TRASHRACK CLEANING
THE PAST – THE PRESENT – THE FUTURE

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Abstract: Intakes of Hydropower plants have always been equipped with trashracks to keep floating debris, leaves, trash, etc., from the turbines, and these trashracks have always had to be cleaned. Initially, trashracks were cleaned by hand with hand-rakes of different types. Even in those early years, employees influenced the development and design of trashrack cleaning equipment - for example, one hand rake was equipped with wheels.
Bigger plants required an enormous amount of staff. In Rheinfelden, Germany, for example, when the leaves were falling, one hundred men were required for trashrack cleaning! That's why already at the transition from the 19th to the 20th century machinery for mechanical trashrack cleaning was being constructed. The development of design changes finally resulted in the large wire rope trashrack cleaners, well known for their use at the big river power stations on the Danube, Rhine, and Parana (Itaipu) rivers, e.g.
At the end of the 20th century, hydraulic trashrack cleaners for small Hydropower plants were developed. The prior tendency, to adapt hydraulic steel structures designed for large Hydropower plants by downscaling them for small Hydropower plants, was reversed. The hydraulic jib trashrack cleaners were upscaled to fit as much as possible the needs of the large plants.

Looking back on energy conversion

4000-2000 B.C.

Sumeria: bucket wheels up to 30 m diameter

Rome: Water wheels with diameters of many meters are state of the art. Vitruvius (Marcus Vitruvius Pollio, born appr. 80 B.C.) describes water wheels, bucket wheels, trick fountains, water pipes etc. In Barbegal near Arles in France, a mill plant was installed with 2 lines of 8 water wheels each, capable of handling 250 - 300 liters per second with a head difference of 25 meters.

Middle Ages:

Water wheels are the basis of the economy of Europe.

Modern Times:

The use of steam makes energy available everywhere and at any time. The importance of Hydropower declines.

1809: Horse-Drawn Railway in Philadelphia (USA)
1825: Steam-Railway, Stockton – Darlington (Northeast England)
1827: First water turbine with 4.5 kW, efficiency 80%, from Benoit Fourneyron (pupil of Claude Budin)
1830: Network of railways worldwide: 332 km
1835: Steam-Railway Nürnberg – Fürth (Germany)
1838: Francisturbine with 170 kW by James Bicheno Francis (USA)
1870: Network of railways worldwide: 221 980 km
1871: 25.000 km network of railways in Germany
1874: First Francis - Turbine in Germany
1880: Network of railways worldwide: 367 235 km
1883: Network of railways worldwide: 443 441 km
1883: Geneva pumping station at the Rhône river (production of electric energy exclusively to power auxiliary equipment inside the plant
1888: Pelton – Turbine by Lester Allan Pelton (USA)
1891: International electrotechnical exhibition in Frankfurt (Germany): electric power transmission from Lauffen to Frankfurt over a distance of 175 km
1893: Breakthrough of alternating current (Tesla and Westinghouse, Columbus World Exhibition in Chicago)
1895: Opening of the Niagara-Hydropower plant
1898: Rheinfelden, Europe's first large run-of-river power station
1898: Kammerl, Europe's oldest rail traction power station
1919: Kaplan – Turbine by Viktor Kaplan (Austria)

1 Development of Trashrack Cleaners

1.1 The past

From middle ages up to modern times, Hydropower has been the most important source of mechanical energy, but until the end of the 19th century, the use of this energy was possible only in those areas close to the power plants. Thus hydropower in energy production was reduced and limited to water mills, hammer works, and other such users close to the Hydropower plants. Energy conversion was carried out by water wheels. The first turbines were not developed until the 19th century. It was only with the rise of steam power that mechanical energy was available almost anywhere. At the end of the 19th century, it became possible to convert mechanical energy to economically transportable electric energy and to reconvert this energy back to mechanical energy at places far from the source of the power. So hydropower became important again and continued to challenge the importance of steam power. In countries with great rivers and smaller rivers with significant river heads, the expansion of hydropower proceeded very quickly. Areas in which coal was readily and cheaply available and which could use “the in perpetual cycle yearly renewed treasure of the running water”[*)] also expanded energy production by hydropower.
At the beginning of the 20th century, there were already many large Hydropower plants in operation. A large number of these plants are described in one of the

[*)] Die Wasserkräfte, A. Ludin, Springer 1913, preface from Geh. Oberbaurat Dr.-Ing. Hermann Keller

standard German works on the subject, Adolf Ludin's *"Die Wasserkräfte"* [2], published in 1913.

In the ancient world Hydropower plants with water wheels obviously were designed so that coarse swimming debris could not reach the water wheels. But I couldn't find any indication, in Vitruvius or elsewhere, about trashracks or similar constructions built to retain debris. Water wheels will keep functioning despite leaves and small debris, but measures had to be taken against coarse trash.

The first turbine was set into operation about 1827. It produced 4.5 kW at an efficiency of 80%. By 1838 the first Francis Turbine, with a power of 170 kW, was in operation [3].

Turbines have a much greater discharge than water wheels, but the through-flow sections of small turbines are far more sensitive to trash than are water wheels. Thus the first turbine plants were already equipped with trashracks. Meißner [1] describes in detail parts of weirs, channels, etc., but does not mention trashracks. The drawings show, however, that already some form of trashracks were in use at the beginning of the turbine area. See Fig. 1 – 3.

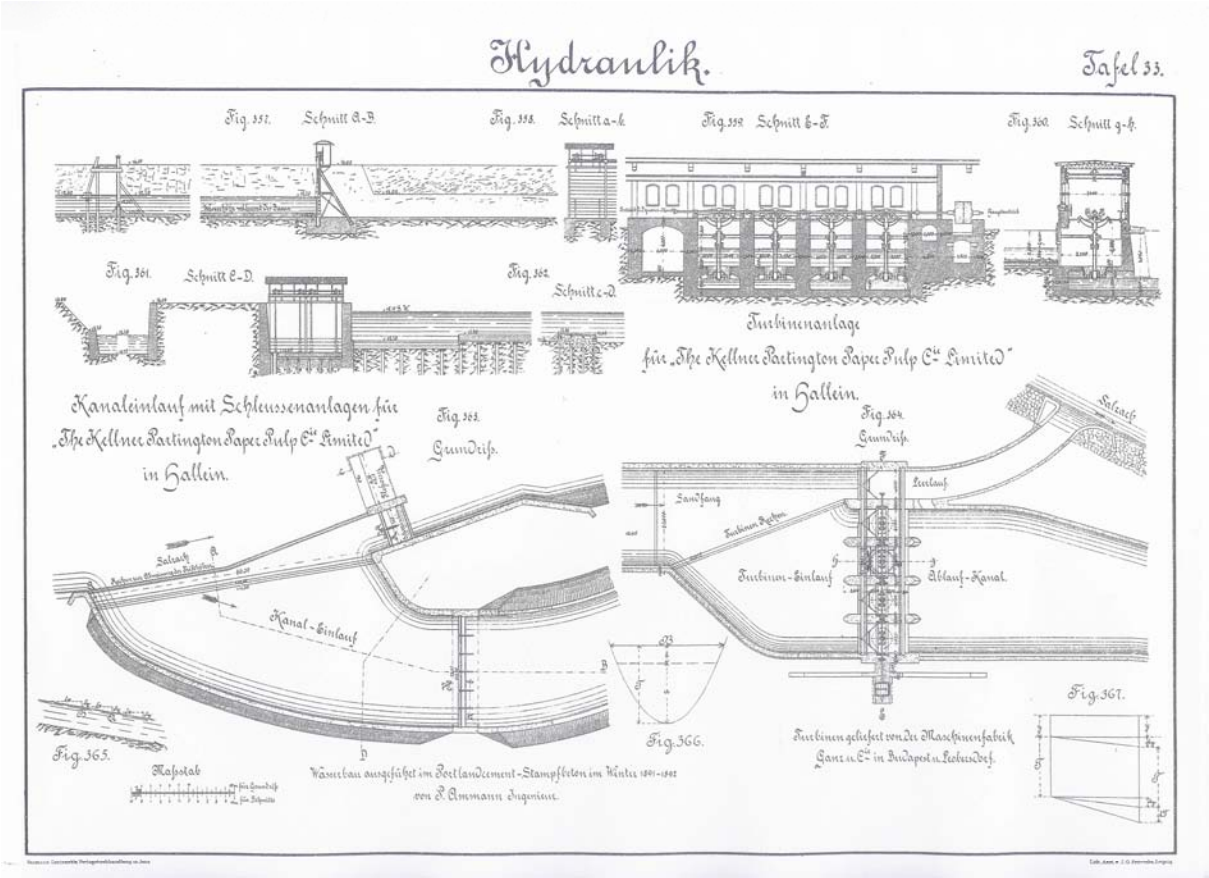


Fig. 1. Hallein Hydropower Plant, erected 1891-1892 [1]

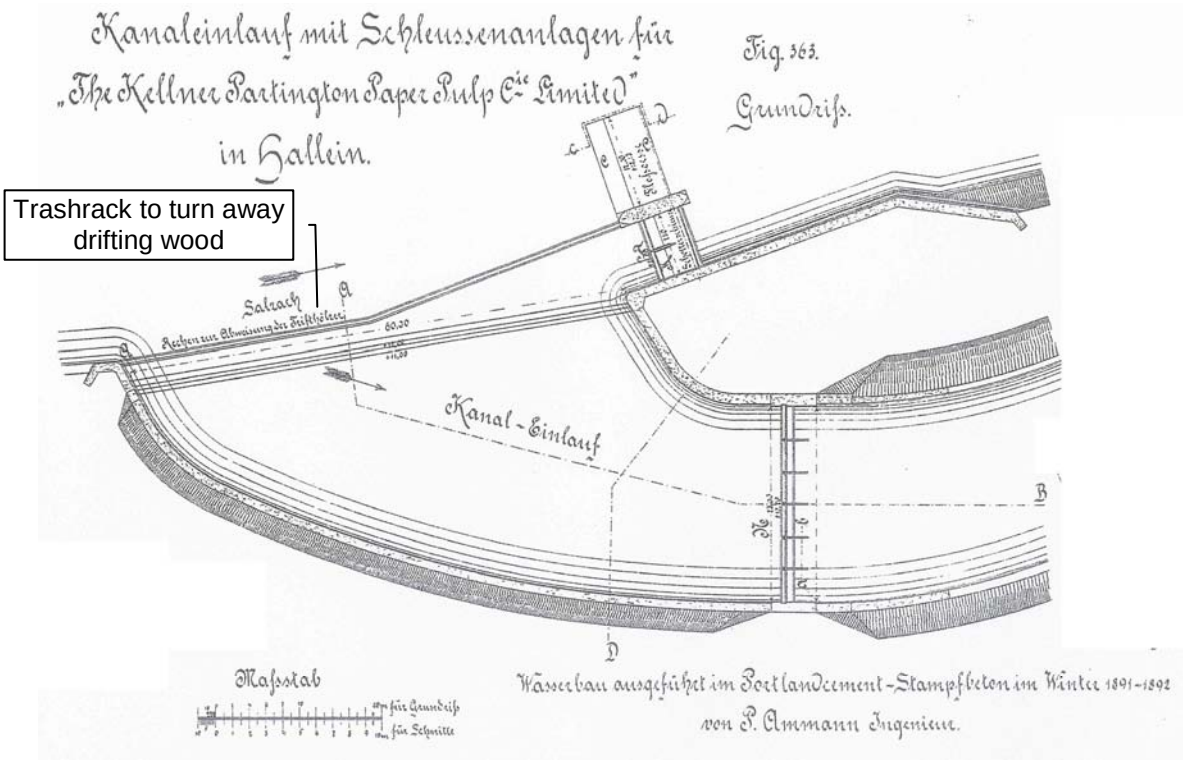


Fig. 2. Hallein Hydropower Plant, Detail from Fig. 1. Coarse screen [1]

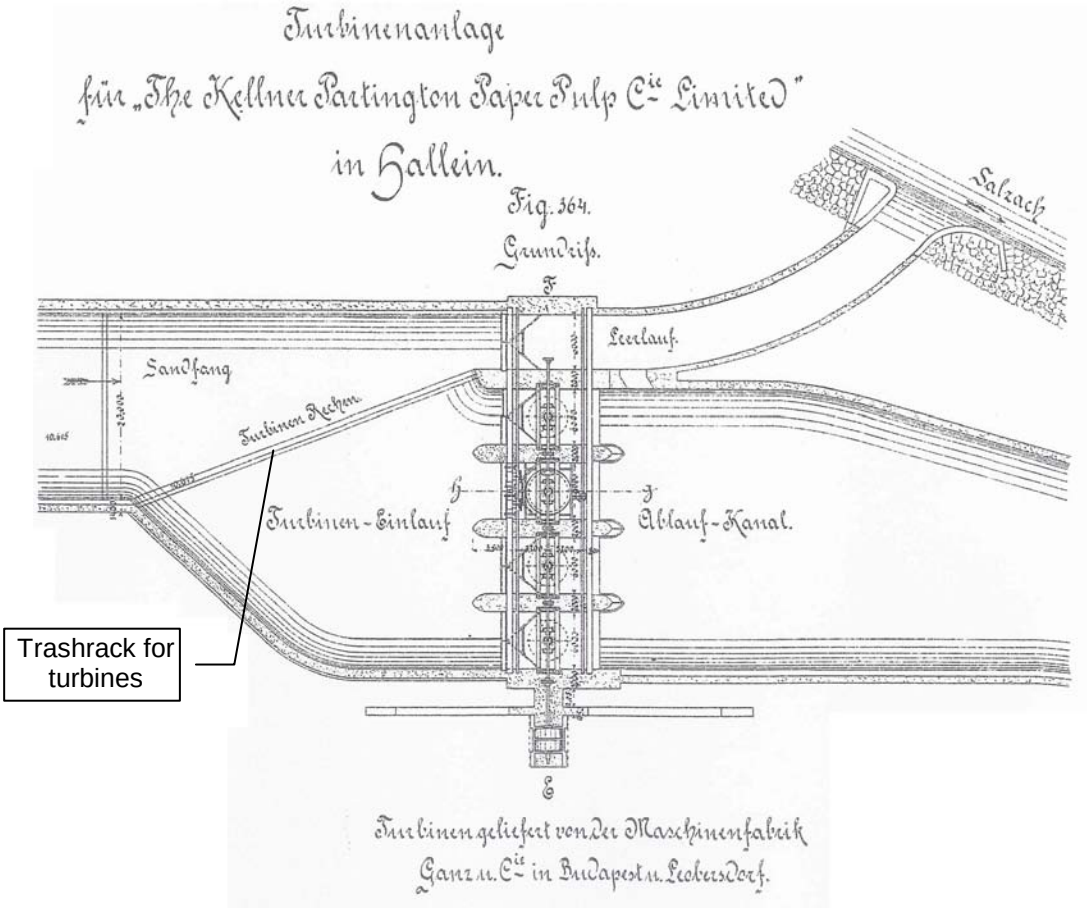


Fig. 3. Hallein Hydropower Plant, Detail from Fig. 1. Trashrack for turbines [1]

1.2 Begin of trashrack cleaning

As long as trashracks have been in use, they have had to be cleaned. Traditionally, they were cleaned by hand with equipment (co)developed by the people that used it, management and staff. Thus the hand rakes became easier and easier to handle. Some of them even had wheels. [2]

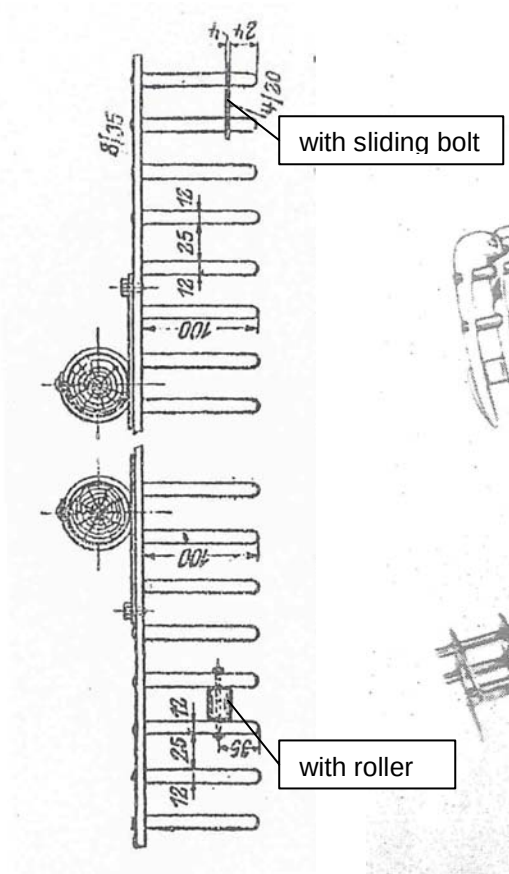


Fig. 4a. Hand rakes with sliding bolts/with rollers, 1913 [2]

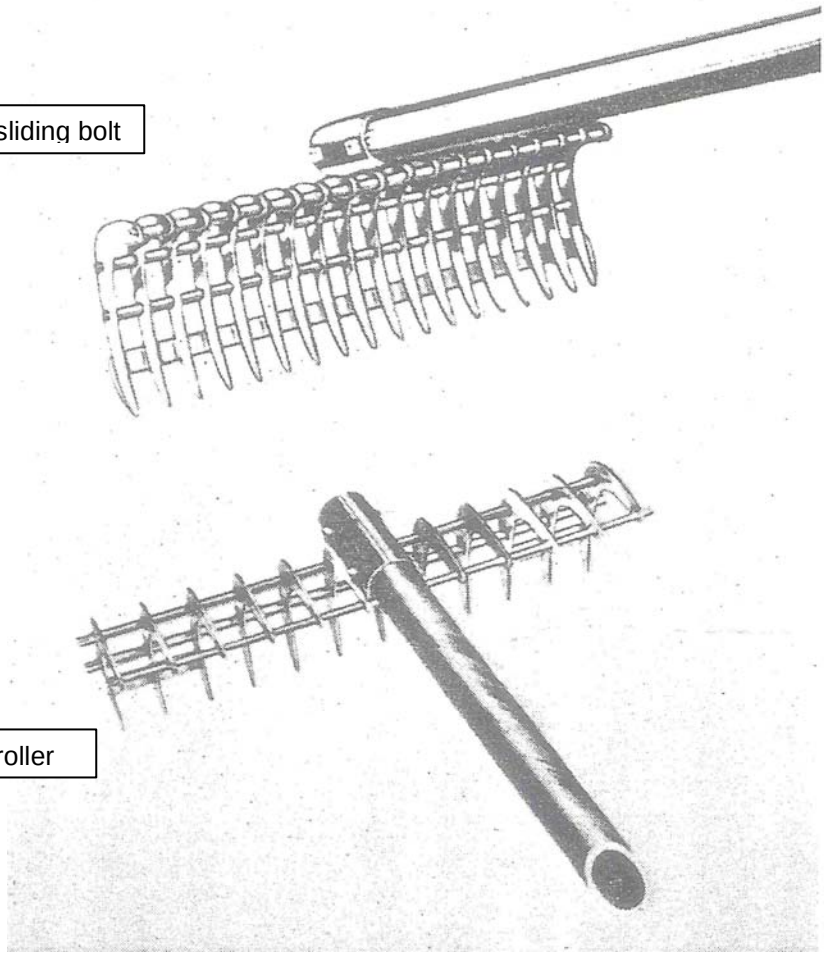


Fig. 4b. Lightweight hand rakes with stainless-steel raking heads, 1960 [4]

(Photo courtesy of Rodney Hunt Machine Company, U.S.A)

In the autumn, when the rivers were full of fallen leaves, a great number of people were needed to clean the trashracks. At Rheinfelden, Germany, for example, up to 100 people were necessary for trashrack cleaning. Even then, at the beginning of the 20th century, it was not easy to get so many people for such a short-time job.

Today, in some areas, trashracks are still cleaned by hand. As recently as the end of the 1980s, I myself was asked by managers of large plants to replace their manual cleaning systems with mechanical trashrack cleaners.

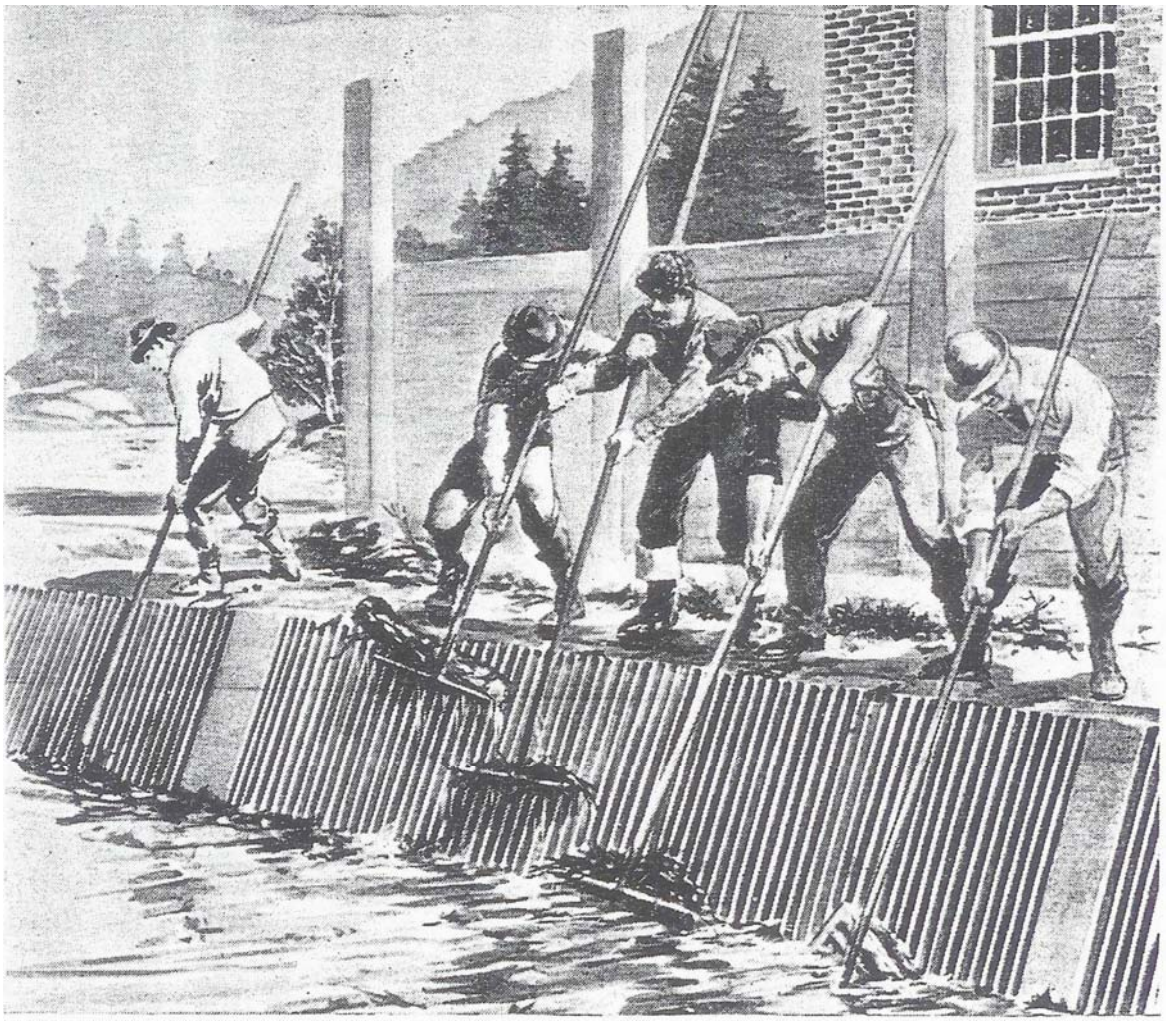


Fig. 4c. "Hand raking of trashracks as commonly performed in the past"

Illustration to the frequently quoted article by Thaddeus Zowski in

"Hydropower", October 1960, page 399 [4]

According to Ludin, to give an illustration, *"During the 8 days between 2 November and 9 November, 1910, 1,648 CMs of leaves were collected. This means that if the normal water quantity of 520 CMs/sek were used, the content of leaves would be 6.5 liters to every 1000 CMs of water.*
To make it easier to lift the hand rakes, the plant manager of the electric power station in Aue near Baden, Switzerland, equipped a handrake with two rollers." [2]

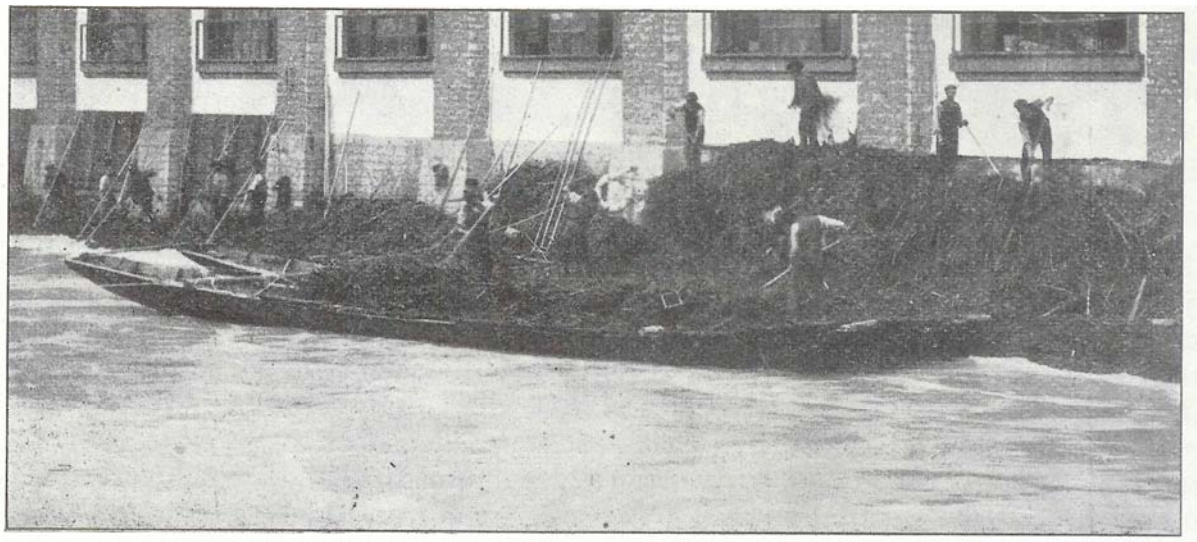


Fig. 5. Normal trashrack work in Rheinfelden during flood (Photo. Ing. Bitteli in Rh.)

"Die Wasserkräfte" [2]

Mention the extremely narrow trashrack platform for the workers!

The size and position of trashracks were influenced by the necessities of manual trashrack cleaning: the depth of water at the trashrack was limited to 5 meters, maximum 6. The flow rate initially was rather high at 1.2 m/sec. As a result, there were so many serious problems that later, at other power plants, they had to reduce the flow rate to between 0.4 and 0.7 m/sec (relative to the inclined height).

Anyway, in Ludin's era (1913), manual trashrack cleaning set the design criterion for Hydropower plants. Nevertheless, in his book he discusses trashrack cleaning machines and proves their economic efficiency. The cost of manual trashrack cleaning at that time was two and a half times more than mechanical cleaning.

Thus the mechanisation of trashrack cleaning was already tackled a hundred years ago. It was something that was obviously destined to come into being.

1.3 Mechanical trashrack cleaning

At the power and pumping plant erected in 1902 near Glüder, in Solingen, a stationary trashrack cleaning machine was installed. The machine, constructed by Amme, Giesecke and Konegen in Braunschweig, was primarily designed to remove leaves.
The trashrack was crossed upwards by a chain driven scraper. The collected trash was dumped onto a cross belt. The drive of the conveyor belt was a three-phase A.C. motor with 3-HP.

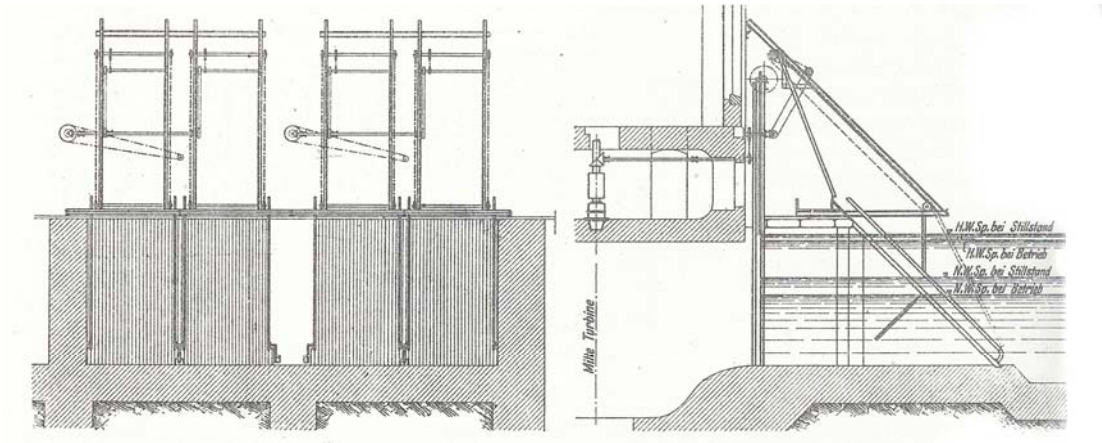


Fig. 6. Trashrack cleaning machine Solingen (Amme, Giesecke u. Konegen).

"Die Wasserkräfte" [2]

Today, chain-driven trashrack cleaning machines of modern design are still used at small Hydropower plants.

"For trashracks with long extension, the acquisition of stationary trashrack cleaners like the one in Solingen would be too expensive. Here the use of a traveling trashrack cleaning machine that cleans the trashrack areas successively would be more practical. At the electric power station in Chèvres, patented equipment of this type has been in operation since May 1910, (see Fig. 7 & 8).

The apparatus runs on rails over the 190 m long trashrack bridge, powered by a 15-HP-three-phase A.C. motor with 120 Volts. Travelling speed is adjustable from 30 m/min to 50 m/min for longer distances.

The rake consists of a movable guiding frame (A), which can hinge about a pivot (B). This guiding frame moves the "stem", made of steel profiles and carrying a sheet steel bag (H), between the wheels. The rake sinks by its own weight only to the basis of the trashrack. It is lifted by a wire rope (D), which is coiled on the drum (E) by means of a motor (F). While descending, the movable frame is fixed by the catch (G) and consequently the bag (H) has a distance of 20 to 60 cm to the trashrack. As the rake arrives at the bottom, the cog (J) hits the buffer (L) at the stem (K), opens the catch (G) and the bag falls to the trashrack. As the transmission (M) is in action, it's enough to move the transmission belt from the loose wheel (N) to the fixed wheel (N') to start lifting the rake. Before the bag reaches the top end of the trashrack, the bevelled slideway (P) rises to the roller (Q) and lifts the rake from the trashrack. Continuing the rise the rake sinks again slowly over the edge of the discharge hopper (S) as close as the now closed catch (G) allows.
Here the bag hits with the catch (u - u') to the buffer (T), starting the tilting of the bag to the position (H - dotted line) in Fig. 8. Still continuing the rise of the stem (K), the cog (X) hits the buffer (Y), and so the transmission belt is moved again to the loose wheel. Now the operator has to act: he loosens the friction brake (*1)* and the stem slides downstairs again, moving also the drum (E). At *4* a manually operated disconnecting lever is installed; at *5*, there is a safety catch in case of a rope breakage.

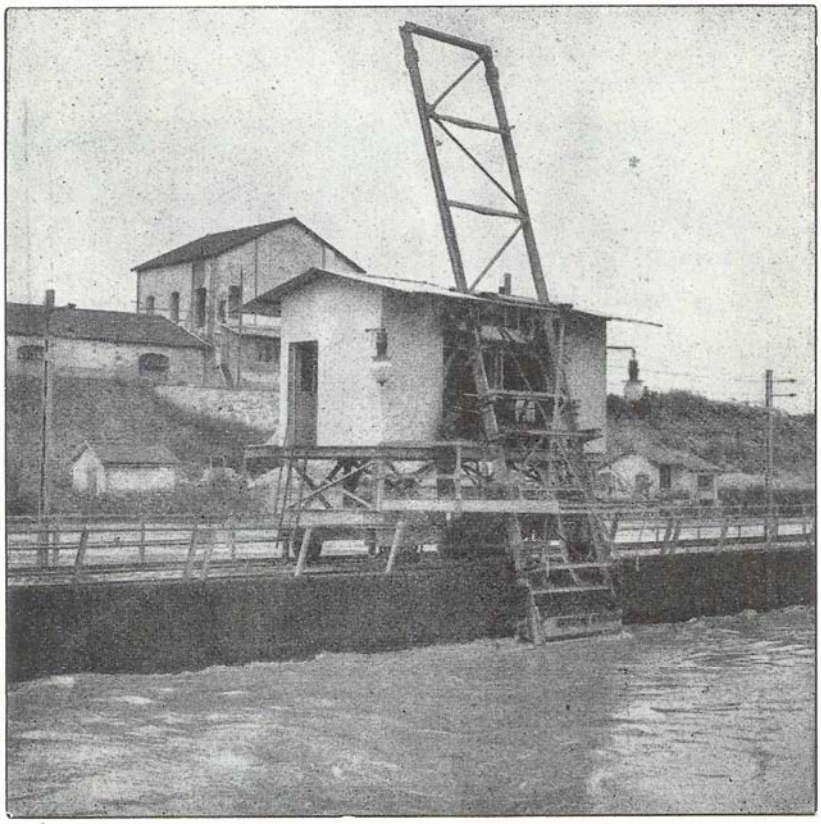


Fig. 7. Trashrack cleaning machine Chèvres in operation (Services techn. Genf)

"Die Wasserkräfte" [2]

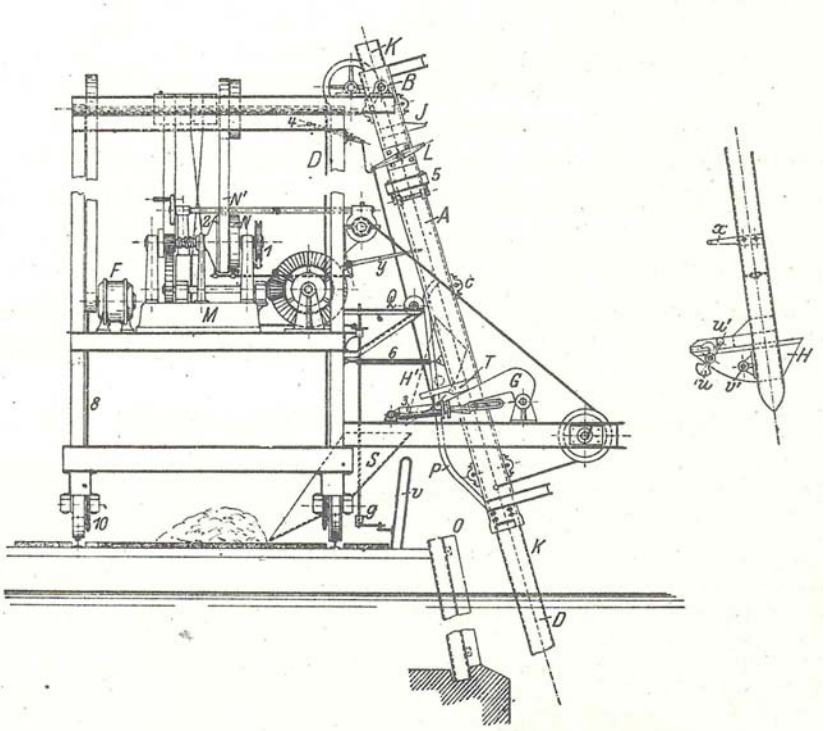


Fig. 8. Trashrack cleaning machine Chèvres

"Die Wasserkräfte" [2]

To operate this kind of rake (Fig. 7), three people are required: one operator at the machine and two others to control the rake and to unload the collected trash.
The time required for cleaning a 2 m wide and 6 m high trashrack area is 1 minute (20" downward movement, 20" upward movement, 20" to move the engine from the actual cleaning position to the next). In the summer of 1910, this kind of machine collected up to 185 CM trash in 24 hours. … "

("Die Wasserkräfte" [2])

It is a small step to the classical wire rope trash rack cleaning machine used today: the "bag" (i.e., rake) no longer runs in a guiding frame, but with big wheels directly on the trashrack bars. By the use of a third rope, the rake is tilted about the wheels, that is, lifted and carried over the wheels, and the toothed rake plate is lifted from the trashrack bars during lowering.
In the lowest position the tilting rope is loosened, the rake turns and the toothed rake plate falls to the trashrack bars. As it rises, the cleaning operation starts.

2 Trashrack cleaning today

2.1 Types – summary

Over the decades countless types of trashrack cleaning machines have been developed. (See also my presentation at the 14th International Seminar on Hydropower plants in 2006 [5].)
For medium-sized Hydropower plants with cleaning lengths up to 20 m only two types of trashrack cleaning machines are used today: the classic wire rope trashrack cleaner and, more recently, the hydraulic jib trashrack cleaner, which is becoming increasingly more important.
For large-scaled Hydropower plants the wire rope trashrack cleaner is still the only possibility.

2.2 Wire rope type trashrack cleaner

This type has been in operation since the beginning of the use of Hydropower for the production of electric energy--therefore for about 100 years.

The main components of this machine type are:

- Baseframe with travelling device
- Winch with rake
- Debris storage and/or debris disposal

Fig. 9. Wire rope type trashrack cleaning machine (HPP Feistritz, Austria)

The essential feature of this machine type is the rake's toothed rake plate. During cleaning the teeth mesh with the trashrack bars. Consequently, objects stuck between the trashrack bars can be caught and removed. Even frazil ice (ice similar to slush) can be removed with the toothed rake.

Many solutions to the debris storage problem have been created, influenced mainly by the practicality of transportation. Examples are integrated containers as buffer storage containers being towed by the cleaner and trucks that follow the trashrack cleaning machine under their own power or by being positioned on a platform connected to the cleaner.
All the possibilities of the materials-handling technology can be used.

Accessories such as timber grabbers or orange peel buckets (Fig. 9,⬆) may be mounted on cranes to remove large objects. Surface rakes that can be lowered (Fig. 9,➡) are used to gather and drift floating debris.

Wire rope type trashrack cleaners can be used for nearly unlimited cleaning lengths. The trashrack cleaner of Itaipu/Brasil has a cleaning length of more than 60 meters.

The inclination of the trashrack should be at least 10 degrees to the vertical.

2.3 Hydraulic jib trashrack cleaner

This type--in the size discussed here -- has been manufactured for only a few years. The main components of this machine type are:

- Baseframe with travelling device
- Pivoted machine house with booms and grab rake

Fig. 10. Hydraulic jib trashrack cleaner (HPP Leoben)

The revolving superstructure of the machine*) enables dropping of the trash besides or behind the railway of the trashrack cleaner. The trash is dropped in a concrete bin or a container to be disposed of later.

The grab rake is designed to pick up oversized trees as well as to push floating debris to the weir. It has a scraper sliding along the trashrack bars, but without meshing between the trashrack bars. So it's not possible to clean the space between the trashrack bars. Also frazil ice cannot be removed.

The grab rake can be rotated to conform to the position of a tree or other debris. Thus floating debris can be pushed to the weir to be drifted and large debris, such as trees, can be picked up by the grab rake and disposed of.

The cleaning length for hydraulic jib trashrack cleaners – from today's point of view – is limited by economical and architectural reasons (overall height!) to about 15 to 20 meters. Greater cleaning lengths require the use of telescopic beams with the result of complex design and enormous weight.

Cleaning of vertical trashracks is possible.

*) Today's standard

2.4 Technical requirements (today's standard)

Wire rope trashrack cleaner	Hydraulic jib trashrack cleaner

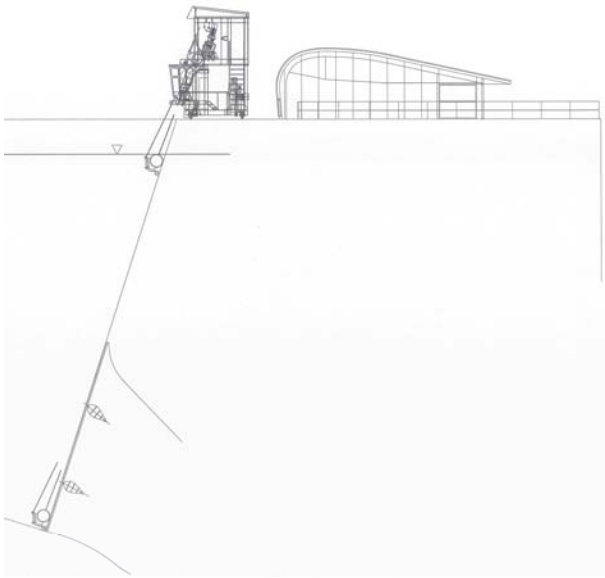


Fig. 11. Wire rope cleaner
cleaning length ~25 m

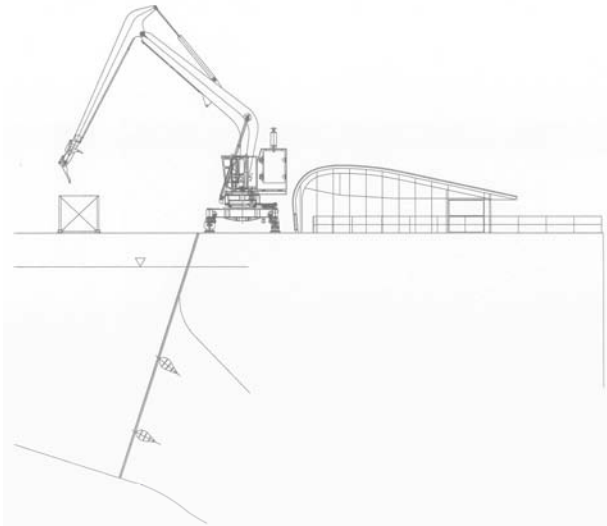


Fig. 12. Hydraulic jib cleaner
cleaning length ~16 m

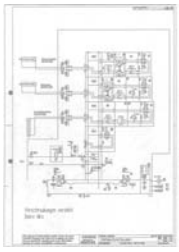
Travelling device	
electric	electric
Lifting device	
electric rope winch tilting of rake: hydraulic	hydraulic booms hydraulic grab rake
Rake plate of rake	
teeth of rake plate mesh between trashrack bars	scraper slides on trashrack bars, no meshing between bars
Electric control system	
approx. 10.000 program lines	approx. 15.000 program lines

Position encoder of rake

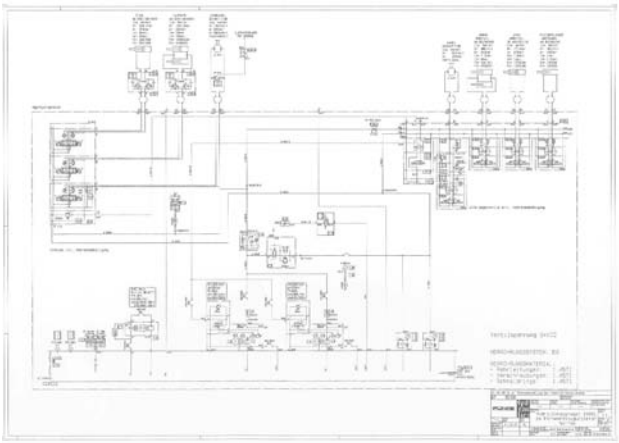
1 shaft encoder (winch) several limit switches	2 distance sensors (in hydraulic servos) several manometric switches for rake

Hydraulic

(Hydraulic schemes: approximately the same scale)



Hydraulic scheme



Hydraulic scheme

hydraulic pipes not submerged	hydraulic pipes submerged
hydraulic only for rake-tilting only directional valves	hydraulic for all movements (except travelling) only proportional valves

Emergency service

easy	difficult to impossible

Installed power

(typical)

winch: 22 kW travel drive: 2 x 4 kW	lifting (hydraulic unit): 45 kW (2x) travel drive: 4 x 2,2 kW

Cycle time

<< 5 min.	approx. 10 – 15 min. incl. travelling time

Maintenance

mechanic, electrician	specialist for hydraulics required

3 The future

Both types of trashrack cleaning machines are already perfected.

The wire rope trashrack cleaning machine consists--completely equipped--of the basic trashrack cleaner and the accessories crane with timber grabber (standardized product!) and surface rake.
The accessories can be adjusted in size and capacity to the existing trash. Retrofitting is possible at any time.
The noise level of the wire rope trashrack cleaner is rather low.

The hydraulic jib trashrack cleaner is an all-in-one machine. Separate crane and surface rake are not necessary. The grab rake has to take over their functions.
Size and additional features of the grab rake have to be specified already before the design is made in order to be adjusted not only to the requirements of trashrack cleaning, but also to the additional functions. A good knowledge of the trash to be collected is basic.
To achieve a low noise level is very difficult and requires a big effort.
As with all the other resources, trashrack cleaning machines also have to be economical.

For economic efficiency the following criteria are decisive:

- Installation costs
- Lifetime
- Operating expenses

As the price is still decisive, the installation costs for both types must be approximately equal.

Experience shows for wire rope trashrack cleaning machines a lifetime of more than eighty years.
A few years ago the author was involved in the refurbishment and automatisation of a wire rope trashrack cleaner constructed in 1923 [5].
The machine was additionally equipped with a crane and is still in operation, fully automatic, unattended.
There is not enough experience available yet to determine the life span of hydraulic jib trashrack cleaning machines, since these machines, at least of the size discussed here, have been in operation for only a few years.

Operating expenses are substantially influenced by the required number and qualification of the maintenance staff and depend also on the availability of the required machine.

Today, programmable controls are used almost exclusively for both types of machines, and every plant electrician is familiar with these systems. The adaption of complex movements requires experience and understanding.
The mechanical and hydraulic components of a wire rope trashrack cleaning machine are rather simple and therefore easy to maintain. No special knowledge is necessary.

To handle sophisticated hydraulic controls as necessary for hydraulic jib trashrack cleaners, specialists are required. In many cases they have to be trained first, or recourse to external specialists is unavoidable.

The future of both types depends whether and how they fulfill the criteria of economic efficiency. Depending on evaluation criteria of the technical capacities, the required staff, the necessary availability (i.e., operational reliability) and last but not least by the personal preferences of the decision maker, both types of machines can be installed. As soon as adequate experiences is gained in the operation of hydraulic jib trashrack cleaners – maybe in twenty years – we will be able to determine which type of machine will be preferable.

4 Summary

For more than one hundred years trashrack cleaning machines have been used to clean turbine intake trashracks. Today for medium sized Hydropower plants – cleaning lengths 15-20 meters--wire rope trashrack cleaning machines are used as well as hydraulic jib trashrack cleaners. For wire rope trashrack cleaners more than one hundred years of operational experience is available. Hydraulic jib trashrack cleaners, within the discussed size, have been in operation for only a few years.

References

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