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Guide to Steam Systems

Part 1

Steam Generation

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"Small enough to care,
large enough to cope."

Guide to Steam Systems Part 1:

Steam Generation

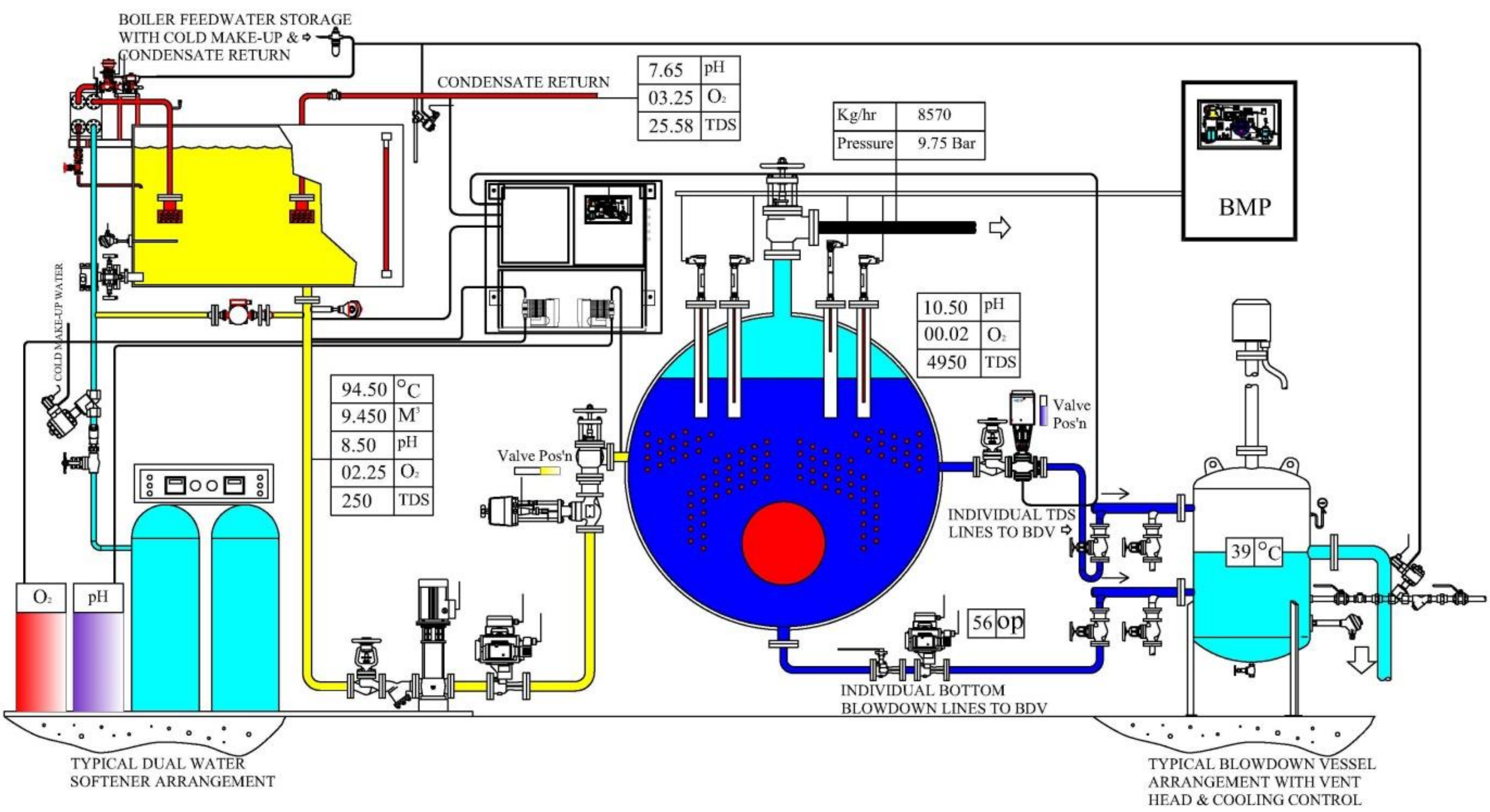
Steam is generated as a means of converting the energy in fossil fuels into usable heat energy for process or heating requirements. The correct generation, distribution and use of process steam and the recovery of condensate are fundamental to most manufacturing processes. Maximum production and hence profitability can only be achieved if they are given the attention they deserve.

Steam systems can be broken down into three sections: -

1. Steam Generation
2. Steam Distribution
3. Condensate & Feedwater Handling and Control

1. Steam Generation

Typical Boiler Layout with Integrated Controls



1.1 The Boilerhouse

The function of a steam boiler is to reliably deliver dry saturated steam at the desired quantity and pressure, not a mixture of steam and water.

Providing the process steam demand is within the boilers "Maximum Continuous Rating' (MCR), reasonably steady and the conditions within the boiler are maintained at optimum levels then today's packaged boilers will carry out their task effectively and efficiently.

The ratio of heating surfaces to water content is relatively small in modern shell boilers; a consequence of which is that the rate of steam release from the water surface is much greater. The higher the release rate the greater the propensity to generate wet steam. Failure to maintain optimum operating conditions within the boiler increases the risk of priming.

Overloading the boiler beyond its MCR, results at best, in carryover of boiler water into the steam space and at worst burner lockout with resultant loss of steam.

Poor quality steam impacts on process heat transfer surfaces, reducing plant efficiency whereas boiler lockout results in loss of steam with loss of production time and product wastage.

Factors governing efficient steam production are:-

- Boiler Efficiency
- Quality of water within the boiler
- Rate of increase in steam demand
- Continuous steam load

1.1.1 Boiler Control

The basic requirements for boiler automatic control are to control the burner firing to meet the load and to maintain a constant water level by feeding in water to match steam output.

The master signal for control is the steam pressure either from individual boilers or from the steam header. A change in pressure signals a change in the firing rate calling for fuel and air changes to match demand.

Either capacitance or conductivity probes or float operated level controls maintain the water level. Modulating the feedwater via an automatic valve or switching the feedwater pump on/off.

1.1.2 Boiler Efficiency

The generation and release of steam in boilers, affects overall plant efficiency in the broadest sense; unscheduled shutdown of boiler plant can be very costly both in terms of production and cost of fuel.

The term efficiency, however, has a more specific meaning when applied to boilers;

Boiler Efficiency is the ratio of heat output to heat input. The heat output is the heat input minus the sum of the losses, which are:

1. The loss due to sensible heat in the exit gases;
2. The loss due to latent heat in the exit gases;
3. The loss due to incomplete combustion; and
4. The loss from the external surfaces of the boiler.

In addition to these, there is the loss due to blowdown, this loss is dependent on feedwater quality and providing heat transfer surfaces are clean and free from scale, have little relevance when calculating boiler efficiency against running load.

At zero output any fuel burnt will be used to make up the losses and hence the rule of thumb that as load decreases boiler efficiency decreases. However, this fall off in efficiency only becomes serious when boilers operate for prolonged periods below 25% of their Maximum Continuous Rating (MCR).

When two boilers operate in tandem automatic "Sequential Burner Control" will ensure that the steam load is evenly shared optimising boiler efficiency, reducing standing losses and saving fuel.

1.1.3 Boiler Water Quality

As a boiler generates steam, any impurities which are in the boiler feedwater and which do not boil off with the steam will concentrate in the boiler. Depending on the nature of the impurities and the conditions inside the boiler, such impurities may either:-

1. Form scale on the hot surfaces of the boiler;
2. Precipitate as finely divided solid particles (forming a suspension or a sludge);
3. Stay dissolved in the boiler water as dissolved solids

Water in its natural state contains minerals, suspended solids and dissolved gases. These impurities have to be chemically treated before the water is suitable for the boiler.

Chemical water treatment may modify the form of the impurities but will not completely remove them and will normally increase the dissolved solids level.

As steam is evaporated the concentration of total dissolved solids (TDS) increases in the boiler water. If the TDS concentration is allowed to get too high then carryover of boiler water will occur. This carryover can cause serious damage to the steam and condensate systems through corrosion and deposition on heat transfer surfaces.

In order to limit the TDS concentration it is normal to drain off, (or "blowdown") boiler water and replace it with relatively low TDS feedwater. Excessive blowdown is very costly in terms of lost energy and water treatment chemicals.

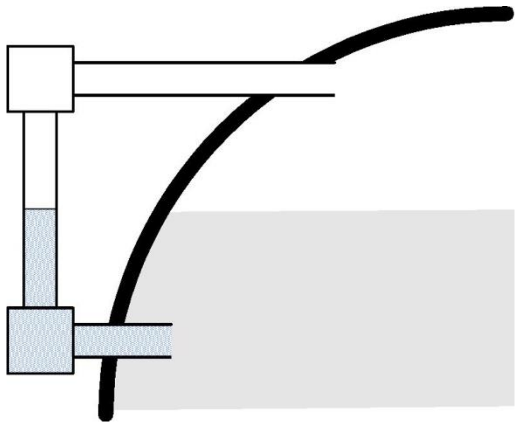
Manual control of boiler TDS is labour intensive, inefficient and costly in lost energy. Automatic TDS control will ensure that the boiler water is maintained at the optimum level. This will reduce thermal losses due to excessive blowdown, reduce the risk of priming and carryover and enable up to 90% of the energy contained in the blowdown to be recovered.

For every 1% reduction in boiler blowdown 0.19% reduction in fuel is achievable when operating the boilers at 7BarG.

1.1.4 Boiler Water Level

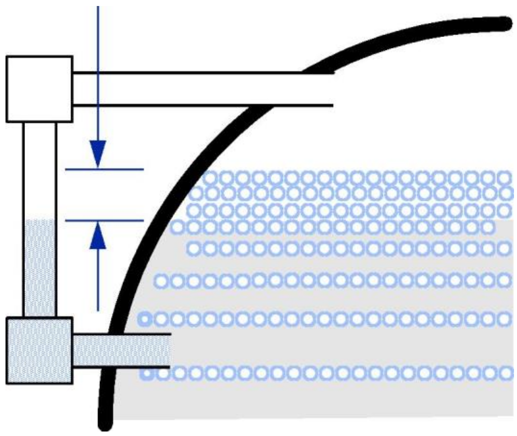
It is not possible to define the exact water level in a steaming boiler because the water surface is made up of a mass of bubbles with a strong horizontal circulation. There will be level variations both across and along the boiler shell. Under these conditions the level gauge glasses will show a lower level than the average water surface level in the boiler shell, since these external fittings contain water of a higher density.

Difference in Level



Boiler off.

No steam bubbles and the level gauge glass shows the true water level in the shell.



Boiler at high load.

Many steam bubbles and a lower indicated level in the gauge glass

The difference between the level in the gauge glass and the level in the boiler shell at high steaming rates depends on such factors as:

- Boiler design: furnace and smoke tube positions
- The boiler steam generation rating.
- The height of the gauge glass water connection into the boiler.
- Water chemical conditions in the boiler.
- The size of the boiler shell.

1.1.5 Heat Recovery from Boiler Blowdown

Blowing boilers down to maintain predetermined TDS levels results in high temperature boiler water discharging to drain. By recovering the flash steam produced and pre-cooling the waste water to below 40^{O}C before discharging it to drain enables up to 90% of the energy contained in the hot water to be recovered. With typical boiler blowdown rates around 12% of the steam generation rate then payback periods of well within 12 months are the norm.

1.1.6 Feedwater Treatment

The purpose of water treatment is to ensure that all parts of the boiler plant in contact with the water remain clean and intact, so that the design efficiency of steam generation and the production of clean, dry steam can be maintained during the working life of the boiler. The prevention of scale or deposit requires that all water entering the boiler plant, via the feed system, must be free from suspended solids, or any substance in solution, which may precipitate as solid by concentration or formed by reaction with other constituents in the boiler water.

Whilst artificially raising the boiler feedwater temperature by direct steam injection does not produce fuel savings, it does however save on the amount of chemical treatment required by the make-up water. Water with a temperature below 100^{O}C will absorb oxygen which unless treated is released inside the boiler causing corrosion: The lower the feedwater temperature the greater the amount of oxygen contained and therefore proportionally more oxygen scavenging chemicals are required.

Equally the higher the Total Dissolved Solids (TDS) content of the stored water the higher the required boiler blowdown rate.
Higher levels lead to boiler instability, foaming and priming. 1% reduction in boiler blowdown will save 0.19% of fuel.

1.1.7 Measurement & Monitoring of Boiler Output

Difficulties in the energy management of steam arise from the fact that it is often treated as a free (unmetered) service. Measurement of the boiler output is essential if savings are to be made.

Whilst combustion efficiency relies on the measurement of CO2 and Oxygen in the flue gases, boiler efficiency and steam costs ultimately depend on the measurement of fuel consumption and steam generated.

Fuel measurement is relatively simple using integrating meters and will provide useful information on burner operation.

Measurement of both production and consumption of steam is essential if savings and improvements in operation and ultimately profits are to be achieved. Any metering system installed to measure steam flow must include density compensation if accurate readings are to be obtained.

The steam pressure at the boiler varies with demand and since, with steam, volume depends on pressure, fluctuating pressure will affect the volume flow. Compensating for these pressure variations enables mass flow to be measured which in turn ensures that accurate and dependable information is obtained under all working conditions.

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