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CHALLENGES IN CONVERTING A COAL FIRED PLANT CONDENSER INTO A COMBINED CYCLE PLANT CONDENSER

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ABSTRACT:

A steam surface condenser is a critical part of a power plant. Proper performance of the condenser is essential in achieving the output from the power plant. A coal fired plant condenser has design features that are different from that of a combined cycle plant condenser. A coal fired plant condenser has a lower turbine exhaust steam flowrate when compared to a combined cycle plant condenser. A combined cycle plant condenser is required to operate for a short or extended duration in the bypass mode. A coal fired plant is equipped with a pressurized deaerator that removes the oxygen from the condensate. In a combined cycle plant the deaeration of condensate is carried out in the condenser. In certain instances a combined cycle plant serves as a cogeneration plant wherein a portion of the steam, extracted from the steam turbine, is dispatched for heating purposes. In such instances, to make up for the steam dispatched for heating purposes, large amount of makeup water is introduced and deaerated in the condenser. In a coal fired plant large quantities of vents and drains are admitted into the condenser directly or through a flash tank. In a combined cycle plant the limited amount of vents and drains are introduced directly into the condenser.

This paper addresses the major differences in the design, construction and operation of a coal fired plant and a combined cycle plant condenser. The hardware and operational modifications are highlighted and precautions to be adopted in operating the condenser in the new role are discussed.

INTRODUCTION:

Extensive capital investment required to modernize ageing coal fired plants, expensive equipment required to comply with present day environmental regulations and lower prices of natural gas have forced numerous generators to shut down the existing coal fired plants entirely or convert them into gas fired plants. In some cases the coal fired boiler is converted into a gas fired boiler. In other instances, the existing coal fired boiler is replaced with a more efficient combination of combustion turbine and heat recovery steam generators (HRSG). In both scenarios, the existing balance of plant equipment is modified and refurbished and pressed into service. When the coal fired plant is shut down in its entirety the equipment in the plant is mothballed or sold on the secondary market.

A steam surface condenser is an important component of a power plant. Although the operating principles of the coal fired and combined cycle plant condenser are the same, there are differences in the design and construction of the condenser internals. A combined cycle plant has higher turbine exhaust steam flowrate when compared to a coal fired plant. The combined cycle plant is often required to operate for a short or extended duration in bypass mode. A coal fired plant employs a pressurized deaerator that removes the oxygen from the condensate. In a combined cycle plant, the deaeration of condensate is carried out in the condenser.

Combined cycle plants, serving as cogeneration plants, dispatch a portion of turbine extraction steam for heating purposes. In such scenarios an equivalent quantity of makeup water is introduced and deaerated in the condenser. In coal fired plants large quantities of vents and drains are admitted directly or through a flash tank into the condenser. In combined cycle plants the limited amount of vents and drains are often introduced directly into the condenser.

There are a number of design features that must be addressed when converting a coal fired plant into a combined cycle plant condenser. A summary of the common and unique design that must be accounted for is included in the following section.

DESIGN FEATURES TO BE ADDRESSED:

Adequacy of Heat Transfer Surface and Support Plate Spacing:

The heat transfer surface in the existing condenser should be sufficient to provide the performance required in the combined cycle application. The existing support plate spacing should be equal to or less than that required for the higher turbine exhaust steam flowrate and the bypass steam flowrate. As the condenser will be required to operate in bypass operation for short or extended periods, it is prudent to increase the thickness of the tubes in the impingement zone. If permissible the two rows of dummy carbon steel tubes should be placed above the impingement zone tubes. This enhancement will protect the impingement zone tubes from steam impingement during normal and bypass operation and avoid tube failures.

Adequacy of Evacuation Capacity:

The existing coal fired plant condenser would be equipped with a steam jet air ejector package or liquid ring vacuum pumps. The performance of the evacuation package must be evaluated to ensure that the evacuation capacity under the new operating scenario meets the HEI guidelines. For vacuum pumps, the evacuation capacity with revised condenser pressure and circulating water inlet temperature at various operating points must be equal or exceed that required by HEI standards. For a steam jet air ejector package, the performance of the first and second stage jets and inter and after condensers must be evaluated under the revised motive steam conditions and the condensate flowrate.

Feedwater Heater in the Steam Dome:

The coal fired plant condenser is usually equipped with one or two low pressure feedwater heaters installed in the condenser neck. In certain instances the low pressure heaters are combined into a single duplex heater. These feedwater heaters are removed when converting a coal fired plant condenser into a combined cycle plant condenser. Extreme care must be exercised in removing the heater and the heater supports so that the condenser internals, especially the tubes, are not damaged. The opening in the steam dome end plate occupied by the feedwater heater must be replaced with a cover plate that is adequately stiffened to withstand the shell side vacuum forces.

The extraction piping located inside the condenser steam dome must be removed. The ends of the extraction piping must be capped and drain connections installed on the end caps. These drain connections must be routed to the condenser hotwell. The extraction piping must be adequately stiffened to prevent vibration related failures.

Bypass Headers:

A combined cycle plant condenser is required to condense the attemperated steam from HRSG when the steam turbine is not in operation. This mode of operation is typically referred to as bypass operation. To facilitate bypass operation, bypass headers are installed in the steam dome in the space previously occupied by the feedwater heaters. Typical bypass operation hardware includes HP bypass header, IP bypass header and LP bypass header. The bypass headers typically have smaller diameter and easily fit into the space vacated by the feedwater heaters.

It is recommended that the bypass headers extend along the length of tubes so as to distribute the bypass steam evenly across the entire cross section of the tube bundle. The bypass header should be equipped with the smallest possible orifices typically 0.25” in diameter so as to minimize the damaging effects of the steam emerging from the orifices. The orifices should be installed along the entire length of the bypass header and should be oriented sideways so that the steam jet is not pointed towards the turbine internals or the condenser tubes. The bypass admission design should be in accordance with the EPRI Report CS2251 titled “Recommended Guidelines for the Admission of High Energy Fluids to Steam Surface Condensers” with appropriate corrections. The condenser internals should not be located within the safe distance from the bypass header orifices, as specified by the EPRI report. The bypass header should be sloped along the length of the tubes. A drain connection with an impingement plate should be installed at the far end of the bypass header to provide proper drainage. It should be noted that the drain connection is intended to drain the condensate collected in the bypass header located inside the steam dome. The drain connection is not intended to drain the condensate in the extended length of piping between the pressure reducing desuperheating valve and the condenser.

The pressure reducing desuperheating valve (PRD Valve) must be designed and operated so as to admit only dry and superheated steam into the condenser. The PRD valve must fail in fail close position. The temperature of bypass steam admitted into the condenser must be carefully monitored. Alarm and trip setting for lower and upper bound temperatures should be established and implemented for all bypass lines. Proper control of superheat and temperature of bypass steam admitted to the condenser will ensure trouble-free operation in bypass operation.

During bypass operation, part of the high temperature bypass steam may travel towards the turbine exhaust and heat the fabric expansion joint or the steam turbine internals and cause damage. Steam turbine suppliers usually limit the temperature of steam migrating into the turbine exhaust. A spray curtain could be installed to limit the temperature of steam migrating into the turbine exhaust. A spray curtain, if required, would be installed just below the expansion joint. The spray curtain nozzles spray cold condensate in the form of a fine mist that covers the entire cross section of the turbine exhaust.

Vent & Drain Connection and Flash Tank:

A coal fired plant condenser has a large number of vents and drains emanating from a variety of equipment in the plant. In certain plants, the large number of vents and drains with different flowrates, pressures and temperatures are admitted into a flash tank that is designed to operate at a pressure above that of the steam surface condenser. The condensate from the flash tank is admitted to the condenser via a loop seal. The vapor from the flash tank is admitted to the condenser through a vent pipe equipped with an orifice plate. In other instances the vent and drain from the flash tank are admitted directly into the condenser above the high-high water level but below the lowermost tube. In either case, the discontinued vents and drains (such as vents, normal and emergency drains from feedwater heaters) should be marked and blanked off. If the existing flash tank is retained then the thermal/hydraulic design of the flash tank, to operate with the reduced number of vents and drain connections, must be carefully evaluated. The operating pressure in the flash tank, the loop seal design for the draining the condensate to the condenser hotwell and the orifice plate design for venting the steam to the steam dome must be carefully evaluated to ensure that the flash tank design is suitable for the combined cycle plant application.

CONCLUSION:

There are substantial differences in the design between a coal fired and a combined cycle plant condenser. These differences must be recognized and appropriate modifications must be made to ensure that the condenser performs satisfactorily in its new role in the combined cycle plant. All modifications must be documented in detail for future references.

REFERENCES:

1. Heat Exchange Institute Standards for Steam Surface Condensers, 10th Edition.
2. EPRI Report CS2251, “Recommended Guidelines for the Admission of High Energy Fluids to Steam Surface Condensers”.

3. **“**Importance of Temperature of Bypass Steam Admitted into a Steam Surface Condenser in a Combined Cycle Plant”, Electric Power Research Institute (EPRI), 2011 Condenser technology Conference, August 3-4, 2011, Chicago, Illinois.
4. **“**Tube Failures During Startup in a Steam Surface Condenser Installed in a Combined Cycle Plant in a Cold Climate”, ASME Paper # PWR-2004-52001, Proceedings of ASME Power 4 Conference, March 30-April 1, 2004, Baltimore, Maryland.

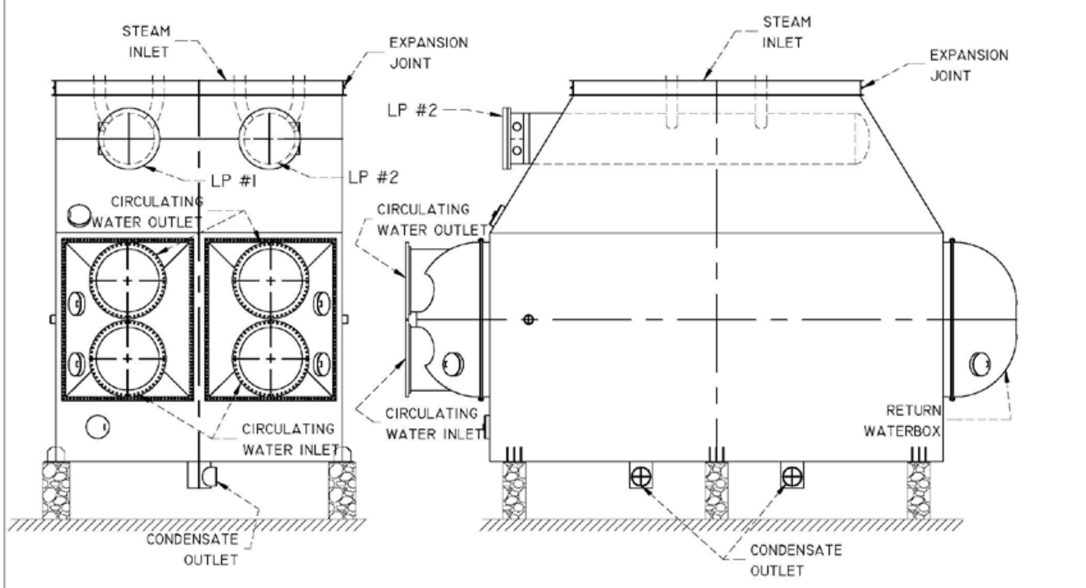

FIGURE 1: COAL FIRED PLANT CONDENSER

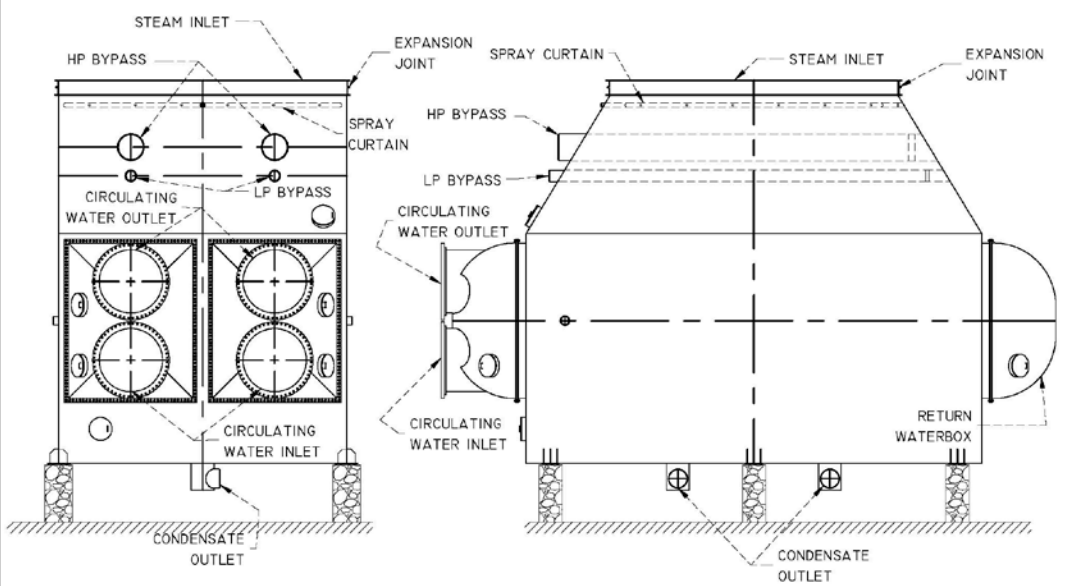

FIGURE 2: COMBINED CYCLE PLANT CONDENSER