POWER PLANT CONDENSER FOULING

Article of Interest by Dewindia Team

Industrial process plants generate steam for power production and process use. Recovering this steam as condensate, and returning it to the boiler, is an economical way to recycle heat. This is usually done in a water-cooled, steam-surface condenser located at the exhaust of a turbine. Poor performance of such a condenser, which is really a large heat exchanger, can significantly decrease a plant's heat-recycling efficiency.

The most-common causes of condenser inefficiency are: microbiological growth on the water side, scale formation on the water side, tube pluggage by debris and air in-leakage on the steam side. These problems can cost a plant dearly. Well-planned treatment programs to combat these causes, however, pay for themselves many times over.

Condenser Effect and Problems

Ideally, when steam leaves the turbine of a condenser, it has used all of its available heat for work and is saturated. The condenser uses cooling water to remove the steam's latent heat and convert the steam to condensate. Condenser pressure depends on cooling-water temperature, which, under normal circumstances, is low enough to produce a strong vacuum. Accordingly, we can calculate the enthalpy of the exhaust steam for various conditions. If, however, all incoming steam exhausts into a vacuum, the situation changes noticeably. Also, some steam is typically extracted from the turbine for feedwater heating, so an increase in condensate temperature would decrease the quantity of steam needed for feedwater heating. Thus, higher condensate temperatures would alter the heat transfer in feedwater heaters. During one of DEWTREAT treatment program we have encountered power plant which was using extra 7,000 tons of coal per month to offset the drop in efficiency. The costs of tube fouling can be considerable.
Microbiological fouling

Condensers, often a good location for microbial growth, are warm and provide a constant source of microbial introduction. In addition, they are usually located so far downstream from a point of biocide injection point that any biocide that actually reaches organisms is too dilute to be effective. Many bacteria colonies that form in condenser tubes secrete a gelatinous film that binds them and a lot of other material, including silt to the tube walls. These films not only retard heat transfer, but can promote corrosion of tube metal. Once formed, the colonies or their secretions can be difficult to remove chemically.

Dew once shock-treated a condenser with chlorine to remove colonies that had coated virtually all of the tubes. The condenser only regained 50% of its lost efficiency, indicating that much material still remained. Only by mechanically scraping the tubes were plant personnel able to restore the condenser to normal performance. Analyses taken of the deposits before tube cleaning indicated organism counts as high as 100,000,000 in a few grams of sample.

Microbiological fouling is usually not difficult to detect. A rise in the condenser's terminal temperature difference (TTD) often indicates this type of fouling. The TTD is the difference between the temperature of the condensing steam and that of the circulating water at its outlet. When condenser waterbox doors are opened for inspection, spongy buildups on the waterbox internals and the tubesheet typically indicate microbial growth. The tubes often have accumulated circumferential deposits of silt that are held in place by the secreted matter. The material looks and behaves much like mud.

Chemical treatment is the best method to prevent microbe buildups, but treatment programs must be set up carefully to be effective. For many years, chlorine was the top choice for treatment programs. However, chlorine's use is questioned because the substance reacts with organics to form chlorinated compounds, which include trichloromethane a trihaloorganic (THO) that is a suspected carcinogen.

Government may include provisions to restrict or ban the use of chlorine. Such regulations would force industry to use other chemicals, such as chlorine dioxide (ClO₂), ozone or nonoxidizing biocides, none of which form THOs. These chemicals, like chlorine, can be effective, though their costs are usually higher. Often, however, the chemical is injected too far upstream of the condenser and has lost its strength by the time it's most needed. A method called targeted treatment injecting chemical at strategic locations along the condenser inlet tubesheet is proving useful. The biggest drawback of this technique is that it typically costs more than conventional systems.

Scaling and deposits

This is a problem that is most frequently seen in recirculating systems. In recirculating systems, mineral compounds in cooling water concentrate several times above makeup levels, often approaching saturation levels. The water then passes through the condenser, becoming heated in the process. Many compounds, most notably calcium carbonate (CaCO₃), become less water-soluble as the temperature rises. When a compound in recirculating water reaches its saturation point in a condenser, the compound precipitates and forms a layer of scale on the tubes. Calcium carbonate scaling is the most common type; however, calcium sulfate and phosphate, manganese compounds and silicates can also precipitate.
Although scaling is usually seen in recirculating systems, it sometimes occurs in once-through condensers. For example, an incidence of CaCO$_3$ condenser scaling was due to a drought. The condenser received its cooling water from a lake that lost much water to evaporation, which caused a large buildup in mineral content. Scale looks different from microbiological buildups. Because the phenomenon involves crystal growth, the deposits are harder and often smoother. Calcium carbonate scale frequently appears as a brown layer because of impurities in the crystal structure. Manganese deposits are often black.

The effects of scaling are similar to those of microbe fouling: The condenser gradually drops off in performance. Scale deposits are harder to remove, however. Calcium carbonate and calcium sulfate can be removed by mechanical scraping, but usually some debris remains. For manganese and silica deposits, or deposits in tough-to-reach areas, chemical cleaning may be the only solution.

A number of chemicals are used for on-line scale treatment. Sometimes adding sulfuric acid to cooling water will keep the pH low enough to prevent calcium carbonate deposition. Often, other chemicals must be added to cooling water. For example, phosphates and phosphonates tie up calcium ions and prevent them from forming scale products, and some polymers modify scaling compounds' crystal structures, preventing them from depositing on the tube walls. No generic treatment can be recommended. Each facility must be evaluated separately, and a custom treatment program developed for each.

**Air in-leakage**

Utility condensers generate a strong vacuum, which makes some air in-leakage inevitable. Thus, they are equipped with air-removal systems to remove gases. But, if the air in-leakage is too great, the equipment cannot handle the extra load. In this case, excess air coats the tubes and inhibits heat transfer. This problem is quite common. Typical points of air in-leakage include cracks in an expansion joint between a turbine and condenser, cracks in a condenser shell at condensate-return lines, explosion diaphragms on a low-pressure turbine, low-pressure heater vents, and condensate pump seals.

Dew have observed a condenser that showed good efficiency at high load, and poor efficiency at low load. Because condenser efficiency changed so drastically depending on load, plant workers realized that the condition was unrelated to tube fouling, but was likely due to air in-leakage. The problem was traced to a faulty trap on a condensate-return line from a gland steam exhauster. The trap had stuck open; but at high loads, enough condensate flowed through the line to minimize air leakage.

At low loads, however, the line was only partially full and the condenser vacuum pulled air back through the exhaust vent. Once the trap was repaired, the efficiency problems vanished. As the above example indicates, an air leak often causes a sudden change in condenser performance, which differentiates it from tube fouling or scale formation. For instance, if an explosion diaphragm fails, the TTD may rise a couple of degrees in a short time. Excess air in-leakage can frequently be verified by examining the discharge from the air-removal system.

A general rule of thumb is that the air-removal rate from a unit should be less than or equal to 1 scfm/100 MW. A condenser-shell failure or other type of air in-leakage problem will often increase this removal rate several fold. Air leaks should be located and repaired as quickly as possible.
Not only does in-leakage cause performance problems, but the excess oxygen entering the system can corrode the condensate-and-feedwater lines. In the presence of ammonia, oxygen can attack copper-based heater and condenser tubes. Ammonia corrosion is most often prevalent in and below air-removal compartments. Ammonia concentrates in these areas and dissolves in the condensate. The condensate then runs down tube-support plates.

When excess air is present from in-leakage, ammonia and oxygen attack copper-bearing tubes at a tubesheet interface. This localized attack can thus cause condenser tubes to fail long before their expected tube life is reached. A common technique used to locate air leaks is helium leak detection.

A helium detector is installed at the discharge of the condenser's air exhauster. Helium is sprayed at various points around the condenser. A leak pulls the helium into the system, upon which it is collected by the air-removal equipment and eventually discharged through the air evacuator. The helium concentrations detected at exhaust vents help determine the size of the leak.

**Tube pluggage**

Another common problem occurs when leaves, vegetation and other kinds of aquatic life pass through worn trash screens and build up on the inlet tube sheet. Such problems can usually be cured with normal equipment repair. More difficult to combat are aquatic organisms that are originally small enough to pass through screens, but grow to a problem size inside the circulating water system. Removal of pests is frequently time-consuming because some travel into the tubes before becoming lodged. They then must be removed physically.

**Programs for condensers**

Good monitoring techniques help detect the hazards listed above. One simple method is monitoring the TTD. As tubes begin to foul, less heat is transferred from the condensing steam to the cooling water. Thus, steam condensate temperatures grow warmer as outlet-water temperatures grow cooler. Plotted over time, the TTD can be a good indicator of tube fouling.

*Dew is currently developing a software program to monitor condenser and heat exchanger efficiency using TTD. We require volunteering organization which can test these equipment at their premise. If you are interested do call or write us.*