TRENDS IN STEAM GENERATOR DESIGNS FOR ELECTRIC UTILITY AND INDUSTRIAL APPLICATIONS

The tremendous growth of electric power during the last two decades, has created a demand for steam generators of increasingly larger inputs at increasingly higher pressures. It has been the successful manipulation and control of the two distinct processes of heat liberation from fuel and heat recovery for steam generation in large unit sizes which, in conjunction with larger turbines, other plant equipment and distribution systems, have made possible the remarkable feat of modern, low cost generation of electric power.

Among the contributions to the development of low cost steam generation probably none has been more universally observable than the drum-type boiler. This is the oldest and yet also the newest type of steam generator. Of particular note is the contribution made by this company of the Controlled Circulation design for high subcritical pressures.

Controlled Circulation

The reliability, availability, and safe operation of Controlled Circulation boilers have justified their selection in power plants throughout the world as demonstrated by the records. During the past 10 years C-E has sold 311 utility boilers with a total capacity of 56,370 Mw. Of these, 114 were of the Controlled Circulation design with a total capacity of 34,105 Mw. which represents 60 percent on a Mw basis.

At this pint it may well be worthwhile to consider some basic relation ships in the steam generation process at subcritical pressure. The common characteristic of all such boilers is the presence of three basic heat recovery surfaces – the economizer, the evaporator and the superheater. For all of these sections we may define circulation as the movement of water or steam, or a mixture of both, through heated tubes. Circulation must be adequate to absorb heat from the tube metal at a rate to keep the tube temperature at or below its design temperature. Circulation should also keep the tube within other physical and chemical limitations required by the inside and outside environment. In contrast to the circulation in economizers and superheaters, the circulation in evaporators, which in modern high pressure units are utilized as furnace wall systems, may have the type of circulation involving only the flow entering and leaving, known as the once-through flow, and also that wich involves recirculation at a flow greater than the throughput of the steam generator.

The natural circulation and the Controlled Circulation units are included in the last group and share the feature of a steam drum as a characteristic of subcritical recirculating units.

For pressures up to the 2000 psig level, furnace wall systems with natural circulation boilers are generally accepted as the best technical and economical answer to the various requirements for steam generation.

Natural circulation boilers employ the effect of the saturated density differential between water and mixtures of water and steam to promote circulation.

Controlled Circulation is a recirculating system at subcritical pressures in wich the driving force of the thermal head is supplemented by an external mechanical force produced by constant-speed circulating pumps within the down comer piping. A comparison of natural and Controlled Circulation for a furnace wall system is shown schematically in Fig. 1.

It can be seen that the most obvious difference between Controlled and natural circulation is in the introduction of a circulating pump between the downcomer systemand the steam generating surface and the introduction of orifices. The circulation through economizer, superheater and reheater is the same for both types.

The basic elements of a furnace wall system in a Controlled Circulation boiler are shown in Fig. 2. The system employs a drum which receives a mixture of steam and water from the steam generating tubes and feedwater from the economizer. Steam drum internals separate the steam from the excess boiler water. The saturated steam containing a minimum of impurities discharges from the top of the steam drum to the superheater portion of the unit. The separated excess water mixes with the feedwater in the steam drum and is returned to the furnace wall by the circulating pump.

All furnace wall tubes are arranged in parallel and in a single upward pass. They are fed from waterwall inlet headers at the lower end terminate in waterwall outlet headers at the upper end. From there the steam-water mixture is relieved to the steam drum.

With a design circulating ratio of 4 to 1, the system provides an average 3 lbs of recirculated fluid for every pound of fluid entering and leaving the boiler. This flow is distributed and stabilized by a system of orifices in the lower water-wall headers at the circuit inlet.

Because the recirculating system is integral with the steam generator and independent of other plant equipment, the protection it affords to the furnace-wall system is present in full force not only during normal operation over load range, but also for startup, extremely low loads, and shutdown. The furnace-wall system, therefore, does not require a bypass system and is immune from failures due to controls and interlocks associated with such systems. The recirculating system is independent of pressure above a minimum as determined by load and will maintain circulation for low- and high-pressure operation during steady-state as well as transient conditions.

Basic Design Principles

Protection of tubes against failure through overheating is achieved, then, by these principles:

1) Recirculation of water at the ratio of 4 to 1, designs into the system a large margin of safety for all system circuits under any operating condition.

2) Low steam quality present over the full length of all tubes which are sized for a mass flow adequate for all flux rates, assures nucleate boiling conditions with the bulk fluid temperature at saturation level in every tube at any elevation.

3) A system of orifices establishes and maintains these safety features by (a) Distributing the total flow through all tubes in relation to the heat pickup of individual circuits or groups of circuits, with the possibility of easy readjustment if required and, (b) Stabilizing the flow under transient flux conditions by the nature of inlet orifices with as much pressure drop as is present in the heated circuit.

With these principles, the design is able to control the metal temperature in a tube panel, as it is influenced by the heat flux, and the inside film coefficient.