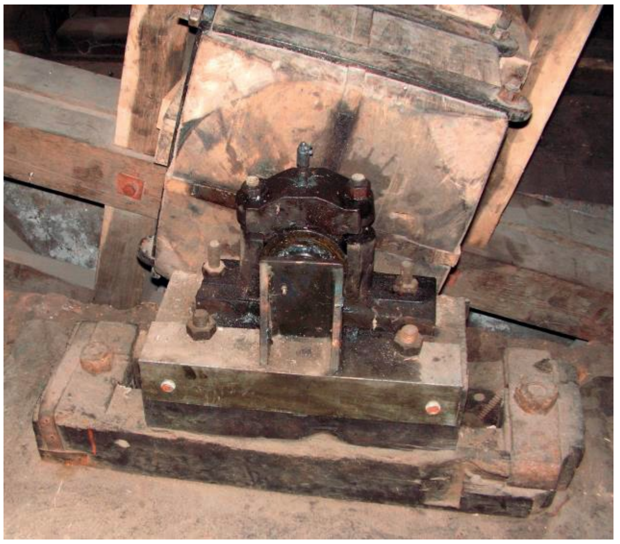


Fig. 6.1.2.3
Self-aligning bearing.
Again, a wing gudgeon and 2 clamp irons around the shaft.

wing gudgeon with collar hoop
clamp iron

At the location of the bearing on a wooden mill shaft, the shaft was rounded and fitted with a wing gudgeon with collar or laid-in gudgeon or bronze strips. Iron bands (hoops) are fitted all around for reinforcement.

Fig. 6.1.2.4
The bearing of a wooden (cam) shaft.
Hoops are fitted in the rounded end, over which a collar was later mounted.
The shaft rotates in a bearing stone.

gudgeon, wings
wing gudgeon with collar
clamp irons

Later mill shafts used the same construction that was used with spindles. At both ends of the shaft, there is an iron wing gudgeon that is keyed into the shaft or a wing gudgeon with collar is used. For reinforcement, hoops are placed around the shaft (see Fig. 6.1.2.2 and Fig. 6.1.2.3). These gudgeons turn both in hard stone bearings and in a wooden or cast iron block containing a bronze bearing seat.

bearing block

The bearing is placed in a bearing block. To prevent the mill shaft from moving longitudinally, there is a metal plate in the bearing block that the shaft rotates against. A bronze bearing for a gudgeon is therefore also U-shaped. Nowadays a self-aligning ball bearing is also used.

self-aligning ball bearing

self-lubricating bearing

Such a bearing can self-correct minor deviations in alignment. It is lubricated with ball-bearing grease using a lubrication gun or grease gun. Self-lubricating sealed bearings are also used, for example as outboard bearings of the mill shaft. These bearings contain enough grease for an extended period of time.

Fig. 6.1.2.5
A cast iron shaft in enclosed outboard bearing with grease pot.

path
lubrication film

A new bearing stone has a cavity no more than 2 to 3 cm deep. The path of the shaft rotates within it. This cavity should be slightly wider than the path of the shaft to ensure proper lubrication (lubricating film) between shaft and stone (see Fig. 6.1.2.6).

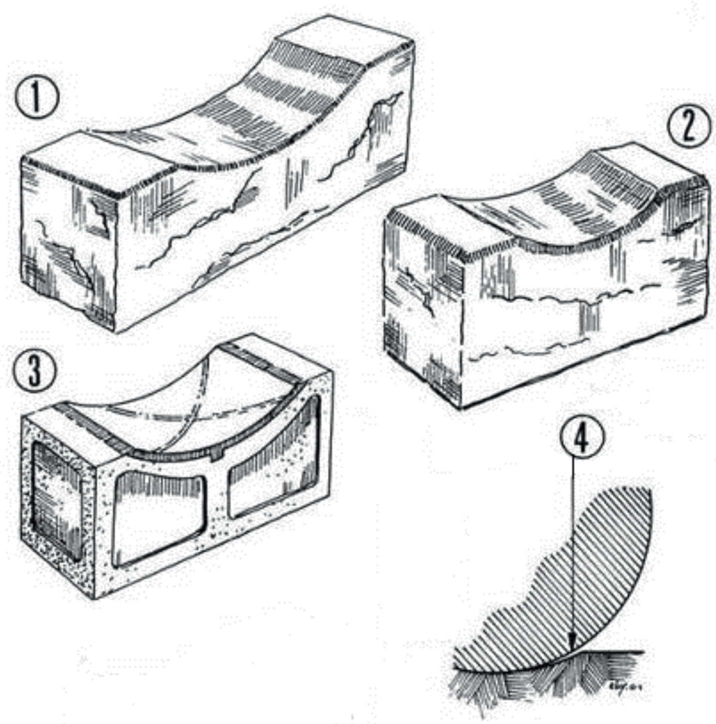


Fig. 6.1.2.6
Bearings:

1. *stone for wooden shaft*
2. *stone for iron shaft*
3. *iron bearing with bronze or white metal lining*
4. *inlet gap for the lubricating grease*

A deeply worn stone carries the shaft over too large a surface, moreover one that should fit precisely, and this prevents lubrication and, more importantly, heat dissipation. The shaft can then become so hot that a fire starts!

running hot

If the shaft is not borne across the full width of the stone, this may also run hot. Possible causes are that the stone has tilted or sagged slightly or that the shaft has sagged. You can spot this by an incomplete lubrication film. Furthermore, the stone may break, causing grease to disappear.
Failure to lubricate or inadequate lubrication can also cause it to run hot.

6.1.2.d Lubrication

pig lard
consistent grease
multi-purpose grease

Shaft bearings are lubricated with (unsalted) pig lard, whether or not in liquid form, or waterproof consistent grease. Multi-purpose grease is used at some mills. This is a soap-based bearing grease. It is waterproof and resistant to high temperatures.

ball-bearing grease
self-lubricating

Ball-bearing grease also comes in the form of a lubricant. Outboard bearings today are often self-lubricating and require very little maintenance.

6.1.3 Central spindle (main upright shaft)

central spindle
crown wheel, cradle wheel

As a rule, watermills with the function of grain mills, hulling mills or a combination of these have a central spindle to drive several pairs of stones. This vertically standing spindle is driven — via an angular transmission — by the pit wheel through a cog wheel (crown wheel) or trundle wheel (cradle wheel).
Originally these spindles were made of wood (oak or pine); later cast iron ones were used in many watermills, especially in Limburg.

transmission shaft

For under-driven grain mills, the central spindle is usually short, up to the stone floor. The spur wheel is located in the hurst frame under the floor of the stone floor. In a mill driven from above, the central spindle is longer because the spur wheel turns several metres above the stones. Sometimes the central spindle was extended and narrowed (smaller diameter) to the top of the mill to drive another horizontal drive shaft (transmission shaft) there for other machinery.

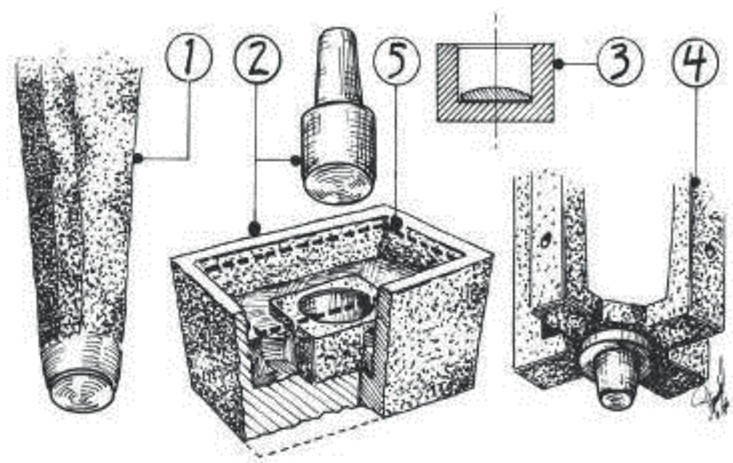


Fig. 6.1.3.1
Lower bearing of the central spindle:

1. *wrought iron gudgeon*
2. *loose gudgeon with toe-brass*
3. *cross-section of bearing pot with tile*
4. *wing gudgeon, cross-tailed gudgeon*
5. *machine oil fill level*

6.1.3.a Bearing and lubrication

bridge tree, support beam
thrust bearing
gudgeon
collar, toe-brass

By its lower end, the central spindle rests on the bridge tree (support beam), and rotates in a thrust bearing. At the bottom of the central spindle is a hardened steel gudgeon with wings (wing gudgeon) or cross-tailed gudgeon. This gudgeon rotates in the toe-brass. The toe-brass consists of a cast iron compartment into which a second compartment of hard steel is cast with lead. A round hole matching the gudgeon is cut out in this second compartment. Sometimes this hole has a bronze lining.

tile

At the bottom of this hole is a hard steel plate: the tile or thrust plate on which the gudgeon from the shaft rotates (see Fig. 6.1.3.1).

machine oil, rapeseed oil, castor oil

Thick machine oil, castor oil or rapeseed oil is used for lubrication in the toe-brass.

bridging box, bridge tree

The toe-brass is also sometimes secured in a bridging box in the bridge tree to allow adjustment of the central spindle.
In the case of iron central spindles, the central spindle rests on a sprattle arch to which a toe-brass is attached.

Fig. 6.1.3.2
Sprattle arch

Iron running gear where the central spindle rests on a sprattle arch. On the sprattle arch is the pivot bearing. Below it the inner bearing of the waterwheel shaft.

St. Ursula Mill – Nunhem

gudgeon
wing gudgeon or cross-tailed gudgeon, 'laid-in' gudgeon
bridge tree gudgeon
bolsters gudgeon

The top bearing of the central spindle consists of either a wing gudgeon attached to it with wings that are notched into the spindle or a wing gudgeon with a collar or a 'laid-in' gudgeon (see Fig. 6.1.3.3). In the sprattle beam, a rectangular space (bearing box) is carved into which two pockwood or bronze bolsters (bearing blocks) are inserted. The gudgeon rotates between these bolsters that are hollowed out in a half-round on one side.

Stauffer grease pot

Some grease is placed around the gudgeon for bearing lubrication. A Stauffer grease pot can also be used for this purpose. Later, ball bearings were also used for these bearing points.

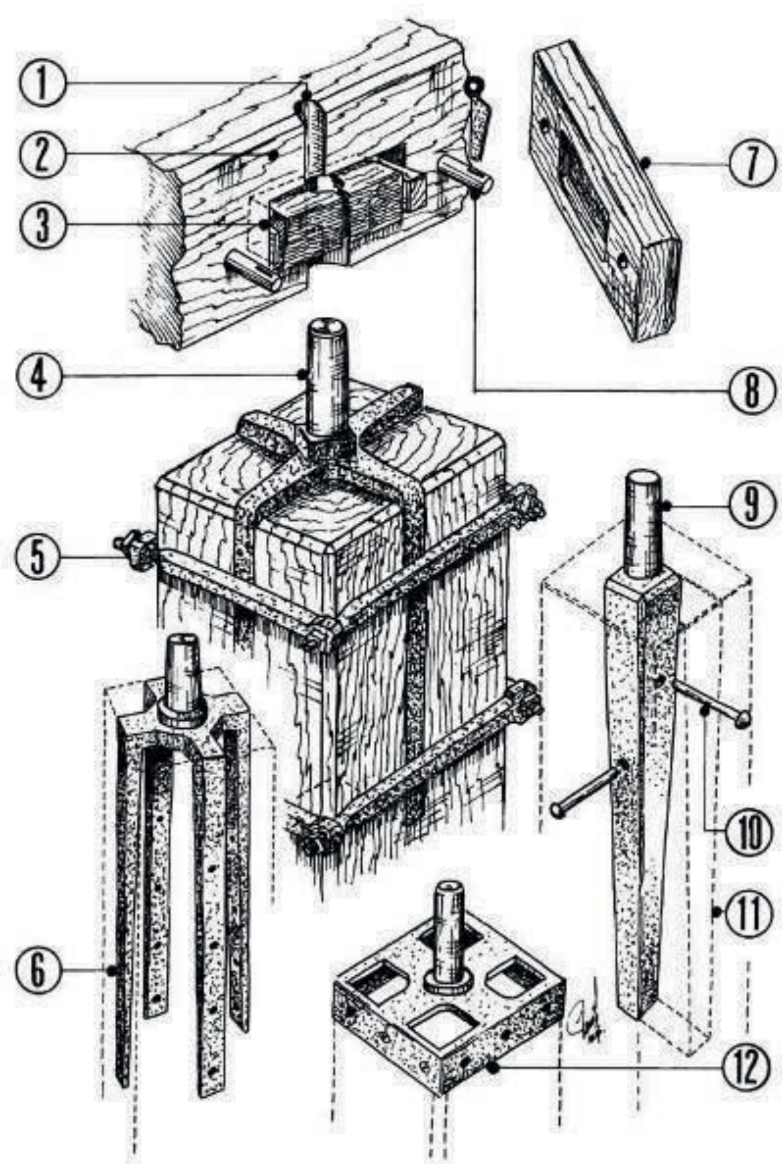


Fig. 6.1.3.3
Upper bearing of a wooden central spindle:

1. *lubrication hole*
2. *sprattle beam*
3. *pockwood gudgeon bolsters*
4. *wing gudgeon*
5. *bridle iron, clamp iron*
6. *wing gudgeon or cross-tailed gudgeon*
7. *lock plate or bearing cover*
8. *bolt for lock plate*
9. *'laid-in' gudgeon*
10. *locking pin*
11. *closure piece*
12. *collar over 'laid-in' gudgeon*

6.1.4 Other shafts and spindles

Other shafts and spindles are covered in the chapters describing their respective mill types and functions.

6.2 WATERWHEELS

Originally, all waterwheels were built of wood. In the Netherlands, some regions later switched to the use of iron in whole or in part, while wooden wheels remained in other regions.
For example, in Twente, the Achterhoek and in the Veluwe, most waterwheels are still made of wood. In North Brabant, most are made of iron and wood. In Limburg, waterwheels are predominantly made of iron.

6.2.1 Wooden undershot wheels

undershot wheel

In areas where the range of stream levels reaches 1 to 1.5 metres, undershot wheels are used. They are usually located on slow-flowing, broad streams with plenty of water flowing through them. Undershot mills can be found in all four regions where waterwheel mills are still present. In fact, it is the only type found in North Brabant.

cross arms, spokes

Wooden undershot wheels are made with cross arms or with spokes. The first type is found mainly in Overijssel and Gelderland, the second in Brabant and Limburg.
An undershot wheel with cross arms is constructed as follows: two of these heavy arms run parallel along the shaft. At right angles to this, two, also parallel, cross arms are attached cross-lapped (with a lap-joint). In the middle, this leaves the square shaft hole through which the mill shaft protrudes. Wedges are used to attach the wheel to the shaft.

shaft hole, mill shaft, wedges

Fig. 6.2.1.1
Wooden undershot wheels with curved cross arms, single rims and extra rings for support.

Singraven Watermill – Denekamp

rim
struts
start, cleats

At the ends of the cross arms is a ring called the rim, which is constructed of wooden segments. Through this rim are inserted wooden cam-shaped struts, spurs or cleats, which are secured to the start — that is, to the shaft side of the rim.
These wedges are often secured again with a stainless steel nail. On the outside of the wheel, the floats are attached to the struts. They stand radially in the wheel or at a slight angle to the rim. Floats were initially flat but later became slightly curved.

float

rings for support, braces

Additional support rings or ring braces, are sometimes inserted between the floats.
To make the distribution of the rim on the cross arms more even, the cross arms are sometimes slightly bent on large wheels.

push wheel

Undershot wheels turn due to water pressure on the floats. In Limburg, they are also called push wheels because of the water pushing on the floats of the wheel to make it turn.

Fig. 6.2.1.2
A single rim with cleats and floats on a wooden undershot wheel with cross arms.

Oldemeule – Oele

spokes

tangential wheel

In North Brabant and Limburg, wooden undershot wheels with spokes instead of cross arms are also seen. Here, the rim is attached to the spokes.
The spokes can run radially, in other words: directed to the centre of the mill shaft or tangentially (at an angle) to the shaft. With a tangential wheel, the spokes are attached around the mill shaft based on a draft or draught circle. It is notable that in the Netherlands tangential spokes are fitted in the same direction of rotation as that of the wheel. In Belgium they are sometimes fitted the other way around and are loaded in a 'forward-slanted' position.

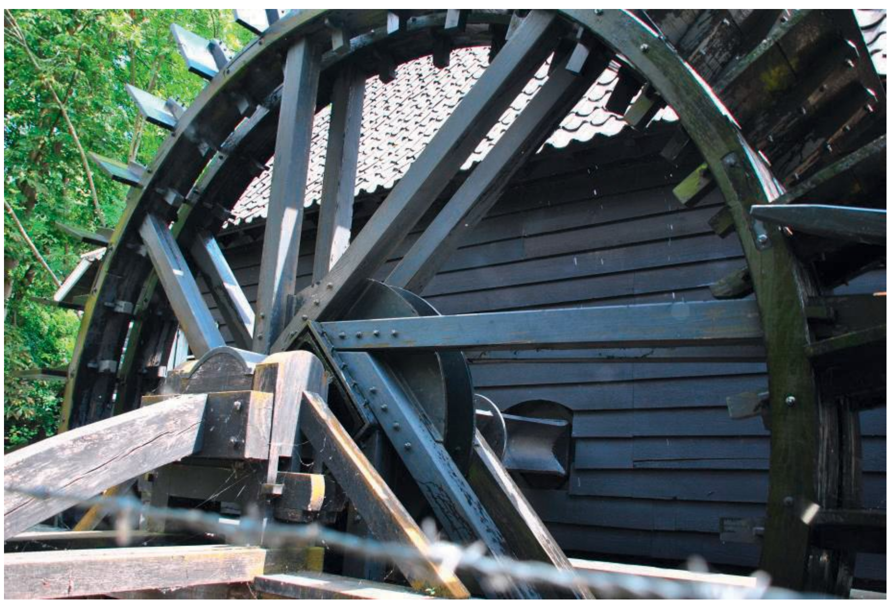


Fig. 6.2.1.3
Wooden undershot wheel with double rims and tangential spokes.

Genneper Mill – Eindhoven

iron support rim

Most wheels have eight (pairs of) spokes, while some have six. With double spokes there are also two rims, except in North Brabant where the pairs of spokes meet at the outer end and are connected by an iron support rim (see Fig. 6.2.4.2).
Undershot wheels have a centre line that varies between about 3 metres and 9.30 metres. The largest waterwheel in the Netherlands is in the Opwetten Watermill. Undershot wheels run at about 5 to 6 revolutions per minute, with larger wheels going slower.

6.2.2 Wooden overshot wheels

overshot wheels

With a fall of water ranging from about 3.5 to 5.5 metres, overshot wheels are used. In the hilly regions of the Veluwe, Twente and Limburg, some streams have such a large fall that overshot wheels are used.

trough, flume, shuttle
bottom hatch, spillway hatch
apron

With an overshot wheel, water is directed past the mill building above the wheel through a high trough or flume. In the flume there is a shuttle (bottom hatch, spillway hatch) above the wheel. When it is opened, water flows onto the scoops of the wheel and sets it in motion. If the hatch is closed, the water runs past the wheel and falls into the apron. Sometimes there is a hatch in the flume in front of the wheel and the water falls into the apron through this hatch. The flume is usually (slightly) narrower than the wheel.

Fig. 6.2.2.1
Wooden overshot wheel with flume. Here there are two bottom hatches: one in front of the wheel, one above the wheel.

Mill De Mast – Vasse

cross arms
rims
floats
bays, buckets

These wheels have a double set of cross arms, which are on either side of the waterwheel. The rims (shroud) on these cross arms are made a bit narrower but higher, as if they are two discs. The floats are attached between the rims. These rims prevent water from flowing sideways out of the wheel. On the shaft side, the floats are boarded up with wood so that buckets that fill with water are formed between the sole boards (or drum boards), the rims (shroud) and the floats.
Overshot wheels are usually much smaller than undershot wheels. Their diameter is between 1.5 and 4 metres. The diameter is about 30 cm smaller than the impounded fall height. This is also approximately the distance between the top

of the wheel and the flume. The speed is about 6 to 10 revolutions per minute when the mill is not under load.
With respect to the flowing water, in overshot wheels the direction of rotation is opposite to that of undershot wheels and breastshot wheels.

6.2.3 Breastshot wheels

breastshot wheel

A type of waterwheel found only in Limburg is the breastshot wheel. This is used with a fall of water ranging from about 1 to 3 metres. About one-third of Limburg's watermills have a breastshot wheel. That means there are more breastshot mills than undershot, overshot or turbine mills.
The diameter of these wheels is between 5 and 7 metres in almost all mills.

tangential spokes

There is one remaining wooden breastshot wheel that also has tangential spokes. This one was also built as 'pushing' (Gitstapper Mill in Vlodrop). (referring to its tangential spoke design) In addition, some mills are equipped with an iron wheel with wooden floats. The remaining breastshot wheels are made entirely of iron.
Breastshot wheels with cross arms are no longer present. Most wheels have eight pairs of spokes, there are a few with six pairs, and the floats are profiled to a greater or lesser extent to improve water flow. All wheels have double rims between which the floats are attached — usually at an angle to the shaft.

iron support rim

Sometimes there is another iron ring for additional support of the floats. In a number of wheels, the rim (shroud) is designed as a high rim to prevent sideways water run-off.

Originally, the wooden breastshot wheel differed little from the undershot wheel; the flat wooden floats did not allow the water to enter too high so as to prevent it from striking over the floats. With the application of curved sheet-iron floats, however, this did allow the water to flow in higher.
The water is now directed onto the floats approximately at shaft height. Occasionally, the distinction high-breastshot or low-breastshot wheel is still made when the water is directed higher or lower than shaft height on the wheel, respectively.

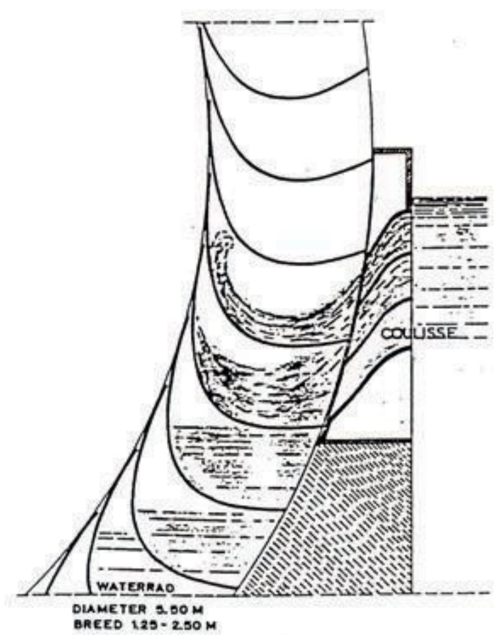


Fig. 6.2.3.1
A breast (apron) with water guideways that provide better filling of the buckets.

breast, apron
breast wheel
water guideways

Because there was a lot of water loss between the weir sill and the buckets, a stone or concrete raised edge was built, the breast that closely butted up to the waterwheel. It is therefore referred to as a breast wheel. Above that breast, sometimes two or three water guideways (see Fig. 6.2.3.1) were made through which the water flow was sent in the direction of the buckets. This caused the water to flow more gently into the wheel and the buckets to fill better.
Another hatch was sometimes inserted at the bottom of the breast (apron). When there was very little water, this hatch was opened and the breastshot wheel acted as an undershot wheel.
Breastshot wheels derive their energy partly from the pressure of the inflowing water and partly from the weight of the water in the filled buckets.
A breastshot wheel has the same rotational direction as an undershot wheel but rotates in the opposite direction to an overshot wheel.

Fig. 6.2.3.2
A neckshot wheel.
The upper flume has a backward-facing outlet for the water.

Bovenste Plasmolen (Upper Lake Mill) – Mook

A special wheel is found at the Upper Lake Mill in Mook.
This mill has two flumes, one low and one high. When using the low flume, the wheel acts as a breastshot wheel. When using the high flume, it acts as an overshot wheel. In doing so, however, it rotates in the opposite direction to the usual direction of rotation for overshot wheels. Therefore, the high flume does not extend all the way above the wheel, and a backward-facing outlet for the water was created. This type of wheel is also known as a neckshot (pitchback) wheel.

neckshot wheel

6.2.4 Iron waterwheels

From the mid-19th century, wooden water wheels were gradually replaced - especially in North Brabant and Limburg - by iron ones.
In Twente this did not happen, and in Gelderland at only a few mills.

For iron water wheels, rolled iron sections and sheet steel were mainly used. These were riveted and then later also secured with bolts and nuts.

Wood continued to be used for the floats for a long time. Later on, floats were also made of sheet steel. This allowed curved shapes that let less water drain over the float. In the case of overshot wheels made from iron, the bucket can hold more water because the thickness of the plate is less than that of wood.

Fig. 6.2.4.1
Iron undershot wheel with single iron support rim, anchors with four arms and wooden floats.

Opwetten Watermill

bushes, spokes

support rim, anchors
arms

floats
four-armed anchor

Waterwheels in the Brabant region are all undershot wheels. Some of them have a distinctive construction not found elsewhere. On the cast iron mill shafts are cast bushes to which eight sets of spokes are attached. Such a set of spokes forms a triangle with the shaft and the bushes. The ends of each set of spokes are connected by an iron support rim. Attached to this are the so-called anchors with two arms on the outside of the support rim and two on the shaft side. However, there are mills that have anchor arms only on the outside (see Fig. 6.2.4.2). The floats are attached to these anchors. These are found in both wood and metal. In four-arm anchors, the two floats attached to them are at an angle so that the overall float is curved, so to speak.

In Limburg, iron waterwheels come in many forms. A rosette, to which spokes are attached radially, is usually cast or constructed on the iron shaft. There are double or single spokes, with an iron support rim on which the metal floats (straight or curved) are attached or with double rims between which the floats are attached.
For wheels with double iron rims, these were sometimes made high to reduce water loss on the side of the floats.

The use of iron led to improvements in the waterwheels such as curved floats and high rims on the side of the wheel, as already mentioned.
Breastshot wheels with high rims (shroud) and a large number of curved floats sometimes look a lot like overshot wheels in terms of construction. The development of (patented) improved waterwheels (see section 6.3) also led to improvements in traditional wheels.

Fig. 6.2.4.2
Undershot wheel type common in Brabant. Eight pairs of spokes connected by an iron support rim. Here with two-arm anchors and flat wooden floats.
Around the shaft there is a bush. In the middle is the coupling between the two waterwheel shafts.

The Kilsdonk Mill – Heeswijk-Dinther

Fig. 6.2.4.3
An iron undershot wheel with eight pairs of radial spokes, double high rims (shroud) and slightly curved floats.

The Bisschop Mill – Maastricht

6.2.5 The efficiency of waterwheels

6.2.5.a Undershot wheels

Undershot wheels are primarily set in motion by the kinetic energy of the water jet. That energy is related to the amount and speed of the inflowing water. The weight of the water on a float is a negligible factor in an undershot wheel.

efficiency

This type of wheel generally has a low efficiency. Only about 30% of the energy in the flowing water is utilized to set the waterwheel in motion.

There are a number of causes for energy loss:
- The duration of the collision of the water jet against the float — during which energy transfer takes place — is limited because soon another float interrupts the water jet. Thus, there is always only one float that can utilize the full water flow for a short period of time.
- Due to the initial collision of the incoming water flow against the float, the speed of the water decreases considerably and thus loses part of its energy.
- The low level of water in the mill race through which the floats rotate deepens as the flow velocity decreases, causing resistance to the floats. (This is the same effect as too high a level in the tail race.)
- After the impact with the float, water can splash back against the rear of the next float; this increases resistance.

water guideway

- Sometimes the floats are too small, causing water that collides with the float to splash away or flow over the float, thereby losing energy.
- Water loss always occurs in the wheel race.

mill race water guideway
inlet sluice

Sometimes there is not a well-fitting wheel race behind the inlet sluice. By making the space between the sides and bottom of the inlet sluice and the floats as small as possible — in other words, about 2 to 3 cm — the loss of energy can be somewhat reduced. Also, the floats should be as close as possible to the inlet sluice.

Various improvements that were implemented:
- For flat floats, a raised edge was provided on the shaft side.
- Sheet iron floats are curved, reducing water flow over the float.
- Iron plates on the side of the wheel or high rims cause less water to flow sideways out of the wheel.
- The wheel race is curved under the wheel and follows the wheel radius so less water is lost under the wheel.
- The floats are set at a slight angle, making it easier for them to 'release' the water at the back, namely sliding instead of scooping. Also, sometimes just after the wheel a small reduction, a step, is made in the apron to make it easier for the water to flow away from the wheel.

step

- The characteristic large Brabant wheels are also an improvement. Due to their large circumference, the floats are further apart from each other. They then benefit from the full flow of water longer before the next float interrupts it.

Apart from improvements in the construction of the wheel race, the inlet sluice and the waterwheel, it is important to adjust the water supply properly. If it is too large, a lot of water will splash out. And considerable churning behind the waterwheel also indicates energy loss.

6.2.5.b. *Overshot wheels*

bottom hatch, shuttle

Overshot wheels are set in motion by the weight of water in the buckets. The flow rate hardly provides any additional energy. It is important to fill the buckets as completely as possible to obtain the maximum weight of water. The fill rate is promoted by a good outflow opening at the bottom hatch, which reduces water splashing and churning. A measured water supply is also important to keep buckets from overflowing. For an overshot wheel, about a quarter of the buckets are always filled with water.
The shape of the buckets can also promote that the buckets release their water at the right time.
Overshot wheels are usually much smaller than undershot wheels but they are also wider. An overshot wheel can achieve an efficiency of about 60%.

Fig. 6.2.4.4
Iron breastshot wheel.
Eight pairs of spokes connected by double support rims and a large number of highly curved floats.

Neubourg Mill – Gulpen

6.2.5.c. *Breastshot wheels*

Breastshot wheels derive their energy partly from the flow velocity of the water (kinetic or movement energy) and partly from the weight of the water on the floats (potential energy).

apron
water guideways

By adding an apron, the wheel can be filled approximately at shaft height, increasing the number of filled buckets. The presence of water guideways bends the inflowing water slightly in the proper direction of flow, causing the paddles to fill more calmly and hold more water. Apron and water guideways provide more and better-filled buckets, which increases efficiency. This can be as high as 70% to 80%.

Water loss is limited by curved floats and/or high rims or side plates.
Floats are also placed at an angle relative to the rim. The they do not 'hit' the incoming water jet flatly, but rather approach it smoothly, causing less disturbance to the incoming water and making the wheel fill better.

6.3 IMPROVED WATERWHEELS

improved waterwheel

By improved waterwheels we mean waterwheels that have been modified in such a way as to provide a significant improvement in efficiency. So this goes beyond the improvements to traditional waterwheels that we saw above (see section 6.2). These seem rather inspired by the advent of improved waterwheels, without violating patent rights, however.

The increase in efficiency was sought not only in adjusting the shape or number of floats but also in the inflow of water.

By proper design of sluices and floats, the aim was to minimize disturbance of the incoming water flow, thereby achieving a higher filling rate of the floats or buckets.

water guideways

apron

Water guideways and curved floats then approximate the shape of the unwinding curve (or involute) of the arc of the water flow. (Think of the rounded shapes of such things as cogs in a wheel.) The apron and water guideways allow more floats or buckets to be filled and to do so better. As a result, the energy present in the water flow is transferred better to the waterwheel.

For improved waterwheels, iron was used although sometimes wooden floats were still fitted.

In the Netherlands, waterwheels are generally narrow. Instead of installing wider wheels — which are heavy and expensive — the preferred option was to install a second (also narrow) wheel.

Worthy of mention are the following improved waterwheels:

1. the Zuppinger wheel
2. the Poncelet wheel
3. the Sagebien wheel

6.3.1 The Zuppinger wheel

Zuppinger constructed his wheels with many floats between shrouds that are attached to either side of the wheel on six or eight pairs of spokes. These floats are curved in shape so that they are perpendicular to the water as the water leaves the wheel.

inflow, water guideway inflow

The water enters the wheel via an 'inflow' or water guideway inflow in such a way that a good water flow line ensures optimal filling.

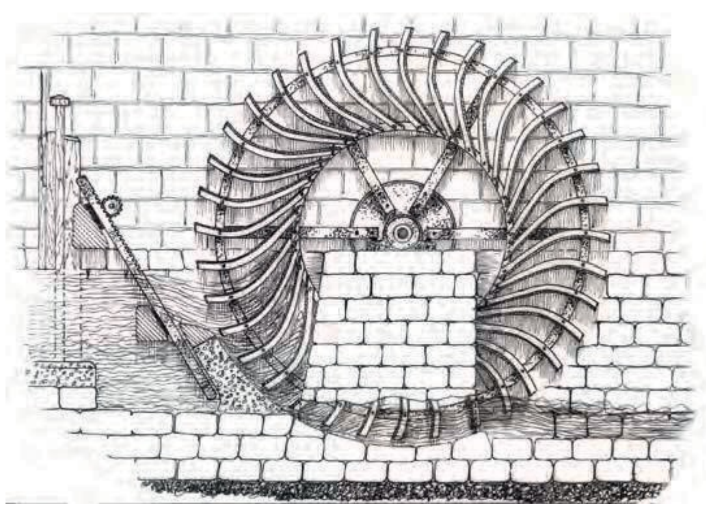


Fig. 6.3.1.2
All-metal Zuppinger wheel, designed as an undershot wheel. Water flows through a double adjustable slider onto the floats.

flow rate

The Zuppinger wheel is primarily a breastshot wheel and it operates with a flow rate of 0.5 to 6 m^3/sec and a fall between 0.6 and 3 metres. The efficiency is 65% to 75%, but in favourable cases it can reach values approaching the efficiency of water turbines.

sliders, water guideways

By opening the lower sliders (water guideways) when water is low, it can also act as an undershot wheel. Zuppinger wheels rotate at about five revolutions per minute.
In the Netherlands, the Upper Mill in Mechelen is the only one that still has a Zuppinger wheel.

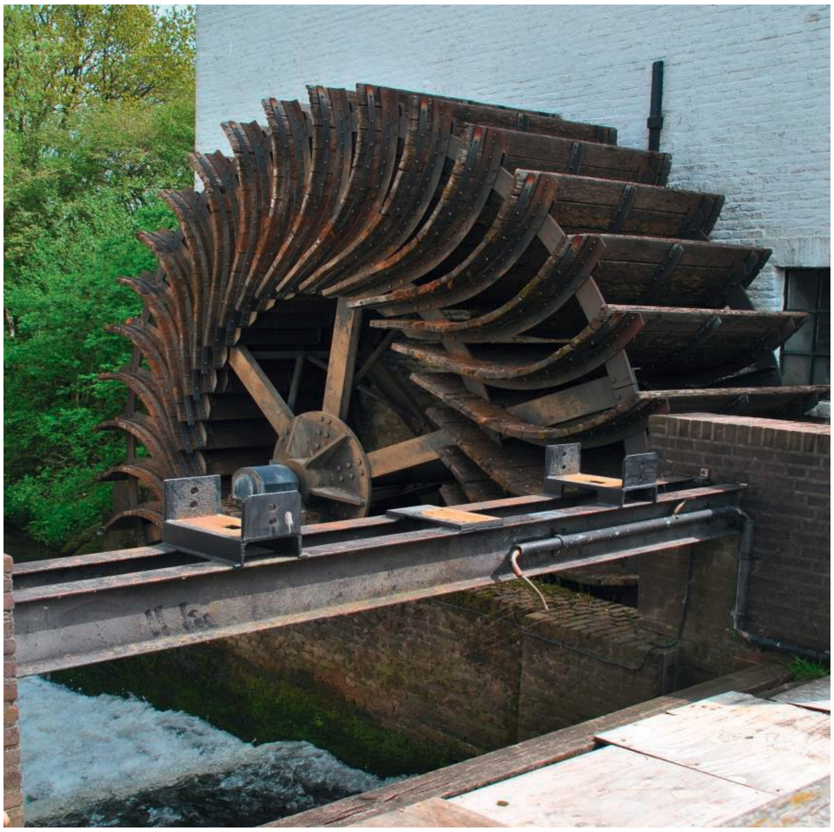


Fig. 6.3.1.1
The Zuppinger wheel with wooden floats, six pairs of spokes and an additional iron support rim for the floats.
Implemented as a breastshot wheel.

Upper Mill – Mechelen

6.3.2 The Poncelet wheel

In 1820, Frenchman Poncelet developed an undershot wheel that has an efficiency of about 70%, even though this wheel operates with only a slight fall. The design is based on two principles: water flows into the wheel without impact and leaves the wheel without speed.
Like an overshot wheel, this type has two high rims so that water does not flow out of the wheel on the side. Also, little water flows away under the wheel because the distance between the wheel race and the wheel is very small.
Because the inlet sluice has been modified, the water flows in a smooth line all the way to the top of the floats. The sluice looks knife-shaped in cross-section. The bottom of the wheel race was also modified accordingly; by adding curves to it, the water flows onto the wheel in a more favourable streamline. Because of the curvature in the floats, the water will leave the wheel perpendicularly, maximizing the transfer of energy to the wheel.
A Poncelet wheel still hangs from the Franse (French) Mill in Valkenburg.

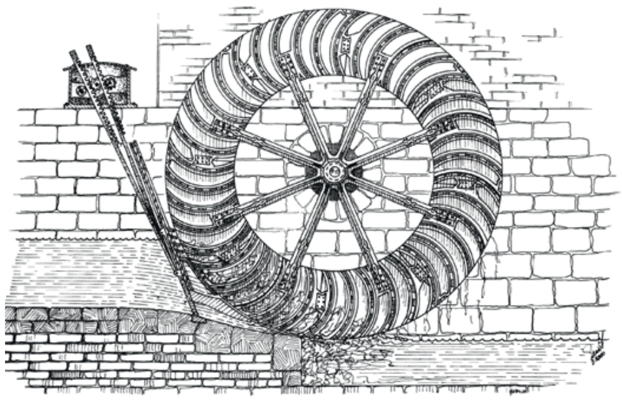


Fig. 6.3.2.1
All-metal Poncelet wheel. This type of wheel was used exclusively as an undershot wheel.

6.3.3 The Sagebien wheel

Frenchman Sagebien developed a very wide wheel with many floats (both straight and curved are possible). These floats are placed at an angle on the circumference of the wheel similar to a scoopwheel of a windmill. The sluice is also angled to provide a favourable flow line for the water here as well.
Like the Zuppinger wheel, the Sagebien wheel matched the efficiency of the Poncelet wheel. The Sagebien wheel still does so even when the water levels vary greatly and also when the fall is slight.

Thanks to the large number of narrow buckets, a good efficiency of about 85% is obtained. However, because the wheel is rather heavy and expensive to purchase, it was rarely seen in the Netherlands. A large wheel in full operation makes about 2 to 4 revolutions per minute and is designed as a breastshot wheel for a fall between 1.5 and 2 metres and a flow rate of 0.5 - 2.5 m^3/sec.
A rotating Sagebien wheel is still on display at the Weaving Museum in Geldrop. From the watermill at Geijsteren hangs a narrow Sagebien wheel since 2020.

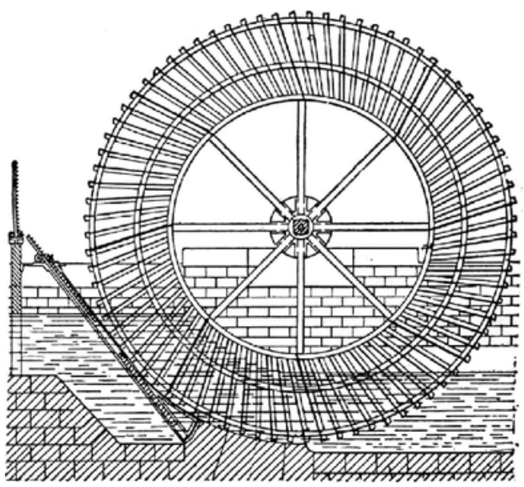


Fig. 6.3.3.1
Example of a Sagebien wheel with iron floats, implemented as a breastshot wheel.

On the right a Sagebien wheel implemented as an undershot wheel.
Watermill – Geijsteren

revolutions

The number of revolutions has been mentioned several times above. For a waterwheel or turbine, this is determined — in the unloaded state — by the fall or water column above the turbine. In other words, it's a fixed amount. When loaded, however, the number of revolutions decreases. Therefore, the number of revolutions is also always in relation to the load required.

6.4 WATER TURBINES

water turbine, turbine impeller blades, rotor, guide blade directing wheel

A further improvement in harnessing hydropower was achieved by the development of water turbines. These turbines have a turbine impeller with blades (rotors) that rotate in a cast iron housing in which guide vanes are mounted (directing wheel). Turbines can be arranged either horizontally or vertically.

turbine room

The water turbine is usually installed as a replacement for the waterwheel and therefore installed in the same position in the watercourse. A masonry or concrete turbine chamber, containing a water shaft into which water flows, is constructed against the mill building. Alternately, sheet iron could be used for construction where the turbine is suspended in a sheet-iron shaft.

shaft, turbine housing working blade, turbine shaft

drive belt, conical pit wheel, adjustable feed valves

From the shaft, water flows into the turbine housing. Through adjustable guide blades, the flow of water is directed onto the working blades of the turbine wheel, causing it to rotate. Attached to the turbine wheel is the turbine drive shaft, which drives the machinery in the mill via drive belts or (conical) pitwheels. By adjusting the guide blades or through adjustable feed valves, the water supply and thus the power of the turbine can be controlled.

axial turbine

When the water flow runs parallel to the turbine axis through the turbine housing, these turbines are referred to as axial turbines.

radial turbine

In radial turbines, water flows into the turbine housing on the side (radially) and out at the bottom (axially).

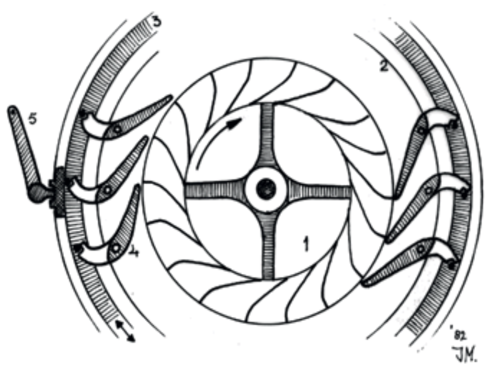


Fig. 6.4.1
Section of a turbine with guide and working blades:

1. *runner with working blades*
2. *directing wheel with guide blades*
3. *regulating ring for the guide blades*
4. *guide blade*
5. *control lever of the regulating ring*

Turbines for several Limburg mills were supplied by the A. Atorf company in Paderborn, Germany, by *Atelier de Construction* G.J. Pasteger of Liege, Belgium (who could also supply hurst frames and running gear), and by the *Nederlands Machinefabriek en IJzergieterij* (Dutch mechanical engineering plant and iron foundry) P. Konings of Swalmen who built some turbines with the associated running gear and hurst frames.

Two types of turbines can still be found in the Netherlands:
The Girard turbine and
The Francis turbine.

6.4.1 The Girard turbine

axial turbine, free-jet turbine

Frenchman Girard developed an axial turbine around 1850, a 'free-jet turbine' in which the upper water flows vertically through the turbine housing. In the turbine housing, guide blades are installed that focus the vertical water flow to the working blades. The energy in the water flow is converted by the working blades into a rotation, after which the water falls out of the turbine housing at the bottom. A characteristic of the Girard turbine is that it must hang freely above the tail water so as not to obstruct the outflowing water.

tail water

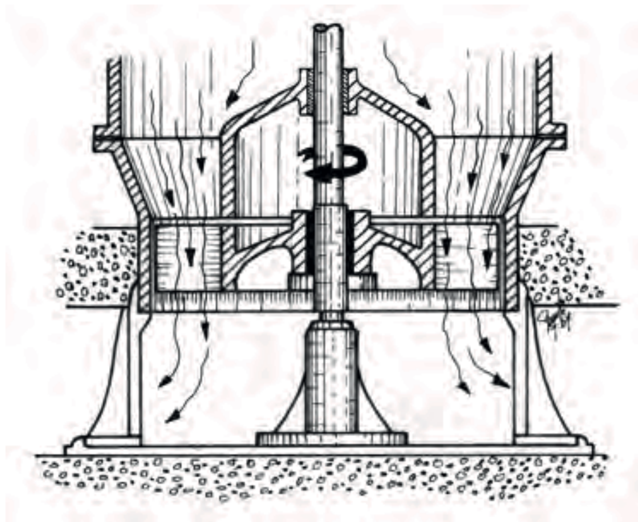


Fig. 6.4.1.1
A cross section of a Girard turbine.
Water flows (axial) into the turbine from above.

If the tail water level is high, the turbine will become suspended in this and that will hinder the flow of the falling water. This will drastically reduce the power and speed of the turbine.

draft tube

For this reason, later Girard turbines were fitted with a draft tube: an extended outlet tube that terminates under water.
When the guide blades were adjusted, sometimes the buckets of the turbine wheel were no longer completely filled. As a result, pressure equalizations and vibrations caused the turbine's efficiency to drop. Girard turbines were therefore quite often replaced by Francis turbines. In Limburg in the early 20^{th}century, Girard turbines or other axial turbines were still being built. These were very easy to construct with simple moulds which made them more economical.
In the Netherlands, the Vlodropper Mill and the Grathemer Mill still have a variation of a Girard turbine.

6.4.2 The Francis turbine

radial turbine

In 1849, the American Francis developed a radial turbine in which water flows (radially) from the side of the turbine into the turbine housing and drives a turbine wheel inside. Francis constructed the blades of this turbine wheel to be strongly curved so that the flow of water is deflected by them and leaves the turbine vertically (axially).
As a result, a Francis turbine can be smaller than a Girard turbine that provides the same power output.

draft tube

Water flows through the turbine wheel in a draft tube that widens slightly toward the bottom. The bottom ends below the surface of the tail water. As a result, the outflowing water creates an underpressure beneath the turbine. The pressure above the turbine is then higher than that below the turbine. Hence, the Francis turbine is also called an overpressure turbine. The turbine will operate at its best when the mouth of the draft tube is below the water level of the tail water and the buckets of the turbine wheel are completely filled with water.

overpressure turbine

In this case, no pressure equalizations and vibrations occur. Complete filling of the buckets of the turbine wheel is arranged by the position of the guide blades. When the underpressure is removed, the power suddenly drops sharply.

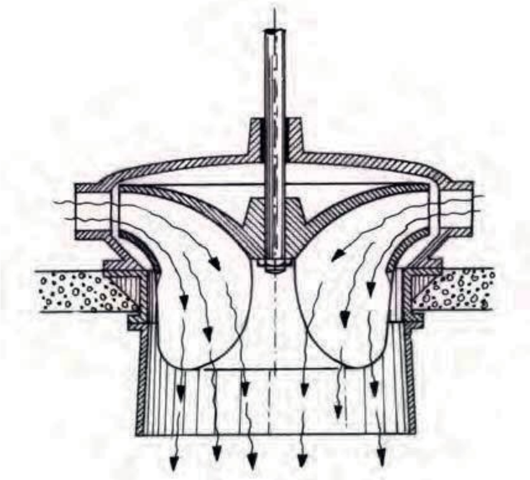


Fig. 6.4.2.1
Cross section of a Francis turbine; water flows into the turbine on the side (radially) and out at the bottom.

In small turbines, the turbine wheel consists of a single casting while larger turbines use sheet iron blades which are cast into the iron. A high wheel with a larger number of substantially curved blades can be used successfully with a limited fall. This results in a higher number of revolutions. At a lower height for the wheel, the curvature (and number) of the blades will also be reduced. This is especially common for larger falls of 1.5 to 10 metres.

flow rate

The speed is primarily determined by the fall and the amount of water flowing through the turbine wheel (flow rate). The speed is between 60 and 80 rpm for a slow-running turbine. These are the ones especially found in the Netherlands.

Fig. 6.4.2.2
A horizontal Francis turbine in a nearly empty shaft:

1. *turbine*
2. *draft tube (curved in this case)*
3. *operating mechanism for guide blades*
4. *rope to pull the plug out of the shaft*

Nordbecks Mill – Halle (Germany)

The efficiency of a Francis turbine is between 80% and 85% when the mill is running at full load on a somewhat larger stream.
Thanks to the draft tube, a Francis turbine can also be placed horizontally. In the Groote Mill in Meerssen, a twin horizontal Francis turbine is still in operation.

6.4.3 Mill water for turbines

Because there is virtually no space between the openings in the turbine housing and the rotating turbine wheel, it is extremely important that the water from the stream be particularly clean. Even small contaminants can cause major damage due to becoming trapped between the guide blades and the working blades. These are very difficult to remove as the turbine must be partially disassembled. However, the turbine is usually not easily accessible because — except for the shaft and regulator for the guide blades — it is completely submerged in the water shaft.

sluice grille, weed rack

Hence, an iron screen with many closely spaced bars, the sluice grille ('weed screen'), was installed in front of the turbine's inlet sluice. The miller will have to regularly remove the debris accumulated against this screen because it impedes the flow of water to the turbine. Also, the pressure of the water on this debris can cause the screen to collapse.
The inlet sluice is used for operating or shutting down the turbine. Together, the weed screen and the inlet sluice stop both large debris and sand. If you close only the turbine feed valves, sand and small debris can collect in the shaft above the turbine.

It is also important that the water turbines are kept in frequent operation. When a turbine sits idle for a long time, the water supply can begin to silt up. Debris can also build up in the turbine and this can cause movable parts such as guide blades and the operating mechanism to seize up. Once this happens, the turbine will have to be completely overhauled.

6.4.4 Turbines versus waterwheel

In the late 19th / early 20thcentury, many waterwheels were replaced by turbines, especially in Limburg. This was because of the expected higher efficiency. Outside of Limburg, this did not happen — with just a few exceptions. In some cases, however, turbines were later replaced by a waterwheel.
Turbines do not have only advantages over a waterwheel.

As advantages of the turbine we can mention:
They occupy little space, deliver a lot of power and run much faster. They are comparatively cheaper and require little maintenance. The speed is easily adjustable and they are less susceptible to ice formation.

But there are disadvantages to them as well: A turbine is much more sensitive to debris and pollution, it consumes proportionally much more water than a waterwheel, it should not be left idle for too long due to silting and — certainly not unimportant: aesthetically, a waterwheel is much more beautiful than a turbine!

6.5 MILL GEARS

6.5.1 Introduction

rotational speed
rotational direction

Gear wheels transmit the rotation of a shaft to a piece of machinery. They ensure that the machinery is given the correct rotational speed relative to the speed of the waterwheel. And also the correct direction of rotation. Wheels also transfer the rotation from one shaft to another. Depending on the type or function of the mill and the machinery present, the number of wheels can vary greatly: from two in a single-powered small grain mill to as many as ten or more in an industrial mill. There is also a lot of variation in size: from a diameter of 60 cm for a stone nut in a grain mill to a diameter of 6 metres for the face gear wheel or pit wheel.
When choosing shape and size, regional habits play a role in addition to function and load.

crown wheel
rim wheel
lantern wheel, wallower, staves

When considering the shape, we distinguish different types of wheels:
- Crown wheels: the cogs are perpendicular to the plane of rotation (wooden crown wheel).
- Rim wheels: the cogs are in the turning plane (spur wheel, one-piece spur pinion).
- lantern wheels (wallowers); two discs or plates with perpendicular staves between them.

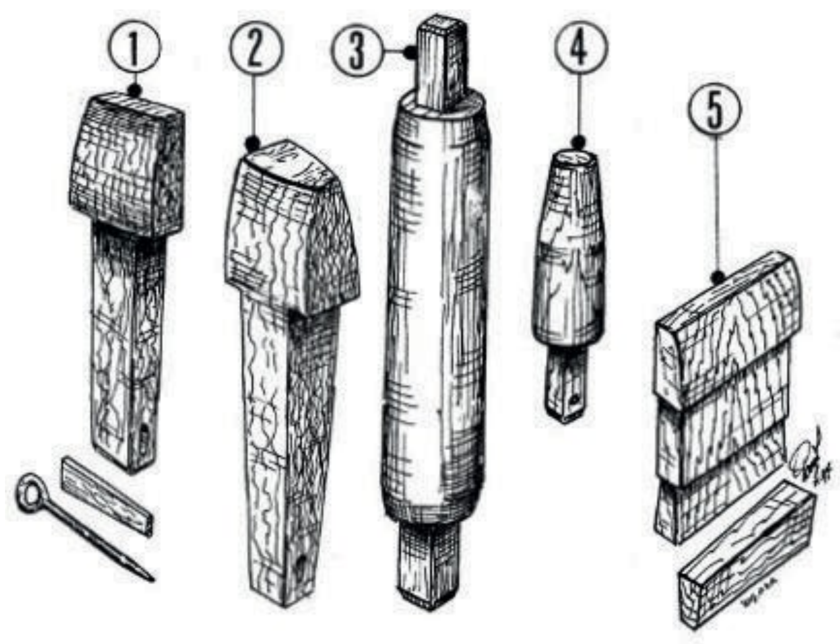


Fig. 6.5.1.1
Cogs and staves:

1. *spur wheel cam with cam pin and peg*
2. *cog for a right-angle drive*
3. *stave*
4. *pin (small stave)*
5. *cog and locking bracket for a cast iron wheel*

equal pitches

However, there are some characteristics that apply to every wheel:
- The centre-to-centre distance between the cogs or staves of one wheel, called the pitch, must be exactly the same for all the cogs of that wheel (see Fig. 6.5.1.2) but also of the other wheel that engages with this wheel. If the cogs are not 'on pitch' this can be heard in the pounding and thumping of the running gear. This causes the cogs to loosen or wear unevenly.
- More even wear is also achieved when a cog of one wheel comes into contact with all the cogs or staves of the other wheel equally. This means that the numbers of cogs or staves of both wheels may not be divisible.

If the numbers are divisible — for example, 36 cogs and 18 staves — then in one revolution each cog always encounters the same stave; twice even in this case. If there are then small inaccuracies in the cog or stave, more wear occurs there than elsewhere.

- The types of wood used for interacting cogs or staves are preferably not the same because, in practice, this too has been found to lead to faster wear, even if the types of wood used are very hard.

holm oak, boxwood, ironwood, balata
pockwood
beeswax

Good combinations include: holm oak and boxwood; ironwood and balata; ironwood and pockwood. Wooden cogs and staves are lubricated with pure beeswax. Other maintenance and checks on gear wheels are discussed in chapter 7, Practical considerations.

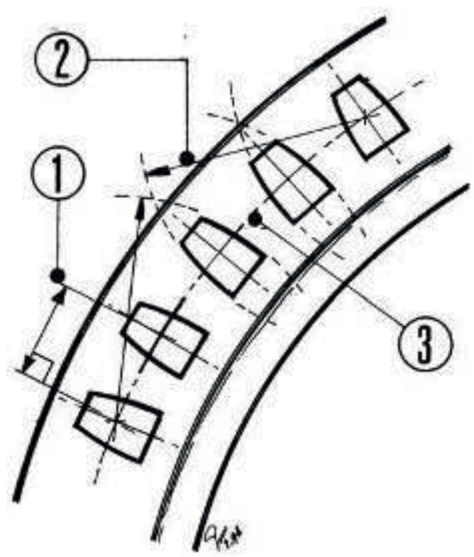


Fig. 6.5.1.2
Pitch:

1. *the distance between the centre lines of the cogs (or staves) is the pitch*
2. *the scribe lines for the cogs*
3. *pitch circle*

6.5.2 The wooden face gear wheel or pit wheel

face gear wheel
pit wheel
crown wheel
rim wheel
wedges
keepers, nailed fillets

Every watermill has a face gear wheel. In the south of the Netherlands it is called a pit wheel. The face gear wheel or pit wheel transfers the rotation of the mill shaft to the stone spindle or central spindle or another shaft.
The face gear wheel is usually constructed as a crown wheel that drives the central spindle or stone spindle via lantern pinion or wallower. Also, the face gear wheel is sometimes constructed as a rim wheel to drive a drive shaft equipped with a horizontal lantern wheel or a vertical rim wheel, such as the camshaft (see Fig. 6.5.2.1). The face gear wheel is fixed to the inner end of the mill shaft with heavy wedges. These wedges are secured against loosening and falling out with the so-called keepers.

cross arms
shaft
shaft hole
cross-lapped
half arms

Construction of the wheel (see Fig. 6.5.2.2) begins by interlocking the four heavy cross arms that are almost as long as the diameter of the wheel. The two-by-two parallel arms are interlocked. The mill shaft is inserted through the square opening in the centre, the shaft hole. There are two methods for interlocking the cross arms. The simplest is the cross-lapped interlocking of the cross arms. The other possibility is a construction with half arms. In this method, two cross arms consist of one piece while the other two consist of two halves. The four *cavity or space*

angled tooth

support wedges, support blocks

half-cross arms clasp the two whole cross arms. A gap of about 2 cm, the cavity, is left open between the half-cross arms.
To cope with the immense pressure of the wedges used to secure the wheel to the axle, the joints between the cross arms are often fitted with an angled tooth. In addition, extra support wedges (support blocks) are sometimes added at the corners between the cross arms and half arms.

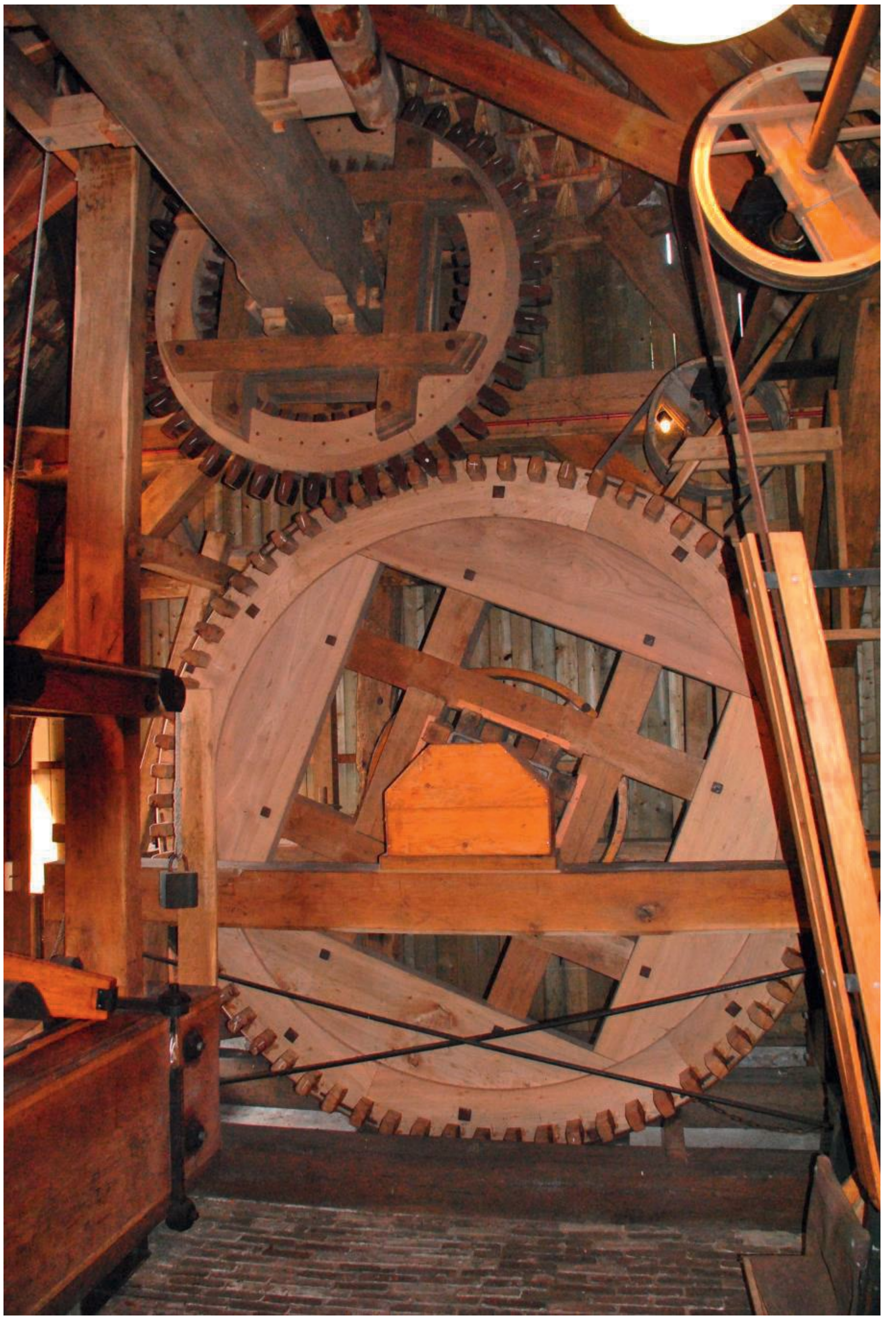


Fig. 6.5.2.1
The pit wheel (a crown wheel) and camshaft wheel (a rim wheel). There is also a pulley on the mill shaft for the belt drive of an iron drive shaft.

The Coll Mill – Eindhoven

cants, rear cants

dovetail joint

At the ends of the cross arms, the cants are attached that ensure the wheel receives its round shape. As a rule, there are four cants but there are also wheels with six or eight cants. The cants are connected to the cross arms by dovetail joints.

angled joints Then they are interconnected by angled joints. The cants are secured to the cross arms with heavy bolts. The cross arms and cants are generally made of oak.

front rim A ring of heavy plates, the front rim, is attached to the front against the cants. Note: The side of the wheel facing the inside of the mill is considered its front!

rear rim Such plates may also be found on the rear of the cant, between the cross arms; together these form the rear rim. Older wheels usually lack the rear rim. That was the original model.

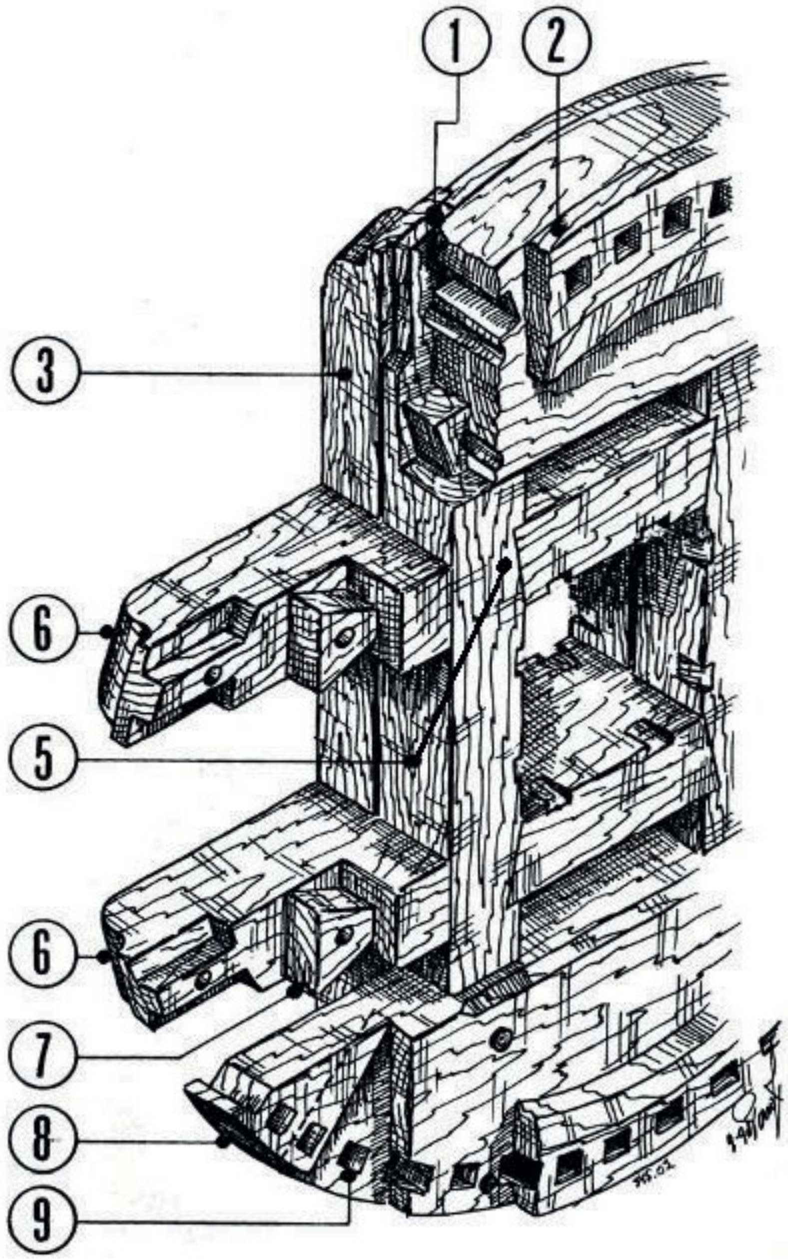


Fig. 6.5.2.2
Construction of a face gear wheel:

1. *rear rim*
2. *front rim*
3. *half arm*
5. *half arm with angled tooth*
6. *cross arm*
7. *dovetail*
8. *cant*
9. *cog hole*

cam Holes are made in the rims and cants, into which the cogs are inserted. Clearly, these holes do not benefit the strength of the various parts. Due to the pressure on the cogs during milling, the wood between the cog holes, the

insets insets, can split, break loose and fall out and as a result the cogs become loose.

elm wood

For that reason, the front and rear rims are made of elm wood. This type of wood is resistant to splitting and is hard, tough and sufficiently strong. The rims are connected to the cants and cross arms by heavy bolts.

cog, head
tail cog nail, peg

A cog consists of a head and a tail (see Fig. 6.5.1.1). The tapered tail protrudes through the cants and the rim(s). This allows the cog to be secured with a wooden cog nail or an iron peg. The cog nails or pegs are secured again with a small nail.

arm cogs
locking pin
knock hole

The cogs at the location of the cross arms, the so-called arm cogs, cannot protrude through the entire wheel. Their shanks are shorter and are secured from the front of the wheel. A wooden locking pin is inserted at an angle into the tail of such a cog through the front rim (see Fig. 6.5.2.3). To remove an arm cog, you first have to drill out the wooden nail. In the cross arm, a knock hole was drilled in the direction of the cog hole so that the cog could later be knocked out of the wheel with an iron rod. Arm cogs are also found on other wheels with cross arms.

holm oak, pockwood, ironwood
acacia, beech, ash

Cogs are generally made of holm oak, pockwood or ironwood, but also of other types of wood such as acacia, beech, ash.

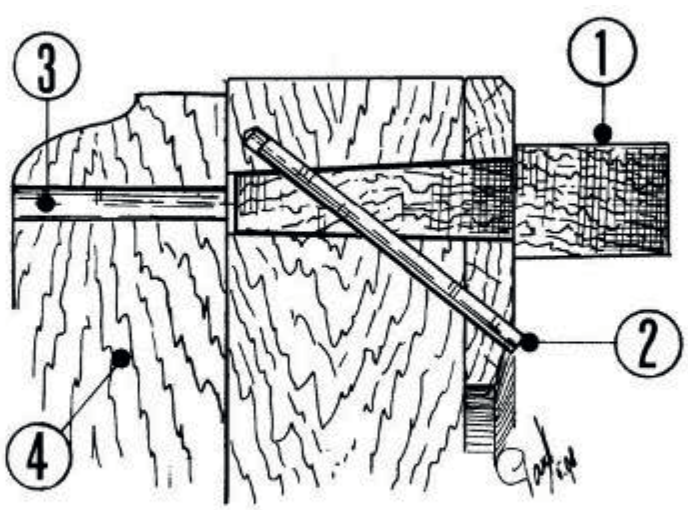


Fig. 6.5.2.3
Fixing arm cogs:

1. *arm cog*
2. *locking pin*
3. *knock hole*
4. *cross arm*

6.5.3 The crown wheel

crown wheel

The crown wheel is used to transmit a rotation at right angles to another spindle or shaft. Crown wheels are used both with the cogs up and down. Sometimes they form a single unit with the spur wheel due to space limitations. The central spindle is often driven by a crown wheel from the face gear wheel.

The crown wheel is secured to the spindle with wedges. Again, the wedges are secured with keepers. A crown wheel usually consists of four cross arms that, like the pit wheel, are cross-lapped together. The cants are fitted to the cross arms by a dovetail joint. These are joined together by an angled joint.
There is a ring, the rim, on the cants. The same types of wood are used for cross arms, cants and rims as for the face gear wheel.

rim

halfmoon-shaped segments

clamping bands

spindle straps

There is also another construction method for a crown wheel. In this process, four halfmoon-shaped segments, made from elm and about 15 cm thick, are interlocked with mortise and tenon joints and then sawn in a circular shape (see Fig. 6.5.3.2). A square opening is left in the middle for the spindle. At the perimeter, the plate is reinforced with one or two iron clamping bands or spindle straps.

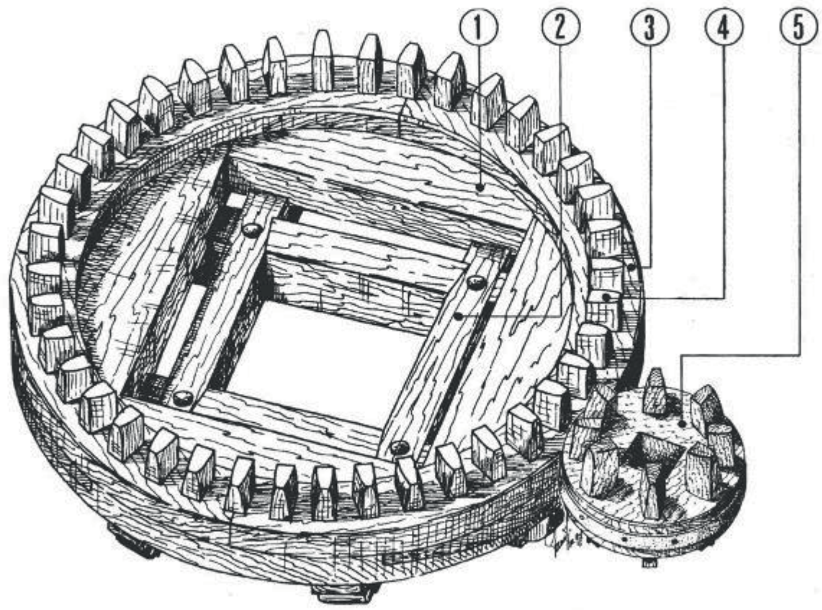


Fig. 6.5.3.1
Crown wheels:

1. *cant*
2. *cross arm*
3. *rim*
4. *cog*
5. *crown wheel for a spur pinion*

pins (small staves)

pin wheels

Square holes are made at the perimeter of the crown wheel, into which the cogs are inserted. Their shape and means of fastening are approximately the same as those of the cogs in the face gear wheel.
Small crown wheels with round cogs, the pins, for lightly running small machinery and gears are called pin wheels.

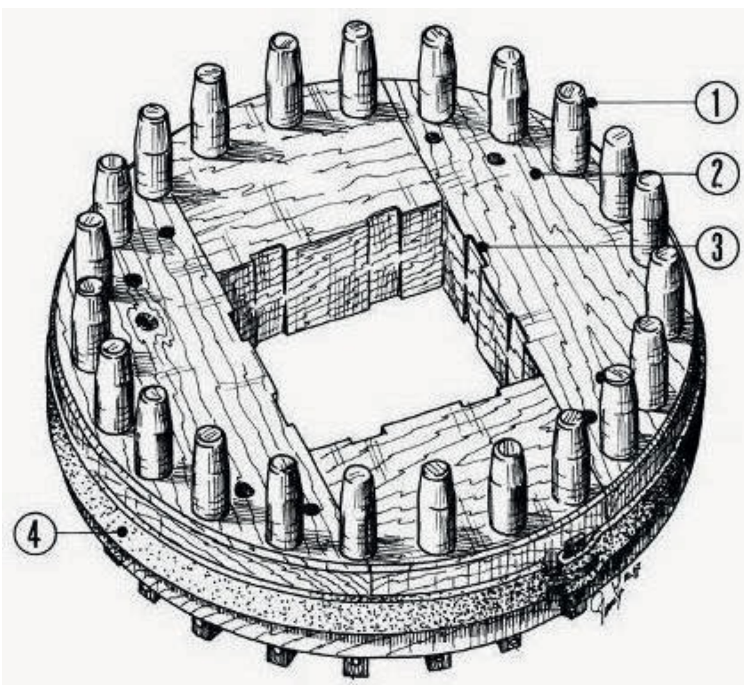


Fig. 6.5.3.2
Pin wheel:

1. *pin (small stave)*
2. *halfmoon-shaped segment*
3. *wedge face*
4. *spindle strap*

6.5.4 The lantern wheel, wallower

lantern wheel, wallower
trundle wheel, stone lantern wheel, stone pinion, stone nut

Lantern wheels or wallowers (see Fig. 6.5.4.1) can be found at various locations in the mill, such as on the central spindle and driven by the face gear wheel. Or the stone gear (stone nut) on the stone spindle in a grain mill. The construction of all these lantern wheels is more or less the same.

elm plate
halfmoon-shaped segment
shaft hole

A lantern wheel or wallower consists of two elmwood plates with staves between them. Each of the two plates consists of four halfmoon-shaped segments. These halfmoon-shaped segment are assembled together with mortise and tenon joints. A shaft hole is also cut out in the centre. Iron bands are clamped around the outer perimeter of the plates to hold the whole thing firmly together. Along the perimeter of each plate, square holes are punched, into which the pegs for the staves go. Again, the plates are elm wood to prevent the insets between these holes from cracking.

staves, elm
insets

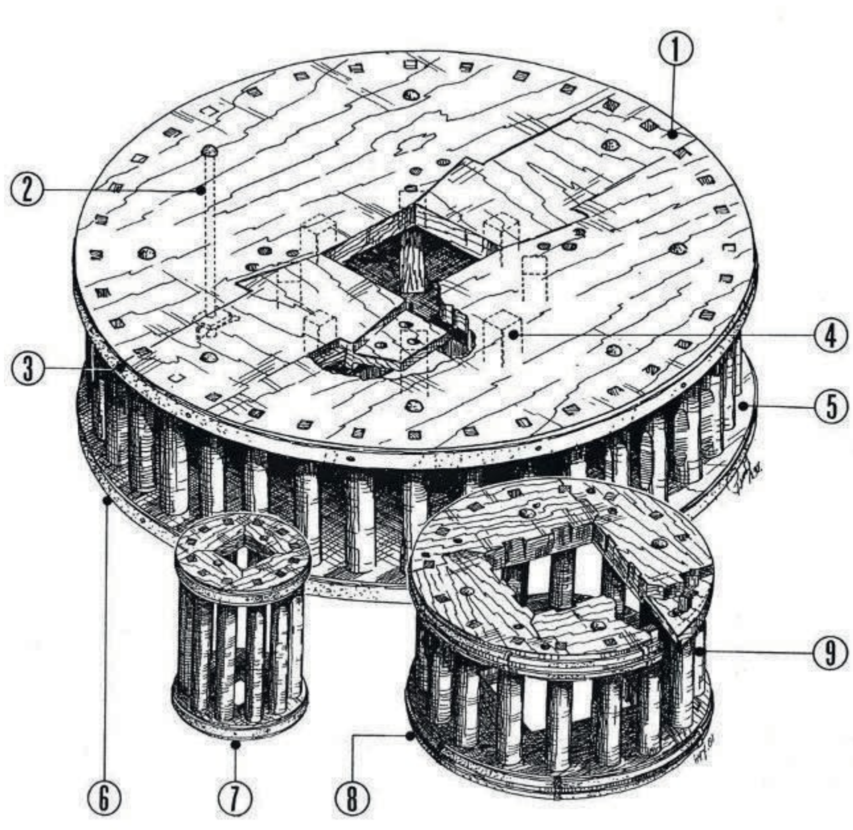


Fig. 6.5.4.1
Lantern wheels:

1. *upper plate*
2. *tie-rod*
3. *clamping band*
4. *stay*
5. *bottom plate*
6. *clamping band*
7. *lantern pinion*
8. *stone nut*
9. *stave*

To attach the staves, holes are widened in the facing inner sides of both plates to form a shallow round hole that is slightly conical, with the square part precisely in its centre. The usually round staves are fitted with a square peg at both ends (see Fig.6.5.4.2). These pegs fit exactly into the square holes of the two plates. The round part of the staves is also made slightly conical at the ends. As a result, the staves fit precisely into the holes in the plates, forming an immovable whole. The two plates are held together with four heavy-duty tie-rods.

tie-rods

The lantern wheel is secured to the spindle by striking wedges between the

spacers
stays

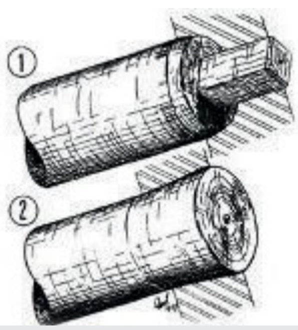
spindle and the edges of the shaft hole. Due to the pressure of these wedges combined with the tensile force of the tie-rods, the two plates at the shaft hole are driven and pulled toward each other. To prevent this, four spacers, called stays, are usually placed close to the shaft hole around the spindle. The advantage of a lantern wheel over a crown wheel is threefold. First, a lantern wheel allows a slight vertical movement: (and in the case of a stone nut) this allows the runner stone to be set further away or closer without losing contact with the spur wheel.

turning of staves

Second, a lantern wheel is stronger because the staves are supported in two places. As a result, they are less susceptible to bending. Third, because of their round shape and square peg, the staves can be turned a quarter turn when worn, creating a new track. This so-called turning of the staves can be done as many as eight times. In fact, the staves can also be placed upside down in the lantern wheel.

slip sticks

One disadvantage of a lantern wheel is that a cracked or broken stave is difficult to replace. To do this, you have to loosen the entire lantern wheel and separate the plates. To overcome this problem, people sometimes applied so-called slip sticks (see Fig. 6.5.4.2 and Fig. 6.5.4.3).



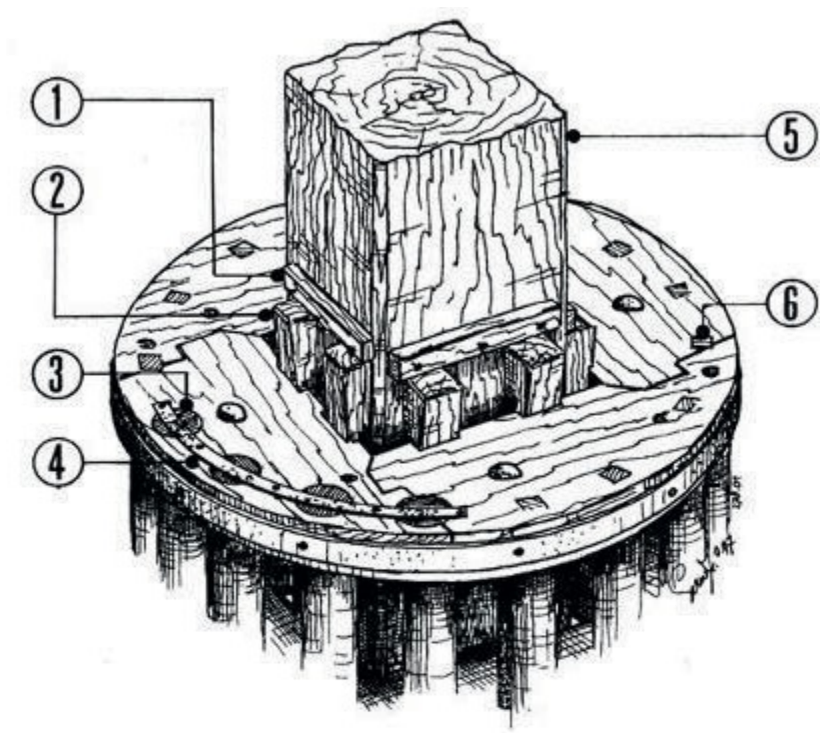


Fig. 6.5.4.2 (top)
Examples of staves:

1. *normal stave*
2. *slip sticks*

Fig. 6.5.4.3 (right)
Lantern wheel with four slip sticks:

1. *keeper*
2. *wedge*
3. *slip sticks*
4. *locking strip*
5. *central spindle*
6. ***peg of an ordinary stave***

locking strip, locking ring

A slip stick has the same shape at the bottom as an ordinary stave. At the top, however, the square peg is missing. At this end, the stave is slightly widened conically. In the top plate of the lantern wheel there are no square holes but rather downward conically tapered round holes. The slip sticks are now inserted into place from above through the top plate. At the top, the staves are secured by a locking strip or ring that is fastened to the top plate of the lantern wheel. By now loosening this iron locking strip, you can easily turn or replace a stave.

Slip sticks are also used in stone gears that must be disabled from working in a simple way. Then a construction with four or five slip sticks and ordinary staves for the rest is applied. Such a construction occurs, among other places, in the under-drive in grain mills. Then some slip sticks are removed from the stone nut on the stone spindle or central spindle.

under-drive

Slip sticks can be turned but they cannot be placed upside down. Just like cogs, staves are generally made of boxwood, balata or holm oak.

boxwood, balata, holm oak

When the diameter of a lantern wheel is less than the height, we refer to it as a lantern pinion.

lantern pinion

A lantern wheel with a slightly conical shape is called a cradle wheel. One plate is then slightly smaller than the other. The staves are at an angle in the plates. The advantage is that a cradle wheel takes up slightly less space than a lantern wheel. A cradle wheel is applied to the central spindle under the spur wheel. The smallest plate is at the bottom and, like a regular lantern wheel, a cradle wheel is driven by the face gear wheel (pit wheel). The cradle wheel is still in use on a few mills (including the Schous Mill in Ittervoort).

cradle wheel

6.5.5 The spur wheel

spur wheel

The spur wheel is found on the main central spindle in grain mills with multiple drives. This wheel is located in the hurst frame under the stones (for under-drive) or above it on the stone floor (in an over-drive)

rim wheel

The spur wheel is a rim wheel: the cogs lie radially in the wheel plane. By means of the spur wheel, the rotation of the main central spindle is transmitted through the stone nuts (or stone wheels) to the stone spindles. Occasionally, a circular flat track is attached to the spur wheel on which the wheel of the friction-driven sack hoist can turn.

stone nut, stone wheel, stone spindle

The construction of the wooden spur wheel begins — as with the face gear wheel — with the cross-lapped interlocking of four cross arms. There are two variants for the further construction of the wheel: with single or double cross arms.

single or double cross arms

In a spur wheel with single cross arms, cants are attached to the cross arms. On these cants there are then single (see Fig. 6.5.5.1.A) or double (see Fig. 6.5.5.1.B) rims between which the cogs are inserted. Unlike the pit wheel, no holes are cut in the rims of the spur wheel for fitting the cogs. Instead, chocks, or loose insets, are used to secure the cogs between the rims.

cant

cant rim

chocks, loose inset

These insets are secured between the rims using bolts that protrude through both rims. The cogs are secured between these insets and then locked with a wedge.

In a spur wheel with double cross arms, no cants are used and the rims are attached directly to the cross arms (see Fig. 6.5.5.1.C). In order to give the rims adequate support and the wheel sufficient rigidity, a second set of cross arms is attached at the top. Thus, the rim is clamped together between a total of four double cross arms. Insets are also installed between the cogs in this variant.
The types of wood used are the same as those used for the face gear wheel: mostly oak for the cross arms and cants, elm for the rims, and ironwood or holm oak for the cogs.

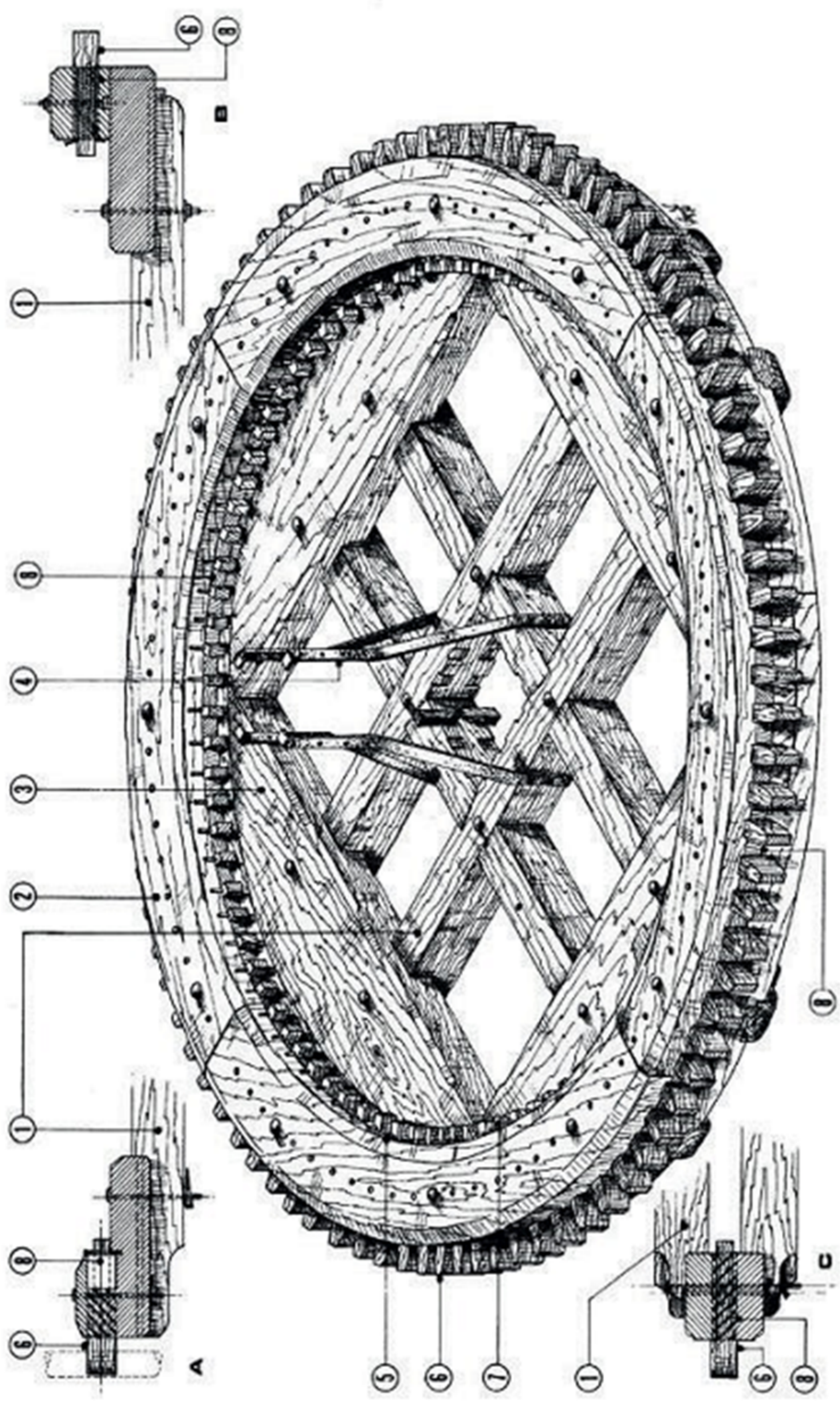


Fig. 6.5.5.1

The spur wheel

1. *cross arm*
2. *rim*
3. *cant*
4. *hanging iron*
5. *cog nail or peg*
6. *cog*
7. *cog tail*
8. *inset*

A. *Spur wheel with single rim and cants*
B. *Spur wheel with double rims and cants*
C. *Spur wheel with double cross arms and rims; no cants*

6.5.6 Spur pinion wheel

spur pinion wheel

A spur pinion (see Fig. 6.5.6.1) is also a rim wheel but it is much smaller in diameter than a spur wheel. As a rule, such a wheel consists of two elm plates between which the cogs are clamped.
These elm plates consist of four parts and are constructed in the same way as the plates for lantern wheels and stone gears.

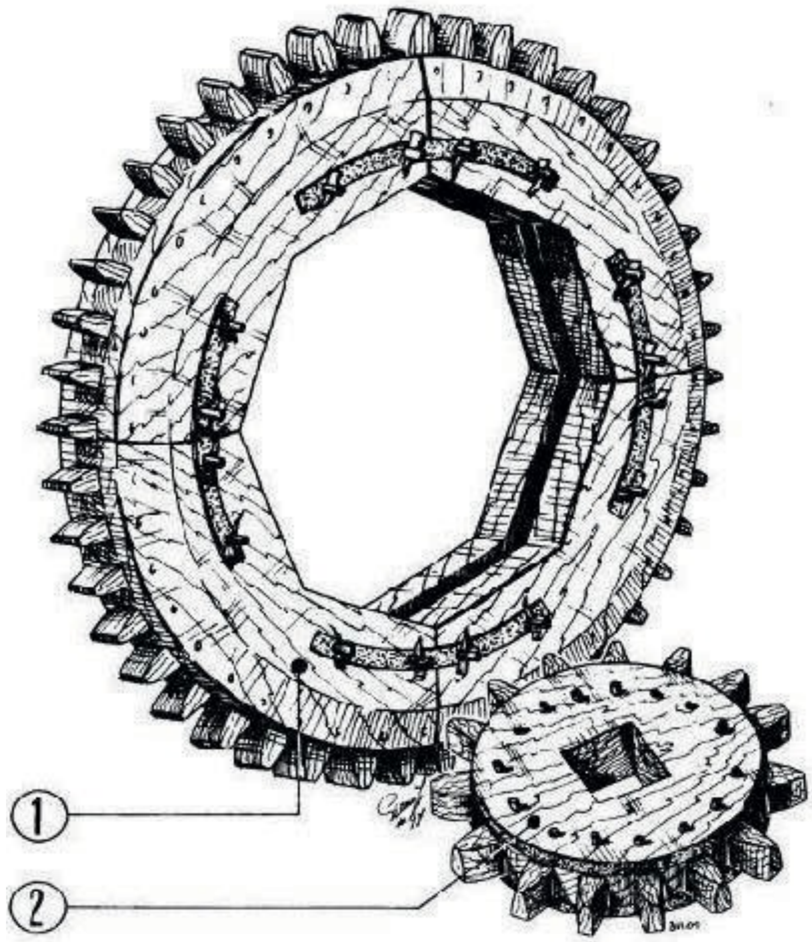


Fig. 6.5.6.1
Examples of spur pinion wheels.

1. *camshaft rim wheel for a transmission*
2. *sack hoist wheel*

The cam holes are sometimes formed by recesses in the two plates but in other cases, as with the spur wheel, are formed by spaces between the loose insets.
Examples of spur pinion applications:
In grain mills to drive a sack hoist using wheels with cogs. In oil mills to drive the stirrer for the oil seed heaters.

6.5.7 Cast iron wheels

cast iron wheel

Especially in watermills in Limburg, many wooden wheels and spindles have been replaced over time by cast iron wheels and spindles. A cast iron wheel is cast in its entirety. When wooden cogs are used, the holes for these are recessed when casting. Smaller wheels usually have cast-on (molded) cogs.
As a rule, cast iron wheels are attached to iron shafts but a cast iron face gear wheel on a wooden mill shaft can still be found in the Netherlands.

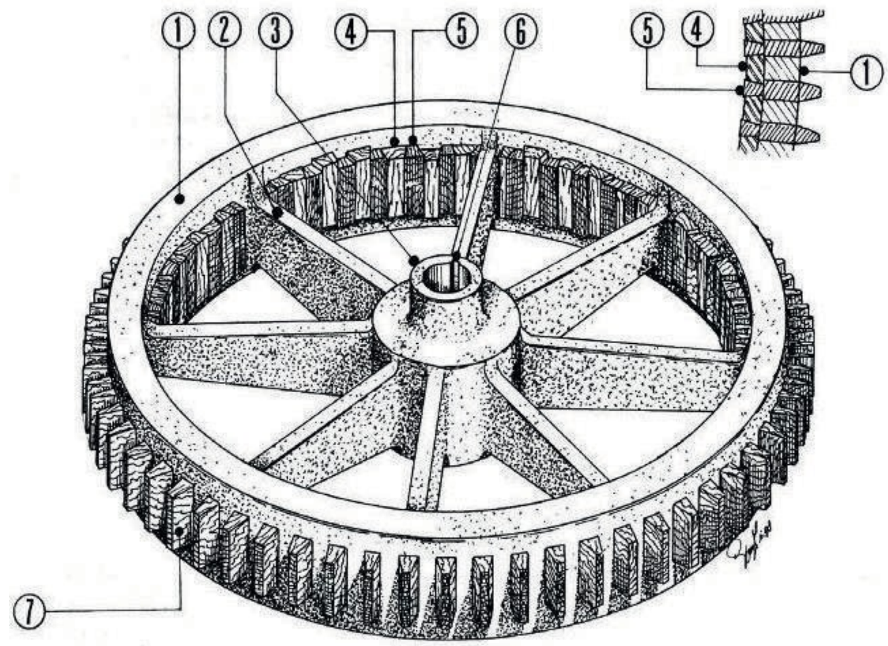


Fig. 6.5.7.1
Cast iron wheel:

1. *rim*
2. *spoke*
3. *hub*
4. *locking bracket*
5. *shank*
6. *keyway*
7. *cog*

hub
keyway
spokes, rim
wooden cog
iron cog
locking brackets
hornbeam
conical wheel

In the centre of the wheel is a heavy round part: the hub which contains a keyway used to fasten the wheel to the spindle or shaft. Attached to the hub are six to eight spokes connected at their ends by a cast iron rim.
As a rule, the driving wheel of two interlocking iron wheels has wooden cogs and the driven wheel has iron cogs. With smaller wheels, iron to iron sometimes occurs. As done with wooden wheels, wooden cogs are inserted through the rim. They are secured on the inside of the rim with trapezoidal locking brackets. Hornbeam wood is often used for these brackets.
For angular transmission in cast iron running gear, the wheels are conically shaped.

6.5.8 Wheels of the hoisting system

Grain mills may have different types of sack hoists: the geared sack hoist, the friction sack hoist and a belt-driven sack hoist. (see section 12.8)

geared sack hoist, sack hoist shaft, sack hoist wheel

In a geared sack hoist, the sack hoist shaft is surrounded by a sack hoist wheel that is implemented as a crown wheel or spur pinion wheel. Sometimes pins (small staves) are used instead of cogs.

sack hoist cable

With a control rope, this sack hoist wheel can be pulled into another rotating wheel, causing the sack hoist shaft to turn and wind up the sack hoist cable. This does not require the mill to be stopped.

friction sack hoist
friction ring
wearing course
wearing course

A friction sack hoist also has two wheels but these do not have cogs. The driving wheel around the central spindle, the friction ring, is composed of cross arms and cants. A wear layer of blocks of willow wood that can be easily replaced are fitted on the cants. The outer perimeter of the sack hoist wheel is given a wear layer of willow wood but sometimes a metal liner or an old car tire is also applied.
The sack hoist wheel is lowered onto the friction ring using a control rope, making the sack hoist shaft rotate.

sending-down

In contrast to a geared sack hoist, a friction sack hoist can also be used to send down bags of mill stock by running the sack hoist wheel over the friction ring in a slipping motion.

A Y wheel is usually attached to the other end of a sack hoist shaft.
This Y wheel consists of two cross arms inserted through the sack hoist shaft or four cross arms fitted around the sack hoist shaft and secured with wedges. At the circumference of the Y wheel there are cants or a rim. Sometimes a Y wheel simply consists of a round wooden plate. On the outer edge of the wheel, the wooden or metal two-pronged forks are attached; the endless hand rope runs between them. A Y wheel is usually made of oak.
The circular, endless hand rope allows the sack hoist to be operated manually and also used to send down sacks.

Y wheel

two-pronged forks
endless hand rope
manual control
sending-down

In a belt-driven sack hoist, there is a pulley (belt pulley) — over which a drive belt runs — on the sack hoist shaft. This belt runs over a second pulley on a drive shaft. A belt tensioner is used to apply tension to the drive belt, and this makes the sack hoist turn accordingly. Pulleys can be made of either wood or iron.

belt sack hoist, pulley, belt pulley
drive belt
belt tensioner

6.5.9 Gear ratio

gear ratio

By gear ratio, we mean the ratio of the number of revolutions of the waterwheel or the turbine and the number of revolutions/movements of the machinery, such as the milling or hulling stone, the camshaft, the saw frame, and so on.
By making the circumference of the driving wheel larger than that of the driven wheel, acceleration occurs. Conversely, you can also slow down a movement, as is done with edge runner stones.

In grain mills, a sufficiently high peripheral speed of the runner stone is required to be able to mill a good product. The diameter of the stone is also important in this regard: a small stone requires a higher number of revolutions. Relative to the waterwheel a runner stone is always accelerated.
For example, if the gear ratio is 1:5.28, then the runner makes 5.28 revolutions while the waterwheel makes one revolution.
A valid gear ratio for a grain mill is usually about 1:5 to 1:7. This ratio matches that of many windmills. For 10 to 15 revolutions per minute of the waterwheel, the runner then makes between 50 and 100 revolutions. But ratios of 1:15 or 1:22 also occur with waterwheel mills. In this case it usually involves a slow-running waterwheel, operating at only 3 to 4 revolutions per minute. Because of the high gear ratio, the runner still obtains a sufficient speed.

How do you calculate the gear ratio? For that, you need to know the number of cogs or staves of the various wheels of the running gear.

Example 1:
For single drive, the calculation is simple: Suppose the pitwheel has 69 cogs and the stone nut has 12 staves. With each revolution of the waterwheel, the stone nut and thus the runner goes around 5.75 times, namely 69/12 = 5.75
The gear ratio is then 1:5.75.

Example 2:
A mill with dual transmission has a pitwheel with 56 cogs and the crown wheel on the central post has 27 cogs. The spur wheel has 78 cogs and the stone lantern wheel has 24 staves.

Here the gear ratio is calculated as follows:

When the waterwheel makes one revolution, the central spindle makes 2.07 revolutions; in other words, 56/27. Therefore, the spur wheel makes 2.07 revolutions, whereby 2.07 x 78 = 161 cogs pass. Therefore, 161 staves of the stone lantern wheel are driven. In the process, the stone lantern wheel goes around about 6.74 times: 161/24.
For each revolution of the waterwheel, the runner goes around 6.74 times. The gear ratio is then 1:6.74.

Summarizing this into one formula we get: (56/27) x (78/24) = 6.74

Example 3:
camshaft wheel
An oil mill has a face gear wheel with 66 cogs and a camshaft wheel with 52 cogs. (Therefore, this transmission produces an acceleration.)
The gear ratio for the camshaft is 1:(66/52), or 1:1.27.
lifting lever
There is a lifting lever with two arms so that with each revolution of the waterwheel, the pressing ram is lifted 2.54 times.
Conversely, for each stroke of the pressing ram, the waterwheel must turn 52/66 = 0.79 times.

king wheel, stone wheel
There is a crown wheel with 41 cogs on the camshaft. The king wheel (stone wheel) has 53 cogs. (Therefore, this gearing provides a speed reduction.)
edge runner stones, edge-mill
Thus, the gearing from camshaft to edge runner stones (edge-mill) is 1:(41/53) or 1:0.77 and the total gearing from waterwheel to edge runner stones is 1:(1.27 x 0.77), or 1:0.98.
So the edge-mill turns almost as fast as the waterwheel.

stirrer gearing, pinion
For the stirrer: the crown wheel on the camshaft has 40 cogs, the pin wheel on the gearing (or transmission) has 42 pins, the crown wheel on the other side of the transmission shaft has 32 cogs, and the pin wheel on the stirrer spindle has 22 pins.
stirrer
The gearing from camshaft to stirrer is then 1:(40/42 x 32/22) = 1.39. And the gear ratio from waterwheel to stirrer is 1:(1.27 x 1.39), or 1:1.77.

For turbines, the gear ratio is usually between about 1:1 and 1:2.5. When the stone spindle is directly driven by the turbine shaft using a drive belt and drive wheels of equal size, the gear ratio is 1:1. The stone then rotates as fast as the turbine.
If the driven wheel on the stone spindle is smaller than the drive wheel on the turbine shaft, then acceleration occurs.

Regardless of the given gear ratio, a stone or other implement is also accelerated or decelerated by varying the power of the turbine.
Valves or adjustable guide blades (vanes) regulate the water flow and thus the power of the turbine so that the millstone receives the desired peripheral speed.
The limit is reached when the turbine delivers maximum power. If the turbine drives the stones not directly but through a mill shaft, the gear ratio is usually greater than 1:1.

6.6 DRIVING GEARS

Various drive versions are found in watermills:
- direct drive, such as from turbine shaft to machinery using a drive belt.
- Single under-drive, with one transmission using cog wheels.
- Dual or multiple drive. Cog wheels as well as drive belts are used in this process. In grain mills, both under-driven and over-driven systems are seen. Chain drive is also used sometimes.

Chapters 12 to 16 describe the various drives used in different types of mills.

6.6.1 Cog drive

For cog drives in water-driven grain mills, a distinction is made between over-drive and under-drive of the millstone.
In over-drives, we find predominantly wooden shafts, spindles and wheels.
In under-drive, metal running gear is also common.
We also find wooden cog wheels in the oil mills, hulling mills and paper mills that are still operating. Cog wheels work in conjunction with crown wheels or lantern wheels.

Fig. 6.6.1.1
Cog drive.
Here, a single under-drive. The wooden face gear wheel drives a small wooden stone nut on the stone spindle.
On the right is a second lantern wheel for an additional drive shaft.

Watermill Frans – Mander (Overijssel province)

6.6.2 Belt drive

Belt drive is common — though not exclusive — to turbine mills, mainly because of the higher speed of turbines compared to waterwheels. By using a belt drive, no expensive modification of the wooden or iron running gear is required after installation of a turbine.
Belts can be used to drive all kinds of machinery, from millstones, saws, sieves, crushers and elevators to mixer machines, etc.
When the driven shaft requires an opposite direction of rotation, the belt is diverted in a crossed fashion.

belt tensioner

To prevent belt slippage, a belt tensioner can be fitted. Pressing this against the belt puts more tension on the belt, preventing it from slipping on the wheels.

The outside (skin side) can also be smeared with linseed oil or cod liver oil; this will cause the belt to shrink a bit, putting more tension on the belt. With crossed belts, the outside of the belt meets the other wheel on the inside so, in that case, it is not possible to work with linseed oil or cod liver oil. When these methods cease to be effective, the belt must be shortened.
The use of belt lubricant or resin is not recommended for drive belts that need to be constantly moved from a loose pulley to a fixed one.

drive wheel, pulley, belt pulley

A drive wheel (pulley, belt pulley) generally has a convex outer surface so that the belt cannot run off the wheel because belts always run to the higher position of the drive wheel, allowing it to self-center as it runs.

6.6.3 Chain drive

Iron running gear sometimes uses chain transmission. This can be applied to cast iron mill shafts but also to a drive powered by an electric motor.

Fig. 6.6.3.1
Chain drive.
The mill shaft drives the millstones. The oil work is driven via the chain and the upper shaft.

St. Ursula Mill – Nunhem

6.6.4 Diagram of drive principles

Below are some of the different versions of the drive for the driving gear. These are mostly examples of grain mills or hulling mills.
In practice, we see a wide variety of versions which are often unique and therefore interesting.

The rotational direction of a machine is determined by a number of factors:

- Is the mill on the right bank or left bank?
- Does the mill have an undershot wheel or an overshot wheel? Undershot wheels rotate in the opposite direction to overshot wheels.
- Is the lantern wheel or crown wheel on the central spindle located at the bottom or top of the pit wheel (face gear wheel)
- A drive belt runs straight or crossed over the pulleys (belt pulleys).

Wood sawmills that are still in operation use belt drives that drive a crank wheel.
In oil mills, usually the pit wheel drives the camshaft wheel. The camshaft can also drive the edge runner stones and stirrer. But the drive for this can also be done with line shafts and/or wheels.
In small paper mills, the mill shaft is also a camshaft that drives the hammers of the hammer bins and also — via several transmissions — the beating engine (beater, Hollander).
In large paper mills, hammer bins and beaters were driven by line shafts.

6.6.4.a Single drive (under-drive)

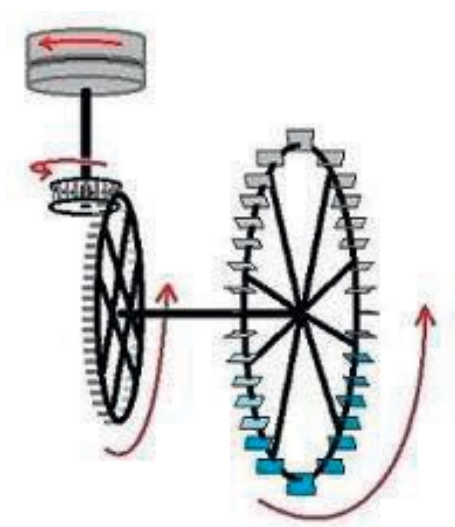


Fig. 6.6.4.a.1
With undershot wheel on the left bank.

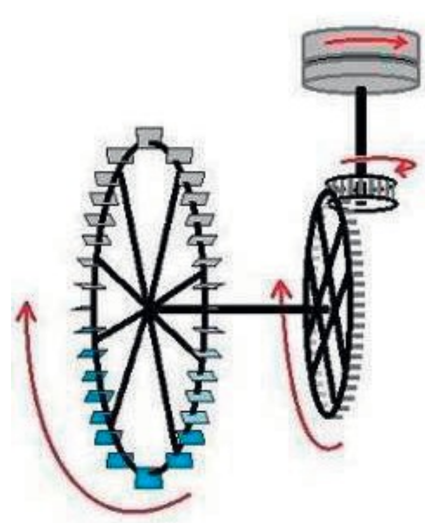


Fig. 6.6.4.a.2
With undershot wheel on the right bank.

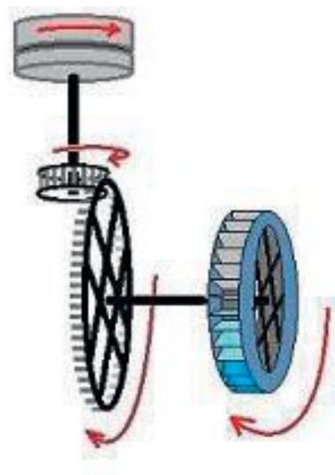


Fig. 6.6.4.a.3.
With overshot wheel on the left bank.

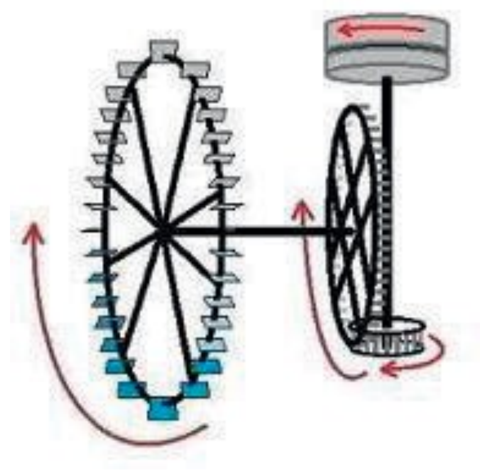


Fig. 6.6.4.a.4
Ditto Fig. 6.6.4.a.2, with placement of lantern wheel at bottom of face gear wheel (pit wheel).

6.6.4.b Multiple drive

When using a spur wheel, several pairs of stones can be driven. Both under-drive and over-drive are possible.

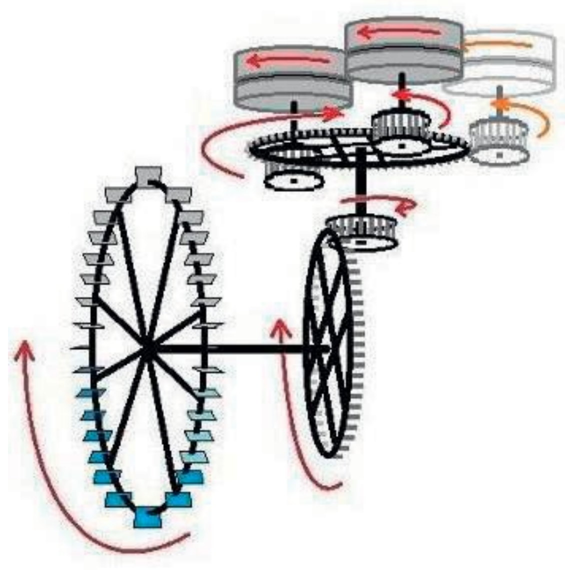


Fig. 6.6.4.b.1
Under-drive with two (or more) pairs of stones with undershot wheel on the right bank.

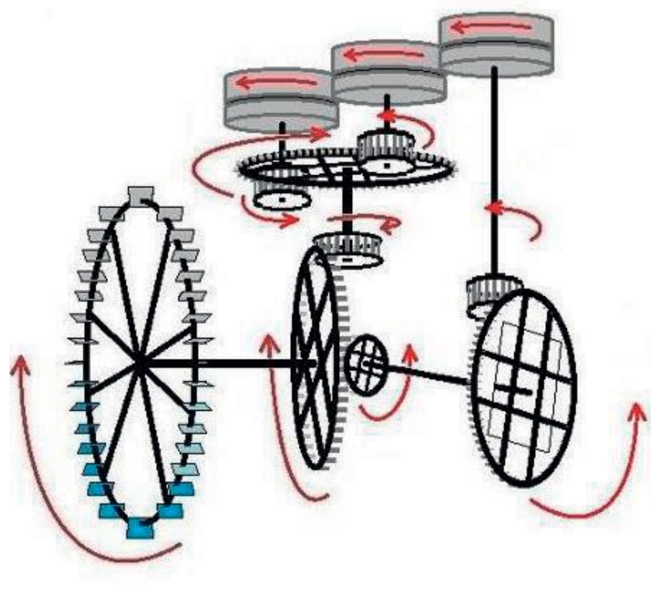


Fig. 6.6.4.b.2
Under-drive with three pairs of stones in line arrangement and line shaft with undershot wheel on the right bank.

The great variety of versions arose primarily because people were always looking for the simplest (or cheapest) solution in the given situation.
Over time, and mostly for economic reasons, mills were given a different layout, sometimes even a different function. Old and new layouts were then combined.

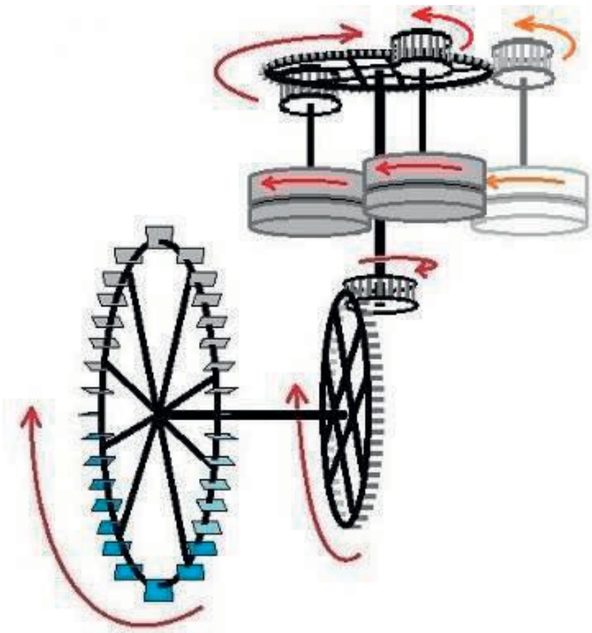


Fig. 6.6.4.b.3
Over-drive of two (or more) pairs of stones with undershot wheel on the right bank.

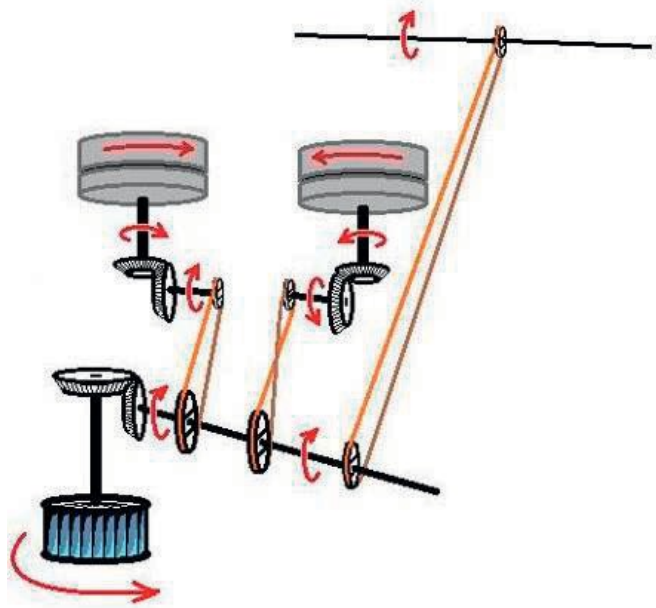


Fig. 6.6.4.b.4
Belt drive by turbine.
(Note: The rotational direction of the right pair of stones is indicated the other way round.)

There are also examples where a changing water supply required a different type of waterwheel to be installed. If this changed the rotational direction of the mill shaft, the running gear also had to be adjusted.

A fine example of a special version of the drive is found in the Wymarsche Mill in Arcen. This mill has both an undershot wheel and an overshot wheel, each driving the same cast iron central spindle with the help of a pit wheel and a crown wheel.
Since the rotational direction of an overshot wheel is opposite to that of an undershot wheel, this was solved with the position of the two crown wheels on the main central spindle: one crown wheel is positioned near the bottom of one pit wheel, and the other crown wheel is positioned near the top of the other pit wheel.
The opposite rotational direction of the mill shafts is thus cancelled out by the opposite drive of the crown wheels.

6.6.5 Taking out of operation

taking out of operation

Originally, larger watermills often had two waterwheels located back-to-back on the same inlet sluice. If they wanted to mill with one wheel, the other wheel would also turn along with the first wheel, but the machinery was taken out of operation. Later, several machines were driven by a single waterwheel.

milling for the Prince

If you want the waterwheel or turbine to turn but for certain machines to be idle, then you disengage them from the running gear. The transmission from the waterwheel or turbine to machine is then disconnected.
Today, the waterwheel often turns for the benefit of visitors without the mill being in operation. In the Netherlands this is called 'milling for the Prince' (for demonstration).

More often, however, there is a business reason for taking stone pairs or machinery out of operation. For example, the woodcutting process should be regularly

interrupted to move anchor irons and beam irons.
In running gear with multiple pairs of stones, sometimes you want to mill with only one pair because of the desired production. Often, however, the available water supply or the power of the waterwheel is insufficient to drive all the pairs of stones at once. Sometimes a pair of stones must be opened up for maintenance. The stone pair or machinery is then taken out of operation.

over-drive
In mills with over-drive, the stone nut is usually pushed out of the spur wheel for this purpose. This can be done in several ways:

sprattle beam
- The sprattle beam in which the stone spindle rotates is moved slightly with the aid of a lever or a rope (see Fig. 12.4.2.2).

glut box or sprattle box
- The stone spindle in the trunnion bearing is shifted with a removable bearing bolster (see Fig. 12.4.2.3).

keep
- The bracket of the trunnion bearing is opened and the stone spindle is moved out of the bearing.

Fig. 6.6.5.1
A stone nut with four slip sticks.

Bels watermill – Mander (Overijssel province)

under-drive
With under-drive, there are also a number of possibilities:

slip stick
- For wooden running gear, three or four slip sticks are removed from the stone nut.

jaw clutch
- A jaw clutch, which can be pushed in or out, can be used on the stone spindle. This is used when there is not enough room to take out slip sticks. But it also works easier than removing staves (see Fig. 6.6.5.2).

stone nut, stone wheel
fork
- For iron running gear, the stone nut (stone wheel) can be pushed up from the spur wheel with a lever or fork; a shim is subsequently placed under it. Sometimes the stone nut is pushed down.
- the vertical moving of the stone nut can also be done with a handwheel and a screw jack.
- A special method was to shift the central spindle plus spur wheel slightly using an iron beam so that either one of the stone pairs was driven. This is still present at the Genneper Mill at Eindhoven.

When driven by means of a drive belt, as is common in turbine-driven mills, among others, the belt pulley can be provided with a clutch.

fixed pulley, loose pulley
shifting fork
belt tensioner

Drive belts can also be moved from a fixed to a loose drive pulley manually or with the aid of a shifting fork to take a machine out of operation.
If a belt tensioner is used, the tension can be taken off the drive belt, stopping the drive.

Fig. 6.6.5.2
A stone spindle with a jaw clutch set further away to disengage the stone.

Oelemeulle – Oele (Overijssel province)

Sometimes a clutch is attached to the mill shaft to interrupt the drive of (part of) the machinery (see Fig. 6.6.5.3).

Fig. 6.6.5.3
A jaw clutch on the oil mill shaft to take the pit wheel — and thus the entire oil mill — out of operation.

Kilsdonk Mill – Heeswijk-Dinter

Chapter 7 Practical considerations

Contents Page

NOTES

7.1 INSPECTION AND MAINTENANCE

7.1.1 Introduction

Almost all mills are part of the cultural heritage of the Netherlands. As such, these are irreplaceable. Good millwork is therefore expected of every miller. That is to say, he or she should manage the mill for which they are responsible in an expert and careful manner. This involves not only turning or milling with the mill but also caring for the mill.
In other words, the miller does everything that benefits the preservation of the mill and refrains from doing anything that might be harmful to the mill.

A miller must be able to judge whether a mill is capable of turning and/or milling. The miller must also be able to assess whether maintenance is needed. And, if so, whether it is urgent or whether it can be justifiably postponed for a while.
The miller must be able to assess whether he/she can do the maintenance themselves or whether a millwright should be engaged. In the latter case, consultation with the owner will usually be necessary. For each mill, the agreements on whether or not to perform maintenance work yourself may vary. That is a decision for the mill owner.

This chapter discusses a number of practical matters that the miller will or may encounter when working with a mill.
Some topics may have been covered in passing in other chapters of this Handbook. For clarity and organisation, everything is listed together here.

Several topics in this chapter are related to those in chapter 10, Safety.
This is not surprising: mills, machinery or materials that are not properly maintained can become a safety hazard. Improper handling can also lead to damage or injury. Meticulous and regular inspection is therefore a key task for the miller.

Some specific practical matters for the grain miller have been added to chapter 12, The grain mill.

7.1.2 Inspections

Before operating the mill, the miller should always verify that the mill is capable of turning. This includes the situation as regards to the water supply. The inspections can take place at two levels. Several things should be checked every milling day and sometimes more than once a day. We refer to this as the 'daily inspection'.

daily inspection

Other items need not be checked every milling day but should receive regular attention.

In a daily inspection, at least all matters of direct importance to the proper functioning of the mill and its machinery must receive attention. These are the kind of things that can lead to damage if neglected. Examples are debris in front of the weed rack, loose cogs or insufficient lubrication.

We perform regular checks to get a picture of the overall condition of the mill and its machinery. In the standing parts and driving gear, changes can occur gradually but need not lead to immediate action or even downtime; some examples are dirty cogs and wear or moisture problems. Even so, these changes need to be noted and must lead to action when necessary!

In practice, the two inspections often intertwine: during the daily inspection, the miller also pays attention to other areas of concern. As milling takes place, the miller looks around and listens to the sounds the mill is making. The better you know the mill the better you know what to pay attention to.

maintenance schedule

Setting up a simple maintenance schedule is recommended. This avoids issues being overlooked, or investigating them too late. Some examples of maintenance schedules are included at the end of this chapter.

logbook

A logbook can be used to record the checks and maintenance work performed. This gives all the millers involved insight into the condition of the mill and the maintenance performed.

7.1.2.a An unknown mill

Anyone who, for the first time, is operating an unfamiliar mill or a mill that has been idle for some time will certainly need to start with a comprehensive inspection to satisfy themselves that the mill can be used for milling. The entire standing parts and driving gear and other items in and around the mill should be thoroughly examined to get a good idea of the maintenance state of the mill.
If possible, inquire with the (previous) miller about the mill's maintenance state and specific areas of concern. Or conduct a comprehensive inspection together with him/her. Keep in mind, however, that not everyone will make the same consideration when it comes to deciding whether something 'can wait' or 'really cannot wait'; some defects creep up on you and do not cause problems at first. In any event, stay alert!
If the previous miller is not available, consult the logbook or maintenance schedule if possible. And if necessary, ask an experienced miller to come with you.

Once the entire mill including all the machinery has been thoroughly inspected and lubricated and everything seems to be in order, then turn the mill — in non-operational mode — very gently. To do this, start with a modest supply of water. Then add more water to increase speed. Listen for sounds, feel if the shaft is not getting hot.
Operate the sluices several times to see whether they work properly.
Once the sluices are functioning properly and the waterwheel, shaft and pit wheel are turning properly, the machinery can be tested one by one. First without a load, then possibly under load.
This provides a picture of what condition the mill and its running gear are in and how the water supply is optimally controlled. It also reveals possible concerns that cannot be observed when the mill is at a standstill.

7.2 INSPECTION OF THE MILL FOR TURNING CAPABILITY

Here we discuss a number of things that the miller should check or perform before operating the mill. Because not every mill's situation is the same, millers will have to take care of their own 'customization'.

7.2.1 Mill pond and the weed rack

mill pond
grating, debris grille, weed rack (near mill pond), trash-rack, mill-grate, screen (near mill & water wheel)

Check for floating debris in the mill pond or in front of the weed rack (debris grille). Branches, bits of wood or other coarse debris can jam a waterwheel or turbine and also damage it. A jammed waterwheel can also lead to broken cogs or staves.
If the waterwheel does get jammed, the first thing to do is to close the inlet sluice. Try then to reverse the waterwheel — to do this, put the mill out of operation. If this does not work, the miller must go into the mill race and manually remove the blockage. Always do this with two millers!

Lots of floating (plant) debris in front of the mill-grate or screen can impede the flow of water. Not only does this decrease the turning speed of the mill, but the pressure of the water on the plant remains and the level difference with the water behind the mill-grate can also cause the mill-grate to break.

pick hook, weed hook, ditch hook

Remove floating debris with a pick hook (weed hook, ditch hook). If stream banks are subject to mowing or if there are more dead plants than usual or blown-off branches in the autumn, debris removal should be done several times a day.

scouring sluice

Sometimes there is a scouring sluice to allow water to flow diagonally past the weed rack, washing away the accumulated debris.
In turbine mills, in particular, there may be a second, fine-mesh grille in addition to a weed rack for keeping debris out.

Fig. 7.2.1.1
Spruce poles in front of the mill bridge to stop floating debris.

Opwetten Watermill – Nuenen

spruce poles

In Brabant, spruce poles are also used; these are posts placed vertically in the water in front of the mill bridge at a short distance from each other. These work so effectively that a mill-grate or screen is unnecessary! At the end of the day

the inlet sluice is closed, the spillways are fully open, and the spruce poles are set aside so that the collected debris can flow away.
Sometimes there are floating beams in the water at some distance in front of the mill to stop floating debris. Remove this debris regularly to prevent it from sinking to the bottom.

Check the water level of the surface water. This could be a mill pond or a mill race with a guideway in the stream.

upper sluice, weir gate

A mill pond often has an upper sluice (weir gate) that can be used to control the flow of water into the mill pond. There may also be an overflow to prevent excessive water levels in the mill pond.

mill race, cut-off branch
upper sluice

Is there a guideway in the stream that controls the distribution of water between the mill race and the cut-off branch? At some mills, millers can operate this upper sluice themselves. Are all these facilities working properly?

rain stream

Is there sufficient water for milling? This may well be a problem for certain mills —especially those located along rain-fed streams — in the summer or during prolonged droughts.
Depending on the water authority's regulations, reservoirs may not be allowed to get too high. Then interim monitoring of the water level is also necessary.

summer level. winter level

Keep in mind the difference between summer level and winter level.
The summer level is usually lower to keep adjacent farmland a little drier.

Fig. 7.2.2.1
Two mill grates and a constriction in the flume at the location of the shuttle. On the right is the pull for the inlet sluice. The shuttle can also be operated from the inside with a pull and is open here.

The Wenum Mill – Wenum

tail water
head water

Check the water level of the tail race, the tail water. If there is a lot of precipitation or water from melting ice, sometimes the water downstream cannot drain away sufficiently quickly. If you do have to mill, then tail water that is too high reduces the power of the wheel.
During winter weather conditions, there is a chance of ice. Check that the sluices and waterwheel are free of ice (see chapter 8.1).

7.2.2 Weir

sluices, gates

Check that the sluices (gates) are not damaged. Can they open and close easily? Are the rabbets (tracks or grooves) clean? Does the operating mechanism for the

sluices work properly? Are there any parts that need lubrication? Can a winch, if present, work unimpeded?
If necessary, close the spillways (almost) before opening the inlet sluice (control gate or shut) so that more water is available for milling. Is the apron free of debris? Remove installed safeguards against unwanted turning (padlocks on sluices, etc.).

7.2.3 Mill shaft and waterwheel

apron wall

Is the lubrication of the outboard bearing of the mill shaft sufficient? Is there any visible damage to the apron wall or the waterwheel?
Are the straps or iron hoops around the shaft still tight?

Fig. 7.2.3.1
Lubricating the outboard bearing. The gudgeon is retained in the shaft by wings. There are straps or iron hoops around this. In the centre, there is an eel basket or eel trap.

Oostendorper Mill – Haaksbergen

Rotate the wheel manually to check for rubbing. This can possibly be done when lubricating the outboard bearing. Is the wheel unbalanced?
Also check that the wedges of the floats are tight.

striking wedges

After a long period of drought or stoppage, check that the waterwheel wedges are still tight. If not, they must be tapped and re-secured.
Tightening the wedges must be done professionally! Care must be taken to prevent the wheel from shifting across the shaft, from ceasing to be perpendicular to the shaft, or from becoming acentric around the shaft. It may start to rub as a result.
Many therefore find it a good idea to have this tapping done by the millwright.
Sometimes the mill owner prescribes it.

If you do perform this work yourself, proceed as follows:
Start on the outside of the wheel. Tap two wedges that are diagonally opposite each other. Then two on the other sides of the shaft. Then the remaining two on the first sides and finally the last two on the other sides. All eight wedges on the outside have now been done.
Note: Don't hit them all at once but work evenly; start with one or two gentle strokes.
In other words, if we number the 8 wedges in clockwise order then the sequence

of striking is: 1-5-3-7-2-6-4-8. This is also possible with a wooden wheel with tangentially placed spokes around an octagonal mill shaft.
After this, do the same with the wedges on the inside of the wheel.
Then go back to the outside of the wheel and repeat the entire cycle. For the second round, start at a different wedge but the sequence should remain the same. Now it may also be struck with slightly more force. A third round may be needed in which you can hit with even more force. It is important to work each round "by feel", using the same amount of impact force on each wedge and working diagonally.
After tapping, check the wheel for rubbing. Then the wedges should be secured again.

Fig. 7.2.3.2
Wooden mill shaft and wheel with tangentially placed spokes. The shaft hole is octagonal.
The outer wedges lie on the inside ones. The gudgeon has two wings.

Baarlo Mill – Baarlo

7.2.4 Inspections and operations in the mill

7.2.4.a Lubrication

grease film

Check that the bearings of shafts and spindles that are supposed to rotate are adequately greased. Adequately means that there should be a thin even film of grease in which you can write with your finger, as it were.
There is a tendency to add new grease during every lubrication, but normally it is sufficient to redistribute the grease that is already present. Excess grease is forced out and causes a lot of contamination in the mill.
Lubrication should include: the inner bearing of the mill shaft, lower bearing and upper bearing of the central spindle, both bearings of stone spindles and drive shafts of machinery.
Note: Checking for adequate greasing of the moving parts will also have to be done during operation. Regularly check that shafts and bearings are not running hot (a maximum of 'lukewarm'). The same goes for the machinery!
Causes of running hot may include:
- Insufficient lubrication. This can also be caused by a fracture in the bearing stone causing the grease to run off.
- The gudgeon is too deeply worn into the bearing stone. This increases the friction surface area and impedes the supply of grease.
- The shaft or spindle is not properly located in the bearing, e.g., because either of them is slightly sagging or skewed.

7.2.4.b Machinery in or out of operation

Set machinery in or out of operation in accordance with usage requirements. Check if they are working properly and if they need lubrication. If possible, make preparations for production while the mill is still idle, unless this requires machinery (sack hoist, windlass).
More on this is described in the chapters on mill functions (chapters 12 to 16).

7.2.4.c Safety

Remove safety devices installed in the mill that prevent unwanted operation. such as a bar through the pit wheel. Provide fencing around moving parts where necessary. Provide an obstacle-free work floor for the miller.

timber lever, pivot wood

If a timber lever and pivot wood are used to open the inlet sluice, place it in the mill after use to prevent improper use by passers-by.
If necessary, take extra safety measures if you are expecting visitors, also if you are working on the bridge and passers-by are coming over the bridge.

After this, the inlet sluice (control gate or shut) can be opened.

Fig. 7.2.4.1
Here, more water (energy) is supplied than the wheel converts to power.
This causes water loss.

inlet sluice, control gate, shut

After opening the inlet sluice, control gate or shut, first check that the water supply is properly adjusted. The water should flow as gently as possible through or into the wheel. Also take note of the outflow: is it happening quietly or is the water churning?
Is the water not flowing over the buckets?
In the beginning, some water loss will inevitably occur due to the slowness of the running gear. Do not add machinery or the stone until the wheel is well underway.
With too little water supply, the mill may run too slowly to mill properly. In that case, add more water.
If there is too much water supply, water loss occurs. This is when more water is supplied than the wheel can convert to power. For example, because the wheel is already providing maximum power. In that case, reduce the water flow.

7.3 REGULAR CHECKS

In addition to items that should be checked each time they are put into operation — as described in the previous section — there are also items that do not require daily attention but do need to be inspected regularly.
The miller can include a cursory look at these during daily inspections or give them separate attention. Those who mill regularly with the mill soon learn when to check what.
This section therefore complements section 7.2.

7.3.1 Wooden waterwheels

wooden waterwheel

Wooden waterwheels constantly become wet and then dry again. This makes them susceptible to shrinking, expanding and warping. Cracks may appear in the wood, the wheel may start to rub, or parts may become loose.
Drying out does not occur only during long warm periods but also during frost when the humidity can be very low and the wood can dry out significantly.

When stationary, waterwheels should in principle not come into contact with water under the wheel. In practice, however, many mills do because the tail water is too high.

unbalanced

The water absorbed by the wood can cause the wheel to become unbalanced. Therefore, it is important that a wooden waterwheel is always stopped in a different position during periods when it is not being turned. This prevents the same part of the wheel from always being in the water. After turning the wheel, however, it must be blocked, as it wants to revert to its old position due to the imbalance.
In the case of overshot wheels, buckets may fill up at the top due to rainwater or water leaking from the flume due to a poorly closing shuttle, for example. This can cause the wheel to become unbalanced and therefore turn on its own.
Previously, the miller's obligation to turn the waterwheel regularly was often included in the miller's contract. The volunteer miller will need to do the same, especially during periods of extended stoppage.
Note:
- Check cracking in spokes, rims or shrouds, cross arms.
- Check loose or damaged s, cleats or wedges.
- Check damage from rubbing.
- Check the straps or iron hoops around the mill shaft.
- From time to time, check that the mill shaft (waterwheel shaft) is still horizontal. Sagging, wood rot or a bearing that has worn down too deeply can cause the shaft to no longer be horizontal and can cause floats to rub.

undercutting

This can also cause undercutting — in other words, water getting under the foundation of the mill.

iron waterwheel

Iron waterwheels require much less attention than wooden wheels. Imbalance due to water absorption does not occur. However, rust can corrode the sheet iron of floats. If an iron wheel has wooden floats then check them as done for wooden waterwheels.

7.3.2 Shaft opening

collar

Sometimes the opening for the mill shaft through the water wall requires the installation of a seal (collar) to keep water out. Check that this collar is still in place and functioning properly.

Fig. 7.3.2.1
A shaft opening with collar.

Filling pieces were fitted around the iron shaft and secured with clamp irons.

Laag-Keppel Watermill

7.3.3 Pit wheel or face gear wheel

pit wheel, face gear wheel

A wooden pit wheel (face gear wheel) has to deal with varying temperatures and humidity. Sometimes it is located in a damp pit, sometimes in a dry, warm space.
In addition, varying forces have an effect on the wheel as a result of working. Shrinkage, expansion and movement can cause cracks in cross arms or rims. Wedges or cogs can also become loose.
Note:
- Is the wheel sitting properly on the mill shaft: wedges tight, properly secured?
- Are clamp irons around the filling pieces sufficiently tight?
- Check for cracking at the intersections of the cross arms.
- Check for cracking around the cog holes in the rim.
- Are the cogs secure? Are shank wedges properly secured?
- Do the cogs have a regular wear surface? Is that smooth or rough?
- Are any insets stuck in the wheel?

locking brackets

Iron pit wheels require less maintenance. If they have wooden cogs, the locking brackets should be checked regularly. From time to time, also check that wooden cogs are still sufficiently lubricated with beeswax.

7.3.4 Central spindle (main upright shaft)

For the central spindle — if present —the bearings are especially important. After running for a while, check that the bearings are not running hot.

upper bearing

Check the upper bearing for play by moving the crown wheel or lantern wheel or spur wheel back and forth briskly.
Note:
- Are the wing gudgeons of both ends of the central spindle tightly fixed?
- Are fitted straps firmly attached to the central spindle?
For lubrication of the bearings: see sections 7.5.3.b and c.

7.3.5 Crown wheel, cradle wheel or stone nut

The attachment of the crown wheel or cradle wheel to the central spindle should be checked from time to time. Wedges tight? Well secured?
For single drive, check the stone nut on the stone spindle. Note:
- Are the wedges fixed and secured?
- Are the cogs fixed and secured?

bite

- Check the 'bite': are the cogs of the pit wheel digging too deeply into the cogs/staves of the crown wheel, cradle wheel or stone nut?
- Is the pit wheel rubbing against the crown wheel?
- Does the wear surface of cogs and staves have a regular shape? Is lubrication necessary?

Fig. 7.3.6.1
The mill pond.
Over time, due to silting and also leaf debris, a mill pond will become increasingly shallow.

7.3.6 Weir

weir

The weir or guideway is not part of the mill but is the responsibility of the water authority. However, the proper functioning of the sluices at the mill is of great importance to the mill. That's why the sluices and their operation are checked every milling day by the miller (see chapter 7.2.2).
From time to time, however, inspect the water works more thoroughly. As well as any upstream guideway, if present.

sluice post, protective post, gate sill
protective beam

Is there any damage to the sluice posts (protective posts), the gate sill (protective beam) or the bridge? Is the water flow impeded by plant growth and the like? Report any damage or problems to the water authority.

silting

Many mill ponds suffer from silting as the water in the pond comes to a halt, causing entrained sand and debris to settle. But leaf debris also forms an increasingly thick layer on the bottom over time. As a result, a mill pond can come to hold less and less water.
Consequently, the period of milling can gradually become shorter and shorter.
From time to time, measure the depth of the mill pond at various points.
Deepening will have to be done periodically.

7.4 DECOMMISSIONING THE MILL

When decommissioning — as with commissioning — the miller must perform a number of actions or take measures to ensure that the mill can be safely left behind after departure.
For each mill, the situation may vary slightly but we will mention a few things. Identify where these need to be modified for your own mill.

7.4.1 Water supply

To stop the mill, the inlet sluice in the weir must be closed. This also happens with turbine mills.
With an overshot wheel, the sluice gate is closed in front of the flume. An existing shuttle in front of the wheel can be opened and/or a shuttle above the wheel closed to prevent flooding of buckets by leaking water or rainwater. However, in the case of a wooden overshot wheel, you may also consider allowing this filling up to take place; if the mill is out of operation, the waterwheel should move slightly every now and then, preventing imbalance.
Note: Whether you want the waterwheel to spin freely or whether you want to properly secure the wheel depends on local conditions: supervision 'during the week', location, safety of passers-by and your own experience with this.

If the spillways were (partially) closed due to milling, reopen them to the extent necessary for sufficient water discharge. If a lot of water (precipitation, water from melting ice) is expected in the days to come, consider opening the spillways a little further than usual.

If the miller has opened the upper sluice in the mill race, it will have to be closed again so that (most of) the water flows past the mill via the cut-off branch. A fish passage or fish ladder closed in connection with milling must be reopened.

Install safeguards against unwanted opening or closing of sluices or turning of the waterwheel (beams, chains, locks, etc.) and place loose components in the mill (timber lever, pivot wood, cranks).

7.4.2 Driving gear

If the mill is left unattended, the machinery will generally be disengaged. Therefore, should the mill unintentionally start turning, it will not cause any damage in the mill.

With grain and hulling mills, you may have other considerations.
For safety reasons, it is good practice for many millers at these mills to put the pair of stones in operation and the stones together ('at rest'), meaning lying on top of each other.
This creates a lot of resistance for the waterwheel, which prevents unwanted turning.
You can also choose to take the pairs of stones out of operation. You do this if you choose to set the waterwheel 'free', so that it can turn slightly. This is to reduce the possibility of imbalance (see chapter 7.4.1).

Another reason not to put the stones at rest may be that moisture and the cooling of the millstones will cause condensation and cake formation.

Fig. 7.4.2.1
Mill taken out of operation by removing some slip sticks from the stone nut.

Bels Mill – Vasse

7.4.3 Other concerns when decommissioning

7.4.3.a Lubrication

Lubricating bearings, and the like will generally be done at the beginning of the day or at least before putting into operation. It may need to be done again during the day.
One reason to lubricate (for example, the outboard bearing of the mill shaft) during the day or at the end of the day is that, at low temperatures, fat is very hard and difficult to smear. At the end of the day, the bearing is usually a little warmer and the fat a little softer and therefore easier to spread.
Make proper arrangements for this so you don't lubricate at the beginning of the day on one day and then lubricate at the end of the day the next!

7.4.3.b Tidying up and cleaning

Tidying up and keeping clean promotes safety. Remains left behind or spilled oil can pose a hazard. The cleaning and maintenance of the work floor should also be done in the interim, if necessary (see chapter 10, Safety).

hygiene code, HACCP

For mills that produce for human consumption, cleaning and tidying up is necessary. We do not want to process or deliver contaminated products, and neither do we want to be a source of food for pests (mice, rats, insects). Regular cleaning is a requirement of the Hygiene Code (HACCP). Therefore, the hopper and the shoe will preferably have to be emptied through milling. After that, everything should be covered properly. Spilled grain and flour must be swept/vacuumed. Bags must be tied shut and stored in a proper place; silos must be closed. Other machinery used, such as a sifter, roller and grain cleaner, will also require regular cleaning. Apart from this daily cleaning, a thorough 'spring cleaning' of the mill will also prove necessary at regular intervals.

7.5 LUBRICATING THE MILL

7.5.1 Introduction

Lubricating the entire mill involves checking all lubrication points inside and outside the mill and providing them with a proper dosage of the correct lubricant. This includes removing old grease residue and replacing old oil with fresh.
Of course, various lubrication points are checked regularly, sometimes even daily, and lubricated as needed.
It is still a good idea to systematically check all lubrication points several times a year. It is advisable to make a simple list for this purpose — a lubrication or maintenance schedule — that lists all the points to be lubricated. Also the date on which the all-round lubrication occurred. Every miller at the mill is then informed about how things stand with regard to lubrication (see chapter 7.6.8).

lubrication schedule
maintenance schedule

all-round lubrication

Lubricating the mill completely — also known as 'all-round lubrication' — is an activity that takes time. So do take the time for it! When using a lubrication schedule, this all-round lubrication can also be done in stages if desired.

7.5.2 Lubricants

Traditional lubricants have been used on mills for centuries. This is still commonplace today because they have proven their worth. In addition, modern lubricants made from mineral oil are also used.
Since each lubricant has specific properties, it is important to apply them correctly. For example, some fats liquefy (too) quickly when they become a bit warmer and then they run. Others penetrate the material to be lubricated and soften it, causing more wear and tear.

7.5.2.a Traditional lubricants

Traditional lubricants were used in mills before lubricants made from mineral oils were developed. Traditional lubricants are:

pig fat, lard
- Pig fat, better known as lard. It is the belly fat from pigs. This must cure for at least six months before it is a suitable lubricant for the mill. It is often hung up in the mill to cure. When the white fat turns yellow, it is usable for lubrication. At low temperatures, it works well when ground finely in an old mincer or chopped into small pieces. It is not recommended to melt lard, as this changes its structure and causes it to partially lose its lubricating properties. Melted lard can also cause problems in the summer because it runs easily at high temperatures. In winter, however, melted lard has an immediate lubricating effect because ordinary lard is too hard then.

horse fat
- Horse fat has similar properties as lard but is less stiff. However, it is more difficult to obtain.

tallow
- Tallow (not to be confused with talc fat, which is a mineral product) comes from animal fats. It is mainly extracted from sheep fat and offal and is available in blocks of about 1 kg. Tallow can be used for lubrication of the mill shaft.

rapeseed oil
- Rapeseed oil is extracted from rapeseed. Just like the fats described above, it has extremely good lubricating ability in slowly rotating bearings or surfaces subject to light friction. It is therefore a good lubricant for thrust bearings.

castor oil
- Castor oil is a greasy oil and very suitable for use in pintles.

beeswax
- Beeswax is used for lubricating cogs and staves.

7.5.2.b Modern lubricants

transmission oil

Modern lubricants are produced by distilling crude oil and other chemical products. Of these machine oils, transmission oil is the most suitable for use in mills. It is specially designed for bearings or friction surfaces that are under high pressure, such as in thrust bearings.
Use the thickest type of transmission oil, designated by the code SAE 250.

7.5.2.c Lubricating greases

lubricating greases, multi-purpose grease
- Multi-purpose grease, a soap-based bearing grease, is the most suitable of all the lubricating greases. It is waterproof and resistant to high temperature.

graphite grease
- Graphite grease is a normal type of grease to which graphite powder has been added to give it more stability. Because the graphite powder adheres to the surface to be lubricated, the grease does not run. It is also less easily washed away in rain. Graphite grease, however, softens wood. That is a disadvantage when it is used on wooden parts. Stains on clothing are difficult to remove.

vaseline
- Vaseline is based on mineral oils.

7.5.3 Lubricating the driving gear

7.5.3.a The mill shaft

Normally, the outer and inner bearings of the mill shaft are checked for adequate lubrication every milling day. If these bearings are closed, then you should check whether there is still enough grease in the bearing and whether it needs to be replenished or replaced. A grease pot will need to be replenished. On a full operating day — especially if the weather is hot — it will be necessary to check every few hours to see if there is still enough grease.

7.5.3.b Upper bearing or top bearing of the central spindle (main upright shaft)

sprattle beam

The upper bearing by which the central spindle rotates in the sprattle beam should be checked at least once a year. With pockwood bolsters, a few drops of castor oil between journal (trunnion) and bolsters is usually sufficient because pockwood is already somewhat oily by nature. If the bolsters are of another material, such as bronze, then we open the bearing and remove the journal from the central spindle. We then check that the bearing is functioning properly and shows no unwanted signs of wear, remove old grease, and apply clean grease. The bearing should also be opened if any play on this bearing needs to be fixed.

The following describes a possible mode of operation if the journal bearing in the sprattle beam needs to be opened. For each mill, the situation and therefore the method of operation may differ.
Begin by securing the central spindle with a rope that is

locking plate, filling shims

wrapped around it, the ends of which are secured around the sprattle beam or other suitable beam. Next, remove the securing wedges or nuts from the locking plate so that you can remove it. After that, any filling shims present are removed. Be sure to remember the placement of these shims, because they were used to true the spindle! Now gently slacken the rope slightly so that the central spindle can be pushed out from the bearing. In the process, the journal bolsters come out on their own. These can now be checked. They should not be too dry and must have an evenly worn surface. The journal should be shiny along the full length by which it runs into the bolsters. A black to blue worn surface indicates hot running of the journal, which means insufficient lubrication has been provided. The remedy is to remove the thin black carbon layer and give the journal a good helping of grease.

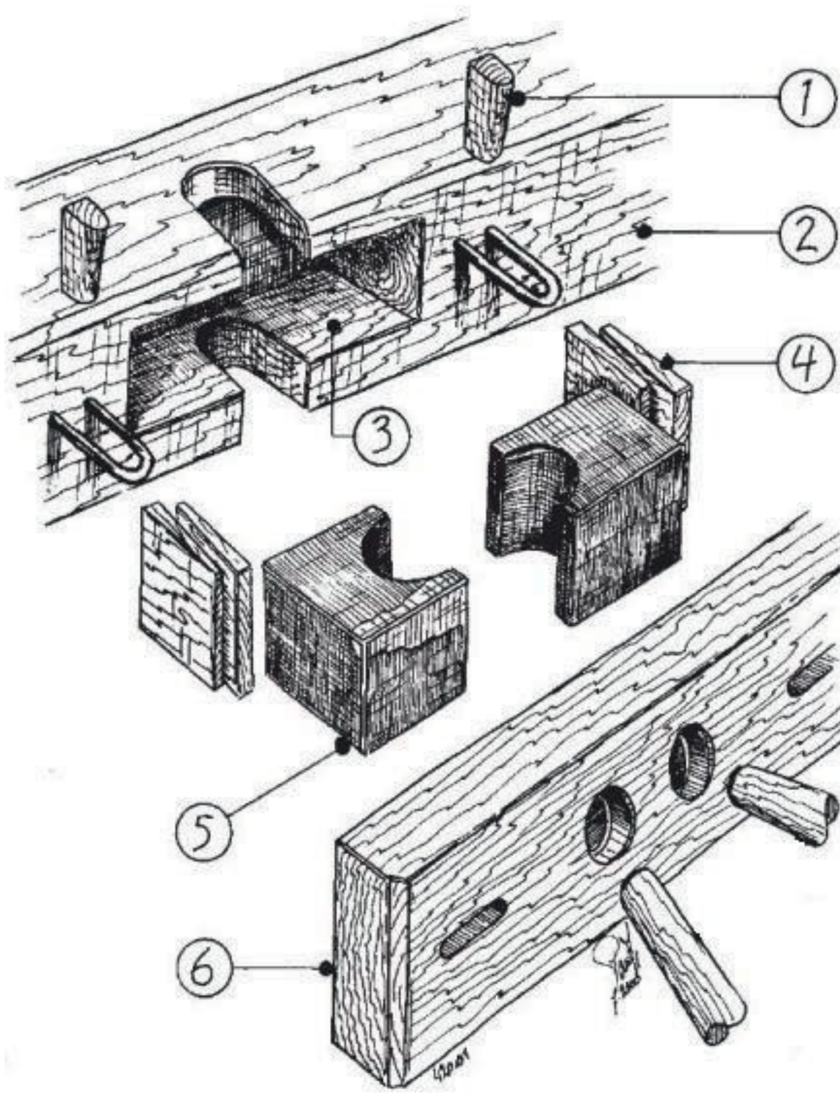


Fig. 7.5.3.1
An upper or top bearing
in the sprattle beam:

1. *securing wedge for locking plate*
2. *sprattle beam*
3. *sprattle box (bearing cover)*
4. *shims*
5. *journal bolsters (bearing blocks)*
6. *locking plate*

After lubrication, everything is put back in place. If the journal bolsters are very worn and they are identical, you can also swap them.
By gently tightening the rope, you pull the central spindle with the journal bolsters back into the sprattle box. Now put the filling shims and the locking plate back in place. Check that the spindle does not rattle in the bearing. If it does, then the bolsters have too much space. Filling shims should then be added.

After several days of rotation, check whether the bearing no longer heats up.

7.5.3.c The thrust bearing under the central spindle

The thrust bearing at the bottom of the central spindle should be checked regularly for heat; warm to the touch (lukewarm) is good. If it becomes hotter then the bearing should be checked.
How often you should change the oil in the foot-brass (or toe-brass) depends on the function of the mill. In dusty mills such as grain mills, it needs to be checked several times a year. Before refilling oil, clean the pintle and foot-brass completely with petroleum.
In the past, castor oil was used but that is less easy to come by these days. Nowadays it is best to use transmission oil of the thickest type.
In dusty mills, the life of the oil can be extended considerably by covering the bearing with a close-fitting piece of leather around the pintle.
In recent years, more and more thrust bearings are being replaced by modern thrust bearings that can accommodate both lateral and downward pressure. You can also use the same oil for these bearings.
If there are maintenance instructions from the supplier for modern bearings, these should be followed, of course.

7.5.3.d Cogs and staves

bite spokes

rollers, lifting lever

The friction surface of cogs, staves and pins (small staves), and the bite should be treated regularly. In an oil mill, this also applies to the areas where spokes and the lifting lever rollers meet.

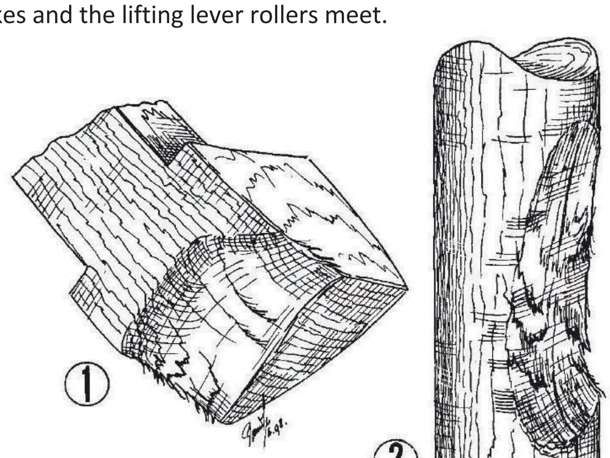


Fig. 7.5.3.2
Examples of flesh on the cogs or staves:
1. *cog head that has been running too long without sufficient beeswax*
2. *a stave with flesh on the bite and edges*

beeswaxing, beeswax

Lubrication or 'beeswaxing' is done exclusively with pure beeswax. To prevent fire, first make the area around the part to be washed thoroughly dust-free. Then heat a cog or stave with, for example, a heat gun or blow dryer and then rub a block of pure beeswax over the heated cog/stave. Because the cog/stave is hot, the wax properly absorbs into the cog.
Another method is to melt the beeswax *au bain-marie* and apply it to the cog/stave with a brush. This goes much faster but it must be repeated more often because the wax does not penetrate the wood. And you will use significantly more beeswax!

It is sufficient to wax only the cogs of the larger of the two interacting wheels. As the wheels turn, the beeswax spreads naturally on the cogs or staves of the smaller wheel.
But some millers beeswax both wheels at the same time.
Be sparing with the beeswax: Do not apply wax to parts that do not touch each other.
For iron wheels that have wooden cogs driving an iron wheel, only the wooden cogs are lubricated.
How often one should beeswax cogs depends on the load on the driving gear and the number of operating hours. The cogs of a mill that only runs for demonstrations does not need to be beeswaxed as often as those of a heavily used production mill.
Poorly maintained cogs make themselves known by producing a squeaking or whining sound, when the mill is running slowly. Another consequence of poor maintenance is that the annual rings in the wood of the cogs and/or staves separate from each other under the heavy pressure. This is called 'flesh on the cogs'. The bite feels rough and the wood is splintering. If two wheels are not in line then the cogs and/or staves pinch each other. This also creates flesh on the cogs.

flesh on the cogs

7.5.3.e The spherical spindle or stone spindle

spherical spindle, stone spindle

The spherical spindle is found in grain mills and hulling mills. It is the shaft on which the runner stone rests. In under-driven grain mills, this is also the spindle that drives the stone. This is why it is often referred to as the stone spindle.

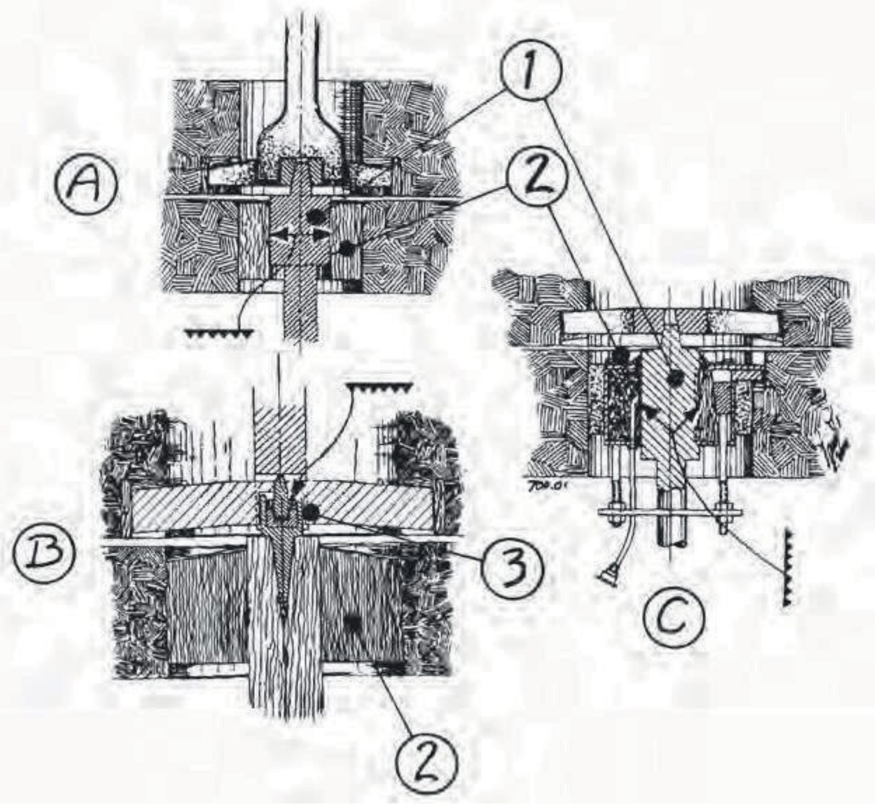


Fig. 7.5.3.3
Lubrication of the neck bearing:

A. wooden neck bearing
B. neck bearing with runner stone suspension
C. metal neck bearing

1. neck of the spherical spindle / stone spindle
2. neck bearing
3. pintle with suspension pin

The serrated edges indicate the areas to be lubricated.

neck, neck bearing

The top of the spherical spindle, the neck, rotates in the neck bearing. In many mills, the neck can only be lubricated when the pair of stones is laid open.

Stauffer pot

Neck bearings are made of wood or metal. Both metal and wooden bearings can be lubricated with a Stauffer pot — or with a grease gun and nipple.

The underside of the spherical spindle is usually implemented as a thrust bearing or footstep bearing fitted into the bridging box on the bridge tree or on the sprattle arch. The same rules apply here as for the thrust bearing of the central spindle (main upright shaft). Given the dusty environment, covering with a piece of drive belt or leather is a necessity here.
In recent years, restoration of millstone assemblies have increasingly turned to a combination of thrust and roller bearings housed in a bearing bush. These must be supplied with heavy transmission oil.

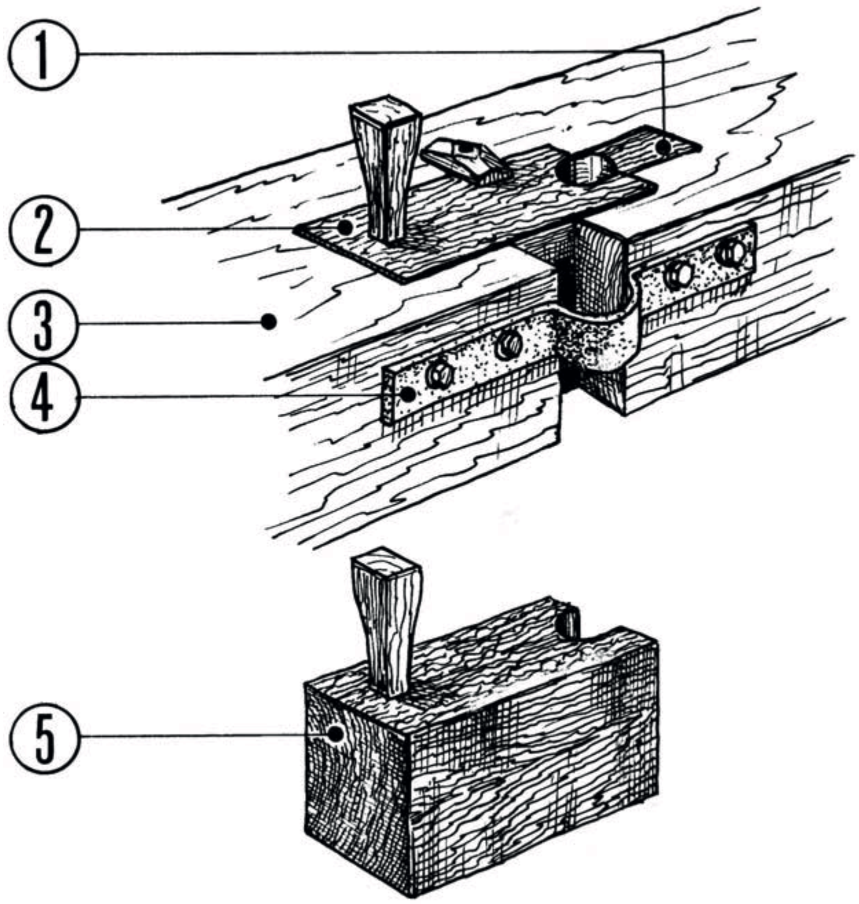


Fig. 7.5.3.4
Top bearing of a stone spindle:

1. *milling bolster*
2. *bolster (bearing block)*
3. *sprattle beam*
4. *stirrup iron (keep)*
5. *removed bolster*

sprattle beam

A stone spindle in a grain mill with over-drive is bearing-mounted at the top end by a trunnion (or journal) bearing in a sprattle beam. This bearing is best cleaned and lubricated by taking out the bolster and pushing the spindle out of the sprattle (or glut) box. Lard can now be greased on the journal or on the bolster. If the bolsters are made of pockwood, a few drops of oil are sufficient.

7.5.3.f Other bearings

Other bearings may be present depending on the function of the mill. Examples might be bearings for the sack hoist shaft, cam shaft, drive shafts for belt drive, etc. These should also be checked during an 'all-round lubrication'.

7.6 MINOR MAINTENANCE

7.6.1 Introduction

identifying defects

In addition to running the mill, an important task of the miller is to identify defects or required maintenance in a timely manner. The miller can prevent things from getting worse by taking action and fixing the problem quickly (or arranging for it to be fixed). Therefore, the miller should keep in touch with the owner about maintenance and repairs and make arrangements about performing the work, etc.

7.6.1.a The duties of the miller

This section lists some maintenance tasks that most millers can do themselves. Some go so far in this regard that they also take on extensive jobs such as all the paintwork. Others have progressed over the years to almost become 'volunteer millwrights' or have even made it their profession.
Everyone is free to choose how far he or she will go in performing maintenance work, and not every miller considers himself or herself skilled at odd jobs. However, you must keep a few important things in mind:

- You may not make alterations in or to historic buildings without permission. The same goes for the choice of colours and materials.
- Doing the work yourself may come at the expense of professional millwrights. Millwrighting is a unique trade where continuity is very important. Experienced millwrights must be able to pass on their expertise to the younger generation.
- If you want to do a job yourself, it should not cause the mill to be out of operation for a long time.
- For work done in-house, use appropriate materials and take into account heritage values and regional details. The finish should not be inferior to that done by a millwright.
- Perform the work safely. Volunteer millers are subject to the regulations of the Dutch Working Conditions Act with respect to working at heights.
- When painting, use only paints that craftsmen or craftswomen and/or millwrights also use. Keep in mind that appropriate colours are often historically determined.

7.6.1.b Specific millwright's work

Adjusting the driving gear, such as two wheels that work together, is millwright's work. Cogs and staves must interact accurately to prevent wear. Poorly aligned or misaligned bearings quickly run hot. Improper tightening of wedges that secure the wheels to the shafts or spindles can cause major damage to cogs and staves or to the wheels themselves. Adjusting mill shaft bearings and hanging the wheels is also millwright's work, as is adjusting a sagging mill shaft.

7.6.2 Loose cogs and staves

loose cogs

Loose cogs and staves rattle or bump together with each revolution of the wheels and this does not promote longevity.

wooden hammer

Loose cogs are easily reattached. By tapping the cog heads with a wooden hammer, you can hear which one is loose. When the loose cog has been found, hit it first with a few vigorous taps. Use a wooden hammer to do this or hold a block of hardwood between the cog and the hammer. Then hammer down the wedge or locking pin that protrudes through the shank.

Sometimes hitting does not help and the cog remains loose. In that case, tap the wedge or locking pin out of the shank and knock the cog out of the wheel. To avoid disturbing the correct centre-to-centre distances of the cogs, place a strip

canvas on the working side

of canvas in the cog hole on the working side: in other words, the side with which the cog pushes or is pushed. Then re-insert the cog. Let the canvas protrude slightly to prevent it from disappearing into the hole with the cog. This

pressure side

keeps the pressure side of the cog in place.

If the cog is still loose, use thicker material or put the canvas around both sides of the shank (see Fig. 7.6.2.1).

loose staves
tie-rods

Loose staves are a bit more difficult to secure. Sometimes it is enough to tighten the tie-rods slightly. The tapered part of the staves is then pressed slightly deeper into the lower and upper plates. If this fails, try securing the

guiding wedge

stave with guiding wooden or iron wedges along the working side of the square peg.

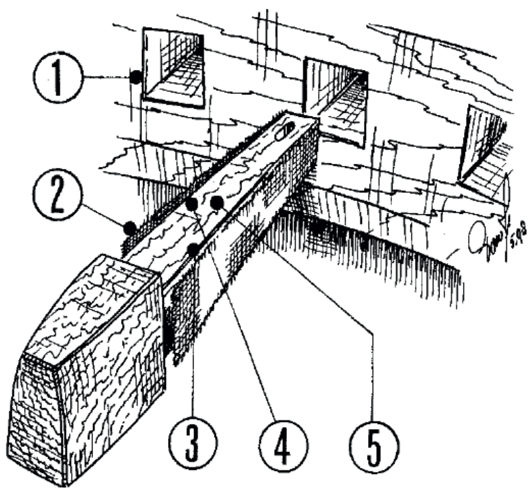


Fig. 7.6.2.1
Applying canvas around the shank:

1. *cog hole in the front rim*
2. *strip of canvas on the working side*
3. *pressure side of the cog*
4. *working side of the cog*
5. *shank*

7.6.3 The interlocking of cogs and staves

mesh too deep

If two wheels mesh too deep, the cogs can get caught between the cogs or staves of the other wheel. In addition to extra wear, this also puts extra stress on the bearings. If there is a lot of space, you sometimes see that the cogs of one wheel push splinters of wood off the back of the other cogs or staves.

out of alignment

When the centre lines of two wheels do not coincide they are not in alignment. This causes more friction and wear.

Furthermore, cogs can touch the plates of a stone nut. This can be seen by wear

mirrors

marks on the cog heads and on the plates; these are called 'mirrors'. The crown wheel and stone nut are then misaligned, possibly due to one of them sagging.

7.6.4 Checking wedges, straps and bolts

If, during a long dry period, in summer or during frost, you can easily tap a wedge back and forth then it is time to check all the wedges of the driving gear.

loose wedges

This is especially true for parts that have been recently renewed, repaired and/or loose. Loose wedges can cause a wheel to shift on the shaft, and in the worst case, this causes major damage. Always knock loose wedges into place immediately.

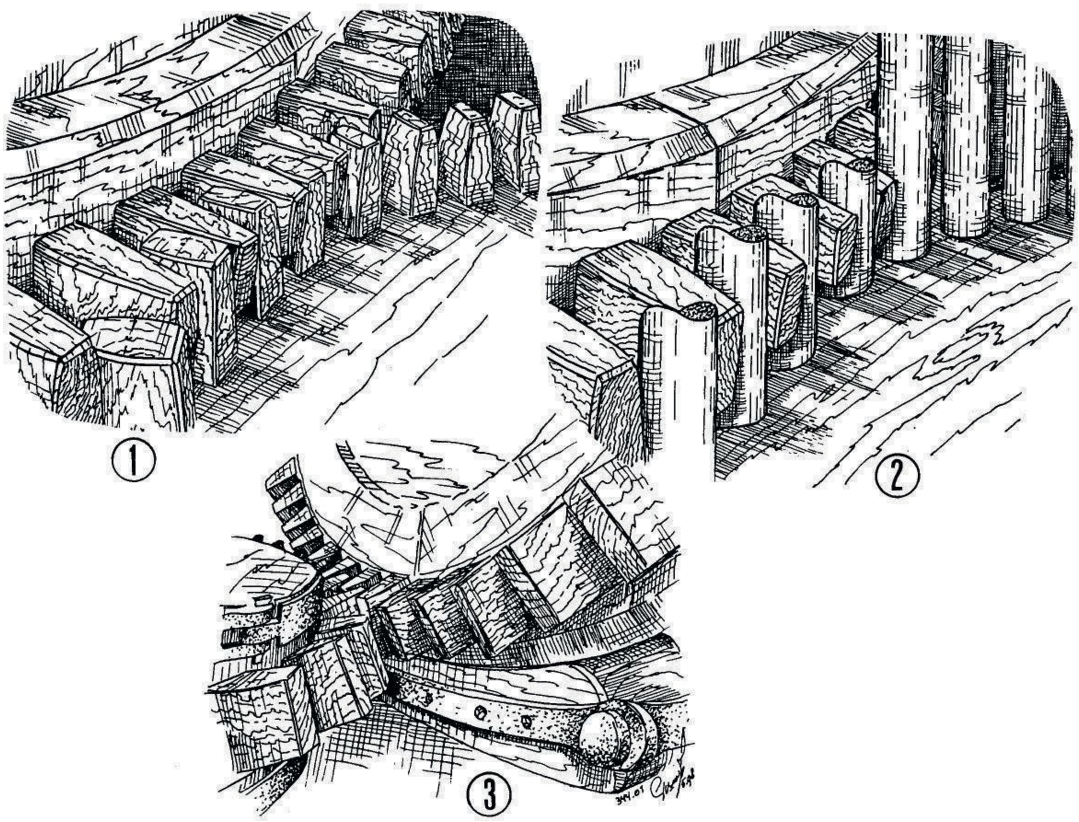


Fig. 7.6.3.1
Examples of proper engagement of cogs and staves with each other:

1. *The upper sides of the cog heads are flush with the back of the driven cog.*
2. *The cogs here extend a few millimetres beyond or are flush with the back of the staves.*
3. *The cogs here interlock for more than three-quarters of the head length.*

Although knocking wedges is millwright's work, there's no need to call the millwright for every loose wedge. You can knock small wedges yourself. Knocking wedges of wheels, beams, etc. should preferably be left to the millwright. Larger wedges should be knocked alternately and evenly.

keepers, pegs
tie-rods
retaining rings
reinforcement straps

Then place the keepers and pegs behind the wedges again. Especially with new wheels, the tie-rods should be checked regularly in the beginning and tightened if necessary. Likewise, do the same with retaining rings and reinforcement straps around stone spindles and heavier shafts that can come loose due to the shrinkage of the wood that must hold them together.

7.6.5 Slipping drive belts

belt lubricant, resin

You can prevent drive belts from slipping by applying belt lubricant or resin to the belt pulley. Another means is to coat the belts on the outside (skin side) with *linseed oil, fish oil*

linseed oil or fish oil, which shrinks them slightly. With belts that run crosswise, however, the use of linseed oil or fish oil on the outside is not possible because then the pulleys will become greasy.

For belts that must be able to be shifted from a fixed to a loose pulley, it is better not to use resin or belt lubricant because then the belt will stick to the pulleys.

If this does not succeed in putting enough tension on a belt, the belt will have to be shortened.
Belt tensioners can also be fitted or tightened to prevent belt slippage.

7.6.6 Painting and tar work

moisture-regulating paints

Good woodwork protection is offered by moisture regulating paints which professionals also use.

Sealing cracks or chinks with a filler or putty is not recommended. Over time, the working of the wood causes this material to loosen and moisture to enter again, which promotes wood rot.

rust-resistant metal paint

Metal mill parts are best treated with rust-resistant metal paint.

coal tar, Black Varnish

Coal tar and 'Black Varnish' were available in the past but they are banned today, and tar substitutes do not have a long life.

Stockholm tar (authentic pine tar)

Old tarred wood is best treated with Stockholm tar to which black powder has been added, as replacement materials are quickly degraded by the old tar layer.

safety glasses

Wear safety glasses when scraping off old coats of paint. Rock-hard splinters that can damage your eyes can jump off from old paint.

face mask

In addition, you must wear a face mask when scraping off any white lead paint, which is highly toxic and now banned.
Safety glasses are also recommended for overhead painting work. After working in this way there will be lots of paint splatters on the glasses.
Take as much paint on the ladder as you can handle in half an hour, for example. Better to have a small can of paint fall down than a five-litre one.

7.6.7 Wood species

species of wood
properties of wood

Both the standing parts and the driving gear of mills contain a great deal of wood. Wooden parts, especially those for the driving gear, are subjected to special loads. Therefore, the wood species used are those that can handle this load without difficulty. This is because each species of wood has its specific properties that make it excellent for one application and less suitable for another.
There are many wood species, and even within one species of wood there are differences in quality. The slower a tree grows, the better the wood will be. On poorer soil and at lower temperatures, for example, a tree grows more slowly but yields heavier wood. It is often more sustainable, too.
But deciduous trees in warmer regions form more even annual rings, which produces stronger wood.
The Dutch saying 'all wood is not wood fit for a carpenter' certainly applies to mills. In addition to suitability, however, availability and price also played an important role in the choice to use certain species of wood in mill construction in earlier times, too.

Nowadays, people also use wood species that were previously unknown in our country. Sustainability and price are important considerations.

Learning to recognize all kinds of species of wood is not easy. It takes practice to learn this. Collecting sample pieces can greatly assist this process. However, a miller need not become an expert. But a miller can be expected to have some knowledge of the species of wood used in their mill and the main properties of that wood.
The following is an overview of various wood species and their possible applications in mill construction.
Coniferous wood or softwood comes from trees with needles that remain evergreen. Deciduous trees have leaves that usually fall off in winter. In general, conifers are softer than deciduous trees.

7.6.7.a Some species of woods used in mills and their applications

Species	Durability	Applications
SOFTWOOD:		
American Pine	moderate/low	Also known as Pitch Pine. Especially suitable for wooden structures and indoor use.
European Pine	moderate/low	Wooden flooring, window frames, roof boarding
Spruce	low	Suitable for areas exposed to water: piles, mud sills, shoring, foundation boards
Larch	moderate	Heavy long beams, floor joists, floor timbers.
Oregon Pine	moderate/low	Also: Douglas. Beams, spindles, window frames, framework, vat for around millstones, carts.
Parana Pine	low	vat for around millstones, meal spouts.
Fir	low	'Scots pine'. Interior carpentry.
Red Cedar	moderate/good	Interior carpentry.
HARDWOOD:		
Afzelia	very good	Tropical hardwood. Waterwheel, crown wheel. Cross arms, cants. Large sizes are hardly available any more.
Azobé	good to very good	Heavy tropical hardwood. Difficult to work by hand. Sinks in water. Cogs and staves. Post and plank lumber for waterworks such as shoring. Vinegar wood moderate/good (from Holm Oak) Expensive. The wood of choice for cogs. Bolsters.
Bankirai	good to very good	Heavy tropical hardwood. Hydraulic construction: shoring, weirs.
Beech	very low	Sometimes cogs. Highly susceptible to woodworm.
Bilinga	good to very good	Good substitute for oak. Mill shaft, heavy duty wheels (excluding rims), shims.
Balata	good to very good	Cogs and staves.
Demerara Ironwood	very good	No longer available. Cogs.
Oak	moderate/good	Heavy beams, wheels (excluding rims), wooden shafts, support beams, bridging joists.
Maple	very low	Staves.
Ash	very low	Cogs for lightly loaded wheels. Hammer handles.
Hornbeam (also called Stone Beech)	very low	Cogs, staves. Hard to obtain, little used.
Hickory	low	Vats for around millstones, hammer handles.
Elm	low	Difficult to split. Rims for wheels, crown wheels, pinion plates, sack hoist wheels.
Meranti, red	good	Window frames, doors, windows, shutters, etc.
Merbau	very good	Weirs, bridge decks, submerged beams in waterways, stop wood under neck stones.
Box wood (Buxus)	good	Available in small sizes only. Staves (thin).

Pockwood	very good	Staves, bearing blocks, bolsters. Difficult to obtain.
Ramin	Low	Interior carpentry, stair treads, framework.
Robinia, Acacia	Good	Most durable native hardwood. Not from the Acacia! Heavy wedges. Sometimes pit wheel, spur wheel, and crown wheel cogs.
Yang (Keroewing)	moderate/good	Bridge decks, watercourse screens and many wet parts.
Zapatero	Good	Staves, cogs. Substitute for boxwood.

7.6.8 Examples of maintenance, lubrication and cleaning schedules.

Monitoring and maintenance schedule

Monitoring of		Name	Annually	Quarterly	Monthly	Regularly	Before turning	*) dated	*) dated	*) dated	*) dated	Action taken
1	**Wooden sluices**											
		Loose parts			X							
		Leakage				X						
		Litter in front of the sluice					X					
2	**Waterwheel(s)**											
		Misaligned wheel				X						
		Imbalance				X						
		Loose wedges			X							
		Loose start/floats			X							
		Loose bracing rods			X							
		Wood rot rims/arms		X								
		Wood rot on apron/apron walls		X								
3	**Waterwheel shaft(s)**											
		Loose journals		X								
		Bearing		X								
		Sagging		X								
4	**Grain mills**											
		Loose cogs/staves		X								
		Cleanliness of millstones					X					
		Vermin				X						
		Mill stock storage					X					
5	**Sawmills**											
		Loose cogs/staves		X								
		Drive belts		X								
		Condition of windlass		X								
		Operation ratched wheel		X								
6	**Mill Building**											
		Hinges and locks		X								
		Leakage		X								
		Trusses		X								
		Floors and stairs		X								
		Fire extinguishers		X								
		Cleanliness				X						
		Water side undercutting			X							
		Birds, mice and rats				X						
7	**Watercourse**											
		Blockage		X								
		Caving		X								

Notes

*) Tick performed operations

Lubrication of	Name	At maintenance	Annually	Quarterly	Monthly	Regularly	Before turning	Lubricant	*) dated	*) dated	*) dated	*) dated	*) dated
1	**Wooden locks**												
	Cleaning track for door		X										
2	**Waterwheel, shafts, outside**												
	Shaft bearings					X		Lard or hard fat					
	Cleaning bearings		X										
3	**Waterwheel shafts, inside**												
	Cogs: face gear wheels		X					Beeswax					
	Bearings: grain mills and						X	Lard or vaseline					
4	**Grain mills**												
	Cogs: crown wheel		X					Beeswax					
	Cogs: spur wheel		X					Beeswax					
	Staves: lantern wheels		X					Beeswax					
	Pintle: central spindle		X					Castor oil					
	Pintles: spherical spindles		X					Castor oil					
	Neck bearings	X						Vaseline					
	Journal stone spindles		X					Castor oil					
	Hinge points: tentering		X					Castor oil					
	Worm and handwheel stone crane		X					Vaseline					
5	**Sawmills**												
	Cogs: spur pinion wheel		X					Beeswax					
	Bearing shaft with driving			X				Vaseline					
	Drive belts			X				Fish oil/linseed					
	Bearings: crank wheels			X				Vaseline					
	Bearing: cranks			X				Vaseline					
	Guide sawing frame				X			Lard					
	Bearing: ratched wheel			X				Vaseline					
	Bearings: lantern wheels,			X				Vaseline					
	Bearings: circular saw		X					Vaseline					
	Bearings: windlass		X					Vaseline					
6	**Mill Building**												
	Hinges and locks	X						Oil/graphite					

Notes

*) Tick performed operations

Cleaning schedule											
	Name	**Annually**	**Quarterly**	**Monthly**	**Regularly**	**Turning**	***) dated**	***) dated**	***) dated**	***) dated**	**Action taken**
1	**Grain mills**										
	Spur wheel and stone nuts		X								
	Hoisting system		X								
	Pull		X								
	Hurst frames: externally					X					
	Hurst frames: internally	X									
	Sweeping the floor				X						
2	**Floor sawmill**										
	Sweeping	X									
3	**Sawmills**										
	Cleaning walls/windows		X								
	Cleaning saw carriage					1)					
	Chock bin, workbench		X								
	Sweeping the floor				X						
4	**Meal floor**										
	Stair cleaning		X								
	Dusting walls pictures		X								
	Exhibited objects		X								
	Meal spout					X					
	Sweeping the floor				X						
5	**Bottom floor (lower level for accessing lowest part of drive gear)**										
	Cleaning walls/windows		X								
	Sweeping the floor		X								
	Sawdust from slotted crank wheels	X									
	Cleaning wheels	X									
6	**Workshop/accommodation**										
	Cleaning walls/windows				X						
	Cabinets, table, chairs				X						
	Sweeping the floor				X						
7	**Watercourse**										
	Flush weed rack				X						
	Branches etc. from mill race					X					
8	**Tow ramp / surroundings**										
	Tidying up				X						

Notes
1) After sawing each log *) Tick performed operations

Chapter 8 The weather

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8 WEATHER

8.1.1 Introduction

Weather generally plays a different role when working with watermills than when working with windmills. Showers, wind gusts or thunderstorms do not pose acute risks to the water miller.
But the water miller still has to deal with the weather. The weather can cause large fluctuations in the water supply, or result in ice formation. The consequences will vary from mill to mill but the miller must be prepared to take action if it becomes necessary.

8.1.2 Precipitation

During periods of heavy precipitation, rivers or streams may have to deal with a lot of extra water within a short period of time. This can lead to drainage problems. The mill's weir presents an additional obstacle. The passage of the stream is often narrower there and the sluices slow down the flow. Furthermore, additional debris can be carried along and accumulate in front of the sluice openings. When downstream water cannot be drained sufficiently quickly, it may result in the tail water reaching too high a level. When there is a lot of extra precipitation, the miller must stay well informed about the situation upstream and downstream. The miller must also be able to assess whether the situation could become threatening to the mill and take timely action if necessary.
For example, by opening the spillways (further) and ensuring that no floating branches, etc. accumulate in front of the sluices.

8.1.3 Frost

ice formation

ice breaker

Frost may prompt additional measures. If there is a lot of ice formation in the mill stream, it can start to accumulate under the bridge and in front of the weir, which can impede the flow of water. Sometimes there is an ice breaker in front of the sluices which causes the ice floes to break up and float through the sluices.
Rising ice can also impede the flow of water through the weed rack.
In a mill pond, ice will not drift but when you start milling, the ice becomes dangerous: the water flows out from under it and the ice can sag and crack. Skaters should then be warned not to venture onto the ice. In the past, millers did try to keep their waterwheels ice-free during frost by leaving the sluice gate ajar. This keeps the water moving and makes it less likely to freeze. One danger with milling in freezing weather is that the mill bridge becomes slippery from freezing splash water. In general, it is best if the water miller does not mill during frost.

8.1.4 Thawing and water from melting ice

In order to mill when thawing sets in, the miller must try to free the waterwheel and inlet sluice. However, making the waterwheel, inlet sluice and mill race free of ice is not without risks.
How to go about it:

ice chisel

- For wooden wheels, try using an ice chisel and hot water to free the wheel.

- In the case of iron wheels, melt the ice with a gas burner.
- if the inlet sluice is still movable, a little running water may be enough to thaw any ice present in the mill race.

But note: as with milling, this can also make the ice unreliable for skating. When thawing sets in, there may still be a lot of floating ice in the water that accumulates in front of the weed rack for quite some time. Check the weed rack regularly!

water from melting ice

Thawing can also bring in a lot of water from melting ice. This can cause the same problems as a lot of precipitation does.

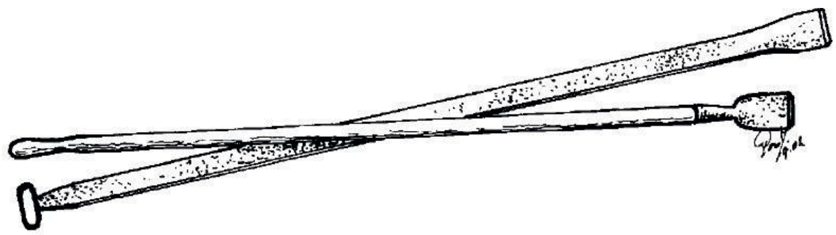

Fig. 8.1.4.1
Two examples of ice chisels

ice chisel

An ice chisel consists of an iron rod approximately 2 metres in length with a flattened lower end and a handle at the upper end. This is used to knock the ice into small pieces. When doing this, you must, of course, avoid the waterwheel and the spillway. Once the waterwheel turns, the ice in the apron quickly disappears.

8.1.5 Ground ice

ground ice

Millers may have to deal with ground ice. This is a phenomenon where, in relatively shallow water, ice seemingly floats up from the bottom.

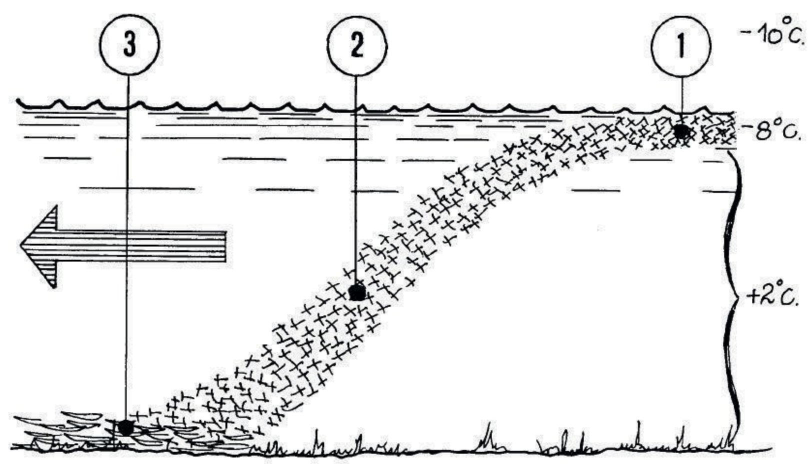

Fig. 8.1.4.2
The origin of ground ice:

1. *The water on the surface cools sharply.*
2. *This very cold water sinks to the bottom.*
3. *Above the bottom, a layer of water forms that can be colder than 4°C (39.2 degrees F) or even be supercooled.*

The flow can cause this water to rise and freeze once it reaches the surface.

Cold surface water can sink to the bottom. When that water becomes colder than 4°C (39.2 degrees F) or even supercooled (below 0°C / 32 degrees F), it becomes lighter than the surrounding water. This situation can occur in the still water of the mill pond. Due to current — for example, because the inlet sluice opens — the water can then rise and immediately freeze when it reaches the surface.

The weed rack should be carefully monitored during very low temperatures while the water is still open. It may close up due to ground ice formation.

Chapter 9 Water supply and management

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9.1 WATER FOR MILLS

9.1.1 Introduction

Just as wind is indispensable for windmills, running water is necessary for watermills.
Water power was used as a source of energy for milling as early as Roman times.
The recipe for a watermill is fairly simple: Find a watercourse with a sufficient, preferably regular, water supply and a sufficient fall. This fall can be obtained by constructing a weir in the water next to the mill. Using two or more sluices (also called locks regionally), the degree of impoundment can be controlled.

sluices
locks

By lowering all or some of the sluices, the water in front of the mill is pushed upstream: this is the head water. Simultaneously, this lowers the water level of the downstream water or tail water that often takes the form of a mill pool, widened and eroded by the scouring action of the falling water. But no two streams are alike, and there are also major differences in water management from region to region. To make the watermill suitable for this purpose, overshot and undershot mills were created, which were later followed by breastshot mills and turbine mills.

head water
tail water, mill pool

Watermills were often built at a junction of a country road (for supplying the mill stock) and a stream or river.

9.1.2 Streams, rivers or artificial streams

A stream is a more or less natural flow of shallow water that flows downstream from a source, often a spring. When several streams merge and become larger in size, they become what is called a river. A rule of thumb for determining whether a watercourse should be called a stream or a river is that a stream is fordable in all places and a river is fordable only in a few places.

artificial streams

On the Veluwe river in the Netherlands, artificial streams were created.

9.1.3 Lowland streams, percolating streams and spring streams

We distinguish between streams according to how they are fed:

lowland streams

- Lowland streams are fed by precipitation and by groundwater seepage. True rain streams/rivers that depend (almost) entirely on rain or thaw — such as those found especially in the Limburg region of the Netherlands — can suffer from water shortages during dry periods. In some streams, the water supply in summer is so low that the mills associated with them are referred to as winter mills.

percolating streams

- Percolating streams are a variant of lowland streams. The difference is that the upper sections (a seepage area) of the stream always carry water because they are fed by pressurised groundwater.

spring streams

- Spring streams are fed by springs from which groundwater rises to the surface.

Combinations of rain streams with percolating and spring streams also occur.

9.1.4 Artificial streams

The few natural streams found in the Veluwe region of the Netherlands are rain streams: they are sometimes too dry and sometimes too wet, so they are always either running or standing still. For that reason, new streams were dug out. The conditions for this in the Veluwe region are very suitable. This is because the ground consists of sandy soil with an impermeable layer at a greater depth. A substantial water buffer is created above this.
Along the line formed by Hattem, Apeldoorn, Arnhem and Renkum, the higher Veluwe Massive slopes rather abruptly into the river valleys of the Rhine and IJssel rivers. By making shallower or deeper excavations known as artificial streams at appropriate places on these edges of the Veluwe Plateau, people naturally encountered the groundwater, which drains regularly and continuously from the enormous water supply under the Veluwe. The place where the groundwater is reached is called the artificial stream head. Most artificial streams are fed by a network of smaller artificial streams before a stream worthy of the name emerges. This is the so-called artificial streams system. For example, the Loenen Stream in the Veluwe had more than 12 artificial stream heads.

artificial stream head

artificial streams system

The average depth of the artificial streams ranges from 2 to 4 metres.

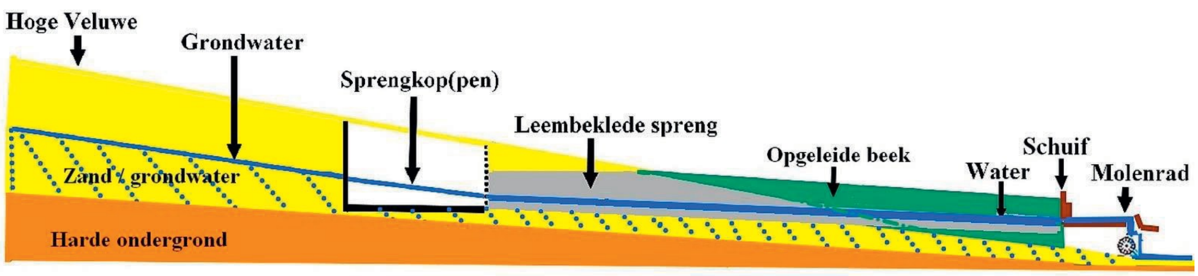


Fig. 9.1.4.1
Cross section through the Veluwe soil with artificial stream head and artificial stream.

Because artificial streams usually run through sandy soil, they are lined with a layer of loam to prevent water from sinking away into the soil. This is also the weak spot of the artificial stream. It happens quite often when cleaning an artificial stream that this layer is damaged and (too) much water sinks into the soil.
Drying out, due to extraction of drinking water and water use for agriculture and by factories has resulted in the groundwater level in the Veluwe becoming much lower.
As a result, artificial streams sometimes temporarily run dry. This can cause drought cracks in the loam layer.
If tree leaves get into these cracks then the crack does not recover much, if at all. All the more reason to keep the artificial streams clean.

9.1.5 Guided stream

guided stream

Where a spring rises above ground level, dikes were constructed. That part is called the guided stream.
Ordinary streams can also be guided to create adequate fall.

9.1.6 Reservoir pond or mill pond

reservoir pond, mill pond, weir

In order to still be able to mill using a stream with a low water supply, large diked reservoirs (mill pond, weir) were constructed upstream. Water is collected and impounded in these. This ensures that the mill will have sufficient water available for a longer period of time. After milling, the pond can refill and it can also be topped up during milling.

Fig. 9.1.5.1
Guided stream, the Sonsbeek in the Netherlands

Bagijne Mill – Arnhem

Fig. 9.1.5.2
The guided stream between the Green Water and the Upper Plas Mill reservoir in the Netherlands.

Additional benefits of reservoir ponds:
- They serve as sand traps to prevent the lower reaches from silting up.
- At paper mills, any iron deposits sink into the water, thus preventing the paper from being coloured pink.

To be able to operate several mills with one stream, a reservoir pond was also used as is the case with the overshot mills of Frans and Bels at Mander in the Netherlands.

9.2 DAMMING WATER

We saw above (see Section 9.1.6) that water was dammed in order to provide the mill with sufficient water for an extended period of time. For that damming, however, the miller must follow laws and regulations.

9.2.1 Weir rights

Writings from the eighth century (Germanic times) show that the use of water as a source of power was free for everyone. The only condition was that it should not cause problems for others.
The king, and later emperor, Charlemagne (747-814) took away this freedom (and other freedoms) by introducing what was called the feudal system. The use of water power (and later also wind) became an imperial right, referred to as regalia ('royal privileges').
Various rights — including mill and weir rights, jurisdiction and the like — were further granted by the emperor in fief to his subordinate lords (vassals) such as bishops and nobles (counts, dukes and so on). These rights became known as manorial rights.
In turn, those granted these rights then lent the mill and weir rights to third parties who had to pay for them. You could not freely build a grain mill.
Other types of mills, though, were in principle free. Grain mills, however, required permission from the lord or later the city, which held the feudal rights.
Further conditions were also imposed, such as requiring grain to be milled at a specific mill or prohibiting it from being milled elsewhere. This was called mill compulsion. The mill was called a compulsory mill. (Soke Mill)

compulsory mill (Soke Mill)

This mill compulsion guaranteed the mill greater turnover and therefore higher revenue for the miller and for the lord of the manor.
The manorial rights and mill compulsion came to an end in the Netherlands in 1798, the Napoleonic era. The French Revolution was directed against the privileges of the nobility. The French used and still use the slogan 'Liberté, Egalité et Fraternité' or Freedom, Equality and Fraternity.

However, mill and weir law in the narrower sense did survive the Napoleonic era with the law of 16 May 1829, S 29. It became a so-called right in rem.
This did need to be maintained to avoid problems between mill owners, upstream and downstream landowners, and local residents.
In the Netherlands, the Public Works Act of 1900 was the last piece of legislation to define the continued existence of mill and weir rights. Court decisions and case law have so far repeatedly upheld these mill and weir rights.
Essential to the right to weir is that sufficient fall can be realized to obtain enough water power. To do this, the water must be dammed.
Therefore, a weir with sluices was built in the stream/river. The miller operates these sluices to raise the water.
In doing so, the miller must prevent upstream farmland from flooding and downstream farmland from becoming water-deficient.

The weir law thus assures the miller of the best possible level difference between the upper and lower flows of water.

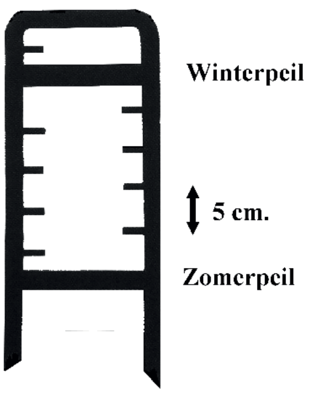
Arguments frequently arose between owners of upstream and downstream farmland and the miller. Also, in the 19th and 20th centuries increasing demands were made on water management.
Many weir rights were bought up by the water authorities. The wheel and sometimes the sluices could then be removed. What remained was a mill building without a soul, which still sometimes milled using motorised power.
In short; without weir rights there is no watermill!

European legislation to improve water quality came into effect in 2000. In the Netherlands, the central government translates the Water Framework Directive into national policy principles.
One of the starting points for this is the ability of fish to swim upstream. Because streams have been diverted for this purpose or fish ladders use too much water, watermills have disappeared or fallen into disuse.

fish ladder

It is now realized that many landscapes around a watermill were created precisely by the damming of water (see section 9.6).

9.2.2 Weir levels

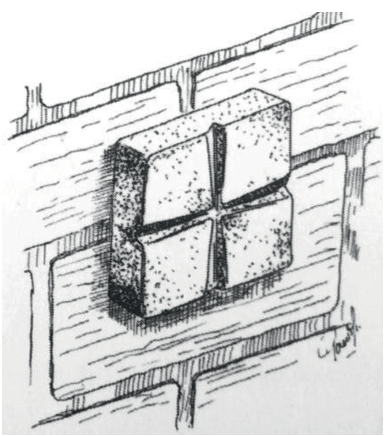


summer level, winter level

Water authorities were established in the Netherlands as early as the 13th century. These boards were charged with overseeing water management.
After the Napoleonic era, the right to set the dam levels of watermills rested with the provinces.
Over time, decisions about mill water levels have been made by the province and/or water authorities for almost all watermills and their weirs. This process involved setting a maximum weir height for artificially dammed water. This could affect the old mill and weir rights. However, restrictions in weir height should not result in the loss of enjoyment and use of the mill. Incidentally, it is legally possible to maintain a minimum as well as a maximum weir level.
When establishing weir levels, a distinction is also made between summer and winter levels. The summer level was often about 20 cm lower than the winter level. This was to avoid, as much as possible, flooding pastures for livestock. At most watermills in the eastern part of the Netherlands, however, summer and/or winter levels are not known.

water level marker

Starting in 1873, this gauge, called a water level marker — consisting of an iron bracket on a wooden pole — was placed about 50 metres upstream in front of the weir.



In the Netherlands, the reference height for height levels, including water levels, was initially the Amsterdam Level (AP). This was one of many regional levels based on the average summer flood level in the IJ River.
Beginning in 1880, the national reference point, the Normal Amsterdam Level (NAP) was prescribed. Since then this has applied for determining the maximum weir height.
To this end, a provincial bluestone water level marker with a horizontal slot — the cross bolt — was bricked into the wall of the mill just in front of the weir.
Water authorities monitor that maximum weir heights are not exceeded, and they increasingly operate the weirs remotely themselves. This eliminates the need and ability of the miller to control the weir height.
In 1890, a blue enamelled iron water-level gauge was placed in the stream bed by the provincial water authorities at a precise location.
Due to soil movement, the NAP is reset once every ten years.

9.3 GRADIENT, FALL AND FLOW RATE

9.3.1 Gradient

gradient

The gradient is the difference in elevation between two points of a stream or river, usually expressed in m/km. Therefore, this is the average slope of the watercourse in the direction of flow. The formula for the gradient is i = h / l, where i represents the gradient, h represents the elevation difference in metres, and l represents length in kilometres. For example, the (average) gradient of the Geul river with an elevation difference of 250 metres on a length of 58 kilometres is 250 / 58 = 4.3 m/km.

meander

With a high gradient, a river cuts into the landscape. If the gradient is slight, a river becomes meandering or winding, which usually reduces the gradient even further. The flow rate also decreases.

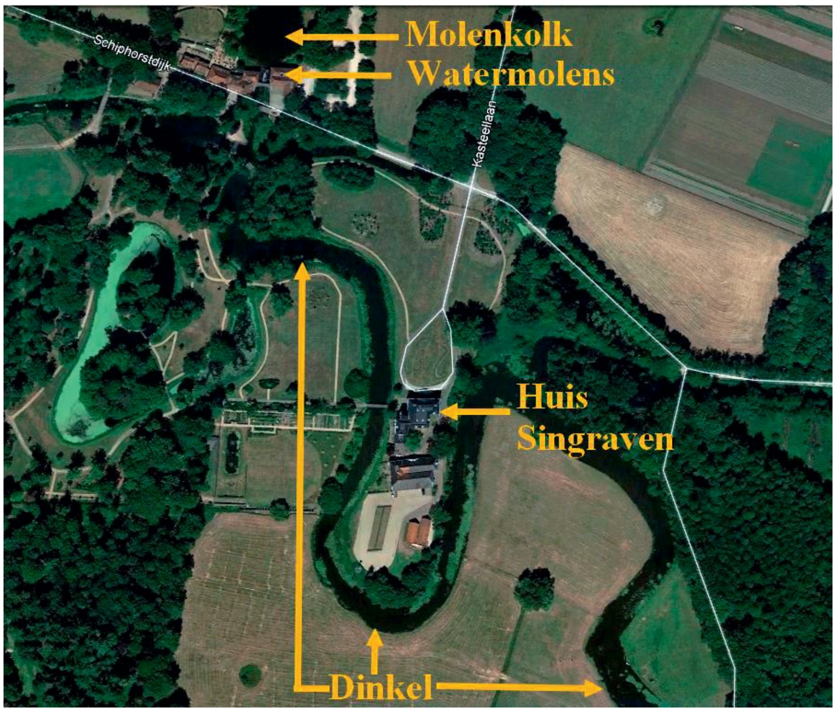


Fig. 9.3.1
With a low gradient, a river becomes extremely meandering.

The Dinkel river, with a gradient in the Twente region of 14.6 / 46 = 0.32 m/km, is a good example of an extremely meandering river.

9.3.2 Fall

fall

The absolute difference in height is called fall. In the mill world, fall is almost always measured at the weir.
A rule of thumb is:
- The gradient was already there before the watermill was built.
- The fall occurred after the construction of the mill's weir.

For example, if the water level before the weir is 20.45 m and after the weir it is 18.70 m then the fall is 20.45 - 18.70 = 1.75 m.

The height of the fall partly determines the type of waterwheel.

Undershot wheels are used with a fall up to around 1 metre. (In the Twente and North Brabant areas of the Netherlands, a fall of up to 2.5 metres is maintained.) Breastshot wheels are used with falls from 1 to around 3 metres. Overshot wheels are used in Limburg for a fall of 3 to 5.5 meters. In Twente and Gelderland, the overshot wheels and the fall are a lot smaller. The centre line of an overshot wheel is about 30 cm smaller than the fall. This is in connection with the water supply via a flume right above the wheel.

9.3.3 Creating a fall

For the construction of a watermill, a suitable site on the stream would be sought. There were four possibilities for this.

9.3.3.a Across the stream

inlet sluice, spillway

mill pool

Construction took place on the original stream. Next to the mill, a truss — equipped with an inlet sluice and one or more spillways for the free passage of water — was placed across the stream. Behind the mill, the fast-flowing water scoured away the banks and a mill pool formed. A disadvantage of this location was that it narrowed the passage of the stream, increasing the risk of flooding above the mill during wet seasons.

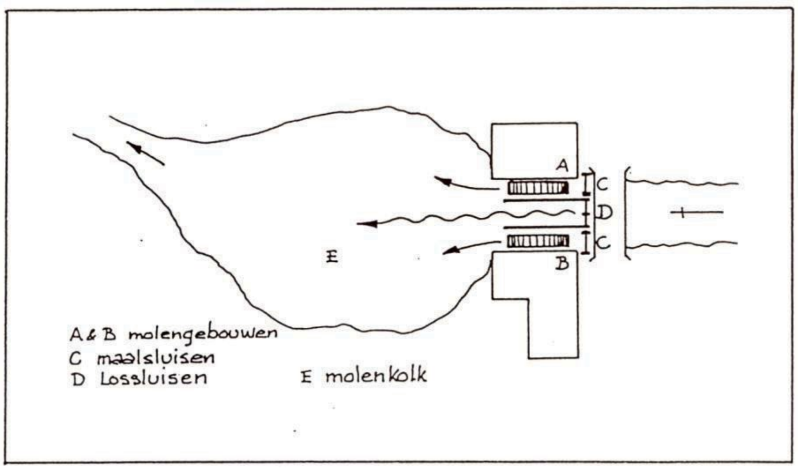


Fig. 9.3.3.1
These mill buildings stand crosswise to the stream.

9.3.3.b Passage in a sharp bend

bypass
guideways

When the course of the stream was extremely meandering, a passage or bypass was dug at a sharp bend on which the mill was built. For the impoundment of water, guideways were built next to the mill and also in the bypass. These consist of a truss with one or more spillways and/or inlet sluices.

9.3.3.c. Parallel mill race

In South Limburg and North Brabant, it was common for a (long) mill race to be dug parallel to the course of the stream. The start of the mill race was also made at a sharp bend. The original stream then acted as a cut-off branch. There were guideways in both branches.

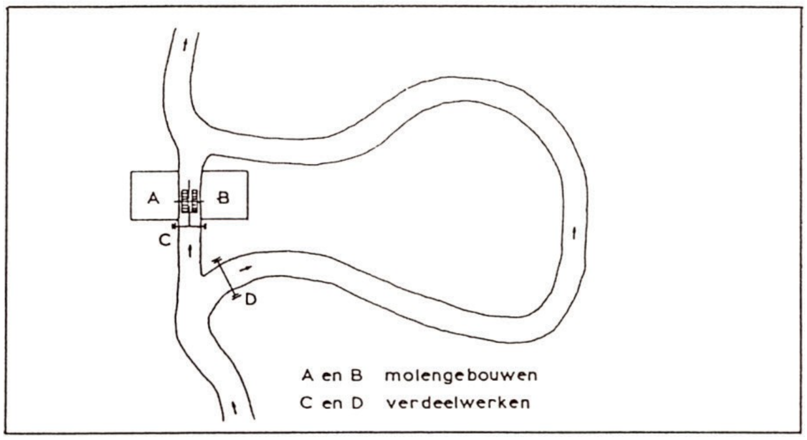


Fig. 9.3.3.2
This mill was built on a sharp bend in the river.

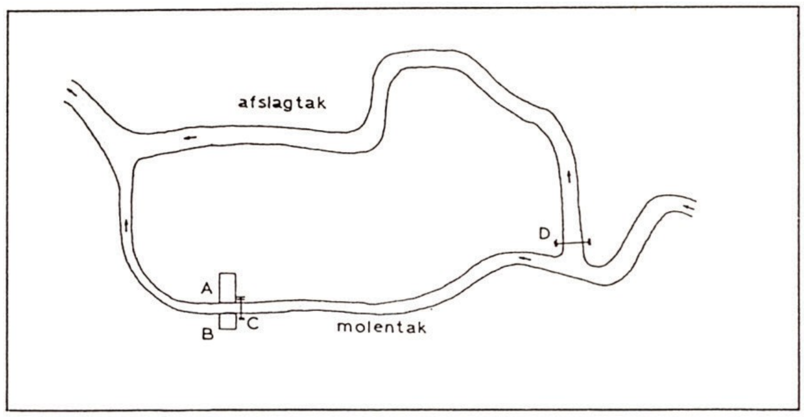


Fig. 9.3.3.3
In front of this mill, a mill race was dug parallel to the river.

9.3.3.d At a reservoir pond

For small streams, usually with a large gradient and making use of springs, one or more mill ponds were constructed in front of the mill. This is where water can be collected and dammed.

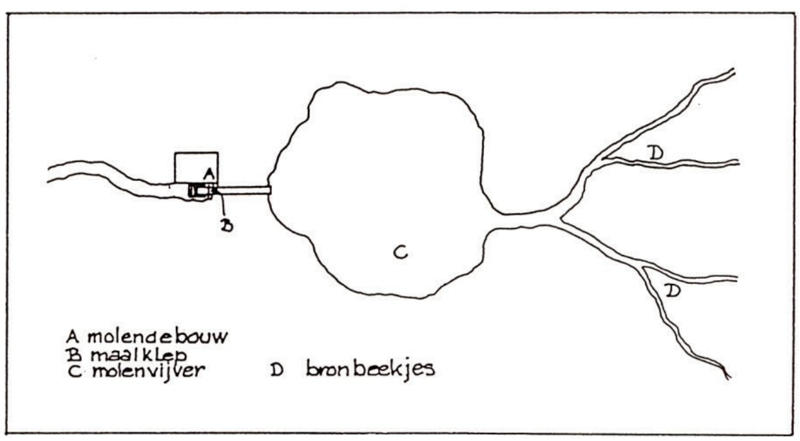


Fig. 9.3.3.4
A reservoir pond was constructed in this stream.

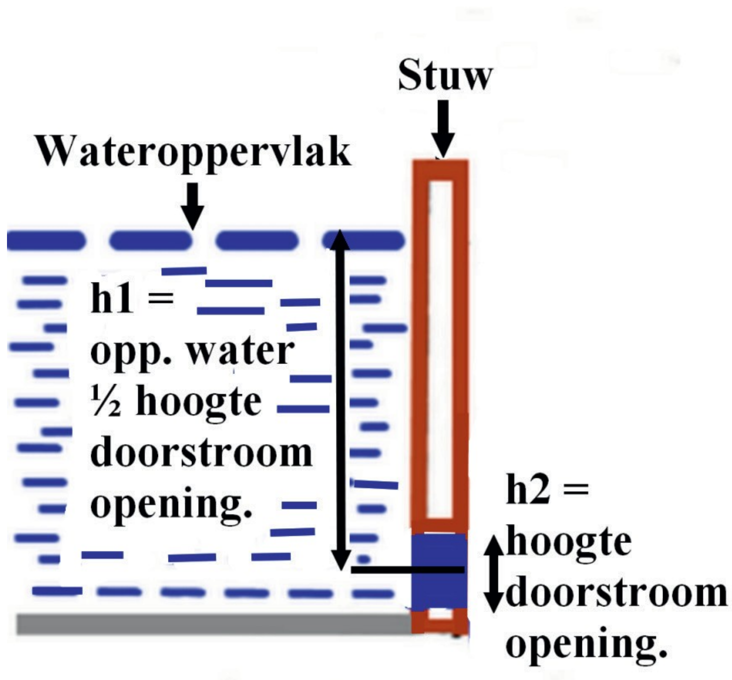
9.3.4 Water flow rate

water flow rate

The water flow rate is the amount of water flowing per unit of time through a plane (for example, an opening in a weir or the bed of a stream).

The water flow rate can be divided among the water use of the wheel and the supply of the stream.
The water flow rate that matters most to the miller is the flow rate for driving the waterwheel, that is, the water flowing through the inlet sluice.
The second thing the miller wants to know is how long milling could be possible with the current supply of water. For this, the miller needs to know the flow rate of the stream.

9.3.5 Flow rate of a waterwheel



Torricelli's law, a derivative of Bernoulli's law, is used to calculate the water flow rate. (Note: Being able to calculate the water flow rate is not a subject on the exam.)

We first calculate the velocity V of water flowing out of an opening in a weir at a constant water level.

The formula for this is: $V = \mu\sqrt{2gh_1}$ (√ is the root)

- V is the velocity of the outflowing water.
- h_1 is the water level measured from the water surface to halfway up the height of the lower opening of the outlet.
- g is the gravitational force, which depends on the location on the earth.
In the Netherlands, the g-force is 9.81 m/sec^2.
(At the equator it is 9.78 and at the North and South Poles it is 9.83. This difference is caused by the earth's rotation. The peripheral speed at the equator is 1,674 km/hour. In the Netherlands it is 1,030 km/hour and at both poles it is 0 km/hour. This peripheral speed produces a centrifugal force that reduces gravity.)
- μ is a correction factor: due to friction and swirling, the edges of the outlet have

an inhibiting effect on the velocity of the outflowing water. Therefore, the flow velocity of the water must be corrected by the factor μ = 0.95 to 0.99, depending on the shape of the opening.
Using the flow velocity of the water, we now calculate the flow rate — in other words, the amount of water flowing through the outlet opening per unit of time.
Flow rate Q = flow velocity of water x area of outlet opening.

As a calculation example, we assume the following situation:
- an average water level $h_1$of 1.30 m. (= height of the water surface to halfway up the height of the lower opening of the outlet).
- a sluice with an opening width of 0.90 m.
- a height of the (lower) outlet opening $h_2$of 0.20 m.
To arrive at a result in cubic metres, it is necessary to use the unit metre for all sizes. So an outlet opening of 20 cm height becomes 0.20 metres.

The flow velocity is: $V = 0.95\ \sqrt{2 \times 9.81 \times 1.30} = 0.95 \times 5.0503 = 4.7978$ m/sec.

The flow rate Q is the amount of water flowing through the outlet opening.

$Q = V \times \text{width} \times h_2 = 4.7978 \times 0.90 \times 0.20 = 0.8636\ m^3$/sec.
Rounded up, this is approx. 52 m^3/minute.
Thus, approximately 52 cubic metres of water flow through the inlet sluice per minute.

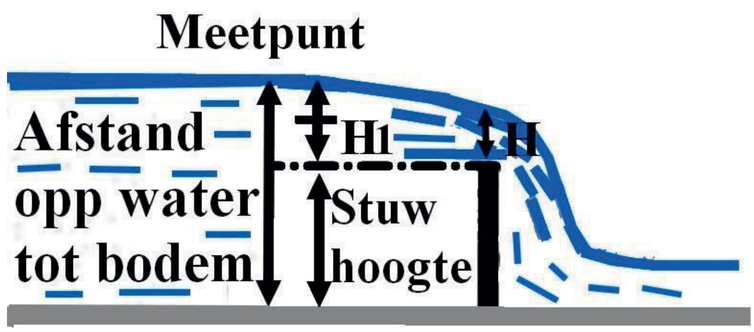
Fig.9.3.6.1
A remote electric sluice operated by the water authority.

9.3.6 Flow rate of a watercourse

Determining the flow rate of a watercourse is done at a weir. There are two options here:
- It is a weir with sluices;
- It is a fixed weir over which the water runs.

Calculating the flow rate at a weir with sluices is the same as calculating the flow rate for a waterwheel: in other words, flow rate x surface area of the sluice.

To calculate the flow rate at a weir over which water flows, basically the same formula applies as for calculating the flow rate of a waterwheel.
For practical reasons, however, the formula used deviates from the one used for a waterwheel (see note below). Use is made of a single value h measured above the weir. The value 0.99 is used as the correction factor μ because the opening above the weir does not have a top, reducing the braking effect.
In general, there will be no disturbances above the weir. In the width, however, there may be disturbances such as beams for bridge supports. We must then add up all the undisturbed openings to arrive at the total undisturbed width.



For those interested, here is a sample calculation. Suppose the water height h = 0.15 m and the (undisturbed) width b = 2.40 m.

The flow velocity is then:
V = 0.99 √ 2 x 9.81 x 0.15 = 0.99 x 1.755 = 1.6984 m/sec.

The water flow rate Q is then: flow velocity V x area of water flow opening. Q = 1.6984 x 2.40 x 0.15 = 0.611 m^3/sec. Rounded, this is: 37 m^3/minute.

This calculation shows that in the above situation the waterwheel has a flow rate of 52 m^3 per minute while the watercourse has a flow rate of 37 m^3 per minute. Since the flow rate of the watercourse is smaller, a reservoir pond is necessary!

Explanation:
To calculate the flow rate of a watercourse, we must basically use 2 heights, specifically h_1 and h_2.
A problem for establishing h_1 is that over some distance upstream of the weir, the gradient is stronger and thus the flow velocity is also stronger.
The height h_1 should therefore be determined well in advance of the weir. To this end, we measure the water level from the bottom to the surface. From this we then subtract the weir height. The result is h, the theoretical water level above the weir without the sloping water surface. We then take half of this to calculate the value h_1.

The problems with this approach are:
- The bottom must run purely horizontally between the measuring point and the weir.

- The measurement should take place in the middle of the flow. This area is often poorly accessible.
The choice for the value of the column h_2 relies on:
- The fact that water columns are generally small.
- The column above the weir is smaller due to the steep fall. As a result, the difference with half of the value h will be slight.

In addition, climatic influences, such as prolonged rainfall or dry periods, result in large changes in the flow of the watercourse. Thus, the flow rate calculation is a snapshot in time.

9.3.7 Tail water

tail water

Sluices in the weir at the mill allow the level of the upper (head) and lower (tail) water to be regulated. The tail water is the part behind the mill and is characterised in many mills by the mill pool. When a mill suffers from high tail water, the water in the apron is higher than the bottom of the floats. (creates a backwatering situation)
This can have several causes:

1. The gradient is too low, causing water to drain too slowly.
2. Damming is done at a downstream mill which results in the water behind the mill not being able to flow away sufficiently. To resolve this, arrangements will have to be made for weirs at the mill located below.
3. There is silting/contamination of the mill pool. This can be solved by cleaning and dredging. Keep in mind the time of year in connection with frogs and the like hibernating in the dredging layer. Do it in stages so that creatures in the water can find refuge.
4. By lowering all or part of the sluices, the water rises above the mill. This could potentially lead to (partial) flooding of the banks of the stream or pond and a rise in the tail water.
5. The situation is due to the levels established by the water authority. This is what occurs with the Singraven mill, for example, because the mill pool level was raised by 30 cm in 1990. After about one hour of milling, there is a tail water situation.
6. Abundant rainfall results in insufficient flowing away or drainage of stream water.

9.4 SLUICES OR LOCKS

sluices, locks
weir

Sluices — also called locks in certain regions — are usually wooden gates, installed in a weir. The weir is a structure in a stream to raise the water level and thus create fall.
Parties interested in the proper functioning of the sluices are the mill owner as well as upstream and downstream landowners. And if several mills are located along that stream, these, too, have an interest in the proper functioning of the sluices. Involvement of all these parties will ensure proper water management of the entire stream.
If the sluices are in poor condition, the water management can be completely disrupted in the event of a sudden breach. Downstream you have a chance of flooding. Upstream, there is a risk of severe water shortage with detrimental effects on the banks and the fish stocks. The weir (truss, sluice work, guideway) does not belong to the mill but is the responsibility of a water authority.

weir, truss, sluice work
guideway

Every miller must be able to operate the sluices. Therefore, we briefly describe how the weir is basically constructed. In practice, though, many versions are seen.

Fig. 9.4.1.1
Wooden wing walls (abutment sidewall) behind the weir. Behind the inlet sluices, these are fitted with boards.

The Stone Table – Borculo

9.4.1 The weir

main beam, sill
sill threshold

A weir is built across the stream or head race. In the simplest case, a row of piles is driven into the ground and a heavy ground beam, the lower main beam (sill, sill threshold), is laid on top. If it was possible to work in the dry creek bed, a masonry wall to which the lower main beam was attached was also sometimes constructed.

sluice post, lock strut, lock post
lock beam, cross beam

Attached vertically to this were a number of sluice posts (lock struts or posts) that were connected at the top by the upper main beam (lock beam, cross beam). The main beams and outer lock beams are fixed in both banks.

apron

This entire framework (sluice frame) has traditionally been referred to as the apron. The name 'apron' is also used for just the water guideway behind an inlet sluice.

wing walls (abutment sidewall)

apron wall

For reinforcement, upstream and/or downstream wing walls (abutment sidewall) were installed that were connected to the sluice posts or main beam. The sides of a wing wall behind an inlet sluice were closed with boards. The wing walls also served to attach the outboard bearing of the mill shaft. Wooden wing walls are by no means encountered at all mills. At many mills downstream of the weir, we see one or more masonry or concrete apron walls on which the mill shaft is mounted.

Fig. 9.4.1.2
A brick apron wall
In the concrete apron is a step. On the right is the former Hofkens Mill.

Leeuwen Mill – Maastricht

leaching (washing out)

apron, stilling basin

inlet sluice (control gate, shut)
spillway gate (by-pass sluice)

To prevent washing out of the soil in front of the weir, a so-called case, into which loam was poured and tamped down, was initially constructed. Later — in front and/or behind the weir — a wooden or concrete floor was installed.
In a concrete floor, a hollow form in which the floats turn was sometimes made at the location of the waterwheel; this limited water loss.
The lower part behind the weir is the stilling basin (stilling basin).
Here the concrete floor slopes slightly, sometimes in steps to speed up the flow of water behind the wheel.
A weir contains one inlet sluice per waterwheel or turbine and, in addition, one or more spillways (by-pass sluice).
Upstream, the mill bridge was laid across the wing walls.

upper weir, upper sluice
weir gate
trough, flume
spillway, overflow

In mills with a mill pond, there is a guideway (upper weir) above the mill with an upper sluice (weir gate) that allows the mill pond to be filled. Near the mill is a sluice gate that allows water to be directed from the pond into the flume. The mill pond has a spillway or overflow to the stream to prevent flooding the pond.
Mills located on a cut-off branch (mill race) of a stream have a second guideway upstream to distribute water between the mill race and the stream.

9.4.2 Operation

Operation of the sluices is done in several ways. Because of the weight of the sluices and the pressure of the dammed water on the sluices, manual power is usually insufficient.

Fig. 9.4.2.1
A timber lever to open the sluice. The pivot wood serves as a pivot point.

9.4.2.a A timber lever and pivot wood.

timber lever
pivot wood

The timber lever is used as a lever to open up the sluice. The pivot wood is used as a pivot point in this process. The pivot wood is also used to close the sluice.

Fig. 9.4.2.2
A pull.

pull

9.4.2.b A pull

This is a wooden lever that can be operated in the mill, such as with a block and tackle. The lever is similar to a brake pole at a windmill. Between the lever and the inlet sluice is a wooden lever for pushing the sluice closed as well.

bottom hatch, shuttle

A pull is also used to operate the bottom hatch (shuttle) in the flume for an overshot wheel.

Fig. 9.4.2.3
Operation of a pull in the mill.

9.4.2.c A winch operated sluice gate

Fig. 9.4.2.4
The sluice is operated by winch or windlass.

9.4.2.d Electric operation

Fig. 9.4.2.5
The sluice is operated electrically.

Sluices are sometimes operated electrically, including those in an upstream guideway. The same is sometimes true of a sluice in a fish ladder. Electrically operated weirs are often operated from a central control room of the water authority but also by sensors (for example, at the Elisabeth Mill). Sometimes, however, such a weir can be operated from the miller's house, as at Oldemeule Mill.

9.4.2.e A threaded spindle

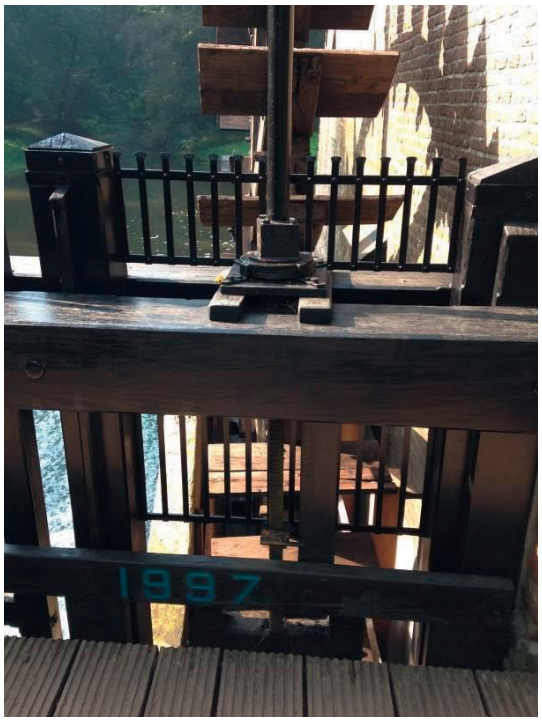


Fig. 9.4.2.6
The sluice is opened and closed with a threaded spindle.

9.4.2.f A rack-and-pinion

crank, crank handle

Either a handwheel or a crank can be used. A crank (crank handle) can be taken inside to prevent unwanted use.

Fig. 9.4.2.7
Operation with a rack-and-pinion

9.4.2.g A lever

Fig. 9.4.2.8
Operation using a lever.

9.4.2.h Manual operation

Fig. 9.4.2.9
Manual operation.

Fig. 9.4.2.10
Manual operation or using a timber lever (lifting lever).

9.4.3 Dealing with sluices

The importance of properly functioning weirs and sluices is more far-reaching than just for the mill: there are many interested parties.
These include:
- The miller, to have sufficient water at their disposal.
- Millers of two back-to-back mills can affect the operation of each other's mills. The miller of the upper mill can hold up the water so that the lower mill receives less water. The miller of the lower mill can push the water up so high that the wheel of the upper mill suffers from high tail water (back watering) and loses considerable power due to the counterpressure.
- Upstream residents. Some mills were prohibited from damming water between 15 March and 15 October. This allowed the higher located river banks to dry out, allowing green fodder for livestock and other crops to be grown. For that reason, these mills are also referred to as 'winter mills'.
- Downstream residents. Damming can result in too little water, causing farmland to dry up.
- Water authorities also have an interest in properly functioning sluices.

The failure of sluices to function properly should be reported to the water authority as soon as possible.

Today, there is an increased appreciation of the significant role of watermills in preventing drought in the landscape. Many weirs held the water in an area for longer, which had a beneficial effect on the level of ground water (see section 9.6).

9.4.4 Undercutting

undercutting

Undercutting is the washing away of the ground under the apron and the foundations of the mill building.
This can be caused by:

seepage water

- Seepage water flowing under the weir.
- The scouring effect of crashing water when sluices are raised.
- The use of wooden piles as foundations instead of solid natural stones. When the water level drops and the wooden piles are above the water surface, they rot.
- The quality of maintenance. Even a well-built or restored mill will soon suffer damage if it is poorly maintained.
- The improper dredging of waterways.
- The permanent pressure of the water.
- Animals, such as water rats.
- Prolonged high levels of the tail water saturate the body of soil under the mill with water; a sudden lowering of the water level causes the body of soil to sink. However, due to the water authorities' current water level management, this is no longer a common occurrence.

Undercutting by seepage water can be mitigated by using seepage water screens. These are placed in the ground along the mill.

9.5 THE WATERMILL BIOTOPE

By this we mean the surroundings of the watermill including what lives in it and the processes that take place in it. It is important for the miller to know how the work with the watermill and what takes place in that environment can influence each other.

9.5.a Debris

It is vital to keep watercourses clear of branches, leaves, debris and dead animals, both upstream and downstream. This is to ensure the proper supply and drainage of water.
After all, if the waterwheel is suddenly blocked by bulky waste, this can destroy the cogs and staves of the running gear and displace the central spindle or the waterwheel shaft.
In addition, branches and debris thrown into the water can cause damage to the waterwheels.
To stop large floating objects such as logs and heavy branches, a floating barrier of logs is often installed in front of the mill. Upright spars (spruce poles) are also sometimes placed in the stream bed. The disadvantage of floating beams is that wood can fill up with water until it no longer floats.

spar (spruce pole)

Often one of the flood gates is also slightly lowered, allowing debris to wash away over it when damming.
To prevent the ingress of water contaminants, an iron or wooden sluice grille (weed rack) is installed in front of the inlet sluice with bars or spars placed as close together as possible. Turbines, in particular, place high demands on clean water so a finer sluice grille is needed.

sluice grille
weed rack, grating, mill-grate

Floating and drifting objects are stopped by this. A pick hook (dung hook or rack cleaner) should be used to regularly remove the trapped debris to prevent the grille from collapsing under the water pressure. Also, as a result of accumulated debris, the water passage will decrease, resulting in the wheel receiving an insufficient amount of water.

pick hook, dung hook, rack cleaner

If the sluice grille is not accessible because it is under a bridge deck, for example, it is usually at an angle to the sluice and located next to a by-pass sluice or spillway gate.
By opening it, the collected debris is removed by the flowing water.

scouring sluice

9.5.b Prolonged rainfall

Prolonged rainfall may require the miller to open the spillway to discharge excess water. This is insofar as there is no electrically operated sluice in a bypass channel operated by the water authority.
The miller should pay attention to:
- extra debris, to prevent clogging;
- undercutting.

9.5.c Amount of precipitation

This can, of course, be measured with a rain gauge. However, what is more important is the amount of precipitation upstream. After all, the local

precipitation has probably drained by now but precipitation further upstream is on its way.
For the Netherlands, daily precipitation from 167 stations can be found at the KNMI website.

9.5.d Separating clean and dirty water

Some mills require clean water for production, such as paper mills.
If these are adjacent to the same stream/spring, a partition is placed in the middle of the stream or artificial stream. This partition allows for the upper mill to discharge polluted water (often due to dyes) on one side of the partition while clean water flows on the other side.
At the lower mill, the wheel is then driven by the polluted water while the clean water is used for production.

Fig. 9.5.1
Separation of clean and dirty water.

9.5.e Frost

Waterwheels are often frozen solid to the underside of the apron due to leaking water from the inlet sluice. Also, the sluices themselves may be frozen solid.
The necessity to continue production hardly occurs these days. It is therefore safer to wait for a thaw.
Should it nevertheless be necessary, you can:

ice chisel

- for wooden wheels, try using an ice chisel and hot water to free the wheel.
- for iron wheels, attempt to loosen the wheel with a gas burner, then —
- if the inlet sluice is still movable — a little running water may be enough to thaw the rest.

When doing this, you must be careful not to turn the wheel before all the ice is removed from it.
When there is a lot of ice on the floats and rim, turning is out of the question from a safety standpoint. Furthermore, millers should beware of frozen clothing and slipping while working. For safety reasons, you should always work in pairs (see chapter 10, Safety).

9.5.f Ice breakers

To prevent ice floes from entering the wheel, ice breakers are often installed in front of the weir. These lie in front of the inlet sluice in the direction of flow, preferably with the head under water.
As the water flows, the ice is then pushed up against the ice breaker and is broken up.

Fig. 9.5.2
Ice breaker

Wassermühle – Lage (Germany)

9.5.g Mill pond

When milling, care should be taken not to lower the water table of the mill pond too much.
If the water in the pond drops too low, the banks can be damaged by the depletion of groundwater for plants and fish may die from lack of oxygen. This overdraining is also sometimes prevented by a fixed weir in the opening from the mill pond to the sluices. The top of this weir is then equal to the minimum level for the mill pond.

9.5.h Fish ladder/ fish passage

Fish naturally migrate through streams and rivers. They do this to reproduce in the headwaters and to find food.
However, a weir blocks their passage. Construction of one or more fish ladders, also called fish passages, allows fish to pass a weir.
Baffles, made of natural materials or concrete or other obstacles, are placed in it. This artificially increases the length of the ladder and reduces the flow velocity. The resulting 'steps' between the baffles have a difference in water height of about 8 cm between the beginning and end of the step.

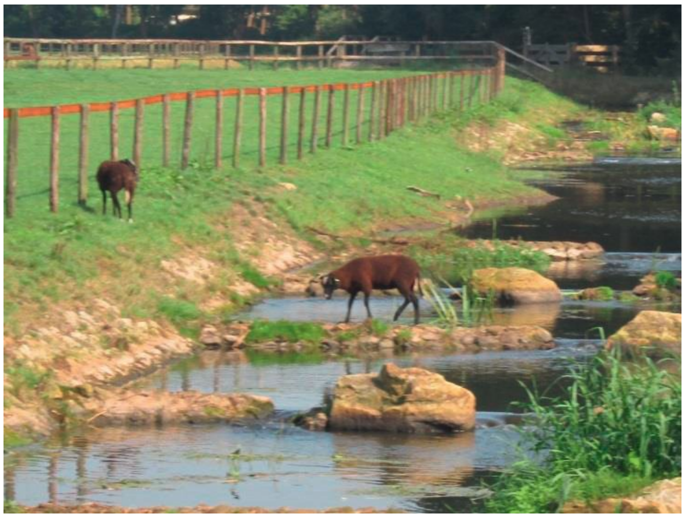


Fig. 9.5.3
Second fish ladder at the Oostendorper Watermill.

So the number of steps and/or ladders depends on the height difference of the water on either side of the weir.
Fish intuitively swim against the current, which is why fish are lured to the fish ladder using a current. By ensuring that the flow from the fish passage is stronger than the flow from the weir, fish are lured to the fish ladder.
The disadvantage here is that the flow of the stream is used to a (large) extent by the fish ladder; this leaves the mill with less water and thus less power.

9.6 WATERMILL LANDSCAPE AND WEIR SHADOW*

Watermills have been of much greater significance to the stream valleys in the Dutch regions of Overijssel, Gelderland, North Brabant and Limburg than had always been thought. As such, not only does the mill as an object have special value as heritage, but the surrounding area is also emphatically part of that heritage. The term 'watermill landscape', which encompasses heritage and water as well as landscape and nature, is used for this.

watermill landscape

9.6.1 Watermill landscape

A watermill landscape is a scenic, cohesive, and often a culturally and historically valuable area consisting of the watermill, associated weirs and outbuildings as well as the dammed stream and other waterways. It includes the ancient road and settlement patterns associated with the mill, but also the area in the stream valley upstream of the mill that is directly or indirectly influenced by the dammed stream, this being referred to as the weir shadow or the hydrological sphere of influence.

weir shadow

9.6.2 Mill biotope

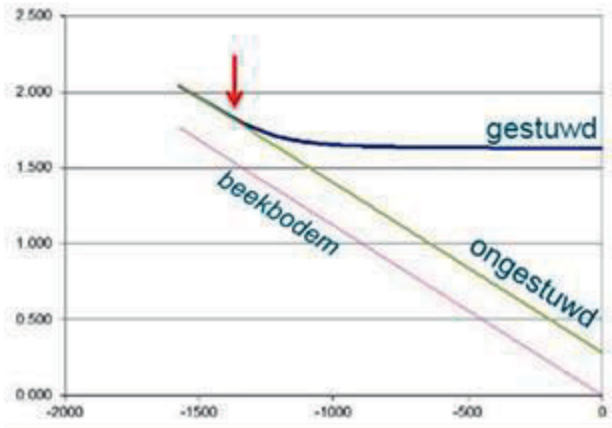
The mill biotope includes all built water and business-related heritage such as the main and ancillary buildings of the mill and weir works, as well as the mill stream, cut-off branches and any reservoir ponds or water meadows.
However, it also includes certain land uses (orchards, pastures) and infrastructure (stream crossings, access roads) that are clearly linked to the mill. It is primarily these scenic elements and land uses that may also be located outside the hydrological influence of the mill.
The biotope, then, is part of the watermill landscape. The latter, however, is often a more broadly defined area because it includes the area of the weir shadow. Especially in areas with relatively few relief differences, the size of the watermill landscape can reach dozens of hectares.
Thus, the extent depends on the geomorphological features of the landscape in which the mill is located, but also on the impoundment (damming and storage) of the water near the mill. (Geomorphology is the science that studies the forms of the landscape and the processes that play or played a role in its formation.)

The weir shadow refers to the hydrological influence that the mill and its weirs exert on the surface water and groundwater system. The impact at stream level is plainly visible. However, the increased stream level also affects the adjacent river banks (valley plain) by increasing groundwater levels there. This is usually much less conspicuous, but highly relevant to land use.

9.6.3 Weir shadow

To determine the weir shadow, the first thing to establish is the degree of impoundment on the stream course upstream of the mill weir, also referred to as weir curve (backwater curve). For establishing this, first of all, the impoundment at the mill must be known (the difference between the lower and upper water levels).

* Section 9.6 is not part of the exam material.



Other factors are the gradient of the stream bed, the average discharge and the so-called roughness of the stream. Of these factors, the stream's gradient is the most decisive. In a hilly landscape, the impoundment effect of a mill upstream simply extinguishes itself more quickly than it would in flatter lowlands (for example, in the Netherlands, the mills on the Dommel river near Eindhoven were located further apart than the mills on the Jeker river in Maastricht).

To determine the gradient, the starting points are the elevation of the stream bottom far upstream of the mill weir and a stream bottom elevation some distance downstream of the mill.
To determine the point to which the impoundment effect of the mill is noticeable under average discharge conditions, the course of the water level in the stream in an undammed condition must also be calculated.
The zero point is then the point upstream of the mill weir where both calculated lines meet. Note that the degree of impoundment shown in the graph says nothing about the actual water depth behind the weir. It may be less due to (centuries of) silting up and filling of the stream and stream valley.

However, there is one more aspect that helps determine the position of that zero point, and that is the roughness of the stream in question. That roughness is a reflection of the nature of the stream. Some streams are channelled with a uniform bed and banks. Others have a much wilder character.
The erratic nature of the banks, the presence of bends and sedimentations, but also the vegetation or even tree trunks in the stream affect the passage of water in the bed. The more erratic the stream, the more resistance (roughness) the stream water experiences, which ultimately causes the effect of damming to continue working further upstream.

The final step is to actually determine the boundaries of the weir shadow based on the previously calculated gradient of the weir curve (backwater curve) to zero. This water level is related to the ground level elevation in the stream valley, after which the drainage can be determined. By this drainage is meant here a water level below ground level at the river banks, often meadows or forests, that corresponds to the (raised) water level in the stream.
In practice, groundwater in this adjacent zone is often somewhat higher because there is almost always some groundwater bulge (outright marshy conditions may occur).

However, the height of that more or less elevated bulge is partly determined by the elevated stream level, but that effect on water levels tapers off upstream.

To determine the extent of the weir shadow, a standard drainage of up to 1.5 metres below ground level was used. The choice of this is pragmatic and dictated by the fact that most stream valleys contain soils which contain loam, clay and peat. These have the potential to deliver substantial groundwater from the subsurface to the ground level.
When the drainage is greater than 1.5 metres below ground level, groundwater is considered to be so deep below ground level that it no longer exerts a significant effect on the river bank areas. This means that the impact of elevated groundwater levels on habitat conditions and thus land use is negligible.

Because weir elevation is so important in determining weir shadow, historic mill levels should preferably be used to determine the watermill landscape. Only then will the historic watermill landscape come into proper focus and also serve as a reference situation for spatial planning.

The elaboration of the watermill landscape outlined above is primarily geared to breastshot and undershot mills. For overshot mills located on the headwaters of a stream and working with guided streams and/or stock ponds, the elaboration differs in parts. Often, due to the more steeply sloping terrain, the weir shadow in this case is less than in the lowlands. On the other hand, the mill biotope may be considerably larger, such as in the case of the presence of artificial streams.

In addition, for overshot mills that rely entirely on mill ponds for their water supply, the minimum flow rate should be defined as the amount of water needed to refill the mill pond(s) at night. The flow rate required for this must be established. Based on that (average) flow rate, the overall size of the infiltration area required for this can then also be calculated and delineated on a map. The infiltration area is the area where the required amount of rainwater sinks into the ground to supplement groundwater run-off to the respective stream.

9.6.4 Examples of watermill landscapes at various streams

Fig. 9.6.4.1
The watermill landscape (purple) of the St. Ursula or Leudal Mill on the Leubeek (Leu stream) near Nunhem in the Netherlands. The relief-rich stream valley produces a narrow watermill landscape. The weir shadow extends up to the mill upstream (the Elisabeth mill).
In the watermill biotope (green), protrusions are formed by the access roads that belong or used to belong to the mill.

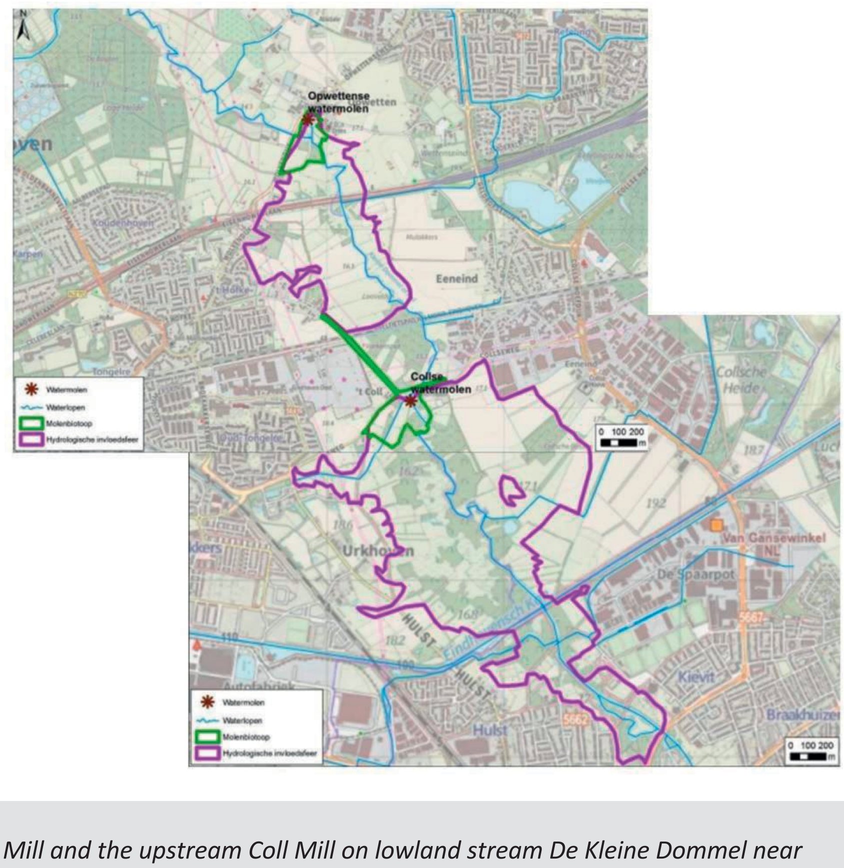


Fig. 9.6.4.2
The watermill landscape of the Opwetten Mill and the upstream Coll Mill on lowland stream De Kleine Dommel near Eindhoven. It can be clearly seen that the watermill landscapes fan out much wider through the flat landscape. Straight borders and sharp corners indicate raised land!

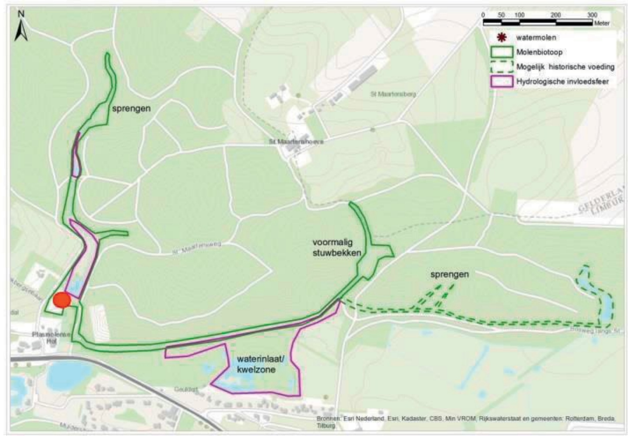


Fig. 9.6.4.3
The watermill landscape of the Upper Plas Mill on the Molenbeek river near Mook, located in the Sint Jansberg area. Here there are artificial streams and stock ponds.

9.6.5 Example of changing landscape due to the disappearance of mills and their weirs

There are still a few mills on the Jeker river in Maastricht, but there were as many as 8 with a total of 10 wheels. With the disappearance of the mills and especially their weirs, the water of the Jeker is no longer retained in the landscape; it now flows rapidly into the Maas river.
The accompanying maps (see Fig. 9.6.5.1) show the drainage of the landscape, with the colours indicating groundwater levels; from more than 5 metres below ground level (very dry) to light blue, where groundwater is at ground level (very wet).

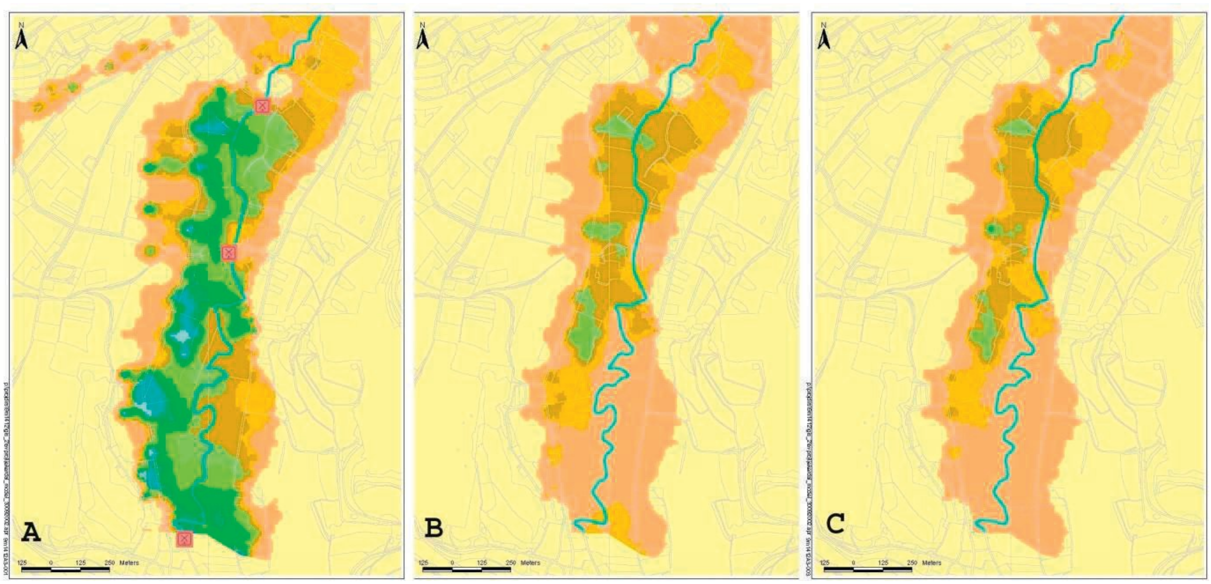


Fig. 9.6.5.1
a) 1850-1900 (b) circa 1970 (c) circa 1995

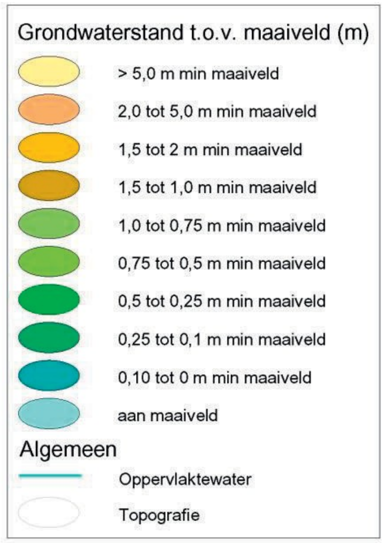


Fig. 9.6.5.1.a
Legend to Fig. 9.6.5.1

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NOTES

Chapter 10 Safety

Contents Page

10.1 INTRODUCTION

In a watermill, people work with retained or free-flowing water and with large wheels rotating outside the mill or completely built-in turbine installations.
True, these wheels are generally placed behind the weir bridge railings, but these railings are often used as monkey bars with the added attraction of the water thundering through the weir.
Children, especially, like to climb on them or be put on the railings by those in charge of them to get a good view of everything. This is life-threatening, however, especially if done during busy holiday periods with many interested parties around the mill. When appropriate, point this out to those in charge of children.

Unfortunately, we still hear too often of accidents at mills. And those are only the major accidents or fires — which are sometimes even fatal.
Like in the recent past when a miller, while actually installing safety devices for the inflow of the waterwheels, fell in the water and ended up in front of the waterwheel.

Anglers sometimes go so far as to stand on the wing walls next to the wheels to catch a fish from the flowing water. Now this is not exactly a model of sensible action as all it takes is one accidental step backwards and the fishing party is over, at least for the day.
Actually, the entire water works should be off-limits to third parties and especially so when the mill is in operation. This obviously does not apply to the bridge deck between the railings if — as in almost all cases — it belongs to the public road.

Even if a mill is not in operation, it can still pose some dangers to the miller and visitors. You need to keep in mind that generally mills are structures varying in age from old to ancient. In the Netherlands, fortunately, mills are in a reasonably good state of repair. But it is precisely from that position that a dangerous situation can arise through over-reliance on this good condition.

A well-maintained mill is a first step toward safe operation.

Small causes often have big consequences. For example, a nostalgic-looking staircase with deeply worn steps is a part of the mill that nevertheless does require attention from a safety standpoint. The same goes for the floors (including the beams underneath) but also for the various floor openings such as spindle holes and also the uprights of the half-timbered construction, etc.

Access doors to the mill must be able to be closed and adequately locked.
For watermills, it is vitally important that the bridge railings be in good condition. However, do not sit on them: you can easily fall off if startled by something!

You have to consider your own safety and that of others, as well as that of the mill. Preventing accidents and working safely is primarily a question of mindset. If you are not willing to work subject to the observance of some safety precautions then

sooner or later this is likely to have consequences.
The tools to be used must, of course, be in good condition; safe climbing equipment is necessary for work at higher elevations. In addition, knowing what to do if medical help or the fire department must be alerted as soon as possible can be vital.

The operation of the mill and the machinery located within it is to be carried out only by trained persons designated for that purpose. Only they are aware of the special requirements for the particular mill and the agreements that have been made.
As for the miller and other volunteers, they should exercise the utmost caution in various activities and especially so when lubricating shafts and/or machinery.

It may seem obvious but smoking and open fire are two things that must not occur in a mill!
If open fire is absolutely unavoidable for some work activities, then a fire inspection should be conducted afterwards or when leaving the mill. Attention is also given to the fact that, when thatching mills, more and more often the so-called spread course is omitted. In that case, the most flammable part of the thatch (in other words, the plume) often protrudes from the thatch on the inside!

If there is a lightning conductor installed on the mill it must be in working order. It should be checked at least once every two years. A free check can be requested from the Lightning Conductor Control Working Group of the Guild of Millers.

Fig. 10.1
This post of the mill's half-timbered structure is in dire need of maintenance.

The following chapters cover all safety aspects. Because of the often unique location, construction and design of watermills, each miller must determine for themselves whether specific additions are needed for their mill.

10.2 MAINTENANCE STATE OF THE MILL

10.2.1 The mill building

What is the structural condition of the building?
Is the masonry of the buildings in good condition?
Is the masonry or brickwork of the walls still stable and showing no cracks, either internally or externally? The wall on the watercourse side deserves special attention. Is the foundation checked regularly at low water levels?

undercutting

Is the mill regularly checked for undercutting?
What is the condition of the roof structure? If covered with tiles: what is the condition of the tiles and the nailing of the ridge tiles and straw bundles (straw dollies)?

straw bundles
straw dollies

Fig. 10.2.1.1
Here the straw bundles are in good condition.

spread course

When laying new thatch, a so-called spread course must be applied under the actual thatched roof.

10.2.2 Floors

What is the condition of the support/tie beams and the supports and of the floor joists, floorboards and any floor hatches?
Are the stairwells and openings adequately shielded so that people or materials cannot fall down?

sack hoist hatch

Sack hoist hatches should fall shut by themselves.
Installing chains under the hatches prevents them from falling open completely. After the sack of meal stock has passed through, they then fall shut by themselves.
Installing wooden blocks on the floor as a solution to this problem carries the danger of tripping over them and is therefore not recommended. In any case, do not apply them in (or near) walking routes.

Fig. 10.2.2.1
Note!
Hatches must always be closed when not in use.

Do the wood floors have sufficient bearing capacity and are they not weakened by woodworm?
Are the walkways adequately shielded and do they have sufficient load-bearing capacity?

10.2.3 Staircases

What condition are the stair stringers, stair steps, handrails or ladder ropes, ladder stiles (stringers or rails) and rungs in? Are they still attached properly? Are the steps not overworn?

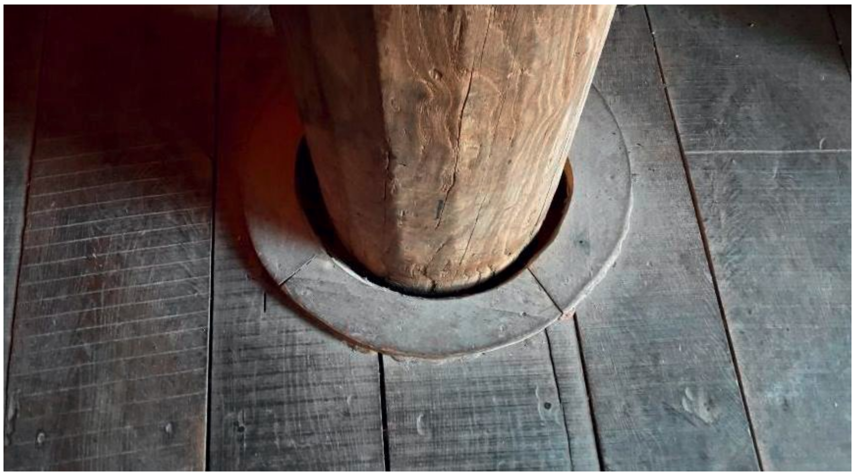

Fig. 10.2.4.1
Shielded spindle or central spindle opening.

10.2.4 Shielding floor openings

Are the floor openings properly shielded?

10.2.5 Entrances

Are the mill doors sufficiently resistant to forced entry?
The hardware should also be burglar-resistant and have good locking capabilities.

10.2.6 Standing parts

What is the condition of the various spindle beams with the bearings located therein?
Are the joists below the mill stones or hurst frame(s) reinforced on site with notched beams, for example?
Given the relatively humid atmosphere in the basement storage space or cellar: What is the condition of the woodwork there, such as the sprattle beam, bridge tree and spindle posts?
What is the condition of the bearing seats and the supports underneath?

10.2.7 Driving gear

What is the overall condition of the various spindles, shafts and wheels? Is all machinery in good condition?

Fig.10.2.8.1
Are the sluices in good condition and easy to open and close?
Is the safety of bystanders ensured during operation?

10.2.8 The water works

What is the overall condition of the weir or mill bridge?
Is the weir itself capable of withstanding the maximum weir height of the water?
Are the by-pass and inlet sluices (also known as spillway and control gates) movable so that they can be opened and closed by one person?
If the weirs are equipped with a crank and rack-and-pinion operation or windlass, what is their state of maintenance and lubrication?

10.2.9 The waterwheel

What is the overall condition of the waterwheel(s)?
Is the mill shaft (or waterwheel shaft) in an acceptable condition?

10.2.10 The mill grounds

What is the condition of the paving and how is the rainwater drainage arranged?
Are the wells not clogged?
Is the fencing of the grounds properly constructed and in good order?

10.3 LIGHTNING CONDUCTOR SYSTEM

10.3.1 Introduction

Many watermills do not have a lightning conductor.
If this is the case, the installation must be done by a certified installer and connected according to the standards (was NEN 1014, since 2009 NEN-EN-IEC 62305). Lightning conductor systems constructed under the old NEN 1014 standard may still be inspected according to that standard.
The system should then be checked at least every 2 years.

Ensure that the system includes all large metal parts. Ensure that the lightning conductor system is properly connected at all times.
The Guild offers the lightning conductor inspection free of charge in addition to the periodic inspection of the mill by a licensed installer.
After inspection, you will then receive a measurement report with any repair recommendations. Members, as well as mill owners who are donors, can request this free lightning conductor system check via the Guild website.
Incidentally, this is conditional on having had repair recommendations from any previous Guild inspection duly carried out.

10.3.2 Ground electrodes

What is the condition and performance of the connection to the induction loop? Are the ground electrodes and connections to them made of copper (8 mm diameter or 50 mm^2)?

10.3.3 Grounding lines

Are the induction loops and outgoing cables properly attached?
Note for any damage: the cables must not be oxidized at clamp connections. For a wooden mill, there must be sufficient distance (min. 4 cm) between the cable and the wooden wall.
The bottom 2 metres of the outgoing cable must be protected by a pipe.

10.4 WORKING SAFELY IN AND AROUND THE MILL

10.4.1 Accident prevention

This chapter is mainly about safe working by millers. But many safety measures also benefit visitor safety.

10.4.1.a Habituation

For the miller, habituation (getting used to) is the greatest danger.
Although a mill is also a heritage building, it is first and foremost a machine from the past.
This function as a machine means that maintenance must be carried out much more frequently than is necessary for a purely heritage building, for example.
In the mill, dangers also lurk in the darkness of the basement storage space or waterwheel shaft cellar.
Due to the construction of the mill, it is virtually impossible to fit windows to this space. So proper lighting here is absolutely necessary.
The work regularly performed at and around the mill can vary quite a bit and includes both the recurring items — those pertaining to a working mill — and those necessary to maintain the mill.

Beware of tunnel vision: don't underestimate safety.

10.4.1.b Team of millers

When working in a team of millers, one miller should be in charge. This miller should oversee the work. In all work requiring the mill to be stopped, all millers present must be informed.

*Fig. 10.4.1.1
For more major work, it is recommended to insert a beam between the arms or spokes of the waterwheel.*

This is to prevent, for example, one miller from greasing the rotating parts and another from moving the water.

New volunteers at the mill should be well-informed about the applicable safety arrangements and special safety aspects.

10.4.1.c Hazardous work

During hazardous work, it is important to have several people present to assist and possibly render aid. Examples are opening up a pair of stones or dragging in a log with the windlass.

10.4.1.d Work in the vicinity of the waterwheel

Always stop the waterwheel. This also applies when lubricating. When conducting more major work on or near the waterwheel, insert a beam between the spokes or arms of the wheel.

Fig. 10.4.1.2
When working on or near the waterwheel, always stop it.

10.4.1.e Fall hazard when working on a narrow wing wall or apron wall

It may not be pretty, but even so, fencing will be able to provide safety when walking and working on such a wing wall or apron wall.

10.4.1.f Fall hazard when working on a wooden platform

A wooden platform between the wheels can be quite slippery. One possible solution is to nail fine chicken wire to it. Also, the application of chicken grit with a binder/preservative makes the surface less slippery.

10.4.2 Safe clothing

Do not wear dangerous clothing such as loose ties, scarves, wide sleeves or other loose clothing. It is best to wear something that is close-fitting all over. Or jeans with a matching jacket. Take care when wearing a jumper (sweater) near wheels: Knitting does not rip if you get caught!
Rings and jewellery can cause serious injuries!

Fig. 10.4.2.1
Loose or wide clothing poses a risk!
Jewellery can also lead to serious injuries.

Hands and feet deserve proper protection from cold and damage from rough and protruding parts. For that reason you should use good work gloves.
A safety helmet or hard hat protects the head from light impacts.
At mills where heavy material must be moved or rolled frequently, it is a requirement to wear safety shoes. Wood sawmills come to mind first but safety shoes are also not an unnecessary luxury to have when opening up a pair of stones at a grain or hulling mill. Safety glasses should be worn when sharpening a millstone.
Clogs or so-called Swedish mules are a widely worn form of footwear.

safety shoes

safety glasses

10.4.3 First-aid kit

Provide an approved first aid kit and other first-aid materials at the mill. Do the millers present at the mill know where to find the first aid equipment? Do they also know how to use it correctly?
Agree on who is responsible for regularly checking and replenishing the contents of the first-aid kit.

10.4.4 Phone & phone list

If there is no landline telephone at the mill always make sure there are one or

more mobile phones. Hang a list of phone numbers, including those of emergency services, out-of-hours GP services, other millers, etc., by the telephone or in another highly visible place.
This list should also include a clear address/location indication of the mill in the event of reports to emergency services.

Fig. 10.4.3
Hang the first-aid kit in a highly visible place.
Preferably, hang a fire extinguisher next to each entrance.

10.4.5 Open fire

Smoking is prohibited in the mill: is this clearly indicated?
Are there sufficient fire extinguishers present (in principle one extinguisher on each floor). Make sure they are of the correct type (water, foam, carbon dioxide, or powder) and in good condition (have them checked once a year!). Are foam extinguishers frost-resistant? Make sure the fire extinguishers are quickly and easily accessible.
Are millers familiar with the operation and handling of the available fire extinguishers?

Are there bins at the entrance for extinguishing cigarettes? Keep in mind that various types of heaters present fire hazards.
Are adequate fire prevention measures taken during activities that increase the risk of fire, such as welding, grinding, paint stripping, beeswaxing the cogs, etc.?
During such work, are the highly flammable materials and structural parts of the mill adequately shielded (for example, the inside of the thatched roof)?
Do not leave an operating burner unattended.
After completion of works that increase the risk of fire, a fire inspection round should be conducted.
Has there been any consultation with, or a drill run by, the fire department at the mill? A fire department that is familiar with the situation on site and with the mill building can save precious time!
The latter also applies to medical assistance and the ambulance.

10.4.6 Smoke detectors

If it is decided to install detectors, it is better to use heat detectors in grain and hulling mills because of airborne dust.
However, the usefulness of detectors is questionable if they are not connected to an alarm centre. They are then audible only inside the mill, and in the immediate vicinity of the mill provided the door and hatches are open. Therefore, if no one is in or near the mill, the alarm will not be detected. Since many watermills consist of one large room, if a fire is present in the mill, it is just as likely to be noticed without this detector. However, there is no harm in having a smoke detector.

10.4.7 Electricity

When leaving the mill at the end of the day, switch off the power. If you do need to keep something on, such as outdoor lights or acoustic mice repellents, make sure they are connected to one separate group.

KEMA quality mark

Use approved devices with the KEMA quality mark. The — often older — heater and refrigerator may not be defective.

10.4.8 Pest control

Many mills such as grain and hulling mills handle goods for human and/or animal consumption. Therefore, the use of acoustic repellents instead of poison is recommended for controlling mice and rats. Experience shows that, even though you cannot hear them, they do work. Several days after being plugged in, no mice or mouse droppings could be found!

Fig. 10.4.9.1
The pivot wood is secured, and the timber lever is inside to prevent unwanted use.

10.4.9 Weir and mill bridge

What is the overall condition of the weir and mill bridge?
Is the weir itself capable of withstanding the maximum weir height of the water? Are the by-pass and inlet sluices (also regionally known as spillway and control gates) operable such that they can be opened and closed by one person?

timber lever
pivot wood

Is the operating mechanism of the sluices (locks) working as it should? If the sluices (or locks) are operated with so-called timber levers, are there two of them at the mill, as well as the associated pivot wood? Always take the timber levers inside after closing to prevent unauthorised persons opening the gates. Are the inlet sluices lockable to prevent unauthorised operation?

10.4.10 Putting into operation

Ensure that there are no obstructions of any kind in or in front of the waterwheel before operating the mill.

Fig. 10.4.10.1
Weir:

The weed rack (left, angled).
The inlet sluice (behind weed rack).
By-pass sluices (right).

If the mill can be put into operation from the inside with a pull, first check that no one is on the wing walls or apron walls or can be caught by the wheels.
At a number of mills, there is a guideway upstream that millers can operate themselves. Before putting into operation, check that this works properly and that no debris has accumulated.

Fig. 10.4.10.2
Pull:

Check in advance that no one is present at the sluices.
A lockable gate and sign keep visitors away.

10.4.11 Working on or near the water works

No one should be on the wing walls or apron wall next to or between the wheels when the mill is in operation.
It should be a firm rule that you never lubricate the outer waterwheel shaft bearings when the mill is running.
If someone must be in the apron or wheel race — for example, to free a jammed waterwheel — always work with at least two people.

10.4.12 Miscellaneous

Has swimming in the immediate vicinity of the mill been declared illegal by a local municipal by-law?
Is there an agreement between the mill owner and the relevant water authority regarding water weirs and outlets for the benefit of the mill?

10.5 SAFETY OF VISITORS AND PASSERS-BY

10.5.1 Introduction

Many visitors to a mill come as a result of all the promotion done for it. Most millers are also in favour of this and accept it as normal. But this is not as normal as it appears. It is typically a development of recent years.
Previously, people were not allowed in mills or only by way of extreme exception, in the same way that factories are currently not open to everyone. Having brought it on ourselves, however, we should also take measures to make the visit as pleasant as possible.

Make sure you provide a welcoming reception and a tour with good explanations. And take the measures necessary for making the visit safe.
For visitors, a mill in operation is a most fascinating and educational thing to see. Receiving visitors during milling can also certainly be done responsibly.
But this requires taking more safety measures than is done when visiting a stationary mill.

As a miller, avoid paying attention to both the milling machinery and the visitors during a tour. If you are alone then it is better to give the tour in a mill whose waterwheel is turning 'for show' instead of a mill that is actually milling.
If you are together with another miller, divide the tasks: While one is conducting the tour, the other can continue milling. Or have a mill guide provide the tour. Depending on the design of the particular mill, it may even be desirable not to mill at all during part or all of the tour. The same is true if too many visitors arrive at the same time.

A miller is familiar with their mill and its safety hazards. For visitors, of course, this is not the case. They have little awareness of the risks. And the design and construction of mills did not take visitors into account.
Visitors should therefore be made aware upon entry of the risks they may face during their visit. This can be done with a brief verbal instruction and also by posting the rules for visitors at the entrance.

Special attention is required for visitors accompanied by children. Children are quite agile and very spontaneous in their behaviour. This can easily lead to accidents at a mill.
Critical advice is to make parents and/or chaperones aware of the safety risks present at the start of the visit and ask that they pay closer attention to their children than usual. They remain primarily responsible for their children's safety and behaviour during the visit.

Apart from working at the sluices or wheel where visitors are absolutely not allowed, many safety measures apply to both millers and visitors.

10.5.2 Moving parts

Moving parts in the mill that are within reach of visitors should be shielded or stopped when visitors are present.
Spaces that are restricted in size and contain hazardous (moving) parts should not be accessible.
The inlet and by-pass sluices, including the operating mechanism and the turning surface of the waterwheel, should be adequately shielded.

10.5.3 The mill grounds and its surroundings

What happens around the mill also requires the miller's attention, especially if it is within the mill grounds.
There may be risky situations in close vicinity to the mill grounds but they are not usually the responsibility of the miller.

10.5.3.a Quays at the mill pond, the mill pool and other water works

The weir or mill pond should certainly be shielded at the sluice gate.
If these and the mill pool are shallow, diving can have fatal consequences. For that reason, there should be signs prohibiting swimming in the mill pond and mill pool.
If there is a picnic area at the quay, fencing is also desirable. To prevent climbing, the fencing should have vertical bars instead of horizontal slats.

Fig. 10.5.3.1
The mill bridge.

The bridge railing must be sufficiently high and the openings should preferably have additional closures.

Oostendorper Mill - Haaksbergen

10.5.3.b Mill bridge
At watermills where passers-by use the mill bridge (or weir bridge), they must be able to do so safely.
Therefore, it must have fencing. If there is no fencing, it represents an unsafe situation. In slippery conditions due to rain, frost or black ice, cyclists or pedestrians are at extra risk of slipping. If that happens, a railing should prevent them from falling off the bridge.

Arrange for the road authority to install a warning against climbing on the weir bridge railings or the beam across the weir sluices.

10.5.3.c Working on the gates

Keep visitors at a distance during all work on the sluices. If there is no platform to be closed off then pay extra attention; if necessary, string red and white tape if the work is going to take a while.
If the mill bridge is part of a cycle path, there is a danger that cyclists could collide with the miller or the timber lever during work on the gates. This is especially true if there is a right-angled turn in the cycle path around the mill. Placing some cones during this work can reduce that danger.

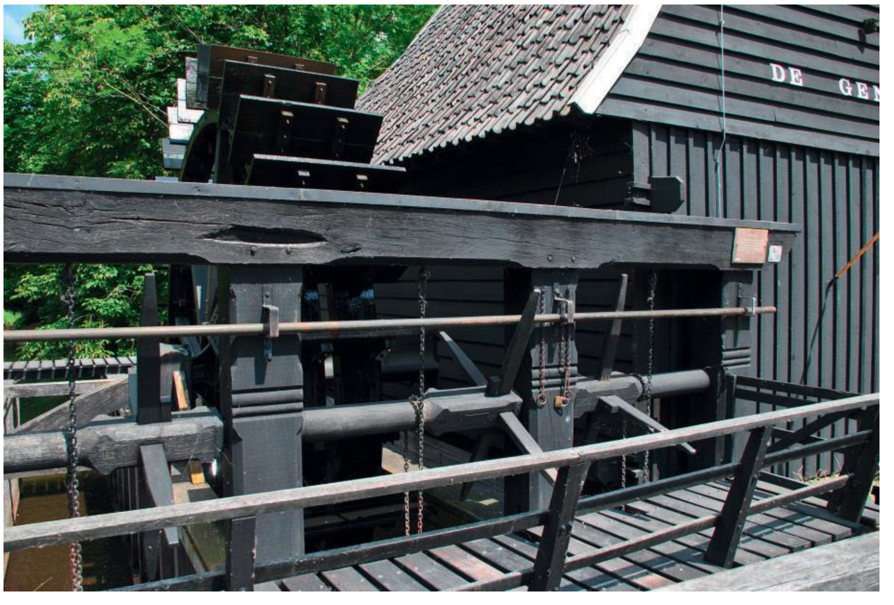

Fig. 10.5.3.2
The sluices here are operated with windlasses. A railing keeps visitors at a safe distance.
A tube and padlocks prevent the windlasses from turning after departure.

10.5.3.d Shielding of sluices and wheels

Sluices and wheels should be shielded from the public if possible. This is especially true in the miller's absence. A separate gate or lockable section of the mill bridge is preferred.

10.5.4 Points to consider when receiving visitors

Given its layout, is the mill suitable for having visitors or do additional measures need to be taken?
On days when many visitors are expected, a staff member must be available on each open floor.
Close all entrance doors (except one) to incoming visitors.

Note: Escape routes must not be blocked!
Are areas that are not accessible clearly marked as such? Are the means of closing them off secure such that visitors cannot undo them?
If the mill is in operation during the visit, are moving parts that pose an immediate hazard to visitors adequately shielded?

When the mill is running, make sure that the various control ropes — for example, those for the sack hoist — and operating mechanisms are secured against use by visitors.
Are hatches and other openings in floors adequately shielded from being stepped in by visitors?
Are floors and stairs in good enough condition that they do not pose a hazard, even if several visitors climb the stairs at the same time?

10.5.4.1 Individual visitors

In general, it is strongly discouraged to allow visitors at the mill to walk around freely. A miller is required to supervise visitors or arrange for their supervision. But there can be no supervision without sight. Signs and barriers/railings alone are not sufficient to relieve you of any liability.
When visitors arrive at an operating mill, who provides the reception and/or tour? Are there arrangements between the miller and the miller's assistants about this?
Is there a mill guide who can welcome visitors and show them around?
Under no circumstances should children under 10 to 12 years old be allowed at the mill unaccompanied.
Point out to parents and/or chaperones that they should not carry children on their shoulders. This is extremely dangerous, no matter how well-intentioned. Mills are usually built in such a way that there is barely enough space above your head anywhere when standing upright.

10.5.4.2 Group visit

In the mill, only take groups that are not too large in terms of the space available and the tour guide's oversight (for example, a max. of 10 people per tour guide).
Point out to parents/chaperones that they should take extra care of their children: the presence of a tour guide does not mean the latter bears responsibility for their children!
Give all visitors a brief instruction in advance regarding the rules that apply while visiting the mill. This should include making them aware of the dangers of visiting the mill.
Also, have the tour guide clearly state what cooperation he or she expects from parents/chaperones.
Some of these concerns, such as group size and number of chaperones, should be addressed as soon as the visit has been arranged.

10.6 SAFETY AT A GRAIN MILL

10.6.1 Driving gear: general

All drives must be shielded in such a way that no one can be caught by them in normal operation.
Ensure that shafts, shaft trunnions and shaft couplings are adequately shielded.
Check bearings and electric motors regularly for contamination and, if necessary, clean and apply new grease.
Check drives regularly for wear, bearing play, lubrication and general condition.
Are all electric motors and other equipment connected in accordance with applicable standards?
Are the thermal protections working properly?

10.6.1.a Shielding the lantern wheel / crown wheel

These must be well shielded. If there are multiple lower drives, also pay attention to the stone nuts that sometimes protrude outside the hurst frame.

Fig. 10.6.1.1
Shielding of the spur wheel and stone nut.

In the case of stones driven from above using a central spindle with a spur wheel and stone spindles with a lantern wheel, the danger is at head height. A slightly taller miller, visitor or a child on a parent's shoulders are at risk there. Of course, carrying a child on the shoulders in a mill should not be allowed in any case. Neither should children climb onto a pair of stones. A (movable) shield around the mill stones is therefore recommended.

10.6.1.b Central spindle (main upright shaft)

The passage of the central spindle through the floor should be shielded with a barrier or with a close-fitting cover around the central spindle.

Fig. 10.6.1.2
Left: underdrift drive.
It would be better to replace the red tape with a barrier.

Right: overdrift drive.
The central spindle opening is shielded by fencing.

10.6.1.c. Exterior hoisting system / open windows

An open hatch or shutter for an exterior hoisting system should have adequate protection. A single chain is not enough.
This also applies to an open window. Especially when the wheel is located right next to that window. Children can easily fall out of these when looking or hanging outside.
With a removable barrier, these dangers are avoided.

Fig. 10.6.1.3
A barrier in front of open doors, windows or hatches.

10.6.2 Various types of drives

10.6.2.a Belt drives

When stationary, regularly check the condition of the belts' welded joints and connectors.
When mounting or removing the belts, stop the belt pulley.
Check belts regularly for proper tracking and slippage.
Any belt drive present should be properly shielded.

10.6.2.b Rope drives

Check rope drives regularly for slippage and the condition of the ropes. When installing rope drives, consult an expert.

Fig. 10.6.2.1
Shielding of a belt drive of a bolter.
Left is closed, right is open.

10.6.2.c Chain drives

With the chain stationary, periodically check lubrication, play and overall condition.

10.6.2.d Direct motor or generator drive

This must be checked regularly for motor or generator contamination, the oil level and venting of any gearbox used.

10.6.3 Machinery in the grain mill

The general condition of the machinery should be checked regularly. When working on a machine, take all possible measures to prevent it from operating.
Is the machinery protected against overloading?
Is the machinery shielded in such a way that it can be worked with safely?
Regularly monitor machinery in operation and pay particular attention to the safety of visitors.

10.6.3.a Bucket Elevator or bucket conveyor

Are the input and output sufficiently protected relating to the cups rotating in the bucket elevator?
Do not allow visitors to open hatches in the elevator legs when the elevator is in operation.

10.6.3.b Screw conveyors

A helix (auger) conveyor that uses a rotating helical screw blade (flight) within a trough must be properly closed from above with a non-removable lid.
When working on the conveyor, make sure it cannot be operated by another person.
Are the input and output adequately shielded?

10.6.3.c Mixers

Never insert objects and certainly not fingers or hands into the input or output openings of rotating mixers.
Especially with mixers, it is very important that all possible measures be taken to prevent the mixer from operating or being adjusted when someone is inside it.
For screw mixers, always fill such a mixer through the chute and never over the edge when the mixer is in operation. The pivot arm and screw can be a hazard in this process.
Is the top fitted with a strong lid when the mixer is in operation?

10.6.3.d Bolter

Is the slide under the hopper of the bolter or feeder not dangerous in any way?
Never insert fingers or objects into the delivery spouts when the bolter is running.
Regularly check the beater of a centrifugal bolter for loose parts.

10.6.3.e Oat roller or oat flaker

The roller must have proper shielding to prevent fingers or hands from becoming trapped between the rollers.

10.6.4 The milling process

If the millstones are used, the entire milling works should be in good condition: strong stone spindles, sound bearings, safe vats and covers for the stones. Also, undamaged stones with strong steel bands around the runner stone and secure adjustment options for grain flow and supply.

Fig. 10.6.4
A magnet in the hopper to remove metal contaminants from the grain.

Hang a magnet in the hopper to stop any metal particles that may have ended up in the meal stock during the processing of the grain at suppliers.
In the event of an emergency, you can quickly stop the milling by sliding the entire supply of grain from the shoe into the eye at once and setting the runner stone completely out of action.
Such an emergency stop can be an option if the sluice gate, inlet sluice or bottom hatch (shuttle) has to be operated from the outside; this can take too much valuable time.
Do not try this emergency stop unless you really have to! The large mass you want to bring to a rapid halt exerts such a force on the driving gear that cogs or staves may break.
If the water supply from the mill can be interrupted with a pull located inside the mill then that is preferable in an emergency. Immediately after, set the stone completely out of action to quickly disengage the driving gear.

10.6.4.a Chock in the sack rope

The sack rope next to the meal spout used to hold open a flour sack must be provided with a cross-piece of wood secured into the rope for safety. Otherwise there is a danger of the miller getting the hook in his face if it slips loose and is pulled up by the weight on the rope.

10.6.4.b Sack hoist

It goes without saying that the hoisting system needs to be very reliable and well maintained. The introduction of meal stock into the mill by means of the hoisting system deserves due attention.
For example, never do this when visitors are present at the mill and do not leave the sack hoist hatch doors open unnecessarily. Do not stand under an open hoist hatch.

Establish good communication: only one person should be in charge when hoisting to avoid misunderstandings.
Working with sacks means stacking well, as little as possible next to open (hoisting) hatch doors and only on a solid surface.

10.6.5 Maintaining a pair of stones

10.6.5.a Opening a pair of stones

Use proper tools when opening the stones. Work calmly and in consultation, and set up the runner and stone spindle safely.
Ensure that, in the raised position, the stone spindle is additionally protected from falling. Never stand in the fall path of the load.
Are the stone crane with accessories and pivot points of the crane checked regularly?
Does the nut on the stone crane turn smoothly?
Check that the peg holes in the stone are clean and more or less in the middle of the stone thickness in relation to the location of the centre of gravity.
When winding up the stone with the nut secured, pay attention to the rotating stone crane bails (tongs) and perform this work in a controlled manner due to the large rotating mass.

Always turn the stone by lifting it up with a twisting motion away from you and not by pulling the stone down! (Don’t pull the stone, push the stone.)

When turning, does the stone not become caught in the stone crane bails?
Place a lifted millstone, in most cases the runner, above a main structural beam of the mill. If that does not work, use additional beams.

10.6.5.b Sharpening (dressing) a stone

Work with good tools!
Pay attention to correct body posture and do not rush.
Work with concentration but remain mindful of the environment in which work is being done, including all the associated dangers.
Wear safety glasses and a dust mask.
When using an electric millstone dresser's lamp, also pay attention to the cord and the lamp itself
(for the maintenance of millstones, see also section 12.9).

Fig. 10.6.5.1
Place the runner on the main construction of the floor.
Inset: the pins of the crane bails should fit well into the stone's peg holes.

Proper stone sharpening requires skills that most millers no longer possess. A stone that is not properly sharpened produces a product of poor quality. For that reason, it is better to leave the sharpening to a professional.
Of course, stone sharpening can also be learned but that is beyond the requirements of a volunteer miller. Those who want to do their own professional milling would be wise to learn this skill from an experienced miller or millwright.

10.7 SAFETY AT OTHER MILLS

10.7.1 Sawmills

Fig. 10.7.1.1
Trimming is not possible but sawing off is.
This certainly applies to fingers.

10.7.1.1 Introduction

For millers of sawmills in particular, it is very important to have cooperation, a good mentality and inventiveness in order to minimize the risk of accidents without affecting the individual character of these mills. Wood sawing by itself does not pose the greatest danger, although one should naturally never unnecessarily approach the front of the saw frames.
The most dangerous work lies between picking up the wood and the moment that this wood is properly secured and ready to be cut on the saw carriage. It starts with the equipment used for dragging the wood, such as the cables, blocks with mounting points, cant hooks and — last but not least — the windlass.
This hoisting equipment must be 100 percent reliable.
The watermills have no pawl feeder for the windlass. The Singraven mill has a belt drive for the windlass that will slip when overloaded. The Wenum Mill operates with a manually operated hoisting tackle.

An absolute rule to be enforced at a sawmill is that the person who operates the windlass while hoisting may never release the control handle in order to

intervene immediately if something goes wrong.
Furthermore, work should be done in close consultation when moving the wood to be cut on the sawing floor. To avoid misunderstandings, only one person should give the directions here.
Once the wood is on the sawing floor, the logs should be well supported to prevent them from rolling away in an uncontrolled manner.

Fig. 10.7.1.2
The tow ramp with choke chain.

Ensure proper attachment of the steel cables or ropes to the windlass.
The cables or ropes and any (pressure) clamps used must comply with NEN 3231/3232.
Are the chains in use at the mill in good condition and in compliance with NEN 3359 and NEN 3360?
Is the windlass drive properly shielded?

Is the other hoisting and towing equipment in good condition, and does it comply with the standards NEN 964 and NEN 965 for shackles, NEN 3508 and NEN 3320 for blocks and NEN 1156 for hooks?

For proper verification of the soundness of the hoisting equipment in use at the mill, the relevant so-called P-sheets must be present at the mill. These sheets list maintenance requirements and rejection standards (available in the Netherlands from the Labour Inspectorate).

10.7.1.2 Safety when working at sawmills

10.7.1.2.a Millers

Are all millers and staff (apprentices) aware that working at a sawmill involves certain dangers?
In addition to safe working clothes, wear safety shoes (steel-toe) with non-slip soles and sturdy leather work gloves.

10.7.1.2.b Lubrication

Lubrication of the crankshaft should be performed with the mill at a standstill. Lubricate the guides of the saw frames with caution, for example with a grease gun.

10.7.1.2.c Tools

Make sure the tools (axes, crowbars, saws, hammers, cant hooks, etc.) are in good condition, sharp and properly ground.
Use tools professionally: in a safe manner.
Return the tool to its stored place immediately after use.

10.7.1.2.d Windlass

It should be a firm rule that the person operating the windlass continues to hold the control handle and the brake rope during operation in order to intervene immediately in case of emergency.
Also maintain the rule that during the hoisting of the wood to be cut, only one person is in charge and giving directions.
Make sure there are at least always four full turns of the cable around the windlass. The windlasses and their associated cables, ropes, blocks, hooks, etc. should be regularly checked for soundness.
Millers should be prepared for the fact that these cables or ropes may break during use and then shoot off in an unpredictable direction.
Care must be taken when bringing the logs in and placing them on the saw carriage, as they may roll or slip unexpectedly.
In connection with the above, millers must ensure they have sufficient space to jump away in case of emergency.

10.7.1.2.e Sawing floor

The sawing floor should be swept, tidied up and cleared of unnecessary clutter on a regular basis.
Provide clear walking and working paths at the saw carriage.
Close the tow ramp at the top and bottom with a chain or plank.

10.7.1.2.f Sawing

Perform checks and conduct work during sawing from the rear of the saw frames as much as possible.
Make sure that no one stands right in front of the saws.

10.7.1.2.g Drying shed

layering between sticks

Once the wood is cut, it still needs to be handled with caution; the planks are layered between sticks in the drying shed to dry.
The stacking must be done carefully and firmly. If the stack becomes three times higher than its width, the stack must be fitted laterally with bolsters for safety reasons.

stickering

This so-called stickering of wood in the drying barns should be done as much as possible on the ground beams or posts of the drying barns and not on layered wood next to them.

Fig. 10.7.1.3
Layering sawn planks between sticks.

10.7.1.2.h The tow ramp

step chocks

What is the overall condition of the tow ramp?
If step chocks are installed on a tow ramp, are they securely fastened?
What is the condition of the support beams of the drying loft?

10.7.1.2.i The mill grounds

Are the logs to be cut stored in an orderly fashion in places where unauthorised persons cannot access them?
While removing a log to be cut from stock, keep in mind that logs can roll.

10.7.1.2.j Visitors

When the mill is in operation, visitors can certainly be received. But not at times when heavy logs or beams need to be pulled into the mill. During this process, the entire sawing crew needs to apply its full attention — cables may break, logs may roll away — and there is no time or space for third parties. Also, keep visitors at a safe distance when aligning on the saw carriage and removing of the sawn wood.
Are the sawing protections — if any — in place?
If not, do not allow visitors to enter the immediate work area!

10.7.2 Oil mills

10.7.2.1 Introduction

An oil mill provides thoughtless or careless people lots of opportunities for making mistakes, both big and small.
It is the type of mill one should be thoroughly familiar with so that work can be done correctly and responsibly.
So, where are the dangers that lie in wait at an oil mill?

10.7.2.1.a Oil

First and foremost, danger lies in the oil itself: if it is not handled with care, a slippery floor is quickly created that can give rise to slips with potentially bad consequences.
Oil-soaked rags can cause fires due to overheating.

Fig. 10.7.2.1
A bottle of linseed oil.

10.7.2.1.b Rams

rams
stampers

The greatest danger lies in the rams for the first pressing and second pressing and the stampers with which the cakes may be broken. This machinery does its work with great force and therefore can be very dangerous. especially for arms and hands.

release levers, release ropes, cleats
wooden toggle, fists
lugs

Regularly check the release levers, release ropes, cleats and wooden toggles.
Are the fists reliable and properly secured in the rams and stampers with the notched blocks and wedges?
What is the condition of the rams for the first pressing and second pressing, especially in terms of pressing and the end of pressing? Are the fixed bolsters not worn irregularly?

releasing wedge, pressing wedge

Are the strings and ropes of both releasing and pressing wedges in good condition?
Is the stamper — especially the stamper end and the attachment of the stamper ring and plates — in good condition?
This also applies to the attachment of the loose stamper bolsters in the stampers. Is each stamper complete with a spacer or locking pin?

spacer, locking pin

10.7.2.1.c Camshaft

Be aware of the dangers associated with the camshaft even when it is rotating extremely slowly. When working on this floor — if you have to move from one side of the camshaft to the other — be careful not to climb over parts of the mill that are not intended for that purpose.
Beware of a cam or spokes rotating with the camshaft.

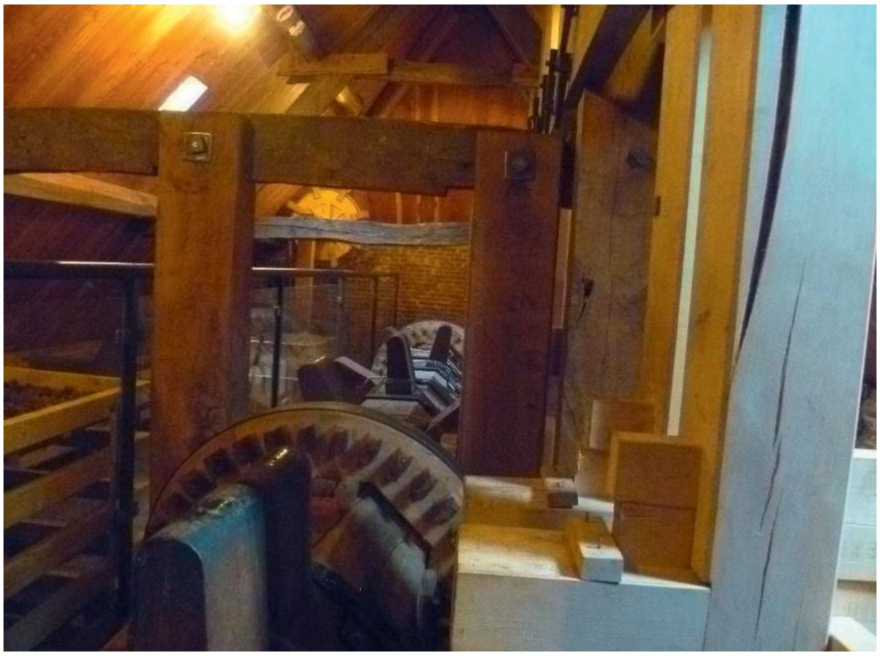

Fig. 10.7.2.2
The camshaft is properly shielded by a glass wall.

Follow the rule that work on the camshaft, including lubrication, must always be done with the mill at a standstill.
What is the overall condition of the camshaft with its associated wheels, bearings and cams?
Are the wheel wedges checked and tapped regularly? Is the cam reliable and properly fixed and secured in the camshaft?
When leaving the mill, always check the temperature of the camshaft bearings.

10.7.2.1.d Edge-mill, Edge runner stones

The edge-mill or edge runner stones are another part of the mill that should be worked on by those who know what they are doing.
Check here at regular intervals the various fixing for the stone framework and those parts that control the tracking of the edge runner stones themselves.
What is the condition of the bearing for the central spindle?

Are the trundle wheels for the camshaft wheel and king wheel (or stone wheel) in good condition?
Are the king wheel and central spindle for the edge runner stones in good condition?
Is the stone framework tight and strong and the bearings of the stones in it in good condition?
What is the condition of the woodwork for the scrapers or sweeps and the movement mechanism for them?
What is the condition of the bedstone (round stone table under the edge runner stones)?
Are the edge runner stones adequately shielded from visitors? In some oil mills, there is a low bedstone where the stone framework rotates at or slightly above head height.

Fig. 10.7.2.3
A safe barrier for the edge runner stones, including for children.

10.7.2.1.e Oil seed heater

For the first or second pressing are the oil seed heaters where the material to be pressed is heated. These are fired with wood, peat or briquettes.
What is the condition of the oil seed heaters: are they free of cracks? Can the fire in the heaters be properly controlled?
ash pan Are the ash pans sound and large enough to hold enough ash and fire?
Are they emptied regularly?

10.7.2.1.f Storage material

Storage of materials also requires attention.
If large stocks are stored in sacks in several layers, check them occasionally for temperature, as overheating of the stored seed leading to waste is not out of the question.
oil cellar If an oil cellar is present, are the doors or hatches on the oil cellar reliable and lockable?
Note: Hang out oil-soaked cloths or store them in an airtight fashion. Leaving it in a heap can cause a fire due to overheating!

10.7.7.2 **Safety when working at oil mills**

10.7.2.2.a Millers

Are all millers and other volunteers aware of what goes on at the mill in terms of safety?
The sound of the striking rams is bad for your hearing and can cause permanent hearing loss over time. Therefore, always wear hearing protection during operation.

10.7.2.2.b Lubrication

Is all lubrication of the various bearings carried out responsibly and with the mill at a standstill?

10.7.2.2.c Edge-mill, Edge runner stones

Putting it into operation should always be done by the person who will also be doing the work. Always warn the others present when the edge runner stones are set in motion.
The raw materials to be processed must be brought up to the inner runner stone and in front of the scraper. Avoid overloading the entire edge runner stone set-up; in other words, do not introduce too much meal stock onto the bedstone at once. The various components, including the central spindle, must absorb torsional forces that should not be underestimated.
When adding water, walk along behind the stones! Never reach — for any reason — between the rotating stones for objects or parts of the mill. Nor to remove any contaminants among the seed.

scraper or sweep

10.7.2.2.d Oil seed heater

Whereas normally the use of fire at a mill is always strongly discouraged, here it is an unavoidable part of the process. Therefore, always be extremely vigilant when heating.
After finishing work, close off the air supply. Check that the fire is extinguished when leaving the mill.
Be careful not to place any flammable material on the hot heaters or leave any on them after the day's work.
Is extinguishing equipment available in the immediate vicinity of the heaters to extinguish an incipient fire?

10.7.2.2.e Pressing block

pressing ram
releasing ram load
releasing wedge

It should be a firm rule that people keep their hands away from the pressing ram or releasing ram when they are in operation.
When breaking loose the load, which is effected by the releasing wedge striking down, this sometimes needs some help in order to break free. Always do this from the back; then there is no danger to hands or arms if one of the rams comes down unintentionally for whatever reason.

release string
locking pin

Secure the release strings properly when stopping the rams to prevent them from being released during loading/emptying. Always secure stopped rams with a locking pin.
Immediately cover spilled oil with an oil absorbent fabric to prevent slipping. This should then be removed as soon as the work allows.

10.7.2.2.f Stamping mill

stamper holes
stampers

Both when filling and emptying the stamper holes, the stampers should not only be out of operation but also always secured.
During stamping, never try to push back into the holes pieces of oil cake that have jumped out of them; that is just asking for trouble.

10.7.2.2.g Visitors

As far as the work at the mill allows, as many protective measures as possible should be taken for the safety of visitors, although this is not always easy due to the mill's highly specific nature. The biggest dangers are crushing hazards and slipping.

10.7.3 Hulling mills

10.7.3.1 Introduction

Barley is not pearl barley until it is hulled.

There is only one watermill left that was built and equipped for the hulling business, specifically the Mallumse Mill at Eibergen (in Gelderland province).
It is a so-called combination mill for both hulling barley and milling grains for consumption. Pearl barley was an important foodstuff.
The first windmills for hulling in the Netherlands are said to have been developed around 1660 in the Zaan region and in Groningen in 1680. In the 19th century, these mills stopped hulling barley and switched to rice hulling.
During the First World War, barley had to be hulled again by order of the Dutch government.
At that time there were 59 hulling mills in Groningen, 7 hulling mills in Friesland and 2 steam-driven hulling mills in the Zaan region. There would also have been several water-driven hulling mills back then.

From the point of view of safety, the hulling mill is almost identical to the grain mill. The main differences are:
- Because there is a chance of the hulling stone splitting apart, it was placed between the floor joists and under the milling floor.
- All the spindles and wheels of the hulling works run much faster.
- The mill can hold more machinery.

As for visitors, it is wise to show people around a non-hulling mill if the groups are larger than five to six people.
The instructions in section 10.4 also apply to this type of mill. In addition, working with the hulling mill involves specific safety concerns.

10.7.3.2 Operations at the hulling mill

10.7.3.2.a Millers

Are all millers and other volunteers aware of what goes on at the mill in terms of hazards? Are they also familiar with the arrangements made for the safety of millers and visitors?
Is it safe to walk on the stone vat covers?
Have measures been taken to prevent excessive dust formation?
There are millers who are sensitive to hulling dust and they contract what is known as hulling fever.

10.7.3.2.b Lubrication

Is all lubrication of the various bearings carried out responsibly and with the mill at a standstill?
Do not perform any work behind and under the spur wheel when the mill is operating.

10.7.3.2.c Hoisting a hulling stone

Is the equipment reliable and well maintained?
Work calmly and in consultation.

Put the stone vat covers away in such a way as to prevent falling over them during other operations.
When opening stone vat covers and removing parts of the vat, avoid cutting your hands open on the sharp hulling rasp.
After hoisting them up, set up the stone spindles in such a way that they do not present a hazard while working.
The attachment of the block and tackle must be checked carefully before lifting the hulling stone.
Before putting the hoisting strap underneath the stone, is it properly tucked under?
Can the hoisting strap support the weight of the stone?
Before putting the stone on its side after lifting, the hoisting strap should be properly secured.
When turning the stone, you should — as with the runner of the grain mill — push it away from you and not pull it towards you; otherwise the hoisting strap may break.
If the stone is placed on its side, immediately tuck it in on either side with the stone wedges.
When replacing the hulling stone, observe the same safety precautions as when hoisting it.
Before returning the mill to operation, check the disassembled parts.

10.7.3.2.d Sharpening

When cutting stone (sandstone), keep in mind that the dust is harmful to your health.
Always wear safety glasses and a face mask when cutting stone.

10.7.3.2.e Renewing the hulling rasp

When producing new hulling rasps, be careful of the extremely sharp points on which your hands can be cut open. Wear appropriate work gloves.

10.7.4 Paper mills

10.7.4.1 Introduction

Paper can be made from several raw materials.

There are only two watermills left in the Netherlands that were built, equipped and operated as paper mills. These are the 'Achterste Molen' (Rear Mill) in the Netherlands Open Air Museum in Arnhem and the 'Papierfabriek Middelste Molen' (Paper Factory Middle Mill) in Loenen.
They produce handmade paper in the old traditional way.

From a safety standpoint, the paper mill is almost identical to the grain mill — except that all the spindles and wheels run much slower and more machinery is in the mill.

As for visitors, it is wise to show people around a non-working mill if the groups are larger than five to six people.

The directions in section 10.4 also apply to these mills.
Additional areas of concern are the camshaft and the hammers: these must be shielded in such a way that they are not a danger to millers or visitors.

Fig. 10.7.4.1
Shielding the camshaft and hammers with just a chain is insufficient.

10.8 RISK INVENTORY AND EVALUATION

As regards safety, the well-known saying applies: prevention is better than cure.

In 1990, therefore, the report 'Safety at Windmills and Watermills', prepared by *Vereniging De Hollandsche Molen* (The Dutch Mill Society) in cooperation with the Working Group on Safety, was published. This report identified numerous areas of concern that are important for safety in and around the mill.

A Risk Inventory and Evaluation (RI&E) plan for mills, also prepared by *De Hollandsche Molen*, was subsequently published in 2003.
This plan was completely revised and updated in 2012. This led to its (renewed) recognition as a safety instrument for the mill sector.
An RI&E is mandatory for those organisations whose work activities carry serious risks. This is also the case with mills. Mills have parts that move with high energy, which can make them deadly. However, an RI&E is not mandatory for volunteer organisations — although they can, of course, certainly benefit from it. Such organisations do have to comply with some health and safety regulations.

The questions in the RI&E folder help the miller/owner to identifiy all risks. A Plan of Action can then be drawn up to reduce the risks. If the measures in the plan are implemented and the agreements made are evaluated once a year, then the mill also complies with the Working Conditions legislation. If something then goes wrong unexpectedly, the owner can prove that they took responsibility and did everything possible to make the mill as safe as possible.

The RI&E folder includes:
1. An introduction with a glossary, answers to common health and safety questions and a step-by-step plan, which can be used to conduct the inventory.
2. A general Risk Inventory, covering the organisation of Occupational Health and Safety issues, special groups of volunteers, preparation for emergency situations, general facilities in the mill, the public and tours, etc.
3. A specific inventory, focusing on the rotating parts in a mill, the sails, working in the cap, winding (rotating), working at heights and fall hazards, etc.
4. Areas of concern by construction method: stage mill, ground-sail mill and mound mill, watermill.
5. Areas of concern by function: polder mill, grain mill, sawmill, oil mill, hulling mill.

The folder then outlines how to create a Plan of Action from the RI&E. The appendices contain all kinds of additional information and examples.
In addition to the Hollandse Molen RI&E, the Netherlands Monuments Watch Foundation also issued a brochure in 2004 with instructions for making arrangements to work with mills in a safe and healthy manner.

10.9 THE LEGAL SIDE OF SAFETY

10.9.1 Safety legislation

Legally, mill owners are the ones who bear primarily responsibility for safety in and around their mills. But what standards should mill safety meet? Because mills were originally set up as machines, safety regulations at the time were governed by the Safety Act of 1934 and its accompanying 'Safety in Factories and at Worksites Decree' of 1938 (VBF 38). Many of its provisions were and still are applicable to mills.
VBF 38 has been succeeded in the Netherlands by the Working Conditions Act (*Arbowet* for short). The Working Conditions Act aims to protect workers. Volunteers are not employees and, since 2007, are therefore only covered by this law if they work either in a relationship of authority, at heights or with hazardous materials. (Note: The relationship of an instructor to a student miller is considered by the legislature to be a relationship of authority.) Of course, many of the protective measures devised for employees can also benefit the volunteer.
This is especially true of the Risk Evaluation and Inventory (RI&E). An RI&E is a systematic method of identifying safety, health and welfare problems. Conducting an RI&E and preparing a Plan of Action are the foundation of safety policy at a mill (see section 10.8).

10.9.2 Liability

A basic rule of Dutch liability law is that everyone bears their own loss or damage unless:
- The loss or damage results from the acts or omissions of another person;
- AND there is a causal relationship between that action and the loss or damage;
- AND that act or omission is culpable.

So it is not the case that someone is always liable. Instead, there is specifically room for an unfortunate combination of events or coincidence. If that is the case, each one bears his own loss or damage.

If liability does exist, the degree of liability is determined on a case-by-case basis according to the following criteria:
- How likely is the chance of risky behaviour?
- How likely is the chance of loss or damage as a result of that risky behavior?
- What is the extent of the damage?
- How onerous are the measures to prevent loss or damage?

In short, the greater the probability of loss/damage and the more extensive the loss/damage, the more measures must be taken to prevent loss or damage.

The mill owner bears the greatest liability for safety at the mill. The mill owner has a duty of care and must provide a safe

environment for volunteers and visitors by notifying visitors in writing of the risks, by setting rules and by shielding the waterwheel and areas where there is a risk of being crushed. Therefore, the owner must take safety measures unless they are too onerous. If someone organises something at the mill then the same applies to that organiser.
In addition to safety measures, supervision is also needed. Both are necessary! Omitting safety measures and replacing them with supervision is not an option.

Visitors should follow the safety rules and pay particular attention to their children. A mill is not a children's playground. The miller is not a babysitter. Signs pointing out the dangers of the mill do not relieve the owner of his duty to take safety precautions. Those signs are there so that the visitor is aware of the danger into which he/she is entering.

The miller is an independently working person and must perform their duties properly. The owner is entitled to assume that the miller has professional competence. The miller must follow safety rules and supervise the compliance with visitor rules.
The instructor has a duty of care for students, particularly when instructing them to do things that involve risk. These include working at heights (fall protection is mandatory for students!) as well as working with hazardous materials or working in situations where there is a risk of being crushed.
Prevent students from having accidents. Accidents involving students are personal tragedies for the student and the instructor. If a relationship of authority was involved then liability comes into play. If insufficient measures have been taken, there may also be criminal consequences.

10.9.3 Youth members and members-in-training under 18 years of age

Young people under 18 can become youth members of the Guild. And a young person can begin training as a volunteer miller from the age of 14. However, any young person under 18 is subject to the rules of the Ministry of Social Affairs and Employment regarding employment of those under the age of 18. These rules also apply to volunteer work that the Guild allows such persons to do at the mill.
In the case of youth members, it is advisable that parents are also sufficiently informed of the applicable rules and are involved in what their child is doing at the mill.
The Guild also recommends that agreements between parents/caregivers and the miller/instructor are set out in writing. A '*Model Agreement between a Member-in-training under 18 years of age, the parent/caregiver and the miller/instructor regarding the miller training offered by The Guild of Millers (GVM)*' is available for this purpose.

10.9.4 Millers contract

The Guild of Millers and *De Hollandsche Molen (The Dutch Mill Society)* have jointly prepared a 'Model Contract for Millers'.
This can include arrangements for opening, maintenance, supervision, etc. In addition, this contract includes a clause about safety that defines the obligations of the mill owner and the miller with regard to promoting safety.

For example, it is important to note that while concern for the safety of those present rests first and foremost with the mill owner, supervision of compliance with the rules is usually delegated to the miller(s).

Furthermore, this contract has a clause regarding insurance that includes something about the miller's liability. Among other things, this can be important for indemnifying claims if the damage from an accident exceeds the insured amount and the miller has acted competently and professionally.
It is recommended that each miller agree on a mill contract with the mill owner.
The model contract can be found at www.gildevanmolenaars.nl under association documents.

10.9.5 Guild insurance

Unfortunately, when working with a heritage building and machinery, mishaps and even accidents can never be completely ruled out. This is true even if all safety procedures have been properly followed and the miller has acted professionally.
If such happens, the mill owner or miller may be held liable for the damage suffered. Or perhaps the miller may suffer permanent physical damage due to an accident.
For that reason, the Guild of Millers offers its members several additional insurance policies.
These are:

- Comprehensive third-party insurance against damage to third parties and/or to the mill.
- Accident insurance, in the event of death or permanent disability of the miller.

This third-party insurance applies to all Guild members; the premium for it is included in the membership fee. Accident insurance is mandatory for members-in-training.

All the information about these policies and their terms and conditions can be found on the website www.gildevanmolenaars.nl .
In the event of damage, mill owners can contact *De Hollandsche Molen* at www.molens.nl. for advice.

NOTES

Chapter 11 The polder mill

Intentionally left blanc:

This topic is not part of the teaching material for watermillers and is therefore not included in this Handbook.

In line with the principle of making the layout of the course materials for watermillers and windmillers as similar as possible, including the numbering of the chapters, this chapter is mentioned but not completed.

Chapter 12 The grain mill

Contents Page

This chapter is taken in part from the publications 'Singing Stones' and 'Around Singing Stones' by former miller D.J. Abelskamp.

NOTES

12.1 INTRODUCTION

Grain kernels are too hard to be consumed unprocessed. They must be broken open and crushed to make them more digestible as nutrients. Milling grain also allows the resulting flour to be made into bread or cake.

millstones

Millstones have been used for the milling process since prehistoric times. In the long history of grinding grain into flour, millstones developed from a simple rubbing stone via the quern — a hand-operated mill — into the millstones which are now familiar.

The watermill was invented in Asia and dates back several centuries before the Current Era. Only in the 8th and 9th centuries was it was introduced in the Netherlands.

Wind-powered milling came to the Netherlands some four hundred years later in the 12th century, when the post mill made its appearance.

bedstone
runner

The milling mechanism itself has remained unchanged for the last two thousand years. It consists of two flat stones of which the lower one, the bedstone, is stationary and the upper one, the runner, rotates.


Fig. 12.1.1
A pounder-rubber stone (left) and a quern (right).

In the Netherlands, the milling business underwent significant changes over the centuries.

manorial mill, soke mill
manorial rights

Until the French era, most mills were manorial or soke mills. The so-called 'manorial rights' included both wind and water rights. And with it the mill right: the right to build mills. Whoever owned the mill right also obtained the weir right. With these rights, the lord of the manor could oblige anyone living in this manor to have their meal stock milled at the mill of the possessor. For that reason, such mills were called 'manorial mills' or 'soke mills'.

These mills were leased, providing income to the owner. Those persons who owned the water and weir rights could also give others permission to build a mill. Because of the costs associated with construction, initially it was almost exclusively wealthy, noble families or monasteries who had a mill built. Later, wealthy citizens followed suit.

toll measure (miller's toll)

Those who wanted grain ground brought it to the mill and waited for it to be milled. Storage space was not needed in the mill. For milling, the miller received an agreed milling fee, either in cash or in kind: some of the grain or the milled flour. In the Gelderland region of the Netherlands, for example, this milling fee was 1/16 part of the milled grain. It was scooped with a special measure and therefore called '*toll measure*' (miller's toll) — in other words, milling charges.

excise duty on the milling

In the French era, 'manorial rights' including coercive rights were abolished (in 1795) but shortly thereafter the government introduced the so-called 'excise duty on milling', which reduced the demand for meal stock.

When this tax measure was abolished in 1855, millers were given the freedom to develop their businesses further. They also became traders; they stockpiled grain and could also deliver from stock.
Some businesses even grew into complete flour mills.

In the late 19th century, however, the practice started to decline. Cheap imports of grain from abroad caused prices to fall. As a result, farmers increasingly switched from agriculture to animal husbandry. Due to toll charges in Germany, meal and flour exports to that country also fell. Around the time of and during the First World War, flour production fell to an all-time low; small mills almost entirely lost their milling function. Government measures in the interest of food supply during the period of 1914-1918 also proved detrimental to small milling businesses because some larger businesses were designated for storage and distribution.
In the early 20th century, farmers organised themselves into agricultural cooperatives and began trading and processing grain into animal feed themselves. Milling was often done in cooperative trading, often using electrically driven hammer mills that no longer required a miller's craft knowledge.

hammer mills

farm milling

Because many mills also lost their farm milling function as a result, they became inoperative, fell into disrepair or were demolished.

Fortunately, we came to the realisation that watermills should also be preserved as an important cultural heritage. Many have been restored and many of them are once again still capable of turning and even milling.

weir right

Watermills always had the weir right for impounding the water needed for their mill. During the last century, when many watermills no longer had a function, these weir rights were bought out on a large scale by the water authorities so that they could reorganize the entire water system.
Streams were diverted or straightened to provide faster drainage.
As a result, a number of remaining watermills face the problem of no longer holding weir rights. As a result, they receive too little water to mill profitably. It is difficult to achieve good production at grain watermills that are not allowed or able to impound.

Fig. 12.1.2
A weir with inlet sluice, two by-pass sluices and a fishing sluice (middle). And weir right!

St. Ursula Mill – Nunhem

12.2 THE DESIGN

The designs of grain watermills vary widely. There are small mills that sometimes consist of only a single space but also large mills in an extensive building with two or three floors. An example of the first type is Watermill Bels in Mander (Overijssel province); an example of the second type is the Upper Mill in Mechelen (Limburg province). Needless to say, there are large differences when it comes to design. Therefore, a description of designs can only be general.

No matter how different the designs are, however, they also have things in common.

mill shaft, waterwheel shaft

cellar

The design and arrangement of the machinery is determined first of all by the mill shaft (also called waterwheel shaft) that enters at the bottom of the mill. This space is sometimes below the ground floor and therefore, if there are multiple floors, is referred to as the cellar or basement.

hurst frame

mill shaft, waterwheel shaft

In the simplest version — which, by the way, has been in use for centuries and can still be found today — there is a small hurst frame. This is a sturdy structure of beams on which the millstones lie. This hurst frame is located near where the mill shaft or waterwheel shaft enters the mill. Sometimes, however, the pair of stones lay on a low mezzanine floor supported by the hurst frame.

driving gear

milling floor

The driving gear is located in the hurst frame. The floor of the building is also the milling floor: this is where you will find the meal spouts, meal bins and the controls for the tentering mechanism.

Processing multiple grains required different dressings, which is why a second pair of millstones was sometimes present. Buckwheat and wheat were milled on one stone, and rye and animal feed on the other.

Initially, there was a second waterwheel for that second pair of stones.

Fig. 12.2.1
A small mill with one pair of stones on a hurst frame. The stone is driven from below.

Bels Watermill – Mander (Overijssel province)

dual transmission

hurst frame, platform

It is likely that dual transmission was used from the 18th century onwards. There are two or more pairs of stones driven by one waterwheel. These stones are located on a hurst frame, a mezzanine floor or platform, or on a separate stone floor.

This arrangement — with one waterwheel and two pairs of stones — is the one most commonly used in watermills.
When the demand for baking flour and animal feed increased in the second half of the 19thcentury, the need for more milling capacity arose. But also storage capacity, such as silos for grain and storage space for bags of flour. More machinery also came into use, such as mixers, sifters, rollers or flakers, oil cake crushers, cleaning machines, sack hoists, bucket conveyors and later on also transport systems via pipes, etc. The buildings became larger, were often made of stone with several floors, and the layout changed accordingly. Some mills grew into comprehensive flour manufacturers. This increase in scale occurred more in the south than in the provinces of Gelderland and Overijssel.

spur wheel
line shaft

The milling capacity was increased by a larger number of pairs of stones. For wooden hurst frames and mill wheels, three pairs of stones were usually the maximum. They were placed in a circle around the spur wheel. Or all three were next to each other: two pairs are then driven by the spur wheel, and a line shaft is used for the third.

Initially, all mills were equipped with wooden hurst frames and wooden shafts and wheels. From the beginning of the 19thcentury, due to escalating industrialisation, cast iron was increasingly used for the columns of the hurst frame, shafts, parts of the waterwheel and later also mill wheels.
Especially around the turn of the 18th/19thcenturies, many cast iron hurst frames, driving gears and waterwheels were installed.
The use of cast iron parts in watermills was seen particularly in the province of Limburg. This was undoubtedly influenced by the proximity of machine factories in both Germany and Belgium.

transmission shaft, drive belt

Cast iron driving gear can be made smaller to easily accommodate 3 or 4 pairs of stones around a spur wheel. In addition, it is quite easy to drive a variety of other machinery in the mill via transmission shafts and drive belts.

turbine
turbine chamber
driving wheels, pulleys

Another development affecting the design of watermills was the use of turbines. Turbines made their appearance around 1900. When a waterwheel was replaced by a turbine, quite a few structural or hydraulic construction modifications had to be made. A turbine chamber was attached, usually where the waterwheel had hung. In many mills, driving wheels (or pulleys) with belt drives or rope drives replaced wheels to power millstones and machinery. This allowed additional machinery to be easily added. As the waterwheel disappeared, the buildings became somewhat less recognisable as watermills.

auxiliary motor

A final development was the installation of an auxiliary motor in mills. In the case of iron driving gear, they could be coupled easily. One reason for this was that turbines, compared to waterwheels, are more susceptible to contamination and to the siltation of the water supply, so that often they could not be used. Siltation was caused in part by reduced water supply in the streams due to increasing development and modifications to the waterways. In the province of Limburg, a lot of stream water was also used for coal preparation. The polluted (black) cleaning water was discharged back into the streams and caused turbine failures.

12.3 DRIVING GEAR

driving gear

By driving gear, we mean the whole system of shafts, wheels and spindles by which the rotary motion of the waterwheel or turbine is transmitted to the machinery. For grain mills, these are first and foremost the millstones but also other tools necessary for milling, such as a flour sifter, a hoisting system or an elevator.

horizontal waterwheel
Greek watermill

The simplest version of driving gear for a grain mill consists of a horizontal waterwheel on which there is a vertical spindle that drives the millstone. This type of driving gear was also found in the so-called 'Greek watermills' we know of from the last centuries before Christ.
These mills required fast-flowing water and could only drive small stones. The use of horizontal waterwheels is not known in the Netherlands.

vertical waterwheel
Roman watermill

Watermills with a vertical wheel and a horizontal shaft, the so-called 'Roman watermills', we know of from the beginning of the Current Era.
A vertical waterwheel requires a right-angled transmission from the mill shaft to the stone spindle or central spindle. For angular transmissions, a crown wheel, lantern wheel, or a cradle wheel is used.

12.3.1 Single transmission

Looking at some smaller water mills in the Netherlands, such as De Mast at Vasse, Bels Watermill and Frans Watermill at Mander, we see many similarities to the Roman mills mentioned above.

mill shaft
hurst frame
pit wheel, face gear wheel
lantern wheel
single driving gear

At the place where the mill shaft enters the mill there is a sturdy wooden structure: the hurst frame on which a pair of stones lies. On the mill shaft is the pit wheel — sometimes called the face gear wheel — which drives the vertical stone spindle and thus the stone via a small lantern wheel.
We call the driving gear as described here a single gear because the rotation of the mill shaft is transmitted directly to the stone spindle by means of a lantern wheel (see Fig. 12.3.1.1). In the past, if a mill had two pairs of stones, each pair was driven by its own waterwheel.
This driving gear is located inside and/or partially under the hurst frame. The latter is the case if the mill shaft and pit wheel are in a recessed area of the milling floor. This space is sometimes referred to as the basement.

basement
platform

Sometimes the pair of stones is not on the hurst frame but on a low floor (platform) above it. The hurst frame then supports this floor.
It is also common for the waterwheel to drive two pairs of millstones, each singularly. There are two pit wheels: each stone spindle is driven directly by the mill shaft. These mills, which are still in existence, have an iron mill shaft and wheels.

12.3.2 Dual transmission

dual driving gear

It is likely that dual transmission was used from the 18th century onwards. Dual means that an additional transmission is located between the pit wheel and the stone spindle. In the dual transmission, the pit wheel drives the central spindle via a crown wheel or lantern wheel (or a cradle wheel), and the stone nuts of the stone spindles are driven via a spur wheel on the central spindle. There are two or more pairs of stones, driven by one waterwheel.

crown wheel, cradle wheel
central spindle spur wheel, stone spindle

The stones are on a hurst frame, a mezzanine floor or platform or also on a separate stone floor (see Fig. 12.3.2.1).

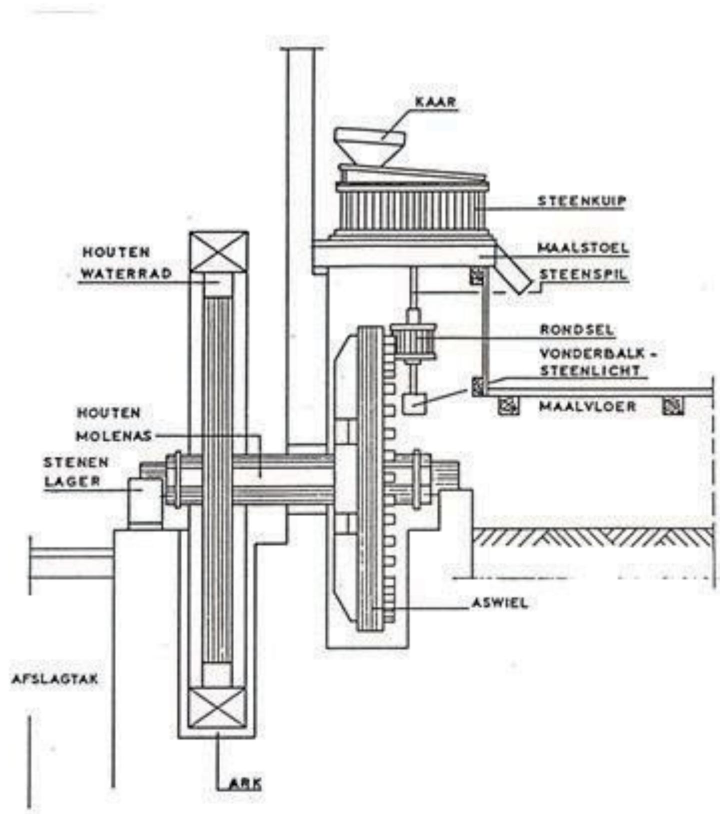

Fig. 12.3.1.1
Single transmission. The pit wheel directly drives the lantern pinion on the stone spindle. This is an underdrift drive.

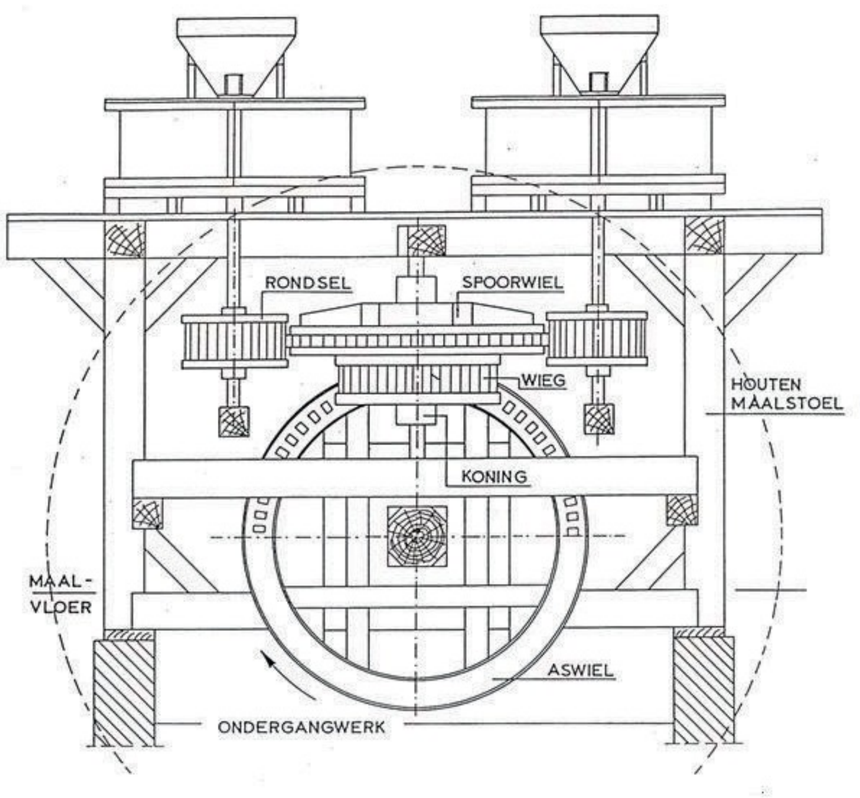

Fig. 12.3.2.1
Dual transmission. The pit wheel drives the stone nuts via a cradle wheel and spur wheel. This is an underdrift drive.

This layout with two or three pairs of stones and a dual transmission is most commonly used in grain watermills.

line shaft

Two or three pairs of stones may be located around the spur wheel. However, if three pairs of stones are present and they are in a line arrangement, a line shaft is used to drive the third pair. That transmission is also dual: a lantern wheel, cam wheel or crown wheel on the mill shaft drives the line shaft; a crown wheel at the other end of the line shaft drives the stone spindle of the third pair of stones.

crown wheel, lantern wheel, cradle wheel

Both a crown wheel and a lantern wheel, or a cradle wheel, can be used to drive the central spindle. With underdrift and the use of wooden wheels, this lantern wheel or crown wheel is often located just below the spur wheel due to the limited space. Sometimes the crown wheel and spur wheel form a single unit. Iron wheels are smaller and are made straight as well as conical.

12.3.3 Multiple transmission

multiple driving gear

With multiple gearing for the pairs of stones, the mill shaft does not drive the central spindle with a spur wheel directly but through a line shaft. The use of two line shafts is also found.

transmission shaft, drive belts

Other machines are also driven via single or multiple transmission. This allows for a large range of constructions, especially if transmission shafts and drive belts are used instead of wheels.

12.3.4 Transmission with water turbines

turbine shaft

conical wheels

drive shaft

Single and multiple transmissions are also seen in turbine-driven mills. Turbines are placed vertically in most mills so that the turbine shaft is vertical. Using drive belts, the stone spindles can then be driven directly. But a (conical) wheel transmission from the vertical turbine shaft to the horizontal drive shaft can also be used.

With a horizontally mounted turbine, the turbine shaft is horizontal and the possible gearings are similar to those of a mill with a waterwheel.

12.3.5 Use of cast iron in driving gear

cast iron driving gear

Cast iron driving gear has less frictional loss than wooden driving gear due to the use of smaller teeth and better bearings. Nevertheless, wooden cogs are still often used in iron wheels to limit noise. Wooden cogs are also easier to replace. In a gearing from wooden to iron cogs, the wooden cogs are always put in the driving wheel.

To limit wear, the numbers of cogs of two interlocking wheels should not share a common divisor to prevent the same cogs from touching each other all the time.

holm oak, boxwood, balata

When gearing from wood to wood — as with all wooden mill wheels — two different types of hardwood are used for the cogs to reduce uneven wear (for example, holm oak and boxwood). Nowadays, balata as well.

When gearing from wood to iron, the choice of hardwood is sufficient.

Fig. 12.3.5.1
A cast iron driving gear for underdrift. Conical pit wheel and trundle wheel. Wooden cogs in the pit wheel and spur wheel. The central spindle is on a sprattle arch. Closed shaft bearing with grease pot.

Bisschops Mill – Maastricht

12.3.6 Taking out of operation

taking out of operation

If you do not want to or cannot use the millstones or other machinery, they can be taken out of operation (disengaged from the driving gear). The connection between drive and machine is then interrupted. At some mills, disengagement from the driving gear is not possible.

overdrift

In grain mills with overdrift, the stone nut on the stone spindle is pushed out of the spur wheel by opening the upper bearing (quant bearing, sprattle or glut box) (see Fig. 12.4.2.3).

underdrift

For underdrift, the most common options are:

- In the case of a single gearing with wooden wheels, some slip sticks are taken out of the stone nut.
- If there was not enough room to remove slip sticks, a jaw clutch was installed on the stone spindle above the stone nut. The wheel will still turn but the stone will not. *(slip stick, jaw clutch)*
- For iron wheels, the stone wheel (stone nut) is pushed — up or down — out of the spur wheel or rotated with the help of a jack, fork (see Fig. 12.3.6.1) or screw jack.

(For taking out of operation, see also chapter 6, Driving gear).

drive belt, belt shifter, pulley, belt pulley
belt tensioner

When driven by a drive belt, this belt can be slid off the pulley (belt pulley) manually or with a belt shifter. If the drive belt is brought under tension with a belt tensioner, you can slacken it so that the drive does not transfer.

Fig. 12.3.6.1
A fork for engaging/disengaging an iron stone nut from the driving gear.
The chain is attached to a hook in the hurst frame above the wheel as a fixed point for the lever.

Bisschops Mill – Maastricht

12.3.7 Gear ratio

To produce a good product, it is important that the runner stone receives sufficient peripheral speed. To do so, this stone must turn (much) faster than the waterwheel. The driving gear is therefore designed to produce an acceleration, by going from a large wheel to a smaller wheel.

gear ratio

Grain mills generally have a gear ratio between about 1:5 and 1:7. That is, the runner turns about five to seven times faster than the waterwheel. (This is the same as the ratio of many windmills.)
Assuming about 15 revolutions of the waterwheel per minute, the runner then makes between 75 and 100 revolutions. The optimum milling speed depends in part on the size of the stone: at the same number of revolutions per minute, the peripheral speed of a large stone is higher than that of a small stone. Therefore, a small stone must make more revolutions per minute.
In waterwheel mills, gearings such as 1:15 or 1:22 are also common. In that case, it usually involves a slow-running large waterwheel that runs at only 3 to 4 revolutions per minute. Because of the high gear ratio, the runner then still receives sufficient peripheral speed.

In turbine mills, we see gear ratios of about 1:1 to 1:2.5.

At a gear ratio of 1:1, the millstone makes the same number of revolutions as the turbine. A drive belt is then used to drive the stone spindle directly from the vertical turbine shaft.
If the maximum speed of the turbine is too low, the implementation of the driving gear will require the millstone to be accelerated to the optimum production speed. The gear ratio will then be greater than 1:1.
In all cases, the maximum power of the turbine will have to be sufficient to give the millstone the desired speed.
The water flow through the turbine — and thus the power — is controlled with the use of removable valves or adjustable guide blades to give the stone the desired speed.
To calculate gear ratios, see chapter 6, Driving gear.

12.4 DRIVING GEARS

12.4.1 Overdrift and underdrift

In water-driven grain mills, the drive of the millstones can be done from underneath or from above. In this regard, watermills differ from windmills, where — with one exception — overdrift is exclusively used.

overdrift
underdrift

In watermills, underdrift is most common. They are almost always seen at mills with one pair of stones — unless the mill has another function, such as hulling — and at mills with iron driving gear.

At the Oostendorper Mill in Haaksbergen, both types of drives are present: two pairs of stones with overdrift, one pair with underdrift.

underdrift, stone spindle

In an underdrift, the runner stones are driven from below by a stone spindle (see Fig. 12.3.1.1 and Fig. 12.3.2.1).

quant, crotch spindle

In overdrift, the runner stones are driven from above by the stone spindle with quant (see Fig. 12.4.1.1). This is identical to what is used for windmills.

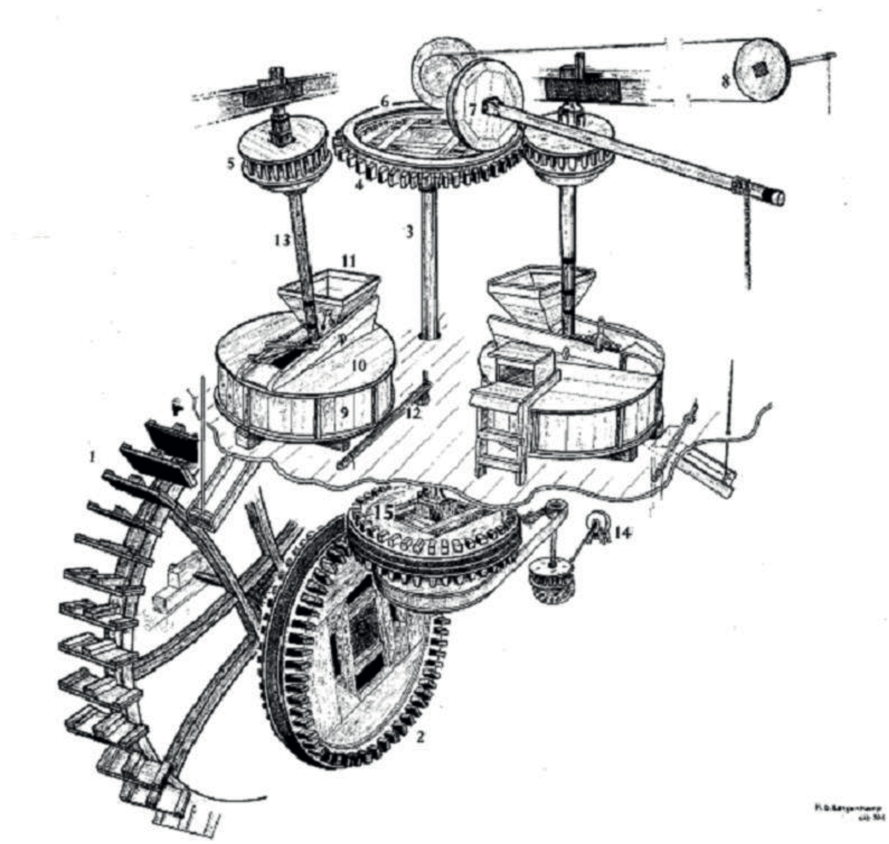

Fig. 12.4.1.1
Two pairs of millstones with overdrift.

1. *waterwheel*
2. *pit wheel*
3. *central spindle (main upright shaft)*
4. *spur wheel*
5. *lantern wheel*
6. *friction ring*
7. *friction wheel interior hoisting system*
8. *sack hoist wheel exterior hoisting system*
9. *stone vat (casing, tun, hoop)*
10. *vat cover, casing cover*
11. *hopper*
12. *lighter staff*
13. *stone spindle, stone shaft*
14. *grindstone – for sharpening knives (outdoors)*
15. *crown wheel*

Den Haller – Diepenheim
(drawing © H.B. Langenkamp)

spur wheel
hurst frame
central spindle (main upright shaft)

When two or more pairs of stones are driven by one waterwheel, a spur wheel located on a central spindle is usually used. That spur wheel is located in the hurst frame under the stones in underdrift; in overdrift, the spur wheel is located above the stones. In that case, it is driven by an extended central spindle.

Underdrift requires less space in the mill than overdrift. Lifting the stones is also easier because there is no need to remove a stone spindle.

12.4.2 Stone spindle and lantern wheel

12.4.2.a For underdrift

stone spindle

shims

The stone spindle in underdrift is a short iron shaft that drives the stone. There is a lantern wheel on this shaft that is driven by the pit wheel or by the spur wheel (see Fig. 12.3.1.1). In the case of a wooden lantern wheel, it is attached to the stone spindle with wedges, with or without the use of wooden shims.

Note: There appears to be a difference of opinion among millers and in the literature about the use of the names "stone spindle" and "spherical spindle" for mills with underdrift.
Some call it a stone spindle because it drives the stone. Others use the term spherical spindle because the runner stone rests on it.
Indeed, with underdrift, this spindle has both functions, so there is something to be said for both names. You should therefore keep to the name used in the region.

For wooden driving gear, the choice of a lantern wheel on the stone spindle instead of a cog wheel has to do with the fact that during the milling process the miller regularly tenters the runner, causing the stone spindle to move up and down (see section 12.7). Therefore, a lantern wheel as a drive for the stones is more suitable than a crown wheel. The cogs of the spur wheel always remain securely engaged in the staves of the lantern wheel during vertical movements.
A second reason is that, as the stones are subject to wear and tear, the stone spindle gradually sinks over time. As a result, the rynd — and with it the stone spindle and lantern wheel — slowly becomes lower and lower.

key, keyway guide ring, locking ring

Iron stone nuts (stone wheels) are attached to the stone spindle by means of a key and keyway and are supported by a guide ring or locking ring. Iron pit wheels and lantern wheels are sometimes conical.
In turbine drives with a vertical turbine shaft, the stone spindle can also be driven directly by a drive belt. A horizontal belt pulley is then located on the stone spindle. But a drive via a mill shaft also occurs in turbine mills.

neck bearing

rynd, eye

The top end of the stone spindle runs through the bedstone in underdrift by means of a bearing, the neck bearing (see Fig. 12.4.4.4). The stone spindle engages the rynd fixed in the eye of the runner. Thus, the stone spindle supports and drives the runner.

bridge tree

footstep bearing, toe-brass

bridging box

The lower end of the stone spindle in a wooden hurst frame rests on the bridge tree; this is part of the tentering mechanism (see section 12.5). In the bridge tree, the stone spindle is bearing-mounted using a footstep bearing. Often this footstep bearing sits in a toe-brass which is fixed in a bridging box (see Fig. 12.4.3.2) secured with wedges in the bridge tree. This allows vertical adjustment of the stone spindle.

bray iron, bridge

In an iron hurst frame with spur wheel, the lower end of the stone spindle rests on a stone tenter suspended in a bridge between the cast iron columns of the hurst frame (see Fig. 12.5.2.1).

sprattle arch

Some mills have hurst frames with two pairs of stones where each stone spindle is supported by a sprattle arch. There is no spur wheel; both stones are driven singularly. See, for example, the Baarlo Mill.

12.4.2.b For overdrift

quant
journal, crotch spindle

The stone spindle in overdrift occurs in two versions: as a continuous iron spindle with wooden cladding; or as a wooden spindle with separate journal and crotch.
The wooden covering is held in place with iron bands (see Fig. 12.4.2.1). The upper end is the journal, the lower end is the crotch (forked end). This forked end engages the rynd (see section 12.4.4) and drives the runner.

sprattle beam
"time-out" bolster
turning bolster

The journal of the stone spindle rotates in a wooden or bronze bearing which is enclosed in a bearing housing (sprattle box or glut box) carved into the sprattle beam. This bearing usually consists of two parts, the "time-out" bolster and the turning bolster, which serve as bearing blocks. The latter is sometimes made from pockwood, sometimes from bronze. If you remove the turning bolster, the stone is taken out of operation (see Fig. 12.4.2.3).

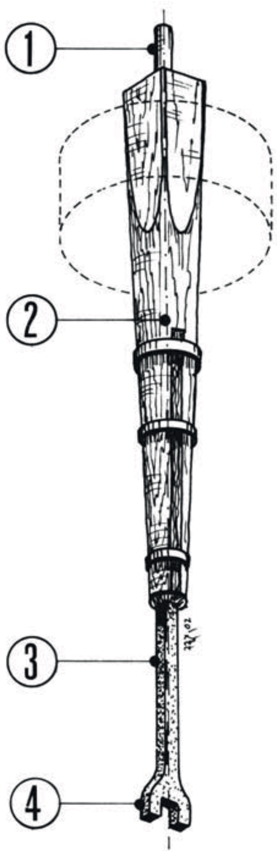

Fig. 12.4.2.1
Stone spindle for overdrift:

1. *journal end*
2. *filler wood*
3. *quant or crotch spindle*
4. *crotch*

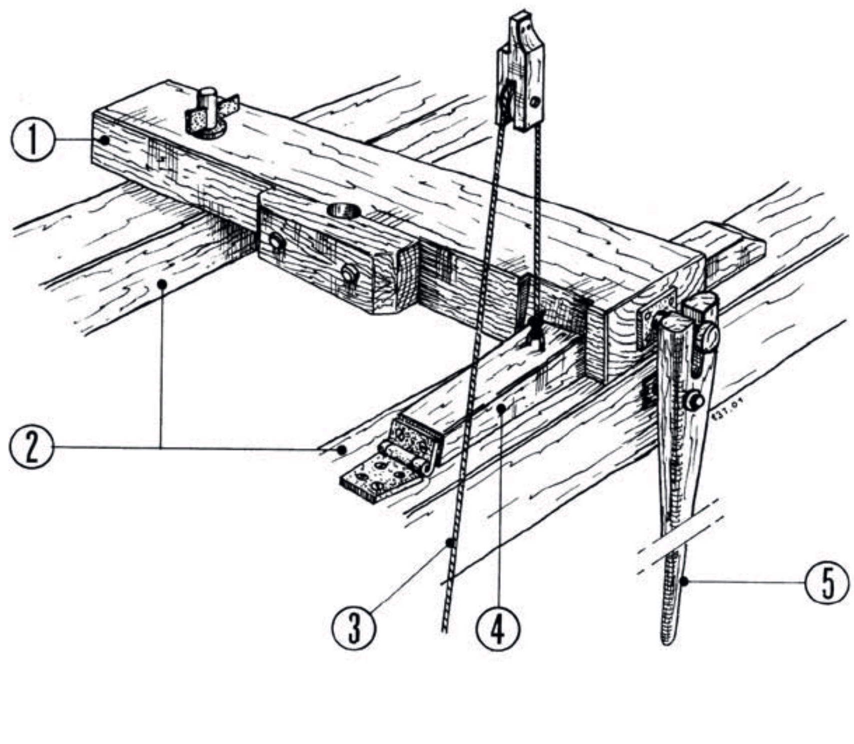

Fig. 12.4.2.2
The sprattle beam:

1. *sprattle beam*
2. *tie beams or floor joists*
3. *steering rope, sprattle beam bolt*
4. *locking chock*
5. *operating lever*

stone nut, stone pinion
tie-rod
stay

The stone nut (stone pinion or stone lantern wheel) is tightly wedged around the square wooden part of the stone spindle. The lantern wheel consists of two elm plates (flanges), between which the staves are anchored. Tie-rods hold the plates together and stays prevent the plates from being pulled together when wedged.

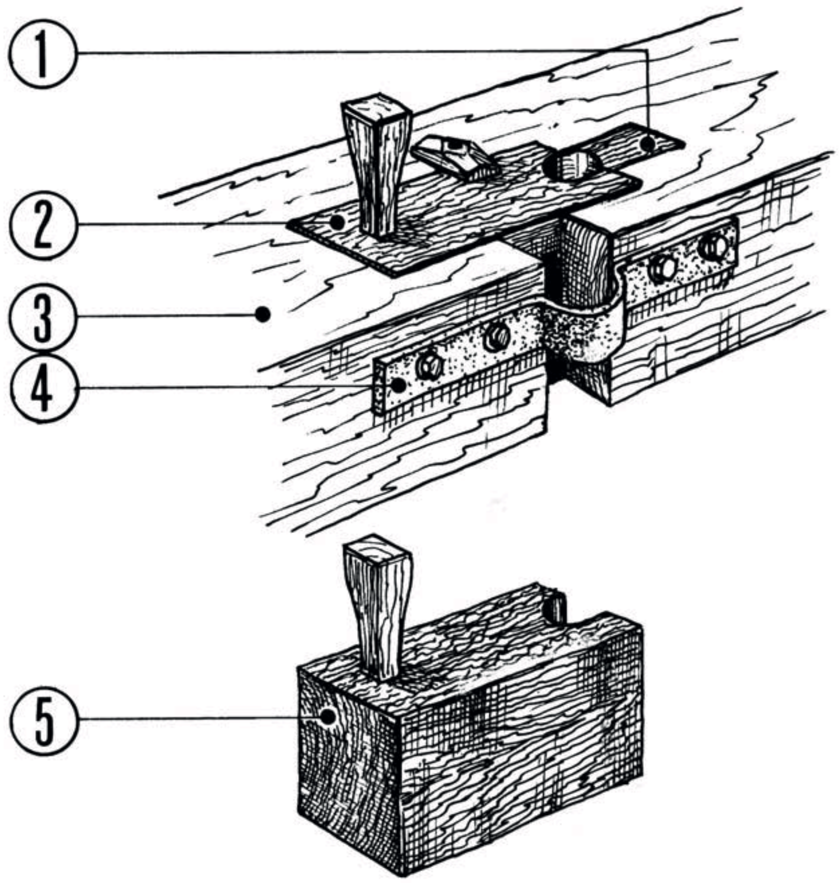

Fig. 12.4.2.3
Journal bearing:

1. *"time-out" bolster*
2. *turning bolster*
3. *sprattle beam*
4. *stirrup iron or keep*
5. *removed bolster*

12.4.3 Spherical spindle for over-drive

spherical spindle

In driving gear with overdrift, the runner is supported by the spherical spindle via the rynd.

pivot
toe-brass,
bridging box, bridge tree

At the bottom, the spherical spindle (see Fig. 12.4.3.1) ends in a pivot that rests in a toe-brass. This foot-step bearing includes a pivot that usually rests in a toe-brass in the bridging-box (centering block) that lies on the bridge tree. Bearings with a ball bearing are also found.
The wooden spherical spindle does not rotate in the runner stone suspension.

pull wedge
push wedge

To adjust the spherical spindle precisely vertically, the bridging-box (centering block) is adjustable in the horizontal plane on the bridge tree by means of pull and push wedges (see Fig. 12.4.3.2).
The pivot is lubricated with castor oil or oil that is not too thin, such as engine oil. Over the toe-brass are two half covers to protect against dust getting in the bearing. On top of the bulb spindle is a cock. On it lies the rynd.

cock, rynd
neck, neck bearing

Below the cock, the spherical spindle has a bulge, called the neck. This neck rotates in the neck bearing, the wooden or iron bearing rotates in the stone hole of the bedstone (see Fig. 12.4.4.4). The neck bearing holds the spherical spindle in a purely vertical position by means of three pockwood bolsters that are adjustable and have wedges placed behind them.

pockwood bolsters
wedges
grease chambers

Between the bolsters in the iron neck bearing are grease chambers for the neck of the spherical spindle.

12.4.4 Rynd

rynd

The rynd is a strong iron structure attached to the bottom of the eye of the runner stone.

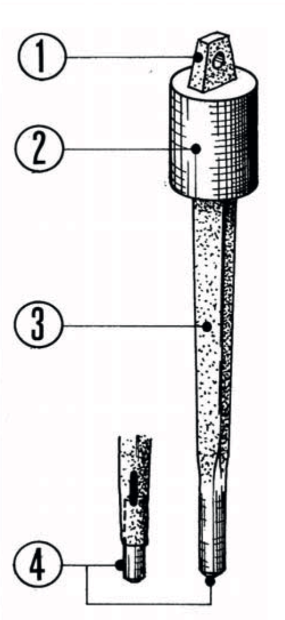

Fig. 12.4.3.1
Spherical spindle:

1. *cock for the rynd*
2. *neck*
3. *shank*
4. *loose or fixed pivot*

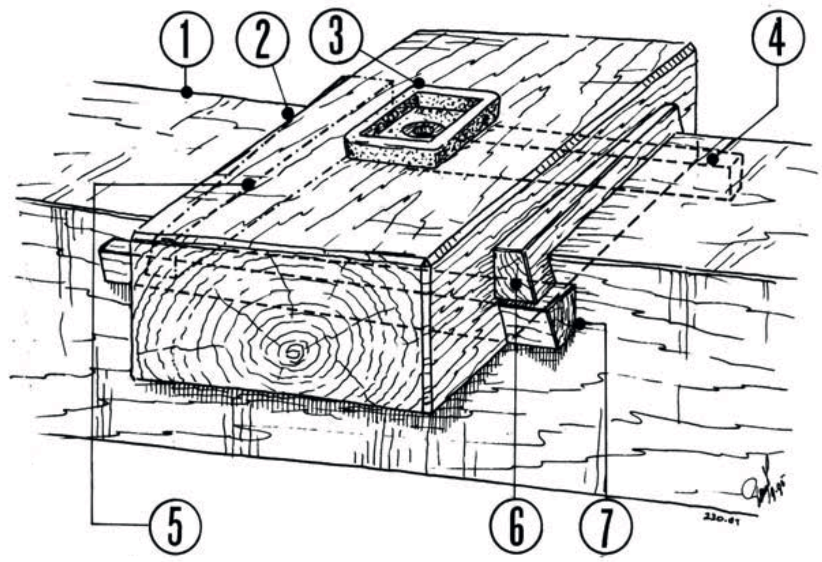

Fig. 12.4.3.2
Bridging box with toe-brass:

1. *bridge tree*
2. *(and 6) push wedges*
3. *toe-brass*
4. *(and 7) pull wedges*
5. *bridging box*

A rynd has two functions:
- supporting: via the rynd, the runner is supported on the stone spindle or spherical spindle.
- driving: the runner is driven via the rynd. In the case of underdrift, the stone spindle (spherical spindle) takes care of that; in the case of overdrift, the crotch of the quant grips around the rynd and against the cock and drives the stone.

cocks

fixed rynd arms (claws)

There are different versions of the rynd. These include the fixed rynd, the balance rynd and the runner stone suspension (see Fig. 12.4.4.1 and Fig. 12.4.4.3).

bridge
rynd

The fixed rynd fits accurately and immovably on the cock of the spherical or stone spindle. The rynd has two, three or four ends, called the arms (claws). These are moulded or wedged into the eye of the runner. The rynd and the runner thus form a single unit. In order for the runner to run absolutely parallel across the bedstone, the fixed rynd must be mounted very precisely in the runner.

A type of fixed rynd found in underdrift mills is the bridge rynd (see Fig. 12.4.4.2). This one has two arms, but it is heavily curved. The bridge rynd rests on the stone spindle.

English balance rynd
inner rynd (mace or driver), outer rynd (bridge, crossbar or bail with a cockeye)

There are several versions of the balance rynd. The most common is the English balance rynd (see Fig. 12.4.4.3). This consists of an inner (driver) and an outer (bail) rynd. The inner rynd rests on the cock of the spherical spindle. The spherical spindle or a quant (for overdrift) drives the stone. It has two round trunnions situated opposite each other. The outer rynd is lying loosely on this so it can make a tilting motion.

recesses
runner stone suspension

The outer rynd has two trunnions perpendicular to the trunnions of the inner rynd. These bear the runner via two recesses.
The runner stone suspension can also balance. However, the spherical spindle does not turn here.
Instead of a cock, the spherical spindle here features a type of socket bearing. In this socket bearing there is a short pivot that can tilt slightly. The top end of the pivot is firmly held in the rynd.
This rynd is two-armed (clawed) and driven by the quant in the usual way. Runner stone suspension is not applicable in underdrift.

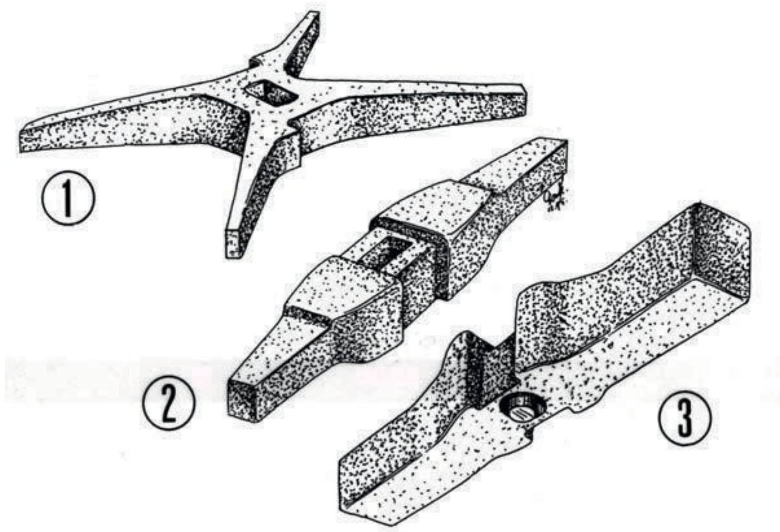

Fig. 12.4.4.1
Various fixed rynds:

1. *four-arm rynd*
2. *two-arm rynd*
3. *rynd for runner stone suspension*

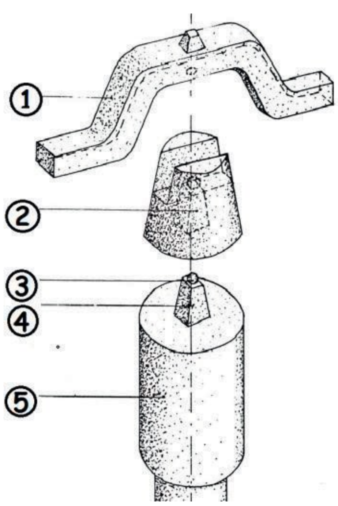

Fig. 12.4.4.2
Bridge rynd:

1. *bridge rynd*
2. *mace*
3. *ball*
4. *cock*
5. *neck of the stone spindle*

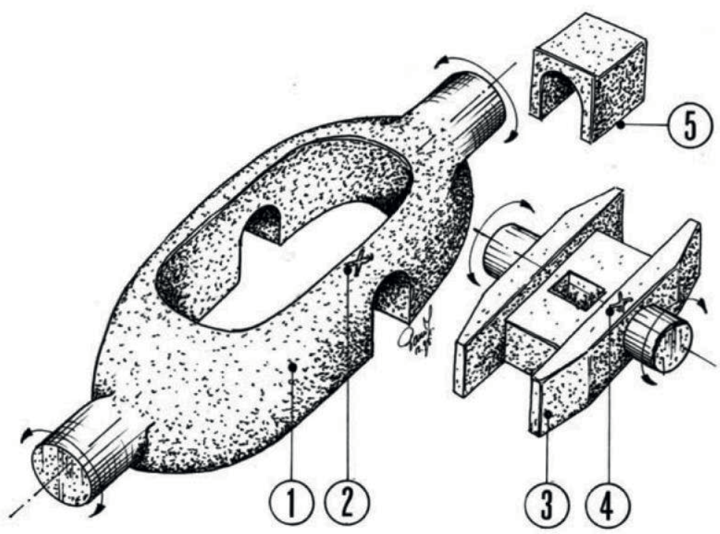

Fig. 12.4.4.3
Balance rynd:

1. *outer rynd (bridge, crossbar, or bail)*
2. *adjustment mark of outer rynd*
3. *inner rynd (mace or driver)*
4. *adjustment mark of inner rynd*
5. *recess*

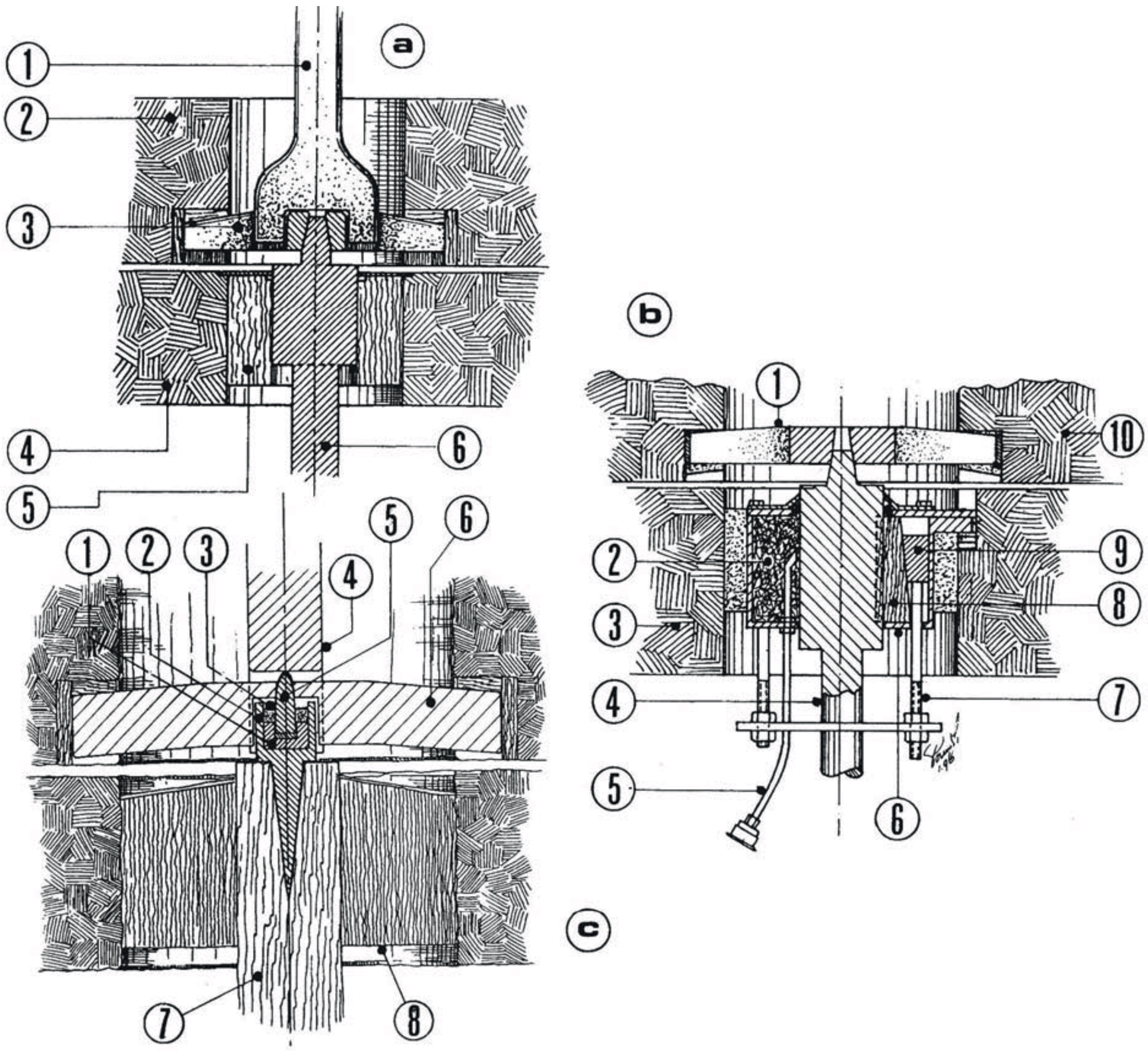

Fig. 12.4.4.4
Various versions of the neck bearing:

a. wooden neck bearing

1. *quant or crotch spindle*
2. *runner stone*
3. *rynd*
4. *bedstone stone (nether stone)*
5. *wooden neck bearing*
6. *spherical spindle*

b. metal neck bearing

1. *rynd*
2. *grease chamber,*
3. *bedstone,*
4. *spherical spindle,*
5. *lubrication channel line,*
6. *metal neck bearing*
7. *tie-rod*
8. *hardwood bolster*
9. *pull wedge*
10. *runner stone*

c. neck bearing for runner stone suspension

1. *hard steel bearing pot or tram-pot*
2. *toe-brass*
3. *lubricating oil*
4. *quant or crotch spindle*
5. *pivot*
6. *rynd*
7. *wooden spherical spindle*
8. *wooden neck bearing*

12.5 THE TENTERING MECHANISM

tentering mechanism
lightering, tentering

To move the runner stone up and down for the purpose of the milling process, a grain mill has a tentering mechanism. This controls the distance between the millstones. We call that lightering and tentering.
We distinguish between tentering mechanisms at wooden or at iron hurst frames because they are quite different in terms of construction. However, lightering or tentering runner stones is always done from below.

12.5.1 Tentering mechanism for wooden hurst frames

With wooden hurst frames and wheels, it makes no substantial difference to the construction of the tentering mechanism whether the mill has underdrift or overdrift. In both types of drives, lightering and tentering the runner stone is done by moving the stone spindle or spherical spindle up and down with a few levers.

hanger
bridge tree

The structure that carries the stone spindle (spherical spindle), the rynd and the runner is called the hanger. The lower end of the stone spindle (spherical spindle) rests with a bearing on the bridge tree. This lower bearing is usually a foot-step bearing that rests on the bridge tree with an adjustable bridging box in which the toe-brass lies. For spherical spindles, a bridging box is almost always used.

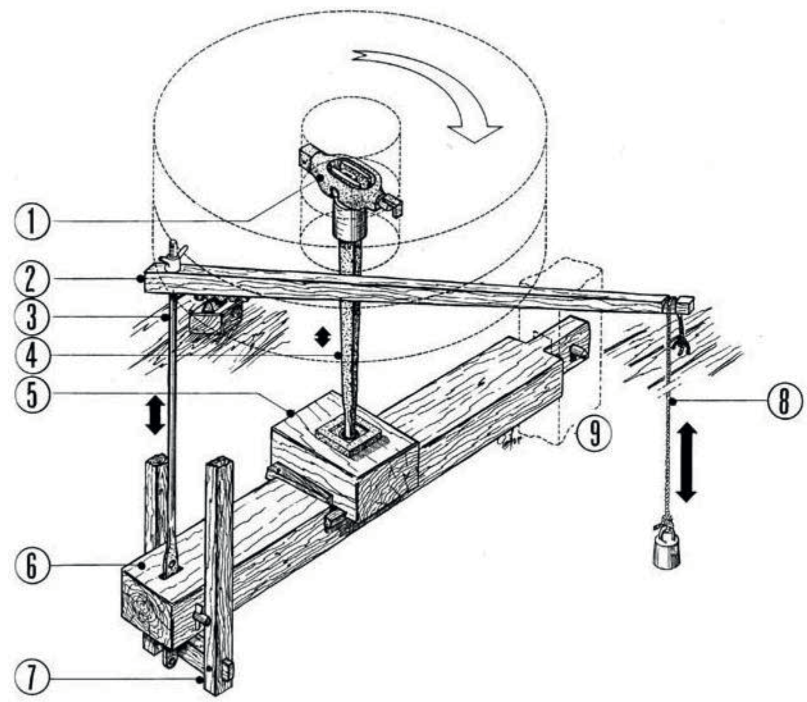

Fig. 12.5.1.1
Tentering mechanism with the tentering beam for overdrift:

1. *rynd*
2. *tentering beam, lighter staff*
3. *bray iron*
4. *spherical spindle*
5. *bridging box*
6. *bridge tree*
7. *hanger*
8. *lighter rope or belt*
9. *hanger*

hanger

The bridge tree hangs with its fixed end hinged in a hanger attached to the (floor) beams of the hurst frame or stone floor. The other end moves in the vertical plane within a wooden framework. This framework prevents lateral sway of the bridge tree. The bridge tree hangs by this same end via a tie-rod, the bray iron, on the short arm of a lever, the so-called tentering beam.

bray iron, tentering beam

Strung around the end of the long arm of the tentering beam is a rope or leather strap secured at one end to the floor or a ceiling beam and equipped with a counterweight at the other end. This control rope is located above the milling floor, within easy reach of the miller.

lightering

Pulling down the counterweight raises the bridge tree via the tentering beam and the runner is lightered; in other words, there is more space between the bedstone and the runner. However, if you raise the counterweight, then the bridge tree descends via the tentering beam precisely and the runner is tentered; there is less space between the two stones (see section 12.7).

tentering

cross bridge tree

In another commonly used construction, there is additionally a cross bridge tree (brayer) between the bridge tree and tentering beam (see Fig. 12.5.1.2). This construction provides an even finer adjustment of the space between the bedstone and the runner.

lighter staff

Instead of a rope around the tentering beam, sometimes a belt with a stick, referred to as the lighter staff, is used.

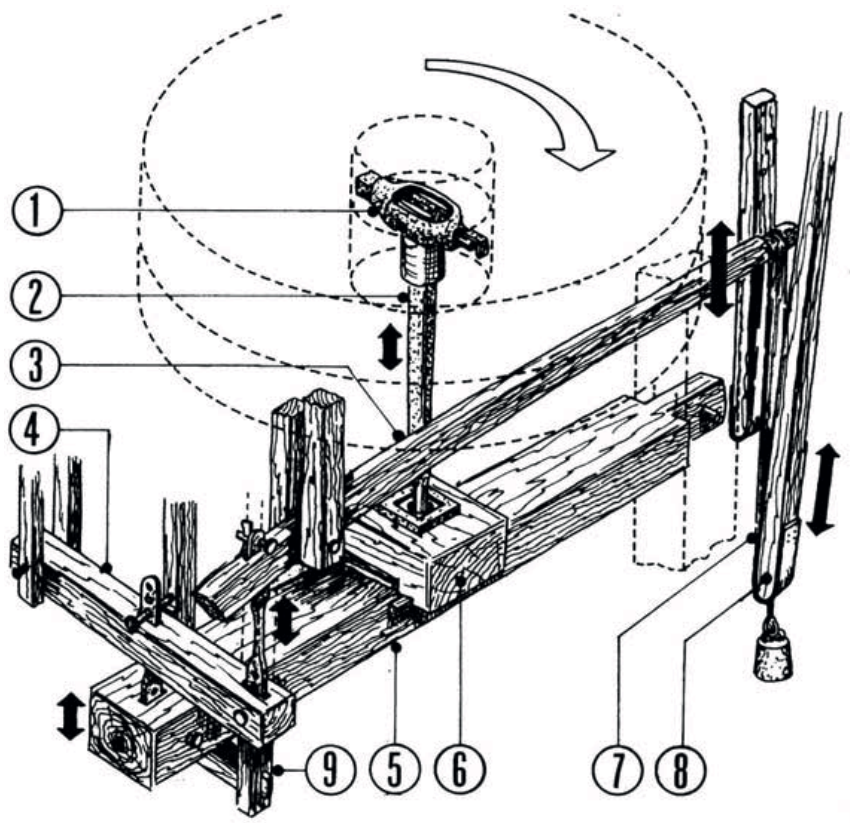

Fig. 12.5.1.2
Tentering mechanism with cross bridge tree for over-drive:

1. *rynd*
2. *spherical spindle*
3. *tentering beam*
4. *cross bridge tree*
5. *bridge tree*
6. *bridging box*
7. *belt*
8. *lighter staff*
9. *hanger*

12.5.2 Tentering mechanism for iron hurst frames

stone tenter
bridge

For iron hurst frames, the construction of the tentering mechanism is not only different, it's also simpler. A common design is that in which the lower end of the stone spindle (spherical spindle) rests on a stone tenter. This stone tenter is suspended from a bridge between two columns of the hurst frame. A handwheel can be used to adjust the position of the stone tenter and thus the height of the runner stone. The passage of the stone spindle or sphere spindle through the bridge occurs by means of a bearing.

Fig. 12.5.2.1
Cast iron tentering mechanism:

1. *stone tenter*
2. *columns of the hurst frame*
3. *stone spindle*
4. *bridge*
5. *tentering or locking ring*
6. *tentering wheel*

The stone nut is pushed up from the work.

Bisschops Mill – Maastricht

spratttle arch
footing
tentering beam

Other versions of the tentering mechanism are those in which the stone spindle or spherical spindle stands with a bearing on a cast iron support, the sprattle arch. This sprattle arch then rests on a concrete or masonry footing.
The bearing rests in the sprattle arch on a long wrought-iron rod, the tentering beam. This tentering beam is operated from the front of the hurst frame with a tentering screw and handwheel.

Some watermills — for example, the Vol Mill in Epen — have a wooden hurst frame containing iron running gear. The tentering bridge is then made of wood. The stone tenter is operated using a handwheel or a tentering beam with a rope or belt.
Sprattle arches in wooden hurst frames support wooden beams in the hurst frame.

12.6 GRAIN SUPPLY AND MEAL REMOVAL

12.6.1 Grain supply

skirting board
millstone curbing vat
vat covers
hopper ladders or horse
hopper
shoe feeder, shoe
eye
agitator, damsel or shaker arm

Just below the surface of the bedstone, a wooden ring, called a skirting board or millstone curbing, is fitted around the bedstone. On it is the wooden vat, tun or stone casing enclosing the runner stone. (Metal is less suitable for this because of the condensation which occurs.) The vat is covered with vat covers. Attached to the vat covers are the hopper ladders. They slope downward at an angle and taper towards each other. On the highest part of the hopper ladders rests the hopper, a square funnel into which the grain is poured. Suspended below the hopper is the shoe feeder or shoe: a wooden chute tapering toward the middle of the vat that ends above the hole in the centre of the runner stone, called the eye (see section 12.7.1). Against one of the sides of the shoe is a bar, called the rap, which extends beyond the quant of the stone spindle. Or, in the case of underdrift, beyond the agitator, damsel or shaker arm. (In Limburg, this is called a *spieleman* or shaker arm; in Twente a *juffertje*, or damsel).

Fig. 12.6.1.1
An agitator, damsel or shaker arm. Behind the shoe feeder or shoe and on the right are the rap and string.

Watermill Frans – Mander (Overijssel province)

slide
hanger rack for adjusting the hanger for shoe control rope
shoe control rope

An accurately adjustable grain feed is indispensable for good meal milling. The grain flows into the shoe feeder via a slide in the hopper. The grain supply to the shoe feeder is controlled by opening this slide to a greater or lesser degree.
The grain supply from the shoe feeder to the stones is also adjustable.
- The slope of the shoe feeder can be adjusted with the hanger rack and string; the more angled the position, the greater the feed.

- The supply is also controlled by the shoe feeder which produces a shaking motion.

rap

This movement is caused by the rap which is pulled against the quant by the angled position of the string. A square quant, when it starts rotating, will transmit a shaking motion to the shoe feeder.

shakers
agitator
shaker arm

If the quant is round then the shaking motion is produced by a number of hardwood slats or metal strips called shakers, which are placed around the quant.
In mills with underdrift, no quant is present. In that case, a so-called agitator (damsel or shaker arm) is attached to the rynd. This agitator is a short spindle with a three or four-sided bulge that ensures the movement of the shoe feeder via the rap (see Fig. 12.6.1.1).
Shaking causes the grain to fall evenly from the shoe feeder into the eye of the runner. As the mill turns faster, the shaking will become faster and more violent and thus more grain will fall into the eye.

withholder (miller's willow)

- A third feature is that the shoe feeder is equipped with what is called a 'withholder'. This is a cord (sometimes also iron wire) that goes from the shoe feeder via several pulleys to a hinged slat on the meal spout (or in its immediate vicinity). The more weights hung on this slat, the less grain will fall into the stone. This is because it increases the distance from the quant to the rap, and the blows against the rap are thereby somewhat dampened. Regionally, we see differences in the implementation of the withholder.

keeper (spring stick)

- Some mills also have a 'keeper' (spring stick). This is a wooden spring — or similar construction — that actually causes the rap to be pulled against the quant with more force.

sack trestle or sack bench

The vat or stone casing usually consists of three or four parts so that it can be easily removed for cleaning, dressing or neck bearing maintenance. Often a trestle or sack bench, on which a sack of grain can be prepared for emptying into the hopper, is set up next to the hopper.
In larger-scale production, silos are often used: the hopper can be filled from a silo by opening a flap on a pipe.

12.6.2 Meal removal

skirting board
spout
meal spout

Between the runner and the vat, approximately 5 cm wide space remains. The meal coming from between the stones falls into this space, of which the skirting board forms the bottom. Inside the skirting board is the spout, a hole in the skirting board that provides access to the meal spout.
Airflow generated by the rotating runner drives the meal towards this spout. However, this airflow is not sufficient to feed all the meal into the meal spout.

ring meal

The meal left behind, the so-called ring meal, would then lie there for a long time and, especially due to moisture from condensation, the remaining meal could form a cake on the meal ring that is prone to decay in which also insects such as flour moths and flour weevils like to nest.

tag, sweeper
meal cake

Therefore, attached to the runner is a so-called sweeper that pushes the meal ahead of it over the skirting board in the direction of the spout so that no meal cake can form. However, using the sweeper does not make regular cleaning of the space between the wall of the vat and runner unnecessary!

bagging chute
dust cover

The meal falling into the meal spout then enters the bagging chute, an elongated (often tapered) wooden container. This container is partially covered at the top with boards and fitted with a dust cover — a piece of linen or canvas — in front of the opening to reduce dust.

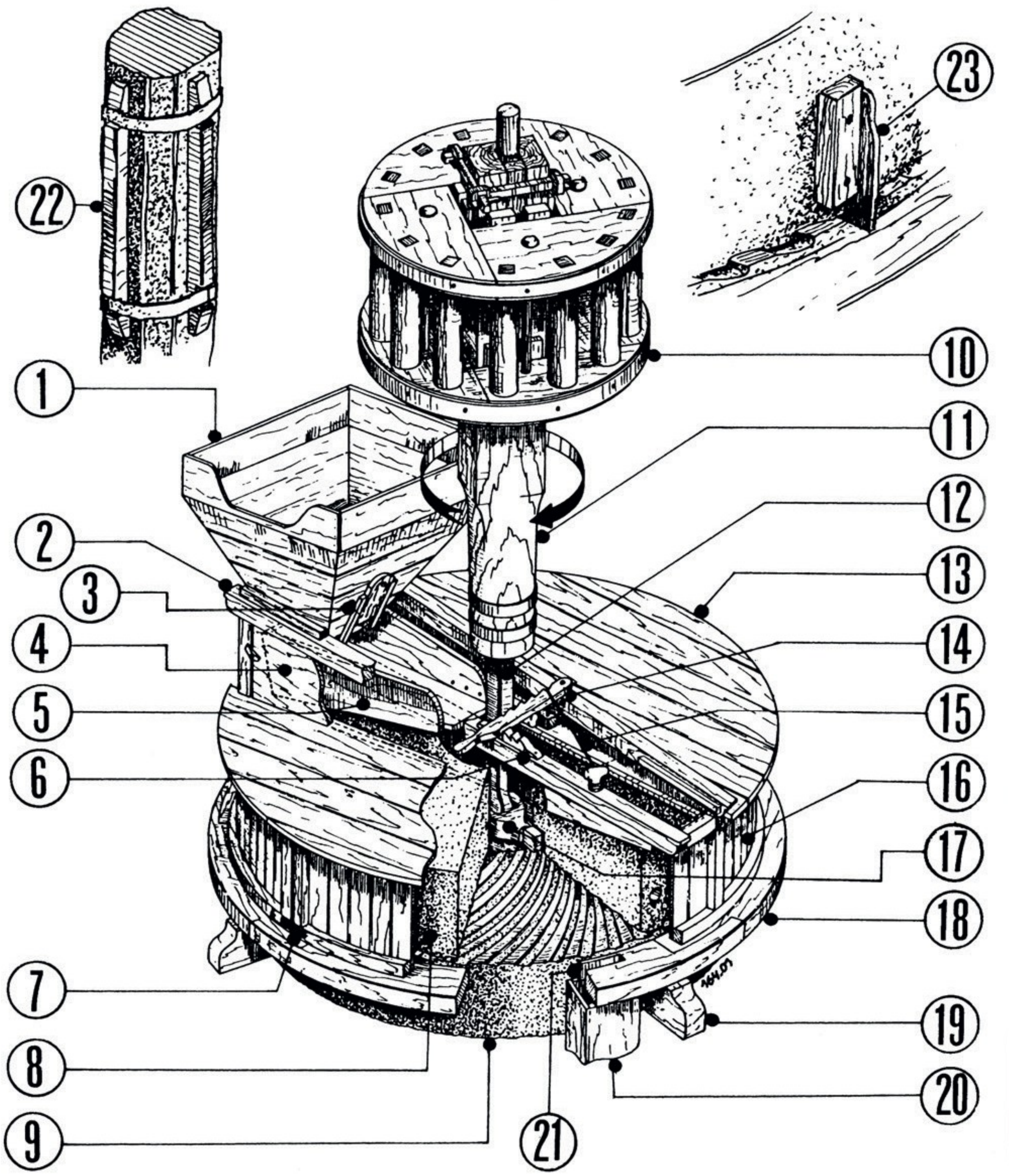

Fig. 12.6.1.2
A complete stone set with stone spindle and stone nut or stone lantern wheel (overdrift):

1. *hopper*
2. *hopper ladder*
3. *slide*
4. *dust board*
5. *shoe feeder or shoe*
6. *hanger rack*
7. *vat lock*
8. *runner*
9. *bedstone*
10. *stone nut*
11. *stone spindle*
12. *quant or crotch spindle*
13. *vat cover*
14. *hanger*
15. *shoe control rope*
16. *vat*
17. *rynd*
18. *skirting board or millstone curbing*
19. *ring block*
20. *meal spout or meal chute*
21. *spout*
22. *shakers*
23. *sweeper*

The flour sack in which the flour is finally collected hangs from two hooks at the bottom of the bagging chute. The meal sack is held open by a third hook attached to a rope that runs over a pulley and to which a counterweight is attached at the other end. A small stop block is inserted in this rope to prevent the hook from hitting the miller's face when the counterweight falls.
The meal sack usually stands on the floor or on a small pallet but in Limburg there is often a separate trestle with a support at different heights on which the sack stands.

Nowadays, milling is often done in paper sacks for hygienic reasons; these are attached to the bagging chute with two metal clamps.

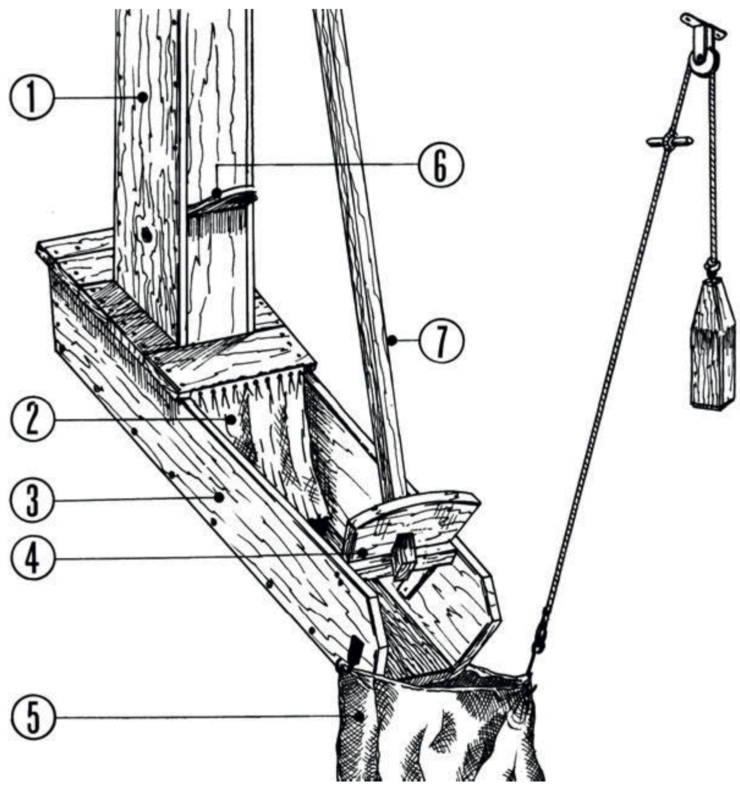

Fig. 12.6.2.1
Meal spout and bagging chute:

1. *meal spout*
2. *dust cover*
3. *bagging chute*
4. *scoop board*
5. *meal sack*
6. *sliding plate*
7. *scoop stick*

scoop board

The open bottom of the bagging chute is closed with the scoop board.
The meal supply to the meal sack can thus be interrupted. This is necessary when the meal sack is full and the miller needs to unhook it and replace it with an empty one. Then the miller removes the scoop board again and the meal supply resumes. The milling process is not interrupted during sack changes.

scoop stick

A scoop stick is sometimes attached to the scoop board, which may also be used to operate the scoop board from the stone floor.

12.7 MILLING PROCESS

12.7.1 Milling grain

poor stone, rich stone

dressing

Millstones work by means of pressure, cutting power and movement. The bedstone should be perfectly flat on the grinding surface while the runner should be slightly concave on the inner part of the grinding surface, which is called a poor stone in technical jargon. A flat stone is called a rich stone.
On the grinding surface of both bedstone and runner there is a dressing (see section 12.7.2). The purpose of this dressing is threefold:
a. to increase cutting power;
b. to draw in cool air for the meal between the stones;
c. to transport mill stock and meal outwards.

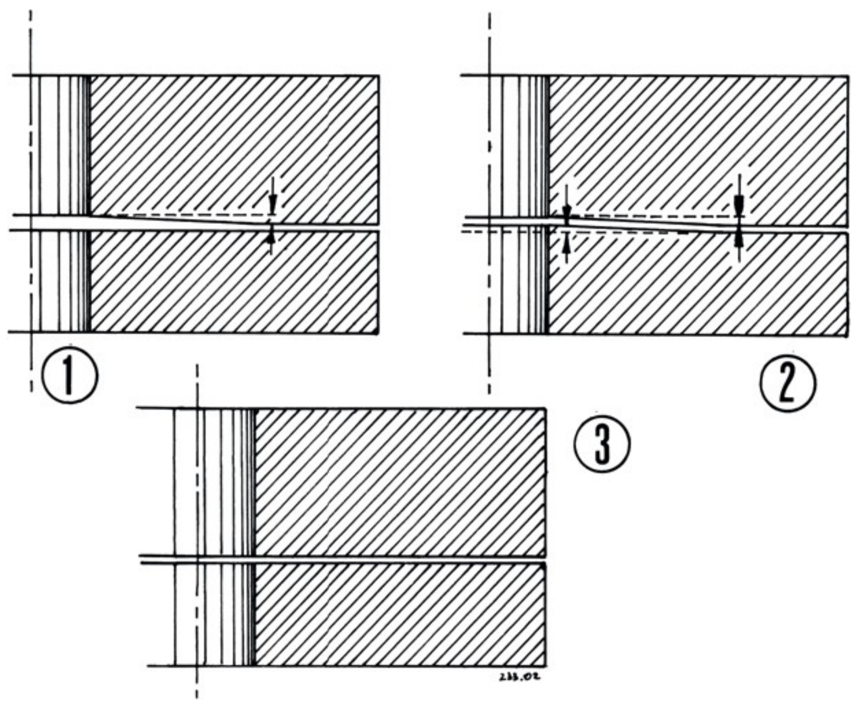

Fig. 12.7.1.1
Rich or poor stones:

1. *example of a correctly dressed pair of stones*
2. *a well-dressed poor runner but the bedstone is too rich*
3. *the runner is too rich*

eye (where grain enters the stones)
bosom
waist
reducing zone
skirt
grinding zone

The inner part of the milling surface, around the eye, is the bosom. This is where the space between the stones is largest and the mill stock is distributed.
The middle part where the space between the stones narrows is the waist or reducing zone; this is where the grains are broken open.
The outer part where the stones come closest together is the skirt or grinding zone: here the broken grains are finely ground into meal.
When the mill rotates slowly, the shaking motion transmitted to the shoe feeder is limited. A small amount of grain gets between the stones and it is easily ground. If the mill is turning faster, this not only allows more grain to get between the stones, but that grain is also fed outwards between the stones must faster due to the faster turning runner.
This produces meal that is too coarse; the reason for this is that the larger amount of grain greatly reduces the pressure per grain kernel.
To prevent that, the miller intervenes.

lighter staff, lighter

With the help of the lighter staff, called the lighter for short, the runner is slightly *tentering*

lowered, reducing the space between the two stones and increasing the pressure. The grain will now be milled again as desired. This action of bringing the stones closer together is called tentering.

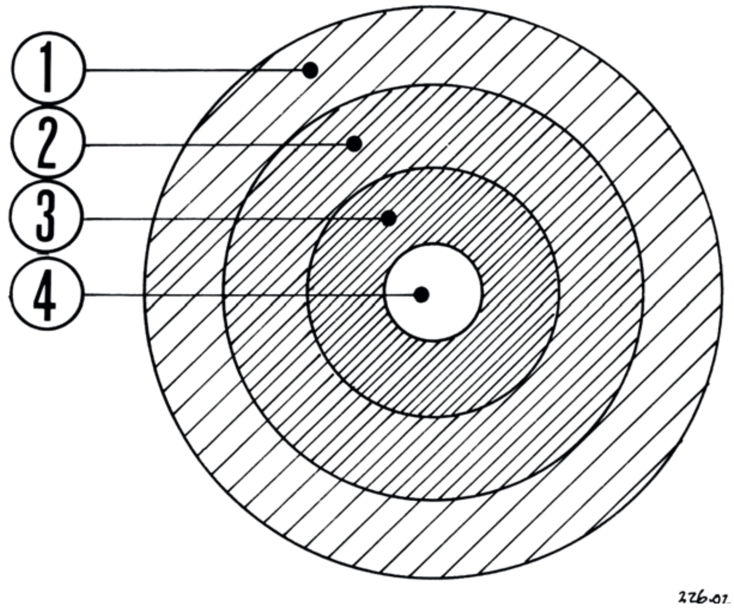

Fig. 12.7.1.2
Schematic layout of the milling zones:

1. *skirt*
2. *waist*
3. *bosom*
4. *eye*

lightering

When the speed of the runner decreases again, the miller increases the distance between the two stones slightly. This operation is called lightering. In doing so, the miller ensures that the fineness of the meal remains as constant as possible because that is what the baker expects: a product of consistent quality.
A miller therefore regularly checks the fineness and temperature of the meal by hand.
With a steady supply of water, a waterwheel or turbine achieves a nearly constant speed and the stone also turns evenly. But good meal also requires a sufficiently high peripheral speed of the stone.
If the miller, when the mill is running evenly, also properly adjusts the supply of grain from the hopper and the shoe feeder as well as the spacing of the stones, then lightering or tentering will require little further attention from the miller.
Because of the steady running and proper adjustment, flour of consistent quality can then be milled without the miller having to be constantly at the lighter.
As regards this point, a watermiller has an easier life than a colleague windmiller. This is because irregular wind strengths also change the speed of the blades and thus the speed of the stones in a windmill. The distance between the stones must then be constantly adjusted.
To automate this adjustment to a degree, the so-called governor was devised for windmills. These are of no use on watermills.

12.7.2 Millstones

German stone
bluestone

Natural stone that is sufficiently rough and rigid and has an open structure (possesses a natural cutting ability) is suitable as a millstone. Like the German stone or bluestone that comes from the Eifel region of Germany and is of volcanic origin.
Bluestone is good for milling wheat. Because it is quite soft, it will need to be dressed more often.

French stone

Another important type is the French burr stone. It is composed of pieces of freshwater quartz which is very hard and also suitable for milling wheat.

composite stones, milling layer
ballast layer

In addition to natural stones, composite stones that consist of a milling and a ballast layer are manufactured (see Fig. 12.7.2.1). The milling layer is made of pieces of natural stone that are cured together with a liquid binder in a trough and made suitable as a millstone. This is called solid composite stone because the surface is uniform in composition (see Fig. 12.7.2.2c). In addition to solid composite stone, there is also artificial stone with a soft bottom. This facilitates sharpening (dressing). In doing so, the bottom area, the part to be dressed, is of a softer stone type than the furrow that is to remain and is made of harder material (see Fig. 12.7.3.2). However, this structure does not allow for another dressing to be introduced.

solid composite stone

artificial stone with a soft bottom area, bottom area

furrow

Composite stones are generally well suited for milling animal feeds such as barley, oats and corn.

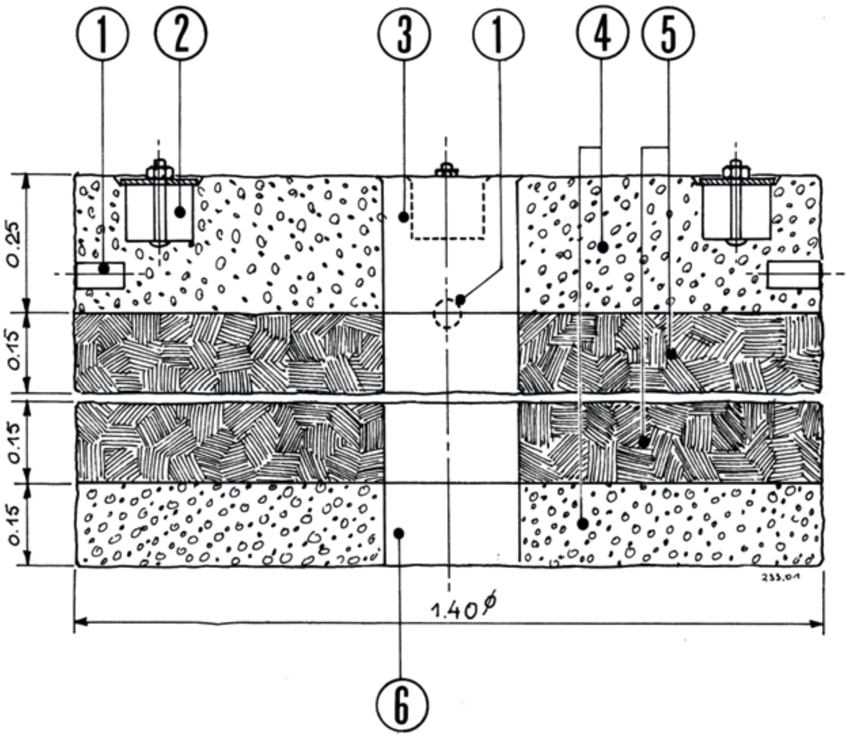

Fig. 12.7.2.1
Cross section of composite stones:

1. *peg hole*
2. *balance box*
3. *eye*
4. *ballast layer*
5. *milling layer*
6. *stone hole*

In recent decades, however, composite stones have also been made using flint. In practice, these 'flintstones' proved to be highly suitable for milling wheat.

flintstone

A new runner is about 40 cm thick, a new bedstone about 30 cm. The weight, of course, depends on the diameter and type of stone. Diameters show great variation. Most common are stones with diameters of 1.50 m and 1.40 m, called seventeeners and sixteeners. Fifteeners, fourteeners and thirteeners, with diameters of 1.30 m, 1.20 m and 1.10 m, respectively, are less common. The name seventeener, sixteener, etc. is said to be based on old girth measurements in Amsterdammers' feet, although there is still no certainty about this. An even smaller millstone measuring 1.01 m is called a 'little wolf' (wolfie).

seventeeners, sixteeners

little wolf

A new sixteener (so, 1.40 m in diameter) runner of bluestone weighs about 1200 kg and a new sixteener bedstone weighs about 900 kg.

The stones are subject to wear and tear during the milling process and, partly because they must be constantly re-sharpened, will become thinner and lighter over time. A runner that has been 'milled out' has too low a weight to still exert sufficient milling pressure. However, it can then still be used as a bedstone. There were also instances when 'milled out' runners had a ballast layer of concrete applied in order to restore sufficient milling pressure.

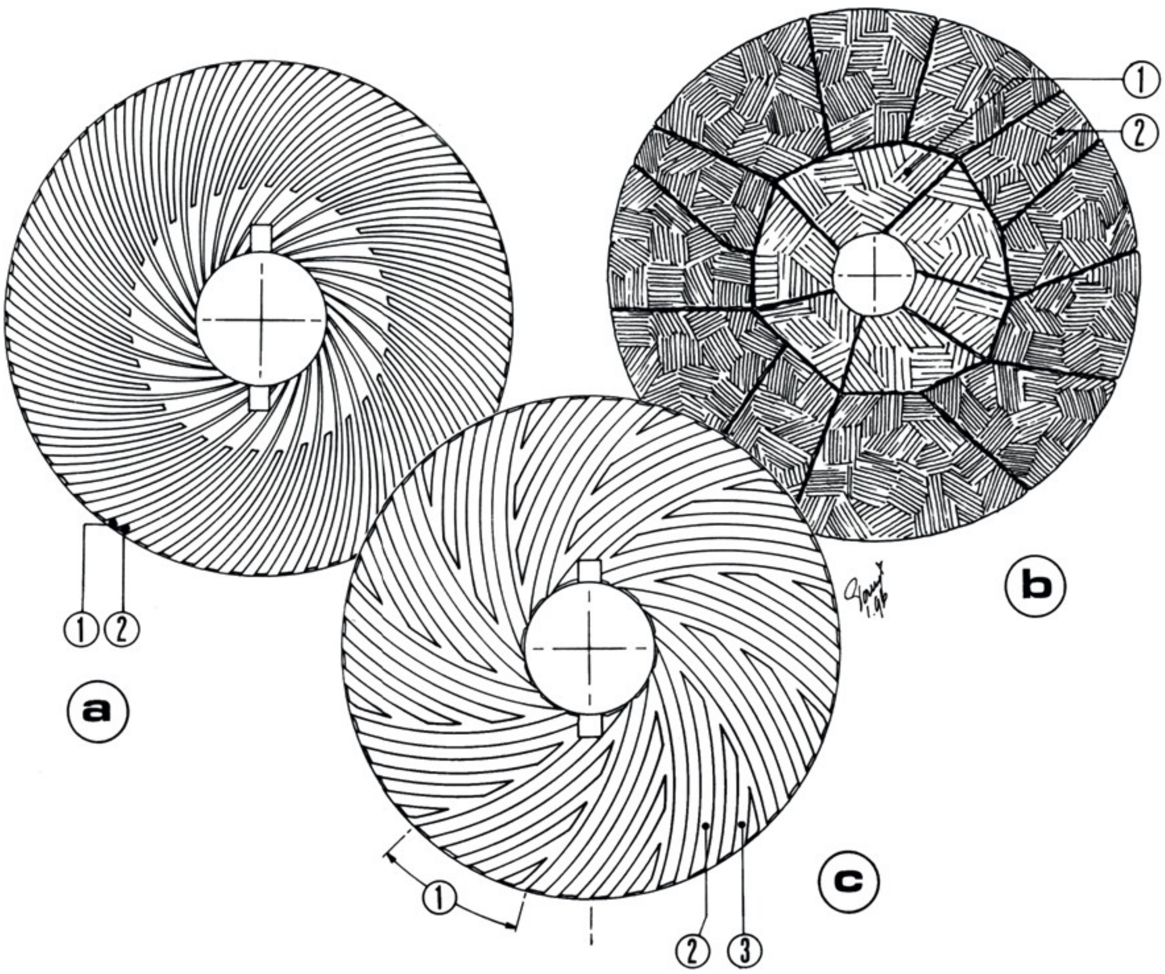

Fig. 12.7.2.2
Millstones with dressings: *a. and c. have draught and turn clockwise.*

a. German bluestone with pendular dressing
1. *groove*
2. *furrow*

b. French burr stone
1. *soft parts*
2. *hard parts*

c. composite stone with quarter dress
1. *quarter*
2. *furrow*
3. *groove*

eye, stone hole
neck bearing

Both the runner and the bedstone have a round hole in the centre. The hole in the runner is called the eye, and the one in the bedstone is called the stone hole. The neck bearing is inserted in the stone hole of the bedstone (see section 12.4.2 and 12.4.3). The stone spindle or spherical spindle is bearing-mounted in the neck bearing and can move up and down. To prevent dust and mill stock from entering the bearing, the stone hole is closed by a (zinc) lid.

peg holes

balance boxes

The rynd and the crotch or the agitator (shaker arm) are located in the eye of the runner. The grain introduced between the stones falls into this hole. Millstones have so-called peg holes in their outer circumference. These crane holes are needed for hanging the stone in the stone crane (see section 12.9.4). Since a (natural) stone is never completely homogeneous in composition, balance boxes are installed in the top of a stone to compensate for a slight imbalance in the stone with pieces of lead.

12.7.3 Dressing

dressing

dress, sharpen

furrows, land areas, bottom of furrow, grooves

The working surface of the runner and bedstone is provided with a grooved pattern, called the dressing. To apply a dressing or make the stone sharp again is to dress or to sharpen. This improves cutting performance, increases meal quality and speeds up the production process.
A dressing consists of alternating adjacent furrows or grooves and land areas; these are the grooves created by cutting away stone material.

Fig. 12.7.3.1
A dressing with furrows and lands.
Here is a pendular quarter dress with draught.

Dressings can vary greatly in form. Which dressing is chosen depends on the structure of the stone, the product to be milled, the desired flour quality and the desired production rate and quantity.
The number of furrows also varies: for wheat stones there are about 60 to 80, but for rye or barley there can be as many as 120 to 140. Furthermore, the distribution over the grinding surface can vary greatly.

12.7.3.a Dressing types

central dress, union or straight dress

sickle dress or circular furrow dress

draught

The furrows can be straight (a central or union dress) or curved (a sickle dress).
The furrow can be aimed at the centre of the eye, but it can also be applied with more or less draught. In that case, the furrow touches, as it were, an imaginary circle around the eye.

quartering, quarters, master furrow journeyman furrow

Furrows can be evenly arranged next to each other but they can also be applied in groups, so-called quarters. These are referred to as quarter dress. Each quarter typically consists of the master furrow, the journeyman furrow, the apprentice (“prentice”) furrow and lastly the butterfly (“fly”) furrow. Both straight and curved furrows can be introduced into quarters.
For central or union dressings, the furrows are often alternately made slightly shorter around the eye to give more space at the entrance (see Fig. 12.7.2.2).

Often, the dressings that a miller applied to his millstones used to be 'the miller's secret'. This was done for competitive reasons: 'Thanks to my dressing, my meal is the best!'

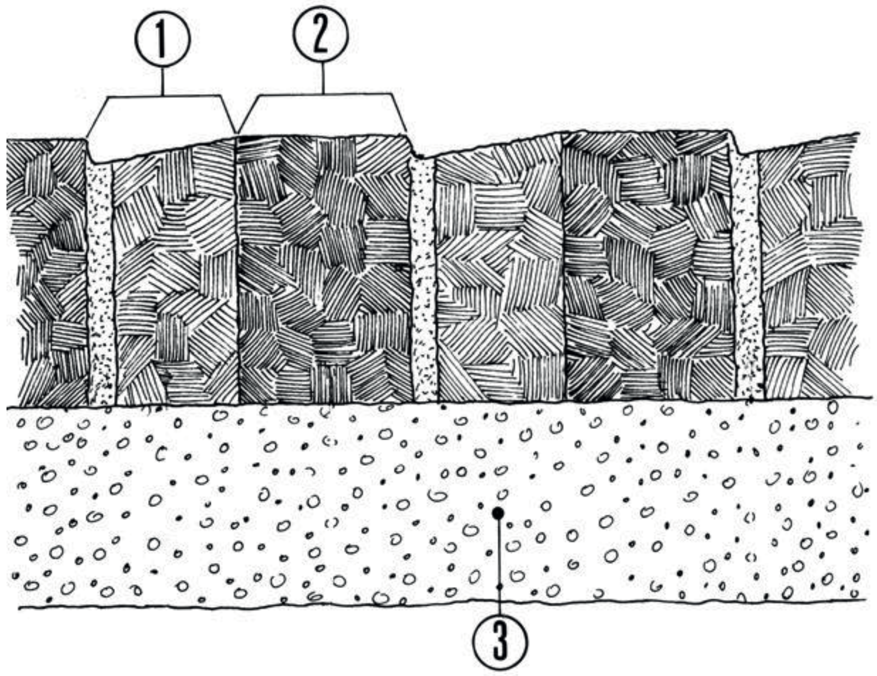

Fig. 12.7.3.2
Cross section of a stone with a soft groove:

1. *groove or furrow*
2. *land, grinding bank or face*
3. *ballast layer*

12.7.3.b Anticlockwise and clockwise dressings

anticlockwise stone, clockwise stone

In watermills, both anticlockwise and clockwise stones are common. The direction of rotation depends on several factors:
- the type of waterwheel. In the case of an undershot or breastshot wheel, the direction of rotation of the mill shaft is opposite to that found with an overshot wheel.
- The type of drive: is it a single or multiple drive?
- the position of the mill: Is it on the right bank or the left bank?
- the position of the crown wheel or lantern wheel: it is driven by the bottom or the top of the pit wheel?

clockwise dressing

anticlockwise dressing

We call a dressing right-handed if the dressing of the bedstone points in the clockwise direction (see Fig. 12.7.2.2.a and Fig. 12.7.2.2.c). If the dressing runs in the opposite direction to the clock, it is called a left-handed dressing.
If the pair of stones is open, then the rotational direction of the lands and furrows of both stones is the same. If the runner lies on the bedstone, the furrows form each other's mirror image and are at an angle to each other. When the stone starts turning, the furrows act like a pair of scissors.

For the sake of comparison: in windmills, dressings are always clockwise, except for the dressing of the front mill in a post mill.

In the past, watermills sometimes reversed the overshot wheel because it stopped functioning properly due to changing water supply. The wheel then began to operate as a breastshot wheel. This changed not only the rotational direction of the wheel but also that of the millstones. And consequently the dressings on the stones also had to be reversed.

12.7.4 Sharpening or dressing

sharpen, dress

We have already mentioned that the stones wear out from the milling process. The furrows become dull. It is then time to re-sharpen (dress) the stones. The grooves are restored to their original depth and the cutting edge of the furrows is sharpened. Dressing is a strenuous and time-consuming job that must also be done very precisely. It requires great skill on the part of the miller.

mill bill

Dressing or sharpening is done using the mill bill. This weighs about 1½ kg and has a wide hard steel pick on both sides. In recent decades, practically only picks equipped with so-called 'Widia' tips have been used. Widia is German and comes from 'wie Diamant' (meaning 'diamond-like'). These tips are so hard that they virtually never become dull.

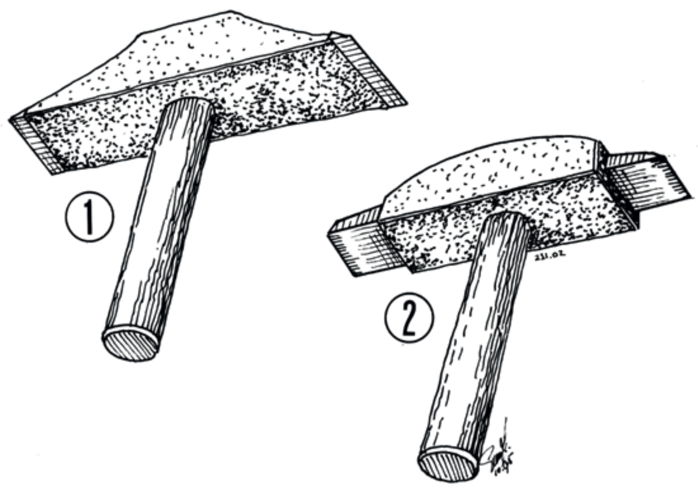

Fig. 12.7.4.1
Mill bills:

1. *mill bill with hard steel tips*
2. *mill bill with interchangeable picks*

stone crane
bails, peg holes
spindle nut

In order to dress the stones, the pair of stones must be opened up. This is done using the stone crane. The stone crane is rotated above the runner, and the pins of the crane bails are inserted into the peg holes of the runner. Then, using the spindle nut located on the arm of the stone crane, the runner is turned upwards and the crane is swung to the side.
The runner is placed on the floor or turned over in the bails for sharpening (see also section 12.9.3).

The stone crane must be able to lift the runner and thus needs to be solid in construction. It is usually made of wood and consists of a vertical upright (post) and a supporting cross beam (arm).

spindle, screw jack

A screw spindle (screw jack) that hangs from the spindle nut protrudes through this cross beam. At the bottom of the spindle hang two bails, fitted with thick pins that fit into the stone's peg holes.

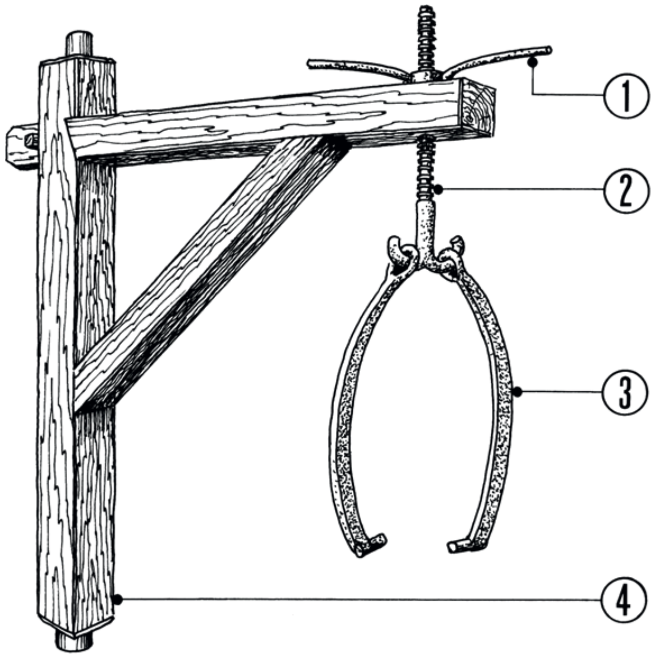

Fig. 12.7.4.2
A stone crane:

1. *spindle nut*
2. *spindle, screw jack*
3. *bails*
4. *crane*

In some mills, instead of a stone crane, there is a drum or Y-wheel with a rope and a windlass to open up the stones.

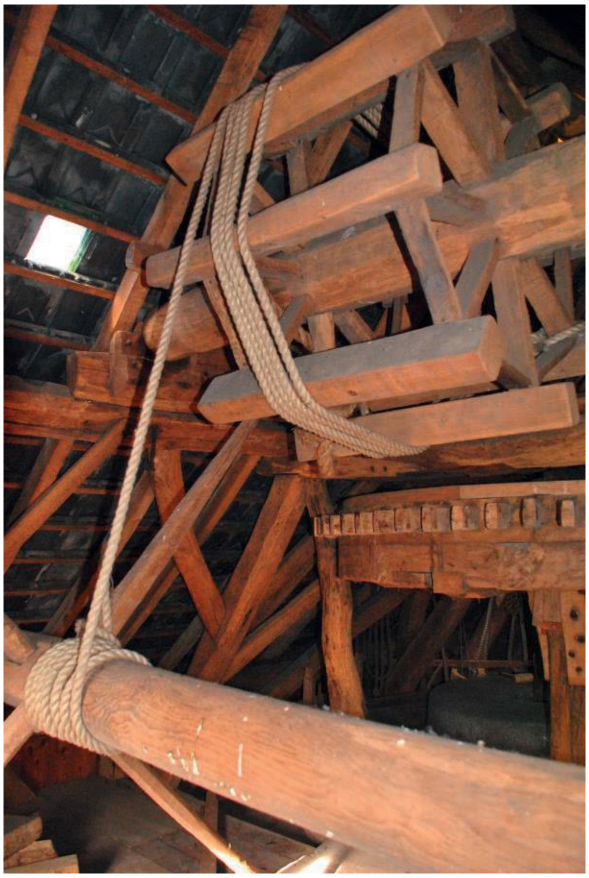

Fig.12.7.4.3
A winding drum with a rope and a windlass for lifting the stones.

Opwetten Mill – Opwetten

12.8 HOISTING SYSTEM

12.8.1 Hoisting system

hoisting, sack hoist
sack hoist shaft
hoist rope, sack hoist cable
sack hoist trap door
sack hoist wheel

Mill stock needs to be lifted. To do that, a hoisting system has been installed at the top of the mill, consisting of the sack hoist shaft and equipped with a sturdy sack hoist rope or cable and a drive wheel. The sack hoist rope runs through the sack hoist trap doors to the floor(s) below. Turning the sack hoist wheel wraps the sack hoist rope around the sack hoist shaft and pulls up a bag of mill stock attached to the end.

interior hoisting system

The interior hoisting system can lift mill stock above the stone as well as bring up meal from the cellar to the ground floor.

exterior hoisting system

Some mills have an exterior hoisting system with which bags of mill stock are raised from the yard to the stone floor or storage floor.
In an exterior hoisting system, the end of the sack hoist shaft with sack hoist rope is located outside the mill and is easily recognizable because it is protected from the weather by a sack hoist pentice roof.

sack hoist pentice roof

Fig. 12.8.1.1
Exterior hoisting system with pentice roof.

Oldemeulle – Oele

two-pronged fork, Y wheel

lowering

The drive for the sack hoist shaft is powered in several ways. The simplest is by hand; the wheel on the sack hoist shaft is then fitted with a number of wooden or cast iron two-pronged forks. Around this Y wheel is a spliced endless hand rope that usually passes through one or more floors. By pulling this rope, a sack of mill stock can be hoisted. If desired, a sack can also be lowered.

12.8.2 Friction sack hoist

friction ring, sack hoist wheel
brayer beam
sack hoist lever
friction sack hoist

In addition to manual operation, water-powered operation is also possible. A disk, the friction ring, is attached around the central spindle or to a horizontally turning mill wheel (for example, the spur wheel). The sack hoist wheel at the end of the sack hoist shaft is located above the friction ring. That end of the sack hoist shaft is bearing-mounted to a brayer beam. With the help of the control cord and a sack hoist lever, the brayer beam can be lowered, which causes the sack hoist wheel to come onto the friction ring and the sack hoist shaft to rotate. This is called a friction sack hoist.

By making a Y wheel at one end of the sack hoist shaft and a friction wheel at the other end, it is possible to hoist using either manual or water power.

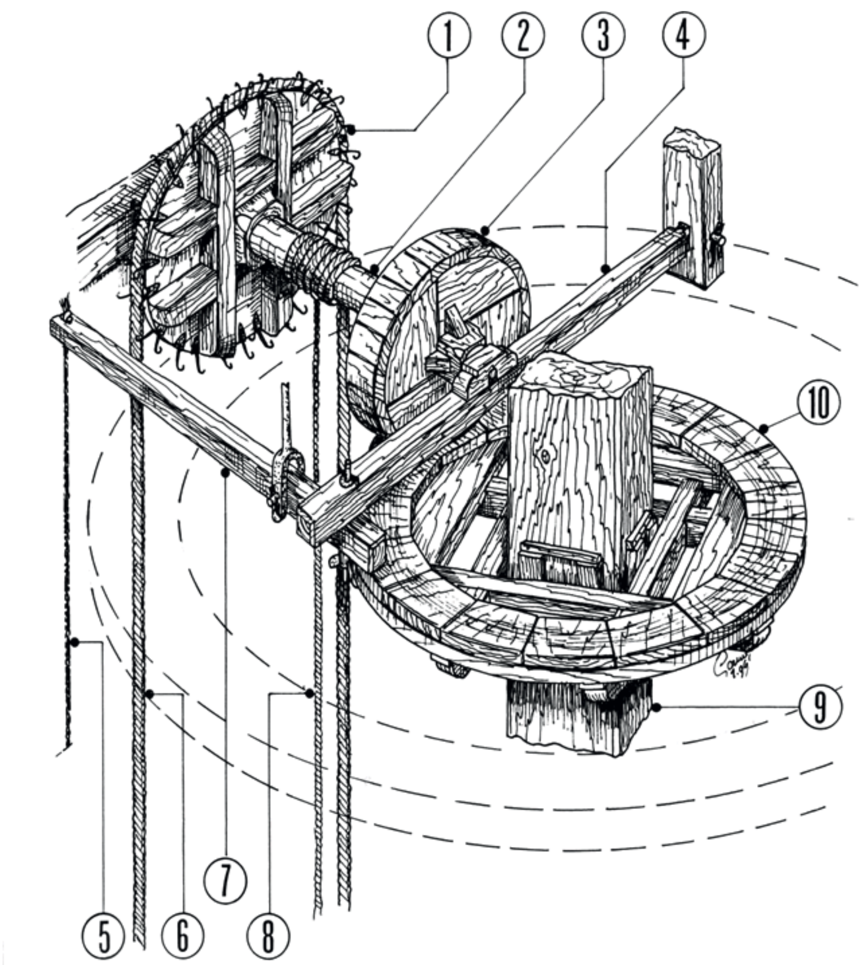

Fig. 12.8.2.1
Friction sack hoist:

1. *Y wheel*
2. *sack hoist shaft*
3. *sack hoist wheel or friction wheel*
4. *brayer beam*
5. *control rope*
6. *sack hoist rope*
7. *sack hoist lever*
8. *sack hoist rope or cable*
9. *central spindle (main upright shaft)*
10. *friction ring, hoisting ring*

12.8.3 Geared sack hoist

geared sack hoist
one-piece spur pinion

Another type of hoisting system is the geared sack hoist. Here, the sack hoist wheel is implemented as a one-piece spur pinion. A control rope is used to lower or raise the sack hoist shaft, pulling the cogs of the one-piece spur pinion between the cogs of a crown wheel or other wheel.

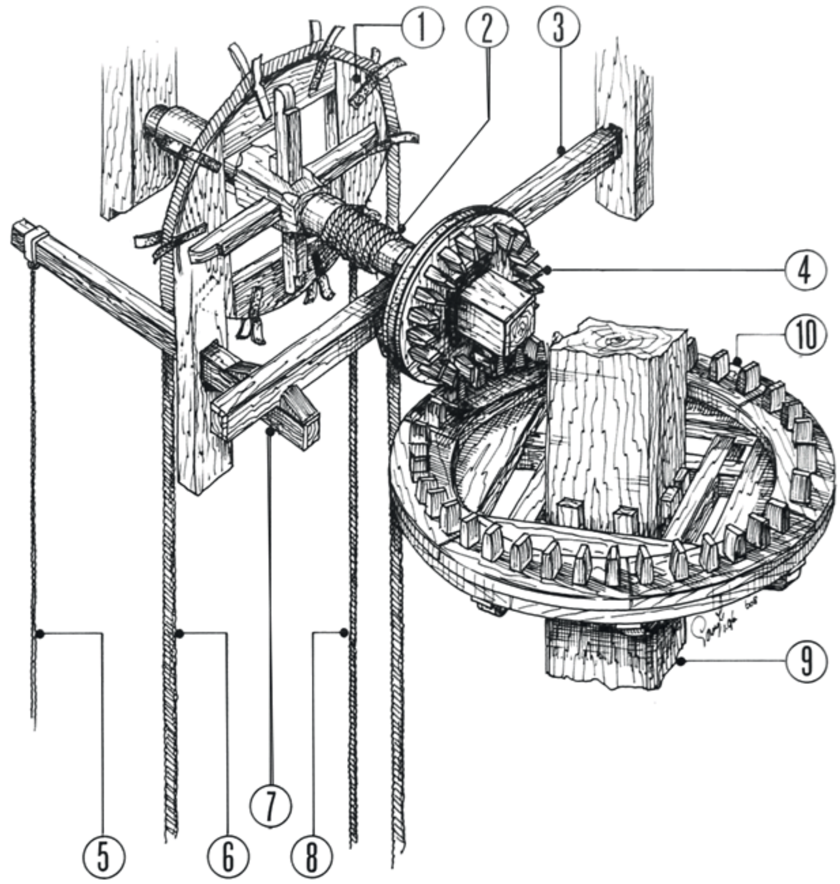

Fig. 12.8.3.1
Geared sack hoist:

1. *Y wheel*
2. *sack hoist shaft*
3. *brayer beam*
4. *sack hoist wheel*
5. *control rope*
6. *sack hoist rope*
7. *sack hoist lever*
8. *sack hoist rope or cable*
9. *central spindle (main upright shaft)*
10. *sack hoist crown wheel*

12.8.4 Belt sack hoist

belt pulley, belt tensioner

The hoisting system can also be driven by a separate drive shaft. This is common with iron driving gear. Belt pulleys and drive belts, equipped with a belt tensioner, are then usually used.
Sometimes the hoisting system is driven by an additional drive wheel on the mill shaft. Electrically powered hoisting systems are also used.

elevator

To transport loosely poured mill stock, mills are also sometimes equipped with elevators that carry the mill stock up into silos. An elevator is a revolving belt in a shaft to which iron buckets (cups) are attached that, once they arrive at the top, tilt and empty into a chute. Elevators can be water-powered or electrically powered.
In a few cases, the elevator is also used to bring meal up from the cellar to be bagged.
Large-scale production often uses a system of pipes through which air is used to transport grain or meal to and from machines or storage silos.

12.9 SPECIFIC DUTIES OF THE GRAIN MILLER

12.9.1 Introduction

The Handbook for Water Miller trains you to operate a mill not under load. In the exam, however, the candidate will be asked to put the machinery into operation. In practical terms, that will usually involve milling a small amount of grain. Therefore, with the exception of section 12.9.2, the material covered in this section is not part of the examination material. However, for millers or apprentice millers who are going to work on grain mills that are still operating, it is important to know about the issues below. (For working safely, see also chapter 10, Safety.)

12.9.2 Putting into operation

12.9.2.a Preparing

To start milling, the mill must be made ready for use:
- Remove interior and exterior safeguards against unwanted turning.
- Check the water level and weed screen; remove debris.
- Check and lubricate bearings according to the lubrication schedule.
- Remove temporary facilities for the purpose of hygiene.
- Stone pairs that are not being used for milling are disengaged.
- The stone pair to be used for milling is put into operation.
- Fill or top up the hopper and check that the eye is not too full.
- Set the shoe feeder approximately in the correct position. The final adjustment can only be determined during milling.

12.9.2.b Milling

'dry milling'

The main concern when you start milling is to prevent the stones from milling 'dry'. The runner should not be tentered if there is too little grain between the stones. The stones then start to abrade and become significantly worn.
Dry milling is not conceivable with current milling practices. When milling used to be done daily, people continued in the morning from where they had stopped in the evening. In today's practice, people sometimes mill only once a week or even less often, and it then makes sense for the miller to empty the hopper and the shoe feeder.
If you want to mill again later, there must be enough grain between the stones before the runner can be tentered.

Besides preventing dry milling, there are further concerns:
- If the mill with the lightered stone is operating at a rapid pace, tentering the stone should be done gently and without jerking.
- As much as possible, the miller wants to avoid too much unground or coarsely ground grain coming off the stones when starting up. If that does not quite work, keep the first mixture of grain/meal separate and feed it again.

The order of actions to start milling will depend in part on the situation. For example, can you open the inlet sluice from the milling floor with a pull inside or do you have to go outside to do so? And how much time does it take to walk from the inlet sluice to the hopper or shoe feeder?
Does the mill start operating quickly or not?

A good procedure might be:
- Lighter the stone.
- Keep the still-empty shoe feeder in position. The hopper is already filled.
- Open the inlet sluice; the mill starts to operate.
- Open the slide in the hopper, and fill the shoe feeder well (afterwards, open about 2 cm)
- Once a handful of grain has fallen into the eye, tenter the stone.
- Listen carefully: is the RPM dropping? Lighter the stone slightly.
- Is there an abrasive sound? Lighter the stone and feed more grain.

A variation of this is to first open the hopper slide and fill the shoe feeder. Withhold the shoe feeder for now and then open the inlet sluice. After the stone gets going, place the shoe feeder and as soon as the first grain falls into the eye, tenter the stone.

If a mill gets going quickly, it may be better to start under load, that is, with the stone tentered. The shoe feeder must be filled and kept in place.
You also need to know how far open the inlet sluice should be to achieve the right speed. Then make sure that, when stopping, only the hopper and shoe feeder are emptied and that some grain is left in the eye. On resumption, the filled shoe feeder is then kept in place and the runner tentered before the inlet sluice is opened.

When we stop milling, we usually want to empty the shoe feeder. Stopping at the right time is then important to avoid 'dry milling'.
If the mill has an inside pull then the moment the last grain falls into the eye is also the moment to cut off the water supply. If you need to go outside to remove the water from the wheel, it will take more time and you will need to act sooner to stop the wheel.
After interrupting the water supply, the runner may be fully tentered.

Preventing 'dry' milling by lightering the stone and only then interrupting the water supply creates the danger of the mill suddenly accelerating because the load is greatly reduced. This is not recommended. Running out of control, however, cannot happen with a watermill.

Milling grain properly requires experience. Adjusting the shoe feeder is very important in this regard. But so, too, is managing the inlet sluice to obtain the desired speed of the stone. An experienced miller as a teacher is definitely needed for this.

12.9.3 Hoisting

The hoisting system is loadable up to about 70 kg. If more is lifted, the hoisting system may no longer come free of the friction ring (friction sack hoist) or the sack hoist crown wheel (geared sack hoist). The sack can then catch on the sack hoist shaft and tear open. Also, don't forget to lubricate the bearings of the sack hoist shaft from time to time.

12.9.4 Opening up a pair of stones

This is an extensive task for the grain miller that also involves some danger. Therefore, the equipment to be used, especially the stone crane, should be in good condition. Those assisting in this task must be well instructed beforehand. A pair of stones is opened for repair or to dress or clean the stones. (See chapter 10.6, Safety at a grain mill.)
The procedure is as follows:
- Successively remove the hopper, shoe feeder, hopper ladders,

dust boards, vat covers and vat parts. For under-drive, also remove the agitator (damsel) or shaker arm. Put these parts far away from the pair of stones that is to be opened up so the parts do not get in the way.

- Make sure that there are identifying marks on the crotch spindle and the rynd; if not, apply them (see Fig. 12.9.4.1).
- For overdrift: next, carefully remove the stone spindle. When swinging it to the side, make sure that the crotch of the spindle does not damage the rynd (see Fig. 12.9.4.2). Raise the spindle to well above the runner, then put it away next to the bedstone and secure it against falling over.

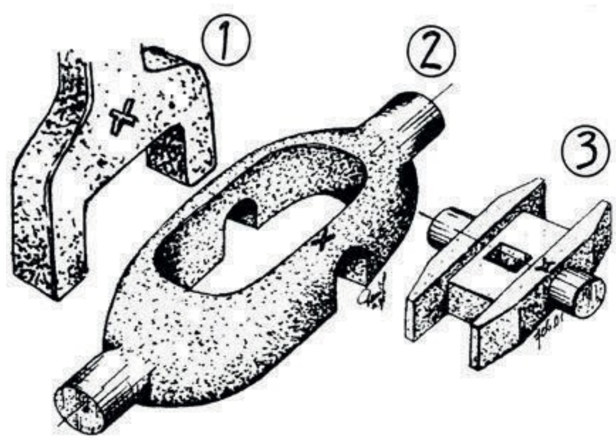

Fig. 12.9.4.1
The identifying marks on spindle and rynd:

1. *crotch of the stone spindle*
2. *outer rynd (bridge, bar, bail)*
3. *inner rynd (driver, mace)*

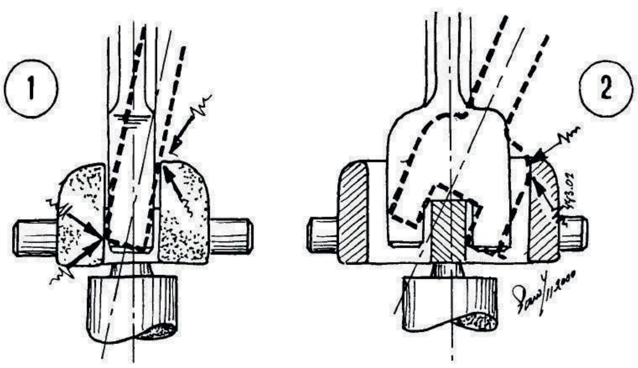

Fig. 12.9.4.2
What to watch out for when removing the stone spindle:

1. *little space when lifting out the spindle*
2. *safer position of the rynd when lifting*

- Now lay open the millstones with the stone crane. Use the correct peg holes: those that are most centred. In a properly functioning system, and after first turning the runner upward with the spindle nut free of the bedstone, you can simply turn the runner further upward by turning the stone itself which tightens the spindle nut. This works easier and lighter than turning the runner upwards with the big nut. If the runner needs to be dressed, tip it into the bails and lay it upside down on the bedstone with a few beams in between.
  Note: Always tilt a stone in the crane bails away from you!
- If you want to dress the bedstone, place the runner — if there is enough space — on the floor next to the bedstone on a few beams. If space is limited, place the runner on its side at a spot where there is a beam under the floor and secure it with two chocks to prevent it from rolling away.
- If the neck bearing needs to be cleaned, lubricated or repaired then remove the stone spindle or spherical spindle from the neck bearing if possible.

In an overdrift this can be pulled out upwards. With underdrift this does not work because of the lantern wheel or stone nut attached to the stone spindle.

- Do not put the spherical spindle with the pivot on the stone because it will damage the grinding surface. This can cause lubrication problems later. Spindles are sometimes difficult to loosen. In this case, lift the spindle as far away as possible and tuck in the rynd. The spindle will then release when you gently tap the bearing.
- To close the millstones back up, perform the above tasks in reverse order. The marks should again end up opposite each other.

12.9.5 Sharpening or dressing of millstones

This Handbook does not provide for learning how to dress millstones. This can only be learned under the guidance of an experienced professional. This is a painstaking task and definitely requires practice and the right tools.
A volunteer miller with no experience should not set about it on their own.
A good millstone can be spoiled faster than it can be repaired.

12.9.6 Adjusting the spherical spindle or stone spindle

toe-brass
pull wedges, push wedges

The most important thing that one can adjust on the spherical spindle is the location of the toe-brass that sits in the bridging box on the bridge tree. Four wedges are available for its adjustment: two pull wedges and two push wedges. With the pull wedges, you move the bridging box in a direction perpendicular to the bridge tree. Using the push wedges, you move the bridging box in the longitudinal direction of the bridge tree. For this extremely important adjustment, we refer you to the book ‘*Zingende Stenen*’ ('Singing Stones') by D.J. Abelskamp.

12.9.7 Adjusting the shoe or shoe feeder

shoe feeder, shoe
shoe control rope
hanger
withholder, keeper

For proper adjustment of the shoe or shoe feeder, use the shoe control rope and the hanger. This is done to give the shoe more or less slope and thus regulate the supply of grain to the eye. By moving the shoe control rope left or right across the hanger, you determine the force with which the agitator or the shaker arm taps against the rap. With a withholder and/or keeper, this 'shaking' can be set even more finely.

12.9.8 Milling for consumption

When you actually want to mill, there are many other concerns in addition to the above. However, these fall outside the purpose of this miller training, namely running mills 'for the Prince' — for demonstration only. We refer aspiring grain millers to the grain milling course taught by the *Ambachtelijk Korenmolenaarsgilde* (Artisanal Grain Millers Guild, or AKG) in cooperation with the Guild of Millers.

cleanliness
hygiene code

One thing we want to urgently bring to your attention is the matter of cleanliness. When milling for human consumption, it is mandatory to work according to the Hygiene Code for windmills, water mills and artisanal grain mills. In this regard, it is very important to keep clean the mill with which you are milling.

Note: The lubrication of bearings and other parts along with the grain miller's specific task of lubricating the spherical spindle / stone spindle is described in chapter 7, Practical considerations.

Chapter 13 The hulling mill

Contents Page

NOTES

13.1 INTRODUCTION

Processing barley into an edible product was already known before 1500. In the Netherlands, pearl barley was a staple food before the arrival of the potato.
It is assumed that barley was hulled with millstones. Using the fixed rynd (normal in those days), the runner was lifted sufficiently far so that the barley grain did not quite fit between them. As a result, the grain was not ground but the husk was stripped from the kernel. More discussion on possible further developments is provided in J.J. Kamphuis's book '*Spieren, water, wind*' ('Muscles, Water, Wind').
Historically, hulling barley with a sandstone fitted with wind furrows and surrounded by a hulling vat is quite new. In 1625, the States General of the Netherlands extended a patent for hulling barley.
In 1639, the first '*windbrief*' (authorisation letter to build a mill) was issued to an expatriate German to build a hulling mill in Koog aan de Zaan in the province of North Holland. The mill that started it all was demolished in 1880 as an oil mill. By then, steam hulling mills had already displaced hulling mills in the Zaan region for decades. With the outbreak of the First World War, exports of rice from Burma to Holland came to a halt. By order of the Dutch government at that time, barley had to be hulled. To what extent this was possible was investigated. In Groningen there were 59 hulling mills and in Friesland 7 hulling mills, plus 2 steam hulling mills in the Zaan region. There is no mention there of water-driven hulling mills.

Unlike the hulling mills in the Zaan region, in the rest of the Netherlands it involved both wind-powered and water-powered mills. These were always combinations of grain and hulling mills.
In windmills there were two pairs of hulling stones, but for watermills we can safely assume that this involved only one pair. Hulling is heavy work for a mill. The power required to drive two pairs of stones would have been too great for a single waterwheel. Even though milling grain calls for less power, it was not usually possible to drive two pairs of millstones at the same time.
When hulling was no longer an economical proposition, the stones remained under the floor where they were not a hindrance.
In Limburg around 1900, the old waterwheels were replaced by the improved wheels and turbines. Internally, the wooden driving gear was also replaced by cast iron wheels. Presumably then, during the redevelopment, the hulling stones permanently disappeared.
In the Twente region and the province of Gelderland, that development did not happen and they died a slow death.
Legal records of the Mallumsche Mill in Eibergen in 1685 mention 5 mill types, but a hulling mill is not mentioned. There is a mention, though, in an auction that took place in 1895. In 1941, the water authority — the last owner — wanted to demolish the mill after its partial collapse. There were then two pairs of millstones, one of which lay partially above the hulling stone.
In Borculo, as well, a hulling mill is not mentioned until an auction in 1831. Zutphen first mentions a hulling mill in 1680 and two in 1830. In 1887, the municipal grain, tanning and hulling mills were put out to tender for demolition.

Currently, we still know of one operational water-driven hulling mill in our country, namely the Mallumsche Mill in Eibergen. This is a grain and hulling mill, with two pairs of millstones and one pair of hulling stones.

13.2 THE DESIGN OF A WATER-DRIVEN HULLING MILL

13.2.1 Driving gears

hulling stone

A hulling stone is used for hulling. This is often a Bentheimer sandstone, although the quality of the English stones is better. To hull well, the stone needs a high rotational speed. Because of this high speed (roughly double that of a millstone), the hulling stone is placed under the work floor between the joists. After all, breakage while turning is not out of the question. It is not possible to place iron bands around the hulling stone.

Fig. 13.2.1.1
The layout of a hulling mill.

1. *partition floor*
2. *hopper*
3. *opened slide*
4. *barley bucket*
5. *hulling stone spindle*

stone nut

To achieve this higher speed, the trundle wheel of a hulling stone is considerably smaller than that of a millstone. The gear ratio for the hulling stone is 1:10; that of the millstone is 1:5.16.

Fig. 13.2.1.2
The trundle wheel of the hulling stone is smaller than that of the millstone, allowing the stone to reach a higher speed.

Fig. 13.2.1.3
The trundle wheel of the millstone.

13.2.2 Hulling stones

bedstone
neck bearing, spherical spindle
four-armed rynd
coarse chisel, furrows

The most important apparatus in a hulling mill is the pair of hulling stones. In a pair of hulling stones, one is referred to as the hulling stone and the other the bedstone. The runner is a sandstone. For the bedstone, basically any type of stone can be used. It serves as the subfloor for the vat. In the middle is the opening in which the neck bearing is placed, containing the spherical spindle, always with a four-armed rynd.
The hulling stone must be perfectly round. With a coarse chisel, vertical furrows are gouged on the circumference of the stone. This is to increase the abrasive effect.

wind furrows
wake iron

Four or six wind furrows are made on the underside of the hulling stone. These wind furrows are fitted on the outside with steel strips, the wake irons. As the stone becomes smaller, the irons must be able to be moved further inward.

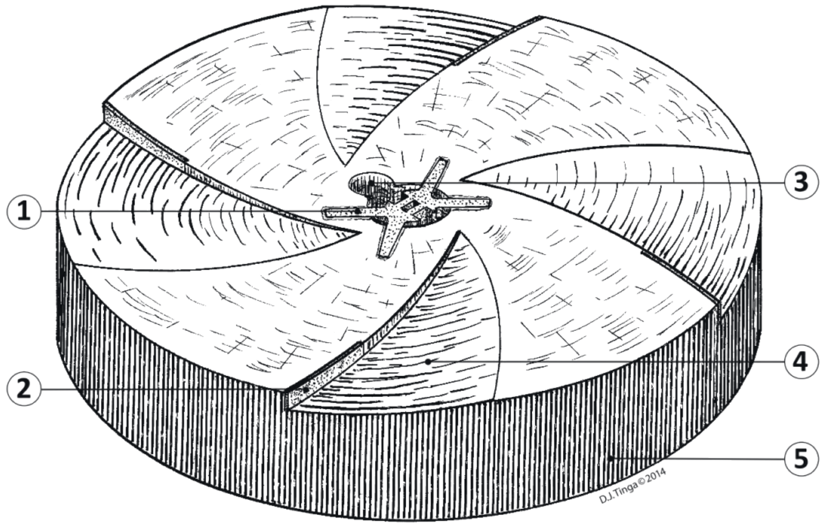

Fig. 13.2.2.1
The underside of a hulling stone in Groningen:

1. *four-armed rynd*
2. *wake iron*
3. *hand hole*
4. *wind furrow*
5. *ribbed outer circumference*

(drawing © D.J.Tinga)

hand hole

A hand hole is made in the stone; this enables the neck bearing to be lubricated.

Fig. 13.2.2.2
Upper side of hulling stone with four-armed rynd and hand hole.

13.2.3 Hulling vat

hulling vat
millstone curbing
rasp

The hulling stones lie in a hulling vat. The bedstone is surrounded by the millstone curbing and on it is placed the hulling vat, consisting of a wooden frame on which the rasp is placed. The hulling vat is placed in a precise circle around the hulling stone with adjustable clamping brackets, spaced about 11 mm apart.

adjustment pieces

As it wears and is dressed, the stone becomes smaller and the hulling vat must also be adjustable. Therefore, several adjustment pieces are available. There are even various sizes of vats.

Fig. 13.2.3.1
The clamping bracket for securing the hulling vat.

nail for piercing the holes

The wall of the hulling vat is mostly made of tin with sharp points. Holes are pierced alternately in this rasp with a piercing nail. The sharp edges on the inside of the vat provide the rasping effect. The outwardly turned edges facilitate the removal of the waste from the vat. Also, this allows the rasp to be used inside out after it becomes blunt.

Fig. 13.2.3.2
The frame on which the rasp is pierced and the coarse chisel used to gouge the vertical furrows or ribbing on the circumference of the stone. Hanging on the wall are the auxiliary slats used to set the vat accurately around the stone.

13.2.4 Other machinery

sieves

Other important tools in hulling mills are sieves, used to separate the hulls from the pearl barley after hulling and to sort the pearl barley by size. Research has not shown that, for example, a fanning mill or fixed sifting system was also present. Barley cleaning may have been done with a movable husk grinder (chaff cutter) as can still be found here and there.

dust room

The sifting system present in the Mallumsche Mill, with a dust room, was designed and created in 1981 by Hans Weerheim. This millwright was employed by the firm Groot Wesseldijk. The Netherlands Department for the Preservation of Historic Buildings and Sites (now the Cultural Heritage Agency, or RCE in Dutch) approved the chosen design. Whether it had originally looked the same is not clear, but it works perfectly.

Fig. 13.2.3.3
The exposed hulling stone with the inside of the rasp.

13.3 BRIEF DESCRIPTION OF THE HULLING PROCESS

lot, hopper

In hulling, a quantity of barley (called a lot) is poured via the hopper in its entirety onto the rapidly rotating stone. This is in contrast to milling grain, where it is fed continuously and evenly.
The barley is flung to the outside where it lands against the rasp and into the approximately 11-mm narrow opening between the stone and the hulling vat. The air flow generated by the 4 or 6 wind furrows in the bottom of the hulling stone, as well as the furrows or ribbing on the outer circumference, prevent the grain kernels from falling down and landing on the bottom of the vat. The grain kernels continue to rotate along in a floating state where they are always in contact with the sharp protrusions of the rasp and with the rough side of the stone. The sharp rasp and full vat create so much resistance that the grain kernels cannot rotate with the speed of the stone.
It is the hulling stone that scrapes along the grain kernels at high speed, grinding a layer off each time. So hulling is not just done by the rasp. The fuller the vat, the more the abrasive (grinding) action of the hulling stone takes place.

Fig.13.3.1
The drive of the sifter with a belt tensioner around the spherical spindle. Under the pillow, the flywheel on the crankshaft for the sifter.

hulling run
sifter
lot bucket

A hulling run lasts about 4 minutes. A longer running time makes the barley hot, which does not enhance the quality. After the running time, open the slide and drain the quantity directly to the sifter. This helps the reduce the quantities as quickly as possible. The lot bucket is still present but it is no longer used as such here.

The sifter can operate only when the hulling stone is not under load. Two portions thus pass over the hulling stone and the sifter a good three times. The intermediate check allows for a bit more variation in the running time so that the portions are equivalent. At the fourth and final hulling run, the two portions are combined. The full vat then causes the hulling stone to do extra scouring ('polishing') so that a good end product is produced.
After this run, we slowly feed the pearl barley over the sieves one more time to then obtain a clean finished product without winnowing.
From the amount of barley to be hulled, between 50% to 60% is retained as pearl barley.
Given the experience of hulling at the Mallumsche Mill and knowing how small the amount of simultaneously deposited barley (a lot) on the stone is — namely about 8 kg. — relative to those at wind-driven mills, then the supply of pearl barley by watermills must have been minimal.

Fig. 13.3.2
The hopper on the mezzanine floor for direct discharge to the sifter.
A collection box with opened dust area, grey sack for small grains and, just visible, the white bag for collecting the final product.

Chapter 14 Oil mills

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NOTES

14.1 INTRODUCTION

oil mill

For centuries, oil has been pressed from seeds that contain oil. This was initially done manually, but later watermills were widely used for this purpose. Still later came horse-driven mills and windmills. Watermills came to the Netherlands about 400 to 500 years after the beginning of the Current Era. After the grain mill, the oil mill was the most common type.

oil cake

An oil mill processes oil-bearing seeds, such as linseed, rapeseed and hemp seed. But also nuts such as walnuts and peanuts.
Linseed oil was and is used for making paint, soap, printing ink and linoleum, among other products. Rape oil was used as lamp oil and cooking oil.
In addition to oil, an oil mill also supplies oil cakes. In the winter, these were used to supplement the cattle's feed of sparse hay. Sometimes oil cake production was a greater source of income for the miller than oil.

single-works oil mill
double-works oil mill

We see two developments at oil mills. The first was the single-works oil mill, followed later by the double-works oil mill. Mills with a single oil works had a pair of edge runner stones, an oil seed heater and a pressing block.
Initially these were watermills and horse-driven oil mills, later windmills as well. Single-works oil mills were common in all watermill regions. They were often combined with a grain mill because there was less demand for the oil cakes for cattle in the summer. Oil pressing was mostly seasonal work for these mills.
Double-works water-driven oil mills are far fewer in number.
In the second half of the 20th century, pressing oil with mills was practically a thing of the past in the Netherlands.

Fortunately, the situation now is that several oil mills have returned to small-scale operation after many years of inaction. To our knowledge, there are 5 water-driven oil mills that are capable of pressing:
- In the Overijssel region: the 'Oostendorper Watermill' in Haaksbergen and the 'Noord Mill' in Delden.
- In North Brabant: The 'Coll Mill' in Eindhoven and the 'Kilsdonk Mill' in Heeswijk-Dinter (a double-works oil mill).
- In Limburg: the St. Ursula or Leu Mill in Nunhem.

first pressing meal
meal bin, meal box
oil seed heater
cloth bag
pressing tray
second pressing
stamper holes, second pressing meal

Briefly, the process of oil pressing is as follows:
Seeds that contain oil are crushed under the edge runner stones and rubbed finely into what is known as first pressing meal. During this crushing, it is moistened.
When this meal is fine enough, it flows into the meal bin or meal box. From here, a measured amount is repeatedly scooped onto the oil seed heater and heated to about 35°C ('lukewarm'). The warm meal is pushed into two cloth bags and placed in the pressing tray where it is pressed. The oil is collected in a container and the meal is pressed into a cake. Sometimes this operation is repeated and a second pressing follows. The cakes are then finely pounded in stamper holes or rubbed again under the edge runner stones into second pressing meal. This is then reheated and pressed.
In the first pressing, about 70% of the oil is pressed from the seed. After the second pressing, the cake contains only 8% to 12% of the oil originally present in the seed.

14.2 THE DESIGN

An oil mill contains several devices for pressing oil:

edge runner stones
oil seed heater, stirrer
pressing block
ram stamping mill, stampers

- Edge runner stones for crushing oil-bearing seeds.
- The oil seed heater with stirrer for preheating the crushed seeds.
- The pressing block with rams for pressing the meal.
- Sometimes, a stamping-mill with stampers for stamping the cakes.
- Other machinery, such as a cake crusher, etc.

Single and double-works oil mills do not differ from each other in terms of operation. We will discuss the single-works mill in this chapter and supplement it with information about the double-works mill.

14.2.1 Driving gear

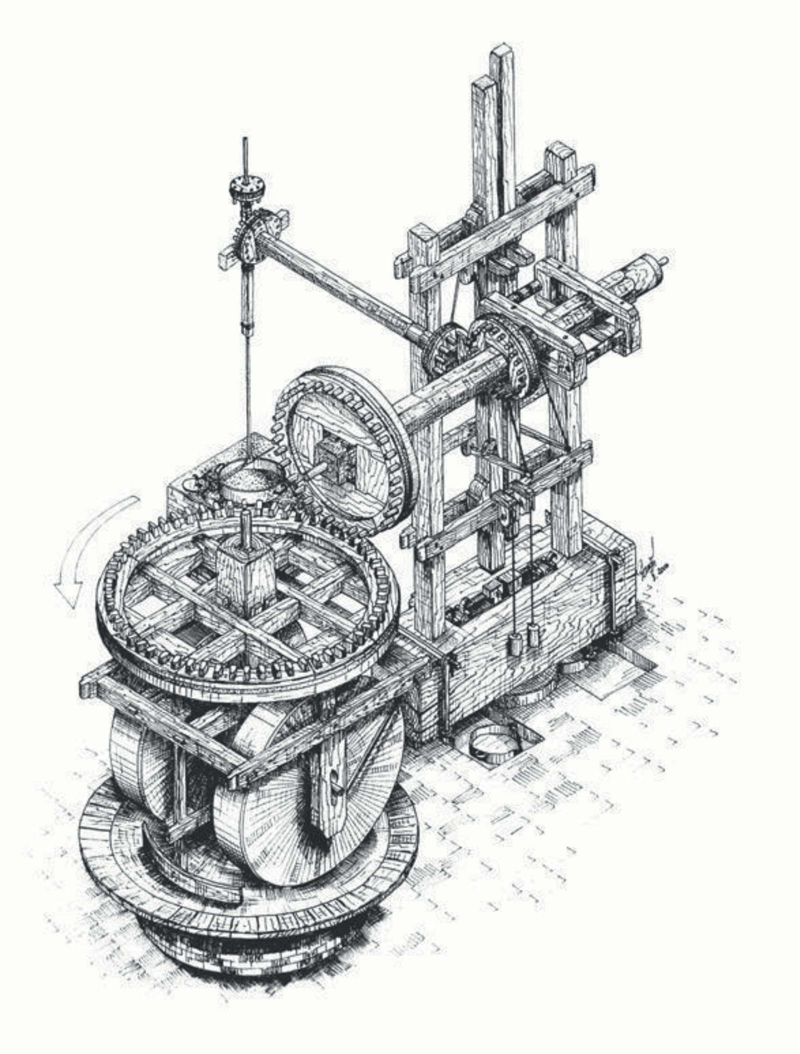

Fig. 14.2.1.1
A sketch of a single oil works consisting of edge runner stones, a pressing block and the oil seed heater.

Holtens Mill – Deurne
(drawing © N. Jurgens)

stamping mill, stamper holes

A single-works oil mill is equipped with edge runner stones, an oil seed heater and a pressing block. Of the existing single-works mills, only the Noord Mill at Delden additionally has a stamping mill with two stamper holes.

first pressing block
second pressing block, stamper holes

The Kilsdonk Mill is a double-works oil mill: this one also has one pair of edge runner stones but two pressing blocks, the first pressing block and the second pressing block. There are also two oil seed heaters and six stamper holes.

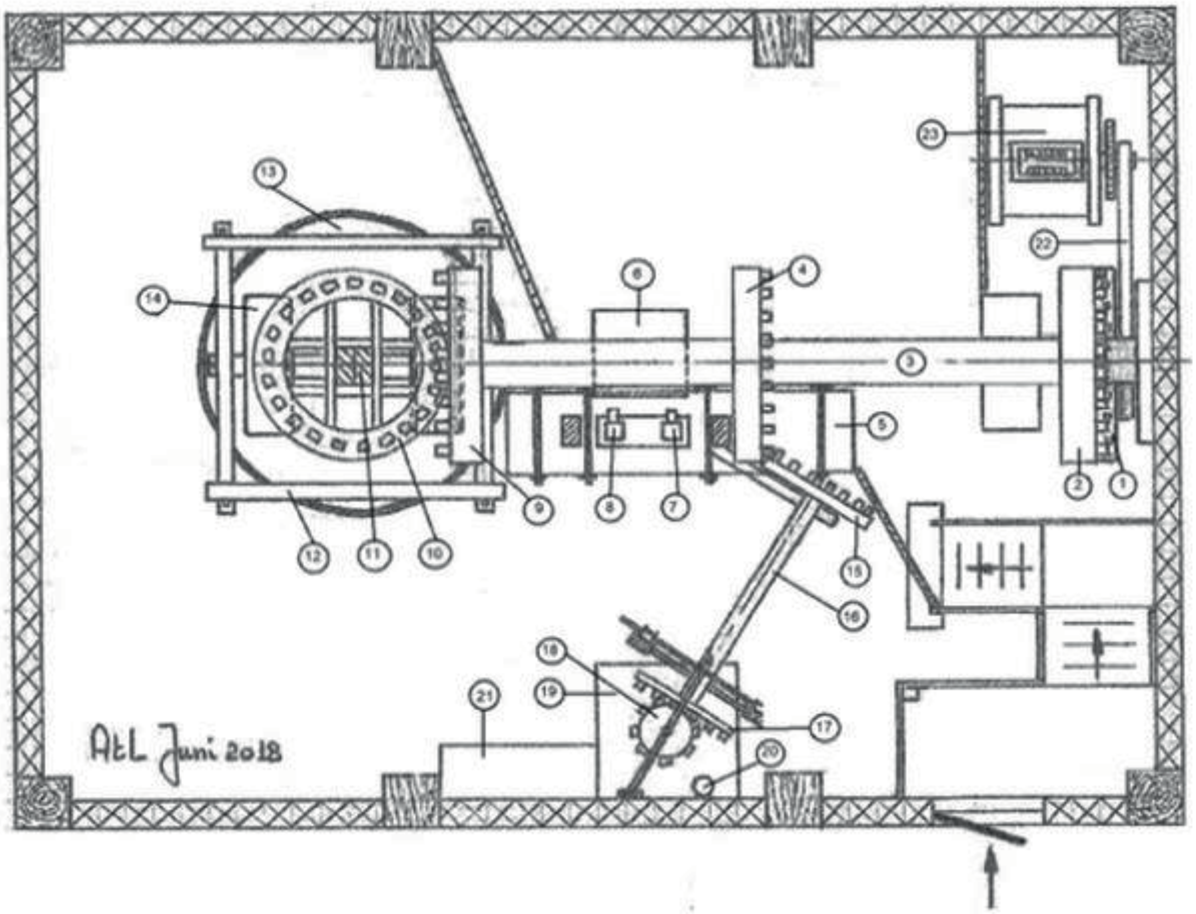

Fig. 14.2.1.2
The design of the Oostendorper Mill at Haaksbergen, a single-works oil mill:
(Drawing © A. ter Laak)

1. *face wheel*
2. *camshaft wheel*
3. *camshaft or tumbler shaft*
4. *pin wheel*
5. *pressing block*
6. *lifting lever*
7. *pressing ram*
8. *releasing ram*
9. *camshaft wheel*
10. *king wheel*
11. *central spindle*
12. *stone yoke*
13. *bedstone*
14. *edge runner stone*
15. *pin wheel gearing*
16. *gearing*
17. *pin wheel stirring spindle*
18. *trundle wheel stirring spindle*
19. *oil seed heater*
20. *flue*
21. *workbench*
22. *cake crusher drive belt*
23. *cake crusher*

14.2.2 Camshaft

camshaft or tumbler shaft

The most important shaft in the oil mill is the camshaft or tumbler shaft. This drives the various machines. This axis is above head height from ground level. Above the pit wheel (face wheel) is a camshaft wheel, sometimes a lantern wheel, which is used to drive the camshaft (see Fig. 6.5.2.1).

king wheel, stone wheel
central spindle, stone spindle

At the other end of the camshaft is also a large crown wheel that drives the king wheel or stone wheel. The yoke with the edge runner stones is driven via the central spindle.

stirring spindle, gearing (pinion)
stirrer

Attached to the camshaft is a pin wheel (or crown wheel) that drives the stirring spindle through the gearing (pinion) that then drives the stirrer for the oil seed heater.
The cam shaft is bearing-mounted in a stone with trunnions or caps, and these bearings are lubricated with lard (see Fig. 6.1.4.1).

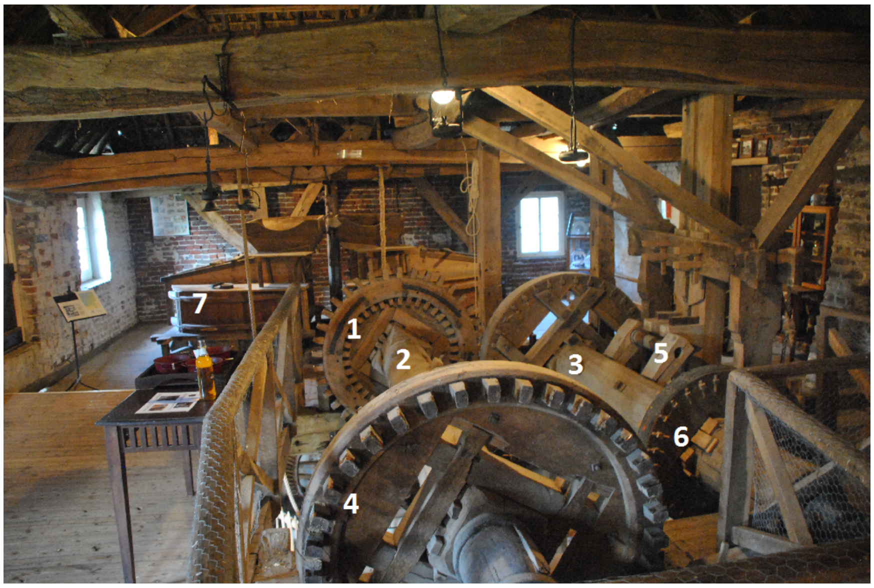

Fig. 14.2.2.1
A camshaft floor or stone floor with two shafts.

Both the left shaft (2) and camshaft (3) are driven by the wheel (1) on the left shaft.
The front wheel (4) on the left shaft drives the edge runner stones.
On the camshaft is the lifting lever (5) and the crown wheel (6) for the gearing of the stirrer. In the background (7) two stone vats.

St. Ursula Mill – Nunhem

lifting lever fist, lug
ram

spokes

The lifting lever is attached to the camshaft. This grabs under the fists (lugs) which are used to lift the rams as they go around. There is a lifting lever at the Coll Mill and at the St. Ursula Mill.
The Noord Mill and the Oostendorper Mill have two spokes instead of one lifting lever. The Kilsdonk Mill also has spokes: two for the first pressing, three for the second pressing and three for the stampers. Three spokes deliver a higher stroke rate than two.

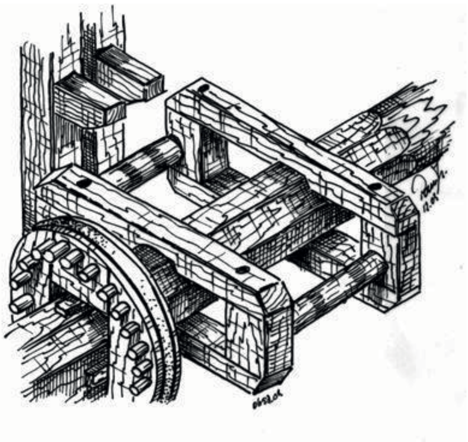

Fig. 14.2.2.2
The lifting lever.

A double wooden framework with two rollers between them for lifting the rams.

14.2.3 Edge runner stones

edge runner stones, edge-mill
crusher mill

bedstone or pan

The edge runner stones (or edge-mill, crusher mill) break up the seed. They have a centreline of 1.50 to 1.80 m, have a width of about 40 to 60 cm and weigh between two and four thousand kilos. They roll and wrench on their edge over an even larger stone, the bedstone or pan. This causes the seed to break open.

bedstone base
parapet
discharge slide
king

The bedstone lies on the base, a masonry round stone table with a solid foundation. Around the bedstone is fitted a wide (wooden) rim — the parapet — which contains an opening that is closed by the discharge slide. As the bedstone (pan) was worn down and cut flat again, a raised part called a king gradually formed in the middle of the pan.
Note: The name "king" is also used for the stone spindle.
Later, they often applied a cast iron pan that wore out less quickly and required little maintenance.
With its three heavy stones, the edge-mill has a very large weight. Because of its position in the mill, it is located on the solid bank, as far away from the water as possible. This reduces the danger in the event of undercutting.

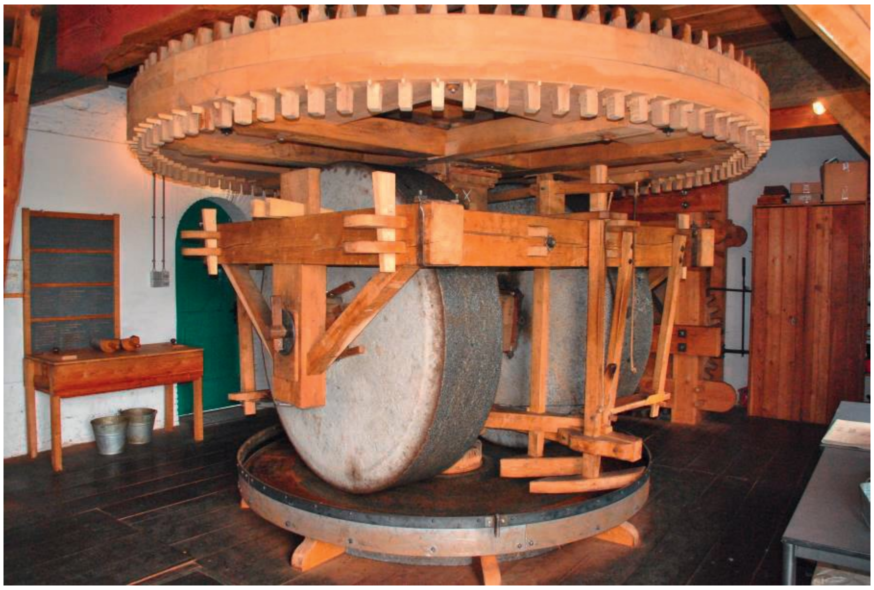

Fig. 14.2.3.1
Edge runner stones

Above is the king wheel, below it the yoke with ear.
On the right, the outer scraper and the outermost scraper (the edge-mill turns anticlockwise).

The Kilsdonk Mill – Heeswijk-Dinther

runners, yoke
central spindle, stone spindle
trunnions, ears

The edge stones (or runners) run in the yoke, a heavy wooden framework that is secured to the wooden stone spindle (central spindle). The ends of the stone shaft — the trunnions — turn in the ears. The holes in the ears for these trunnions are oblong. As a result, the trunnions have some play and can move up and down as the runners roll over the seed strewn on the bedstone. Also, when the stone wears down, the trunnions can move down with it.
An edge-mill in watermills can be driven anticlockwise or clockwise.

king wheel, stone wheel

Above the yoke, the king wheel (also called stone wheel) is fitted to the stone spindle.

spratt le beam pivot
stone spindle, toe-brass
king
inner stone
outer stone
ploughs, (inner) scraper)
scraper
outer scraper, outermost scraper

The upper end of the stone spindle is bearing-mounted in the sprattle beam.
The stone spindle rotates with its lower end on a hard steel pivot in a toe-brass placed in the centre of the base on a block, the king.
The edge runner stones usually do not run in the same track; there is an inner and an outer stone. The seed on the bedstone is alternately pushed in front of the inner and outer stone by rotating ploughs (scrapers). The inner scraper sweeps past the central spindle, pushing the seed to be crushed under the outer stone. After half a revolution, the scraper agitates the seed and pushes it in front of the inner stone, and so on.
The outermost scraper sweeps the parapet clean. In the remaining oil mills, however, the parapet is not inclined but vertical, so there is usually no outermost scraper. The outer scraper is then sometimes extended to the parapet rim.

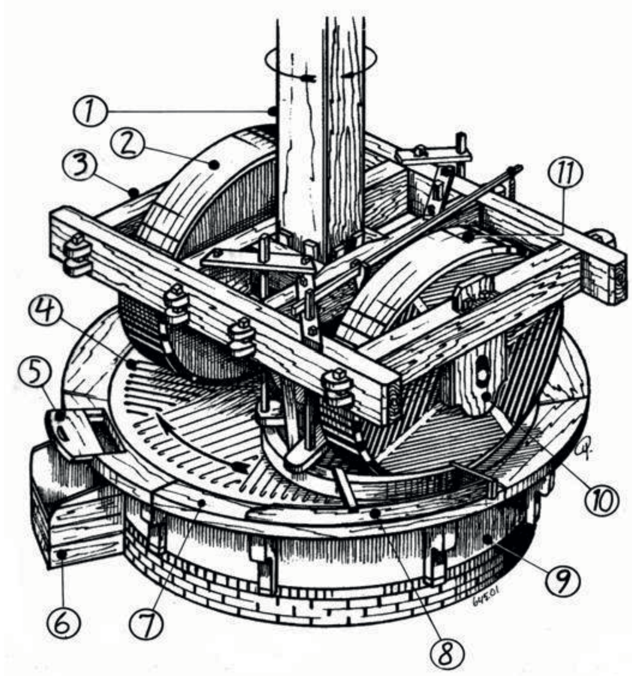

Fig. 14.2.3.2
Edge runner stones

1. *stone spindle (central spindle)*
2. *inner stone*
3. *yoke*
4. *cast iron plate on the bedstone or pan*
5. *discharge slide*
6. *meal bin*
7. *parapet*
8. *king (inner) scraper/discharge arm*
9. *bedstone (pan) and base*
10. *ear*
11. *outer stone*

discharge arm
meal bin, meal box
first pressing meal

When the seed is sufficiently crushed, the oil presser lowers the extended part of the king scraper, the discharge arm. This slides the meal over the parapet, causing it to fall into the meal bin (meal box) through the now-opened discharge slide. This meal is called first pressing meal.

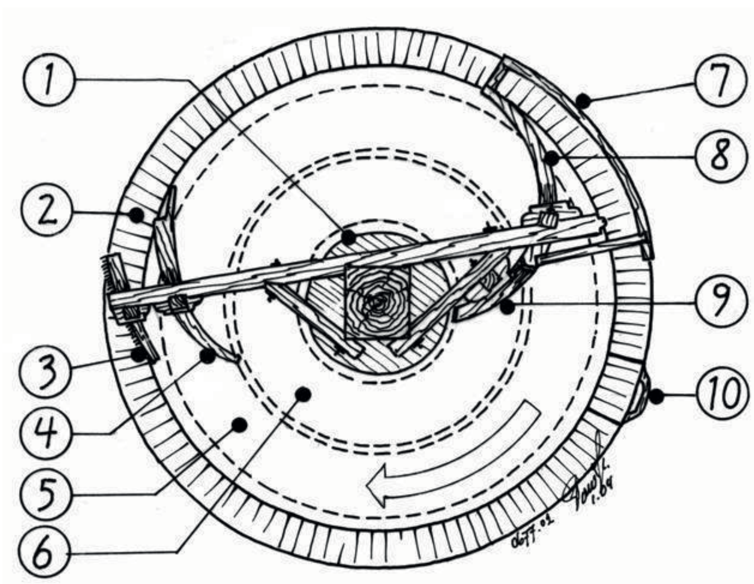

Fig. 14.2.3.3
The ploughs (scrapers) and the discharge arm:

1. *central spindle with toe-brass*
2. *parapet*
3. *outermost scraper*
4. *outer scraper*
5. *path (track) of the outer stone*
6. *path (track) of the inner stone*
7. *discharge arm*
8. *discharge arm*
9. *king (inner) scraper*
10. *discharge slide*

(The edge-mill turns clockwise.)

14.2.4 Oil seed heater

oil seed heater
heater plate

Before the first pressing meal is pressed, the oil presser heats it on the oil seed heater to make the oil more fluid, which allows more oil to be pressed out. The oil seed heater is a block-shaped masonry stove in which peat or wood is stoked to obtain an even and fire that’s not too hot. The oil seed heater is covered with an iron heater plate that protrudes at the front about 20 cm.

hopper, cloth bag

In this overhang are two rectangular holes under which small hoppers are inserted. A sack (cloth bag) is hung under each hopper.

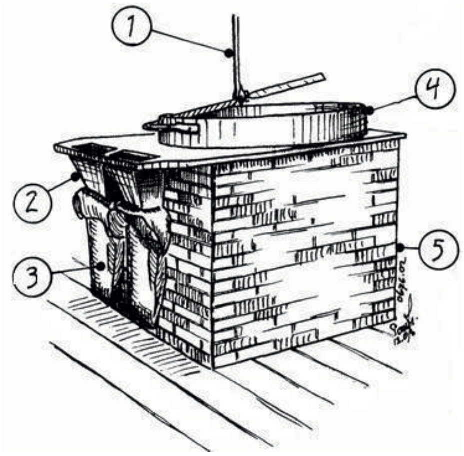

Fig. 14.2.4.1
Oil seed heater:

1. *stirring rod, stirring spindle*
2. *hoppers*
3. *cloth bags*
4. *slide ring or heating dish*
5. *oil seed heater*

slide ring, heating dish, stirrer
stirring rod, stirring spindle

On the plate is the slide ring, a pan without a bottom. The stirrer rotates in this ring, driven by the stirring rod (stirring spindle). This keeps the meal moving, heating it evenly and preventing burning. When the meal is sufficiently preheated (lukewarm, about 35° to 40°C), the oil presser raises the stirrer and pulls the slide ring toward itself, causing the meal to fall through the hoppers into both cloth bags.

Fig. 14.2.4.2
An oil seed heater with slide ring, hoppers and a cloth bag.

Oostendorper Mill – Haaksbergen

14.2.5 Pressing block

pressing block
pressing tray
bridle irons
sills
tray, pressing set
pressing plates, fixed pressing plates
spacing block, filling piece
pressing wedge, releasing wedge

The pressing block is located opposite the oil seed heater. This contains the pressing tray. The pressing block is a heavy oak beam reinforced with wrought iron bridal irons.
The pressing block rests on a heavy stone or wooden foundation, the sills. Carved out of the pressing block is a space called the tray. The pressing set is placed in the tray; the pressing set consists of two sets of irons (called pressing plates and fixed pressing plates), two wooden spacing blocks, a filling piece, and the pressing and releasing wedges.

Fig.14.2.5.1
A pressing block

In the middle is the pressing wedge (left) and the releasing wedge (right).
To the left and right of the sill, there are two oil trays under the spout openings.
Behind the pressing block is the oil seed heater.

St. Ursula Mill – Nunhem

pressing sack

The oil presser now places each cloth bag with heated meal into a pressing sack. This is a sack which is braided from horsehair and fitted with a leather cover. Nowadays, people do use other materials, such as plastic, rope or boards.

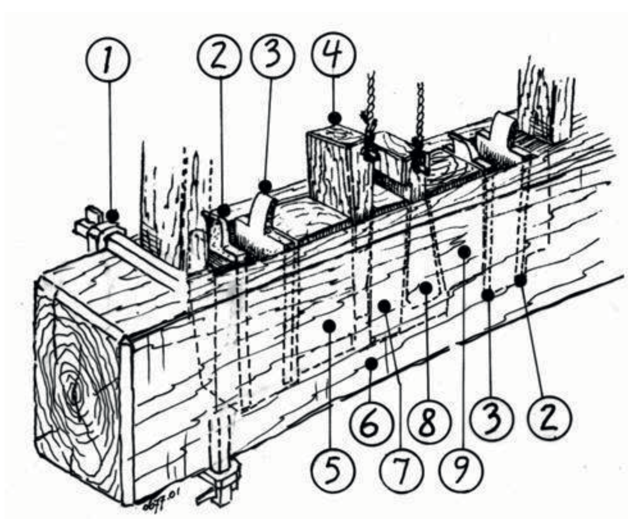

Fig. 14.2.5.2
The tray with the pressing set:

1. *bridle iron*
2. *fixed pressing plate*
3. *pressing plate*
4. *pressing wedge*
5. *spacing block*
6. *pressing tray*
7. *filling piece*
8. *releasing wedge*
9. *spacing block*

pressing plates
fixed pressing plates, pressing ram
pressing wedge
spout openings

Both these pressing sacks are placed between the pressing plates and the fixed pressing plates. Then the pressing ram is released. This drives down the wedge-shaped wooden pressing wedge with which, during 40 to 50 strokes, the pressure between the pressing plates is raised to about 250 hPa, forcing the oil out of the meal. Oil runs out of the tray through spout openings in the pressing block and is collected in oil trays under the pressing block.

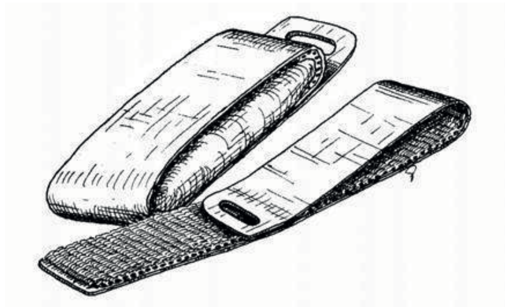

Fig. 14.2.5.3
Pressing sack.

A braided horsehair sack covered with leather.

releasing ram
releasing wedge
oil cake

If the pressing wedge will not go any further and the pressing ram begins to 'bounce', the oil presser stops pressing by suspending the pressing ram. Then the oil presser releases the releasing ram. This presses down on the releasing wedge, a counter wedge, and with a few strokes, lifts the pressure in the tray and allows the pressing sacks to be removed from the tray.
The high pressure of pressing turned the meal into a hard oil cake.

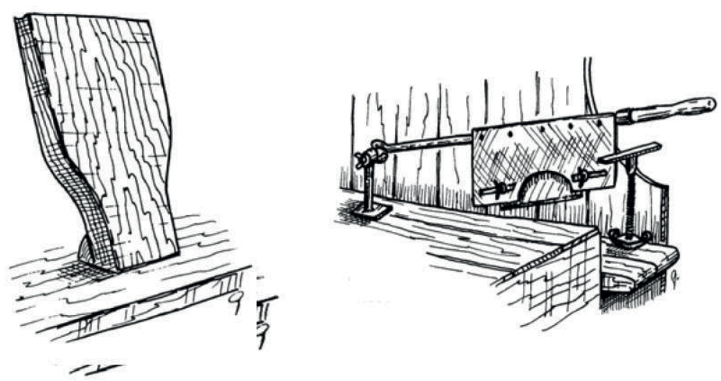

Fig. 14.2.5.4
The kaak (a wooden form to remove the oil cake from the bag) and cake knife for processing the oil cakes.

kaak (form for oil cake removal)
cake knife
scraps or pieces cut off from oil cake

The oil presser uses the kaak (a wooden form the size of the bag) to remove the oil cakes from the cloth bags. The cake knife is used to cut the cakes into oil cakes of a set size.
The scraps, the cut ends, then contain residual oil. They go back to be pressed again.

crushing, second pressing
oil cake crusher
stamping mill

Sometimes this pressing process is repeated one more time. We call this the crushing or second pressing. To do this, the oil cakes must first be broken up. This is done in an oil-cake crusher after which the pieces are finely rubbed under the edge runner stones into second pressing meal.
If a mill has a stamping mill, then the cakes and scraps are finely re-stamped into meal in the stamper holes.
The second pressing meal is heated again and pressed.

Additional oil is extracted from the meal during the second processing, thus increasing the oil yield. On the other hand, the price of a second pressing cake is lower since there is less oil and therefore less nutritional value in the cake.

Fig. 14.2.5.5
An oil-cake crusher.

It is driven by a drive shaft and drive belts from the mill shaft.

The Coll Mill – Eindhoven

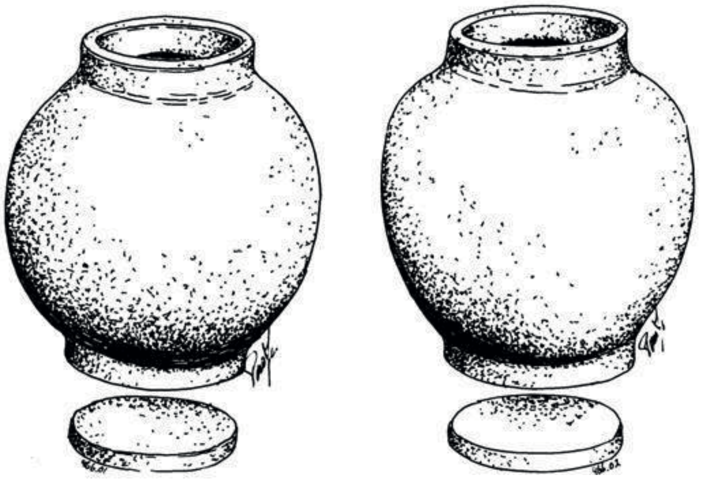

Fig. 14.2.5.6
Different shapes of stamper holes.

14.2.6 The double-works oil mill

From the 17th century onwards, there was a huge increase in industrial oil mills, especially in the Zaan region. Here oil was pressed in shifts, six days a week, 24 hours a day. The milling crew consisted of 5 to 6 men.
Far fewer industrial oil mills sprang up in the rest of the Netherlands.
And with water mills, there has been virtually no such development.
The Kilsdonk Mill is the only remaining double-works water-driven oil mill.

Perhaps the power of a waterwheel or a turbine was too low to drive both a first pressing and a second pressing as well as an edge-mill. Sufficient water for industrial production was also needed throughout the year.

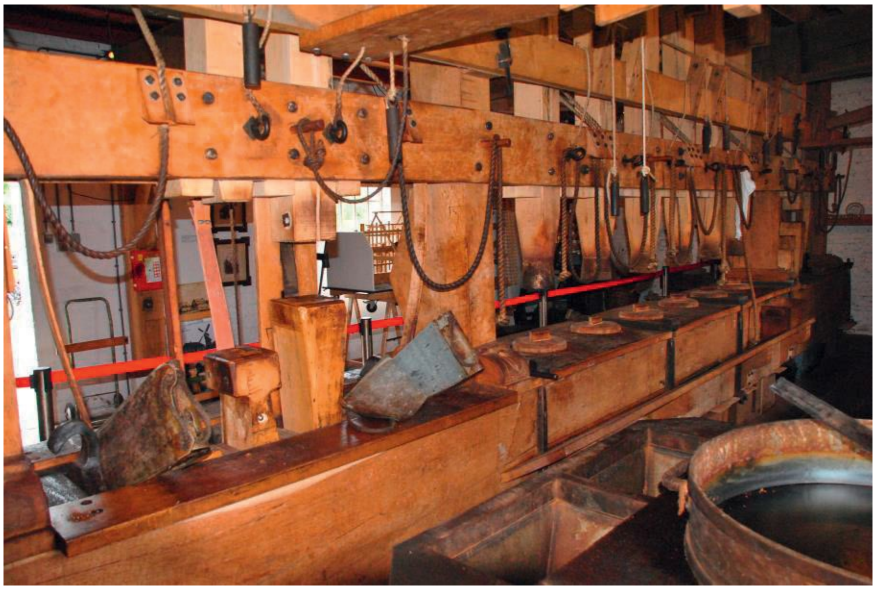

Fig. 14.2.6.1
A double-works oil mill.

On the left is the front beater for first pressing, in the middle is the stamping mill with six stampers, and at the back is the rear beater for second pressing. At the front on the right, the first pressing oil meal heater.

Kilsdonk Mill –Heeswijk-Dinther

stamping mill
stamper holes
stamper
second pressing meal, second pressing oil meal heater

A double-works oil mill has both a first pressing block and a second pressing block. It also has a so-called stamping mill which contains several (often six) cast iron stamper holes. These stamper holes can have different shapes. Often the stamping mill forms one unit with a pressing block. On the camshaft there are three spokes per stamper so three strokes per revolution.
In a double-works oil mill, the cakes go from the first pressing block into the stamper holes. There, they are finely stamped by the stampers into second pressing meal. This second pressing meal is heated again in the oil seed heater and pressed once more in the second pressing block.
The processing in the second pressing is the same as that in the first pressing. The second pressing also has three spokes on the camshaft and gives three strokes for each revolution. This is in contrast to the first pressing which has two spokes.
That fact that oil still comes out of the meal in the second pressing is due to the pressure in the second pressing being higher than that in the first pressing. This is achieved by giving the second pressing wedge a more pointed shape than a first pressing wedge. The second pressing tray is also narrower and thus the cloth bags are smaller.
Due to this higher pressure of about 350 hPa, about 5 to 10% more oil is pressed out of the meal in the second pressing.

14.3 OTHER INFORMATION

14.3.a Rotary speed

In principle, a structure such as a cam shaft with a lifting lever or with spokes can rotate too fast. This is the case when the camshaft rotates so fast that a ram or a stamper does not have enough time to fall before the lifting lever or next spoke grips under the fist. The stamper then falls with its full weight on the emerging lifting lever or spoke. This so-called 'spoking' can lead to damage.
With a camshaft with one lifting lever (in other words, two arms) or with two spokes, that risk is less than with a camshaft with three spokes.
This 'spoking' is a real concern for wind-powered oil pressers but not for water-powered oil mills.
The number of revolutions of the camshaft is usually lower than in a windmill and, with a good water supply, can also be kept more constant.

14.3.b Taking out of operation

The camshaft and edge runner stones are not disengaged separately. Rams and stampers can be suspended, allowing the edge runner stones to operate independently of the rams.
At some mills it is possible to put the entire oil works out of operation, such as to use all available power for the grain mill or to run the mill 'for the Prince' — for demonstration only.
For example, at the Kilsdonk Mill, a coupling was installed on the mill shaft to disengage all the oil mill's driving gear. At the St. Ursula Mill, the chain drive of the oil works can be disconnected.

14.3.c Storage

Oil pressing at single-works mills or 'farm oil mills' was mainly seasonal work. Production was not very high and was mainly for regional use. The oil was stored in barrels and these were transported by road or water. Large storage capacity was not available.

We do not see this small scale of operation in industrial (wind) oil mills. Large oil mills that operated in continuous production could process as much as 390 tonnes of seeds per year. That produced about 110,000 litres of oil and 270,000 kilos of oil cakes. The oil was stored in large oil cellars. When the price at the exchange was favourable, the oil was pumped out into barrels and sold.

oil cellar

The Kilsdonk Oil Mill, for example, has two oil cellars of 4,000 litres each. After the fire in 1842, this industrial oil mill — possibly the only one ever in East Brabant —was rebuilt with the use of iron and steel, which was rapidly expanding at the time. The mill was built to produce a lot of oil; oil cakes were a by-product. The oil was transported by water toward 's-Hertogenbosch.

Often oil mills were combined with a grain mill. What was striking about this was that the oil and grain mills were almost always located on opposite sides of the stream and were rarely housed in the same building.

Chapter 15 The sawmill

Contents Page

NOTES

15.1 INTRODUCTION

Dutchman Cornelis Corneliszoon van Uitgeest was the first to adapt the windmill into a sawmill by using a crankshaft. From this, the paltrok and the cap winding sawmill were then developed.
However, the water-powered sawmill was used long before its time in Normandy and the Black Forest.
Wind-powered sawmills have a crankshaft that usually drives three vertical saw frames. Water sawmills usually have a single saw frame.
Three water-powered sawmills and one remnant remain in the Netherlands as of 2020. These include:

Hackfort Mill in Vorden

The mill functions as a grain mill and sometimes as a sawmill. A saw table with a circular saw can be driven by the mill via a pulley and belt. The saw table is placed outside the mill for this purpose. The circular saw is used for cutting firewood.

Fig. 15.1.1
The Mills of Singraven
The left-hand building houses the sawmill on the left and the grain mill on the right. The building on the right was an oil mill but the fixtures have been removed. Only the undershot wheel is still there.

The Mills of Singraven in Denekamp

The sawmill is a hulling mill that was converted in 1896. Singraven's mill features one vertical saw frame driven from below by a crank wheel. Thus, there is no crankshaft and also the upper transmission to the saw frame consisting of the connecting rod (pitman) and rotary head is missing. The Singraven sawmill does have the following parts or tools: drive, log pond, tow ramp, windlass, saw carriage, pawl feeder, saw frame and circular saw.
The sawmill has a large wooden undershot wheel and is believed to be the only water-powered sawmill known in the eastern Netherlands.

Wenum Mill in Wenum

A sawing installation with a horizontal saw frame and saw wagon was installed in this grain watermill when it was restored around 1984. This was in addition to

the milling function.
This sawing installation was constructed in the early 20th century by Jan Oudt for his cartwright's business in Avenhorn, North Holland.

Fig. 15.1.2
Wenum Mill
The basement behind the double entrance doors houses the sawmill.

Wenum Mill has an overshot wheel, made of Bilinga or Opepe wood with a diameter of 2.8 m and a width of 1.6 m. The fall is 3.0 metres.

Fig. 15.1.3
Wenum Mill is equipped with an overshot wheel.
On the right is the pull for the sluice gate, in the middle the pull for the shuttle (or bottom flap).

Opwetten Mill in Nuenen

A saw installation was added to the grain mill building in 1918. Except for the vertical saw frame, the saw installation is still complete.
Perhaps in the future the sawmill will be completed and also put back into operation.

15.2 DRIVING GEAR

The two sawmills that still operate regularly — Singraven and Wenum — have vastly different layouts. Both are discussed in detail in this chapter.

15.2.1 Driving gears

drive belt
drive belt pulley

As mentioned above, water-driven sawmills — unlike wind-driven mills — do not have a crankshaft, connecting rods (pitman bars) and rotary heads.
One or more driving belts are used instead. On the mill shaft is a large pit wheel (face wheel) that drives a shaft via a crown wheel with a dual-gear drive belt pulley for each implement to be driven (only the drive of the windlass at Singraven is single-geared; see section 15.2.7). The number of machines or tools to be driven is four in the Singraven sawmill and one in the Wenum Mill.
The double version is necessary for bringing a machine into or out of operation.

fork, belt puller
loose and fixed pulley

The drive belt is moved sideways on the machine side with a fork or belt puller from a loose to a fixed pulley or vice versa.

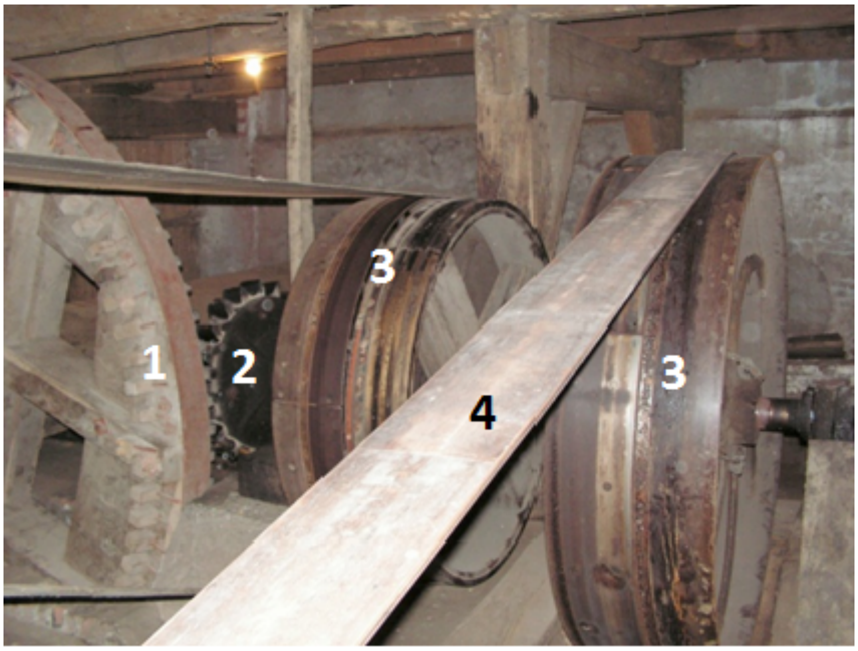

Fig. 15.2.1.1
The sawmill of Singraven.

On the left is the pit wheel (1) with the one-piece spur pinion (2) behind it and two of the four double belt pulleys (3) with the leather drive belts (4).

Water-powered sawmills in Germany (Nordbecks Wassermühle in Halle, municipality of Uelsen) and Belgium (Klaaskens Mill in Neeroeteren) also use this form of drive.

To drive several machines at the sawmill in the Opwetten Mill, a second spur wheel was installed on the grain mill's central spindle.
Three one-piece spur pinions could be attached to this second spur wheel.

- One drove the vertical sawing machine via a transmission shaft with iron gears and pulley.

- One drove the circular saw via a transmission shaft with iron cogs and pulley.
- One probably drove a saw sharpening machine.

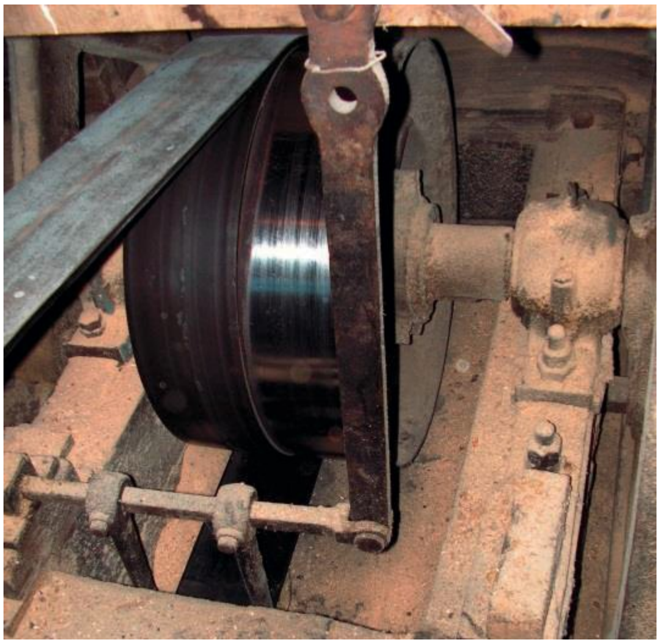

Fig. 15.2.1.2
The iron 'fork' for moving the drive belt. At the Wenum Mill, this fork is called a 'belt puller'. The fixed belt pulley can be identified by its sheen.

belt tensioner

Over time, drive belts slip — especially if it is not fitted with a belt tensioner. Which is not the case with either sawmill.

fish oil or linseed oil

To prevent this slipping, the skin side of the drive belt is rubbed with fish oil or linseed oil at regular intervals.
If that no longer works then the belt will have to be shortened.

belt lubricant

The use of belt lubricant such as resin is not recommended here because the drive belt must be frequently shifted sideways when taken in and out of operation.

15.2.2. Saw frame drive

In transmission to the saw frame, the rotary motion of the pulley must be converted to an up-and-down motion in the case of a vertical saw frame or a back-and-forth motion in the case of a horizontal saw frame.

crank wheel, vertical saw frame
connecting rod
counterweight

Crank wheels are used for this purpose. The Singraven mill with one vertical saw frame uses two crank wheels, placed under the saw frame, and two connecting rods, one to each upright of the saw frame. Due to the weight of the saw frame, a counterweight is installed in the crank wheels. This weight descends as the saw frame goes up and ascends when the saw frame goes down. In this way, a balanced load Is achieved.

horizontal saw frame

The Wenum Mill with one horizontal saw frame uses a crank wheel, placed next to the saw frame and connecting rod.
A counterweight in the crank wheel is not necessary in connection with the back-and-forth motion of the saw frame.

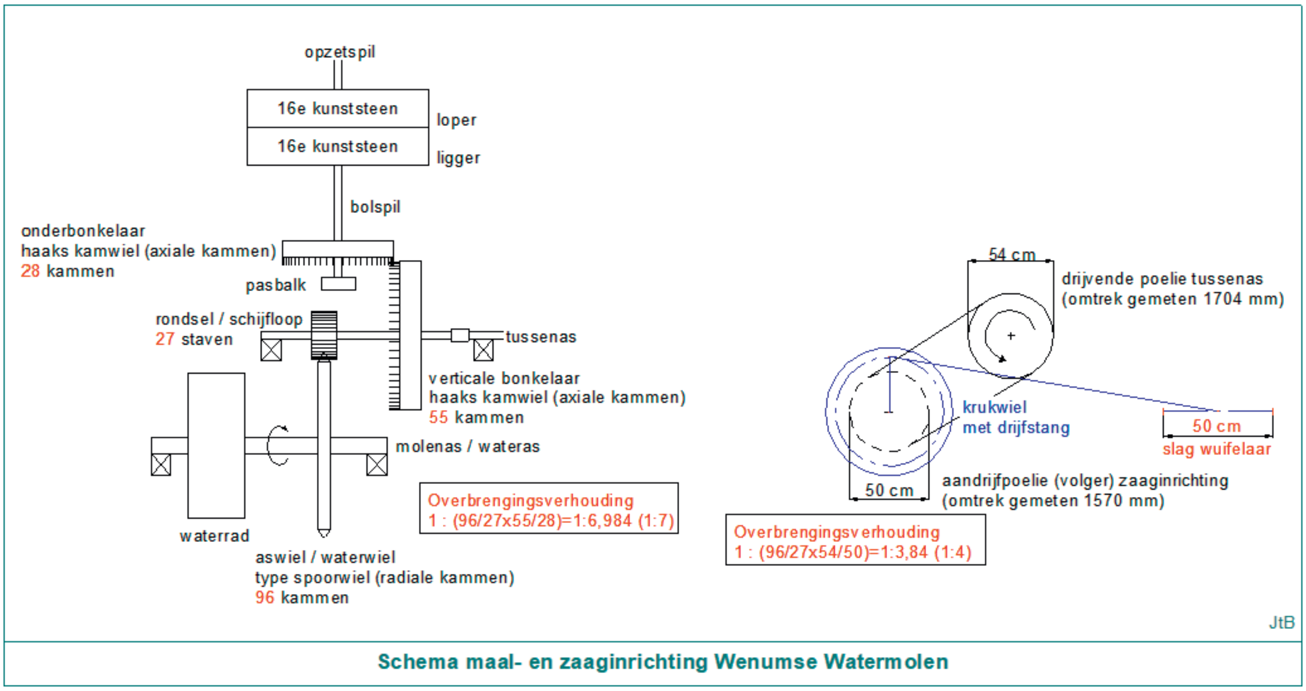

Fig. 15.2.2.1
Diagram of the Wenum Mill drive.
The sawmill has a horizontal saw frame. The grain mill has under-drive. The gear ratio is 1:7
The gear ratio waterwheel / drive belt pulley sawmill is 96/27 x 54/50 = 1:3.84 (1:4).
The saw stroke is 50 cm.

(drawing © Jan ten Böhmer)

Fig. 15.2.2.2
Drive of a horizontal saw frame. The crank wheel (left) drives the horizontal saw frame using a wooden connecting rod.

Fig. 15.2.2.3
Drive of a vertical saw frame
One of the crank wheels (1) with a connecting rod (2).
Behind it are the loose and fixed belt pulleys (3).
Bottom left of the crank wheel is the counterweight (4).

Fig. 15.2.2.4
Drive of a vertical saw frame
On the right along the upright (1) is the top of the connecting rod (2) and its attachment to the frame (3)

15.2.3 Saw frames

There are two types of saw frames: the vertical saw frame and the horizontal saw frame. Multiple vertical saws can be attached in a vertical saw frame. In a horizontal saw frame, a single horizontal saw is attached.

15.2.3.a Vertical saw frame

uprights
tensioning beam, upper and lower crossheads
trimming plates
chock bin
wedge, keyhole
saw-blade holder

The saw frame is composed of two uprights connected from top to bottom by the tensioning beam with two braces and the upper and lower crossheads. Both in the floor above the saw frame and in the saw floor are guides for the saw frame. The ironing plates that in other sawmills give the saw frame a forward pendulum motion are absent from Singraven's mill. Between the upper and lower crossheads, several saws are inserted in a precise vertical position. Between two saws, wooden chocks are used to control the distance between them. For this purpose, they have a large number of chocks of various sizes that are sorted and stored in the so-called chock bin.
For tensioning, the saws are fitted with a wedge with a keyhole at the top and a saw-blade holder at the bottom.

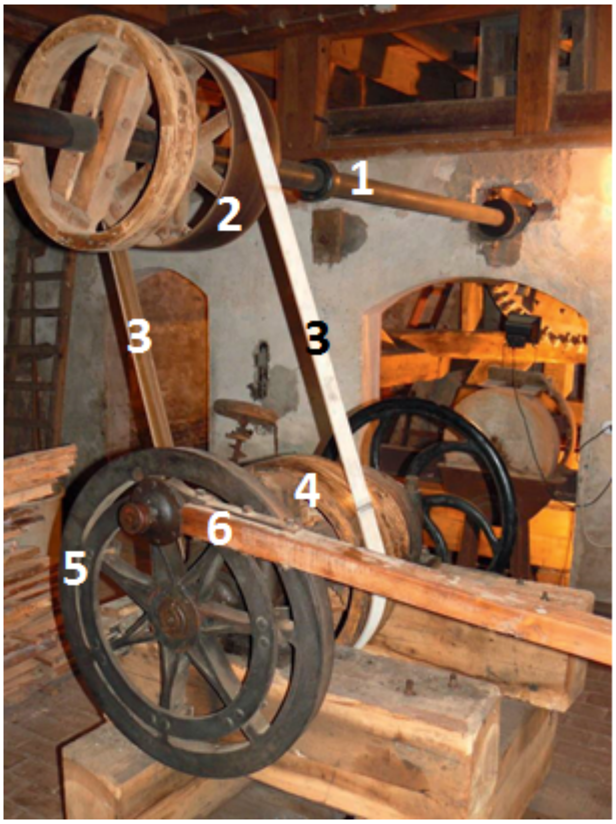

Fig. 15.2.2.5
Drive of a horizontal saw frame.

On the drive shaft (1) there is a wide iron belt pulley (2).
A drive belt (3) runs to a set of wooden pulleys (4) on a shaft below. One belt pulley is loose and one is fixed.
Attached to this shaft is a crank wheel (5) with a rod (6) for driving the horizontal saw frame.
A fork (belt puller) is used to manually move the drive belt between the loose and fixed belt pulleys.

15.2.3.b. Clamping saws in the vertical saw frame

upright
key

When clamping, the saw is raised vertically, parallel to the crossheads, through the upper crosshead to the point where the saw-blade holder can be inserted through the lower crosshead. Then the saw is turned a quarter turn and pressed top and bottom against the chocks between the upright (the first saw) or an already clamped saw. After this, the saw is tensioned by knocking a key through the wedge.
A vertical saw frame can house several saws but these saw only in the downward stroke. Saws must be fitted before placing the log due to the alignment of the log on the carriage.

15.2.3.c Horizontal saw frame

A horizontal saw frame is installed in a wooden framework. This slides over a set of guides fitted both above and below the saw frame. A horizontal saw frame can hold only one saw but cuts in both the forward and return motions.
The sawing layout is suitable for logs up to 55 cm in diameter.

15.2.3.d Clamping saws in the horizontal saw frame

nuts
tentering screws

The saw is tensioned using a set of nuts. There is also an adjustment option for horizontal tensioning of the saw.
The saw frame is adjustable in height. This is done using vertical tentering screws to the left and right of the saw frame. A crank and conical gears on a horizontal shaft on top of the sawing installation allow the saw frame to be moved up and down.

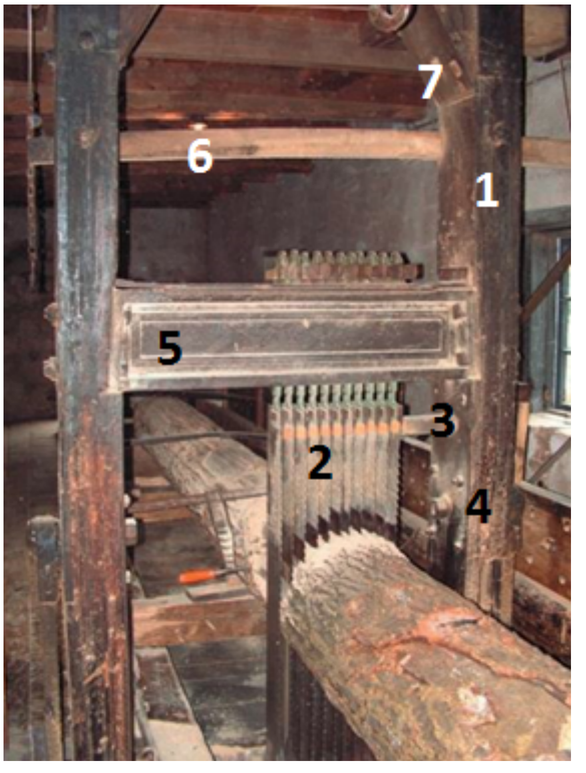

Fig. 15.2.3.1
The clamped vertical saw frame (1) with yellow spacer chocks (2) between the saws. The first chock on the right (3) must be long because the connecting rod bearing (4) protrudes from the inside of the frame.
Also, the log for cutting is generally wider at the root end. The feed bar (6) is attached horizontally to the saw frame above the crosshead (5).
The braces for the tensioning beam are fully visible above (7)

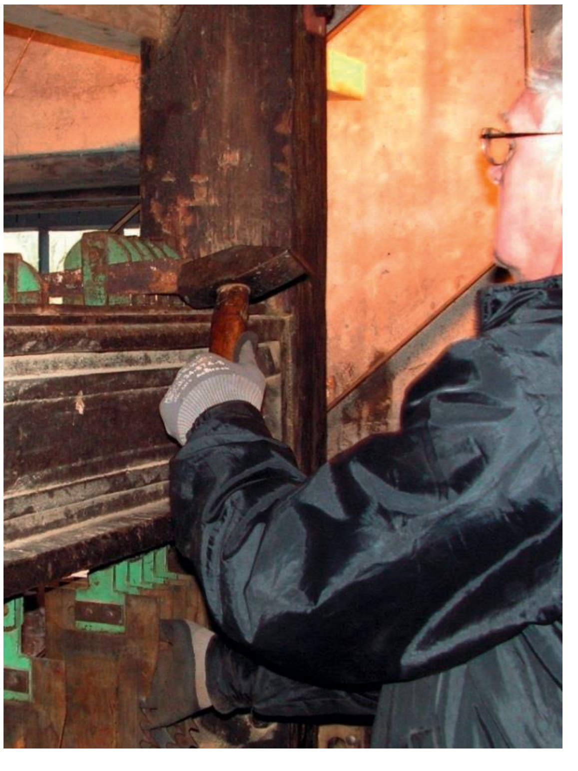

Fig. 15.2.3.2
Knocking a key into a wedge, inserted through the upper crosshead.

Fig. 15.2.3.3
The horizontal saw frame in the Wenum Mill.

ear nuts

To prevent unwanted movement of a horizontal saw frame, it must be secured before sawing is undertaken. This is done using two ear nuts (a precursor to the wing nut), one at each of the vertical tentering screws in the frame.

A weight of about 70 kg hangs from the framework of the sawing device on both the left and right, from a pulley block.
This is necessary for the stability of the whole construction.

In addition to the Wenum Mill, the Klaaskens Mill in Neeroeteren (Maaseik) in Belgian Limburg also has a horizontal saw frame.
It is an undershot mill with an iron waterwheel.
This restored sawmill is again fully capable of operation.

Fig. 15.2.3.4
The clamping of a saw blade on the right side of the saw frame.
On the left is the adjustment facility for clamping of saw horizontally.
On the right is the nut.

Fig. 15.2.3.5
Frame with conical gears for height adjustment of the saw frame.
On the left is the pulley block for the weight.

Fig. 15.2.3.6
Crank for height adjustment of the saw blade (board thickness).

Fig. 15.2.3.7
One of the weights on the framework that provides stability for the whole construction.
On the right, an ear nut to secure the saw frame.

15.2.4 Circular saw

ripsaw frame, ripsaw floor, squaring

Wind-powered sawmills have a ripsaw frame and ripsaw floor for squaring the sawn boards — in other words, cutting away the irregularly shaped side of the board.

circular saw

These ripsaw frames are missing at Singraven and in the Opwetten watermills but they have a circular saw in their place. The speed of the circular saw must be much higher than that of the belt pulley on the shaft that is driven by the one-piece spur pinion. It is raised in three steps by driving a small belt pulley coupled to a large belt pulley. Moving a drive belt between the loose and fixed pulleys engages or disengages the circular saw.

squaring

In this process, the board to be squared is passed along the circular saw on an iron plate on rollers across rails.

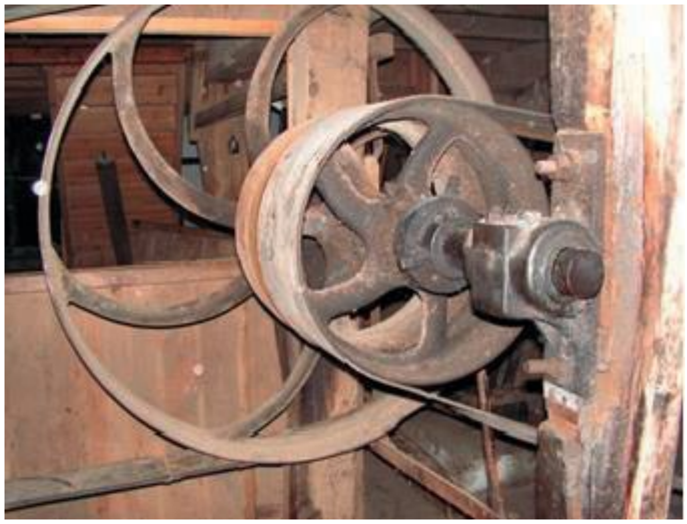

Fig. 15.2.4.1
Drive of a circular saw.

The first step in the acceleration. The large belt pulley sits on the same shaft as the small belt pulleys.
Around the small pulleys is the drive belt for the next step.

15.2.4.a Riving knife

riving knife

Behind the saw blade is the riving knife, a crescent-shaped attachment to prevent the saw blade from jamming in the saw cut.
The riving knife is thicker than the saw blade but thinner than the width of the teeth.
A rule of thumb for the thickness of the riving knife is: thickness of saw blade + 1 x the setting.
Assume the thickness of saw blade = 4 mm.
Teeth setting = 0.3 mm alternately left/right.
Thickness of riving knife = 4 + 0.3 = 4.3 mm.

Fig. 15.2.4.2
The circular saw with iron plate, rails and riving knife.

15.2.5 Bandsaw

bandsaw

drive wheel, tensioning wheel

The Nordbeck sawmill previously mentioned is equipped with a bandsaw. In terms of layout, this mill resembles a mill with a reciprocating horizontal saw frame but there is a fixed setup in which the saw rotates. This saw runs over a drive wheel and a tensioning wheel. In the middle between these driving and tensioning wheels is a wheel by which the rollers can be brought together. After opening the protective covers, the saw can be inserted or removed.
The bandsaw cuts in only one direction, of course.
The plank thickness is controlled by moving the saw vertically. This is done electrically via two conical wheels, both at the drive wheel and at the tensioning wheel.

Fig. 15.2.5.1
With the blue wheel between the driving and tensioning wheels, the rollers are brought together to be able to apply the bandsaw.

15.2.6 Saw carriage and saw wagon

A log pulled into the mill with the windlass or a block and tackle is attached to the saw carriage (Singraven) or the saw wagon (Wenum). Both of these provide transport through the saw frame.

15.2.6.a Saw carriage

saw carriage

side member, lay-board
front cross-beam, rear cross-beam

side member with hole-boards

With a vertical saw frame, the saw carriage is used to transport the log.
This type of saw frame is a large rectangular framework consisting of two long beams called side members or lay-boards. These side members are connected at the ends by a front cross-beam and a rear cross-beam.
One side member runs outside and the other runs inside the saw frame.
A side member with hole-boards, each with three rows of staggered holes, is attached to the side member that runs outside the saw frame.

hole-boards

Between the horizontal side members with hole-boards are nine vertically placed hole-boards. These hole-boards have two columns, each with five staggered holes.

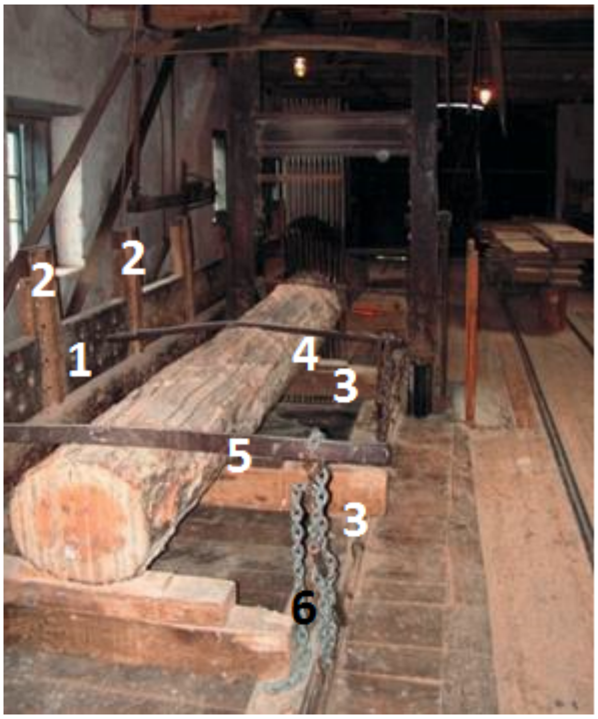

Fig. 15.2.6.1
Saw carriage with log.

1. *hole-boards*
2. *side member with hole-boards*
3. *anchor bars*
4. *wedges*
5. *beam irons*
6. *choke chains.*

rack and pinion
trundle wheel
iron shoe

To move the saw carriage, there is a rack and pinion under each side member that is driven by one trundle wheel per side member.
The carriage itself lies in/on a wooden U-profile and slides on iron shoes. This is in contrast to wind-driven sawmills where the carriage is moved over hardwood bolsters.

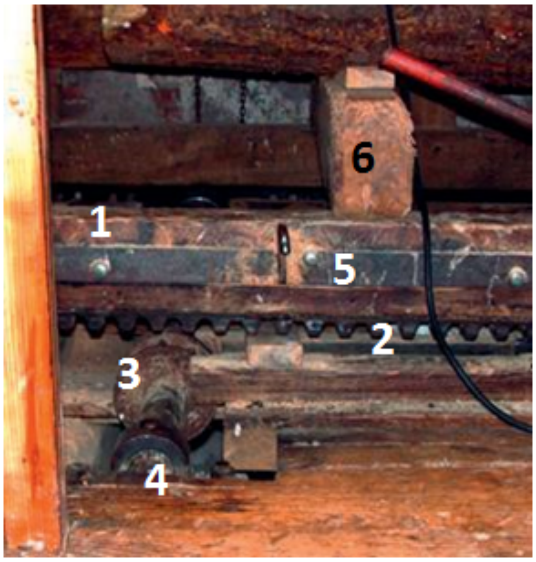

Fig. 15.2.6.2
Drive of a saw carriage

1. *side member*
2. *rack*
3. *pinion*
4. *drive shaft with trundle wheel and bearing*
5. *metal strip with hook for securing a choke chain*
6. *anchor bar*

On the side of the side member is a metal strip with hooks to which the choke chains are attached as well as the iron rods to clamp them down.

Fig. 15.2.6.3
Under the side member, the wooden U-profile with one of the iron shoes.

15.2.6.b Pawl feeder

pawl feeder, feed bar
pawl feeder
setting block
ratched wheel
rack-and-pinions

During cutting, the saw carriage must be moved forward. This is the job of the pawl feeder. Attached to the saw frame is a beam, the feed bar, which is connected to the feed pawl via the slotted lever. On the pawl feeder is an adjustment block in which the pawl is attached. This pawl engages a large gear, the ratched wheel. Via gears, this ratched wheel drives a shaft with two trundle wheels that engage the rack-and-pinions under the side members.

Fig. 15.2.6.4
The pawl feeder (1)

1. *feed bar on the saw frame*
2. *slotted lever for the pawl feeder*
3. *feed pawl with the adjustment block*
4. *pawl hinged in the adjustment block*

adjustment block
pawl return

Each time the saw frame moves up, the pawl pulls the ratched wheel one or more teeth further. The number of teeth are adjustable via the adjustment block on the feed pawl. To prevent the ratched wheel from turning back again, a pawl return is present. Using chains, the pawl and pawl return are engaged and disengaged.

Fig. 15.2.6.5
The pawl feeder (2)

1. *pawl that grips the ratched wheel (out of operation)*
2. *pawl return (lying on the floor)*
3. *ratched wheel*
4. *a gear that drives the feed shaft*
5. *drive belt for retracting the saw carriage (here on the loose belt pulley)*

15.2.6.c Saw wagon

saw wagon

rack-and-pinion

In sawmills that saw horizontally, the log lies on a saw wagon that runs on wheels — fitted with a groove — over thin rails with T-profiles. In the middle below the saw carriage is a rack-and-pinion for effecting the moving.
To cope with the varying lateral forces of the saw on the saw wagon, a heavy T-profile is installed under the saw wagon at the Wenum Mill. Its raised edge passes between two closed roller bearings mounted side by side on a beam on the saw floor, under the saw frame.
The position of these roller bearings is adjustable using a nut and bolt.

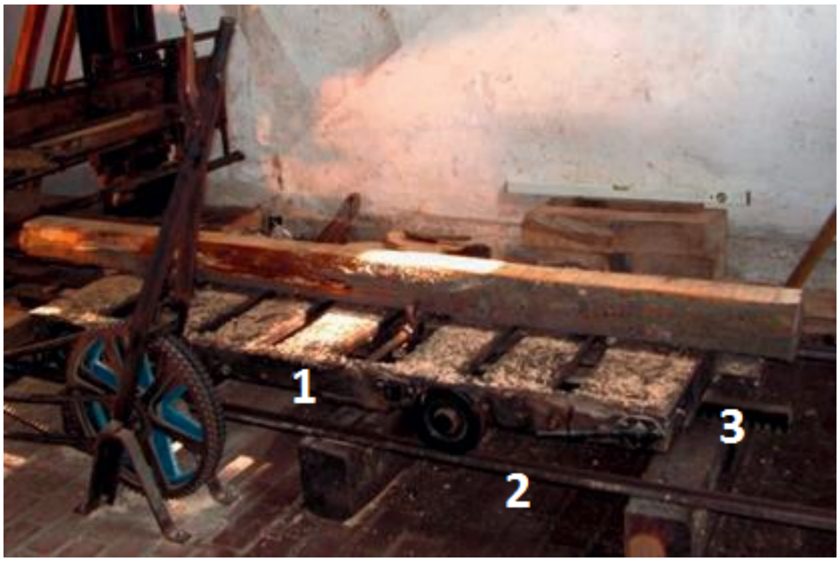

Fig.15.2.6.6
Saw wagon (1) on rails (2). On the right is the rack-and-pinion for effecting the moving (3).

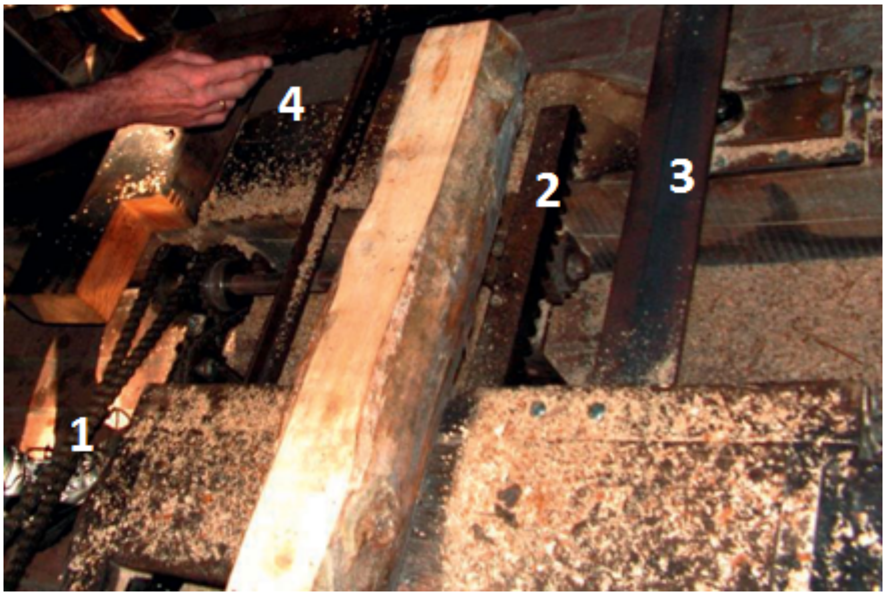

Fig. 15.2.6.7
Saw wagon:

1. *drive chain*
2. *rack*
3. *T-profile with the straight roller bearing.*
4. *saw (horizontal)*

15.2.6.d Propelling the saw wagon

saw wagon

The sawing device installed in the Wenum Mill originally had no feed and return mechanism. The saw wagon was pushed by hand.
Millwright Vaags installed a manual feed and return mechanism consisting of a lever, a chain drive and gears to a shaft with a trundle wheel under the rack-and-pinion.

Fig. 15.2.6.8
The feed and return mechanism for the saw wagon.

This was chosen for cost reasons. A mechanical drive with a pawl feeder would have cost ten times as much.
Squeezing the lever (fitted with a spring) of the feed and return mechanism releases a pawl and allows the lever to move forward and backward.
In the 'saw position', the saw wagon and thus the log moves 2 cm forward or backward at a stroke of 50 cm of the lever.
By sliding the pawl to the side and thereby switching between gears, the mechanism enters the 'fast position' and the transport goes 4x faster (forwards or backwards). This is especially important when reversing the saw wagon.
Thus, the saw wagon can be operated from one workstation.
The log to be cut is slowly guided into the saw with a small bite so that the saw does not jerk or deviate from the intended cut.
At mills in Belgium and Germany, a driving belt or an electric motor is used to transport the saw wagon.

15.2.7 Windlass

windlass, tow ramp

Using the windlass, a log is dragged into the mill from the tow ramp, with the root end of the log last.
This windlass consists of a drum around which a cable with a chain at the end is wound. This drum sits about 1 metre in front of the saw frame. The drive belt is coupled to a small pulley via a belt pulley. This small pulley uses a V-belt to drive a larger pulley on the drive shaft.
Attached to the drum is a large gear. This is driven by a small gear on the drive shaft. After releasing the brake with a wooden lever, the drive shaft is coupled to the large pulley by moving the pulley in the direction of the drive shaft. This causes the drum to rotate, pulling the log inwards.

brake

There is also a brake on the drive shaft. In terms of design, this brake is very similar to a band brake. By releasing the brake from the drum with a rope, the cable can be run out and the chain attached around the crown end of the trunk to be dragged.

Fig. 15.2.7.1
Running out the cable from the windlass.

Fig. 15.2.7.2
A chain to drag the log in.

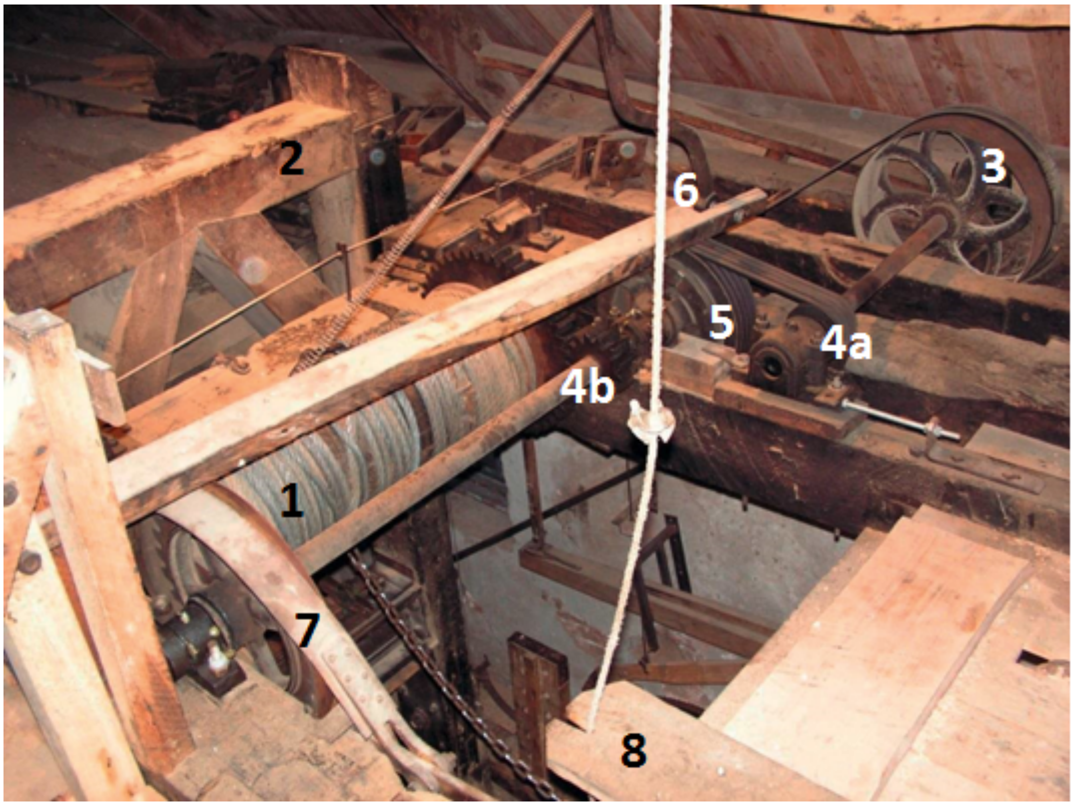

Fig. 15.2.7.3
The windlass (Singraven sawmill).

The drum with cable (1) and chain end is hanging in front of the saw frame (2). At the top far right is the drive belt and fixed belt pulley (3). Via a shaft, pulleys, V-belts and gears (4a/b), the drum is driven in a delayed manner. Above the drum is the mechanism (6) for coupling the large pulley (5) with the drive shaft (4b). On the left on the shaft in front of the drum is the brake (7). Pulling the rope releases the brake. When the rope is hooked into the notch in the board (8), the brake remains released.

15.2.8 Different method of bringing in logs

Since the sawmill of the Wenum Mill is housed in the cellar, the logs to be sawn are brought from the courtyard through the former entrance doors into the cellar and placed on the saw wagon with a hand hoist, tensioning straps and ropes. Given the limited space in the sawmill and in part depending on the weight of the logs, the logs are a maximum of 2.9 metres long with a maximum diameter of 55 cm.
Preferably this is 2.5 m in length and 50 cm in diameter.

Fig. 5.2.8.1
Transport with hand hoist.

Fig. 5.2.8.2
The log is placed on the saw wagon.

15.3 OTHER FEATURES

15.3.1 Log pond

log pond

In the log pond, softwood (coniferous wood) is watered in gently flowing water for a minimum of one and a maximum of two years. This is done to flush the sap out of the log. For this purpose, the logs are placed in the water with the root end upstream. Unlike other sawmills, the hardwood (non-coniferous wood) logs at Singraven are not watered. The log pond at Singraven is not next to the mill, as is customary. Therefore, the watered logs have to be transported to the tow ramp by crane truck.
At the owner's request, no watering has been done at Singraven for several years. This is because the log pond is next to a public road and there is concern that children might play on the logs and get caught between them.

15.3.2 The tow ramp

The logs to be cut are stored on the tow ramp. They are laid down so that the root end is lower.

Fig. 15.3.2.1
The tow ramp.

15.3.3 Sawdust collection bin and sawdust pit

sawdust bin

In the Singraven sawmill, the sawdust bin is located under the saw frame between the connecting rods and above the belt pulleys.

sawdust pit

This is a sloping chute that removes the sawdust to an adjacent area, the sawdust pit.
This keeps the drive gear free of sawdust. The circular saw is also connected to the sawdust pit via a chute.

15.4 SAWING PROCESS

15.4.1 Placing the log on the saw carriage

To position the log to be sawn, the saw carriage is pushed back to the tow ramp using water power. Then the windlass is used to pull the log from the tow ramp into the saw carriage. It then lies on the floor. When the log reaches the saws, the cable to the windlass drum is now vertical and the top end is pulled up. If this end is raised high enough, a beam called an anchor bar can be placed under the log beyond the centre (toward the tow ramp), perpendicular to the carriage and with the notch downwards on the side of the side member with hole-boards. (Otherwise it will not be level.) Lowering the top end then raises the root end where a second anchor bar is placed. By then pulling up the top end again, an anchor bar can be placed there as well. The log is then turned so that the straight felling notch (an angled cut for the direction of fall made when felling) lies flat on the rear anchor bar for the stability of the log and for easier removal of the anchor bar. If the felling notch is missing, then a straight support surface at the root end is made with a chainsaw.

anchor bar

side member with hole-boards

felling notch

Fig. 15.4.1.1
Measuring rod with sliders.

The log is then is aligned using a crowbar. This is done initially by eye. For more precise work, a measuring rod is used at Singraven. It is equipped with two bolted sliders. These sliders are adjusted near the saws in such a way that when the measuring rod is held against the side member with hole-boards, the bolts are exactly in front of the first and in front of the last saw blade. This measures the distance between the log and the side member with hole-boards at the top and root ends. Also, if the log is curved, the course of the saws at the curvature can be determined. The same is true when cutting boards (log sections sawn through once). Here it can be determined very accurately whether the bark is sawn off.

measuring rod

boards

15.4.1.a Fixing the log on the saw carriage

After alignment, wedges are inserted between the log and the anchor bars and

beam irons
hole-board, choke chain
choke bar

the log is secured with beam irons. For this purpose, one side of the beam irons are inserted into the side member with hole-boards and secured with a choke chain tautly stretched with an iron choke bar.

Fig. 15.4.1.2
Securing the log with beam irons and choke chains.

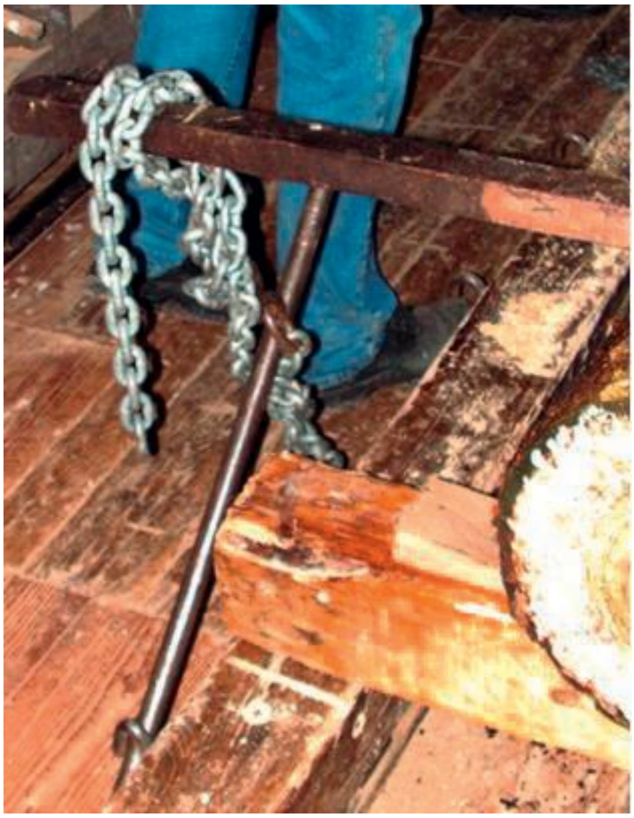

Fig. 15.4.1.3
A fastened choke chain.

The choke bar in the chain is turned so that if it should come loose, the lower (= longest) piece shoots away in the direction of the carriage and thus does not strike the legs of the miller or a visitor.

boards

To create boards or beams, a log must be cut twice. After the first cut, the boards — after retracting the saw carriage toward the ramp — are again placed on anchor bars on the carriage, aligned and secured. For heavy boards, a trolley is used to do this and hand hoists are used for moving the boards between the saw carriage and trolley.

Fig. 15.4.1.4
Saw carriage with boards on the anchor bars.

15.4.2 Placing the log on the saw wagon

With the same hand hoist used to bring the logs into the Wenum Mill, and using round poles as rollers with beams as levers, the log to be cut is placed on the saw wagon.

15.4.2.a Securing the log to the saw wagon

collet chucks

Beam irons and choke chains cannot be used when cutting horizontally. Collet chucks fitted to the carriage are used to secure the log. Four collet chucks are available: two on each side which can be moved over two tentering screws mounted transversely under the saw wagon.

strip

Under both tentering screws is a steel strip with a number of evenly spaced holes.

Fig. 15.4.2.1
A collet chuck.
Under the tentering screw the strip with holes.

Fig. 15.4.2.2
Application of loose extension pieces for high clamping.

The fork-shaped underside of the collet chuck has holes and laterally encloses the steel strip.
After manually 'positioning' the collet chucks relative to the log, a pin is inserted through the holes in the collet chuck and the strip between them, allowing the collet chuck to tilt around the pin.
Using a wrench, the nuts in front of the collet chuck on the tentering screw are alternately tightened so that the claws of the collet chuck bite into the wood.
During the sawing process, the nuts sometimes need to be re-tightened slightly. Because the collet chucks must remain under the saw, they grip low down in the log. For thicker logs, separate extensions for the collet chucks have been made to heighten the point of engagement of the claw on the log.
To obtain the best planks/beams from a log, filling shims and/or wedges are used as needed. A lifting beam is also often used.

15.4.3 Sawing

After placing the saws and aligning the log or boards (in other words, wooden boards after sawing once, over the width of the log and with the desired thickness), the saw frame can be put into operation.
At Singraven, to do this, there is a wooden lever on the saw floor with which the drive belt of the 2nd of four belt pulleys can be moved to the belt pulleys of the crank wheels between the loose and fixed belt pulleys. The

saw frame begins to move.

pawl return

Then the pawl return is pulled into the ratched wheel and then the pawl. Both are operated by chains. These actions bring the ratched wheel into operation and sawing begins.
The speed at which the saw carriage moves is usually 3.5 metres per hour but it can be set faster or slower. For tough wood this can possibly be done slower or, when there is not much sawing to do, to have stock for demonstrations.
Once an anchor bar reaches the saws, sawing is stopped to place an anchor bar with beam iron and wedges directly behind the saws. Then the anchor bar, beam iron and wedges in front of the saws are removed. This sequence, especially at the log ends, is important to prevent the log moving when hammering the wedges.
If part of the log has been cut, then a large clamp is placed on the cut part or a rope or tensioning strap is tied around the log to hold the boards, planks or beams together.
When sawing is stopped at the end of the day, the carriage is retracted slightly by manually turning the ratched wheel; about 2-mm thick iron plates are hammered into the saw cut to reduce the pressure on the saws' settings.
When oak is sawn, the entire log is sawn — if possible — to prevent the saws from remaining in the log for a week. The saws would then rust because of the acidic sap in the wood. If it is not possible to saw the oak log in its entirety, diesel oil is sprayed on the saws which, however, has the disadvantage that the wood becomes greasy and difficult to paint.

15.4.3.a Emergency stop

Sawing may have to be stopped quickly — for example, because there is metal in the log.
At Singraven this is done as follows:
Disengaging the saw frame by moving the drive belt is less suitable for this purpose. Due to the kinetic energy contained in the crank wheels, the saw frame goes up and down at least 20 times after being taken out of operation. The saw carriage is also then still being transported through the pawl feeder. The pawl return is therefore pulled out of the pawl feeder, thereby immediately stopping the transport of the saw carriage. Then the drive belt of the saw frame is moved.
At the Wenum Mill, in the event of an emergency stop, the belt puller is used to move the drive belt from the fixed drive belt pulley to the loose belt pulley.

15.4.4 Layering (Stickering) sawn parts

After cutting the log, the boards are placed on a trolley with wooden slats between them. This allows them to dry. Here, it is important that the slats (sticks) between the various boards are on top of each other to prevent warping due to pressure at an unsupported location.
Sawn boards are later placed back on the saw carriage to be cut into planks or beams. To do this, the saw carriage is pulled towards the tow ramp and the trolley with the boards to be cut is driven alongside it. A log is generally sawn twice. The vertically cut boards come to lie flat on the saw carriage. So, they are turned a quarter turn.
The sawn boards or beams are also layered (stickered).

Fig. 15.4.4.1
The trolley on rails parallel to the saw carriage.

Fig. 15.4.4.2
The layering (stickering) of boards with slats.

15.5 SAW

The saw of a horizontal saw frame that cuts in both directions has differently set teeth than those of a vertical saw frame that cuts only in the downward motion or a bandsaw that always cuts in the same direction.

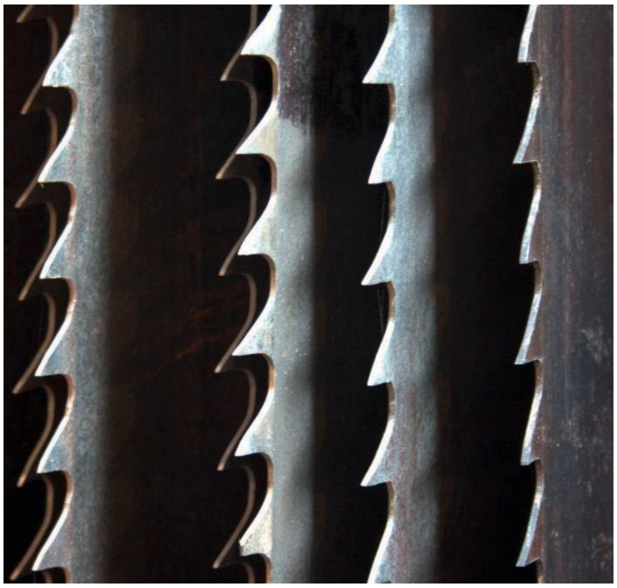

Fig. 15.5.1.1
Tooth profile of unidirectional saws.

Fig.15.5.1.2
Tooth profile of a bi-directional saw. The teeth are set alternately.

Wenum Mill – Wenum

15.5.1 Saw trimming, setting and sharpening

saw vise, file buck

A properly set and sharp saw is a prerequisite for good sawing. This setting and sharpening should be done after approximately every 30 metres of sawing. To trim, set and sharpen a saw, the saw is clamped in a saw vise (also called a file buck).
In Wenum, all these operations are done manually. In Singraven, although manual setting is carried out, saws are sharpened by machine.

15.5.1.a Trimming

First, the teeth are lightly trimmed. This is done to make the tooth points *trim line*

equal in height (an equal trim line). This is important so that all teeth perform the same amount of work.
For trimming, a trim block is used in which an old mill saw file is clamped over the teeth of the saw blade.
Trimming creates a small flat surface on each tooth that is not the same size everywhere. This indicates that the tooth points were not evenly aligned.
At Singraven, saw teeth are not trimmed. This is because all teeth are included in the sharpening process.

15.5.1.b Setting

saw set

Setting the saw consists of alternately bending the teeth to the left and right. For setting, pliers are used to roughly set the tooth after which a saw set is used to bend it more precisely. This set is placed just behind the tooth point, which is then gently bent. The extent of the setting is determined for each tooth using a dial gauge. In general, the less bending the better. A tooth that is bent too often will eventually break off.

Fig. 15.5.1.3
The saw in the saw vise while bending a tooth with the saw set. In the left hand, the gauge to measure the angle.

setting

Depending on the type of wood to be cut, the setting is larger or smaller.
For hardwoods such as oak and chestnut, 0.4 mm to the right and left is maintained. For softwood, 0.7 mm is used and for tough elm, even 1 mm.
Because of the desired optimal setting, different saws are used at Singraven for hardwood and softwood.
At the Wenum Mill, the teeth are set at 0.5 mm for all types of wood.
If the setting is too small, the saws will heat up and they may become stuck in the wood. A setting that is too coarse results in a washboard effect on the surface of the sawn parts, in addition to the unnecessary loss of wood due to a wide cut.

At some sawmills a different setting is also used, such as two teeth to the left, two upright and two to the right, etc. Or one tooth to the left, one upright and one to the right, and so on.

The reason given for this is that the upright teeth provide a better disposal of sawdust when the vertical movement of the saw frame is smaller than the diameter of the log. For example, the vertical movement of the saw frame at Singraven is 40 cm when cutting logs up to about 60 cm diameter. Thus, the teeth in the centre of the log do not extend outside the log. At Singraven, this presents no problem with sawdust disposal despite the lack of upright teeth.

15.5.1.c Sharpening

After setting, the teeth are filed to give them a sharp point. In fact, those tooth points act like small chisels.
The saw blade is now placed low in the saw vise so that the bottom of the tooth is about a centimetre above the saw vise. First, the teeth that are set away from the filing direction are filed. Filing is done at right angles to the saw blade as much as possible (right-angled filing).

right-angled filing

However, perfectly right-angled filing is impossible without causing the saw blade to vibrate and 'scream'. Also, this does not make the sawing surface nice and smooth, and the file quickly becomes blunt.
Therefore, the tooth backs in particular are filed at a slight angle.
Furthermore, it is important that filing is done only away from you; you should never file while pulling the file back ('backward filing')!

tooth face

Filing of the tooth face (the front of the tooth)

First the tooth face is filed. This is filed 'poorly', which means primarily the tooth point. With the round side of the file, the correct shape and depth is brought to the tooth gullet. Care must be taken to prevent the tooth from losing its pitch.

Fig. 15.5.1.4
A grinder.

Filing the tooth back (the opposite side to the face)

tooth back

After filing the face of the tooth, the tooth back is filed. The tooth point

is formed in the process.
Filing of the back proceeds along the entire length, from the base of the tooth to the point. In doing so, however, the point should not end up below the trim line.
Thus, when half of the teeth have been sharpened, the saw is turned in the saw vise and the remaining teeth are sharpened.
After all the teeth have been sharpened in this way, the saw is ready for use.

At Singraven, saws are set by hand but sharpened by machine. According to the instructions accompanying the grinder, the teeth should be filed at an angle of:
- 8˚ to 12˚ for hardwood.
- 14˚ to 16˚ for softwood.

At Singraven, the teeth of all saws are machine sharpened at a 12˚ angle.

15.5.1.d Setting and sharpening a bandsaw

Because of its shape, a bandsaw cannot be placed in a saw vise.
Therefore, the saw is laid on a structure comprising a number of supports with wheels. The teeth are set left and right and sharpened by machine.

Fig. 15.5.1.5
The bandsaw from the Nordbeck Mill at the electric grinder.
The saw is turned one tooth further each time.

15.6 SAFETY

- At the sawmill, dragging or hoisting logs is not without danger.
  If any cables become loose or break, accidents can occur due to carelessness and lack of attention. Dragging and lifting equipment (hoists, lifting straps, ropes, etc.) must therefore be one hundred percent reliable. While dragging, someone next to the windlass operation should be ready to intervene and visitors should be kept at a distance. This is true not only inside the mill but also for viewers outside.
- Working with cant hooks involves the risk of entrapment.
- The choke rods of the choke chains must be tensioned so that if they become loose, they shoot away in the direction of the carriage.
- The saw frame, when in motion, must be shielded and you should work behind the saws as much as possible.
- During sawing, someone always stands by the chain to pull the pawl return out of operation, thus stopping the sawing immediately.
- The shaft, face wheel (pit wheel) and one-piece spur pinion, belt pulleys and drive belts as well as crank wheels should be shielded so that the public cannot approach or touch them.
- When working between the wheels and belt pulleys, fellow millers should always be warned and the mill, of course, brought to a standstill.

At a minimum, the tow ramp must be closed to the public with a chain and a 'do not climb' sign. It can be very slippery, especially in wet weather.

Chapter 16 The paper mill

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NOTES

16.1 INTRODUCTION

The first properly writeable material was papyrus, made from the papyrus plant which the ancient Egyptians had been using for writing since around 3000 B.C. Around 700 B.C. parchment, made from animal skin, arrived from Pergamon in western Turkey. Parchment supplanted papyrus.
Around 200 B.C. paper as we know it was invented in China. From the Arab world, it reached Europe via Spain (then also Arab) where the first paper mill emerged around 1100.
Nearly 500 years later, in 1586, the first Dutch paper mill (a tide mill) was founded in Zwijndrecht by Johannes van Aalst, a native of Antwerp (Belgium) with the help of fleeing Protestant papermakers, and the first wind-powered paper mill also soon arrived in Alkmaar.
Formerly, you could buy French (Troyes) and Italian (Lombardy) paper in the markets in the major cities of Brabant and Flanders. That was the case until the Fall of Antwerp in 1585, when the Spanish captured what was at the time a Protestant city.
Because the tide mill was not ideal for paper making — the hammers could not work here for 12 hours at a time — a boat mill near Tiel on the Waal River was converted into a paper mill. Since this was also not optimal for supply and removal, Van Aelst received a permit in 1591 to build the first Veluwe paper mill at Arnhem on the Sint Jansbeek or Sonsbeek river. He was required to 'press white, white-grey, grey, blue and board paper'.

In the west of the Netherlands, wind-driven paper mills were built. These were stage mills with long barns because a lot of drying space was needed. The only working wind-driven paper mill left in the Netherlands is the Schoolmaster Mill in Westzaan.
In the south and east of the Netherlands, water-driven paper mills were built. Especially in the Veluwe region, where there were about 170 of them. There they had ample access to the clean, clear water needed for the manufacture of white paper. The remaining working water-driven paper mills are the Middle Mill in Loenen and the former Rear Mill of Loenen, which is now in the Netherlands Open Air Museum in Arnhem.

Fig. 16.1.1
This plaque, depicting the interior of a paper mill, comes from the premises at Damrak 98 in Amsterdam, built in 1649 for the Amsterdam paper merchant Pieter Haack. These premises were demolished in 1908.
The stone is currently installed in the building at Herengracht 105 and corner of Leliegracht.

16.2 THE DESIGN OF A WATER-DRIVEN PAPER MILL

In the production of paper, the raw material has to undergo several processes. This requires multiple facilities and spaces.
We distinguish:
- the reservoir pond or mill pond;
- the mill with machinery;
- the drying-loft.
These will be discussed further in the following sections.

Fig. 16.2.1
The Veluwe paper mill with overshot wheel.
(collection of the Netherlands Open Air Museum')

16.3 BRIEF DESCRIPTION OF THE PRODUCTION PROCESS

1. Sort old clothes and rags by colour and type.
2. Using the scythe blades, tear the clothes into pieces, remove buttons, etc.
3. Wash and beat the fabric into half stuff in the hammer bins.
4. Allow the half stuff to settle in the stuff-chest in which heating also occurs.
5. Grind it further into whole pulp in the refining beater or Hollander.
6. Let the ground whole pulp run off from the refining beater into the stuff-vat.
7. Transfer the stuff into the dipping-vat.
8. Mould paper with the moulding form and couch into a post of 125 pieces.
9. Bring the post under the wet press.
10. Hang the paper in the drying-loft.
11. Press paper flat in the dry press.
12. Sort by thickness and press again if necessary.
13. Take writing paper to the sizing kettle.
14. Press sized paper again and dry in the drying-loft.
15. Package the paper.

16.4 RESERVOIR POND OR MILLPOND

There are several types of paper that can be made with mills. In the beginning, Veluwe paper mills made white writing and printing paper, grey packaging paper and the blue confectionery paper. Printing and packaging paper was made from cotton, writing paper mainly from linen which is finer in texture.
When, in the 17th century, the mills in the Zaan region began to concentrate more on fine white writing paper and blue packaging paper, the Veluwe region papermakers began to make mainly white printing paper, the less fine writing paper and the ordinary packaging paper.
In the 18th century, the Veluwe letterpress printing paper was world renowned for its hardness, durability, firmness and colour fastness, even surpassing French paper in quality at the time!
This was mainly due to the fact that it was so white, which has to do with the water. The stream water not only drives the mill but it is also piped in from the trough (flume) to fill the hammer bins, hollander and dipping-vat. The clearer this water, the whiter the paper.

trough, flume

Fig. 16.4.1
The reservoir pond of the Veluwe paper mill.

reservoir pond
collection pond, mill pond

Clear water is therefore important and that is what the reservoir pond (collection pond, mill pond) is designed for. It contains the supply of water for powering the mill but also interrupts its flow rate, causing debris and impurities to settle so that the water is made as clear as possible. The clear water of the Veluwe streams is due to the sand layer deposited during the Ice Age on the ice-pushed ridges of the then-formed Veluwe. This sand forms a filter for rain water. This rain water cannot settle into the groundwater because of the loam layer beneath this sand layer. You can see from the vegetation that the soil on the Veluwe hills is locally moist. When you dig down to this, an artificial stream head is created from which water wells up.

artificial stream head

This water can be run to mills through excavated stream systems, the artificial streams. There have been more than 1,000 artificial streams on the Veluwe.

artificial streams

Because of the colour it would deposit on the paper, water containing iron (ferruginous water) cannot be used.

Consequently, ferruginous artificial streams were expressly kept separate from those with clear water (there were even small viaducts at intersecting streams).
Making 1 kilogram of paper required 150 to 175 litres of water.
So that the water never came into contact with iron even in the mill, all pipes were made of lead or copper. This was especially done in white-paper mills to avoid rust stains in the paper. For packaging-paper mills, this was less important; packaging paper may be off-white.

Fig. 16.4.2
The overshot wheel of the Middle Mill in Loenen has a partition wall downstream — in the middle of the stream — to separate the clean water (left) from the polluted water (right) for the lower mill.

Dyes were also used in paper production and their waste products were discharged into the stream. To prevent a lower mill from suffering from stained water during paper production, a partition wall was placed along the entire length of the stream (see Fig. 16.4.2).
This keeps clean water from the stream separate from the wastewater.
This also allowed the lower mill to have clean water.
The polluted water ran over the wheel there and the clean water was directed inside.

bottom hatch, shuttle

wooden plug

sill, threshold

In the trough (flume), just before the bottom hatch (shuttle) — which causes the water to flow onto the wheel — there is a hole that can be closed with a wooden plug. When the plug is removed, the water flows through the pipe system into the mill to fill the hammer bins, refining beater or hollander and the dipping-vat. A removable wooden sill is placed between the hatch and the hole to ensure that there is always enough water left in the trough for this filling.

16.5 THE MILL

16.5.1 Providing the raw material

sieve
blades

Inside the mill is the sieve, a wooden container with a metal grille as the bottom that holds two knives, the blades. Here two women or children worked to process the rags that came in after they had been sorted by type and colour.

Fig. 16.5.1.1
Sieve with blades.

blades, tearing knives

White paper mills processed only white rags. On the grille, dirt and dust was also beaten out of the rags. The blades (also called tearing knives) were used to remove buttons, hooks, buckles, etc. and to tear the rags into narrow strips or pieces.
This was filthy, dusty work; the rags were not clean and were full of lice, fleas, mould and scabies.

chopping blocks, rag bins
hammer bins

The coarser fibres of hemp and the torn linen and cotton rags were chopped into small shreds on the chopping blocks in the rag bins. These shreds and those from the sieve were taken to the hammer bins to obtain the fibres from them.

hammers, cams
waterwheel shaft
whole stuff

The hammer bins are carved into an oak log with the bins tapering inward at the bottom. At the bottom is a thick metal plate. Most hammer bins are equipped with five or six heavy oak hammers. These hammers are lifted by the cams on the waterwheel shaft. At the bottom of the hammers are blunt metal blades that could pound the rags into whole stuff in about twelve hours.

half stuff
stuff-chest

After the invention of the hollander, this was reduced to six hours of pounding into half stuff, after which the hollander further processed this half stuff into whole stuff. This is done after the half stuff first settles in the stuff-chest and heats up (which fades the cloth).

The number of hammer bins is determined by the power of the waterwheel; with greater power, more hammer bins can be placed. However, the maximum output of the waterwheel depends on the amount of available water.

On average, a Veluwe waterwheel can deliver about 3 hp.

The number of hammer bins is also related to the type of paper to be made; two, three and four-bin mills make packaging paper, five-bin mills make letterpress printing paper and six-bin mills make writing paper.

In the packaging paper mills only, the bottom of the hammer bins and the blades of the hammers may be made of iron. Iron in the water here is less harmful. The hammer bins emit a dull rumbling sound and were in use day and night.

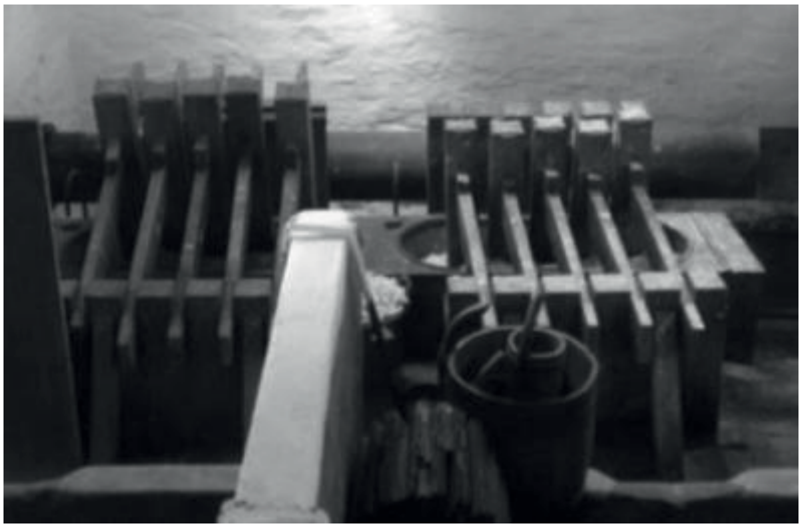

Fig. 16.5.1.2
Hammer bins.

16.5.2 Grinding

refining beater, hollander

Grinding is done in the refining beater or hollander, which was invented in the Zaan region and in 1672 perfected there and made suitable for making white paper. It was a major technical improvement in paper making.

beating engine

In the Veluwe, this is also known as a beating engine.
However, most papermakers in the Veluwe region continued to work primarily with hammer bins. For them, the refining beaters were too costly, as they required a lot more energy that could not always be supplied by the streams.

Fig. 16.5.2.1
The opened refining beater, with the beater roll visible.

bin wheel

The refining beater is driven by two gears accelerated by a large bin wheel that is roughly 70 cm in size. The refining beater, filled with about 2 m^3water, is a heavy wooden bin measuring about 3 x 1.5 m, with rounded inside corners. A central wooden partition about 6 cm thick, the ends of which extend to the beginning of the curve, divides the beater into two parts. In one side is an elevation, the saddle, which contains the grinding plate: a heavy metal threshold whose top has sawtooth-shaped furrows along its full length. Above this grinding plate rotates a 65-70 cm diameter hardwood roller, the grinding roller (beater roll).

saddle, grinding plate
furrows
beater roll

Fig. 16.5.2.2
The closed beater, with the hood with the button catchers in place. In the background is the crane which was used in the past to fill the hollander with stream water. On the right is the stuff-vat.

battens, furrows

Metal battens are inserted into the roller and protrude from it; two furrows per batten are cut into each batten.

beater

The flat part, 8 to 10 mm wide, is the beater. In white-paper mills, the grinding plate and battens were made of yellow copper, but cheaper soft iron was used in grey-paper mills.

corner fillet
inner and outer gap

Behind the grinding plate, the saddle follows the grinding roller (beater roll) to 5 cm below the top edge of the refining beater and then lowers at an angle of about 40°. That last part is the corner fillet. The roller rotates on an iron shaft of about 10 x 10 cm which is bearing-mounted on the inner and outer gap. The papermaker uses this to set the distance between the grinding roller (beater roll) and the grinding plate.

riser
hood

During the grinding process, the grinding roller pulls the material across the grinding plate via the riser, causing it to tear apart. The material then falls down over the corner fillet and floats via the rounded inner sides in the refining beater back to the saddle, and so on. A hood is placed over the roller to prevent splashing.

stuff-vat

When the cloth is completely fibrillated (fiberised), the mass is allowed to drain through a slide in the refining beater into a stuff-vat, a masonry container about 2 x 2 x 2 m in which the stuff is stored until it is needed in the dipping-vat.

scoop, dipping-vat

Using a scoop, it can be scooped from there into the dipping-vat. As more material is scooped into the dipping-vat, heavier (thicker) paper will be able to be formed.

16.5.3 Forming the sheet

dipper, coucher
moulding form, rim, deckle (lid)

Two men work at the dipping-vat: the dipper and the coucher.
Together, they use two moulding forms and one loose oak rim or deckle.
A moulding form consists of a wooden rim with, in between, a number of small narrow

ribs

laths, the ribs over which a very fine grid of thin copper wire is stretched. This produces 'laid' paper. When a sieve of copper mesh is used instead of copper wire, the paper dipped with it is called 'vellum'.

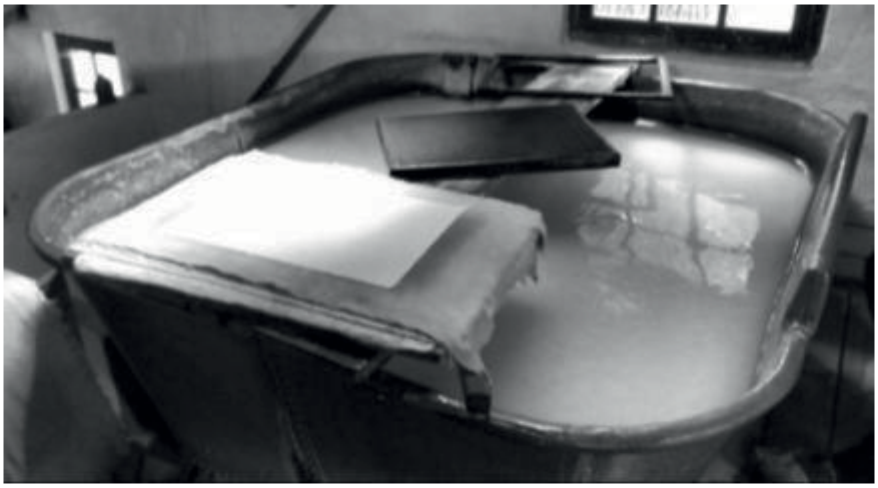

Fig. 16.5.3.1
The dipping-vat with the bridge in the middle on which can be seen from front to back: couch-board with felt and couched paper, the moulding form and deckle.

mark

On the moulding form it is possible to apply a mark by using a thin wire to create a figure or name. This figure, the mark, is woven onto the sieve and provides a watermark in the paper. Many paper mills had their own mark that allowed people to see who made the paper.

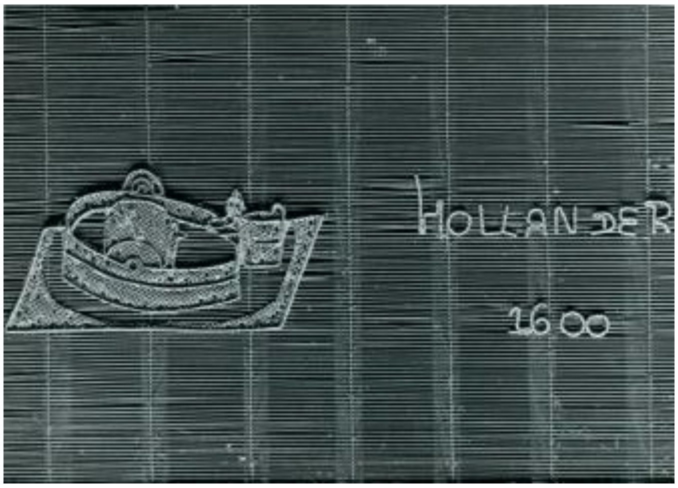

Fig. 16.5.3.2
Example of a laid moulding form with watermark.

(collection of the Netherlands Open Air Museum)

dipper

bridge

The dipper immerses a moulding form with a deckle vertically into the vat, turns it horizontally at the bottom, and thus scoops the stuff. Removing the mould from the water, the dipper, by shaking the moulding form, distributes the fibrous stuff evenly over the entire surface, felting the fibres into a sheet and draining away most of the water. After this, the dipper slides the moulding form over the bridge to the coucher.
He removes the loose deckle and uses the second moulding form to dip the next sheet.
The water and the stuff in the dipping-vat are heated to about 30°C.
The hot water runs through the sieve faster, increasing production.

Fig. 16.5.3.3
The paper dipper of the Netherlands Open Air Museum has just dipped a sheet.
(Photos: © Willie Bosch)

Fig. 16.5.3.4
The dipped sheet is couched. With his left hand, the coucher presses the edge of the moulding form onto the felt and with his right hand pushes the moulding form with the sheet onto the felt. Once the entire sheet is on the felt, the coucher pulls up the moulding form with his right hand, leaving the sheet on the felt. The moulding form makes a tilting movement during couching.

coucher, couch stool
couch-board, felting

The coucher stands next to the couch stool, a platform between the dipping-vat and the wet press. On this couch stool is a couch-board on which the felt is spread.
The coucher turns the moulding form around in a fluid motion onto the felt he has prepared so that the sheet remains on it. The empty moulding form goes back to the dipper and the coucher covers the sheet with a felt.
In rotation, the two moulding forms carry on until a full stack of 125 sheets of paper has been produced each time; this is called a post.

post

The post is covered with a felt, and on top comes another couch-board to transfer pressure from the pressure plate of the press to the entire felt and paper surface.

16.5.4 Paper pressing

wet press

The post of 125 sheets of wet paper and felt, stacked on a couch-board and covered with a second board, is pulled across the couch stool to under the wet press. This consists of a heavy wooden structure and an approximately 10-cm thick spindle that is used to force water out of the post under very high pressure.

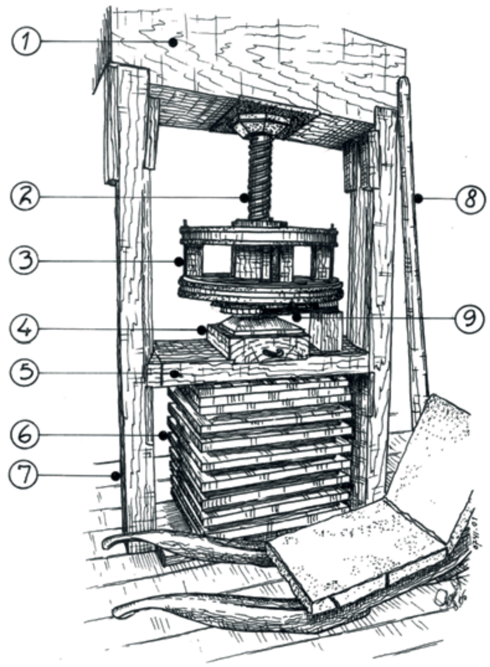

Fig. 16.5.4.1
A wet press:

1. *cross-beam*
2. *spindle or screw*
3. *lantern gear with four supports*
4. *bearing*
5. *pressure plate*
6. *paper to be pressed*
7. *upright*
8. *press pole*
9. *pawl for lantern gear*

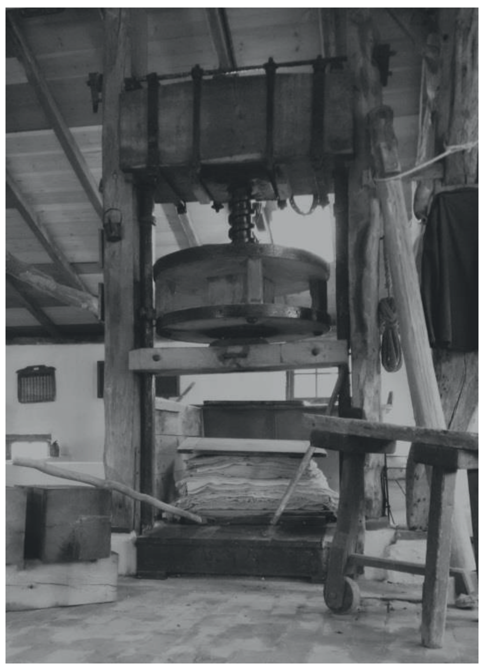

Fig. 16.5.4.2
A wet press.
On the right is the lay stool on which the layman places the pressed paper.

Netherlands Open Air Museum – Arnhem

press pole

Tightening the press is done first by inserting the press pole into the lantern gear and tightening it by hand.

windlass
layman
drying-loft

Next, the windlass rope is tied to the press pole and the windlass then retracts it. After the wet press, the layman separates the sheets of paper and felt and the paper is taken to the drying-loft.

Fig. 16.5.4.3
The press (left) can be tightened; the press pole is in the lantern gear and is connected to the windlass (right) by the rope.
Pulling the spokes of the windlass around tightens the press.

16.6 THE DRYING-LOFT

drying-loft

Paper mills in the Veluwe region are characterised by drying-lofts, visible from the outside by the shutters in the side walls.

husks
treble-lines
hanger

The hanging room is arranged with loose beams, the husks, hanging between the trusses of the room between which the treble-lines of rope are stretched. The paper is hung up by the hanger or loftsman, sheet by sheet over the ropes, to dry.
The side walls have full-length shutters all around. Depending on weather conditions, some of these are opened on the sheltered side. The drying time is at least 24 hours in dry weather.

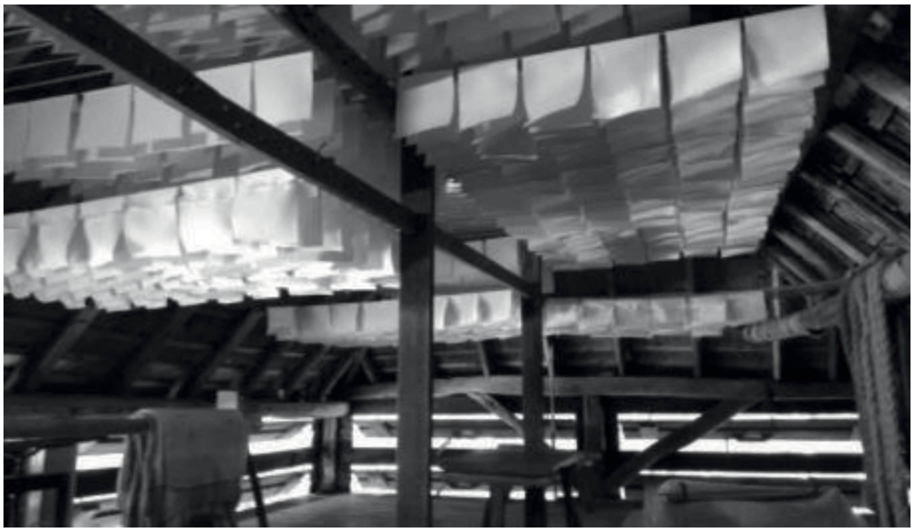

Fig. 16.6.1
Sheets of paper hang on the drying lines in the drying-loft to dry.

flat press

The tension that gets into the paper when dipping causes it to warp during drying. Also, the paper is still very rough. To make it flat, the paper is pressed in the flat press. The flat press works in the same way as the wet press. After being turned once, a second round of pressing follows after which the paper is removed from the press.

screening

Before the paper goes into the flat press, the sheets are screened to check for dirt, holes, folds and tears.

sizing kettle

White paper must become capable of being written on. To achieve this, the paper was sized in the sizing kettle with a hot mixture of water, animal glue and alum.
After this sizing phase, the paper goes back to the drying-loft and is pressed once more.

folio
book
ream

On the packaging table, the paper is counted sheet by sheet and checked for quality. Then the sheets might be folded in half (folio) or left unfolded; 24 sheets joined together made a book. Twenty books packed together make up one ream (480 sheets). The top book is called 'retree'; in it are sheets with spots or folds. The bottom book is called 'seconds'; this includes sheets with a tear or where a corner was missing. The remaining 18 books are in sound condition. This was a regular practice, as many sheets became damaged or soiled during the process.

ream wrapper

The ream is packaged in a ream wrapper on which was printed an image indicating what type of paper it contained and the name of the manufacturer. This was someone who sold raw materials and bought them back after one or more processes had been performed on them, in this case by the paper mill.

Fig. 16.6.2
Image with the name of the manufacturer and the quality of the paper.

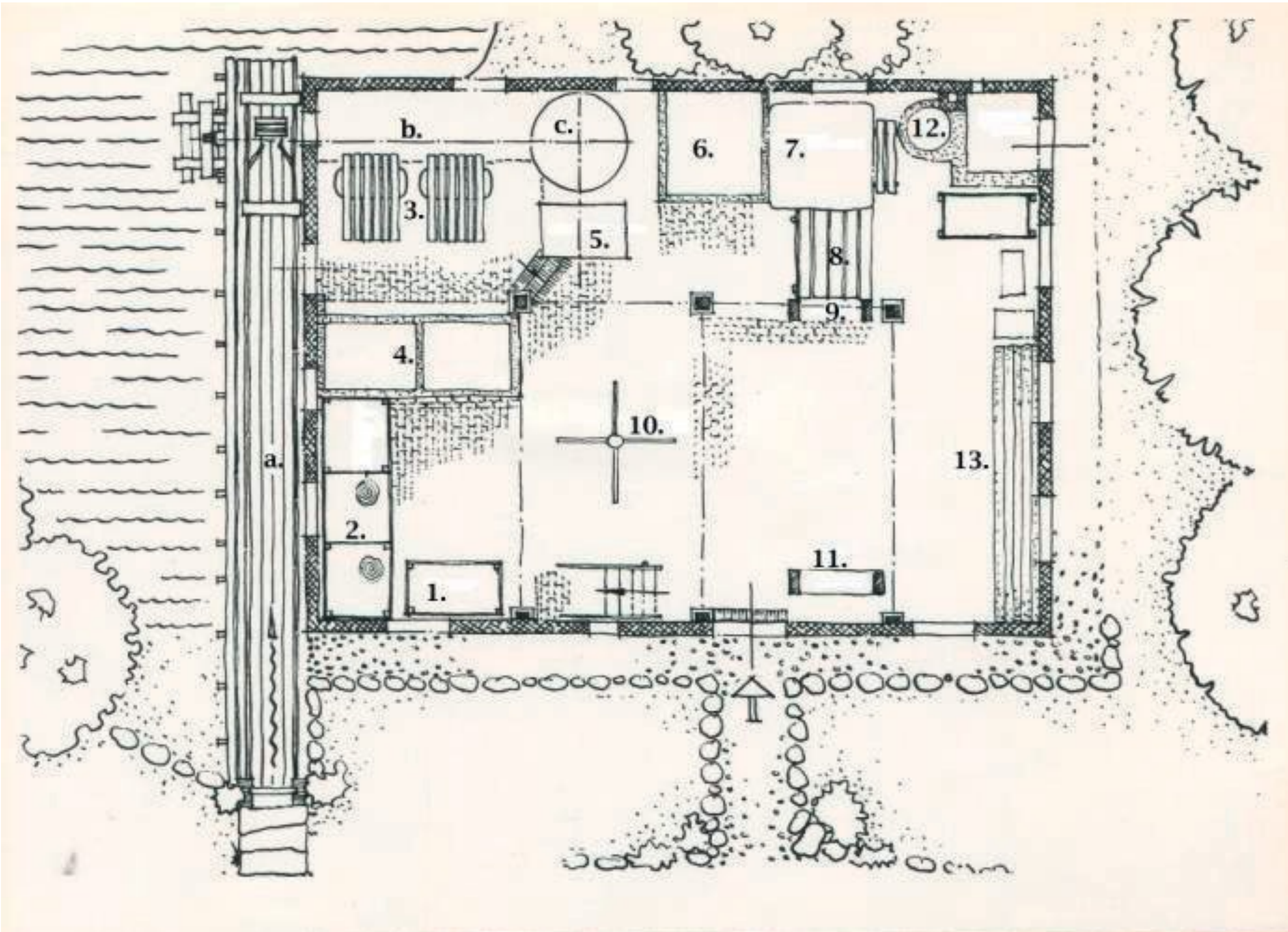

Fig. 16.6.3
Map of the Veluwe paper mill:

1. *sieve*
2. *rag bins with chopping blocks*
3. *hammer bins*
4. *stuff-chests*
5. *hollander / refining beater*
6. *stuff-vat,*
7. *dipping-vat,*
8. *couch stool,*
9. *wet press*
10. *windlass*
11. *dry press*
12. *sizing kettle*
13. *packaging table*

a. trough or flume
b. waterwheel shaft with the overshot wheel under the trough to the left
c. cam wheels for the

16.7 PAPER MILLS 1850 - 1900

The above description relates to paper mills in the Veluwe region as they operated between roughly 1590 and 1850. Some mills went on to be modernised after this — while still retaining water power — although steam as an auxiliary power source also came into play, or rather steam as the main power source and water as an auxiliary power source.
The Middle Mill near the Veluwe town of Loenen is located a few hundred metres upstream from where the Rear Mill (now in the Netherlands Open Air Museum) stood. Due to a fire in the second half of the 19th century, more modern means were also used in its reconstruction there.
Meanwhile, around 1875, wood began to be used on a large scale as a raw material for paper production, and mills are not well suited to processing the wood for this purpose. A few paper mills were subsequently converted into laundries but most were converted into factories. What remains is the stream because clean water is still needed!

Fig. 16.7.1
The Middle Mill in Loenen

The trough or flume with pull.

drum, edge-mill
edge runner stones
long-wire paper machine

To process the rags into fibre, in the more modern mills they are first boiled in a drum to soften them and then they go under the edge-mill.
The softened rags are rolled into fibres under the edge runner stones of the edge-mill. The fibres go into the refining beater or hollander, after first sifting out any remaining knots and coarse pieces in a knot drum. The rags are made into whole stuff as they come out of the refining beater. This whole stuff enters the paper machine via a chain-pump, a kind of conveyor belt of straining cloth (made of copper mesh), where the whole stuff (pulp) flows out over the long wire and the water drains out.

Fig. 16.7.2
Drum.

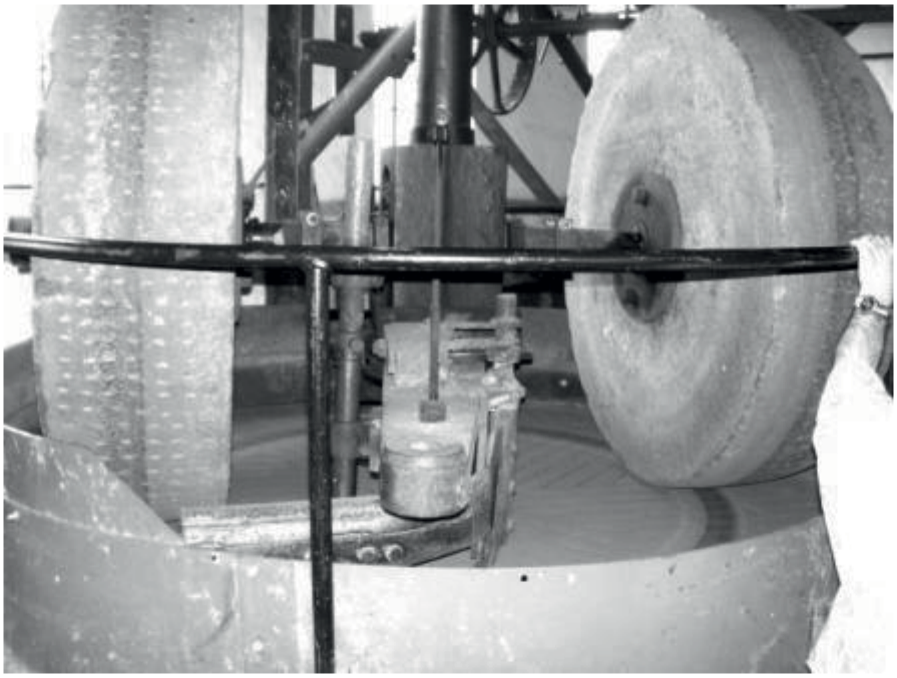

Fig. 16.7.3
Edge-mill.

pulp

Once the water is drained, the pulp slides through to a felt roller. This roller ensures that the pulp comes onto a layer of felt. The thickness of the paper can be controlled by adjusting a slide that allows portions of pulp to pass through. By means of two rollers with a space, levers operate a knife that cuts the partially dried paper to size.
The paper can then be dried in a drying machine.

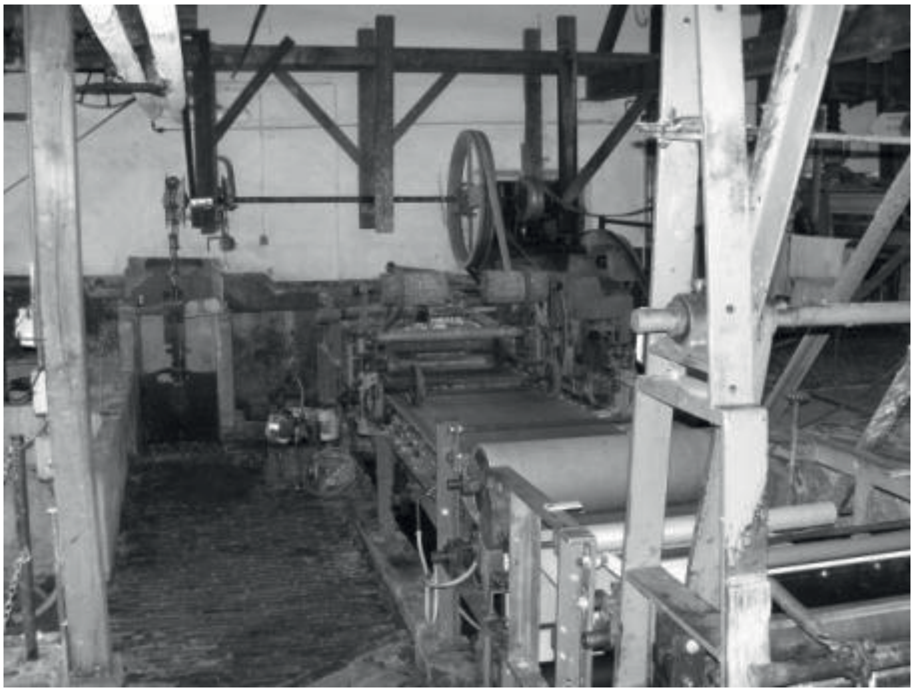

Fig. 16.7.4
Paper machine.

Paper is being manufactured again in both of the Veluwe paper mills.
At the Netherlands Open Air Museum since 1933 when, through the efforts of the Dutch Association of Paper Manufacturers, the Rear Mill of Loenen was built and completed there in order to keep the craft of paper-making alive. Here mainly the coarse white (printing) paper is made from pulp sheets sourced from the mill's former neighbour, the Middle Mill. These pulp sheets consist of cotton fibres with wood cellulose. Rags are no longer used for this purpose because all too often they are made from artificial fibers or synthetic and contain plastic (polyester).

That recovery also applies to the Middle Mill, which, following a period of decline, resumed paper-making in 1991, mostly using the paper machine but also made by hand. The raw materials used here are linen, hemp, cotton (including jeans fabric), which are also supplemented with wood cellulose if necessary. Also, dried faecal matter from elephants (which eat only plants), for example, can be used.
Besides ordinary paper, watercolour and etching paper for artists is also manufactured as well as the fibrous paper used for restoring the paper of old books, etchings, drawings and archives.

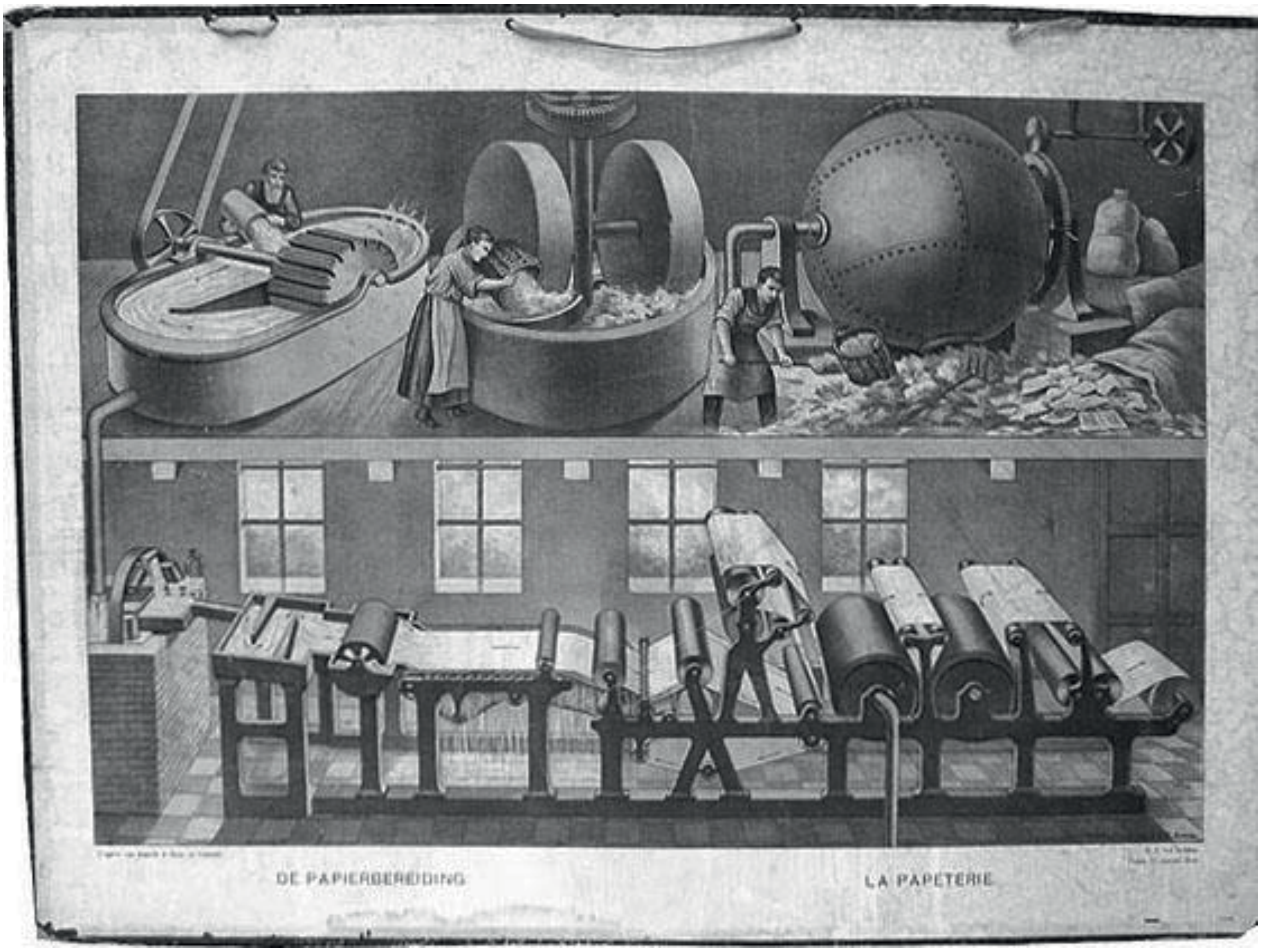

Fig. 16.7.5
An old educational poster about paper-making.
The processing is shown on the top from right to left and then to the bottom: at the top right is a cooking drum, next to it an edge-mill and the refining beater after which the pulp or whole stuff exits below at a long-wire paper machine.

Chapter 17 The windmill and the horse mill

Contents Page

NOTES

17.1 INTRODUCTION

Those who are not so closely involved with mills often have the idea that all mills are the same. But nothing could be further from the truth. Experts even say that no two mills are alike! Sometimes the differences are easily observable even by non-experts but often you really have to be an expert and pay attention to details to identify the differences.

Mills have many uses and take on many forms in the Netherlands. Various classifications can be made, for example, by the source from which they obtain their energy, by design, location, function, etc.

energy source

A first, easily distinguishable classification arises if we pay attention to the energy source. If a mill is driven by flowing water with the help of a waterwheel, then we speak of watermills (water-driven mills).

watermill

Those are what most of this teaching material is about.

windmill

If the mill is driven by the wind with the help of a sail cross, we speak of windmills (wind-driven mills).

horse mill

A third group are mills powered by muscle. These include handmills or animal-driven mills such as the horse mill. These used to be common but now there are only a few still remaining.

polder mill

Incidentally, the term 'watermill' can cause confusion. This is because besides the 'real' water mills in the regions of Overijssel, Gelderland, North Brabant and Limburg, what is referred to elsewhere in the Netherlands as watermills are usually 'polder mills' (water pumping mills).

sail cross
sail stock, sail frame
wind-board
end

As their name implies, windmills obtain their energy from the wind. The mill is equipped with a sail cross for this purpose. The assembly consists of two heavy wooden or metal beams, the sail stocks, to which the sail or lattice frame and wind-boards are attached. Together, these parts form the four sails as they are popularly known. In professional parlance, they are referred to as four ends of the sail cross. The sail frame can be further fitted with canvas sails to increase wind capture. Metal stocks are usually welded, but riveted stocks are also still seen. They are fixed in the end of a large wooden or cast iron shaft, mounted in the cap of the mill. The machinery is driven via a wheel that is also mounted on this shaft.

The craft of milling was listed for the Netherlands as an intangible cultural heritage by UNESCO in 2018. That creates obligations!
This chapter is included to provide water millers with some insight into the world of windmills as well. For the same reason, the teaching materials for windmillers includes a chapter on watermills.

In the current examination format, watermiller exam candidates are not asked questions about windmills. Thus, this chapter is primarily informative. Those who would like to learn more about windmills after reading this brief chapter can find all the course material on the Guild of Millers website (www.gildevanmolenaars.nl)
Guild members can log into this and access the Handbook Wind Millers.

17.2 BASIC FORM

No country has as many different types of mills as the Netherlands. The mills can be described as functional in all respects. Nothing about them is superfluous apart from sparse embellishments.
We can divide these mills into groups in several ways.
In the classification below, we start with the basic form of the structure and the model. We then arrive at the following classification.
The images are accompanied by the most common functions of the type of mill in parentheses. Incidentally, these have changed quite a bit over the years.

17.2.1 Square mills

body, buck

A characteristic feature of these mills is that the body or buck has a square or rectangular cross-section. We call these square mills, but they are actually 'rectangular' (four-sided) mills, because the cross sections are usually rectangular.
In this group we include:
- post mills
- wip or hollow post mills
- spider or farm drainage mills
- paltrok mills
- meadow-mills

Fig. 17.2.1.1
Post mill
(grain mill).

Fig. 17.2.1.2
Wip or hollow post mill
(polder mill, some as grain mills).

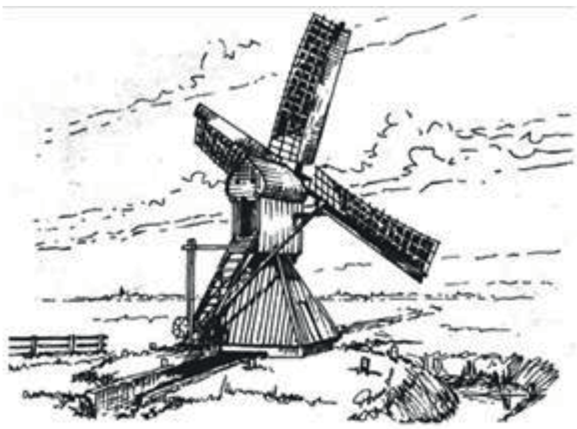

Fig. 17.2.1.3
Spider or farm drainage mill
(polder mill, mainly in Friesland).

Fig. 17.2.1.4
Meadow-mill
(polder mill).

Fig. 17.2.1.5
Paltrok mill
(wood sawmill).

17.2.2 Octagonal mills

winding
outside winder, inside winder

This type of mill has an eight-sided body, usually made of wood. The cap revolves; it is rotatable ('wind-able'). The winding of the cap can be done from the mill yard or stage/gallery (outside winder) or from inside the cap (inside winder). These mills are called Cap Winders.

Fig. 17.2.2.1 *Outside winder* *(especially polder and grain mills).*	*Fig. 17.2.2.2 (bottom)* *Small smock mill* *(polder mill, Friesland).*	*Fig. 17.2.2.3* *Inside winder* *(polder or drainage mill).*

17.2.3 Hexagonal mills

In addition to the common eight-sided mills, there are also eight six-sided mills in the Netherlands.

'De Schoolmeester' (The Schoolmaster) paper mill in Westzaan and 'Het Jonge Schaap' (The Young Sheep) sawmill in Zaandam are well-known examples. The rest of the six hexagonal mills are grain mills.

Fig. 17.2.3.1
Hexagonal mill
(usually grain mills).

17.2.4 Polygonal mills

In the Netherlands there are also 2 twelve-sided stone polder mills, namely the 'Lijkermolen' (Corpse Mill) No. 1 and No. 2 in Rijpwetering (South Holland) and a sixteen-sided wooden grain mill, 'De Hoop' (The Hope) in Horn (Limburg).

17.2.5 Round mills

tower mill

Round mills have a brickwork body. In the oldest versions, the tower mills, the body is cylindrical.

Fig. 17.2.5.1
Tower mill
(grain mill).

There are still five of these tower mills preserved in the Netherlands. All of them are grain mills. All other round stone mills have a conical body shape.

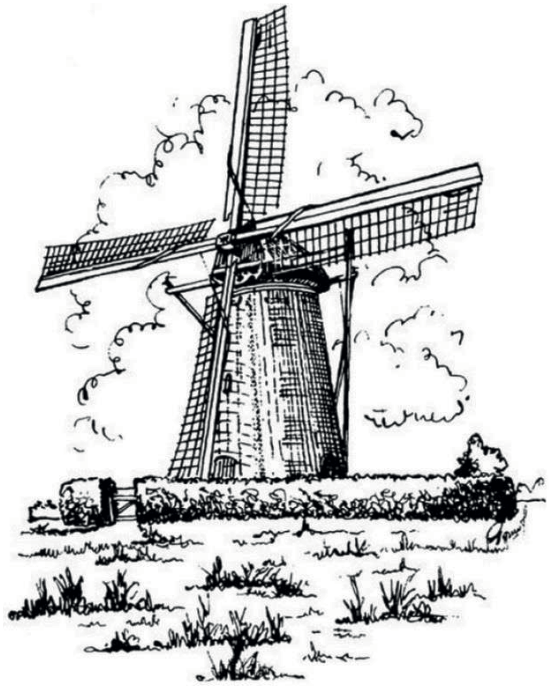

Fig. 17.2.5.2
Round stone mill
(especially polder and grain mills).

17.2.6 Other types of windmills

tjasker

A special type of windmill is the tjasker. This is a small polder mill designed to drain a small plot of land. They are found in the regions of Friesland and Kop van Overijssel.

post tjasker, trestle tjasker

There are two versions: the post tjasker and the trestle tjasker.

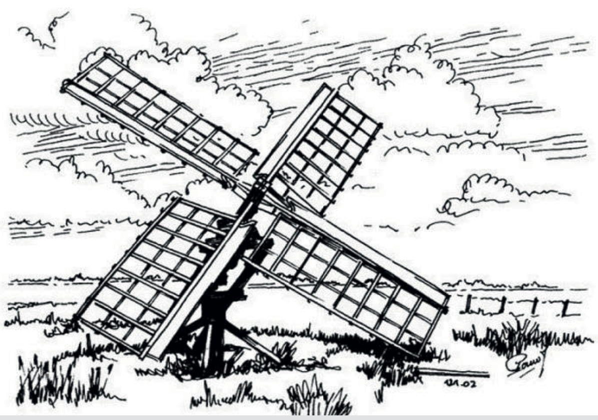

Fig. 17.2.6.1
Post tjasker
(polder mill).

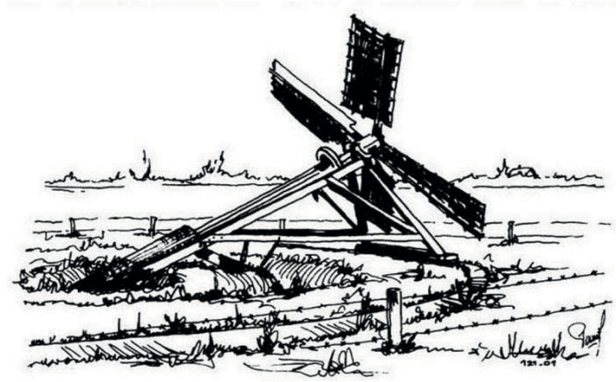

Fig. 17.2.6.2
Trestle tjasker
(polder mill).

17.3 DESIGN AND PLACEMENT

Mills can be classified by placement and design.

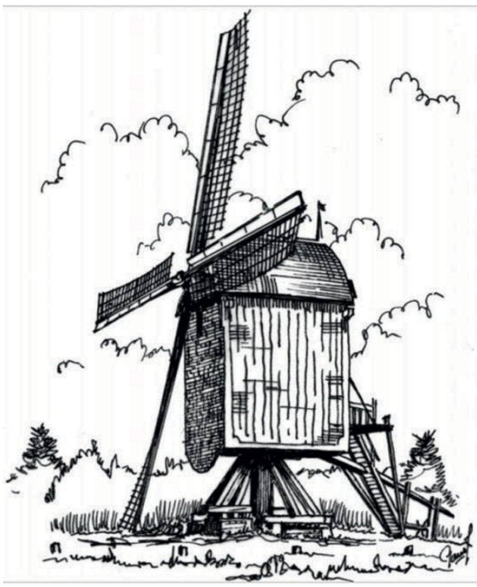

Fig. 17.3.1
Ground-sail mill.

This type of mill needs an open environment for wind capture.

Fig. 17.3.2
Mill on a mound or mound mill.

A mound provides more wind capture and extra storage space.

Fig. 17.3.3
Stage mill or gallery mill.

For adequate wind capture in built-up environments.

Fig. 17.3.4
Stage mill on a barn.

These always involve industrial mills.

17.4 WINDING SYSTEM

winding

Yet another classification is one which looks at the way in which the sails can be turned to the wind, the so-called winding.

17.4.1 Place of operation

outside winder

inside winder

- Outside the mill: the structure to capture wind for the mill is located outside the mill. This type of mill is therefore called an outside winder.
- Inside the mill: the structure for winding the mill is located in the mill cap. This is then referred to as an inside winder. Some tower mills and many polder mills in North Holland are inside winders.

17.4.2 The pivot point: Where does the mill turn when winding?

cap winder

ground winder

body

buck

collar winder

Mills with only the cap turning when they are winded are called cap winders. Paltrok mills stand on a masonry pier and a low rink wall and rotate in their entirety: these are called ground winders.
There are also mills in which the lower tower or base is fixed and the body or buck rotates when winding. These can be referred to as middle winders but that term is seldom used. They are also called collar winders.

17.4.3 Implementation of the winding gear

17.4.3.a Collar winding gear

collar cap gear

lower collar, upper collar

In collar winding gear, two surfaces formed by heavy beams slide over each other. Mills with a collar winding gear can be classified into two groups.
The first group is equipped with one collar. This includes post mills and meadow-mills. The paltrok mill can also be counted among them, in a certain sense. The second group of collar winders is formed by the wip mills. These mills have two collars, a lower collar and an upper collar.

17.4.3.b Friction winding gear

winding floor, curb ring,
carters (bearing blocks)
dead curb with cap sliding on shears
carters winding gear

curb ring

This type of winding gear is encountered on cap winders. The underside of the cap slides over a curb track or curb ring, which may or may not be fitted with carters.
There are two versions using a dead curb including: the cap sliding on sheers and the other using winding gear with carters. In the former type, the cap lies with the cap sheer and the support for the cap directly on a wooden ring, the curb ring.
In the case of the winding gear with carters, the cap winds over winding carters placed radially in the curb track. These carters serve as sliding plates or bearing blocks.

17.4.3.c Live curb

curb
winding rollers

shot curb (curb with English rollers)

This type of winding gear is found at many mills, both at cap winders and at paltrok mills. In the case of the paltrok mills, this is combined with a collar.
Between the curb track and the bottom of the cap, the cap circle, is a large number of wooden or iron winding rollers contained in roller cages.
There is also a distinction to be made in the type of rollers; there may be ordinary live curb or the so-called shot curb (using English rollers).

17.5 SAIL CROSS

sail cross

The sail cross is that part of the windmill that catches the wind and converts it into a rotational movement. Thus, the windmill's sail cross has the same function as the waterwheel has in watermills.

sail cross, cross, sail stocks
poll end (canister), sail clamps
stock wedges
point irons

The sail cross, or cross for short, consists of two sail stocks crossed through the poll end or canister. They are anchored with sail clamps. Further, the sail stocks are fastened in the poll end with poll wedges.
Finally, the poll wedges are secured with point irons.

When the first windmills were created, sail crosses were made entirely of wood. It was not until the second half of the 19th century that wooden sail stocks began to be gradually replaced by metal sail stocks. These were originally riveted; today they are welded.

ends
lattice frame (sail bars)
mill sails, wind-boards
storm board

Each stock has two ends. Into these ends are inserted the sail bars. Mill sails can be laid on the sail bars or lattice frame. The sail bars protrude slightly at the front and the wind-boards are attached to them.
The lowest wind-board (storm board) can be easily removed.

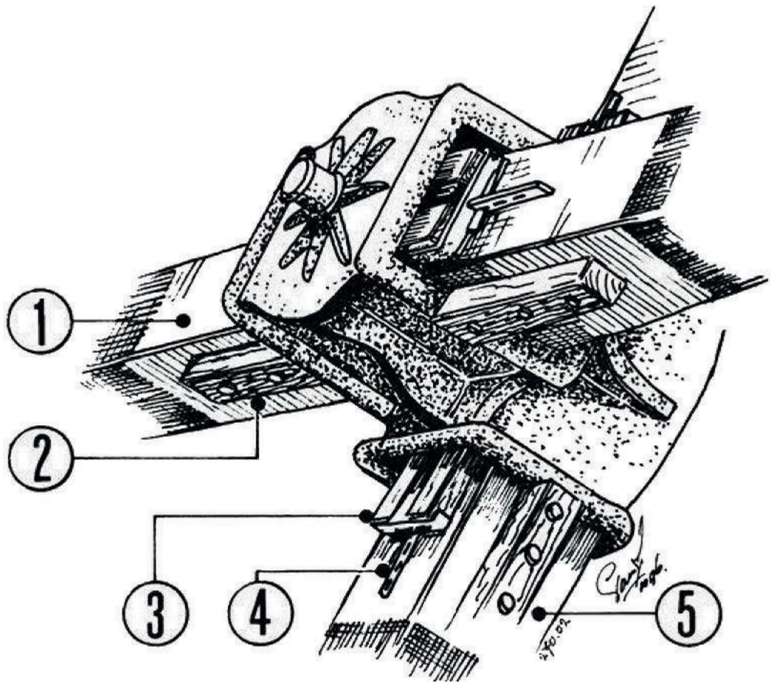

Fig. 17.5
Fixing the sail stocks in the poll end or canister:

1. *outer stock*
2. *sail clamp*
3. *poll wedge*
4. *point iron*
5. *inside stock*

Common sail system

The above description of the sail crosses concerns the common sail system. (single-sided) However, there are other versions as well.
The main objective is to increase the efficiency of the sail cross or to increase the ease of operation for the miller.
A number of images of various (improved) sail systems in use follows.

17.5.1 common sail system

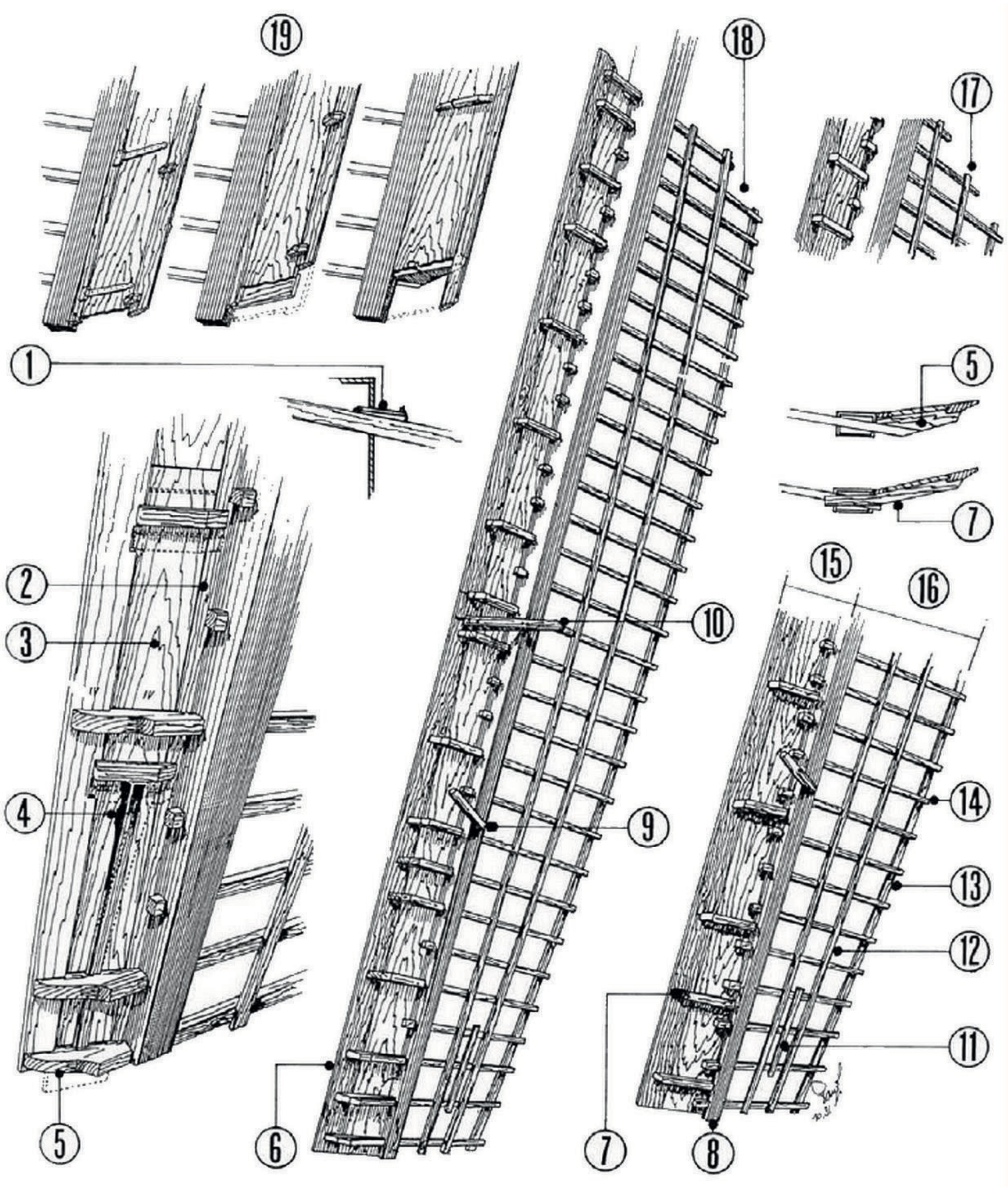

Fig. 17.5.1
Common sail system:

1. *sail bar wedge*
2. *board jambliner (narrow bar against the stock),*
3. *storm board,*
4. *catch spring,*
5. *triangular wind board bracket*
6. *leading hemlath*
7. *wind board bracket*
8. *sail stock*
9. *short sail cleat*
10. *long sail cleat*
11. *small sail cleat (for sail rope)*
12. *middle hemlath,*
13. *outside hemlath,*
14. *sail bar,*
15. *leading edge (board side)*
16. *trailing edge (sail frame side)*
17. *double stepped heel,*
18. *single stepped heel,*
19. *various wind-board latches*

17.5.2 Self-reefing

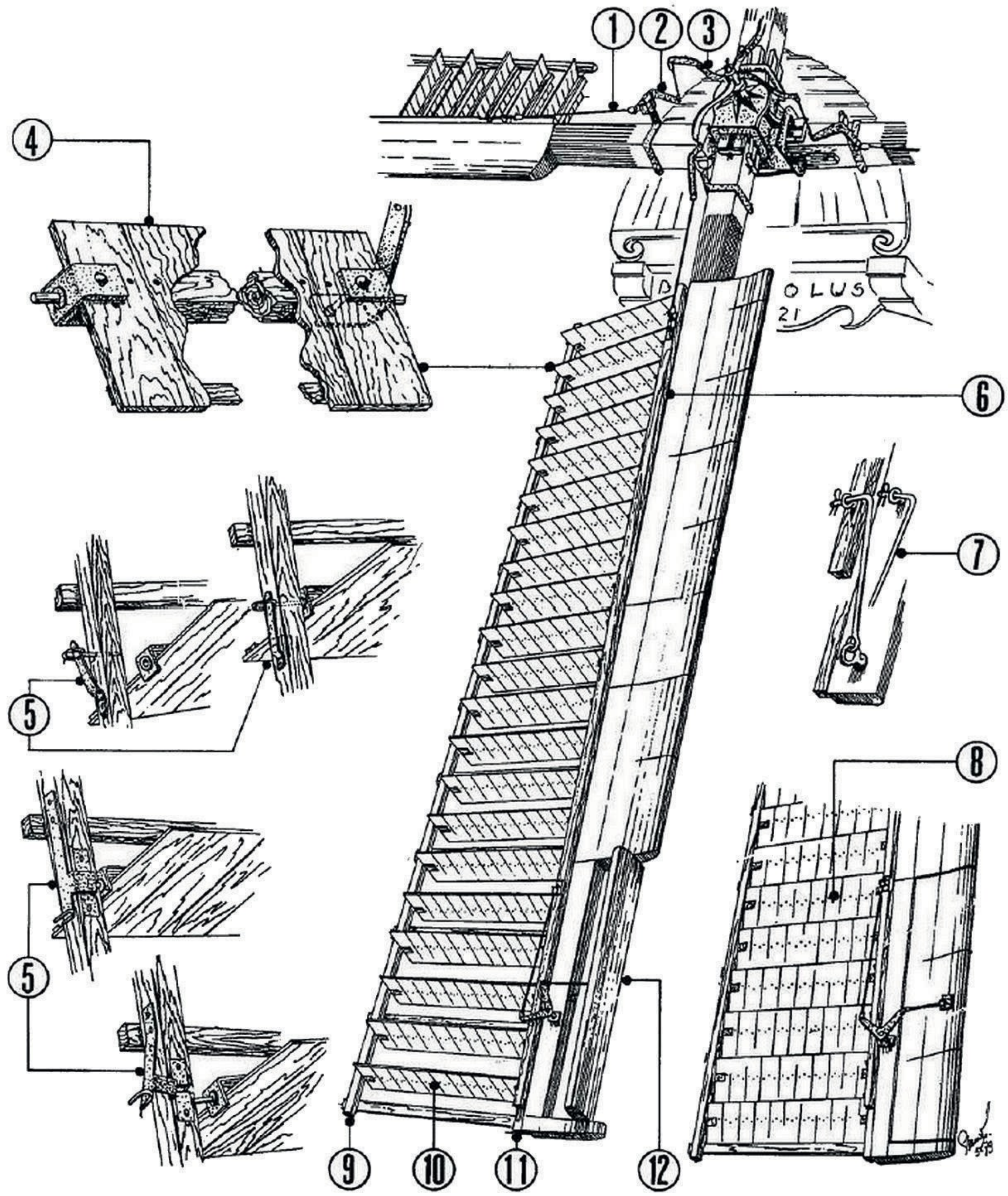

Fig. 17.5.2
Self-reefing:

1. *fork iron*
2. *elbow iron or triangle iron*
3. *spider*
4. *shutter*
5. *various latches*
6. *shutter bar or working uplong*
7. *latch hook to protect against slamming shut*
8. *closed shutter*
9. *outer uplong*
10. *opened shutter*
11. *inner uplong*
12. *air brake*

17.5.3 Dekker sail system

streamlined body

In this system, the wind-boards on the front of the sail stock are replaced by a streamlined body that wraps entirely around the stock and part of the sail frame. When the sail cross starts to move, this streamlined profile provides additional torque. This aerodynamic shape also reduces the air resistance of the sail stock.
The sail frame and sails are narrower than in the common sail system.

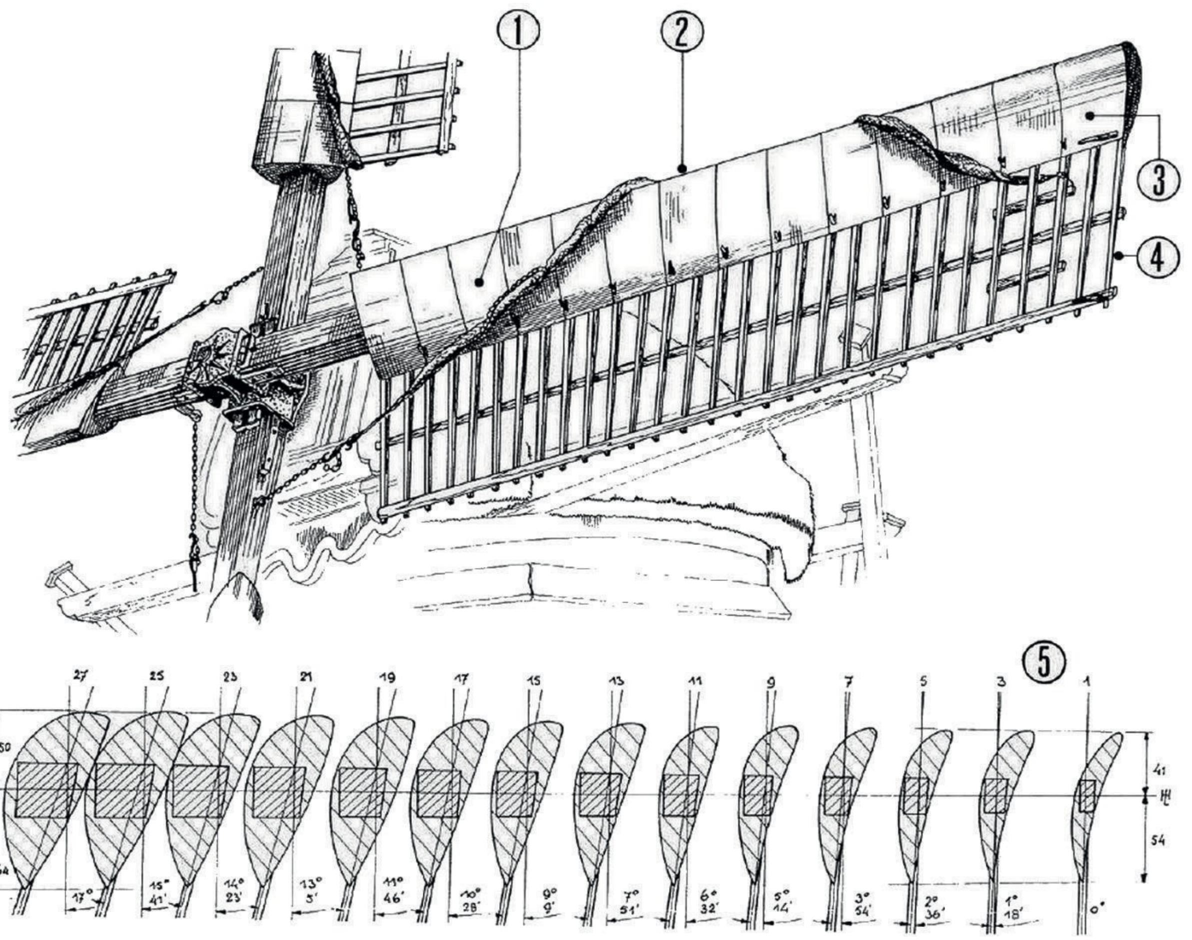

Fig. 17.5.3
Dekker sail system:

1. *convex profile section*
2. *streamlined profile*
3. *concave profile section*
4. *sail frame with two hemlath slats*
5. *the various profiles*

17.5.4 The Van Bussel streamlined leading edge

streamlined leading edge

Millwright Van Bussel replaced the wind-boards on the front of the stock with a streamlined leading edge. This provides more torque than a wind-board.

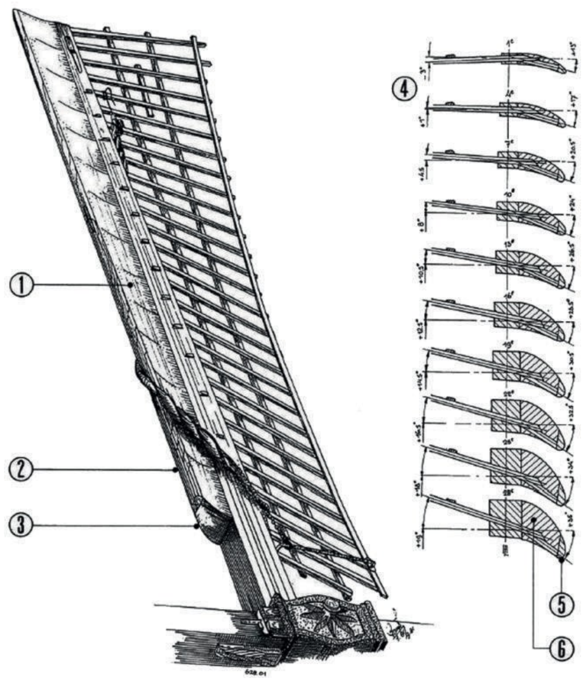

Fig. 17.5.4
Van Bussel streamlined leading edge:

1. *concave front*
2. *leading edge*
3. *convex back*
4. *various profiles*
5. *blunt front*
6. *profile*

17.5.5 Jib sails

An engineer named Fauël replaced the wind-boards with a curved shutter which has a gap between the shutter and the stock. The shutter works just like the jib on a sailing ship.

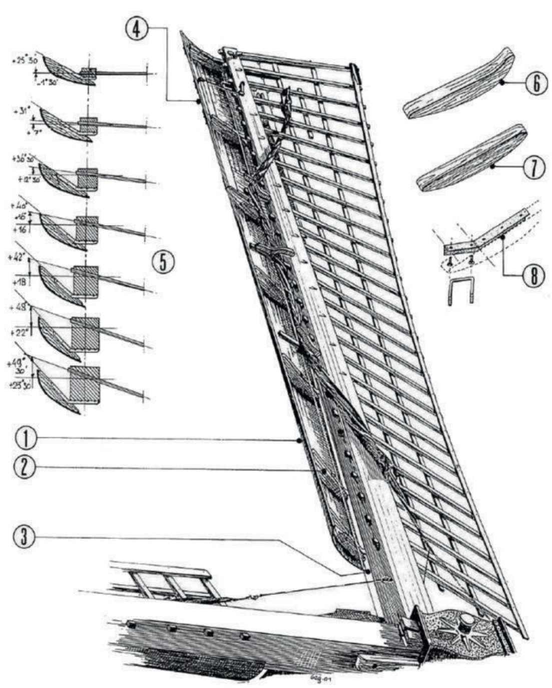

Fig. 17.5.5
Jib sails:

1. *jib*
2. *shank*
3. *air gap*
4. *air brake*
5. *various shank positions*
6. *shank with double-jet profile*
7. *shank with single-jet profile*
8. *jib support*

17.5.6 Bilau sail system

An iron streamlined plate is attached to the front of the stock, and an adjustable flap is attached to the back. This is still to be found at two mills.

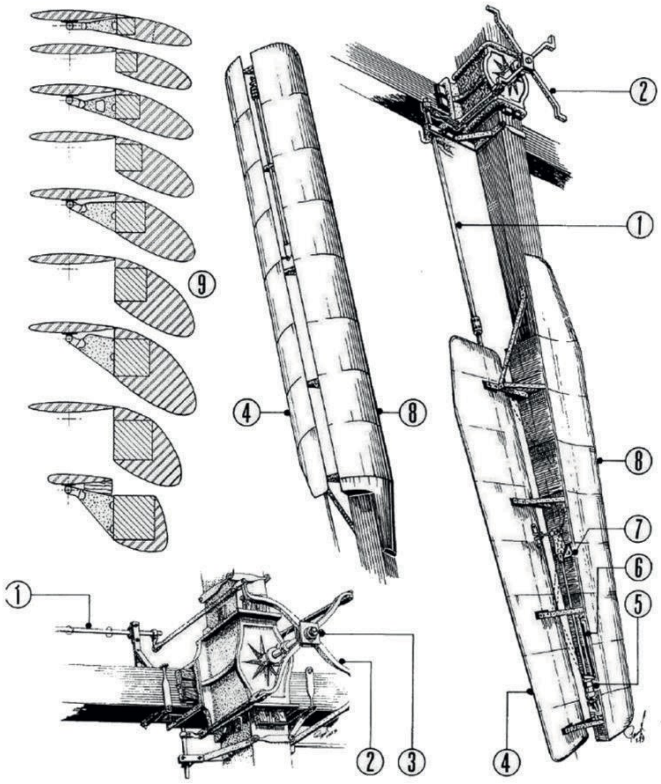

Fig. 17.5.6
Bilau sail system

1. *flap shaft*
2. *spider*
3. *striking rod*
4. *flap*
5. *regulator weights*
6. *regulator spring*
7. *triangle or tumbler*
8. *streamlined leading edge*
9. *various profiles*

17.5.7 Van Riet sail system

flap

A millwright named Van Riet replaced the sail frame and sail with a flap that rotated around a flap shaft parallel to the stock. He replaced the wind-boards with a streamlined plate. Three mills in the Netherlands are still equipped with this sail system.

17.5.8 Ten Have sail system

Another millwright, named Ten Have, also replaced the sail frame and sail with a large, slightly concave flap which consists of four sections attached to a flap shaft parallel to the stock. The flap lies in a framework of hemlath slats. The Ten Have sail system is almost always fitted in combination with a Van Bussel streamlined leading edge. This system has been widely used on grain mills in the eastern part of the Netherlands.

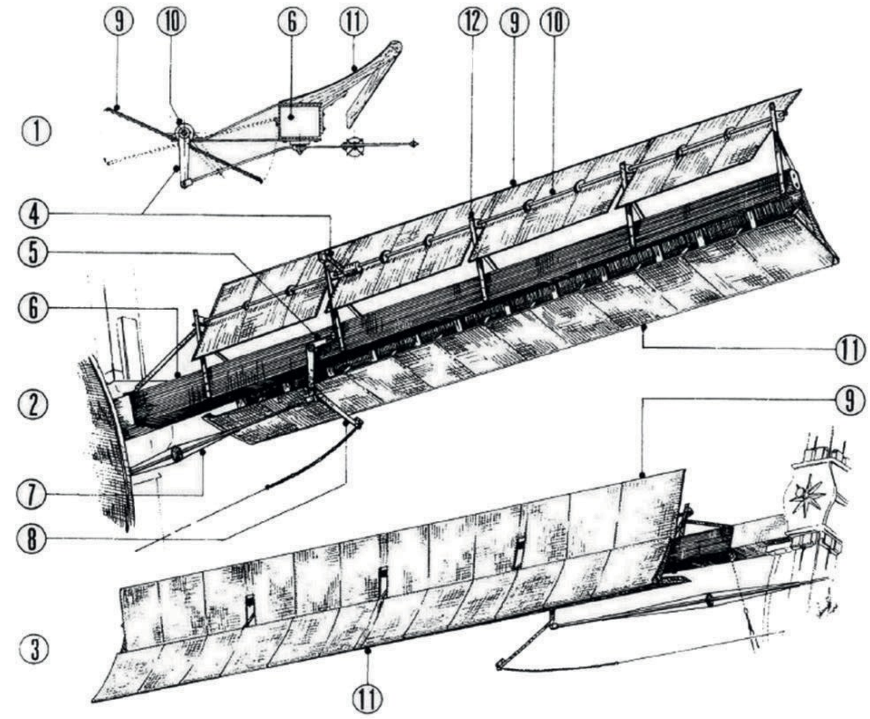

Fig. 17.5.7
Van Riet sail system:

1. *cross section*
2. *sail with open flap*
3. *sail with closed flap*
4. *Flap control lever*
5. *elbow lever or elbow iron*
6. *inside stock*
7. *striking rod*
8. *arm for regulator spring*
9. *flap*
10. *flap shaft*
11. *streamlined leading edge*
12. *flap bearing support*

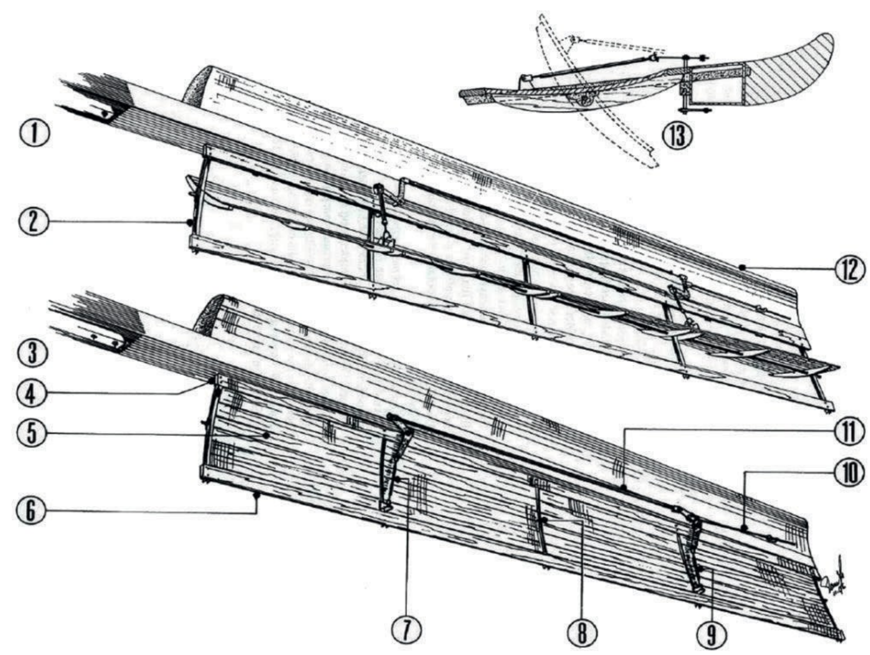

Fig. 17.5.8
Ten Have sail system:

1. *sail with open flap*
2. *flap bearing support*
3. *sail with closed flap*
4. *leading hemlath*
5. *closed flap*
6. *outside hemlath*
7. *inner flap rod with elbow lever*
8. *separation between flap parts*
9. *outer flap rod with elbow lever*
10. *locking bar*
11. *flap coupling rod*
12. *Van Bussel streamlined leading edge*
13. *cross section*

17.5.9 Air brake or control flaps

braking

Sail improvements led to mills being able to mill with less wind. Soon, however, it became clear that streamlined sails were more difficult to brake (immobilise) in strong winds, if at all.

air brakes, control flaps

This problem was solved by applying air brakes or control flaps (adjustment boards).
The opening and closing of the flaps can be done manually (via an air brake) but also automatically through centrifugal force on a weight and a counteracting spring (a control flap).
In manual operation, the upper shaft is perforated to run a striking rod through it.
Perforated shafts are also found on mills with several types of improved sails systems.

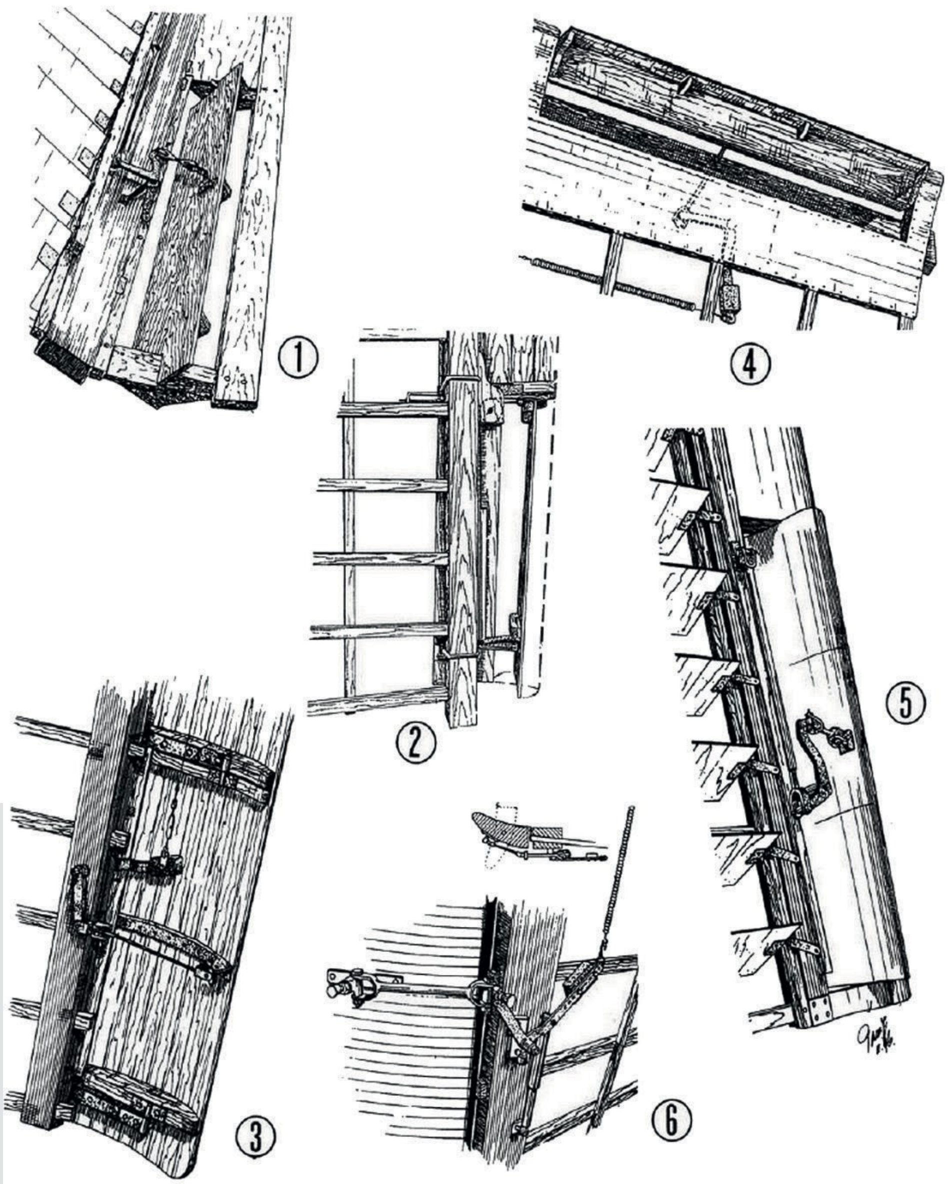

Fig. 17.5.9
Air brake and control flaps

1. *wooden air brake in common sail wind-board*
2. *air brake in a jib sail of a spider/drainage mill*
3. *control flap in a jib sail*
4. *control flap in a Dekker sail*
5. *air brake in Van Bussel leading edge and self-reefing*
6. *control flap mechanism with hydraulic damper*

17.6 FUNCTION

In addition to all the aforementioned classifications of mills, we can also distinguish mills by function: what was/is the mill used for?

17.6.a Polder mills

A large number of mills in the Netherlands are or were in use as polder mills. These were used to drain the polders (areas of low-lying land being reclaimed from the sea or other bodies of water) so that people could live there and also use the land for livestock breeding and arable farming. The extracted water was drained through a basin.
In addition, large numbers of mills were used to pump the water out of large lakes or peat ponds. Such as was done for the reclaimed lands in North Holland.
The types of mills used for polder drainage include wip mills, round stone mills, octagonal (both inside and outside winders), spider or farm drainage mills, tjaskers and meadow-mills. The mill mechanism is a scoop wheel or an Archimedean screw, sometimes a pump.
A special type of polder mill is the basin mill, which lifts the water from a lower basin into a higher one. Example: The polder mills at Kinderdijk are, with a few exceptions, ground-sail mills.

17.6.b. Grain mills and hulling mills

Mills for milling grain form a second large group. Almost every village used to have a grain mill to provide flour for the population. Common types of grain mills are octagonal and round stone mills. All surviving post mills are also grain mills. In addition, a few wip mills used as grain mills still exist.
Grain mills located in built-up areas are often constructed as stage mills or mound mills.
Many grain mills were equipped with hulling stones in addition to the millstones, with the former being used to hull barley into pearl barley.

17.6.c. Industrial mills

Work done today using internal combustion or electric motors was often done in the past using mills. There were thousands of industrial mills in the Netherlands. Most of them have since disappeared.
Consider, for example, the making of gunpowder (gunpowder mill), the felting of wool into cloth (fulling mill), the grinding of oak bark for the tanneries (bark mill or tanning mill) or the grinding of chalk for the paint industry (chalk mill).
Fortunately, a good number of industrial mills have survived. They are still kept in operation by expert and enthusiastic volunteers, and the traditional knowledge is passed on to future generations.
Here is a list of several types of remaining industrial mills: sawmills, oil mills, hulling mills, malt grist mills, snuff and spice mills, mustard mills, a paper mill, a dye-stuff mill and a hemp stamper.

Industrial mills are often recognizable by the large barns on which they are built.

17.7 HORSE MILL

horse mill

In the strict sense, a horse mill is a mill driven by a horse. But they also include mills driven by other animals.
The horse mill has its origins in hand-driven mills or rubbing stones where production is obviously very limited. As early as Graeco-Roman times, people were looking for better methods and milling tools powered in other ways. Wonderful examples of these kinds of primitive tools can be found in the museums of Pompeii (Italy) and Niedermendig (Germany), for example.

tongue or pole, single tree

cog wheel

A horse mill is usually a small mill but some are quite large. Inside the mill is a heavy vertical shaft to which is attached a tongue (pole) with a single tree (swingle-tree, whiffle-tree) at the end. One or two horses can be hitched to this. This shaft has a large cog wheel, a kind of spur wheel. The various machines are driven via this wheel.

Fig. 17.7.1
The horse-oil mill at Zieuwent (now the Netherlands Open Air Museum)

Collection of the Netherlands Open Air Museum

Horse mills can have various functions. They can be oil mills, groat mills, grain mills, churn mills, threshing mills and also rope mills. Some are still preserved in the Netherlands including at the Netherlands Open Air Museum in Arnhem, in Lievelde and in Zeddam.
In oil mills, the tongue sometimes directly drives the edge runner stones and the cog wheel ('stone wheel') drives the camshaft and oil seed heater.

17.7.1 Groat mill

A formerly common horse mill was the groat mill. But watermills were also used as groat mills. In particular, the constant speed of these mills was important for the production process and made them more suitable for this purpose than windmills.

In the groat mill, buckwheat seed was processed into groats or buckwheat flour. In the 18thand 19thcenturies, before the arrival of the potato, groats or buckwheat flour was an important and cheap staple food, especially for the less affluent part of the population. People made groats porridge or pancakes from it.

The production process went as follows:
After harvesting and threshing, the buckwheat was first sieved and cleaned.
kiln Then it was dried and heated in the kiln for a few hours. A kiln is a masonry container with holes in the bottom under which a fire burns.
break frame Then the seed went to the hurst frame — which was called the break frame here. The seeds were not milled but crushed or broken so that the hard shell
crushing stone came off. We therefore refer to crushing stones rather than millstones.

The buckwheat was then sieved again and put through the fanning mill to remove the husks and dust. The broken buckwheat could be sold as groats but it could also be milled into flour in a second hurst frame.

A groat mill could produce about 300 kg per day but that did not provide a sufficient reason for its existence. In such a groat mill, beans, peas and the like were sold in addition to groats and flour. Later, such a groat mill became a grocery.
Because of the limited turnover, groat mills were also commonly found next to bakeries or near farms or grain mills.
A groat mill often also housed a mustard mill.
The arrival of the potato and mechanized mills heralded the end of groat mills.

The horses were always relieved after an hour; there was an hourglass in the mill for timing this.
The groat millers, however, stood all day long in the heat and lots of dust.

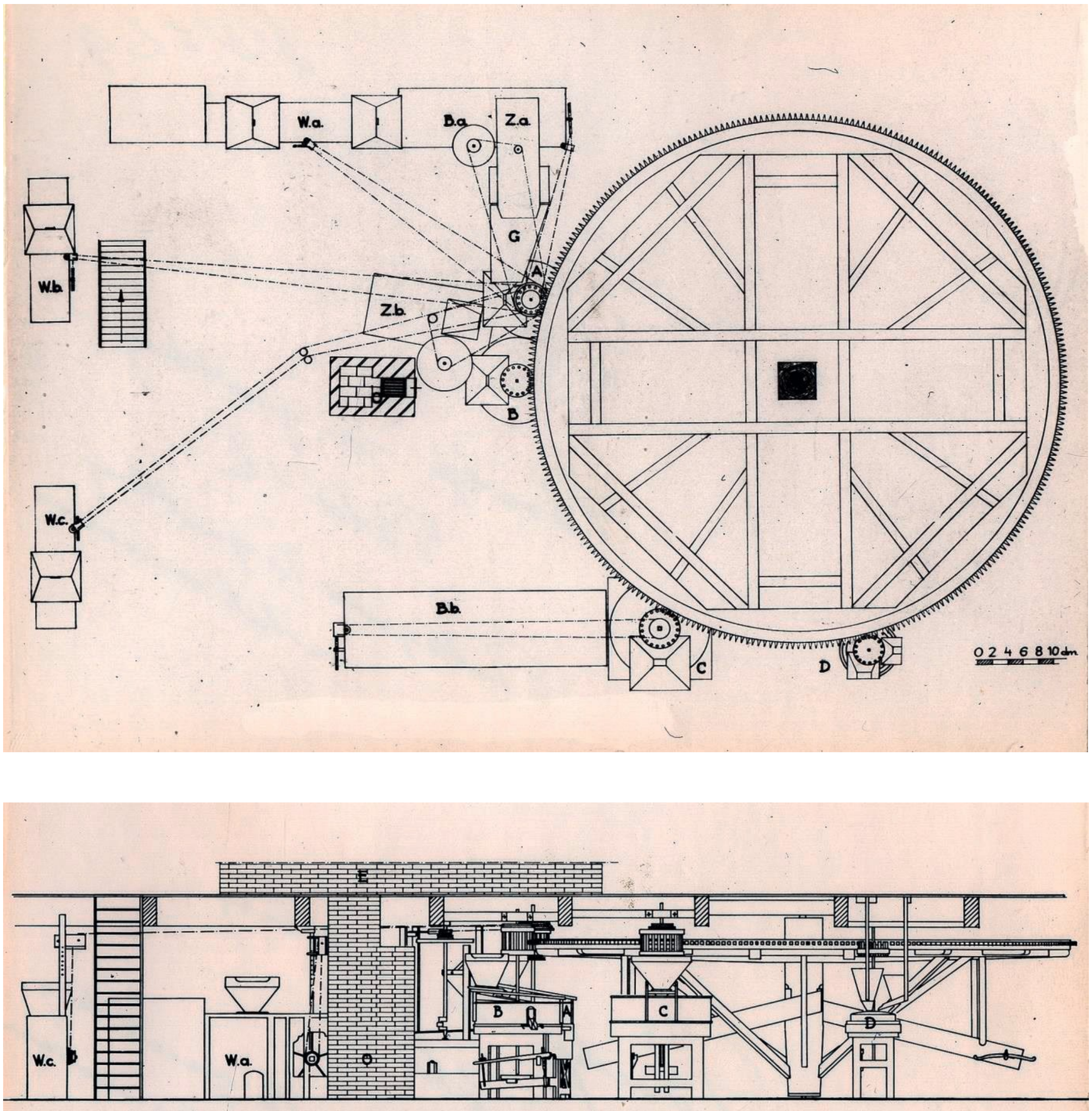

Fig. 17.7.2
Map and cross-section of a groat mill.

These relate to the former Van Dillewijn Groat Mill in Wormerveer. Two horses worked this mill. The mill was transferred to the Netherlands Open Air Museum in 1922.
Drawings: Collection of the Netherlands Open Air Museum

A, B, C	*stone nuts and the resulting powered stones.*	*D*	*crown wheel with mustard mill*	*B.b*	*sifter*
A and B	*crushing stones*	*Z.a*	*upper sieve*	*O*	*oven*
C	*millstones*	*Z.b*	*break sieve*	*E*	*kiln*
		W.a, W.b, W.c	*fanning mills*	*G*	*trough*

Note: The dashed lines are belt drives.