4.1 Background:

With the age of steam condensers approaching twenty-five years for nuclear plants and forty years for fossil units, the cost of operating and maintaining this equipment is increasing. The frequency of testing, cleaning, repairs and re-tubing efforts is increasing because of the age and condition of the equipment. In addition, there are performance losses associated with befouling and air/water in-leakage. Long-term reliability of the condensers is important to maintain load and performance in power plants .

Issues with condensers were characterized by the words, “air in-leakage, baffles and tube integrity.” The responses were about even as to whether or not the condenser equipment needed further attention. The topic of condensers was again discussed at the August 2000 meeting of the NMAC Site Coordinators with the following issues identified:

1. Tube sheet.
2. Leak detection.
3. Tubing material issues.
4. Plugging issues.
5. Cleaning tubes.
6. Mechanical issues with shields and baffles.
7. Vibration.
8. General inspection and testing off-line.
9. Testing off-line.

4.2 Trouble-Shooting Condenser Problems:

This section on trouble-shooting condenser problems deals with the fouling and operating conditions of air binding and air-removal equipment problems, excessive air\water in-leakage.

4.2.1 Fouling:

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, fouling impacts the output of the plant as it affects the condenser backpressure, the 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 cause in:

- Reduce heat transfer rates.
- Decrease cooling water flow.
- 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.

4.2.2 Air Binding Problems:

Air binding is a term used to describe the insulating effect of air on condenser tubes when the space between the tubes is filled with air. Although this condition can occur in many areas, it is primarily found in the air-removal zone when the air in-leakage rate exceeds the capacity of the air-removal equipment, the possible causes of air binding are:

- **Steam bypassing the air cooler zone of the condenser:**

When the steam bypasses the air removal zone through cracks in the piping or the seal plates, the steam leaking into the air removal piping reduces the amount of air removed by displacing air. This raises the vacuum pump seal water temperature.

- **Insufficient capacity of air-removal equipment:**

This can be due to equipment wear and equipment under-sizing or high seal water temperature.

- **Design limitations of dual pressure condensers:**

If one vacuum pump/steam jet air ejector is operating or the air-removal sections of the low-pressure and high-pressure condensers are tied together, then air binding can occur. Removal of the air in the high-pressure condenser displaces the air that could have been removed from the low-pressure condenser with higher pressure steam.

- **High air in-leakage:**

With a high concentration of air in the steam entering the condenser, a pressure drop exists between the outer tubes and the air-removal section. This might result in the accumulation of air outside the air-removal zone. In addition, high air in-leakage will increase the pressure drop in the suction piping of the air-removal equipment, resulting in a further decrease in air-removal equipment capacity. The pressure drop between the condenser shell pressure and the pressure at the suction of the air-removal equipment can be more than 1 inch of mercury (1.5 cm Hg).

4.2.3 Air-Removal Equipment Problems:

4.2.3.1 Poor Vacuum:

Poor condenser vacuum caused by problems with the steam jet air ejectors is indicated by one or more of the following conditions:

- **Low steam pressure:**

Each ejector nozzle is specially designed for the steam pressure specified for the application. If the pressure is less than design, the system cannot achieve the desired vacuum and the following should be checked:

1. Compare the steam pressure at the inlet to the ejector steam chest with the rated pressure. If it is not possible to increase the supply steam pressure, check with the manufacturer for possible nozzle changes to allow for the lower steam pressure.

2. Check whether there are any obstructions in the steam supply system that might be causing the low pressure.

3. Check whether any pressure-reducing valve in the system is functioning incorrectly.

- **Superheated steam:**

Mass flow through a given nozzle is less for superheated than for saturated steam. Note that saturated steam passing through a pressure-reducing valve will become superheated. Steam supplied to a steam jet air ejector should never contain moisture because this can cause erosion as well as performance problems. If the motive steam is not dry saturated but is superheated, the ejector manufacturer should be alerted. The design of the steam jet air ejector can be adjusted to meet this steam condition.

- **Total condenser air in-leakage:**

Check the main condenser air in-leakage with the probe provided on the discharge of the after-cooler for a condensing ejector system. If air leakage is excessive, check the vacuum system for tightness.

- **Loop seal drain too short:**

Condensate drain lines and loop seals must be properly designed to prevent short-circuiting of the air between the main turbine condenser and the inter-cooler for a condensing ejector system configuration.

- **Excessive discharge pressure at ejector atmospheric stage:**

Excessive discharge pressure on any ejector stage can cause unstable operation, starting at the final ejector stage, discharge pressures should be checked and compared with design values.

- **Poor main condenser operation:**

When condenser equipment has been in operation for extended periods of time, deterioration in performance is often attributed to the ejector vacuum system, however the main turbine condenser might itself be the source of the problem, some of the possible causes include high cooling water temperature, insufficient cooling water flow or excessive fouling of the condenser tubes.

4.2.3.2 Gradual Loss of Vacuum:

Some of the causes for a gradual falling off in vacuum could be attributed to the following problems:

- **Ejector nozzle or diffuser eroded or corroded:**

It is recommended that the parts be inspected periodically and a record made of the wear found. If replacement of these parts occurs too frequently, the cause of failure must be determined. Usually, it is found to be wet steam.

- **Leaking ejector system cooler tube:**

Check for any leaks by applying a hydrostatic test on the vapor side of the inter- and after-coolers, in order to locate the tube that is leaking, it will be necessary to remove the water box cover and close the inter- and after-cooler drain valves. Replace or plug any damaged ejector cooler tubes.

4.2.3.3 High Outlet Water Temperature:

Typically, the cooling water supply to the ejector system is the condensate from the main turbine condenser, at low turbine loads the condensate flow might be insufficient to sustain proper cooling within the ejector system, If no alternative source of freshwater supply is available to replace the condensate flow, a loss of vacuum can result, along with high discharge temperatures on the outlet of the ejector condensers.

4.2.3.4 Faulty Operation of the Steam Jet Air Ejectors:

There are at least seven possible causes of faulty operation of a steam jet air ejector. It will be necessary to check for any one or more combinations of these conditions if trouble is experienced with the ejectors.

- **Insufficient cooling water:**

An insufficient supply of cooling water can be determined by observing the temperature of the water entering and leaving the air ejector, if the temperature rise in the ejector inter-cooler does not exceed the design condition, then the cooling water supply is adequate.

- **Steam nozzles plugged with scale:**

A scale deposit might form in the throats of the steam nozzles, consisting of chemicals used in the treatment of the feed water, when this occurs, the scale should be removed with drills of the same diameter as the nozzles.

- **Water flooding the inter-cooler of the condensing ejector design.**

Flooding of the intercooler with water can be caused by faulty drainage, this can usually be established by observing the temperature of the intercooler shell.

- **Low steam pressure.**

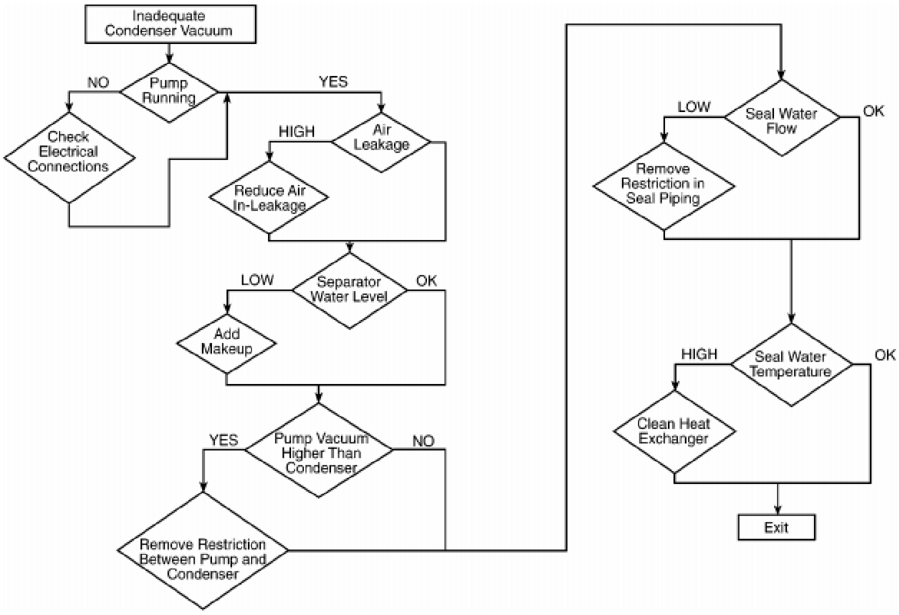
Low steam pressure might be due to clogging of the steam strainers or orifice plates with pipe scale or sediment, improper operation of the regulating valve or the pressure of the steam supply to the pressure regulators being too low.

- **High backpressure at ejector discharge.**

High backpressure at the discharge of the ejector sometimes occurs when it discharges into a common exhaust system together with other equipment, If this happens, it will be necessary to provide an independent discharge from the ejector to the atmosphere.

4.2.3.4 Problems with Liquid Ring Vacuum Pumps (LRVPs):

The principal elements for trouble-shooting potential problems with LRVPs are shown in Figure (4.1).



Fig(4.1)Trouble-shooting problems with (LRVPs)

The first response to a poor condenser vacuum is to check whether a sufficient number of pumps are in operation. The air in-leakage is then checked and steps taken to reduce the leakage if needed. If modern instrumentation is available, air in-leakage and pump capacity in terms of either ACFM (Actual Cubic Feet per Minute at operating conditions) (cubic meters per hour) or mass flow rate can be checked. If the capacity is low, the pump will need attention. This includes adjusting the operating conditions or performing maintenance. Assuming the above conditions have been met, the separator level should then be examined and if low, makeup water should be added, air leakage at the LRVP shaft packing gland should be checked. If a leak is suspected, a hose with a small stream of water can be sprayed on the rotating shaft to temporarily stop the leak.

A measurement of the disappearance of the leak can be made using the LRVP exit rotameter or by measuring the mass flow rate or ACFM (cubic meters per hour) capacity on the suction side of one LRVP, as mentioned above. If problems persist and the pump vacuum is higher than the vacuum in the condenser, there might be a restriction or a closed valve between the condenser and the pump. Similarly, if the seal water flow is low, there is probably a restriction within the seal water piping.

Finally, if the seal water temperature is high, it probably indicates a problem with the heat exchanger, fouling would be suspected to cause a problem with the heat exchanger.

4.2.4 Water In-Leakage Effects:

Any leakage present will travel from the cooling water (tube) side to the condensing steam (shell) side. Although the condensing steam (condensate) must be kept extremely pure, the cooling water chemistry is usually maintained at higher levels of impurities. This is the result of using raw water drawn from lakes or rivers or cycled through cooling towers. This water can contain chemicals added to control biological fouling, scale and/or silt. When condensate contamination occurs, the amount depends on the chemistry of the cooling water and the size of the leak.

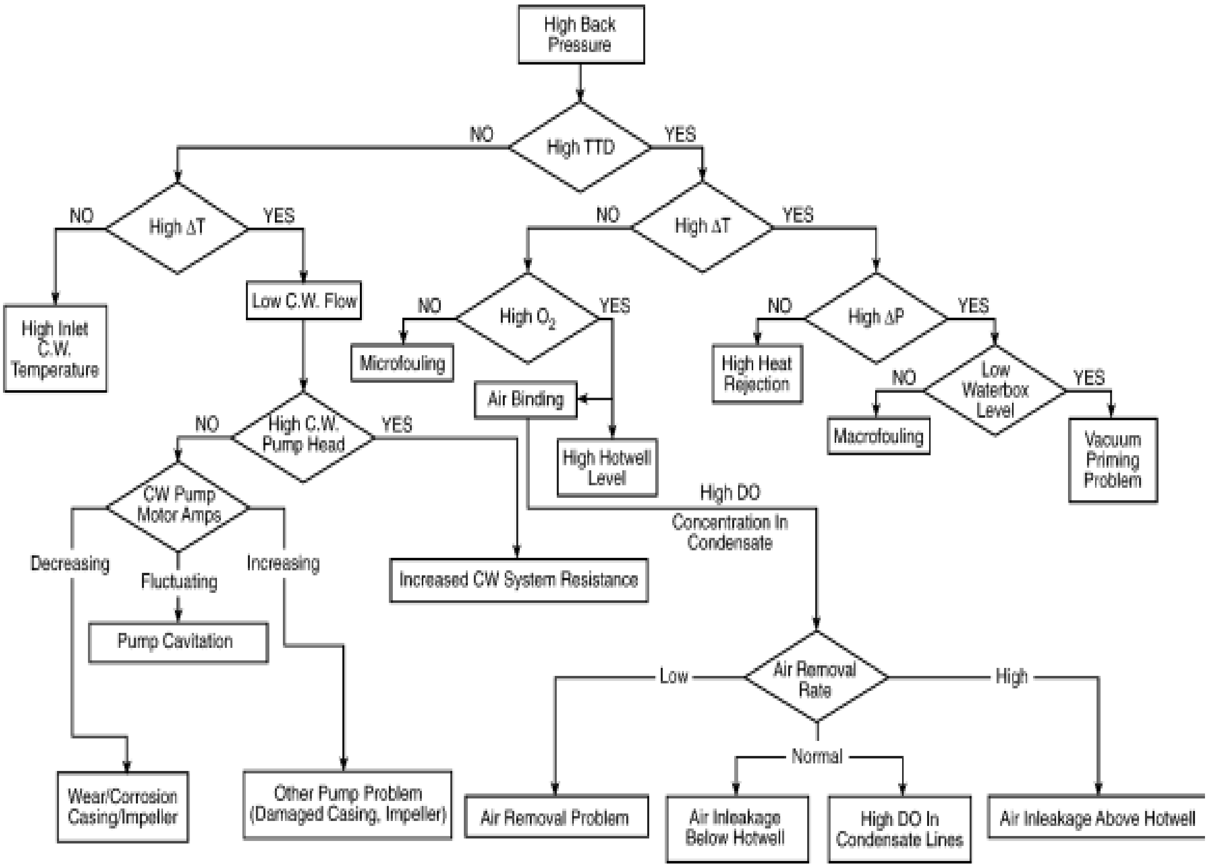
Circulating water in-leakage into the condenser has been the major source of impurities introduced into the condensate and a major factor in corrosion. There are a number of possible causes of water in-leakage, including:

1. Improperly rolled tube joints.
2. Poor condenser design leading to tube failures caused by steam impingement or from damage by other components loosened by steam impingement .
3. Improperly supported tubes, which can lead to tube vibration failures.
4. Tube manufacturing defects.
5. Galvanic incompatibility of materials.
6. Under deposit pitting corrosion.
7. Tube leaks caused by corrosion The condenser tubes and tubes sheets act as barriers between the relatively impure cooling water and the high-grade condensate. Due to the vacuum inside the condenser, any tube leakage will cause contamination of the condensate by the cooling water. This can lead to increased corrosion of the secondary system.

4.2.4.1 Abnormal Water Level of Condenser (Rise):

- **Phenomena:**
    1. Vacuum drops slowly.
    2. Super cooling degree increases.
    3. Inlet pressure and the current of condensate pump increase.
    4. When copper pipe of condenser leaks, the hardness of condensate water increases.

- **Reasons:**
  1. The copper pipe of condenser leaks or the expansion port of pipe plate leaks.
  2. Make-up water for condenser is too much or make-up water valve is opened by mistake or the condenser is filled with water from other place.
  3. Condensate pump fails or the output is not enough.
  4. The check valve of standby condensate pump is not closed tightly.



Fig(4.2) Condenser diagnostics flowchart (Source: Han Moy, consolidated Edison of New York)

4.3 Solution of problems:

When we talk about solutions we mean the maintenance operation to make the condenser works well and to a void and protect it from troubles shooting that happens by the environment effects and the humans faults and we all believe in fate everything is happen for better , because when we make that maintenance the efficiency will increase , the problems list is show you the general problems that happen to the condenser .

In our study we write a solution about many cases that face the engineers in BAHRI thermal power station and we will discuss their effect in the efficiency also increase or decrease in the Mega Watt output.

4.3.1 General Principles of Maintenance:

1. Keep the operation of condenser under the favorable vacuum and the vacuum should be higher than (86.3Kpa).
2. The sub cooling degree of condensate water is no more than (2^oC), the temperature differential at both sides is no more than (2^oC) and the end difference of condenser is no more than (7^oC).
3. Clean the secondary strainer frequently.
4. If the dissolved oxygen of condensate water increases, check and adjust the sealing water of each part timely. If the oxygen content is more than (30μg/L), check the leakage.
5. If the hardness and conductivity of condensate water are not qualified, check and adjust them in time. If the steel pipe leaks, contact with the maintenance department to fix it; When the hardness of condensate water increases to (5~10μmol/L) and it does not drop after (8 hours) of treatment or the (hardness is

>10μmol/L), the condenser should be shut down for further treatment.

We have to know first there are two condition of maintenances , during the normal operation of condenser and during the shutdown this problems solution can’t be calculated in the efficiency of the power plant because we have to shut it down immediately.

4.3.2 Condenser On-Line Cleaning Systems:

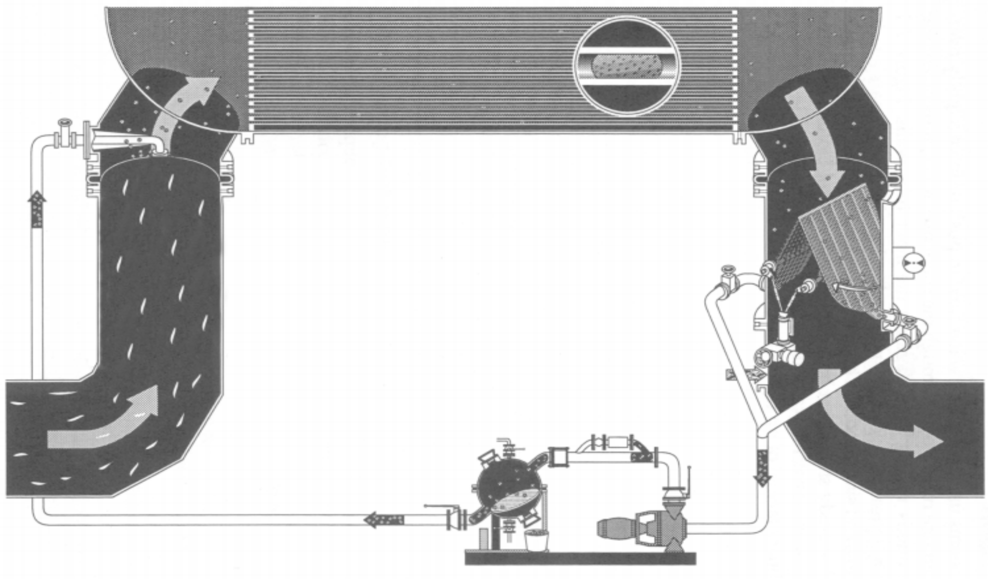
1. Sponge ball system.
2. Brush and cage system.

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

4.3.2.1 Sponge Ball System:

Ball systems use the cooling water flow to push or force slightly over-sized sponge rubber balls through the condenser tubes, this action provides a continuous wiping action against the inner tube walls. Figure (4.3) shows a typical ball cleaning system developed in Germany and modified by French, Japanese and American companies.

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



Fig(4.3) Typical ball cleaning system

- **Some of the advantages of the sponge ball cleaning system are:**
  1. Continuous cleaning of the tubes .
  2. Reduction or elimination of the need for befouling chemical addition .
  3. Reduction or elimination of shutdown for manual cleaning .
  4. Operation is automatic .
  5. System can prevent under-deposit pit corrosion .
  6. Start-up costs are lower than for brush and cage systems .
  7. Different balls are available for different foulants .
  8. Condenser efficiency can be greatly improved .
- **Some of the disadvantages of the sponge ball cleaning system are:**
  1. Labor required for frequent ball inspection and replacement.
  2. Adjustments to mechanized system components and controls are required.
  3. There is tube abrasion of soft metals.

4. Operating costs are higher due to increased maintenance, auxiliary power consumption and ball replacement.
5. System is susceptible to the introduction of debris.
6. Capturing balls can be problematic. A major escape of balls into a body of water can cause problems.
7. An uneven distribution of balls might not clean tubes uniformly.
8. Space and outlet piping configurations can influence retrofit.
9. Balls can become lodged in tubes, causing blockage.
10. Collection screens might experience fouling that increases water side pressure.

4.3.2.2 Brush and Cage System:

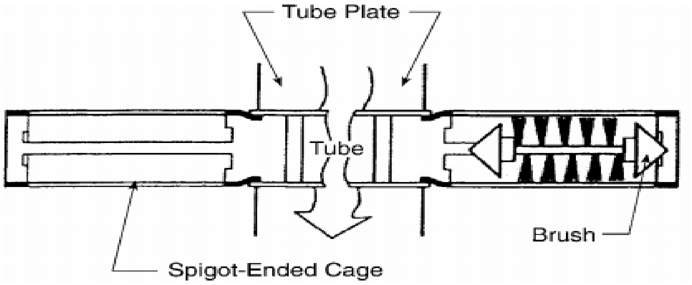
Another on-line condenser tube-cleaning method is the brush and cage system. This is used by some large power plants, smaller power plants, cogeneration plants, industrial heat exchangers and refrigeration chillers.

A typical arrangement is shown schematically in Figure (4.4). 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.

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 epoxy cages break off easily but are easy to repair, flow reversal is usually initiated automatically on a timed cycle but 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 water boxes can result in loss of brushes and serious damage to the cages.



Fig(4.4) 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:

1. Hydraulic transients in the system.
2. Transient decrease in heat transfer rate.
3. Transient rise in condenser backpressure.
4. Drop in turbine-generator output.

- **Some advantages of the brush and cage system are:**

1. Elimination of shutdown for manual cleaning but might require. load reduction for backwashing.
2. Ensures cleaning of each tube.
3. Except for flow-reversal valves and brushes, no moving parts.

4. Low operation and maintenance costs.
5. Limited operations and maintenance personnel attention.
6. Good at removing soft fouling material.
7. Reduces/eliminates need for befouling chemicals.
8. Split condensers and two-pass condensers can be accommodated.

❖ **Some disadvantages of the brush and cage system are:**

1. Reverse-flow piping and valves required.
2. More susceptible to debris lodging in cages and restricting flow.
3. Tube leak detection difficult because cages obstruct tube ends.
4. Used in straight tubes only.
5. Initial capital cost is high but lower than the sponge ball cleaning systems.
6. Imprecise cleaning throughout the tube.
7. Unit must be shut down for the brush and cage replacement.
8. Requires high tube velocities for effective cleaning.

4.3.3 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.

Table No(4.1) Typical off-line cleaning methods and their effectiveness

	Off-Line Cleaning Methods			
Type of Fouling	**Brushes**	**Scrapers**	**Hydro-Blasting**	**Chemical Cleaning**
Severe Scale	Not Effective	Good	Fair	Good
Organic Growth, Mud, Slime	Good	Good	Fair	Not Effective
Shells	Not Effective	Good	Not Effective	Not Effective

The method of cleaning should be evaluated for the tube material, type of deposit and cleaning time required.

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

1. Air/water-driven systems (bristly brushes, air/water, pigs and scrapers).
2. Mechanically driven systems (rotating brushes).
3. Pressure-driven systems (water lances).

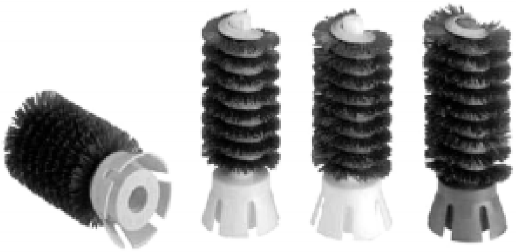
4.3.3.1 Air/Water-Driven Systems:

One of the simplest off-line tube cleaning methods uses a bristle brush quite 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 water box. Brushes with nylon or metallic bristles can be used, depending on the nature of the fouling. Figure (4.5) shows a typical water-driven bristle brush and Figure (4.6) shows a propellant gun, soft rubber plugs or plastic scrapers can be used in place of brushes if fouling conditions warrant.

Another method is simply shooting (200-400 psi) is (1.38-2.76 Mega Pascal) of air and/or water through the tube, this is the fastest method but is not appropriate for most cleaning.

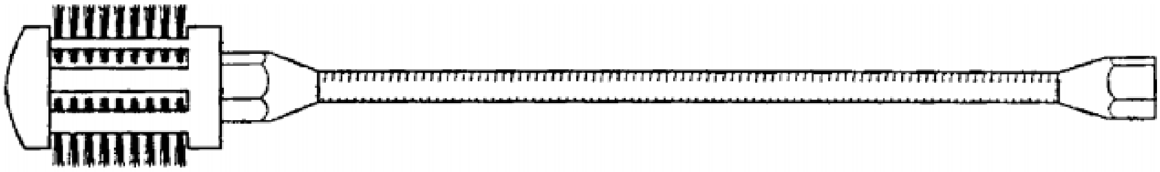
If the foulant is too hard to be removed by bristle brushes, then scrapers can be used. These are driven with 200-400 psi (1.38-2.76 Mega Pascal) of water pressure. Scraping edges should be spring-loaded to match the specified tube diameter



Fig(4.5)Typical water bristle brushes Fig(4.6)Water gun for brushes and scraper

4.3.3.2 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 (4.7).

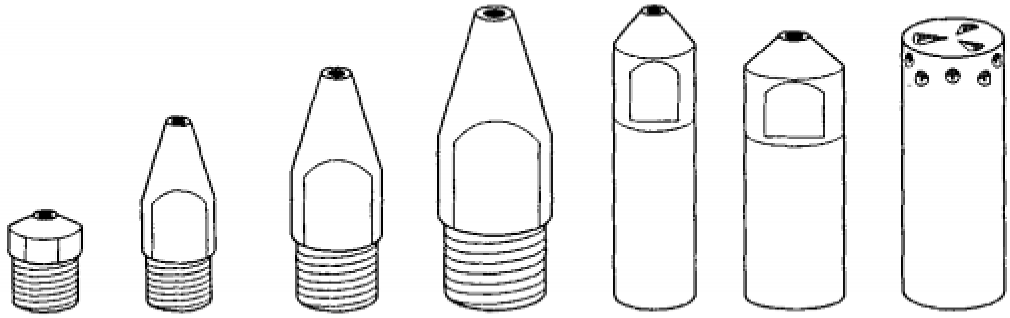


Fig(4.7)Mechanically Driven Brush

4.3.3.3 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) is (55 to 69 Mega Pascal's) are normally used and pressures as high as (18,000 psi) is (124 Mega Pascal) can be used. Operators need to take extreme safety precautions.

These high pressures can collapse tube ends, collapse tube inserts, damage tube sheet coatings, and damage tube-to-tube sheet joints. 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.



Fig(4.8)Typical water lance heads

4.3.4 Air In-Leakage Effects:

For maximum thermal efficiency, corresponding to a minimum backpressure, a vacuum is maintained in the condenser. This vacuum encourages air in-leakage, to keep the concentration of non-condensable gases as low as possible, the condenser system must be leak tight, together with any part of the condensate system that is under vacuum, failure to prevent or remove the non-condensable gases can cause serious corrosion in the system, lower heat transfer properties and/or increase plant heat rate due to the backpressure rise associated with a high in-leakage.

4.3.4.1 Correcting Air In-Leakage:

When the source of an air in-leakage has been located, it should be corrected, good judgment has to be exercised when determining how to conduct the repair and how permanent to make it at that time, much will depend on the severity of the leak, if the leak can be reduced to an acceptable level without taking the unit out of service, this might be more important than providing a more permanent solution immediately, methods for correcting the air in-leakage will depend on the nature and location of the leak.

4.3.4.2 Piping Repair or Replacement:

Good pipe-fitting practice will determine how to repair or replace piping or pipe fittings where air is leaking into areas of the condenser and turbine system that operate under sub-atmospheric pressures. In the case of leaks detected in any piping that lies within the water box, the pipes should be corrected or replaced before the unit is brought back on-line.

Leaks found in those pipes that have easy external access can be corrected or replaced in accordance with good practice, often these pipes can be repaired with the unit remaining in operation, good pipe-fitting practice also applies when correcting penetrations where air is leaking.

Many of these incorporate pipe fittings close to the penetration or else leaks can develop in welds around the penetration. These can often be corrected while the unit remains in operation.

4.3.5 Water In-Leakage:

The condenser tubes and tube sheets act as barriers between the relatively impure cooling water and the high-grade condensate. Due to the vacuum inside the condenser, any tube leakage will cause contamination of the condensate by the cooling water. This can lead to increased corrosion of the secondary system.

Circulating water leakage into the shell side of the condenser can become extremely serious because it allows corrosives and other undesirable dissolved solids to gain entry into the condensate hotwell.

Leaks will eventually cause serious damage to the piping, steam generators (or boilers) and turbines, on-line leak detection and/or chemistry indications can determine the tube bundle that contains the leaks, the tube bundle is then isolated and the leaking tubes can be identified and plugged. If the leaks cannot be located, a full forced outage might be required.

4.3.5.1 Water In-Leakage Detection Methods:

1. Most leak-detection methods is to full the side of shell by water with chemical subject and notice the leak of water in the other side of tube .
2. This consists of spraying a layer of foam on the tube plates at both ends of the condenser while a vacuum is maintained on the steam side, if there is a leak the associated tube will be put under vacuum and the foam will enter the tube, thus easily identifying it, of course it is absolutely vital for the success of this method that the foam should be stable, i.e. it should adhere to the tube plate for a considerable time as a thick layer.

3. Bubbler leak A tedious but positive method. One end of the condenser has its tubes plugged, a vacuum is maintained on the steam side and the bubbler is connected to each tube in turn at the other end. Should there be a faulty tube, air bubbles will pass through the bubbler.

4.3.5.2 Correcting Water In-Leakage:

1. If the corrosion was caused by the chemical composition of the cooling water source, a chemical treatment program might need modifying.
2. Perhaps the tube material is unsuitable for the available source of water, possibly the corrosion was due to galvanic action between incompatible metals.
3. To ensure that the leak has been sealed, the tube identified as leaking has to be plugged when the number of tube excess (20%) of the total number .
4. Re expanding the tube-to-tube sheet joints(mousing).
5. Water box repairs.
6. Tube sheet repairs.

If the water in-leakage was due to the erosion/corrosion of tube inlet ends, this can often be circumvented by placing plastic inserts, thin-walled metal inserts, or shields in the tube inlet ends. Sleeves can be installed in damaged sections of the tube, coatings can be applied to tubes, tube sheets, and water boxes to restore material surfaces, damage from tube vibration can be reduced by staking the tube bundles appropriately.

4.3.6 Chemical Cleaning

Chemical cleaning techniques can be applied to open and closed cooling water systems. 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-line and off-line chemical cleanings have been performed in the industry. On-line cleanings can be as simple as injection of 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 (on-line versus off-line techniques) is based on the foulant, materials, design issues, schedules and so on.

4.4 Calculations :

To study the effect of previous problems of condenser in power plant efficiency , we collected this data from BAHRI THERMAL POWER STATION- PHASE TOW- UNIT THREE from control unit for period of the three years latter (2013-2014-2015) , for one hour (every two minute) in random day.

The table(4.2) display the data and calculation of the(plant efficiency- condenser efficiency- LMTD- Heat rejected to condenser- Heat transmission rate- Quantity of cooling water- CW flow rate) by using this laws in excel sheet, but before we begin the calculation we add the saturation water table to the Microsoft Office Excel to find (h_1,h_2,h_3,h_4), the add is (water97-v13).

- **Plant efficiency** = $1-[(h_3-h_2)/(h_4-h_1)]$
- **Condenser efficiency** = Actual temperature rise / maximum temperature rise

Actual temperature rise = $C.W_o - C.W_i$

maximum temperature rise = $TET - C.W_i$

- **LMTD** = $[(\theta_1- \theta_2)/Ln(\theta_1/ \theta_2)]$

$\boldsymbol{\theta_1}$ = $TET - C.W_i$

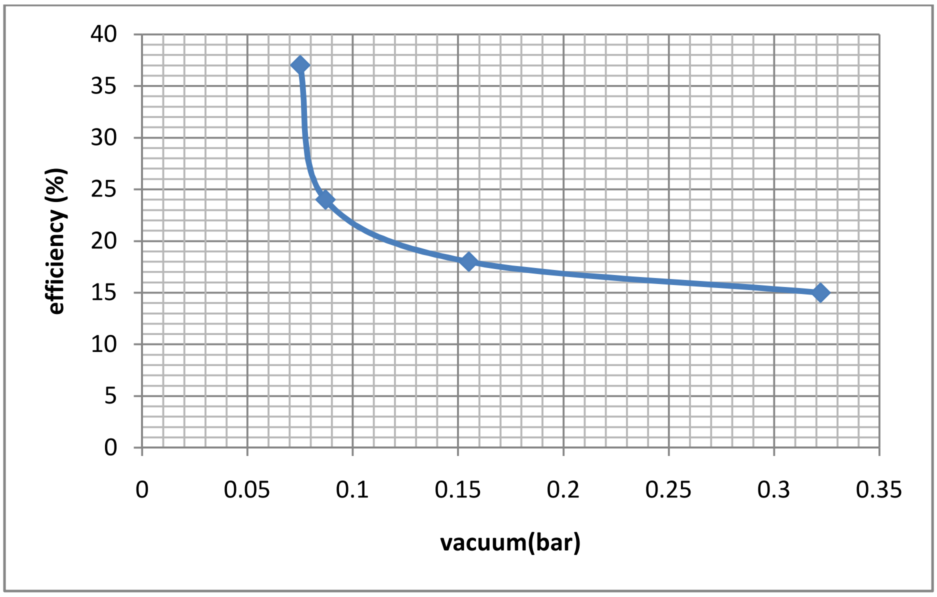
$\boldsymbol{\theta_2}$ = $TET - C.W_o$

- **Heat rejected to condenser** = $ms*(h_4-h_1)$
- **Heat transmission rate** = $[(ms*(h_4-h_1))/ (A_{surf}* LMTD)]$
- **Quantity of cooling water** = $[(ms*(h_4-h_1))/ (Cp_w * C.W \Delta \mathbf{T})]$
- **Cooling Water flow rate** = Q * v

Table (4.2) show the data and calculation

Items	03 03 2013	15 06 2014	28 04 2015	Normal
Cooling water –inlet (deg C)	25.361	25.915	26.258	28
Cooling water –outlet (deg C)	34.802	37.638	38.149	37.29
Exhaust steam temp (deg C)	48.847	65.883	77.842	40.2
Exhaust steam pressure (vacuum) (bar)	0.087	0.155	0.322	0.075
Turbine inlet pressure (bar)	88.28	52.723	74.209	87
Turbine inlet temp (deg C)	509.5	427.514	322.4368	510
Surface area of tube(m^2)	8336.448	8336.448	8336.448	1.476
Gross load (MW)	50.0077	39.717	38.6142	60
Generator efficiency	0.99	0.99	0.99	0.99
Mechanical efficiency	0.99	0.99	0.99	0.99

Main steam flow (Kg/s)	53.4185	46.947	49.8977	62.491
Fuel oil flow (Kg/s)	3.5729	3.335	3.4832	168.7596
Economizer inlet FW pressure (bar)	96.3055	94.49707	94.8783	
economizer inlet FW temperature (deg C)	207.0897	203.1433	200.1945	
Heat consumption (KJ/KW hr)				9609.32
enthalpy(h_1) (KJ/Kg)	180.538	228.7831	296.0795	
enthalpy(h_2) (KJ/Kg)	887.42	869.69	856.56	
enthalpy(h_3) (KJ/Kg)	3413.3	3259.1	2910.9	
enthalpy(h_4) (KJ/Kg)	2104.2	2179.6	2039.2	
Calorific Value (KJ/Kg)	44510	44510	44510	44510
Plant efficiency	24%	18%	15%	37%
Condenser efficiency	40%	29%	23%	76%
θ_1 (deg C)	23.486	39.968	51.584	12.2
θ_2 (deg C)	14.045	28.245	39.693	2.91
LMTD (deg C)	18.36277	33.76803	45.37914	6.481624
Heat rejected to condenser (KJ/Kg m^2)	102759.1	91585	86977.7	
Heat transmission rate (KJ/Kg $m^{2o}C$)	0.671276	0.32534	0.229917	
Quantity of cooling water (Kg/s)	2603.911	1869	1749.9	2399.16
CW flow rate (m^3/s)	9374.08	6728.4	6299.641	8636.976



Fig(4.1) Relation between efficiency & vacuum