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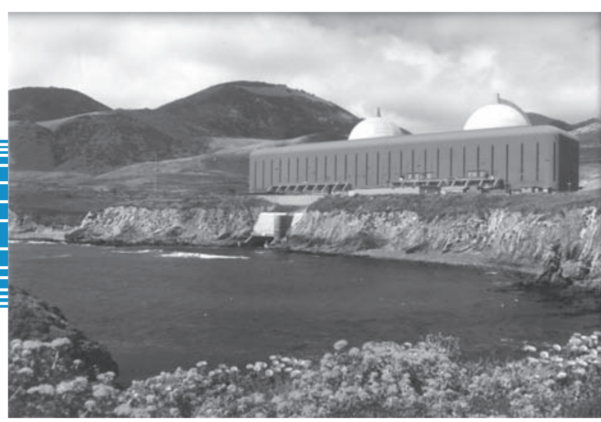
# Nuclear Maintenance Applications Center: Condenser Cleaning Equipment Maintenance Guide

Plant
Maintenance
Support

Reduced
Cost

Equipment
Reliability



# Nuclear Maintenance Applications Center: Condenser Cleaning Equipment Maintenance Guide

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# REPORT SUMMARY


This report provides power plant maintenance personnel with current maintenance information on condenser cleaning systems. The report will help these personnel to improve the reliability and reduce the maintenance costs for the condenser cleaning equipment used in power plants.

### Background

Nuclear Maintenance Applications Center (NMAC) members use a variety of cleaning systems in their facilities, including on-line as well as manual systems used during planned outages. On-line cleaning systems, when used, can provide operators with an effective way to clean the condenser tubes while they remain in service, thus improving plant efficiency. A variety of successes has been experienced by member facilities for this common system used at many power plants. Members have also experienced difficulty in obtaining optimal performance from these systems. Problems include ineffective operation, cleaning media loss, and maintenance challenges.

### Objectives

- To describe typical condenser cleaning equipment
- To provide preventive maintenance, repair and replacement, modification and upgrade, and troubleshooting recommendations for condenser cleaning equipment

### Approach

This report addresses various engineering, maintenance, and operations issues regarding condenser cleaning equipment. Key equipment suppliers were solicited for assistance to ensure that the guidance reflects the latest technologies available in the industry. In addition, a technical advisory group was formed that consisted of Electric Power Research Institute (EPRI) NMAC utility members and industry personnel. Input was solicited for current maintenance issues with the equipment. Experience-proven practices and techniques were identified during this effort and are compiled in this report.

### Results

This technical report describes system design parameters and familiarizes power plant maintenance and engineering personnel with the components used for on-line condenser cleaning equipment. The report provides guidance on performing preventive and corrective maintenance on the equipment and recommendations on repairing and replacing components. In addition, components that are typically repaired or refurbished on site are described, and troubleshooting guidance is provided for applicable components.

**EPRI Perspective**

The information contained in this report represents a significant collection of technical and human performance information, including techniques and good practices, related to on-line condenser cleaning equipment commonly used at many power plants. Through the use of this report, EPRI members should be able to significantly improve and consistently implement the processes associated with the reliable operation of their condenser cleaning equipment.

**Keywords**

Condensers
Maintenance
Preventive maintenance

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# 1
# INTRODUCTION

In 2001, Electric Power Research Institute (EPRI) Nuclear Maintenance Applications Center (NMAC) prepared the report *Condenser Application and Maintenance Guide* (1003088), which contains an extensive discussion and overview of all aspects of condenser design, operation, and maintenance. Through various EPRI activities, the importance of maintaining the condenser's cleanliness and the resulting impact on plant performance and efficiency have been repeatedly demonstrated.

The condenser is a major component in the steam cycle of power plants, and its proper operation is an important element in overall plant efficiency. One of the factors that can affect this efficiency is the cleanliness of the condenser tubes and components.

Recent surveys of the NMAC membership have revealed that, in some instances, problems are still being experienced in the areas of condenser cleaning and condenser cleaning equipment maintenance and techniques.

## 1.1 Purpose

This report provides power plant personnel with guidance on effective maintenance practices for systems and components associated with condenser cleaning both on-line and while the plant is shut down.

Recommendations in this report are based on published literature and the experience and expertise of numerous users and manufacturers. Data sources include the following:

- Power plant maintenance, operating, and engineering personnel
- Condenser cleaning equipment manufacturers
- Results of surveys of NMAC members
- EPRI reports and other technical publications

## 1.2 Organization of This Report

This report is organized as follows:

- Section 1 provides an introduction and general discussion of the guide's purpose and organization.
- Section 2 provides a basic overview of condenser cleaning equipment, including component descriptions and typical applications in power plants.
- Section 3 presents information related to equipment failure modes and causes.
- Section 4 provides troubleshooting information for condenser cleaning equipment.
- Section 5 offers preventive maintenance recommendations for the various components used in condenser cleaning equipment.
- Section 6 describes condition-based parameters that can be used to monitor equipment health as well as possible upgrades to older equipment.
- Section 7 presents a list of references used in the preparation of this report.
- Appendix A includes a recommended operating procedure for Taprogge (Amertap) on-line cleaning equipment, and Appendix B provides a sample off-line mechanical tube cleaning procedure.
- Appendix C lists the Key Points highlighted in this report, and Appendix D compiles the report's accompanying training slides.

## 1.3 Key Points

Throughout this report, key information is summarized in “Key Points.” Key points are bold-lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a key point is to emphasize information that will allow individuals to take action for the benefit of their plant. The information included in these key points was selected by NMAC personnel, consultants, and utility personnel who prepared and reviewed this report.

The key points are organized according to the three categories: O&M Costs, Technical, and Human Performance. Each category has an identifying icon, as shown, to draw attention to it when quickly reviewing the guide.

**Key O&M Cost Point**

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

**Key Technical Point**

Targets information that will lead to improved equipment reliability.

**Key Human Performance Point**

Denotes information that requires personnel action or consideration in order to prevent injury or damage or to ease completion of the task.

Appendix C of this guide contains a listing of all key points in each category. The listing restates each key point and provides a reference to its location in the body of the report. By reviewing this listing, users of this guide can determine if they have taken advantage of key information that the writers of this guide believe would benefit their plants.

# 2
# CONDENSER CLEANING EQUIPMENT

Fouling of the condenser includes any organisms—organic or inorganic—that interfere with the circulating water in the tubes and ultimately with the heat transfer process. When there is an increase in condenser pressure and a decrease in cooling water flow, fouling is the most likely cause. Other indications of fouling include an increased pressure drop and a reduction in temperature change for the inlet and outlet cooling water. Because it affects the condenser backpressure, fouling impacts the output of the plant. In addition, plant availability can be affected during seasonal changes that produce annual fish runs, grass movement, seaweed deposition, accumulation of leaves, and so on.

The deposits on the tube reduce heat transfer rates, decrease cooling water flow, and increase pumping costs. The formation of these deposits is a function of the cooling water environment, flow velocity, and the season. In addition, the solubility of certain compounds, such as calcium carbonate, decreases with increasing water temperature.

Section 5 of the EPRI report *Condenser Maintenance and Application Guide* (1003088) presents an additional discussion of condenser fouling.

The primary objective of cleaning is to remove corrosion, fouling, and scaling material from the inner surface of the condenser tubes to bring heat transfer performance back to specification. The two types of available cleaning applications are on-line and off-line. This report focuses on the on-line mechanical and some commonly used off-line options that are available in the industry.

On-line cleaning techniques include the sponge ball system, brush and cage system, abrasive cleaning, and self-aligning rockets. These systems can require a large capital investment. A continuous cleaning system offers the advantage of keeping the tubes clean without any fouling buildup. Some additional maintenance and operations attention is required, however, because the constant scraping of the tube inside walls can cause tube thinning.

Off-line cleaning techniques include the use of brushes, scrapers, and hydroblasting. The equipment costs for these systems are relatively inexpensive. The unit must be derated or off-line in order to clean the tubes. Tube cleaning can be scheduled during refueling or boiler outages or during a scheduled load reduction. The cleaning process requires an operator, and the air and water pressures used can impose a safety concern.

Each type of off-line cleaning system has limitations. Brushes are effective for cleaning soft fouling deposits; metal scrapers and high-pressure water lances are more effective with harder scale deposits. In some instances, it is necessary to chemically clean the tubes and then use mechanical devices to remove deposits.

The following are some of the characteristics of on-line techniques:

- They require a comparatively large capital investment.
- They clean a thin layer of foulant with each pass; therefore, foulant cannot build up.
- No interruption in service is required.
- Continuous cleaning of each tube can lessen the need for biofouling chemicals.
- They require limited maintenance and operator attendance.
- Constant wiping action of balls can remove tube wall material: brushes scrape the inner surfaces of the tube, removing material and possibly reducing wall thickness.
- Balls must be inspected and replaced frequently, and broken or abraded balls must be removed.
- Balls can be stopped by debris and can plug up tubes.

The following are some of the characteristics of off-line techniques:

- The equipment cost is low.
- Tube cleanliness might begin to deteriorate as soon as tube cleaning is complete.
- Full or partial interruption in service is required.
- Fouling can take on different characteristics; therefore, the scraper or high-pressure water might have to deal with a hardened, tightly adherent material that is difficult to remove.
- They require an operator or a technician during cleaning. Some equipment poses a safety hazard because of the high air or water pressures that propel cleaning devices through the tubes.
- Lances, rotating scrapers, and brushes can gouge and damage tube walls if they are used aggressively or incorrectly.
- Only water lance systems do not wear out or require periodic replacement. Consumables must be purchased for each cleaning event.

The successful diagnosis and resolution of condenser performance problems related to fouling are based on the identification of the fouling mechanisms and the corresponding effective cleaning technology. The effectiveness of the cleaning technology applied and the heat transfer loss from the deposits vary dramatically from site to site. Common investigative methods to determine fouling include the use of fouling monitors, sampling of the tube deposits, and single-tube heat transfer testing. This testing involves extracting a tube from the condenser, measuring the heat transfer coefficient, cleaning the tube, and re-measuring the heat transfer coefficient. The results of this testing have been used to verify the condenser performance testing, assist in locating the source of the performance loss, optimize the cleaning methods, and monitor the performance of cooling water chemical treatment methods. For more information on these techniques, see “Diagnostic Technique for the Assessment of Tube Fouling Characteristics and Innovation of Cleaning Technology” [1].

No one technique for cleaning biofouling is ideal under all conditions. Sometimes chemical cleaning is required to complement mechanical cleaning or vice versa. Chemical cleaning might be needed to reduce the fouling thickness followed by mechanical cleaning with scrapers or high-pressure water lances to remove the remaining fouling thickness. Chemical biocide treatment might be needed to disinfect copper alloy tubes from bacterial attack, supplementing a ball cleaning or brush cleaning technique. Many utilities that use on-line ball cleaning also use brushes or water lances during outages to remove debris or tenacious films on the tubes. These films might not be biological but rather corrosion products, mussels, or debris.

## 2.1 On-Line Cleaning Systems

Condenser on-line cleaning systems include the following:

- The sponge ball system (this is the most common type)
- The brush and cage system
- Self-aligning rockets

Generally, on-line cleaning systems offer the advantage of reducing unit downtime. However, installation of some of the cleaning systems is capital intensive.

### *2.1.1 Sponge Ball System*

Ball systems use the cooling water flow to push or force slightly oversized sponge rubber balls through the condenser tubes. This action provides a continuous wiping action against the inner tube walls (see Figure 2-1).

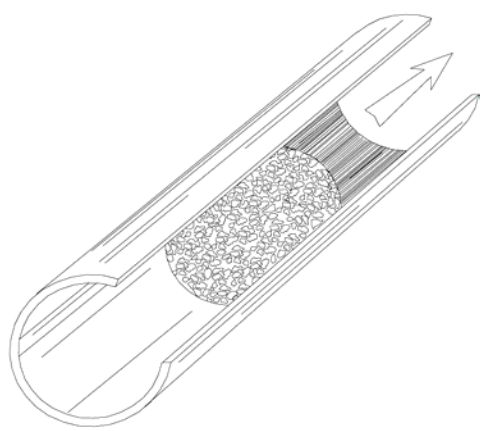


**Figure 2-1**
**Ball in Tube System**

Figure 2-2 shows a typical ball cleaning system developed in Germany and modified by French, Japanese, and American companies.

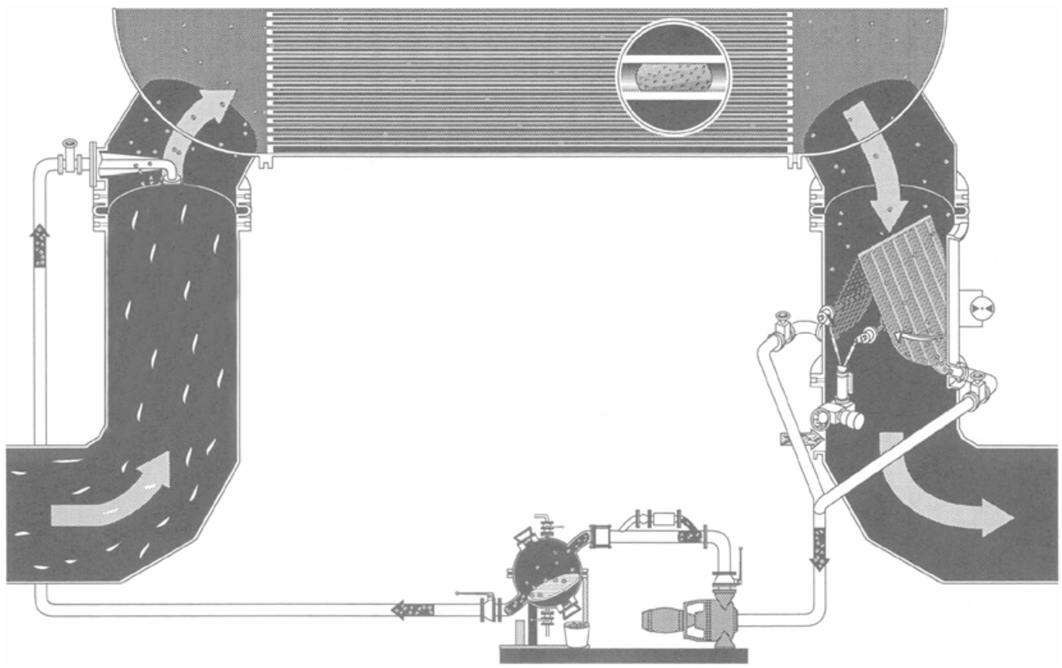


**Figure 2-2**
**Typical Ball Cleaning System**

This sponge ball cleaning system includes three steps: ball injection, tube cleaning, and ball collection and return for re-injection.

- **Ball injection.** The balls are injected into the circulating water upstream of the condenser inlet, most commonly in an elbow bend, as shown in Figure 2-2. To provide good ball dispersal, injection is against the direction of inlet cooling water flow. When deaerated, the balls are approximately the same density as the cooling water. They should enter the tubes randomly so that no section of tubes will be preferentially cleaned or neglected. A charge of balls equal to 5–15% of the number of condenser tubes per pass is sufficient to maintain cleanliness. With this ball count and continuous injection, each tube is expected to receive a cleaning ball about once every 5 to 10 minutes.
- **Tube cleaning.** Experience shows that the actual physical distribution of balls might not be uniform, which can lead to inadequate cleaning or excessive wear of some tubes. This depends on tube material, ball abrasiveness, and cooling water conductivity. The ball distribution is affected by the location of ball injection and by the flow patterns in the inlet waterbox.

A ball cleaning system can also deal with strongly attached foulants by replacing some of the normal sponge rubber balls with balls that have an abrasive coating bonded to them. Granulate rubber balls have also been used to maintain the cleanliness of titanium tubes without scratching the tubes. When the foulant has been removed, normal service with plain sponge balls can resume. This practice must be monitored closely, however, because of potentially rapid erosion of copper alloy tubes by the abrasive balls.

The constant wiping action of the balls can also remove tube oxide coating and wall material. Overcleaning soft base metals, such as copper alloys, results in erosion/corrosion of the tubes in high-conductivity cooling water. Overcleaning tubes removes the protective film; undercleaning may leave a thick film that can inhibit heat transfer.

The erosion/corrosion of copper alloy tubes and the action of ball cleaning might produce trace metal effluents that affect water quality standards. Because of their inherent toxicity, copper alloy condenser tubes are less susceptible to biofouling than are stainless steel or titanium tubes. Using copper alloy tubes in clean seawater requires less sponge ball cleaning to maintain optimum cleanliness and tube service life. Under these conditions, one cleaning cycle per week should be sufficient. If the seawater is polluted or contains specific fouling agents that could produce pitting or other localized corrosion, the sponge ball cleaning frequency might have to be increased to prevent under-deposit corrosion.

When cleaning titanium or stainless steel tubes with abrasive balls, loss of wall material is less of a concern than it is with softer base metals.

**Key O&M Cost Point**

The supplier should be consulted in order to establish a recommended abrasive and normal ball cleaning procedure specific to plant requirements.

- **Ball collection and return for re-injection.** After the balls have traveled through the condenser tubes, they must be caught without impeding the flow of water. They are caught by a specially designed strainer system mounted downstream of the cooling water outlet waterbox. The balls are then discharged to the ball collection by recirculation pumps. At the collector unit, the operator can visually inspect the balls, manually size them, and replace any undersized balls. Balls then flow from the collector unit to the injection locations at the inlet waterbox, where the cycle begins again.

  Operators use a round pan with appropriately sized holes to check the dimensional tolerance. New balls must achieve the right density to operate properly. They must be deaerated mechanically or by agitation in the collector using the ball recirculation pump before being released into circulation. These operations are labor intensive, requiring about 2 hours by one operator every one or two weeks. Many users replace all balls without sizing based on an average ball lifetime determined from experience, which reduces the labor required to operate the system.

The ball strainer can become clogged with debris or undersized balls. When the differential pressure across the strainer becomes high, it is backflushed into the cooling water discharge section. The ball cleaning system is quite susceptible to the introduction of debris. If debris clogs or obstructs the tubesheet at the inlet waterbox, the tubes cannot receive cleaning balls. If debris lodges within a tube, there is a high probability that the tube will further become plugged with balls and/or more debris. Ball system manufacturers and others supply a number of upstream debris filter designs that address this problem.

The debris filter systems can add significantly to the condenser capital cost. Because of the additional pressure drop across the debris filter, the circulating pump motor power consumption can increase, resulting in higher operating costs.

**Key O&M Cost Point**

The capital costs of the sponge ball system and the increased maintenance costs must be compared to heat rate improvements from cleaner tubes and tubesheets.

For existing systems, space and outlet piping configurations can influence the retrofit of a ball cleaning system. If debris affects the effectiveness of the ball system and a filter is required, space limitations at the inlet piping and in the condenser waterbox should be considered. The outlet piping affects the location, design, and cost of the ball collection strainer. All remaining system components (such as small pumps, collectors, and valves) can be installed wherever space exists. Inlet piping, waterbox design, and the resultant hydrodynamics affect the location and number of ball injectors required. A retrofit of the new designs is feasible except in difficult applications in which the inlet and outlet piping is embedded in concrete.

The greatest source of dissatisfaction among sponge ball cleaning system users has been the cost associated with system operation and maintenance. The piping systems, valves, and plugs can experience accelerated corrosion. The linkages of the older designs become loose, and the instrumentation and controls require maintenance. Ball wear is a normal condition that results in the loss of undersized balls that pass through strainer catch screens. Full-size balls can lodge behind debris or collection grids and become lost after a routine backwash operation. Ball hiding occurs at stagnation points in waterboxes and other areas in which low fluid velocity allows balls to stop moving. As the strainer section screen condition deteriorates, the balls are easily lost.

Ball replacement is a normal operating cost associated with proper system operation. Because of ball wear, the manufacturers normally recommend replacing a complete charge of balls approximately once a month.

Strainer design is crucial to successful operation. Over time, strainers become clogged with debris, undersized balls, or ball fragments. A differential pressure measuring system can be installed on the strainer section to indicate debris loading and to initiate a screen backwash procedure that occurs if a predetermined differential pressure is reached. Some designs backwash by canting the screens. Trapped debris is flushed from the front side of the screen and out to the cooling water discharge destination, and the strainer screens are then returned to their normal operating orientation.

The primary disadvantage of the older design multiple-screen strainer is the large number of moving parts in the upper screens, lower screens, shutoff flaps, and throttle flaps. All of these are shaft mounted and operated by linkages and mechanisms from outside the strainer section. Failure of any of these movable parts will eventually lead to significant ball loss and maintenance effort. The moving parts are actuated by both motor and mechanical operators; the operators require periodic maintenance and replacement. Figure 2-3 shows the older design strainer system, and upgrades to these older designs are described in Section 6.

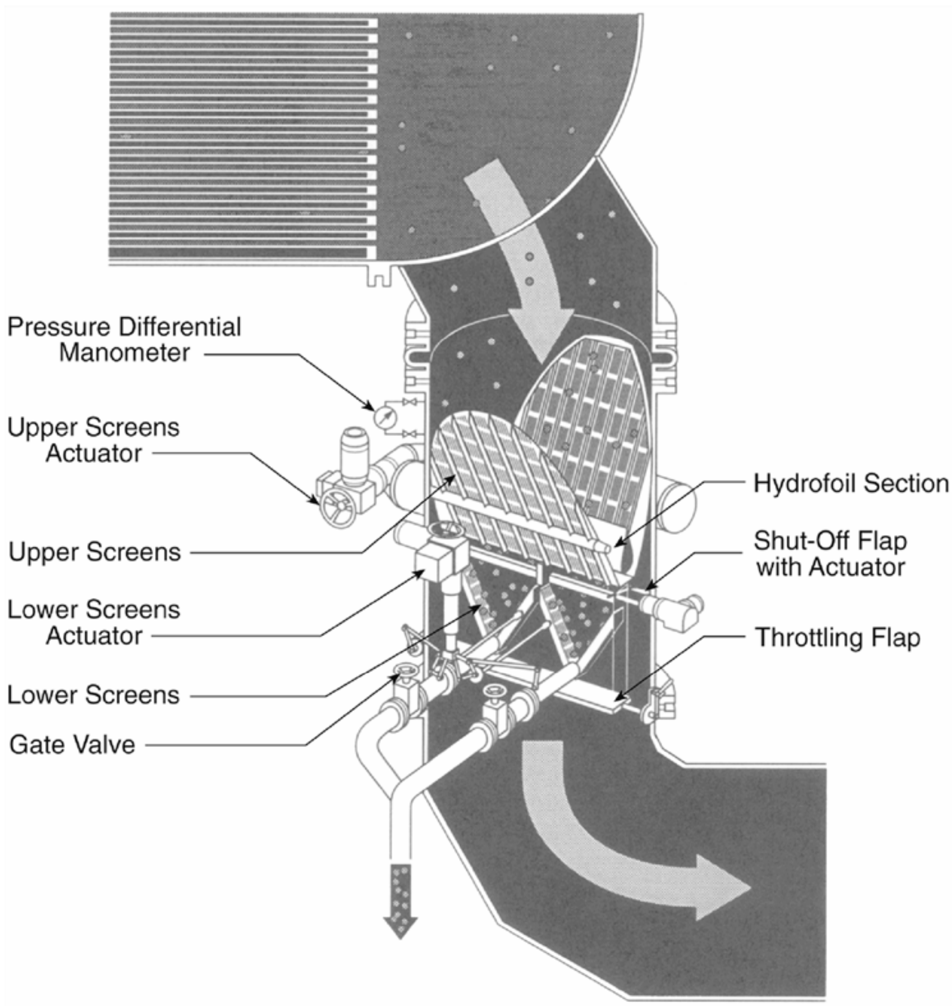



**Figure 2-3**
**Older Design Ball Strainer System**

The newer, simpler design is shown in Figure 2-4. This design uses a ball recovery system based on turbulence-inducing vortex vanes located on the trailing end of the screen. The hydrofoils create small, localized vortices that remove the balls from the screen surface and keep them in suspension until they reach one of the extraction ports located at various points along the extraction blocks. This type of design has fewer moving parts. The multiscreen strainer design can be modified to the simplified dual-screen strainer design. This modification is cost effective if the existing upper screens are in good condition or require only minor repair. If extensive repairs are required for the upper screens, replacing the strainer with a newer design might not be cost effective.

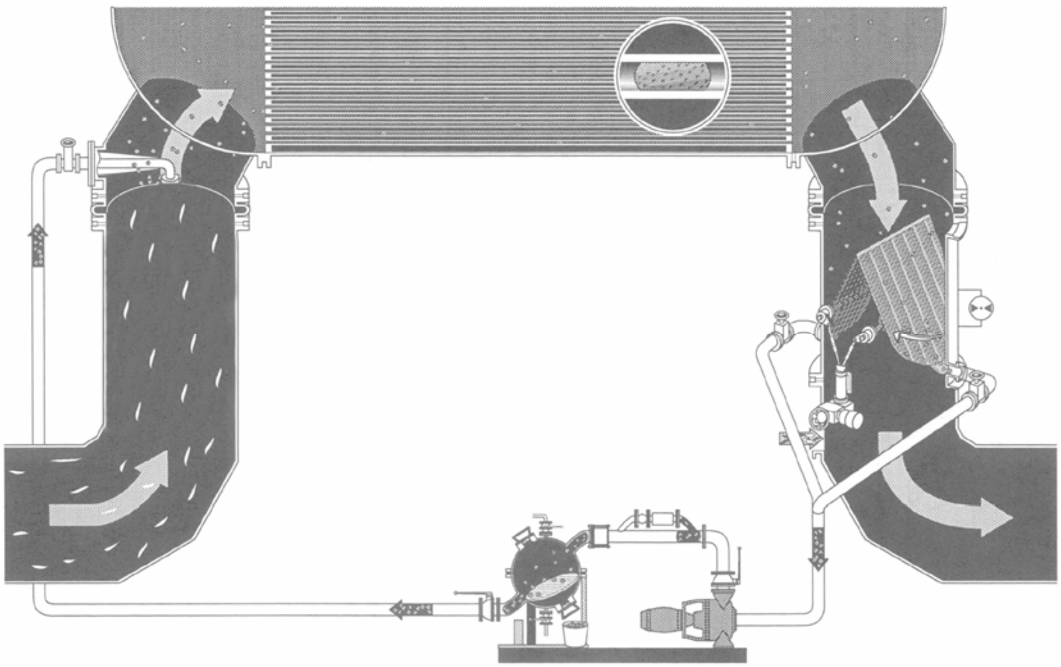


**Figure 2-4**
**Newer Design Ball Strainer System (Type D2)**

One type of ball recirculation system (shown in Figure 2-5), found in older designs, requires reinjection pumps that remove the balls from one half of the strainer section and inject them into the other half. Other pumps are used to extract all of the balls from the strainer section and circulate them through the collectors to the condenser inlet. The balls are then reinjected into the incoming cooling water. These designs were originally designed to reduce the length of recirculation piping and reduce the size of the reinjection pumps required, and many of these systems have been upgraded to current standards.

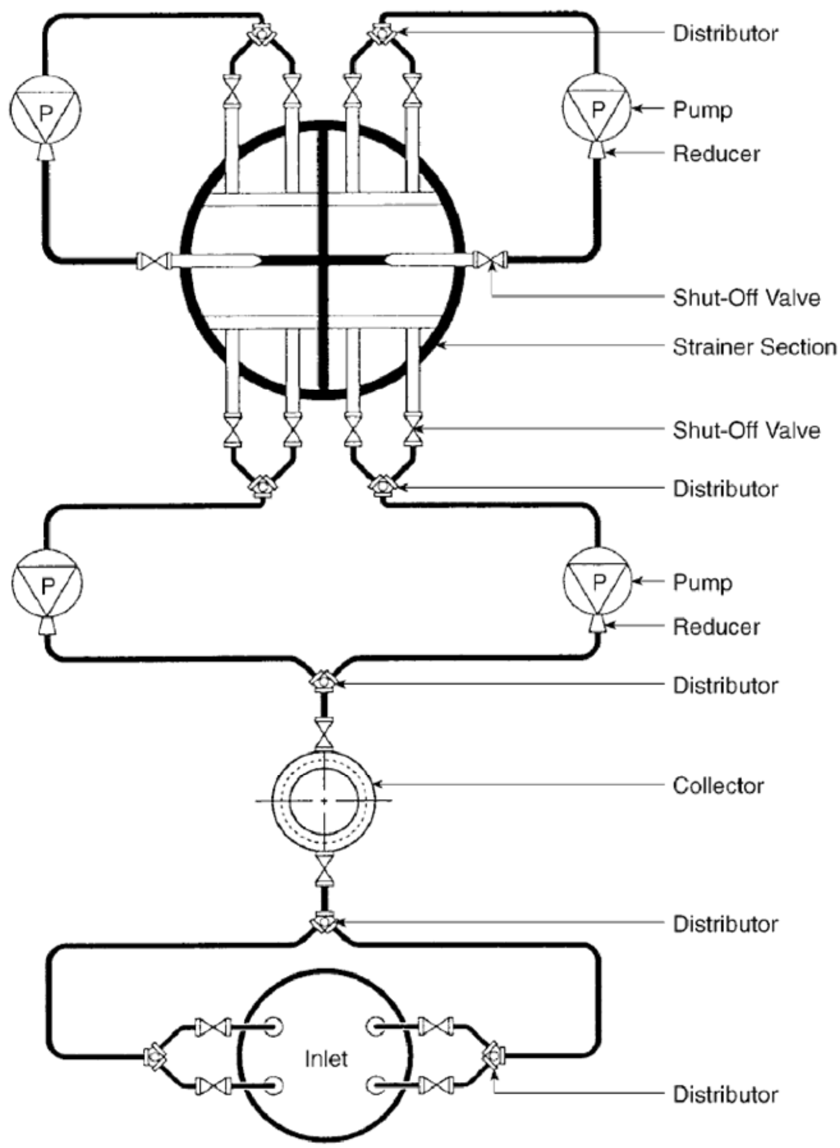



**Figure 2-5**
**Sponge Ball Recirculation System (Older Design)**

There are both advantages and disadvantages to using the sponge ball cleaning system.

Advantages include the following:

- The tubes are cleaned continuously.
- The need for biofouling chemical addition is reduced or eliminated.
- The need for shutdown for manual cleaning is reduced or eliminated.
- Operation is automatic.
- The system can prevent under-deposit pit corrosion.

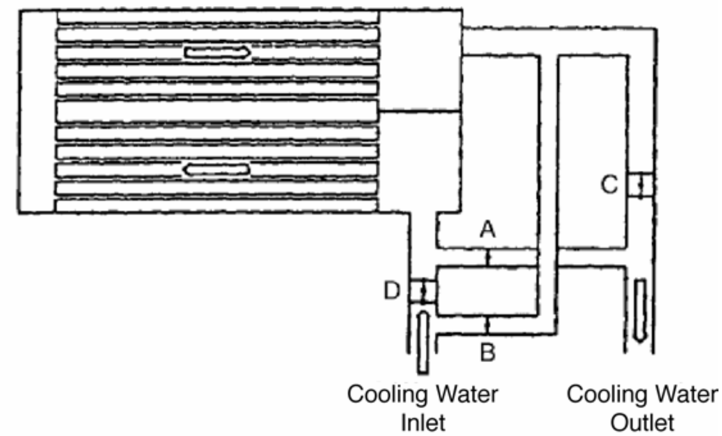
- Startup costs are lower than those for brush and cage systems.
- Different balls are available for different foulants.
- Condenser efficiency can be greatly improved.

Disadvantages include the following:

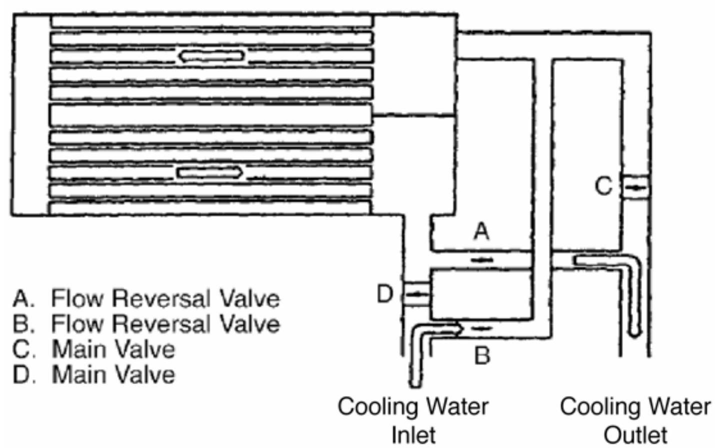
- Labor is required for frequent ball inspection and replacement.
- Adjustments to mechanized system components and controls are required.
- Tube abrasion of soft metals occurs.
- Operating costs are higher because of increased maintenance, auxiliary power consumption, and ball replacement.
- The system is susceptible to the introduction of debris.
- Capturing balls can be problematic. A major escape of balls into a body of water can cause problems.
- An uneven distribution of balls might not clean tubes uniformly.
- Space and outlet piping configurations can influence retrofit.
- Balls can become lodged in tubes, causing blockage.
- Collection screens might experience fouling that increases waterside pressure.

### 2.1.2 Brush and Cage System

Another on-line condenser tube-cleaning method is the brush and cage system. This is used by some large power plants, smaller power plants, cogeneration plants, industrial heat exchangers, and refrigeration chillers. A typical arrangement is shown schematically in Figure 2-6. In this arrangement, a captive brush is shuttled back and forth through each condenser tube by reversing the direction of flow through the condenser. Flow reversal requires appropriate valves and piping.




**Normal Cooling Water Flow Direction**




**Reversed Cooling Water Flow Direction**

**Figure 2-6**
**Typical Brush and Cage System**

There are several ways to install this flow-reversal mechanism. The type of flow diverters used depends on the site piping configuration. There is no need for a strainer; the cleaning brushes are caught by nylon cages attached to each tube end with epoxy or screws. The epoxied cages break off easily but are easy to repair. Flow reversal is usually initiated automatically on a timed cycle; however, remote manual operation is also possible from the system control panel.

The brush and cage system requires limited maintenance or operator attendance. Other than the flow-reversal valves and the brushes, there are no moving parts. The brushes are usually guaranteed for five years. For a typical large power plant condenser, it is recommended that approximately 500 spare brushes and cages be purchased to replace units that might fall off the tube ends. Large debris in the waterboxes can result in a loss of brushes and serious damage to the cages. Figure 2-7 shows a typical arrangement for the brush and cage system.

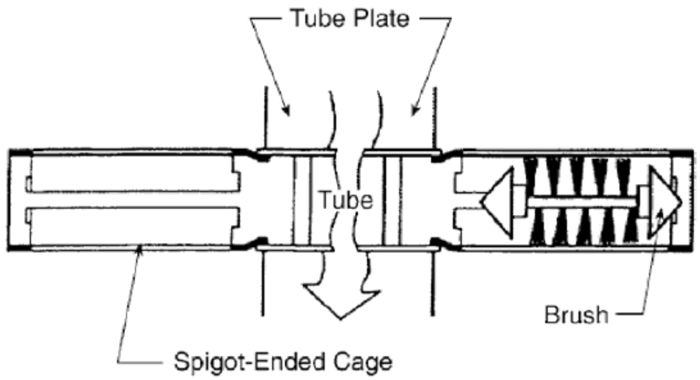



**Figure 2-7**
**Typical Arrangement for a Brush and Cage Tube Cleaning System**

The most significant area of concern for potential users of the brush and cage system is the need for an expensive flow-reversal system, particularly in large steam condenser applications.

Reversal of established cooling water could cause the following to occur:

- Hydraulic transients in the system
- A transient decrease in heat transfer rate
- A transient rise in condenser backpressure
- A drop in turbine-generator output

Some advantages of the brush and cage system are the following:

- The need for shutdown for manual cleaning is eliminated (although load reduction for backwashing might be required).
- The system ensures that each tube is cleaned.
- With the exception of flow-reversal valves and brushes, there are no moving parts.
- The system's operation and maintenance costs are low.
- Limited attention from operations and maintenance (O&M) personnel is required.
- The system effectively removes soft fouling material.
- The need for biofouling chemicals is reduced or eliminated.
- Split condensers and two-pass condensers can be accommodated.

Some disadvantages of the brush and cage system are the following:

- Reverse-flow piping and valves are required.
- The system is more susceptible to debris lodging in cages, restricting flow.
- Tube leak detection is difficult because cages obstruct tube ends.
- The system is used in straight tubes only.

- The initial capital cost is high (although lower than that of the sponge ball cleaning system).
- Imprecise cleaning throughout the tube occurs.
- The unit must be shut down for the brush and cage replacement.
- High tube velocities are required for effective cleaning.

### 2.1.3 Self-Aligning Rockets

This system consists of on-line mechanical tube cleaner rockets (see Figure 2-8) and a tube cleaner recovery system. The tube cleaner rockets consist of a two-part construction. The body is made of hard wear-resistant material that provides long life. The cleaning element, an elastomeric disk, determines the level of cleaning and can be made of abrasive material, if required. The self-aligning design of the body helps with passage through the tubes. The rockets can be hydraulically injected into the suction of the circulating water pumps (shown in Figure 2-9), which ensures even distribution throughout the volume of the cooling water.

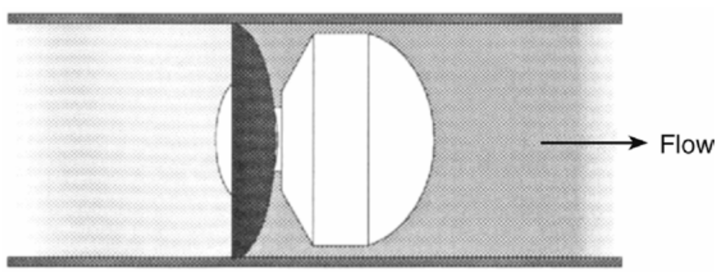



**Figure 2-8**
**Tube Cleaning Rocket**

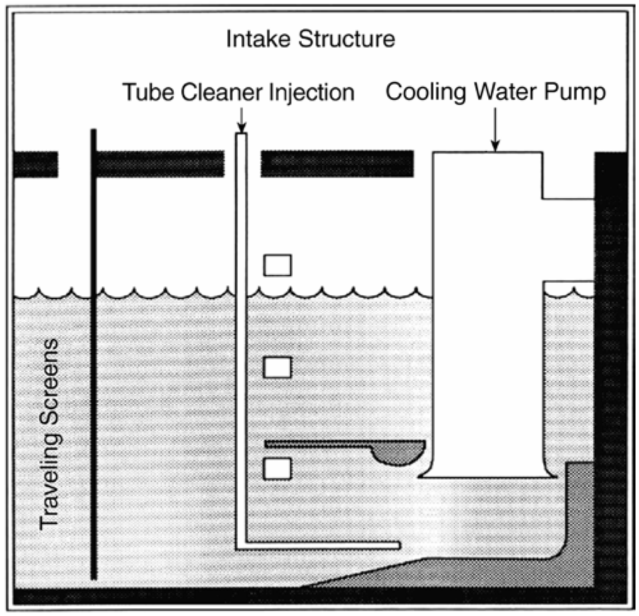



**Figure 2-9**
**Tube Cleaning Rocket Injection System**

The recovery system simply consists of modified oil spill recovery booms, a tube cleaner recovery unit, and a way to recirculate the recovered cleaners. In most cases, the cleaners can be hydraulically conveyed to the injection point. After the cleaners are discharged into the canal, the tube cleaners will gradually rise to the surface. Once on the surface, the system of skimming booms channel the cleaners to a common collection point for recovery. The recovery device is a pontoon-mounted traveling screen that retrieves the cleaners, rejects the floating debris, and carries the cleaners to shore for inspection and reinjection.

The primary advantage of this system is that no permanent, expensive installation is required. Experience with this system, however, is limited. One type of self-aligning rocket (Sidtec Rockets) has been successfully used by some utilities in their power plants.

## 2.2 Mechanical Off-Line Cleaning Systems

Many off-line cleaning systems are available. All methods are manual and require full or partial outage of the condenser. Typical off-line cleaning methods and their effectiveness are outlined in Table 2-1.

**Table 2-1**
**Typical Off-Line Cleaning Methods and Their Effectiveness**

| Type of Fouling | Off-Line Cleaning Method | | | |
|---|---|---|---|---|
| | Brushes | Scrapers | Hydroblasting | Chemical Cleaning |
| Severe scale | Not effective | Good | Fair | Good |
| Organic growth and mud scale | Good | Good | Fair | Not effective |
| Shells | Not effective | Good | Not effective | Not effective |

The method of cleaning should be evaluated according to the tube material, type of deposit, and cleaning time required. An example of mechanically cleaning tubes is shown in Figure 2-10.

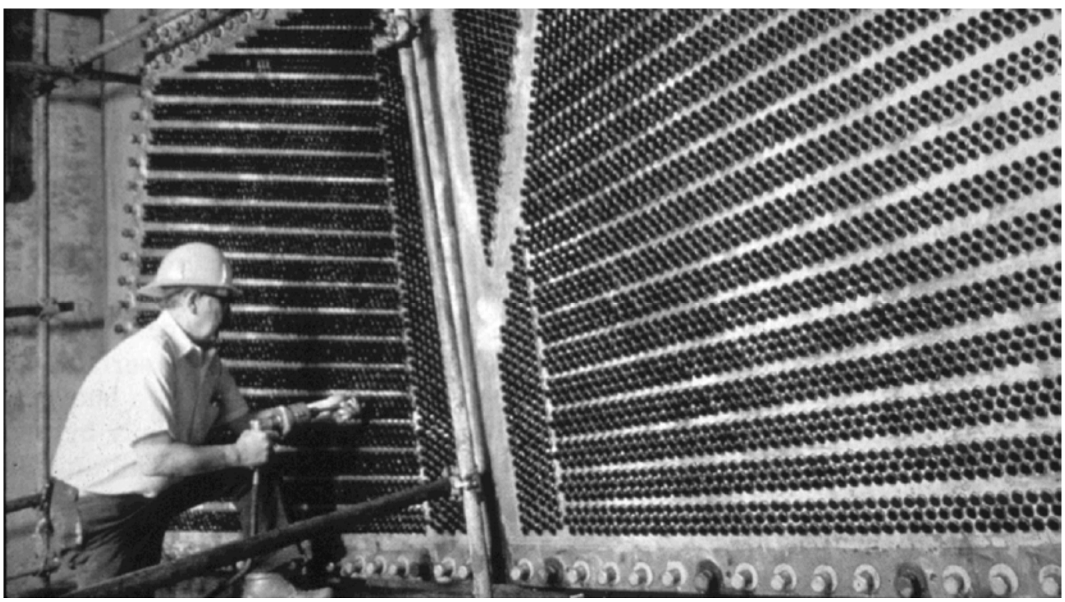


**Figure 2-10**
**Mechanically Cleaning Tubes**

The following are the most common types of off-line tube-cleaning equipment:

- Air- or water-driven systems (such as bristly brushes, air or water, “pigs,” or scrapers)
- Mechanically driven systems (for example, rotating brushes)
- Pressure-driven systems (such as water lances)

A sample mechanical tube cleaning procedure, developed by Conco Systems, Inc., is presented in Appendix B. In addition, a confined space permit might be required when working in the waterbox.

### 2.2.1 Air- and Water-Driven Systems

One of the simplest off-line tube cleaning methods uses a bristle brush similar to (but with denser bristles than) the brush used in the on-line tube cleaning system. The cleaning brush is inserted into one end of a dirty tube and propelled through with a blast of compressed air, pressurized water, or a combination of the two. Removed material is flushed out along with the propelling medium as the brush moves along the tube and into the outlet waterbox.

Depending on the nature of the fouling, brushes with nylon or metallic bristles can be used. Figure 2-11 shows a typical water-driven bristle brush, and Figure 2-12 shows a propellant gun. Soft rubber plugs or plastic scrapers can be used instead of brushes if fouling conditions warrant. Another method is simply shooting 200–400 psi (1.4–2.8 MPa) of air and/or water through the tube. This is the fastest method; however, it is not appropriate for most cleaning.

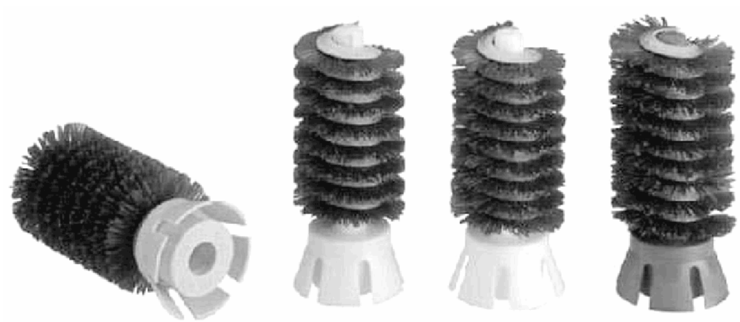


**Figure 2-11**
**Typical Water Bristle Brushes**
*Courtesy of Conco Systems, Inc.*

**Figure 2-12**
**Water Gun for Brushes and Scrapers**
*Courtesy of Conco Systems, Inc.*

If the foulant is too hard to be removed by bristle brushes, scrapers can be used. These are driven with 200–400 psi (1.4–2.8 MPa) of water pressure. Scraping edges should be spring-loaded to match the specified tube diameter.

There are two types of scrapers: plastic and metal. Figures 2-13 and 2-14 show plastic and metal scrapers, respectively.

**Figure 2-13**
**Plastic Tube Scrapers**
*Courtesy of Conco Systems, Inc.*

C3S Cleaner for Hard Deposits

C4S Cleaner for General Purpose

C2X, C3X Cleaner for Thin, Tenacious Deposits

CB Cleaner for Hard, Thick Calcite Deposits

**Figure 2-14**
**Metal Tube Scrapers**
*Courtesy of Conco Systems, Inc.*

Scrapers have one or more rims that expand to conform to the shape of the tube. The scraping edges are spring-loaded to press against the tube surface, and the scrapers are propelled by water.

Scrapers are one of the most effective off-line tube-cleaning methods developed. Because they are strong enough to remove hard deposits, they retard under-deposit tube pitting. Properly used, scrapers will not stick to the inside of a tube unless the tube is already damaged or obstructed. When metal scrapers are used to clean condenser tubes, it is important to verify that they are not left in the tubes after cleaning because they might promote subsequent tube failure by blockage erosion. Completely obstructed tubes should be plugged.

### 2.2.2 Mechanically Driven Systems

The most difficult foulants can be removed by motor-driven scrapers. Scraper heads are available in a variety of configurations. Most are equipped with flexible shafts or universal joint shafts and are motor driven; some are adjustable to accommodate varying tube bores. An example of a motor-driven scraper is shown in Figure 2-15.

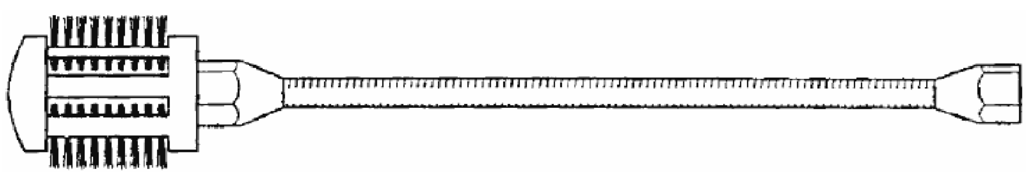


**Figure 2-15**
**Mechanically Driven Brush**

### 2.2.3 Pressure-Driven Systems

In water lancing, the foulant is removed by shearing the layers with high-pressure, high-velocity water jets. Water pressures of 8,000–10,000 psi (55–69 MPa) are normally used; pressures as high as 18,000 psi (124 MPa) can be used. Operators need to take extreme safety precautions: these high pressures can collapse tube ends and tube inserts and damage tubesheet coatings and tube-to-tubesheet joints.

During water lancing, water is pumped through a flexible hose or rigid metal shaft, the end of which is attached to a stainless steel head. The head is drilled with several orifices to define a particular spray pattern that will usually provide self-propulsion as well as tube wall cleaning. Lance head design is critical to foulant removal. Typical water lance heads are shown in Figure 2-16.

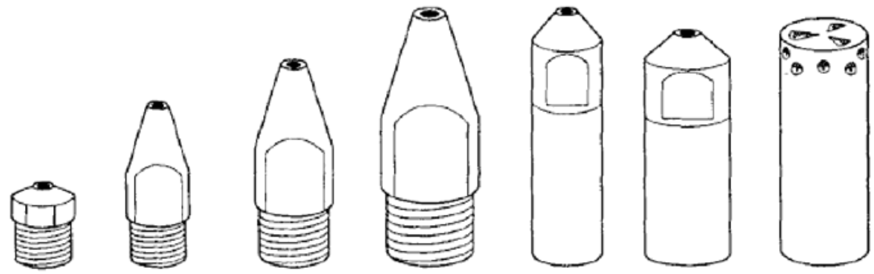


**Figure 2-16**
**Typical Water Lance Heads**

This technique, also called *hydrolancing* or *hydrolasing*, uses a high-pressure water spray to remove fouling deposits. Water is pumped through a flexible hose or a rigid metal shaft fitted with a steel spray head at the end. The head is designed to allow the spray pattern to impinge on the tubes to remove scales. The water pressure also propels the head forward.

The water can also be treated with chemical inhibitors to protect steel surfaces or copper alloys. Some utilities add surfactants to the water to accelerate scale removal. Because the high-pressure water can damage weakened tubes, the condenser should always be leak-tested after hydroblasting. Hydrostatic testing (that is, filling the condenser hot well with water) should be sufficient.

### *2.2.4 Waste Disposal*

Dry off-line processes require an industrial vacuum cleaner with a filter to collect removed deposits and limit airborne dust. Tarps or plastic wraps can also minimize airborne dust.

When cleaning closed cooling water systems, wet processes might require containment, testing, and disposal of debris-laden water. Temporary traps or temporary rigid plastic channel covers can contain water locally. Using detaining drums and/or temporary screens can limit the discharge of large particles into the water drain system.

Passivation and deposit-removing chemicals added to the water can complicate waste disposal. Water containing chemicals might require treatment or off-site disposal.

When cleaning open cooling water systems, the debris is generally released into the outlet waterbox. It then flows to the discharge of the cooling water piping.

### *2.2.5 Advantages and Disadvantages of Off-Line Systems*

Off-line cleaning systems offer several advantages. They cost significantly less than on-line systems and require no maintenance or monitoring as compared to on-line equipment. There are no balls to replace, no backflushes to initiate, nor any reverse-flow system transients. When the off-line cleaning is completed and the unit is back in service, the cleaning components are stored and require no attention.

A principal disadvantage of off-line tube cleaning equipment, however, is that it interrupts service. The condenser cannot function at full load while it is being cleaned, and reducing load can be costly—especially with forced outages. Off-line cleaning can be scheduled during refueling or boiler outages or during scheduled load reductions.

On- and off-line tube cleaning systems share the objective of maintaining tube cleanliness and ensuring intended heat transfer rates. Tube cleanliness is maintained continuously by on-line systems and might begin to deteriorate soon after an off-line tube cleaning is completed. If this situation can be tolerated because of very conservative design margins, off-line systems can be sufficient.

Each type of off-line cleaning device has limitations. For instance, although using bristle brushes driven by relatively safe water pressures of 200–400 psi (1.4–2.8 MPa) is the most common off-line cleaning method, the brushes might be effective only for the softest foulant. Scrapers and high-pressure water lancing might be more effective against more tenacious deposits, but they might need help where fouling buildup has been allowed to get too thick and hard.

When high-pressure water lancing equipment must be used, it presents a potential safety hazard to operating personnel because of pressures as high as 8,000–10,000 psi (55–69 MPa). Often this equipment is used by a contractor who specializes in high-pressure equipment. Propelling the cleaning devices through the tubes with high-pressure air or a combination of air and water also presents a safety hazard because of very high travel speeds.

As a final choice, rotating brushes, cutters, and scraping heads are possible—but they are too slow to use for routine surface condenser tube cleaning. These methods are used where serious problems exist in the tubes and other off-line methods are unsuccessful. These tools can easily damage tube walls if they are used incorrectly.

All off-line tube cleaning methods use consumable cleaning devices that wear out and require periodic replacement.

The following are the advantages of air- and water-driven bristle brushes, rubber plugs, and plastic pigs:

- The equipment is significantly cheaper than on-line alternatives.
- The cleaning devices require no special maintenance or monitoring.
- The cleaning operation is fast.

The following are the disadvantages of air- and water-driven bristle brushes, rubber plugs, and plastic pigs:

- The equipment must be out of service, which leads to lost revenues from downtime, or cleaning must be scheduled during refueling or boiler outages or during scheduled load reductions.
- There is increased labor cost to operate the equipment.
- The equipment might not be effective on the types of deposit present.

The following are the advantages of water-driven scrapers:

- The scraping edges are spring-loaded to match the specified tube diameter.
- The scrapers can collect a tube deposit sample for testing.
- The scrapers are safe and fast.

The following are the disadvantages of water-driven scrapers:

- The equipment must be fully or partially out of service.
- The scrapers can damage the tube walls if used incorrectly.
- The scrapers can become lodged in the tubes.

The following is the advantage of water lances:

- Water lances use high-pressure water spray to remove scale.

The following are the disadvantages of water lances:

- The equipment must be fully or partially out of service.
- There is a potential hazard to operating personnel.
- The water lances can damage the tubesheet coating.
- The water lances can collapse thick tube walls at the tube-to-tubesheet joint.
- Degraded tubes can be damaged and begin to leak.

## 2.3 Chemical Cleaning

Chemical cleaning techniques can be applied to both open and closed cooling water systems, and chemicals are selected based on the scale composition to be removed and the condenser materials. Typically, a removed tube and/or corrosion coupon is used in bench tests to verify solvent compatibility with the condenser materials. Pulling tubes can be used for process optimization. Visual inspections and eddy current measurements are used before and after cleaning to evaluate cleaning effectiveness.

Both on- and off-line chemical cleanings have been performed in the industry. On-line cleanings can be as simple as injecting the cleaner into a closed cooling water cycle. Off-line chemical cleaning involves the use of temporary equipment for chemical injection, condenser water recirculation, and vapor removal. The type of chemical cleaning selected for a specific plant (that is, on-line versus off-line techniques) is based on factors such as the foulant, materials, design issues, and schedules.

Typically, on- and off-line chemical cleaning techniques remove 3–10 mils (76–254 µm) of deposit in 30–60 hours. On-line techniques are applied to one waterbox at a time or to the entire condenser; off-line techniques apply to the entire condenser. Chemical cleaning of the condenser typically regains lost megawatts.

# 3
# CONDENSER CLEANING EQUIPMENT PROBLEMS

## 3.1 On-Line Equipment Problems

Prior to beginning the development of this report, NMAC conducted a survey of its members to determine the type and nature of the problems with on-line condenser cleaning equipment that were being experienced by its members. The following summarizes the results (as cited by members) and identifies the most common problems being experienced:

- "The system doesn't work. Haven't used it in 5 to 7 years."
- "Wear from rotation on ball collection screens."
- "We've had problems with cast iron pumps and abrasive balls (replaced pumps with ones of a different material)."
- "Have blown out two Plexiglas covers on the collection tanks."
- "Obsolete parts."
- "Problems with tubercles in the screen spool pieces preventing (and in some cases destroying) operation of the screens."
- "Lack of maintenance/experience knowledge on this system."
- "The primary issue is ball recirculation reliability; particularly the lower screens."
- "Our strainer model has not been updated with later modified designs. Current original plant design has a large set of upper screens and a lower screen section within a funnel box. The lower screens tend to foul with river water-type clam shells and plastic fill material from the cooling towers. Once screens are fouled, backwashing of screens is not effective in debris removal. Debris becomes jammed within screen bars."
- "We experience sponge ball fouling of the upper screens in one or more quadrants. It appears that higher cooling water velocity is driving balls harder into the screens, resulting in sliced sponge ball fragments trapped in screens."
- "An issue with ball recirculation is shutoff flap mispositioning due to drive motor-shaft coupling slippage. Match marking coupling has aided diagnosis of shaft slippage to identify mispositioning of shutoff flaps at entrance to lower screen funnel box."
- "Problems in the pickup system of cleaning balls because of large amounts of seaweed intrusion."
- "Questions as to the correct loading of cleaning balls. The vendor recommendations have been found to overload the new collector tanks."

- “Aging equipment.”
- “The piping systems, valves, and plugs can experience accelerated corrosion.”
- “The linkages of the older designs become loose, and the instrumentation and controls require maintenance.”
- “Ball wear is a normal condition resulting in the loss of undersized balls that pass through strainer catch screens. Full-size balls can lodge behind debris or collection grids and become lost after a routine backwash operation. Ball hiding occurs at stagnation points in waterboxes and other areas where low fluid velocity allows balls to stop moving.”
- “As the strainer section screen condition deteriorates, the balls are easily lost.”

# 4

# TROUBLESHOOTING ON-LINE CONDENSER CLEANING EQUIPMENT PROBLEMS

## 4.1 Troubleshooting Operational and Equipment Problems

Table 4-1 identifies common operational problems that can be experienced with ball type on-line condenser cleaning equipment, likely causes and recommended solutions. The supplier's service department should be contacted with specific questions and assistance requirements.

**Table 4-1**
**Typical Operational and Equipment Problems Experienced with On-Line Condenser Cleaning Equipment**

| Operational Trouble | Cause | Remedy |
|---|---|---|
| Poor ball catching results (below 90–95%) | Main condenser equipment data have changed since the original commissioning and may not be valid as a basis for ball selection. | Check data and consult the supplier for correction of the chosen operational ball size and quality. |
| | The presence of "dead spots" in the system, for example, within the waterbox and cooling water pipe. | Screen or shield dead spots (consult the vendor representative for advice).<br>Correct or improve existing dead-spot coverings. |
| | The presence of leaky partition walls within the waterboxes. | Install new gaskets. |
| | Air is in the waterboxes. | Check or install waterbox vents. |
| | Bleeder pipes, vent bleeder, or drain valves between the ball injection and strainer section are not covered or screened. | Check that drain lines and the vent piping are screened off. |
| | Balls are impeded by debris in the waterbox, tubes, or strainer section. | Thoroughly clean the entire cooling water system of debris.<br>Check the debris filtering system, and improve it as necessary.<br>Extend the ball catching and screen backwash time.<br>Backwash the screens more often. |

**Table 4-1 (continued)**
**Typical Operational and Equipment Problems Experienced with On-Line Condenser Cleaning Equipment**

| Operational Trouble | Cause | Remedy |
|---|---|---|
| Poor ball catching results (below 90–95%) (continued) | Pressure drop across the condenser tubes is too low. | Increase the quantity of cooling water, if possible. Otherwise, consult Taprogge for a new ball selection. |
| | There is excessive cooling water in the strainer section (that is, balls are pressed onto or through the screen bars). | Attempt to prevent exceeding the specified limit of cooling water quantity. Consult Taprogge for the selection of larger or harder balls. |
| | Ineffective, worn balls are being lost (that is, balls are in the system for too long a period of time). | Contact the vendor for a different operating ball selection.<br>Sort balls regularly and replace worn balls more frequently. |
| | Balls are being destroyed, and pieces are passing through bars of the screen (that is, balls are too old or are being stored incorrectly). | Replace balls with a new charge of balls.<br>Check the condition of the ball recirculation pump impellers.<br>Check for improper storage of sponge balls. Follow sponge ball storage requirements. |
| | Screens do not close correctly or they are damaged. | Check the condition and alignment of screens and their actuation. Repair damaged screens according to the manufacturer's specifications. |
| | The collector ball-catching screen does not close correctly. | Check the ball catching screen for obstructions and/or repair the collector ball catching screen and its actuation. |
| | Operational error can lead to poor results. | Review and follow the steps listed in the operating instructions. Request classroom or site-specific operator training from the manufacturer. |
| Increased ball wear and/or damage | There is a rapid deposit accumulation in the condenser tubes. | Contact the vendor for further information and recommendations. |

# 5
# MAINTENANCE RECOMMENDATIONS FOR CONDENSER CLEANING EQUIPMENT

## 5.1 Preventive Maintenance Recommendations

Table 5-1 provides recommended inspection and preventive maintenance practices for equipment commonly found in on-line condenser cleaning equipment.

**Table 5-1**
**Preventive Maintenance Recommendations for On-Line Condenser Cleaning Equipment**

| Part or Subassembly | Operation | Frequency |
|---|---|---|
| **Strainer Section** | | |
| Strainer section | Inspect the general condition of the strainer section and its components such as screens, bearings, sealing, and the actuating mechanism. Inspect the internal coating or rubber lining and external paint or prime coating. Touch up or repair damaged areas as necessary. | Yearly |
| Screens | Inspect the movement of screen shafts. | Monthly |
| | Check the operational positions of screens and ensure that the positions are in accordance with the position indicator labels on the gears. | Monthly |
| | Backwash the screens. | According to O&M |
| Inspection hole (manway) | Check the wear and tear on the gasket. | Yearly |
| | Check the nuts and bolts. | Yearly |
| **Ball Recirculation Pump and Motor** | | |
| Pump | Inspect the shaft, impeller, casing wear, ring, mechanical seal, and shaft seal. | Yearly |
| Motor | Inspect the rotor, fan, and paint finish. | Yearly |
| Motor and pump | Check for noise and high temperature. | Daily |

**Table 5-1 (continued)**
**Preventive Maintenance Recommendations for On-Line Condenser Cleaning Equipment**

| Part or Subassembly | Operation | Frequency |
|---|---|---|
| **Ball Collector** | | |
| Collector | Inspect the ball screen, catch lever, covers and gaskets, sight glass, and paint finishing. | Yearly |
| Ball screen bearing | Check tightness. | Monthly |
| Sightglass | Clean. | Weekly |
| **Ball Valves** | | |
| Ball valves | Inspect the body, ball seats, seals, O-rings, stem, and paint finish (if applicable).<br>Check tightness, freedom of movement, and bolting | Yearly<br>Monthly |
| **Differential Pressure Measuring System** | | |
| General | Inspect and perform general cleaning of the entire system. | Yearly |
| Transmitter/indicator | Check electrical functions and the zero point. | Yearly |
| Sensing lines | Check tightness; check for any leakage of the silicone oil. | Weekly |
| **Actuators** | | |
| Actuators | Inspect the general condition and painting finish.<br>Check for wear. | Every six months<br>Monthly |
| Torque switch and limit switch compartments | Check for correct setting of limit and torque switches in accordance with vendor guidelines. | Yearly |
| **Control Panel** | | |
| Control panel | Inspect the control panel, including all components.<br>Check all connections.<br>Check the control program (that is, the programmable logic controller) for automatic operation. | Yearly<br>Yearly<br>Yearly |

## 5.2 Corrective Maintenance Recommendations

A review of several members' maintenance documents revealed that there appears to be a general lack of detailed instructions or guidance on specific maintenance tasks associated with condenser cleaning equipment.

**Key Technical Point**

Documented maintenance instructions can improve the effectiveness of the equipment and consistency in maintenance tasks.

Specific maintenance instructions are typically provided by the system supplier. If copies cannot be located at your plant, contact your supplier for additional copies. A compilation of recommended tasks on selected components in the system, specific to the D2 strainer section is presented next.

### *5.2.1 Strainer Section Bearing*

If, under extraordinary circumstances, damage to the screen shaft and bearings occurs, the following procedures regarding bearing disassembly must be followed.

**Key Human Performance Point**

Before beginning any work, make sure that the following work procedures and precautions are observed and completed:

- Shut down the condenser tube cleaning system completely.
- Make sure that the cooling water discharge piping and the strainer section are completely isolated and drained.
- Shut off current supply to the control panel.
- Observe all applicable plant safety precautions before beginning any work.

### *5.2.2 Front Screen Bearings*

Take the condenser cleaning system out of operation according to the shutdown procedures that follow.

To disassemble the screen actuator, perform these steps:

1. Electrically disconnect and remove the actuator from the worm gear assembly.
2. Remove the worm gear pointer cover after removing the hex head bolts.
3. Disengage the clamping assembly between the screen shaft and the worm gear stem nut.
4. Remove nuts and washers from worm gear mounting studs, and remove the worm gear from the intermediate flange.
5. Remove the stem nut and clamping assembly, as a unit, from the screen shaft.

6. Clean the screen shaft end completely.
7. Support the screen shaft and fix its position using wedges (for example, hardwood) or similar material from the inside of the strainer section.

To disassemble the front bearing of screens, perform these steps:

1. Loosen the socket head bolts and remove the gasket washer together with the outer O-ring.
2. Loosen the hex nut and remove the intermediate flange.
3. Tap the bearing bushing from the back side and remove the bearing bushing, O-ring, and the bearing and distance ring, as a unit, from the bearing nozzle.
4. Remove the O-ring from the bearing nozzle.
5. Check the O-rings, the bearing bushing, and the bearing and distance ring for signs of wear or damage. Replace worn or damaged parts.

Reassemble the front bearing carefully in reversed sequence. Light greasing of the parts facilitates the reassembly work.

Observe the screen position. The actual position of the screen surface is indicated by a position indicator on the shaft cover plate. The end positions (that is, operating and backwash positions) of the screen are marked by position labels.

If the clamping assembly has slipped from its original position, adjustment of the screen position is necessary.

In such cases, the following procedure should be used:

1. Open the inspection hole.
2. Move the worm gear all the way to the “Operate” position, and then turn back approximately 5% of its traveling range.
3. Loosen and remove the clamping assembly.
4. Turn the screens from inside the strainer section fully into the Operate position. Avoid excessive force.
5. Carefully clean the shaft end, clamping assembly, and worm gear bushing.
6. Check for possible shaft damage.
7. Insert the clamping assembly and torque the clamping screws to 10 ft.lb (13.6 J) according to the required installation procedure.

   **Notes:** Do not overtighten the clamping assembly screws.
   Light greasing of the parts facilitates reassembly work. Use only silicone-based grease.
   Insert the adjusting washer before mounting the flange.

### 5.2.3 Rear Screen Bearing

To disassemble the rear screen bearing, perform these steps:

1. Support the screen shaft and fix its position using wedges (for example, hardwood) or similar material from the inside of the strainer section.
2. Remove the hex nuts and washers from the rear bearing studs and carefully slide out the rear bearing bushing, including the distance ring. Remove the O-ring.
3. Check the O-ring, the distance ring, and the inner surface of the rear bearing for signs of wear and/or damage. Replace if necessary.

Reassemble the rear bearing carefully in reversed sequence.

**Key Technical Point**

Important! The correct adjustment of the operational positions of the motor-operated screen, along with the proper setup of the actuators, guarantees the proper functioning of the strainer section.

### 5.2.4 Ball Collector

The following process should be used for replacement of the ball catching flap (BCF) O-ring.

**Key Technical Point**

**Note:** Site-specific drawings should be used at all times. Contact the system supplier if copies are not readily available.

Replace damaged or worn inner parts as follows:

1. Remove the BCF actuator from the collector lantern.
2. Loosen and remove the hex nuts, washers, and retainer. Remove the lantern and bushing from the collector as a unit. If the bushing is worn, remove and replace it.
3. Remove the shaft and key as a unit. Note the location of the shaft keyway with respect to the collector housing for reassembly purposes.
4. Inspect all of the dismantled parts.
5. Remove and replace the O-ring mounted in the retainer. Install a new gasket between the collector housing and the retainer.

Reassemble the components in reverse order.

Use only a silicone-based grease to lubricate all metal parts.

**Key Technical Point**

**Note:** When the previous steps are complete, be sure to do the following:

1. Readjust the BCF to ensure smooth operation.
2. Check the torque and limit switches of the actuator and readjust as necessary.

## 5.3 Lubrication

Proper lubrication is important for moving parts. Equivalent grease may be substituted where available.

To lubricate the strainer section (which is the drive system for screens), follow the guidance provided in Table 5-2.

**Table 5-2**
**Lubricating the Strainer Section**

| | Subassembly | |
|---|---|---|
| | **Thrust Gear** | **Bevel Gear** |
| Recommended grease or oil type | Grease type KL3N according to DIN 51502 (or equivalent*)<br>Temperature range: -22°F to +284°F (-30°C to +140°C)<br>Walk penetration according to DIN 51818 220 to 250 | |
| Filling method | Grease gun | Grease gun |
| Initial charge quantity | Approximately 3.5 oz (100 g) | Approximately 8.8 oz (250 g) |
| **Initial Grease Charge** | | |
| Quantity | Approximately 3.5 oz (100 g) | Approximately 3.5 oz (100 g) |
| **Grease Replacement** | | |
| Frequency | Replace grease after 20,000 hours up to 3 years maximum | Replace grease after 20,000 hours up to 3 years maximum |
| Replacement charge quantity | Approximately 3.5 oz (100 g) | Approximately 8.8 oz (250 g) |

* Equivalent greases are EXXON Beacon 3, Mobil Mobilux 3, Shell Alvania R3, Texaco Multifak 30, and BP Energrease LS3.

**Key Technical Point**

**Note:** Greases of different soap bases (for example, lithium or sodium) may not be compatible when mixed. Prevent such intermixing by completely purging the bearing of old greases.

To lubricate the actuators, follow the guidance provided in Table 5-3.

**Table 5-3**
**Lubricating Actuators**

| | Subassembly | |
|---|---|---|
| | **Strainer Section Screens** | **Collector Ball Catching Screen** |
| Recommended grease or oil type | Exxon Nebula EP-0 | Exxon Nebula EP-0 |
| Filling method | Grease gun | Grease gun |
| **Initial charge** | | |
| Quantity | Gearbox capacity | Gearbox capacity |
| **Replacement** | | |
| Frequency | 18 months or 500 cycles (whichever comes first) | 18 months or 500 cycles (whichever comes first) |
| Replacement charge quantity | Gearbox capacity | Gearbox capacity |

To lubricate the ball recirculation pump and motor, follow the guidance provided in Table 5-4.

**Table 5-4**
**Lubricating the Ball Recirculation Pump and Motor**

| | Subassembly | |
|---|---|---|
| | **Mechanical Seal** | **Motor** |
| Recommended grease or oil type | N/A (service-water lubricated) | U.S. Motors No. 83343, Chevron SRI Grease No. 2, Exxon Unirex N2, Shell Alvania No. 2, or Texaco Premium BRB No. 2 |
| Filling method | Direct | Best method |
| **Initial charge** | | |
| Quantity | N/A | N/A |
| **Replacement** | | |
| Frequency | Perpetual when primed before operation | Every six months |
| Replacement charge quantity | N/A | N/A |

# 6

# UPGRADES FOR CONDENSER CLEANING EQUIPMENT

One of the more common on-line cleaning systems in use by members is the "Amertap" system, now supplied by Taprogge[1]. From the 1950s through the mid-1980s, Amertap supplied three different "HE" design strainer sections: the HE-2, HE-4, and HE-8.

The HE-2 strainer consisted of two large primary screens (upper) to collect the circulating sponge balls and direct them to a smaller secondary set of screens (lower), which diverted the sponge balls to the ball extraction points. Similarly, the HE-4 consisted of 4 upper screens and 8 lower screens, and the HE-8 consisted of 8 upper screens and 16 lower screens (see Figure 6-1).

[1] Taprogge (formerly Amertap) is a company that supplies commonly used on-line condenser cleaning equipment. Amertap was the previous name of this equipment and the company that supplied it.

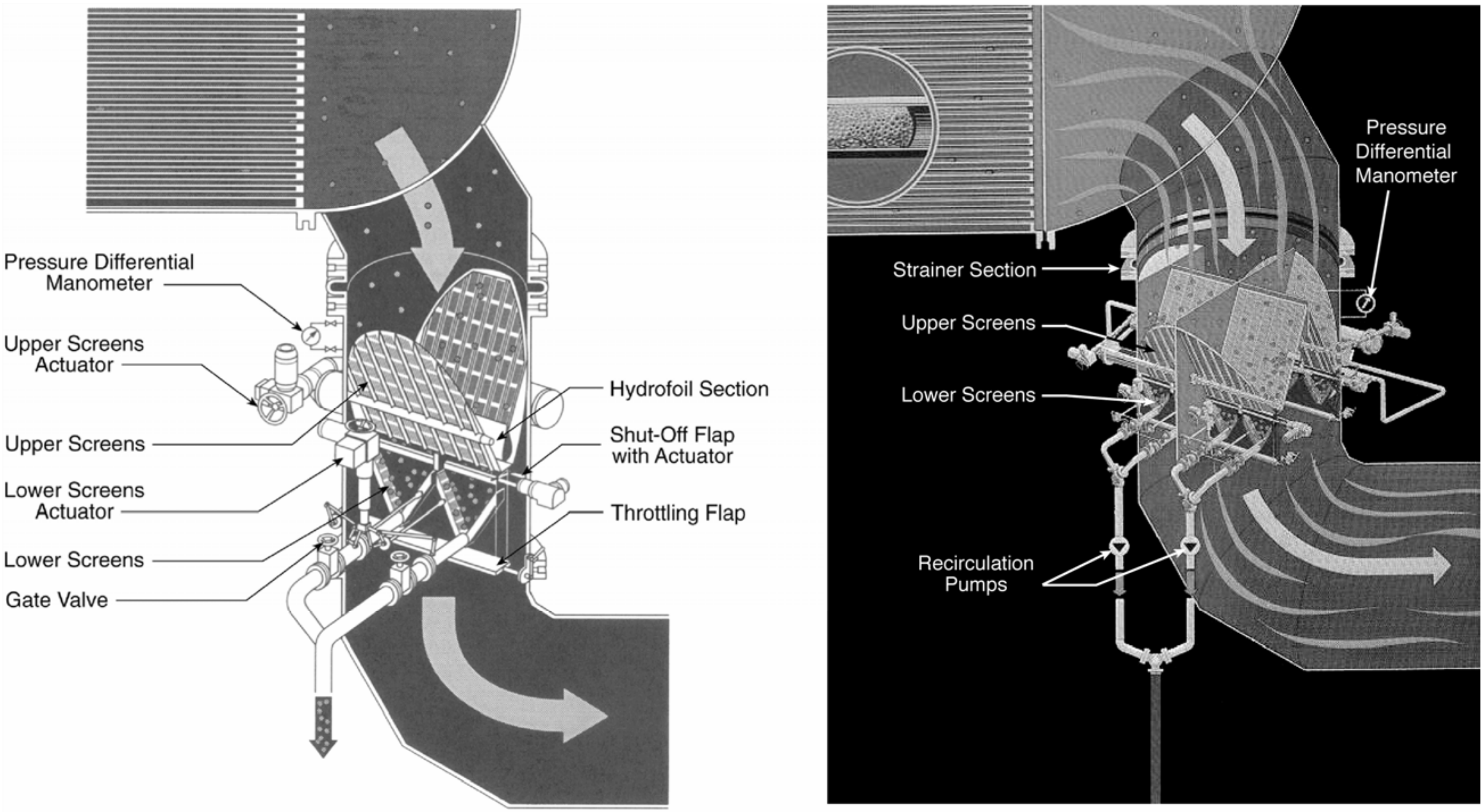



**Figure 6-1**
**"Old" HE-2 and HE-8 Design Amertap Systems**

**Key Technical Point**

Movement of the balls down the screens to the extraction points depends on specific flow conditions in the screen sections and on proper screen alignment.

Sometimes flow conditions can be affected by trapped debris or biological growth in the lower screen surfaces that can prevent good circulation and ball extraction. Maintaining proper adjustment of the multiple sets of screens with multiple sets of levers, links, and connecting rods can be difficult.

The current Taprogge strainer design, "D2," consists of two semielliptical screens installed in an inverted "V" configuration (see Figure 6-2). Unlike the HE design, the D2 does not have the complicated lower internal components, including lower screens, shutoff flaps, and throttling flaps. Externally, the lower screen actuation, spindles, linkages, connecting rods, and motor operators are also not required. Where the HE design used all of these components to concentrate the balls, the D2 design uses small hydrofoils located adjacent to the extraction pipe to create a localized hydraulic vortex that transports and extracts the balls from the cooling water flow.

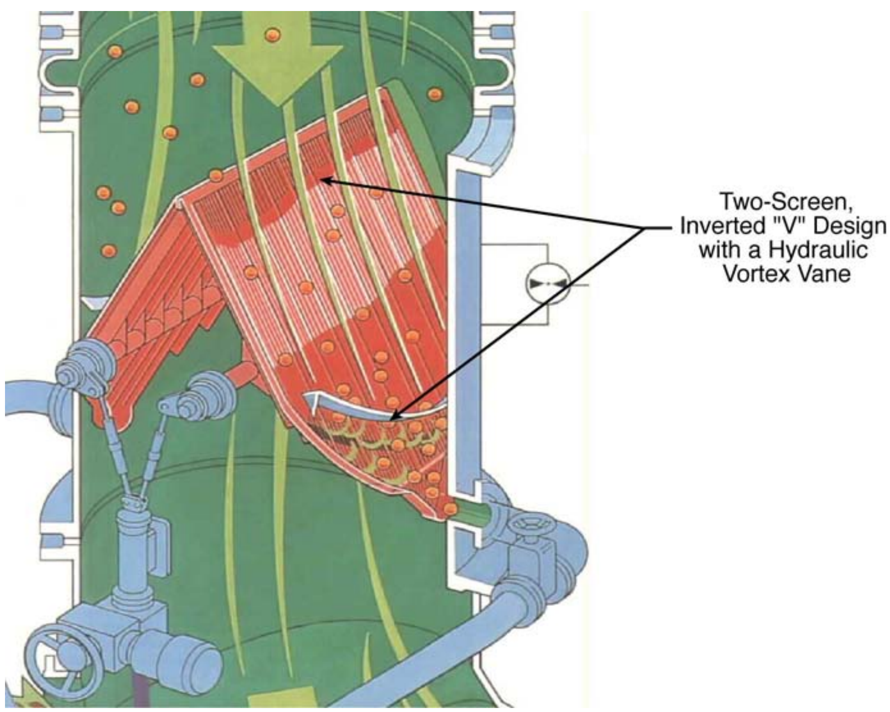



**Figure 6-2**
**"New" D2 Strainer Section**

The hydrodynamic design principles of the D2 have been carried over into the design modification of the older HE systems. This simple modification eliminates the entire lower screen assembly and mechanisms and replaces them with a stationary extraction block(s) having no moving parts at all. Figure 6-3 illustrates the hydrofoil principle; Table 6-1 quantifies the eliminated components for each of the HE strainer sections. This extraction block (or blocks) is secured between the upper screens and includes small hydrofoil sections and two ball extraction ports.

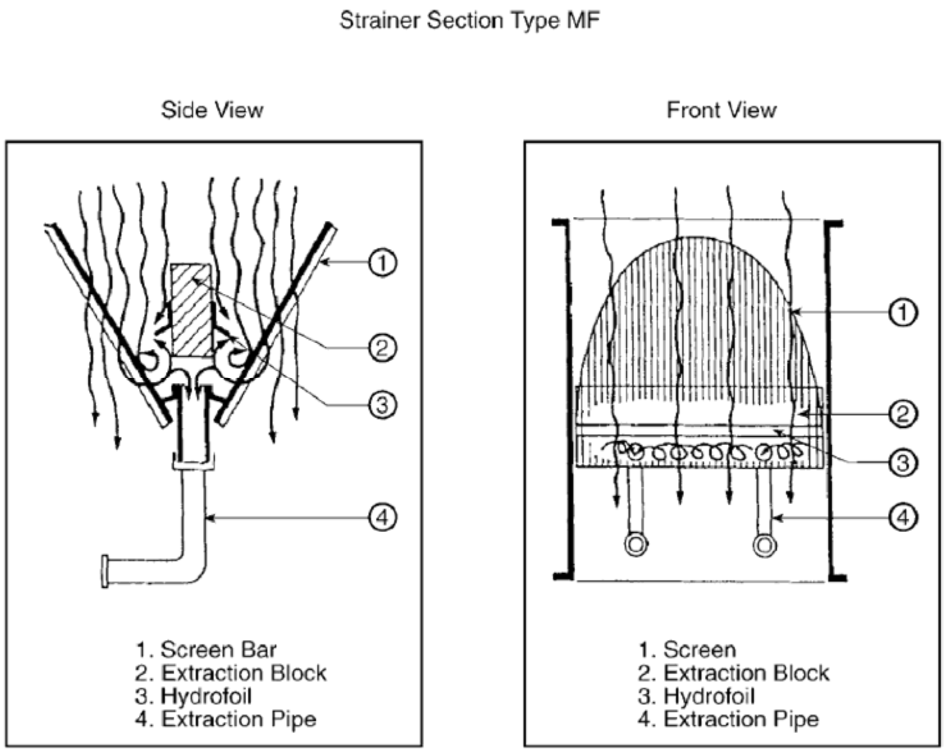



**Figure 6-3**
**Ball Extraction Using the Hydrofoil Principle**

**Table 6-1**
**Comparison of Strainer Section Components and Strainer Section Type**

| Strainer Section Components | Strainer Section Type | | | | | |
|---|---|---|---|---|---|---|
| | HE-2 | HE-2 Modified | HE-4 | HE-4 Modified | HE-8 | HE-8 Modified |
| Number of upper screens | 2 | 2 | 4 | 4 | 8 | 8 |
| Number of electric actuators | 1 | 1 | 2 | 2 | 4 | 4 |
| Number of lower screens | 4 | 0 | 8 | 0 | 16 | 0 |
| Lower screen controls (for example, spindles and rods) | Yes | No | Yes | No | Yes | No |
| Number of lower screen actuators | 1 | 0 | 2 | 0 | 4 | 0 |
| Number of shutoff flaps | 1 | 0 | 2 | 0 | 4 | 0 |
| Number of shutoff flap actuators | 1 | 0 | 2 | 0 | 4 | 0 |
| Number of throttle flaps | 1 | 0 | 2 | 0 | 4 | 0 |

Existing sponge ball recirculation pumps and other recirculating components are unaffected by the HE/MF conversion. From the "controls" side, the number of motor operators is reduced by two-thirds for every strainer section. A simple before-and-after illustration of the HE strainer section is provided in Figure 6-4. Figure 6-5 is a photograph of lower screens and other components that were removed from HE-2 strainer sections.

**Key O&M Cost Point**

This modification of installed HE strainer sections can be accomplished easily without removing the strainer section from the cooling water piping.

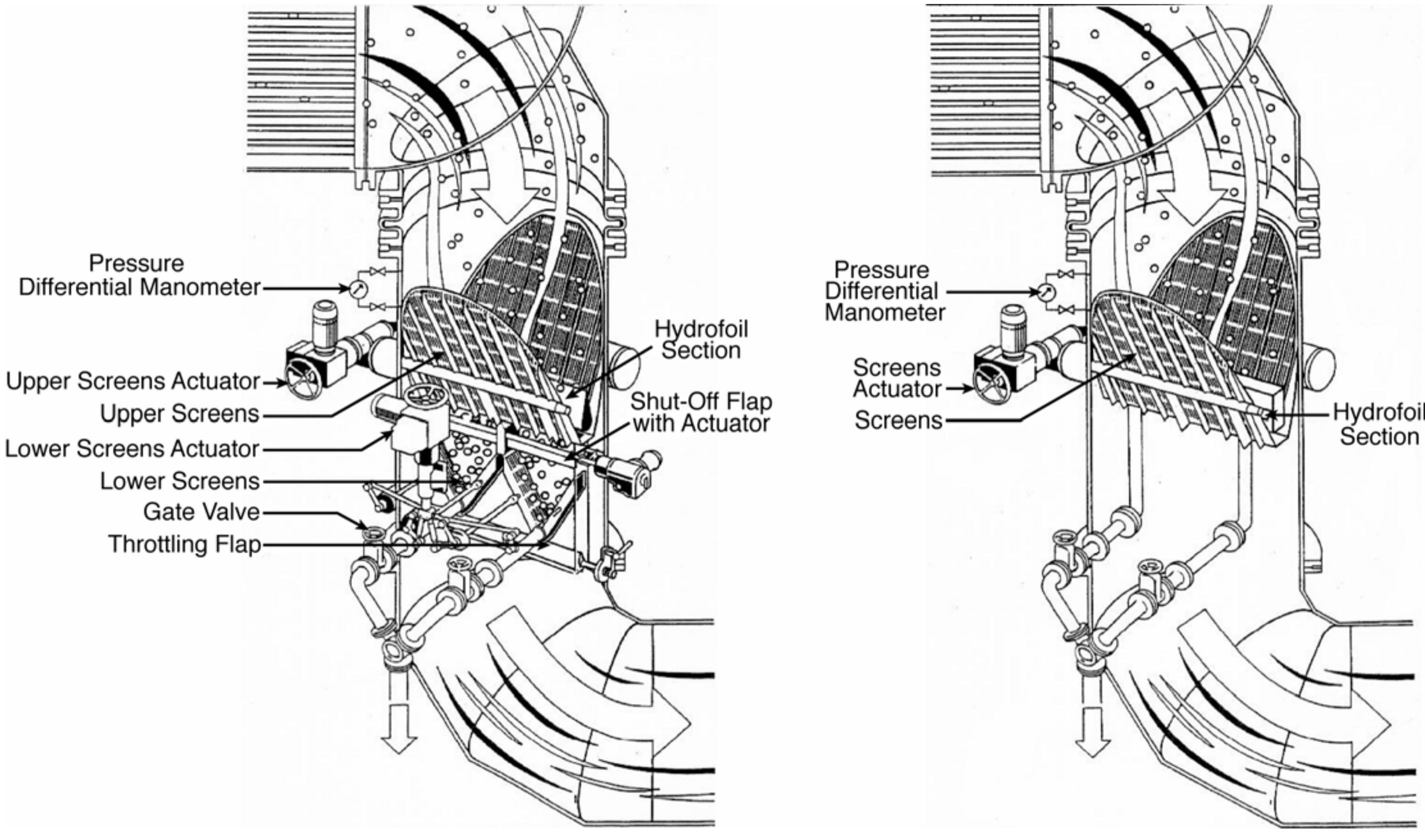



**Figure 6-4**
**HE-2 Strainer Section Before and After Modification**

**Figure 6-5**
**Obsolete Parts Removed from HE-2 Strainers**

In extreme cases in which the upper screens have been damaged beyond repair or outlived their 30-year life expectancy, Taprogge has installed newly designed, segmented upper screens with solid shafts and junction plates. After the old upper screens were demolished, the new, stronger, segmented screens are then transported through existing manways and bolted to the new shafts and junction plates. In addition, new bearings and actuation are installed external to the strainer section shell. The new “externals” also use present design bearing standards with locking assemblies instead of old-style keyed shafts with packing. Although the scope of a new screen replacement is greater than the modification of the lower screens alone, all work is done internal to the strainer shell without having to remove the spool piece from the cooling water pipeline. In addition, all ball extraction connections remain the same with the exception of the lower screen connections, which are simply capped off.

In addition to the strainer sections, additional upgrades are available for other system components for charging, storing, agitating, releasing, and collecting sponge balls, including control panels. These components can all be upgraded or replaced by dimensionally equivalent new components; contact the vendor for additional recommendations.

# 7
# REFERENCES

## 7.1 In-Text Reference

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*Preventive Maintenance Basis, Volume 34: Main Condensers*. EPRI, Palo Alto, CA: 1998. TR-106857-V34.

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# A

# RECOMMENDED OPERATING PROCEDURE FOR TAPROGGE (AMERTAP) CONDENSER CLEANING EQUIPMENT

Proper operating steps are essential for the effective operation of condenser cleaning equipment. A review of several procedures in use by Nuclear Maintenance Applications Center (NMAC) members revealed that, in most cases, important elements or steps recommended by the equipment manufacturers were often left out of operating procedures. Following are the recommended operating steps for the most common on-line cleaning system used by NMAC members. It is recommended that operating procedures be reviewed to ensure that the proper steps are being followed during system operation.

## A.1 Operating Description and Parameters of the Condenser Cleaning System

### *A.1.1 General Description*

Most tube materials, such as titanium or stainless steels and copper alloys, are partially susceptible to both organic and inorganic fouling and pitting corrosion.

Organic fouling is caused by the presence of bacteria, which can grow into a thick, adherent film on tube inside surfaces. These films trap sediment, which further restricts cooling water flow and heat transfer. Copper alloy and non-copper tube materials can also suffer from scaling by precipitation of salts such as calcium carbonates from the cooling water. Again, these scales decrease cooling water flow, degrade heat transfer, and promote pitting corrosion.

Both organic fouling and pitting corrosion can be prevented by the careful monitoring of the tube cleaning system operation.

The number of screen backwashings is determined by the amount of debris in the cooling water, which is monitored by the differential pressure measuring system. Screen backwashing is done automatically by the control system. Typical ball life under continuous circulation is approximately one month. The sponge balls should be collected and sized at least once per week; according to the results, the basic ball charge should be replaced partially or completely. Typically, 25% of the balls will be replaced on a weekly basis.

### A.1.2 Project-Specific Operating Recommendations

For optimum condenser and condenser tube cleaning system (CTCS) performance, the following operating parameters are recommended:

- Operation mode: Automatic
- Operation frequency: Continuous
- Screen backwash: Twice monthly (or as required)
- Ball collection for check: Twice monthly (or as required)
- Ball collection for replacement: Once monthly (or as required)
- Ball type(s): As recommended by the vendor at your plant
- Ball quantity: 300 per collector
- Condenser: At least 4000 gpm (908 m3/hr) cooling water flow rate per strainer section (8000 gpm [1817 m3/hr] total) to maintain the minimum required pressure drop across the condenser

### A.1.3 General Basic Position of the Condenser Cleaning System

The CTCS is designed for automatic, continuous cleaning and is controlled by the control panel and monitored by the differential pressure measuring system.

Operation begins from the “Basic,” out-of-service position, which is defined as follows:

- Strainer screens: “Backwash” position
- Ball catching flap (BCF): “Collect” position
- Collector inlet ball valve: “Open” position
- Collector outlet ball valve: “Open” position
- Collector drain ball valve: “Closed” position
- Collector vent ball valve: “Closed” position
- Collector lid: In place and tight
- Ball recirculation pump(s): “Off” position
- Strainer extraction valves: “Open” position
- Injection nozzle valves: “Open” position
- Distributor isolation valves (present on combined tube cleaning systems only): “Open” position

Check the equipment positions prior to running the circulating water pumps. If this is not possible or the ball recirculation piping and/or equipment are not complete, the isolation valves at the ball extraction and injection points must be closed.

## A.2 Startup of the Condenser Cleaning System

### *A.2.1 Pre-Startup Inspection*

Follow these steps to conduct a pre-startup inspection:

1. Inspect waterboxes for possible “dead spots,” screened-off vents and drains, and protruding condenser tubes that can trap cleaning balls. Clean tunnels and waterboxes of all construction debris. Condenser tubes should be flush with the tubesheet. Vents, waterbox takeoffs, and any penetrations into the waterbox or into the system between the injection and extraction points must be screened to avoid ball hideout. All biological growth (that is, barnacles) in the condenser waterbox must be removed completely.
2. Set the motor operator limit and torque switches as required on the strainer section actuators and the ball collector.
3. Check the strainer section screens for proper mechanical operation using handwheels on motor operators.
4. Check the position of all valves (that is, injection, collector inlet and outlet, and strainer outlet). Ensure the watertight integrity of all recirculating piping, including the collector and pump.
5. Check the control panel wiring and field wiring for correctness.
6. Check the pump for proper lubrication.
7. “Bump” all motors for proper rotation. Make sure that the control panel is in the “Manual” mode.

### *A.2.2 System Startup*

Follow these steps to start up the system (required cooling water must be circulating):

1. Place the two-position selector switch on the control panel in the Manual mode. This mode of operation enables all pushbuttons on the face of the control panel “mimic.”
2. With the ball recirculation pumps off and the collector inlet non-return flap blocked open (or removed), flood and reverse-flush all interconnecting piping for 2–3 hours. All recirculation system valves must be open (except for the collector vent and drain).
3. After backflushing the system, remove the block from the check flap (or reinstall the check flap). Replace and tighten the ball collector access cover. Open all valves (except the collector vent and drain) and flood the system completely.
4. Start the ball recirculation pumps using pushbuttons. The light indication changes from red to green.

5. Check that the strainer screens are in the Backwash position. Ensure that the light indication matches the actual position of the screen. The light indication is green at the Backwash position.
6. Place the strainer screens in the Operate position using the appropriate pushbuttons. Ensure that the light indication matches the actual position of the screen. The light indication is red at the Operate position.
7. Check the operation of the collector BCF using the applicable pushbuttons. Make sure that the position of the collector BCF matches the light indication. In the Collect (Closed) position, the light indication will be green. In the Operate (Open) position, the light indication will be red.

## A.3 Operation of the Condenser Cleaning System

### *A.3.1 Manual Operation*

All operations in this section are accomplished using the pushbuttons located at the panel mimic (except where noted). To start, place the two-position selector switch in the Manual mode, set the collector BCF to the Collect position, and place the strainer screens in the Operate position.

#### A.3.1.1 Circulate Balls (Manual Mode)

Follow these steps to circulate balls when in the Manual mode:

1. Manually close the collector inlet valve and the collector outlet valve.
2. Open the collector drain and vent valves manually. Drain out approximately 75% of the water in the collector housing and manually close the collector drain valve.
3. Open the collector lid/sight glass assembly and add the sponge ball charge. Prior to putting the cleaning balls in the collector, expel the air from the sponge balls by squeezing them beneath the surface of the water in a bucket kept nearby specifically for this purpose.
4. Close the collector lid/sight glass assembly and engage the clamps to secure the lid in place and make a watertight seal.
5. Vent the air from the collector by very slowly opening the collector outlet valve to the full Open position (water will begin to fill the collector).
6. Close the vent valve after the collector has been fully vented and filled with water.
7. Check to make sure that the strainer screens are in the Operate position before releasing the balls into the system. The light indication is red.
8. Fully open the collector inlet valve.

9. Start the recirculation pump (the light indication turns red).
10. Allow the balls to agitate in the ball collector for about 3 minutes.
11. Move the collector BCF to the Operate position. The light indication is now red. The balls are released into circulation.

The system is now in the manual "System On" mode.

#### A.3.1.2 Collect Balls (Manual Mode)

Before starting this procedure, ensure that the system has been put into operation as described in Section A.3.1.1.

1. Move the collector BCF to the Collect position. The light indication turns green.
2. After 30 minutes, manually close the collector inlet valve.
3. Immediately shut off the ball recirculation pump. The light indication turns green.
4. Manually close the collector outlet valve.
5. Vent and drain the collector by gradually opening the manual vent and drain valves.
6. Open the collector cover. The cleaning balls will be in the bottom of the collector's perforated basket. Remove the balls.
7. Place the strainer screens into the Backwash position. The light indication turns green.

The system is now in the "System Off" mode.

**Note:** After the sponge balls are collected, undersized balls should be removed. Undersized balls are defined as having an outside diameter of 0.01 in. (0.25 mm) or less oversize compared to the inside diameter of the condenser tubes. (Ball sizing is accomplished by using the Taprogge ball sizing gauge provided.)

All of the balls must be replaced at least once every four weeks, regardless of their size.

#### A.3.1.3 Normal Backwash (Manual Mode)

If, during normal operation of the condenser tube cleaning system, the differential pressure (DP) across the strainer section screens rises to 10 in. w.c. (2.5 kPa) above the clean screen reading, the screens should be backwashed. In addition, the screens should be backwashed at least biweekly to minimize debris buildup and to exercise the screen drive mechanism. Prior to backwashing, the balls in circulation must be collected. Use the following procedure:

1. Move the BCF to the Collect position. The light indication will change from red to green. The balls will begin to accumulate in the collector.
2. Collect the balls for 30 minutes or longer if necessary.
3. Open the strainer screens. The light indication changes from red to green when the screens reach the Backwash position.
4. During normal backwash, the ball recirculation pumps remain on. The balls that have been collected will remain inside the collector because the BCF is in the Collect position.
5. Check the DP cell reading. With the screens in the Backwash position, the DP across the screen will now be considerably reduced.
6. After 1 minute, close the strainer screens. The light indication changes from green to red when the screens reach the Operate position.
7. Recheck the DP reading. It should return to the normal clean screen value.
8. Move the BCF to the Operate position to release the cleaning balls. The light indication changes from green to red.

The system is now back in the System On mode. Balls are now in circulation.

### *A.3.2 Automatic Operation (Continuous)*

Before placing the system into Automatic operation, make sure that the CTCS is in the Basic position (defined in Section A.1.3).

The Basic position is attained with the system in the Manual mode using the appropriate pushbuttons. Manual ball valves must be checked visually and moved by hand to the appropriate positions.

Sponge balls should be added to the system as described in Section A.3.1.1. After the balls have been added, the collector must be vented and filled, and all 3 in. (76.2 mm) isolating valves must be open. The collector is now ready to operate.

### A.3.2.1 Circulate Balls (Automatic Mode)

Operation of the system in the automatic mode to recirculate the balls should be performed as follows:

1. Place the two-position selector switch on the control panel into the Automatic position. All pushbuttons on the control panel mimic are now disabled. Place the other two-position selector switch in the Continuous position.
2. Press the "Auto On" illuminated pushbutton on the panel door. The red illuminated pushbutton will flash, showing that the system has begun to move into the Circulate Balls mode of operation.
3. The screens will move into the Operate (closed) position. The red Operate illuminated pushbutton will flash, indicating that the screens are moving toward the Operate position. The green Backwash illuminated pushbutton will remain lit until the screens reach the Operate position. The red Operate illuminated pushbutton will remain on (the flashing stops) when the screens reach the Operate position. The green Backwash light will extinguish.
4. When the screens reach the Operate position, the recirculation pumps will start. The red Start illuminated pushbutton will be illuminated, and the green Stop illuminated pushbutton will be extinguished.
5. The balls are held in the collector for 30 minutes (that is, the ball agitation time) with the pumps running to expel any remaining air.
6. After 30 minutes, the BCF will move to the Operate (open) position and release the balls into circulation. The red Operate illuminated pushbutton will flash, indicating that the BCF will be moving toward the Operate position. The green Collect illuminated pushbutton will be extinguished, and the red Operate illuminated pushbutton will remain on when the BCF is in the Operate position.

Failure of the system to proceed through the preceding sequence within the preprogrammed time allotted will cause the amber "General Alarm" light to be illuminated and any connected customer-supplied alarm to activate. "Operation Time Exceeded" will be displayed on the panel message display. The General Alarm light can be extinguished (and the horn can be silenced) by pressing the Alarm Reset pushbutton in the Manual mode. The equipment problem can now be diagnosed and corrected (for example, failed motor starter or limit switch). When extinguished, the Operation Time Exceeded timer will reset itself and begin to time down once again, causing the alarm condition to repeat if the equipment problem has not been corrected. Upon correction of the problem, all components should be returned to the Basic position as described in Section A.1.3 before returning the system to the Automatic mode of operation.

### A.3.2.2 Collect Balls (Automatic Mode)

The system should now be in the Circulate Balls: Automatic mode as just described. The two position selector switches on the control panel are in the Automatic position and the Continuous position.

1. Press the Auto Off illuminated pushbutton on the panel door. The green illuminated pushbutton will flash, showing that the system has begun to move into the Collect Balls mode of operation.
2. The BCF closes. The green Collect illuminated pushbutton will flash, indicating that the BCF is moving toward the Collect position. When the BCF reaches the Collect position, the red Operate illuminated pushbutton will be extinguished, and the green Collect illuminated pushbutton will remain on.
3. After 30 minutes (that is, the ball collection time), the ball recirculation pumps will stop. When the pumps have stopped, the red Start illuminated pushbutton will be extinguished, and the green Stop illuminated pushbutton will remain on.
4. Strainer screens will now move to the Backwash position. The green Backwash illuminated pushbutton will flash, indicating that the screens are moving toward the Backwash position. The red Operate illuminated pushbutton will be extinguished, and the green Backwash illuminated pushbutton will remain on when the screens reach the Backwash position.

The system is now in the System Off mode. All applicable light indications will be green.

The collector may now be serviced by closing the collector isolation valves and opening the vent and drain valves. The collector access cover can be removed after the collector has been vented and drained.

Failure of the system to proceed through the preceding sequence within the time allotted will cause the amber General Alarm light to be illuminated and, simultaneously, the message display will indicate “Operation Time Exceeded.” The alarm light can be extinguished by pressing the Alarm Reset pushbutton with the system in the Manual mode so that the equipment problem can be diagnosed and corrected (for example, failed motor starter or limit switch).

The General Alarm light and the message display can be extinguished only in the Manual mode. Once extinguished, the Operation Time Exceeded timer will reset itself and begin to time down once again, causing the alarm condition (Operating Time Exceeded message and General Alarm light) to repeat if the equipment problem has not been corrected. Upon correction of the problem, all components should be returned to the Basic position as described in Section A.1.3 before returning the system to the Automatic mode of operation.

See the note in Section A.3.1.2.

### A.3.2.3 Normal Backwash (Automatic Mode)

The two-position selector switches on the control panel are in the Automatic position and Continuous position. Automatic backwashing of the strainer section screens is controlled by the control panel. When the DP cell senses a 10 in. w.c. (2.5 kPa) increase across the screens due to a debris buildup, the system enters a "Normal Backwash Cycle." A 2-minute time delay is used to prevent initiation of the Normal Backwash Cycle by a transient pressure spike. After the 2-minute timer expires, the Normal Backwash Cycle is initiated and the following occurs:

1. The green Auto Off light begins flashing.
2. The collector BCF moves to the Collect (closed) position. The light indication changes from red to green.
3. The system remains in the Collection mode for 30 minutes.
4. After the 30-minute ball collection timer expires, the strainer screens move to the Backwash position. The green light flashes while the screens move toward Backwash. After reaching the Backwash position, the green light remains illuminated, and the red light is extinguished.
5. During the normal Backwash sequence, the ball recirculation pumps remain on.
6. After 5 minutes, the screens move back to the Operate position. The red light flashes while the screens move toward the Operate position. After reaching the Operate position, the red light remains illuminated, and the green light is extinguished. If the screens have been cleaned, the indicated screen pressure drop will fall to the normal clean screen values and the sequence proceeds to Step 7. If the screens are still fouled, the sequence repeats at Step 4 until the screens are cleaned.
7. As soon as the screens have closed, the collector BCF moves to the Operate position. The light indication changes from green to red. The ball agitation timer is bypassed.
8. The green Auto Off light is extinguished, and the red Auto On light is illuminated.

The system is now back in the System On mode.

Failure of the system to proceed through the preceding sequence within the time allotted will cause the amber General Alarm light to be illuminated and, simultaneously, the message display will indicate Operation Time Exceeded. The alarm light can be extinguished by pressing the Alarm Reset pushbutton with the system in the Manual mode so that the equipment problem can be diagnosed and corrected (for example, failed motor starter or limit switch).

The General Alarm light and the message display can be reset only in the Manual mode. When extinguished, the Operation Time Exceeded timer will reset itself and begin to time down once again, causing the alarm condition (Operating Time Exceeded message and General Alarm light) to repeat if the equipment problem has not been corrected. Upon correction of the problem, all components should be returned to the Basic position as described in Section A.1.3 before returning the system to the Automatic mode of operation.

#### A.3.2.4 Emergency Backwash (Automatic Mode)

The two-position selector switches on the control panel are in the Automatic position and the Continuous position. If a heavy influx of debris causes a rapid rise in the DP across the strainer screens of 20 in. w.c. (5 kPa) or more before the normal Backwash cycle has had enough time to complete its sequence, the "Emergency Backwash" cycle is initiated. When the DP cell reaches the "High-High" set point, it energizes a 4-minute time delay that is used to prevent transient pressure spikes from initiating the Emergency Backwash cycle.

After the 4-minute time delay expires, the following occurs:

1. The "Screens Overloaded" message is displayed, and the General Alarm light is illuminated.
2. The screens move to the Backwash position. The green light flashes while the screens move to Backwash. After reaching the Backwash position, the green light is illuminated, and the red light is extinguished. The pumps are shut off.
3. Because the DP cell had to cross the first screen backwash set point (that is, DP High), a normal backwash cycle will already have been in progress for 2 minutes. The collector BCF will have moved to the Collect position prior to the Screens Overloaded alarm, and some of the balls will have been collected prior to the pumps being deenergized.
4. Reset the alarm message and alarm light in the Manual mode.
5. The system is now in the Basic position as described in Section A.1.3. After the cause of the Screens Overloaded alarm condition has been found and corrected, the CTCS can be put back in service.
6. If the cause of the Screens Overloaded alarm has not been corrected and the system is put back into operation, the system will once again proceed through this sequence beginning with Step 1.

Failure of the system to proceed through the preceding sequence within the time allotted will cause the amber General Alarm light to be illuminated and, simultaneously, the message display will indicate Operation Time Exceeded. The alarm light can be extinguished by pressing the Alarm Reset pushbutton with the system in the Manual mode so that the equipment problem can be diagnosed and corrected (for example, failed motor starter or limit switch).

The General Alarm light and the message display can be extinguished only in the Manual mode. When extinguished, the Operation Time Exceeded timer will reset itself and begin to time down once again, causing the alarm condition (Operating Time Exceeded message and General Alarm light) to repeat if the equipment problem has not been corrected. Upon correction of the problem, all components should be returned to the Basic position as described in Section A.1.3 before returning the system to the Automatic mode of operation.

### A.3.3 Automatic Operation (Intermittent)

Intermittent operation of the tube cleaning system is possible only if the control panel is in the Automatic mode. Adjustment of the time span and frequency of intermittent operation is possible by adjusting timers. However, it is not recommended that these timers be adjusted except by a qualified Taprogge service engineer. These timers will be adjusted and set during the commissioning of the system.

During intermittent operation, the screens will be backwashed during the Out-of-Service time span.

All system functions behave similarly to the behavior described in Section A.3.2. The frequency and duration of system operation are determined by programmable logic controller timers.

## A.4 Shutdown of the Condenser Cleaning System

### A.4.1 Shutdown of the Condenser Cleaning System During a Short Unit Outage

During a short-term outage (that is, three days or fewer) in which the cooling water flow is not shut off, all system isolating valves may be left open (the collector isolating valves should be closed). All other system components (that is, the strainer section and recirculation pump collector) should be placed in the Out-of-Service (Backwash) position after all sponge balls have been collected.

Before performing an internal inspection of the strainer section, make sure that the cooling water line, which contains the strainer section, is thoroughly drained.

**Note:** All necessary plant safety precautions must be observed before opening and entering the strainer section.

### A.4.2 Shutdown of the Condenser Cleaning System During an Extended Unit Outage

During an extended unit outage (that is, more than three days), all system components must be thoroughly drained, rinsed with fresh water, and dried with cool, fresh, dry air. This is especially important for corrosion protection for systems exposed to seawater. All isolating valves should be closed. All mechanical components must be rotated at least once per week. The pump casing can be drained using the drain plug. The pump motor and all motor actuators should be covered with plastic to prevent moisture damage. Fuses should be taken out of the control panel and stored.

Stagnant water, especially seawater with chemical additives such as chlorine, can cause pitting and crevice corrosion—even on the stainless steel internals. Therefore, to help prevent corrosion damage, avoid letting water either stagnate in or dry on the system components.

# B

# SAMPLE OFF-LINE MECHANICAL TUBE CLEANING PROCEDURE

The following is an off-line tube cleaning procedure developed by Conco Systems, Inc. A confined space permit might be required when working in the waterbox.

To prepare the condenser, perform the following steps:

1. Drain and open the waterbox, and clean off the tubesheet.
2. Verify that there is a safe atmosphere and temperature in the waterboxes.
3. Install low-voltage lights for both ends of condenser.
4. Verify that there is a safe atmosphere and temperature in the waterboxes.
5. Install floorboards if needed.
6. Install scaffolding in the inlet waterbox if needed, or have scaffolding close by to use when needed. It is best to shoot in the direction of the cooling water flow.
7. Hang a tarp approximately 2–5 ft (0.6–1.5 m) away from the tubesheet in the outlet waterbox.
8. Cover all drains and openings to prevent a loss of cleaners.
9. Post all safety signs, barriers, and tags.

To prepare the system, perform the following steps:

1. Verify the availability of approximately 200–300 psi (1.4–2 MPa) of water pressure at 35 gpm (2.2 L/s) for each water gun being used. Hook up the guns to the water source; eliminate all leaks and/or restrictions in the lines.

   The water source can be the plant's water, condensate water, or ash sluice system.) A portable booster pump can increase the water pressure to the required 200–300 psi (1.4–2 MPa).

   The recommended hose to the gun must have a working pressure of 800 psi (5.5 MPa), with pressed-on 3/4-in. (19-mm) outside diameter National Pipe Thread fittings.
2. Install the guns at the swivel base 3/4-in. (19-mm) National Pipe Thread female fitting using the 3/4-in. (19-mm) hose. (The combination of the swivel and hose reduces wrist fatigue for the shooter.)

Never use air pressure. Never use quick disconnect hose connections.

To "shoot" the condenser, perform the following steps:

1. Test 5 to 10 cleaners before loading a large amount. Make sure that the tube cleaning system is in working order and that cleaners are correctly sized.
2. Insert cleaners in the tubes. It is best and fastest to load as many cleaners as possible and then shoot with as many guns as possible (that is, 2000–3000 tube cleaners or 25–50% of the total number of tubes per waterbox).
3. Insert the gun behind the cleaner and lock the gun into the tube by pushing the gun straight in and cocking down and to the side—all in one complete motion. Hold the gun firmly in the cantilevered position, and pull the trigger.
4. Cleaners travel at about 10–20 ft/s (3–6 m/s). If these times are not met, check the hoses and the water supply for restrictions. Otherwise, the tubes might be very badly fouled.
5. Make sure that cleaners go all the way through the tubes by watching a gauge at the front of the gun. As the cleaner exits the tube, the gauge should show a pressure drop. If the pressure does not drop or climbs to the line pressure, the tube might be dented or totally clogged.

To check the tubes, perform the following steps:

1. After all of the tubes have been "shot," check all tubes with a high-intensity light. Hold a light at one end, and have someone at the other end look through the tubes. If any tube is blocked, a faint light or no light at all will be visible. Mark these tubes and re-shoot as follows:
    1. Re-shoot using only one gun to obtain the highest pressure possible.
    2. Re-shoot obstructed tubes using a water pump set at a higher pressure.
    3. "Rod out" any obstructed tubes using a flexible fiberglass rod.

To ensure proper clean up and storage, perform the following steps after the job is completed:

1. Wash off cleaners, air dry them, and store them properly.
2. Remove all debris from the waterbox.
3. Wash down the floors of the waterboxes.
4. Clean up the work area.
5. Sign off.

# C
# KEY POINTS

**Key O&M Cost Point**

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

| Section | Page | Key O&M Cost Point |
|---|---|---|
| 2.1.1 | 2-5 | The supplier should be consulted in order to establish a recommended abrasive and normal ball cleaning procedure specific to plant requirements. |
| 2.1.1 | 2-6 | The capital costs of the sponge ball system and the increased maintenance costs must be compared to heat rate improvements from cleaner tubes and tubesheets. |
| 6 | 6-5 | This modification of installed HE strainer sections can be accomplished easily without removing the strainer section from the cooling water piping. |

**Key Technical Point**

Targets information that will lead to improved equipment reliability.

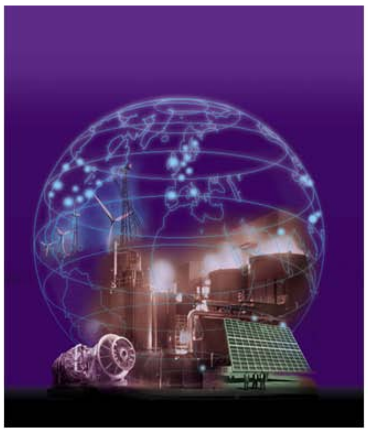
| Section | Page | Key Technical Point |
|---|---|---|
| 5.2 | 5-3 | Documented maintenance instructions can improve the effectiveness of the equipment and consistency in maintenance tasks. |
| 5.2.3 | 5-5 | Important! The correct adjustment of the operational positions of the motor-operated screen, along with the proper setup of the actuators, guarantees the proper functioning of the strainer section. |
| 5.2.4 | 5-5 | **Note:** Site-specific drawings should be used at all times. Contact the system supplier if copies are not readily available. |
| 5.2.4 | 5-6 | **Note:** When the previous steps are complete, be sure to do the following:<br>1. Readjust the BCF to ensure smooth operation.<br>2. Check the torque and limit switches of the actuator and readjust as necessary. |
| 5.3 | 5-7 | **Note:** Greases of different soap bases (for example, lithium or sodium) may not be compatible when mixed. Prevent such intermixing by completely purging the bearing of old greases. |
| 6 | 6-3 | Movement of the balls down the screens to the extraction points depends on specific flow conditions in the screen sections and on proper screen alignment. |

**Key Human Performance Point**

Denotes information that requires personnel action or consideration in order to prevent injury or damage or to ease completion of the task.

| Section | Page | Key Human Performance Point |
|---|---|---|
| 5.2.1 | 5-3 | Before beginning any work, make sure that the following work procedures and precautions are observed and completed:<br>• Shut down the condenser tube cleaning system completely.<br>• Make sure that the cooling water discharge piping and the strainer section are completely isolated and drained.<br>• Shut off current supply to the control panel.<br>• Observe all applicable plant safety precautions before beginning any work. |

# D
# TRAINING SLIDES



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Nuclear Maintenance Applications Center: Condenser Cleaning Equipment Maintenance Guide
Training Slides

EPRI Report 1015059

## Project Background

- Most NMAC members use a variety of cleaning systems in their facilities, including on-line systems and manual systems, during planned outages.
- On-line cleaning systems can provide operators with an effective way to clean the condenser tubes while they remain on-line, thereby improving plant efficiency. The intent of the *Condenser Cleaning Equipment Maintenance Guide* is to address various engineering, maintenance, and operations issues regarding equipment maintenance.
- Experience-proven practices and techniques were identified during this effort and are compiled in this report.

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## Project Background (continued)

- EPRI NMAC has developed a traditional maintenance guide on condenser cleaning equipment that investigates and reviews maintenance issues with this equipment and provides maintenance and inspection recommendations.
- Key suppliers of condenser cleaning equipment were solicited for assistance to ensure that the guidance reflects the latest technologies available in the industry.
- This technical report provides an overview of system design parameters and familiarizes power plant maintenance and engineering personnel with the components used for on-line condenser cleaning equipment.

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## Guide Contents

- An overview of condenser cleaning equipment, including:
  - On-line equipment
  - Off-line equipment
  - Chemical cleaning
- A list of common problems being experienced with on-line condenser cleaning equipment
- Troubleshooting guidance for operational and equipment problems on Amertap (Taprogge) equipment
- Preventive and corrective maintenance recommendations for condenser cleaning equipment
- Upgrade information for older designs of on-line equipment

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## Guide Contents (continued)

- Appendices
  - Recommended operating procedure for Amertap (Taprogge) systems
  - Sample off-line cleaning procedure
  - Key Points summary
  - Guide training material

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## On-Line Cleaning Systems

- Sponge ball (the most common on-line system)
- Brush and cage
- Self-aligning rockets

## Mechanical Off-Line Cleaning Systems

- Air- and water-driven systems
- Mechanically driven systems
- Pressure-driven systems
- Waste disposal

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## Common Failure Mechanisms for On-Line Systems

- Based on surveys of NMAC members, the following are their most commonly cited problems with sponge ball on-line cleaning systems:
  – System doesn't work or never worked
  – Lack of experience with the system
  – Parts' obsolescence, wear out, erosion, and aging
  – Improper operation of screens and linkage adjustment; wear
  – Ball loss, balls stuck in screens, and ball damage
  – Lack of maintenance procedures and instructions
  – Old (outdated) control designs and technology

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## Troubleshooting

- Provides troubleshooting guidance for commonly encountered problems
- Presented in a matrix format that includes the problem, the likely cause, and recommended corrective actions

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## Maintenance Recommendations

- Consists of both preventive and corrective maintenance recommendations for:
  - Strainer and ball collection screens
  - Ball collection and injection system
  - Controls
- Corrective maintenance instructions include step-by-step detail on various tasks, including disassembly, reassembly, and adjustment
- Also includes a recommended lubrication schedule for various components

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## Upgrade Recommendations

- Provides recommendations for the upgrading of older Amertap (Taprogge) systems most commonly used in power plants, with the following benefits:
  - Simpler design
  - Better component construction
  - Reduction in the number of parts

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## Operating Recommendations

- Provides recommendations for the operation of Amertap (Taprogge) systems most commonly used in power plants, including:
  - Complete operating description of the system and components
  - Step-by-step actions for startup, operation, and shutdown of systems

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## Off-Line Cleaning Procedure

- Provides a recommended procedure for cleaning condensers off-line, including the following processes:
  - Preparation of the condenser
  - Setup of the cleaning equipment
  - Cleaning operation
  - Inspection of the tubes
  - Cleanup and storage

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## Key Points Summary

- The summary identifies key information contained in the guide and provides its location.
- The primary intent of a Key Point is to emphasize information that will allow individuals to take action for the benefit of their plant.
- The Key Points are organized according to three categories: Operation and Maintenance (O&M) Cost, Technical, and Human Performance.
- Each category has an identifying icon to draw attention to it when quickly reviewing the guide.

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# E

# TRANSLATED TABLE OF CONTENTS

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# 报告概要

这份报告为电厂维护人员提供了冷凝器清洁系统的当前维护信息。报告将帮助这些人员改进可靠性和减少用于电厂的冷凝器清洁设备的维修费用。

### 宗旨

- 描述典型的冷凝器清洁设备
- 提供定期检修、修理和替换、改进和升级以及对发现并修理冷凝器清洁设备故障的建议

# 内容

# 图片目录

# 表格目录

# RÉSUMÉ DU RAPPORT

Ce rapport fournit au personnel de maintenance des centrales électriques des informations courantes de maintenance des systèmes de nettoyage des condenseurs. Ce rapport aidera ce personnel à améliorer la fiabilité et à réduire les coûts de maintenance des équipements de nettoyage des condenseurs utilisés dans les centrales électriques.

## Objectifs

- Décrire les équipements typiques de nettoyage descondenseurs
- Fournir des recommandations de maintenance préventive, de réparation et de remplacement, de modification, de mise à niveau et de dépannage des équipements de nettoyage des condenseurs

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# LISTE DES TABLEAUX

# 復水器洗浄装置保全ガイド

## 報告書の要約

本報告書は、発電所の保全技術者に対し、復水器の洗浄装置に関する現行の保全情報を提供するものである。本報告書は、保全技術者に，発電所で使用されている復水器の洗浄設備の信頼性の改善および、保全コストの低減を支援するものである。

**目的**

- 典型的な復水器の洗浄設備を説明すること
- 復水器の洗浄設備の予防保全（PM）、修理および取替え、改造および性能向上、ならびにトラブルシューティングについての推奨事項に関するガイドを提供すること

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# 表のリスト

# RESUMEN DEL INFORME

Este informe ofrece información actual sobre el mantenimiento de sistemas de limpieza del condensador para el personal de mantenimiento de las centrales  El informe le servirá a este personal para mejorar la fiabilidad y reducir los costes de mantenimiento de los equipos de limpieza del condensador utilizados en las centrales.

## Objetivos

- Describir los equipos de limpieza del condensador típicos
- Ofrecer recomendaciones de mantenimiento preventivo, reparación y sustitución, modificación y mejora e identificación y resolución de problemas para los equipos de limpieza del condensador.

# CONTENIDO

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# LISTA DE TABLAS

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