

Online Cleaning of Condenser Tubes

W. Czolkoss

TAPROGGE Gesellschaft mbH, Wetter (Ruhr), Germany

Summary

The online cleaning of turbine condensers by means of sponge rubber balls (TAPROGGE process) has become the state of the art for the avoidance of cooling water-side deposits in tubes. For the different fouling problems various types of cleaning balls have been developed. The effectiveness of the process depends not only on the correct selection of cleaning balls but also on the proper operation of the system and the trouble-free function of all components.

After describing the different fouling problems this lecture will give a short survey of the individual solutions and the historical development. Subsequently the TAPROGGE process and the selection of the individual cleaning balls for the relevant application will be explained. Finally, possible malfunctions and failures of system operation will be treated. Advice and recommendations for error tracing will be given, as well as for the monitoring and optimization of tube cleaning.

1. Fouling problems in condenser tubes

On the cooling water-side surfaces of condenser tubes deposits and covering films may develop that impair heat transfer and cause corrosive damages. Such undesirable layers and deposits are also referred to as "fouling". The most essential fouling mechanisms are:

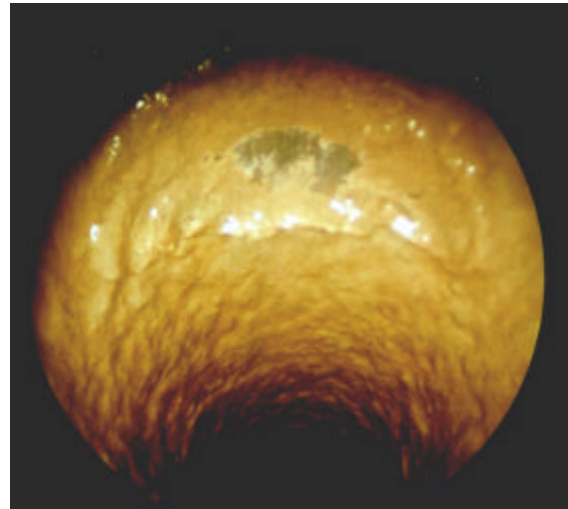
Deposits of suspended matter from the cooling water

Depositing of suspended matter principally depends on the flow velocity and concentration of suspended matter of the cooling water.

The flow velocity should not fall below 1.5 m/s; with solid matter contents exceeding 15 mg/l continuous tube cleaning is required [1].

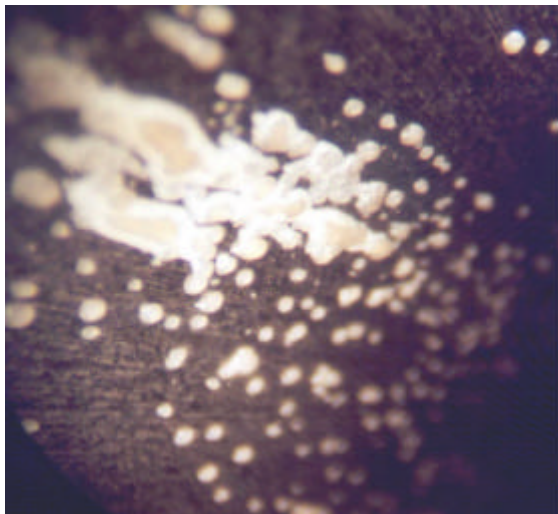
Biological Fouling (Biofouling)

Especially with titanium and stainless steel tubes, settlements of micro-organisms develop on the tube surfaces engendering slimy layers and dramatically impairing the heat transfer. With stainless steels, pitting corrosion can be caused. Copper alloys are less affected due to the toxic effect of copper [3, 4].



Crystallization of Salts (Scaling)

Once the solution equilibrium is surpassed, e.g. caused by the temperature increase in the condenser tube, salts may crystallize and form very hard scales. One typical example are calcium carbonate scales.



beginning calcium carbonate precipitation



hard calcium carbonate scale

Corrosion Products

With copper alloys undesirably thick oxide layers and deposits of other corrosion products may happen impairing heat transfer and causing local corrosion [2, 5].

2. Survey of cleaning processes

2.1 Offline process

By various offline processes deposits that have developed during operation may be removed. Those processes require a shutdown of the turbine and draining of the condenser and are thus used only during regular inspections for maintenance purposes, or during unit shutdowns. The costs for these cleaning works may exceed DM 5.- per condenser tube. Added to this are losses and corrosion damages already occurred during operation, and limitations of availability.

Flushing

By flushing of individual tubes with pressurized water (fresh water), salt residues and – with sufficient pressure – loose mud deposits may be removed to a limited extent.

Tube obstructions are eliminated. Strongly adhesive deposits, biofouling, scaling and corrosion products are not removed by flushing.

Projectile Shooting

There are different methods according to which brushes, plastic bodies or metal scrapers are shot through the condenser tubes by compressed air or pressurized water. By this process even stronger adhesive deposits of suspended matter and, to a limited extent, also slimy biofouling can be removed.

Removing scaling and corrosion products is possible but not in any case. The metallic scrapers that are used for this purpose may damage the tube surface whereby new deposits may be aggravated.

Jet Cleaning

According to the water jet high pressure cleaning method probes are inserted into the tube from which one or several water jets with very high pressures (up to approx. 1000 bar) penetrate. In this way even strong scaling layers may be removed on condition that the high pressure cleaning is performed carefully (slow insertion of probe, sufficient pressure).

Pickling

Pickling serves for the removal of scaling layers and corrosion products by means of organic or anorganic acids. As, with big turbine condensers, it is very difficult to perform the pickling and dispose of the pickling solution, this method is used only seldom in this field.

Boring

If hard incrustations (e.g.: calcium carbonate) have grown to a thickness of more than 1 mm, mechanical boring may be the last chance to remove them. For this purpose special tools and processes have been developed. However, there is always the risk of damage to the tubes.

2.2 Online Process

By means of the online cleaning processes the formation of tube fouling during operation shall be avoided. For turbine condensers principally 3 processes are used:

Brush Cleaning System (MAN process)

According to this process both ends of every condenser tube are provided with cages that contain brushes. By the reversal of the cooling water flow direction the brush is flushed from the relevant cage through the tube into the other cage and, in doing so, is meant to clean the tube. However, this process was not successful due to its small cleaning effect, the regularly required flow reversal and other problems. The installed systems were exchanged against TAPROGGE Systems.

ABEKA System

According to this principle hard, spherical cleaning bodies – smaller in diameter than the inner tube diameter – are flushed through the tubes with the cooling water. By alternating wall contacts they shall keep the inner surfaces free from deposits. The balls are caught by a funnel screen in the cooling water outlet pipe, sucked off by a pump, and re-injected into the cooling water inlet pipe. These systems were common in the former Eastern bloc. Their function and cleaning effect were largely insufficient. Nearly all ABEKA installations were replaced by the TAPROGGE Systems.

TAPROGGE Process

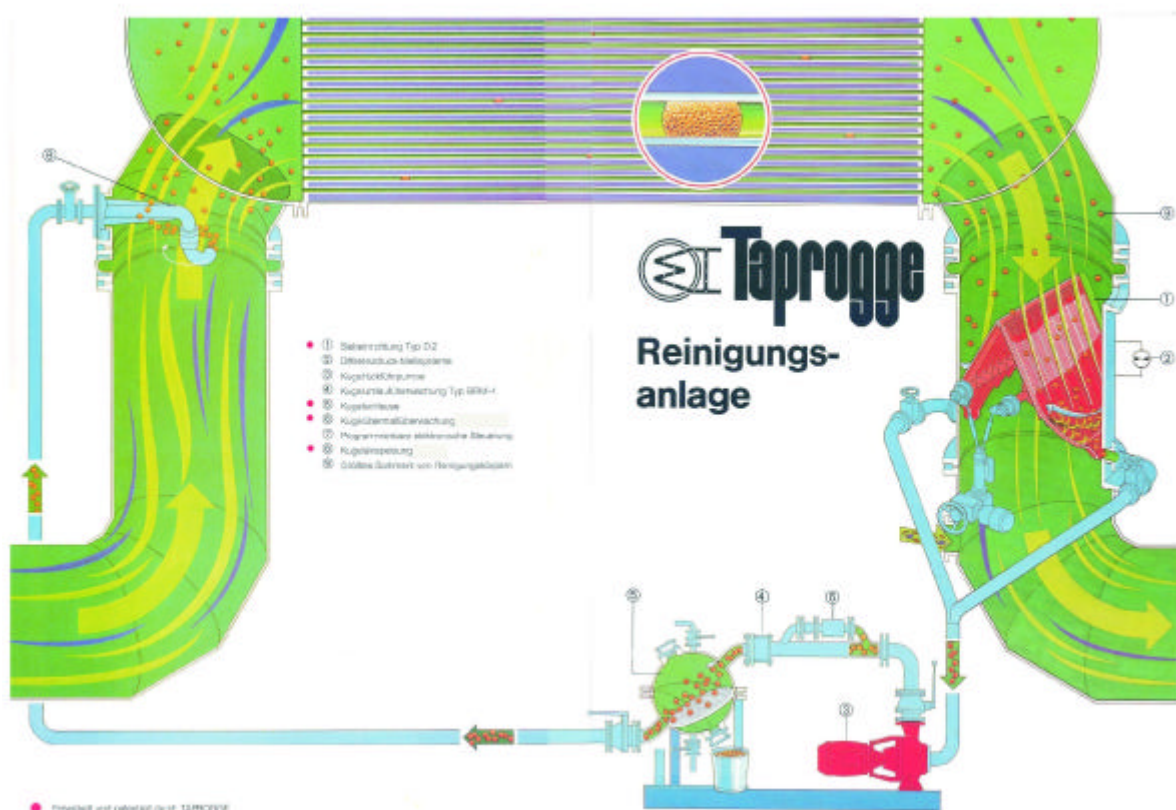
The TAPROGGE Process was developed and patented in 1950. Applied for this process are cleaning balls of elastic sponge rubber that are larger than the inner tube diameter. Given the fact that they have contact with the cooling tube over its entire length and diameter their cleaning effect is by far better than with the aforementioned ABEKA system. The strainers in the cooling water outlet can be turned, so that it is possible to clean them by backwashing.

The TAPROGGE System is worldwide accepted and represents the state of the art. Its function will be explained hereinafter.

3. The TAPROGGE Process

3.1 Operating Principle

Sponge rubber balls are injected into the cooling water flow upstream of the condenser and are flushed through the condenser tubes. Their diameter and hardness are adjusted to the inner tube diameter, so that the differential pressure between tube inlet and outlet can push the balls through the tube. In this way they have a maximum contact pressure against the tube wall, however without getting stuck in the tube.



Installed in the outlet pipe is a strainer section that leads the balls to an extraction point. The screens are movable and can be backwashed by turning. In such a way fouling can be removed which would have otherwise hindered the balls from rolling down on the screen.

From the extraction point the balls are guided into the ball collector by a special ball recirculating pump. The balls get into operating position by the cooling water through the collector to the ball injection point. By closing a screen, a flap, respectively, the balls are separated from the cooling water flow in the ball collector ("caught") and, subsequently, can be taken out and replaced.

The number of circulating balls (ball collector charge) is generally determined in such way that every tube is cleaned by a ball every 5 minutes. Depending on the ball circulation time, the collector charges approximately correspond to 10% of the number of tubes with single pass condensers.

The tube cleaning system is normally operated in continuous mode – only in exceptional cases, such as, with ferrous sulfate dosing, or perturbed formation of covering film, will it be operated discontinuously, for example during 1 hour per day. Depending on operational circumstances and the condition of the inner wall surface the balls have to be replaced every 2 – 4 weeks. Further information in this respect is provided under [6].

3.2 Cleaning Balls

For the various fouling problems and applications a large-scale range of different cleaning balls have been developed. All types are based on sponge rubber of vulcanized natural rubber. Other materials have not proven successful for the use as cleaning ball.



By the addition of polishing or grinding agents, or by coatings, abrasive effects varying in strength may be reached. With big waterboxes cleaning balls of different specific weights can be applied to support their uniform distribution. For high temperatures (80 – 120°C), or with chemically burdened cooling water, special rubber mixtures are required.

For the cleaning of turbine condensers the ball types as indicated below are mainly used:

Sponge Rubber Ball

Standard ball for tubes of copper alloys with low salt content cooling water that does not tend to scaling or biofouling. Sponge rubber balls are available in 2 options: with the "S" type the skin that is formed on the ball surface as a result of the production process is ground off. As for the "L" type, this type has an open-cell skin as a result of special production measures; the skin thus remains on the ball.

Polishing Ball

The special feature of the "P" type ball is the addition of fine polishing agent in the ball material. With growing ball wear more and more of this polishing agent enters to the ball surface and intensifies the cleaning effect. Moreover, there is a polishing effect on the tube surface. The wear caused to the tube material is negligible.

Due to its intensified cleaning effect the polishing ball masters even biofouling by micro-organisms that nearly always occurs with titanium and stainless steel tubes. The regular sponge rubber ball is not able to remove such fouling.

That is why the polishing ball is the standard ball for stainless steel and titanium tubes. Additionally it is applied for tubes of copper alloys to smooth the surface in the case of increased ball wear.

If, temporarily, a stronger polishing effect is required for tube smoothing, "TP" type balls with a coating of polishing agent can be applied. If they are used in tubes of copper alloys for a limited period, firmly adhesive inherent oxide cover films can be kept.

As the polishing balls are applied due to their intensified cleaning effect, they should wear down to a residual oversize of 0.5 mm in relation to the inner tube diameter only and then be replaced.

Granulate Ball

The "G" type granulate ball is a sponge rubber ball coated with plastic granulate. The hardness of the granulate is below that of the tube materials. It can thus master harder deposits than the sponge rubber or polishing ball without attacking the tube material – which means that it acts in a fouling-abrasive way. Normally the softer plastic granulate will be worn

off within one day. In that case the ball will have only a weak cleaning effect due to its small oversize and should be replaced at short notice.

The granulate ball can be applied for stainless steel and titanium tubes in completion to the polishing ball if, for a limited period, a stronger fouling-abrasive effect than achievable by the "P" type polishing ball is required. The granulate ball can also be used with copper alloys for the temporarily intensified cleaning without harm to the covering film.

Corundum Ball

The corundum ball is coated with very hard corundum. Therefore it has an abrasive effect on the tube material. Corundum balls are applied for all tube materials to remove deposits and layers (e.g.: calcium carbonate), and, with copper alloy tubes, to eliminate corrosion products and perturbed covering films to achieve a basic cleaning before a new covering film is built up, as well as for tube polishing.

The "R" type corundum ring ball is coated only with a ring of corundum whereas the "T" type total corundum ball is coated on its entire surface.

Type, cleaning frequency and number of corundum balls to be injected must be determined by TAPROGGE for each individual application on the grounds of a cleaning test of tube samples, a condenser inspection, or according to empirical values [6].

How quickly the corundum balls lose their abrasive effect by the wear-down of the corundum particles depends on the surface condition of the tubes to be cleaned, as well as on the plant-specific conditions. Regularly the abrasive effect will be used up after an operating time of 1 – 3 days. At the beginning of a corundum ball cleaning with very rough deposits it may even be appropriate to replace the corundum ball charge already after one shift (8 hours).

Through the application of corundum balls at copper alloy tube materials the release of copper to the cooling water may be temporarily increased. In such a case, limit values have to be observed and, particularly with cooling tower circuits, the corundum ball cleaning has to be adjusted to the operational mode and conditioning of the cooling water circuit.

In addition to the type of cleaning ball that is governed by the cleaning task, *diameter* and *hardness* must be stipulated. These values have to be adjusted in such a way that the cleaning ball engenders a maximum contact force acting against the tube wall without getting stuck. For their determination the cooling water flow rate must be indicated, in addition to tube diameter and length, and number of tubes. If necessary, circulation tests must be performed with different balls to find out the optimal solution. A wrong selection of cleaning balls may entail tube blockages or reduced cleaning effect. Resulting thereof are quality requirements for the cleaning balls in terms of uniform hardness and diameter with small tolerances.

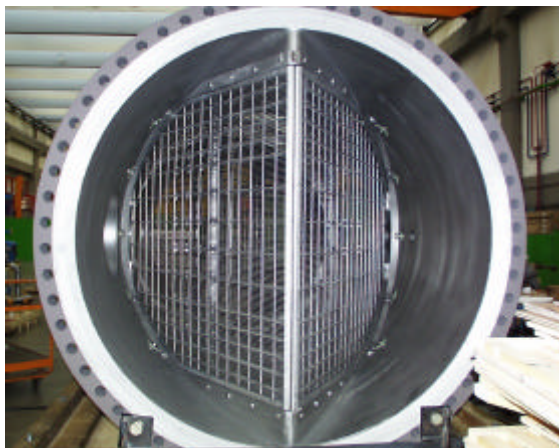
3.3 System Components

The components of a TAPROGGE Cleaning System are determined for the individual application. They consist of the following:

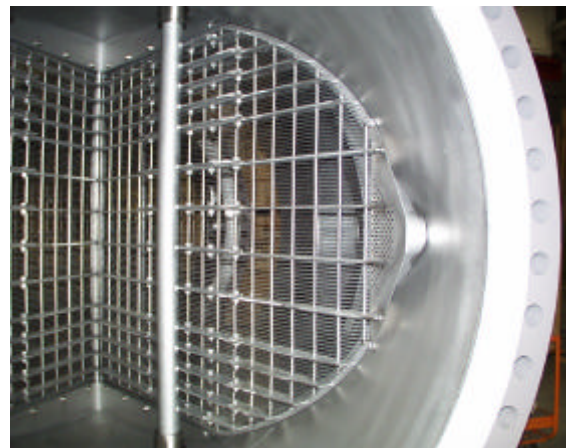
Strainer Section

The strainer shall separate the balls from the cooling water and guide them to the extraction point. It has a composite structure made of edge-wise screen bars. This structure guarantees high rigidity and corrosion resistance at low pressure loss. For the selection and lay-out of the strainer section the cooling water velocity and flow profile upstream of the strainer section are evaluated and, based on those data, the screen angle in relation to the pipe axis as well as the gap width are fixed.

The differential pressure measuring system controls the pressure loss across the screens. An increase beyond a limit value signals screen fouling. In this case the screens must be washed by swinging them open, after the balls have been caught.



view in flow direction



view against flow direction

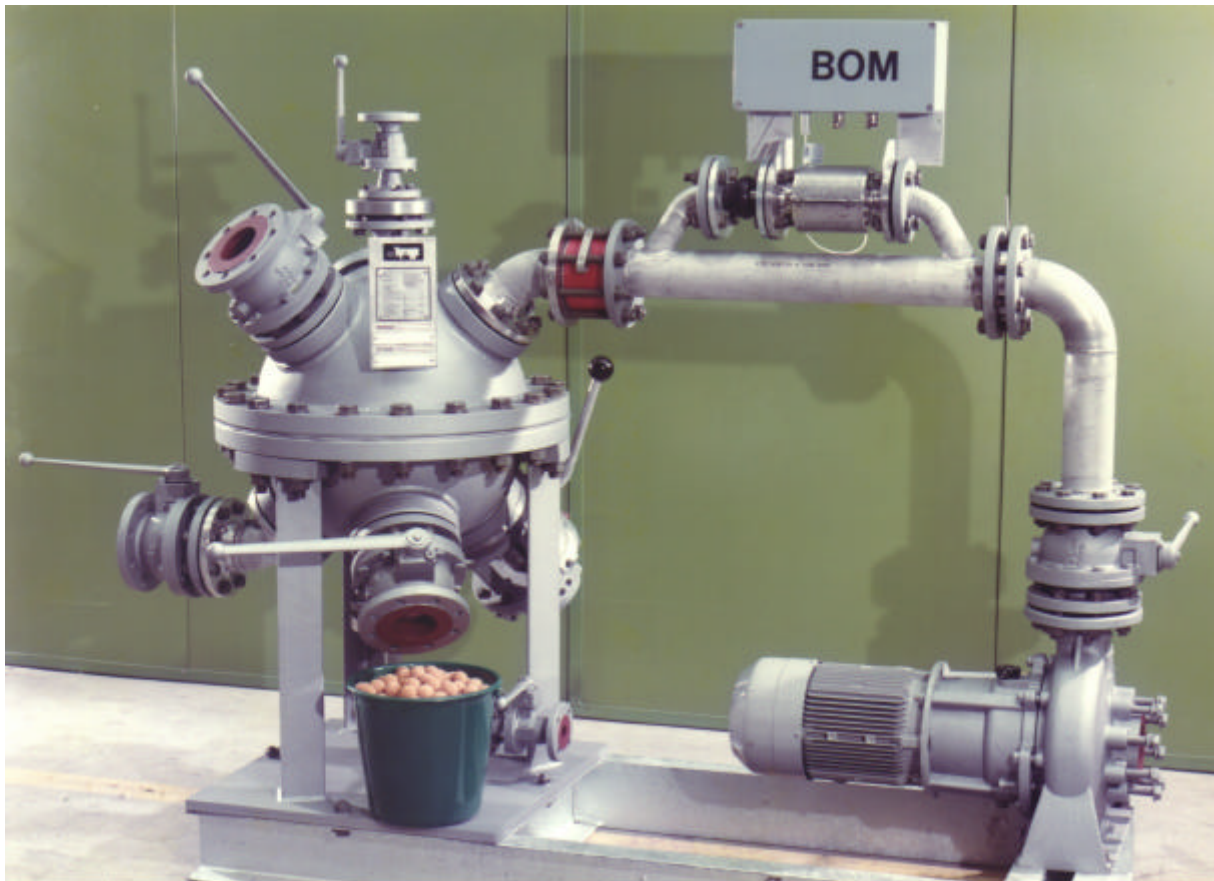
Ball Recirculating Pump

The ball recirculating pump engenders the flow necessary for the ball transport from the extraction of the strainer section at the condenser outlet through the collector to the ball injection.

It is executed as a special non-clogging pump with big passage for smooth ball transport and is rated in correspondance with the required pump head and capacity.

Ball Collector

In the ball collector the cleaning balls can be caught by closing the catching flap, turning a built-in screen, respectively, and, upon isolating the inlet and outlet, can be taken out and replaced. A non-return valve avoids that balls roll back after the ball recirculating pump has been switched off. Collector type and size are determined by the required number of balls.



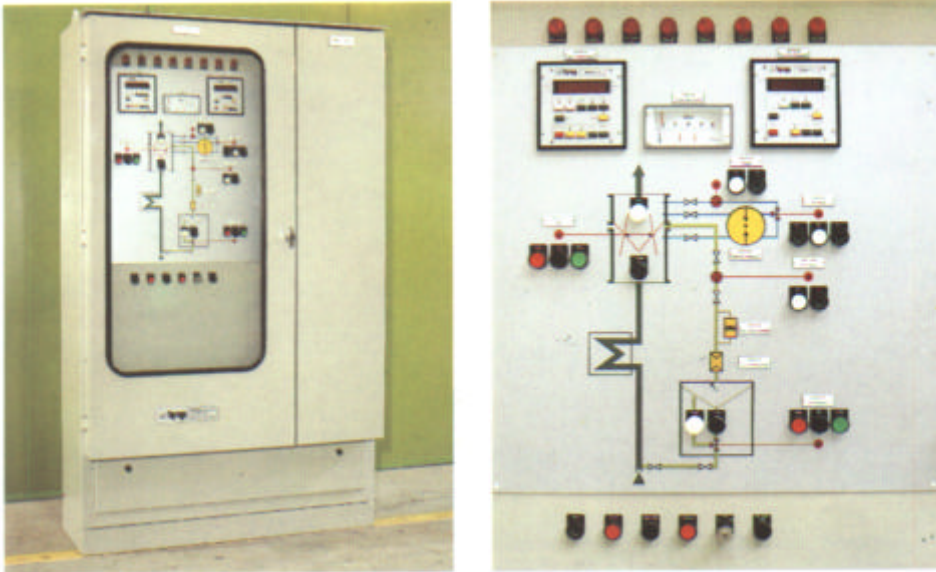
Complete ball recirculating unit with ball collector C40, ball recirculating pump KRP, ball oversize monitor BOM, and ball recirculation monitor BRM

Ball Injection

For the uniform cleaning of all cooling tubes it is imperative that the balls are evenly distributed in the cooling water pipe. That is why the cleaning balls are injected via up to 4 nozzles, depending on the diameter of the cooling water pipe.

Control

The actuation of the screens and the ball collected can be performed manually, or by actuators. The control of the tube cleaning system can be automatized to any extent by programmable electronic control systems. Even the automatic exchange of cleaning balls is possible (TAPROGGE Autonomous Cleaning System TACSY).



Control panel with programmable electronic control system

Monitoring Devices

Various monitoring systems for recirculation (Ball Recirculation Monitor BRM) and effectiveness (wear and tear) of the cleaning balls (Ball Oversize Monitor BOM, Ball Efficiency Monitor BEM) are available. In addition to that, a special monitoring system (Condenser Monitoring System CMS) controls the heat transfer of single condenser tubes and signals beginning tube fouling. Via modem there is even the possibility of remote monitoring of the cleaning system and the condenser condition by experts in order to immediately identify and eliminate problems.

4. Operational Problems, and how to avoid them

It may happen in practice that fouling occurs in the tubes despite the operation of a tube cleaning system. Reasons therefor are mostly perturbations in the ball circulation, or the wrong selection, late exchange, respectively, of the cleaning balls. Such fouling is often recognized only at inspections during regular maintenance outages. At that time performance losses will already have taken place, and the fouling may have become so severe that it can be removed by means of corundum balls or cost-intensive manual cleaning (see 2.1) only.

4.1 Replacement of Cleaning Balls

To avoid this problem the permanent monitoring of the cleaning balls with regard to wear and tear and circulation is required. If there is a risk of scaling it is particularly important that the tubes be permanently and effectively cleaned in order to prevent nuclei from building up on the tube surface. Also if there is the danger of biofouling the settlement of micro-organisms must be avoided by the continuous cleaning with effective polishing balls. In the case of the risk of scaling and biofouling the optimal ball selection and timely replacement once a residual oversize of 0.5 mm in relation to the inner tube diameter has been reached are of particular importance.

Manual ball sorting by means of a measuring gauge, as was practised earlier, cannot be recommended due to the high inaccuracy of this method. An automatic counting and sorting device for extracted balls works more reliably. We advise to exchange the entire ball charge rather than sorting out individual balls. For the assessment of the wear condition random samples of cleaning balls can be taken out and measured (measuring cone), or a monitoring system is used (BOM, BEM, BROM). For the replacement of the balls there should be no fixed time interval, given the fact that the wear behaviour of the balls is influenced by the operational and cooling water conditions. From the ball wear conclusions can be drawn with regard to the tube condition: growing wear may indicate beginning scaling (formation of nuclei) or corrosion (with copper alloys). If necessary, a different ball type must be applied on a temporary basis to enhance the cleaning effect and smooth the tube surface.

4.2 Perturbed Ball Circulation

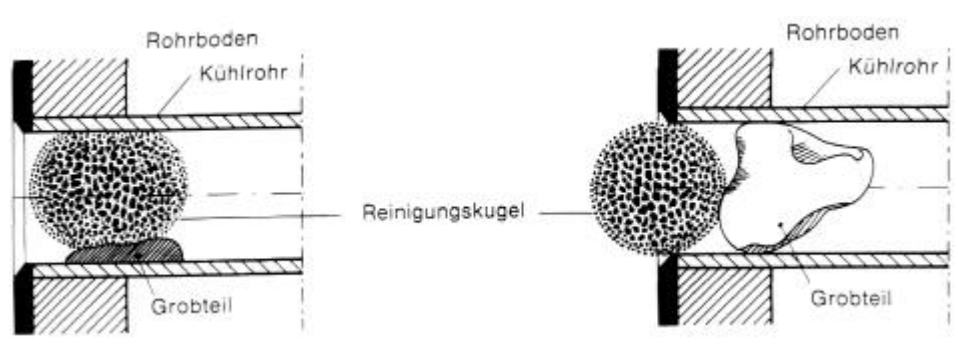
The cleaning ball circulation can be watched through sightglasses at the collector and at the distributors of the ball transport pipes. Monitoring systems enable continuous control and emit alarm signals in the case of malfunctions (BRM, BROM). Perturbations of ball circulation, and ball losses, must be eliminated as quickly as possible to guarantee permanently effective cleaning, especially if there is the risk of scaling or biofouling.

Possible sources for perturbations of ball circulation may be:

Blocking of balls in the tubes

caused by reduction of water flow, wrong ball selection, thick deposits in the tubes, or macrofouling (coarse debris) where balls get stuck.

In the case of changed flow rates and thick deposits in the tubes the ball type must be adapted accordingly. If macrofouling is prevalent, not only the waterbox but the entire cooling water system is to be cleaned, and a debris filter should be installed upstream of the condenser.



Ball cleaning perturbed by macrofouling in the condenser

Depositing of cleaning balls in the cooling water system

In the waterboxes of some condensers there are dead spots (areas of low flow pattern) where gradually more and more balls settle down. Those dead spots must be covered or filled up.

If new balls have not been sufficiently watered, or the waterboxes not completely filled, balls can rise and accumulate in the waterboxes. In such a case it must be seen to it that the balls are sufficiently watered and the waterboxes deaerated.

Perturbed rolling down behaviour of balls on the screen

Macrofouling on the screens obstructs balls in rolling down to the extraction points. The balls remain on the screen, and the differential pressure increases. As a consequence, the balls are pressed against the screen even more strongly and additionally hindered from rolling down. In this case the screens must be backwashed more often, depending on the degree of fouling. It can also be advantageous to use harder balls – which may be applicable for an increased cooling water flow rate as well.

Ball losses

Ball losses occur with damaged or not closely fitting screens, or if fouled screens are backwashed and balls are still stuck on the screens. Other frequent reasons are operating or control errors (e.g.: backwash without preceding ball catching).

If, due to a malfunction of the ball recirculating pump, the balls cannot be sucked off from the screen, they will also get lost during the next screen backwash. The same applies with a defectuous non-return flap in the ball collector: the balls can roll back after switch-off of the ball recirculating pump and get lost with open screens.

Ball losses are often attributable to insufficiently serviced system components (screens, actuators, relay control), or to misoperation. In this connection the functional safety should be kept by appropriate maintenance of the components and modernization measures (strainer modification, replacement of trouble-susceptible relay controls by programmable control systems, ...). Available for these tasks is an efficient service department.

5. Summary and Recommendations

The online cleaning of condenser tubes is an essential part of modern power station operation for the optimization of the "cold end" of the power station process. The efficiency of the power station is enhanced, and the lifetime of the condenser tubing prolonged.

In practice the operation of the tube cleaning system is often not paid appropriate attention to because performance losses or corrosion caused by tube fouling are often not recognized immediately. Under the influence of lack of personnel and cost pressure, the maintenance of the components is neglected and cleaning balls are not checked and replaced in due course. However, the additional cost incurred for extra fuel consumption, reduced power generation, respectively, for special measures of removing deposits during regular inspection outages, for premature re-tubing and reduced availability, exceed the cost of an optimized operation of the tube cleaning system by far. That is why the expenditure for optimized cleaning balls, maintenance and monitoring of the tube cleaning system pays back that quickly.

Also investments into additional monitoring devices with remote control (by modem connection) by specialists who constantly check the tube condition and optimize the cleaning process often pay back within 1 to 2 years, as is proven by examples.

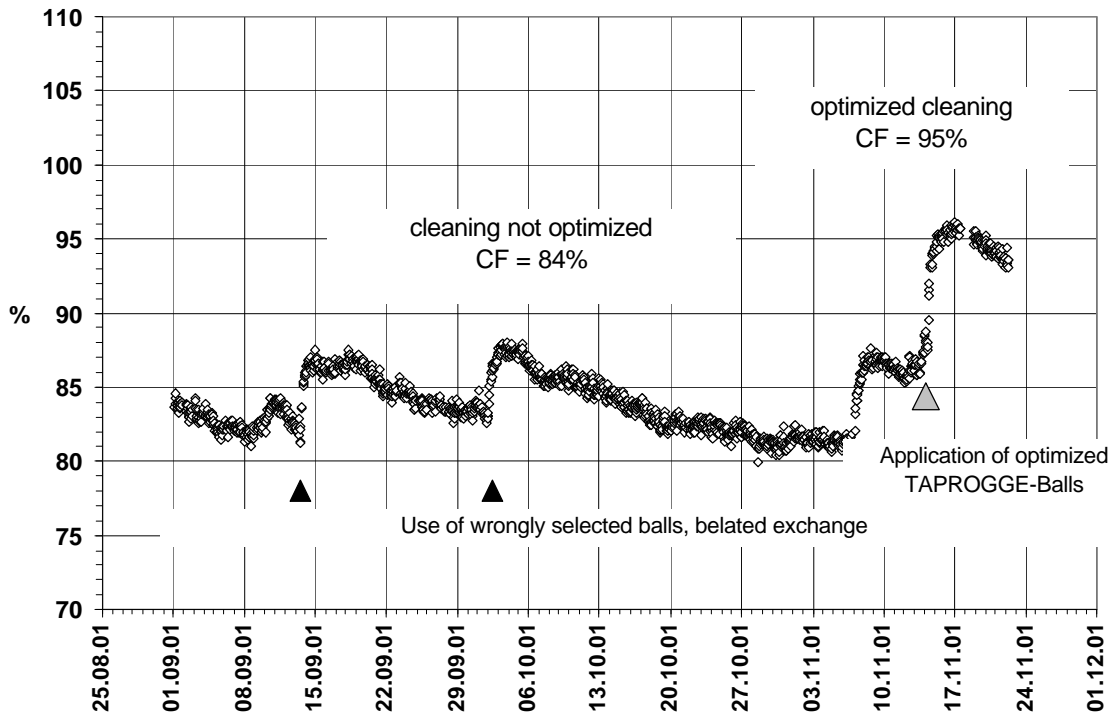
For all those reasons the tube cleaning system must be regarded as a valuable tool for cost saving – even if it is placed in the basement of the power house and insufficient tube cleaning is not instantly recognized.

Literature

- [1] VGB-Guideline "Kühlwasserrichtlinie – Wasserbehandlung und Werkstoffeinsatz in Kühlsystemen" (VGB-R 455 P). VGB-KRAFTWERKSTECHNIK GmbH, Essen, 2000.
- [2] VGB-Guideline "Rohre für Kondensatoren und andere Wärmetauscher – Teil A – Kupferlegierungen" (VGB-R 106 L), VGB-KRAFTWERKSTECHNIK GmbH, Essen, 1988.
- [3] VGB-Guideline "Rohre für Kondensatoren und andere Wärmetauscher – Teil B – Nichtrostende Stähle" (VGB-R 113 L), VGB-KRAFTWERKSTECHNIK GmbH, Essen, 1989.
- [4] VGB-Richtlinie "Rohre für Kondensatoren und andere Wärmetauscher – Teil C – Titan" (VGB-R 114 L), VGB-KRAFTWERKSTECHNIK GMBH, Essen, 1990.
- [5] Czolkoss, W., Fichte, W. und Schleithoff, K. "Deckschichtstrukturen auf Kondensatorrohroberflächen", Der Maschinenschaden 64 (1991), H.5, S. 194 – 201
- [6] TAPROGGE Technical Bericht 92-30 "Recommendations for the Selection of Cleaning Balls and Optimal Cleaning Frequency", 1992.

Increase of Cleanliness Factor CF by optimized Tube Cleaning

NPP 900 MW



Increase of Terminal Temperature Difference and Capacity by Optimized Tube Cleaning for NPP 900 MW

