Special Print

Taprogge

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Heat Exchanger Cleaning Systems

1. Introduction

The worldwide installation of heat exchangers increased enormously after World War II when power stations, chemical plants and refineries needed to be rehabilitated and reconstructed.

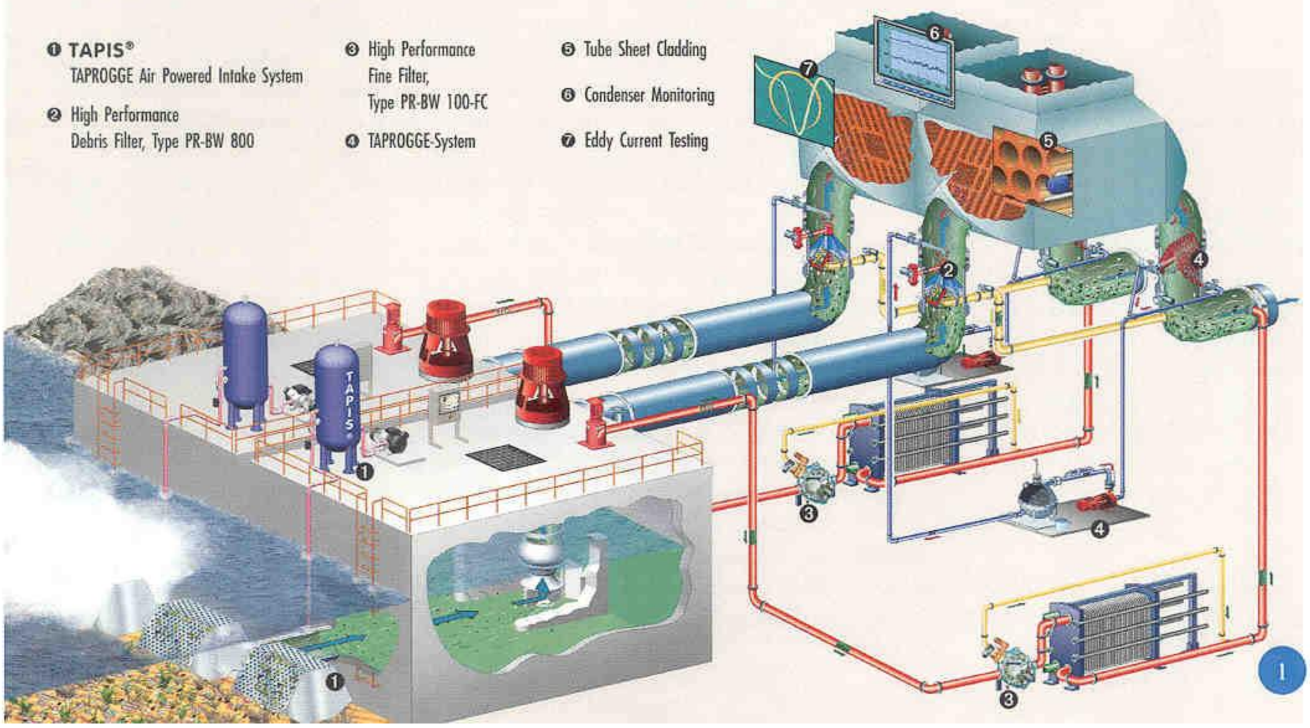
In the early fifties, TAPROGGE managed to make a breakthrough in the field of cleaning of heat exchangers without disrupting operation by introducing its automatic tube cleaning system using sponge rubber balls as cleaning agents. The global application of almost 12,000 units of such systems throughout the recent decades has led to the acknowledgement of this process as state-of-the-art for turbine condensers and many other applications. For the most part, TAPROGGE Systems are already being prescribed in the project stage.

Precondition for the smooth, continuous circulation of the sponge rubber balls is free tubes and tube sheets, which is why debris filters for the coarse filtration of cooling water were developed at the beginning of the sixties, whose effectiveness was permanently being enhanced up to today's fourth generation. Also the pre-screening system as preliminary stage of effective filtration was clearly optimized by TAPROGGE through new developments which are reflected in the IN-TA-CT® concept.

For the continuous control of heat transfer of turbine condensers, TAPROGGE has developed the Condenser Monitoring System (CMS). It serves for monitoring the heat transfer of single condenser tubes, so that tube fouling is detected immediately and the cleaning frequency of the sponge rubber balls can be adapted

Contents

IN-TA-CT® INTEGRATED TAPROGGE CONCEPT pic 1



accordingly. The last step in this process is the remote data transfer via satellite to the TAPROGGE Service Department whereupon the necessary recommendations will be signalled directly to the end user.

For heat exchangers in the sector of air conditioning and chemical production of small capacities, special concepts were developed to respond to industrial needs. The cleaning systems CCS and ICS can be operated stationary as well as mobile, and partly also in the „off-line" sector for difficult products (high pressures and temperatures, aggressive) in the heat exchanger tubes. For this field, too, the automatic backwash filters FC and DYNAMIC with finenesses of up to 50 µm can be installed.

In the following, we will give brief descriptions of the basic problems of heat exchangers in terms of fouling and macrofouling.
By means of practical examples, various solutions and selected components will be presented.

2. Basic Problems on the Cooling Water Side of Shell and Tube Heat Exchangers

The design of heat exchangers has to allow for a certain fouling on the inner tube surface. By using the so-called Fouling Factor, the heat transfer surface will be increased correspondingly to make good for the fouling to be expected. In the USA [1] the theoretically necessary heat transfer surface is increased by 10% up to 500%, with an average value of approx. 35%. Such calculations start from the assumption that fouling will impair the heat transfer of one or both sides of the transfer surfaces.

The heat transfer surfaces are often reduced by macrofouling, such as mussels, fish, algae, pieces of wood, leaves, grass, stones, or internal construction parts of cooling towers. Reductions of transfer surfaces also occur if cooling tubes, which are perforated by corrosions, have to be plugged in order to avoid mixing of substances. For such problems there is a modern solution by the installation of bar screens with prescreening systems installed upstream as per the IN-TA-CT® concept (graph).

The second type of fouling which frequently occurs is microfouling. It is caused by mud, sand, clay, micro organisms, bioslime, corrosion products and inhibitors. A further important type of fouling is the so-called scaling. In this case, solution equilibriums are surpassed as a consequence of increased temperatures in the cooling water which leads to precipitations of calcium carbonate, silicates, calcium sulfates and magnesium salts. For such problems, automatic ball cleaning systems with elastic sponge rubber balls have been applied most successfully for nearly five decades.
Tube clogging and fouling layers „cause considerable cost by necessary overdoses, energy loss and reduced thermal efficiencies, higher pressure loss, cleaning and installation costs and production loss during down times of plants for cleaning" [1].
According to [2.1], for the design of turbine condensers fouling resistances of 0.020 to 0.050 m^2K/kW are recommended for copper alloys, and of 0.015 to 0.032 m^2K/kW for stainless steel and titanium.

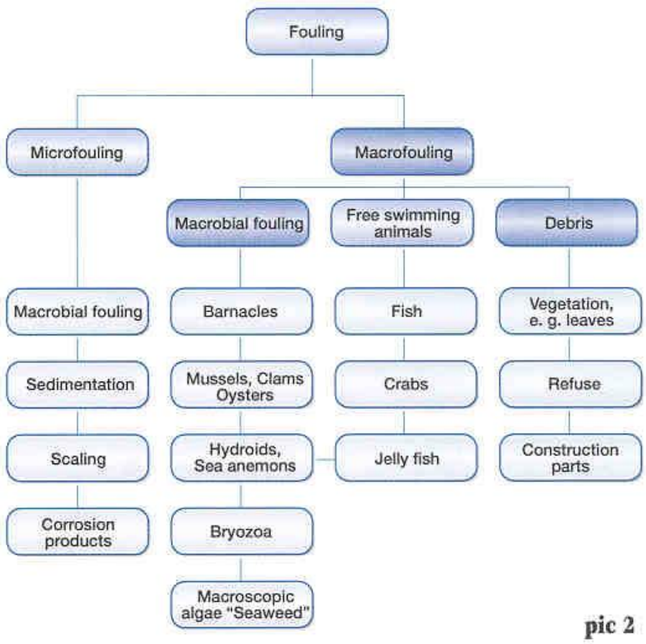
Layers in cooling tubes not only reduce the heat transfer coefficient, but are frequently also the source of tube corrosion if copper alloys and stainless steel are used as cooling tube materials.

The following recommendations and explanations for avoiding tube corrosion are given in [2.2] for copper alloy, and in [2.5] for stainless steel.

Layers in condenser tubes (made of copper alloys) considerably impair the protective film formation, or they can destroy an existing protective film by corrosion as a result of the formation of differential aeration cells. That is why it has to be safeguarded so that layers are avoided. They can develop by the separation of suspended solids from the cooling water, by the precipitation of suspended substances once the limits of solubility have been reached, and by the growth of micro organisms.

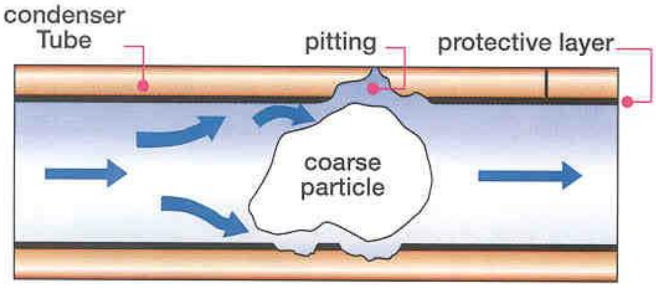
In this connection it is recommended to regularly analyze the cooling water. One method to avoid layers is the use of a tube cleaning system. Such a system is part of today's state of the art and should always be present" [2.2].
„... the danger of corrosive attacks underneath mineral or organic fouling is especially imminent in the case of stainless steel. Because of the possible crevice corrosion, the use of continuously operating tube cleaning systems, generally with sponge rubber balls, is urgently recommended for tube materials of this group, having PRE (= „Pitting Resistance Equivalent") formulas of W < 35% [% Cr + (3,3 x % Mo); W.-Nr. 1.4401, 1.4439] and operating in cooling waters with higher contents of salts and suspended solids. Compared therewith, corrosion underneath deposits has up to now been unknown in connection with titanium surfaces, so that this material is very well suited for heat exchangers that shall be operated with cooling water containing high suspended solids. The higher susceptibility to biofouling of copper-free materials may call for occasional or regular cleaning treatment during which special cleaning balls are used in the cleaning system, e.g., balls with plastic granulate or corundum coating, or balls filled with pumice powder" [see picture 6]. Unsuitable cooling tubes made

Fouling Typology



pic 2

pic 3: Pitting



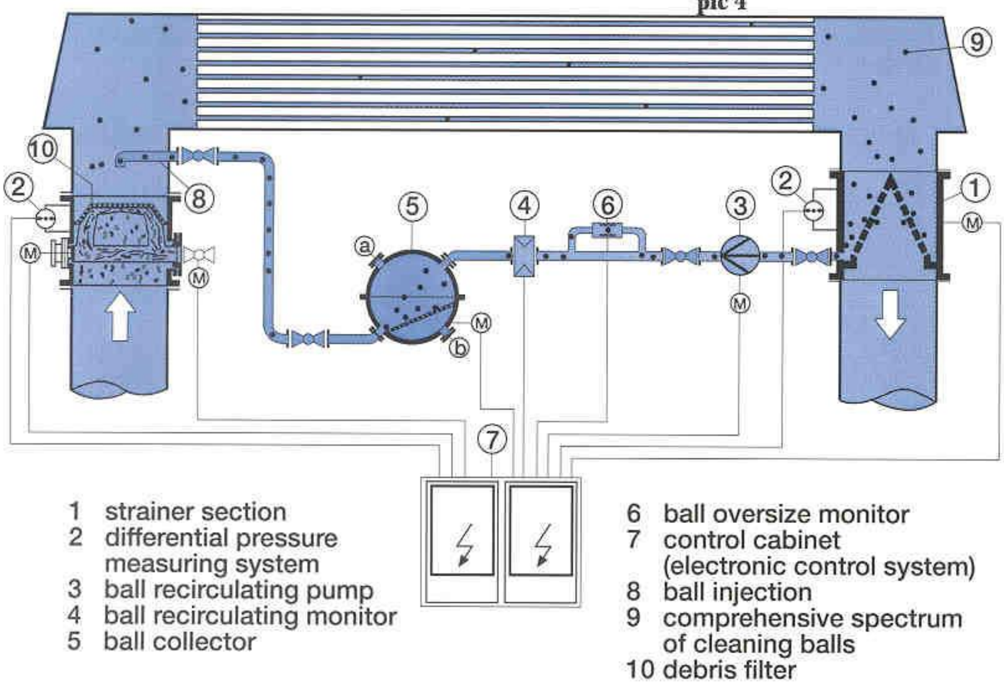
of brass showed stress corrosion cracking near the rolling-in spots at the tube sheets which was caused by the formation of ammonia as a result of the decomposition of organic substances.

In the vicinity of coarse particles which got stuck in cooling tubes, tube perforations due to turbulent flows and destroyed protective films developed very quickly, and in the case of stainless steel there is the risk of crevice corrosion between coarse particles and cooling tubes (pic. 3). By installing debris filters and tube cleaning systems (pic. 4) the heat exchangers are kept free from clogging, and the cooling tubes free from layers.

The supplier of such systems guarantees clean heat transfer surfaces on the cooling water side.

condensor tube cleaning system and debris filter in operating position

pic 4



3. Task of Tube Cleaning Systems with Sponge Rubber Balls

The automatic tube cleaning system for shell and tube heat exchangers has the task to

keep the cooling tubes free from layers

so that

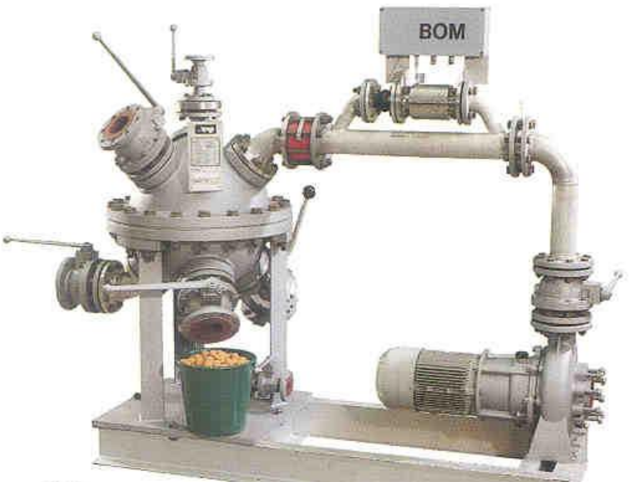
- the heat transfer coefficient remains constant
- tube corrosions through layer formation are avoided.

3.1 Operational Principle of the Tube Cleaning System

The elastic sponge rubber balls are poured into the collector of the ball recirculating units (see picture 7) from where they pass into the cooling water inlet pipe of the heat exchanger. Transported by the cooling water flow they pass through all cooling water tubes without impairing the operation of the heat exchanger. The cleaning balls are in constant circulation and, during their lifetime, pass through the tubes thousands of times. The driving force that moves the cleaning balls through the tubes results from the differential pressure of the heat exchanger which forces the ball through the tubes without additional energy.

Via a strainer section (see picture 8) the balls are screened off the cooling water circuit after each passage. The fouling of the screen is monitored by a differential pressure measuring system. Once the pressure drop reaches the pre-set value, the balls are caught in the ball collector, and, during operation, the screen turns to backwash position, so that the rear screen surfaces are in flow direction. Via the ball recirculating unit the balls are again fed into the cooling circuit. According to customer's requirements, all processes are generally performed automatically.

The number of the balls in circulation amounts to between 10 and



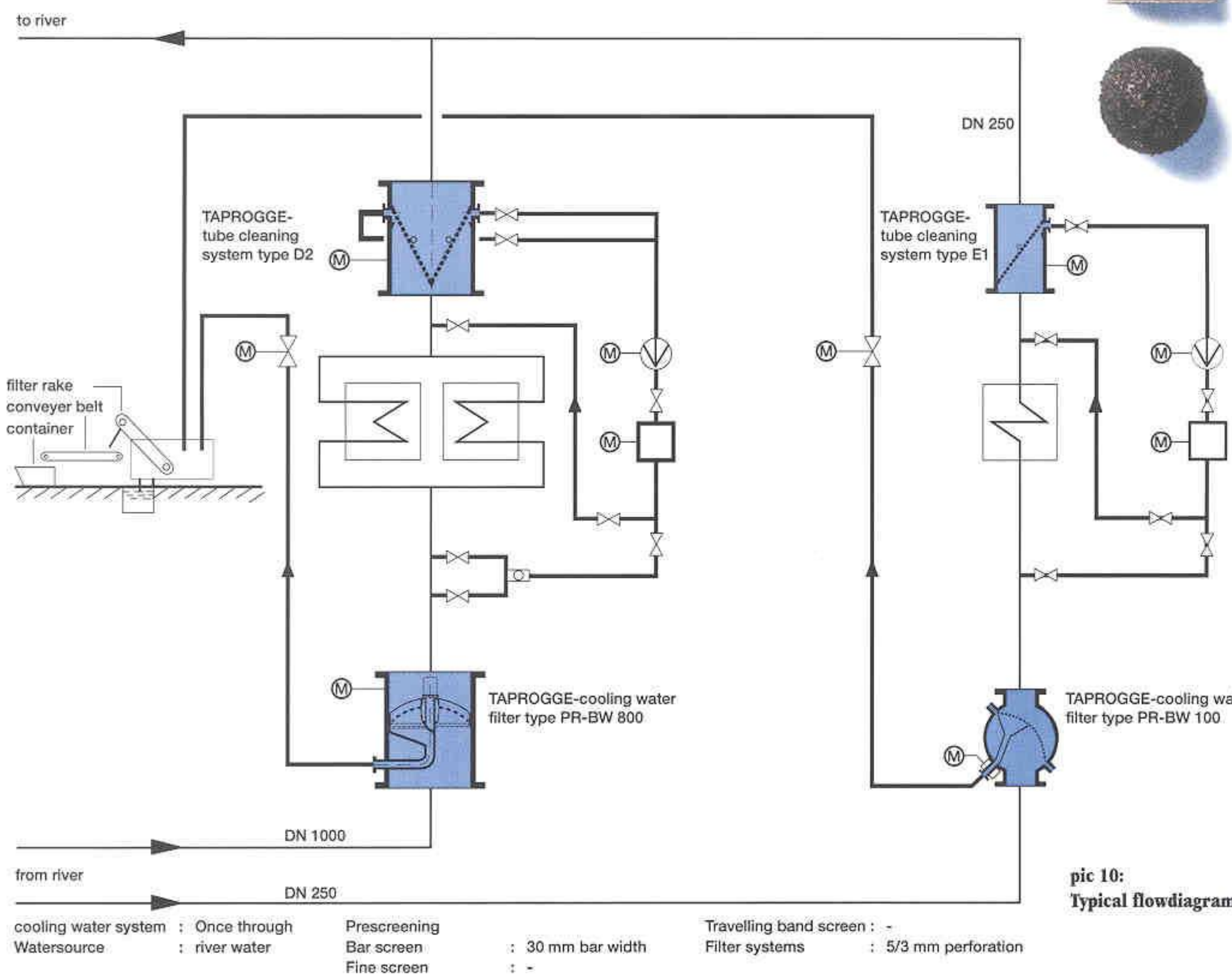
pic 7:
ball recirculating unit

pic 8:
CTCS-strainer section

30% of the number of cooling tubes of one pass. This number is sufficient to safeguard smooth heat exchanger operation.

To make sure that all tubes are cleaned and not only certain sections of the tube sheet, special measures are taken for an even distribution of the balls. On one hand, sinking or rising balls are developed to influence the specific weight of the sponge rubber balls. On the other hand, an even distribution of balls is effected by the installation of orifices or distributors. The simple proof of the effectiveness of the procedure is furnished by the heat exchanger reaching its original terminal temperature difference again because it now has at its disposal the full exchanger surface.

pic 9:
Tube analysis after application of a tube cleaning system, titanium with manganese layers.
From top to bottom:
original condition
100 ball passages
800 ball passages
corundum ball



pic 10:
Typical flowdiagram

pic 6:
various types of cleaning balls

3.2 The Cleaning Ball

The cleaning balls must in any case have a larger diameter than the inner diameter of the cooling tube. This means that balls without such an oversize will not have a cleaning effect. Only due to this size are deposits detached and carried away. The detachments do not penetrate into the balls, nor do they foul them, but are detached by means of a hydraulic jet which is created in front of the ball, and are driven through the tube.

In the course of numerous ball passages, the balls wear down and get smaller. Once they are smaller than, or equal to, the tube inner diameter, they have to be replaced. Depending on the kind and degree of fouling, this may be necessary after about four to six weeks, a mean value which may considerably be surpassed, but also remained under.

The selection of the optimum cleaning ball depends on many factors:

- tube material
- kind and degree of fouling
- temperature
- design of waterboxes
- cooling water velocity in the tube
- type of inhibitors, etc.

To respond to different demands, numerous ball types have been developed: there are balls with and without special coatings, such as plastic granulate, corundum, or special polishing balls, as well as high-temperature balls. All of them are available in different hardness degrees.
Figure 6 shows from left to right:

- standard sponge rubber ball
- sponge rubber ball with low sinking velocity
- sponge rubber ball for particularly high demands
- sponge rubber ball with plastic granulate coating
- sponge rubber ball with addition of polishing agent
- two sponge rubber balls with corundum coating.

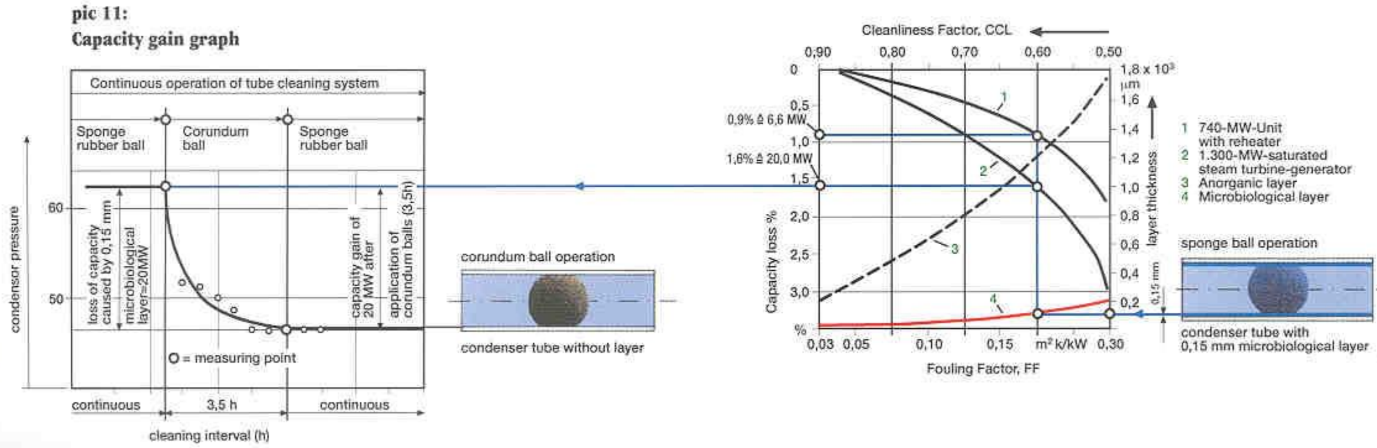
Should the heat exchanger be used for different tasks, the cleaning system can be adapted by switching to suitable cleaning balls.

The following picture shows that already microbiological layers in the tubes of 0.15 mm causes capacity loss of 20 MW at a 1300 MW unit, and of 6.6 MW at a 740 MW unit.

After the application of TAPROGGE corundum balls over a period of 3.5 hours, the condenser pressure decreased by 16 mbar, and accordingly the turbine performance rose by 20 MW

Capacity gain of 20 MW at a 1300 MW-Unit after the application of corundum balls over a period of 3,5 hours

pic 11:
Capacity gain graph



4. Task of the Cooling Water Debris Filters

The automatic backwash filters have the task to mechanically clean the cooling water, so that cooling tubes and tube sheets of the heat exchanger installed downstream remain free from obstructions, the tube cleaning system works impeccably, and tube corrosion caused by clogging is avoided.

Upstream of plate-type heat exchangers, backwash filters with a filter fineness of 1-2 mm are installed, often in combination with backwash devices for the plate-type heat exchanger itself. At a filtration grade of 200 – 300 µm, a backwash device can be renounced on. The filters essentially reduce the suspended solids contained in the cooling water, so that the exchanger surface fouls more slowly and manual cleaning can be performed at longer intervals.

4.1 Problems

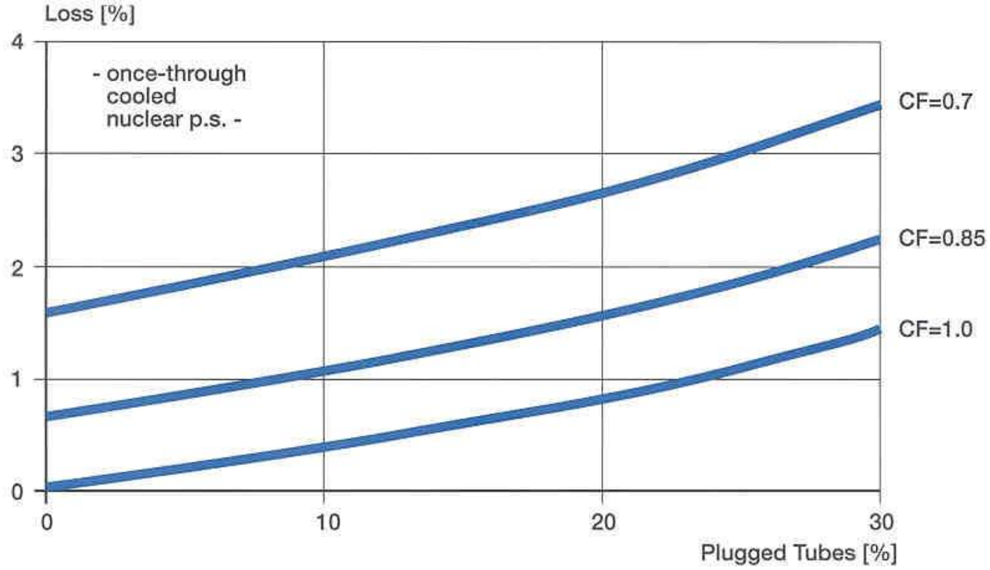
There is a great risk to tubular, or particularly to plate-type heat exchangers from coarse particles contained in the cooling water. Those particles block the cooling tubes or canals in the plate-type heat exchangers partially or completely.

Clogged tubes and canals reduce the available heat transfer surface of the heat exchangers. Through the limited cooling water flow in the blocked tubes, the growth of microfouling is particularly fostered. Cleaning of such tubes by sponge rubber balls is possible only to a limited extent, if possible at all. In addition to that, erosion and crevice corrosion may be initiated in the vicinity of the jammed coarse particles.

Already 15% of clogged tubes increase the specific heat consumption per kWh by ☞

approx. 0.15% and reduce the turbine capacity by approx. 1.5 MW (in the case of a 800 MW unit).

From tube cloggings, cleaning balls are retained, so that the number of circulating balls becomes correspondingly smaller. The fouling of the heat exchanger surface and thus the condenser pressure increases accordingly.



pic 12: Loss of Turbine Efficiency versus Number of Plugged Tubes and Cleanliness Factor CF of Non-Plugged Tubes

4.2 Operational Principle of the Cooling Water Debris Filters

All substances in the cooling water that are larger than the perforation diameter in the filter section or the gaps in the filter cartridges are retained in the filter. From the increasing fouling load of coarse debris or suspended matters on the filter surfaces, the pressure drop increases. Once the differential pressure across the filter section or the filter cartridges reaches the limit value pre-set at the differential pressure manometer, the backwash valve is opened in the automatic backwash filters, and the backwash rotor is set in operation.

Due to the differential pressure between the filter and the end of the backwash pipe, a partial volume flow of the already filtered cooling water flows from the filter section or the filter cartridge to the end of the backwash pipe, transporting the macrofouling and suspended matters that have accumulated there out of the filter.
The backwash time of the automatic backwash filter amounts to between approx. 30 seconds and several minutes. In the case of larger perforations, the backwash flow is about 3% of the entire cooling water volume; if the filter perforation is smaller, this value increases correspondingly.

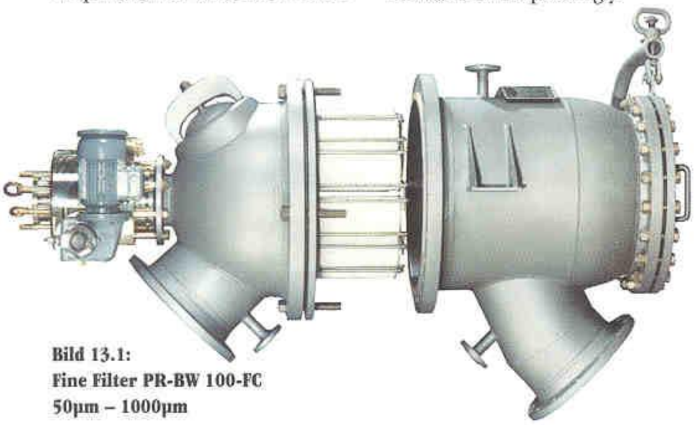


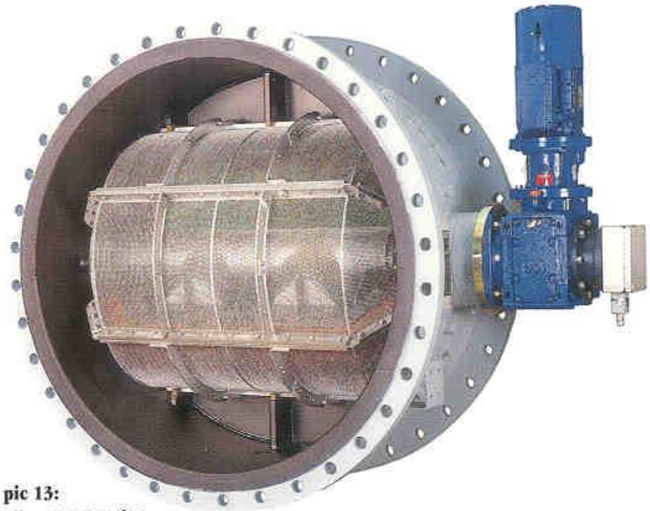
Bild 13.1:
Fine Filter PR-BW 100-FC
50µm – 1000µm

The backwash procedure is completed by switching off the backwash rotor and closing the backwash valve.

Via conventional prescreening systems (e.g.: drum screens, travelling band screens with safety valves) which wear down quite quickly, macrofouling enters into the main cooling water pipes.

Mussel larvae are transported into the piping system and have the opportunity to grow in zones of lower velocity, all the more so as a continuous food flow is passing along.

In addition, corrosion products escape from the cooling water pipes which may be several hundreds of metres long, and get in front of the condenser.That is the reason why cooling water debris filters, whenever possible, are installed immediately upstream of heat exchangers or condensers.



pic 13:
Filter PR-BW 600

5. Economy of mechanical tube cleaning systems

The equipment of turbine condensers with automatic backwash filters and tube cleaning systems to reach a better vacuum resulted in ameliorations of the terminal temperature difference of 0.5 up to 3%.

In many power plants, the addition of biocides could be reduced or completely avoided. Manual cleaning of condensers could be eliminated.

Through the application of high-performance debris filters, the installation of drum screens and travelling band screens was avoided in some plants, with only bar and fine screens being necessary for prefiltration.

Due to different parameters, such as cooling water composition, plant configuration and demands on availability, the economic application of debris filters and tube cleaning systems for heat exchangers and their grade of automation is to be checked for each individual case.

6. IN-TA-CT®

The INTEGRATED TAPROGGE CONCEPT (Fig. page 1) comprises, in addition to the components tube cleaning systems and automatic high-performance debris filters as mentioned before, also the TAPROGGE products

1. **TAPIS®**
   TAPROGGE Air Powered Intake System

and

6. **CMS**
   Condenser Monitoring System

which will briefly be described hereinafter. The sections 5 „Tube Sheet Cladding" and 7 „Eddy Current Testing" are also part of the entire concept but will not be treated here.

6.1 TAPIS®

6.1.1 Tasks of TAPIS®

The TAPROGGE Air Powered Intake System **TAPIS®** serves for the extraction of cooling water out of the sea, a river, a canal or a harbour. In contrast to conventional concepts where the cooling water intake is realized in several steps, i.e. in form of rakes and/or travelling band screens / drum screens, **TAPIS®** combines the mechanical cooling water treatment upstream of the cooling water pumps in only one step. Therefore, **TAPIS®** replaces the traditional prescreening system.

The genuine conceptional idea leading to the development of **TAPIS®** originates in the fact that the condenser/heat exchanger to be cooled requires cooling water that is free of coarse debris – a demand which had to be covered. Whereas conventional systems try to meet this by removing from the cooling water coarse particles in form of fish, jelly fish, pieces of wood, polystyrene, mussels, algae etc., which subsequently require disposal, with **TAPIS®** those particles remain in the water – cooling water is withdrawn from the mixture „coarse particles - water" and not vice versa.

6.1.2 Functional Description

For the extraction of water from the sea, rivers or lakes, polyhedrally shaped screens are installed below water level and connected to a closed pump well via supply pipes. The intake velocity of the water into these polyhedral screens is only <0.5 m/s, thus selected low enough to ensure that marine organisms, like fish, algae or jelly fish, are not impacted.

The screen design, as supporting construction, consists of stainless steel (1.4439 for seawater, 1.4401 for fresh water), and serves to incorporate the screen elements which are selected specifically for the fouling to be expected. Those elements are preferrably made of plastic DELRIN with cling-free screening media. Based on our experience, only cling-free offers the best protection from fibrous debris. That is why seagrass, algae etc., jelly fish, mussels, starfish, pieces of wood, or man-made debris such as plastic bags, foils or cans, do not present any problem for **TAPIS®.**

When water is withdrawn from a river, lake or the sea, **TAPIS®** allows a reliable water passage to the cooling water system by holding back all debris of sizes larger than the perforation.

To remove this accumulated debris, the physical property of air in water is made use of, which means that by way of a compressor, a certain volume of air is compressed in an air receiver to 10 bar, and is then transported into the inside of the polyhedral screen in the form of an air pulse.

Led through the specially arranged air nozzles, the air removes the debris from the screen surface, first by a pressure impact and secondly by the lifting force of the air cloud. The current of the sea or the river will transport the debris away from the intake screen; however, the volume of air also ensures a widely spread distribution of the air-backwashed debris.

Once the pressure inside of the air receiver has fallen below a certain value (in accordance with the installation depth of the intake screens), the pneumatic valves close and the compressor starts filling the air receiver. When the pressure inside of the air receiver has reached 10 bar, the compressor stops, a signal lamp on the control panel indicates „ready for flushing", and the process may be restarted.

Economy is achieved through the simple design that results in a screen without moving parts, minimum maintenance requirement and simplified installation.

Environmentally friendly, **TAPIS®** protects aquatic life and renders compliances with environmental regulations easier.

Retrofit possible, that is to say existing, traditional intake machinery systems can be replaced by **TAPIS®**.

pic 14:
Polyedral intake screen

6.2 CMS – CONDENSER MONITORING SYSTEM

6.2.1 Task of CMS

The correct application of tube cleaning systems and debris filters is a precondition for optimum operational results. The monitoring of the tube cleaning system is of particular importance, because the formation of layers can be avoided only through continuously efficient tube cleaning. For this purpose, circulation and effectiveness of the cleaning balls must permanently be monitored. Per-turbations of the ball circulation must immediately be identified and avoided. Worn-out balls have to be replaced upon reaching a minimum effectiveness.

Experience has shown that the necessary monitoring of the tube cleaning system is not always safeguarded. The measuring technology normally available in a power plant does not always allow the exact and quick assessment of the condenser condition.

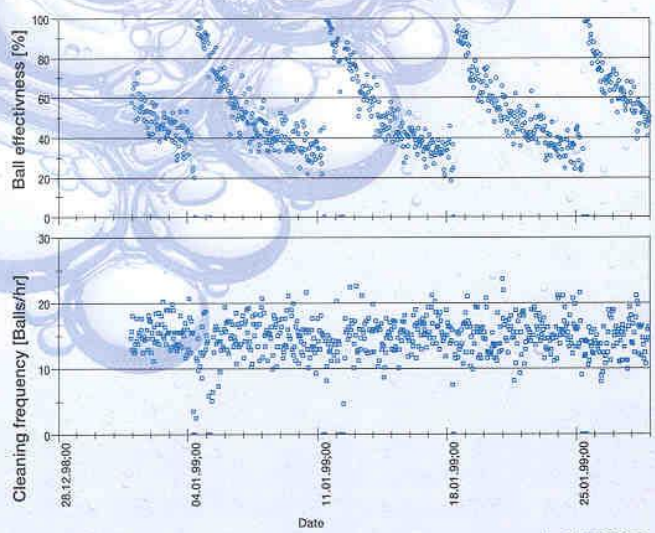
That is why tube fouling which is a result of temporarily insufficient cleaning is often not identified. In such a way it is understandable why fouling and layers are detected only during a condenser inspection yet have in the meantime often caused considerable performance loss and corrosive defects. The main reason is the late exchange of cleaning balls.

6.2.2 Solution

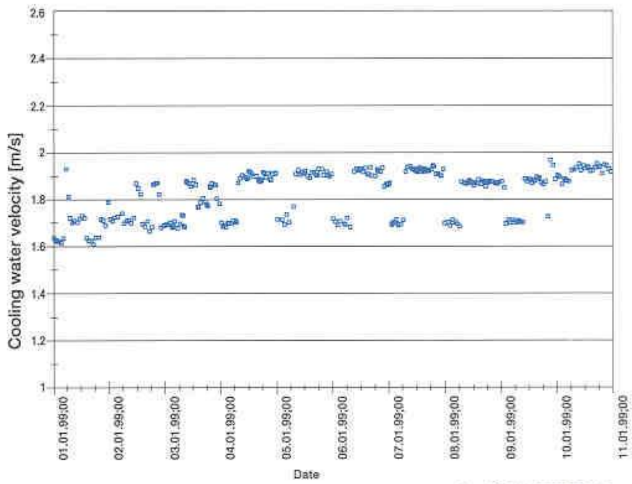
As a solution to this problem, TAPROGGE has developed the modulardesign THERMO-VEBROM for condenser monitoring.

Basis is a measuring technology which has been developed especially for this purpose. It offers an accurate and very quickly reacting temperature measurement at inlets and outlets of individual condenser tubes. By measuring and evaluating temporal temperature profiles at these individual tubes, the following monitoring functions are realized:

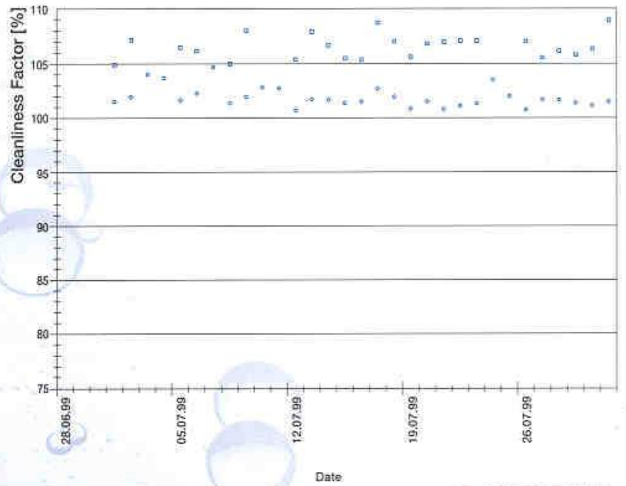
1. Monitoring of the recirculation and effectiveness of cleaning balls by recording and analyzing temperature signals at tube outlets (BROM).
2. Determination of the cooling water velocity in the individual tube by comparison of temperature profiles at tube inlet and outlet (correlative flow measurement) and monitoring of the heat transfer coefficient (k-value) by additional measurement of the steam temperature. Special condenser areas which are particularly susceptible to fouling can be monitored specifically (THERMO-VE).
3. Recording and evaluation of all measured data by means of a special software in the measuring panel.
4. Remote transfer of data to the control room of the power plant or, by modem and telephone line, to the TAPROGGE Service Depart-ment where an analysis of the condenser condition is performed. Such a selective assessment guarantees highest availability of the entire plant.



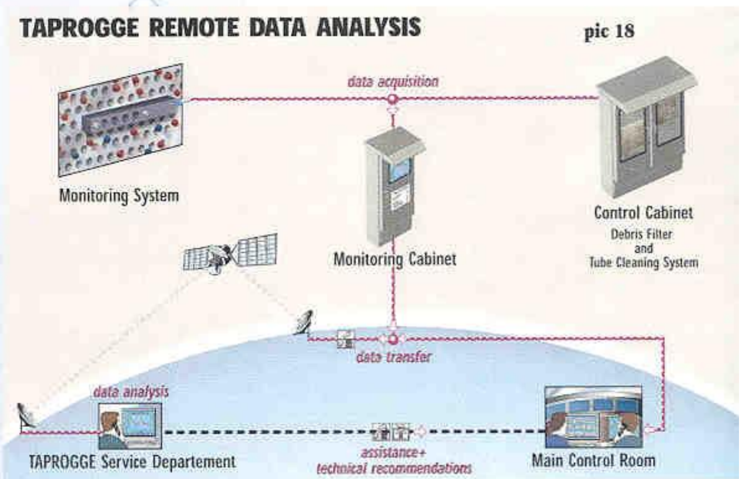
pic 15: BROM



pic 16: THERMO-VE



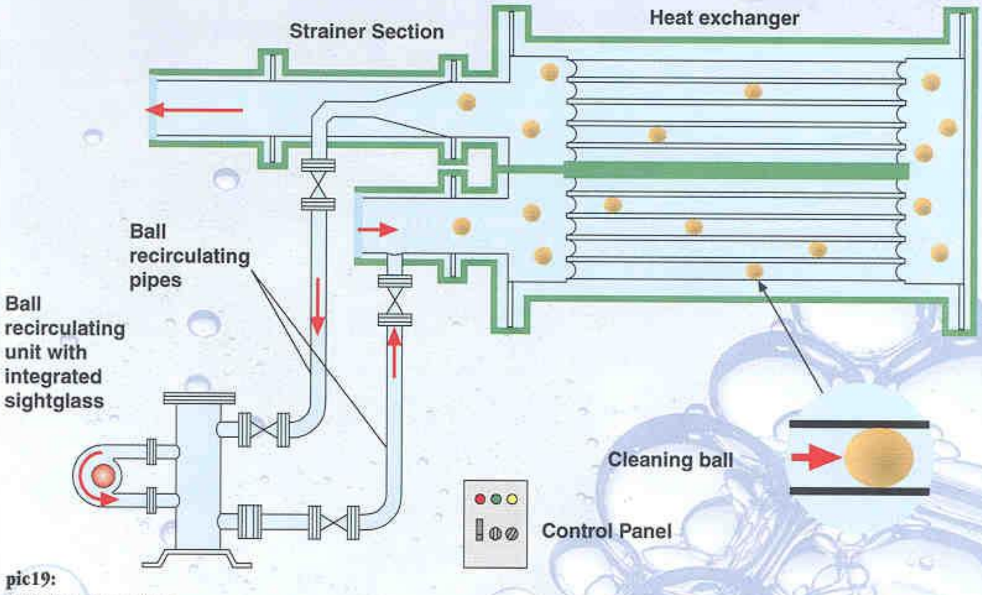
pic 17: THERMO-VE



pic 18

7. Tube Cleaning and Filter Systems for Air Conditioning and Chemical Industry

In the sectors air conditioning and chemical plants, different concepts are required because considerably smaller heat exchangers are applied here. Cooling water connection diameters between DN 500 and DN 80 are common, whereby it is also possible to operate the cleaning systems off-line. For this field TAPROGGE offers two different, low-cost systems.



pic19:
CCS-Cleaning system

7.1 CCS for on-line operation from DN 500 to DN 150

Function:
By way of fixed pipes or flexible hoses (mobile plant), the individual heat exchanger, or group of heat exchangers, is connected to the cooling water inlet pipe and to the strainer section which is installed in the outlet pipe directly downstream of the heat exchanger. The system is started via the control panel. Its operation may be manual or automatic, with the CCS always operating according to clock pulses, in batch operation. The cleaning balls do not enter through the pump itself, but are either kept in the ball collector by means of a movable ball catching flap, or are re-fed from the ball collector to the heat exchanger in a certain time interval. The ball transport can be monitored through the integrated sightglass in the collector cover.

Given the fact that the strainer section is equipped with a fixed screen, any macrofouling which may eventually occur has to be removed by a filter upstream of the heat exchanger. For this purpose, TAPROGGE has developed various automatic backwash filters, e.g. the Dynamicfilter with a filter fineness of 50 µm up to several millimetres.

pic 21:
CCS-Strainer section

pic 20:
CCS-Ball recirculating unit

pic22:
Dynamicfilter DN 150, 50µm

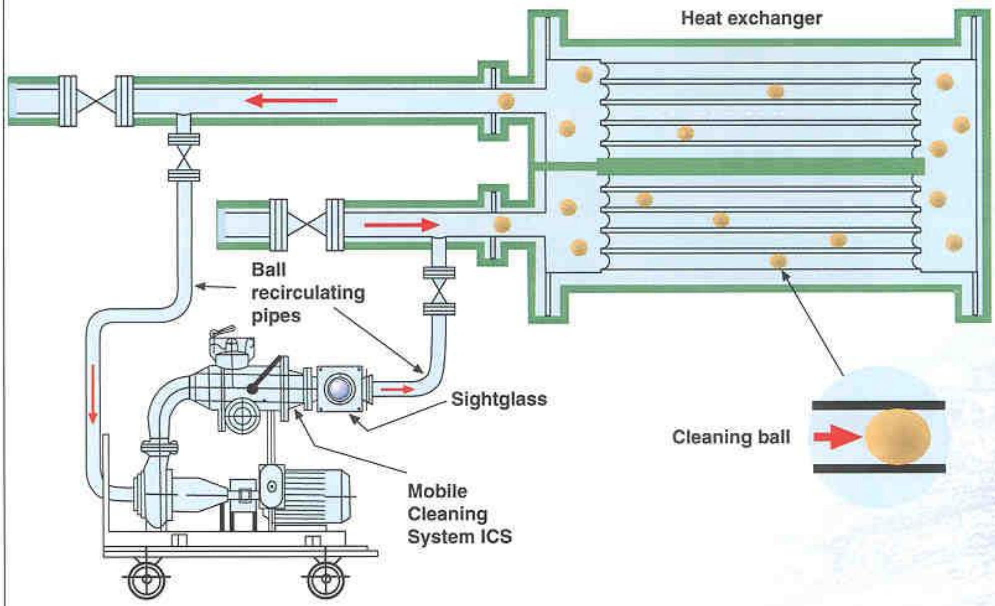
pic 23:
Dynamicfilter DN 300, 1000µm

7.2 ICS for off-line operation from DN 150 to DN 80

The ball transport pipe of DN 80 is dimensioned similar to the main cooling water pipe. If it was operated on-line, it would thus transport the same heated cooling water flow from the outlet pipe of the heat exchanger back to its inlet which would sensibly disturb the heat balance, so that the desired terminal temperature difference would not be reached.

That is why the ICS can be operated only off-line. It does, therefore, not require any strainer section but only a debris separator. The cleaning balls remain in the new short circuit. However, the cooling water pump has to overcome all resistance of this circuit including heat exchanger. A filtration of the cooling water is not necessary.

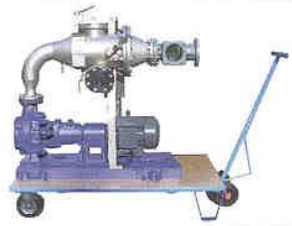
The ICS is suitable for intermittent operation, which means if cleaning can or must take place outside of production time, if high temperatures or pressures prevail, or if the product is aggressive or toxic.



pic 24:
ICS-Mobile Cleaning System

Function
In the case of the mobile ICS, the individual heat exchanger, or the group of heat exchangers, is connected to recirculating and output pipes by flexible hoses, the cooling circuit is shut off, and the short cleaning circuit is opened and filled. The system is now ready for operation and is started via the integrated switch. Operational mode is either manual or automatic. The debris particles can be controlled through the sightglass.

A nozzle in the separator renders debris discharge possible.



pic 25:
ICS-Mobile Cleaning System

8. Summary

Automatic tube cleaning systems with sponge rubber balls have proven successful in nearly all fields of condenser cleanliness.
Subject to correct layout taking all requirements into account, and on condition of the careful operation of the tube cleaning systems with sponge rubber balls and of the automatic backwash filters, manual cleaning of heat exchangers is no longer necessary.
The economy of tube cleaning systems for smaller heat exchangers, e.g. in chemical plants, can be demonstrated less easily than is the case with turbine condensers of major power stations. Yet also specially developed small systems for reduced requirements have stood the test, and there were good chances of amortization within adequate periods.
Often the lifetime of a heat exchanger can be extended considerably by merely installing coarse and fine filters.

In many sectors of industry, TAPROGGE Systems are indispensable and represent the latest state of the art.

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