A stop-start business

Once through heat recovery steam generators (OTSGs) are being used in many applications worldwide that require quick response times. Jim McArthur and Anthony Hinde of Innovative Steam Technologies report.

Due to recent trends in the power generation industry the profitability of a combined-cycle power station can be dependant on the operating conditions that it can meet. Operation modes such as daily start/stop, peaking or load following are commonplace today to meet dispatching requirements. The transient response and cycling capability of steam generators must be considered for successful long-term operation of modern power stations.

The OTSG is unique in that it produces steam without the use of a drum. While reducing the water inventory, the lack of a drum also allows the boiling section of the OTSG to move freely throughout the tube bundle as dictated by the operating condition.

Long-term reliability

With current trends towards more efficient, higher-pressure cycles, ramp rate of the HRSG is becoming a critical issue. The OTSG may be the only option for long-term reliability when quick transient responses are required. The once-through steam generator, in its simplest form, is a continuous tube in which preheating, evaporation, and superheating of the working fluid takes place consecutively (Figure 1).

In practice, of course, many tubes are mounted in parallel and are joined by headers thus providing a common inlet for feedwater and a common outlet for steam. Water is forced through the tubes by a boiler feedwater pump, entering the OTSG at the 'cold' end.

The water changes phase to steam midway along the circuit and exits as superheated steam at the 'hot' or bottom of the unit. Gas flow is in the opposite direction to that of the water flow (counter current flow). The highest temperature gas comes into contact with water that has already been turned to steam. This makes it possible to provide superheated steam.

The advantages inherent in the once-through concept can be summarised as follows:

- Minimum volume, weight, and complexity
- Inherently safe as the water volume is minimised by using only small diameter tubing
- Temperature or pressure control are easily achieved with only feedwater flow rate regulation.

The once-through steam generator achieves dissolved and suspended solids separation external to the steam generator by pre-treatment of the OTSG feedwater. Any solids remaining in the feedwater, either suspended or dissolved, can form deposits on the OTSG tubing and/or be carried over to the steam process. Dissolved oxygen control is not a critical issue for the IST OTSG, which is made of alloy tubing.

OTSGs have been supplied in both horizontal tube/vertical gas flow arrangements (Figure 2) as well as vertical tube/horizontal gas flow arrangements (Figure 3) to match customer requirements. Unlike traditional natural circulation or forced circulation HRSGs, the OTSG does not have a steam drum. Water enters at one end of the OTSG through the inlet header and exits the other end of the OTSG as superheated steam through the outlet header. The evaporator section is free to move throughout the bundle depending on the operational load.

Traditional circulation

In traditional natural circulation (Figure 4) or forced circulation HRSGs, the steam drum forms a distinct boundary between the economiser, evaporator and superheater. This limits the flexibility of load following for the steam generator. Without a boundary for the steam generator, there is no concern of producing steam in unwanted sections, as is the case with drum type HRSGs.

At different loads the economiser outlet temperature can approach the drum saturation temperature. If this occurs, the economiser is referred to as 'steaming'. Economiser steaming can lead to water hammer or steam blanketing. Steam blanketing of an economiser can lead to corrosion failure, expansion problems or performance degradation.

Other problems associated with part-load operation can be reduced steam temperature that can adversely affect operations of the steam turbine.

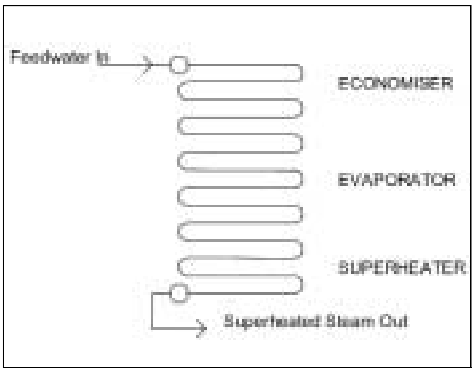

Figure 1 – characteristics of once through steam generators.

Figure 2 – horizontal tube/vertical gas flow arrangement.

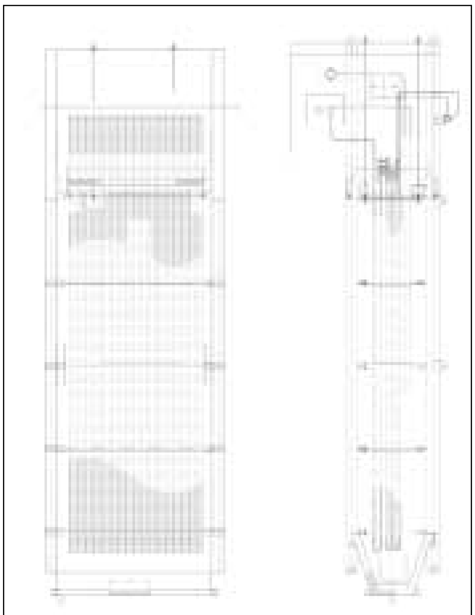

Figure 3 – vertical tube/horizontal gas flow arrangement.

Alternatively, the OTSG provides maximum flexibility for load swings. The evaporator section is allowed to float through the steam generator depending on steam demand. Table 1 illustrates the ability of the evaporator section of a single pressure OTSG to float

Table 1 - Load comparison for OTSG

	United Full Load	United Part Load	Fired Full Load
Exhaust Gas Flow (lb/hr)	1,112,400	1,112,400	1,112,400
Gas Temperature (°F)	839	839	839
Duct-Firing Temperature (°F)	N/A	N/A	1,200
Stack Temperature (°F)	332	544	309
Steam Flow (°F)	139,750	70,000	255,000
Steam Outlet Temperature (°F)	475	839	475
Total number of tube rows	32	32	32
Number of economiser rows	18	2	16
Number of exaporator rows	18	2	16
Number of superheater rows	4	28	2

through unfired, fired and part-load conditions.

For a fixed gas turbine load the OTSG can operate at part-load conditions without the requirement for gas or steam bypassing. By throttling back the feedwater flow to the OTSG and desuperheating at the outlet header, the OTSG can adapt to wide-load swings. From full-unfired load to part-load, the evaporator rows are reduced from 18 rows to 2 rows. As the OTSG transitions to full-fired load the evaporator section again increases. If fixed economiser, evaporator and superheater sections were provided; these wide swings in load would not be possible. The only solution for part-load operation, in a standard HRSG is to use the bypass valve for throttling, which is inaccurate, or to use an additional condenser for the unwanted steam.

Filling mass

In the OTSG, there is no water circulation and the water inventory is much less than either the forced circulation or natural circulation units. Water volume is typically one-eighth to one-tenth that of a conventional drum-type HRSG. As a result of this water inventory, traditional HRSGs respond slower to transients. The OTSG contains significantly less water than a drum type unit during operation. In fact the OTSG is started dry, therefore the unit does not have to wait until the large volumes of water contained within the drum heats and begins to evaporate as in traditional HRSGs. This gives the OTSG the ability to achieve very fast start-ups.

Unlike conventional HRSGs, OTSGs do not have steam drums, mud drums or interconnecting piping. The elimination of these components reduces the heat accumulation of the OTSG and the thermal lag associated with them. The OTSGs small diameter tubing, lack of drums and interconnecting piping results in the OTSG being approximately 60 per cent of the weight of traditional HRSGs. The elimination of drums also simplifies the control of OTSGs. Traditional problems of drum level shrink or swell with potential for scaling and carry-over are eliminated in fast start-up transients.

The success of IST's OTSG and steam system is based on overall system simplicity. This carries over into the control system as

OTSG installed at Black Hills Cogen plant, Modern Continetla South Inc, Las Vegas in 2001" 4 x LM6000, 43MW units.

well. For a typical dual pressure OTSG, there is a single controlled analogue output to the feedwater flow control valve, which modulates feedwater flow rate to obtain the desired superheated steam outlet temperature or outlet pressure. Normal operation will be at a steam outlet temperature or steam pressure set point.

The goal of the control system is to generate as much energy from the gas turbine exhaust heat as possible, while limiting the maximum steam temperature to a value, which can be tolerated by the steam process.

To provide both rapid response to gas turbine load transients and accurate control of steam temperature, a dual element control is recommended. The two elements consist of a predictive, or feed forward element, and a trim, or feedback portion. The two command

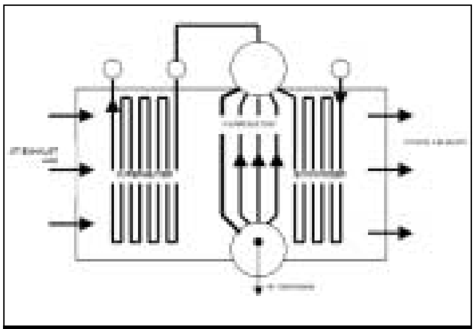

Figure 4 - drum-type HRSG.

signals are summed to obtain the total feedwater flow command signal. During steady state gas turbine operation, feedwater flow rates are adjusted via feedback control loops, which maintain the superheated steam temperatures at the desired set point. This set point may be constant or a function of incoming gas temperature.

Applications

- Gas turbine steam injection – the OTSG is uniquely matched to the demanding operational requirements of gas turbine steam injection applications. Gas turbines are injected with steam for NOx control, power augmentation and/or cooling. Steam injection is most often applied to plants requiring peaking and cyclic service. These applications require fast start capabilities and response to quick-load changes.

In peaking duty, most of the time the OTSG is in cold standby waiting to be dispatched. This type of operation can be very challenging for traditional drum type HRSGs.

- OTSGs coupled to compressor drives – gas turbines are quite often used as compressor drives on natural gas pipelines. The load of the gas turbine is dictated by the needs of the pipelines. The load following capabilities of the OTSG are required to supply a reliable source of steam during the daily swings caused by natural gas demands.

Traditional drum type HRSGs are limited in their fast response and transient capability by the steam drums and associated water inventory and mass of metal. Using an OTSG and eliminating the drums and interconnecting piping, the fast start and transient capabilities are vastly improved. The high degree of flexibility inherent in an OTSG without the need for fixed boundaries between the superheater, evaporator and economiser sections makes the OTSG the best choice for any system requiring fast transients. IPG

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