

Water Treatment for High Pressure Boilers in Sugar Plants

Introduction

A number of studies have been carried out in India by various Organisations which indicate tremendous potential for power generation in sugar factories through cogeneration scheme. In view of this, Government of India is encouraging sugar plants to go in to cogeneration and provides incentives for plants installing cogeneration scheme.

Sugar plants, when they go in for cogeneration have to install high pressure boilers of 66 ata and above with a definite aim to generate surplus power for feeding to the grid. High pressure boilers (operating above 60 kg/cm²(g)) are normally designed close to the limiting conditions of the heat transfer, tube metal temperature, circulation etc. to make the units compact and economical. The principal problem in modern high pressure boilers is the control of corrosion and steam quality. Internal corrosion and deposition may cost the sugar plants lakhs of rupees in repairs and lost availability. Modern steam turbines rated for high capacities call for stringent steam quality to avoid damages. Without strict control of impurities in steam, deposits will be formed over turbine blades and nozzles and output will be reduced. Thus the successful operation of high pressure boiler / turbine units require a thorough understanding of the aspects of water treatment.

Impurities of Water

Impurities present in water used for steam generation and other power plant and process duties may cause trouble by forming deposits on component and equipment surfaces, thus impairing heat transfer, fluid flow etc. Such deposits may also contribute to corrosion of metal surfaces, degrading equipment reliability. The main groupings of impurities are dissolved mineral and organic matter, dissolved gases, suspended matter, taste and colour and microbiological organisms.

The nature and amount of contained impurities depends on the water source. Surface waters often contain organic matter such as, leaf mold as well as insoluble silt, sand and other inorganic material. Industrial pollutants compound the contaminants. Ground water picks up impurities as it seeps through layers of rock, dissolving some part of almost anything it contacts. The natural filtering effect of rock and sand, however, usually removes suspended matter.

Insoluble matter constitutes the most readily recognized impurity. Known as turbidity, it includes sediment-coarse particles that quickly settle out of standing water. Content ranges from near zero points per million (ppm) in most ground waters and some surface supplies to perhaps 60,000 ppm in muddy river water. Turbidity is objectionable for most uses.

Calcium and magnesium lend to water the quality of 'hardness'. These occur as bicarbonates, sulfates, chlorides or nitrates in descending commonality. Effects shows up when water evaporates, leaving deposits hat can clog fluid systems and inhibit heat transfer across equipment or piping surfaces. Units of hardness are expressed as equivalent ppm of calcium carbonate or in milligrams per liter (mg/l) of impurity.

Iron, manganese and silica have the same effect as hardness is producing deposits in water systems. Most common in silica, ranging from 1 to 100 ppm or more in natural waters. It can form hard scale in boilers and cooling systems with resulting mechanical and heat transfer problems or pass over with steam at high pressures to form glassy deposits on turbine blades.

Iron occurs in concentrations upto about 15 ppm. Associated problems can be more widespread than those from silica. Most common form is ferrous bicarbonate. It deposits upon exposure to air as a yellow or reddish-brown sediment that stains on contact. Manganese, rarest of the three, occurs in similar forms. Creating deposits and black stains, it spells trouble in industrial and municipal supplies-increasingly with today's deep reservoirs and impoundments which lack oxygen (O₂). Pipeline deposits form rapidly with as little as 0.2 ppm.

Soluble gases primarily comprise oxygen, nitrogen, carbon-di-oxide (CO₂) and hydrogen sulfide. While nitrogen is inert, Oxygen is corrosive to iron, zinc, brass and other metals. Both are found in surface and aerated waters, little in deep wells.

Free CO₂ is present in most natural supplies. Generally, surface waters contain less than ground waters, though upto 50 ppm of CO₂ may be found in some. Concentrations can be insignificant in ground waters or so high that CO₂ bubbles out when pressure is relieved; well waters contain 2 to 50 ppm, depending on location, time of year etc, Innately corrosive the gas can also accelerate corrosion by O₂. Hydrogen sulfide is infamous for its odour of rotten eggs. Its presence makes water distasteful and corrosive to most metals.

Sodium and potassium salts can lead to corrosion in high pressure boilers and carry over with steam to the after boiler section. Extremely soluble, they do not deposit unless highly concentrated. They cannot be tolerated in high purity water.

Biological growths are usually found in surface waters, sometimes in ground water and seldom in deep wells. They comprise microorganisms that include diatoms, molds, bacterial slimes, algae, iron and manganese bacteria, surface reducing bacteria, etc. Aside from being a detriment to drinking water, they can result in deposits that clog piping. Also acid excretions and differential oxidations cells can produce corrosion.

Water Treatment for High Pressure Boilers

Make up Water Treatment

Water treatment is very important in high pressure boilers to protect the system from corrosion, scale and deposits.

Total solids and silica are required to be maintained at low levels in drum water at high pressures to maintain desired steam quality. Silica, in particular, is carried over in the form of a vapour at high pressures and the amount of silica needs to be maintained very low for example at less than 0.4 ppm at a drum operating pressure of 80 kg/m²(g). Feed water is used as desuperheating spray and any contamination or feed water directly enters superheated steam. Impure feed water increases blow down which is uneconomical. Hence feed water is to be very pure for high pressure boilers. This, in turn, necessitates high purity for make-up water. Demineralisation can only produce acceptable make-up quality for high pressure boilers of the order of specific electrical conductivity less than 0.5 mmho/cm with hardness completely removed and silica less than 0.02 ppm. When dissolved solids are removed by demineralisation, suspended solids, organic matter and turbidity are to be removed in the pretreatment stage normally comprising of chlorination, coagulation, clarification and filtration. The removal of suspended impurities is important for efficient operation of demineralised and to avoid problems inside boilers.

Controlling Corrosion

Deaeration

The principal contributors to corrosion in boiler systems are deposits, (particularly with copper tubed feed water heaters) and low pH. As is well known, O₂ dissolved in boiler water having traces of chlorides and solids can cause pitting corrosion of metal surfaces. The resulting condition may be severe, even at low pressures.

Oxygen (O₂) and other gases are removed from feed water before they can enter the boiler. Removal is accomplished both mechanically and chemically. Mechanical deaerators are either of the vacuum or pressure type. With proper operation, either can reduce O₂ content to 7 ppb (parts per billion) or less.

Vacuum deaerators, use steam-jet ejectors or mechanical pumps to pull the necessary vacuum on the condenser air-removal section, the degree depending on water temperature.

Pressure type deaerators are preferred for use on heated feed water streams, when they serve on contact heaters. Also known as deaerating heaters, they use steam to break up water into a spray or film, they sweep the steam across and through it to force out dissolved gases. O₂ can be reduced below detectability. Typical unit has a heating / deaerating section plus storage for hot deaerated water. A separate tank is usually provided above, alongside or underneath to hold about a 20 minutes supply at rated capacity.

Designs fall into two broad categories, spray and tray or combinations. Entering steam meets the hottest water first, to thoroughly scrub out the last remaining fraction of

dissolved gas; Letter is carried along with steam as it flows through the deaerator. Direction of steam movement may be cross flow, downflow or countercurrent; it picks up more noncondensable gas as it goes through the unit, condensing as it heats the water.

Spray / tray units feature a waterbox at the top, a spray area immediately below and a tray section. Below the tray bank is a temporary storage area for deoxygenated water. In most larger units, the entire heater is mounted above an expanded storage tank for volume retention. In some smaller units, the bottom of the heater serves as the storage area.

Effect of pH

The reaction of feed water and steel is spontaneous and rapid at high temperatures. The only reason that boiler steel can survive normal operating conditions is that corrosion and product, magnetite (Fe_3O_4) forms a protective barrier on the metal surface, which stifles further corrosion. In the simplest analysis, the function of alkalinity control is to maintain an environment in which the oxide film is stable and protective. The objective of water treatment in boilers is to protect this film against the aggressive action of impurities introduced into the boiler with the feed water.

The protective oxide is solubilised at pH values below 5.0 and above 13.0. Minimum corrosion is indicated at pH values of 9.0 to 11.0. Although corrosion is low over a wide band of pH values, unfortunately corrosion occurs by concentration at the local tube metal and not by concentrations existing in the bulk boiler water. Local concentrations change the pH drastically and corrosion takes place. Due to the limitations of chemicals used, an optimum pH of 8.8 to 9.2 is recommended for feed water. Boiler water pH is elevated to the recommended level by the use of trisodium phosphate. The use of caustic soda is not recommended for this purpose, as it has the danger of concentration and destruction of protective oxide film to cause corrosion.

Boiler Water Treatment

It is recommended to use coordinated phosphate - pH treatment method for high pressure drum type boilers. This method treatment excludes free caustic from the boiler water. Caustic present in boiler results in ductile-gouging type corrosion. Even if bulk boiler water does not contain large amount of free caustic, there is a great potential for caustic to concentrate and cause corrosion. Internal metal oxide deposits provide sites for concentration. AS steam is produced, dissolved solids concentrate in the thin film between tube water and bulk fluid. Low sloped tubes permit concentration. It has been well established that phosphate even concentrated under hide-out conditions is not aggressive to the tube metal.

Volatile treatment is another method of treatment but it is primarily to control corrosion of heater surfaces in the preboiler circuit. Chemicals such as ammonia, cyclohexylamine and morpholine are volatile at higher pressure boiler water temperatures. AS a result there is no significant buffering of boiler water pH due to these chemicals. Any ingress of

condenser leakage contaminants requires the immediate addition of phosphate to prevent the depression of pH and the incidence of hydrogen damage. The main attraction of volatile treatment is that it assures good steam purity.

Deposit Control

Boiler deposits result from impurities carried in with feed water. Their source is either makeup water containing mineral salts or condensate containing process contamination, corrosion products, or in the case of condensers-in-leaking cooling water. Excess hardness or other mineral impurities in make up may be the result of inefficient operation (or absence) of pretreatment equipment; chemical treatment added to a boiler to condition these impurities often will contribute to boiler deposits.

Incoming solids can accumulate within the boiler under the concentrating effect of steam generation. As steam (pure water) exits the boiler, these impurities remain behind. Higher boiler temperatures cause some dissolved impurities to precipitate out of solution. Suspended solids, often too heavy to remain in normal flow patterns, start to accumulate in low spots or in areas of low flow.

Boiler deposits form an insulating layer on the metal heat transfer surfaces, reducing the efficiency of conversion of fuel energy to steam. The insulating effect, moreover, increases the boiler tube temperatures at points of inefficient heat transfer. Temperatures can easily exceed the design limits of boiler metallurgy and a point of metal stress is created. Beneath deposits, chemical environments can create highly corrosive conditions under deposit corrosion. In modern boilers designed for very high rates of heat transfer, hot spots caused by waterside deposits can quickly lead to boiler failures.

Deposit control and inhibition are accomplished by mechanical and chemical means. Mechanical controls exercised through boiler blowdown to limit impurity concentrations in the water. Limits may be based on solids content, alkalinity, silica etc., which are keyed to operating pressure. For boilers operating at 50 to 300 psig, for example, the American Boiler Manufacturers Assn. recommends a maximum of 700 to 3500 TDS in boiler water; the limit range drops with rising pressure with 100 ppm the suggested limit for pressures exceeding 60 kg/cm²(g). Alkalinity varies similarly going from a maximum of 700 ppm at very low pressures to 25 ppm at 60 kg/cm²(g).

Continuous blowdown of boiler water maintains impurity concentrations fairly constant, enabling the water to be held automatically within desired analysis limits. Connection for continuous blowdown is taken from the part of the boiler circulation containing the most concentrated water. In modern units, most of the solids are in solution and are best taken from the steam drum at some point below water level. With this kind of system, intermittent bottom blowdown valves need only be opened occasionally-but on a regular schedule-to discharge sludge from the mud drum or lower header.

But blowdown alone is not sufficient to inhibit deposit formation. It must be accompanied by chemical treatment.

Cooling Water System Treatment

Scale, corrosion and fouling (including biofouling) of cooling water systems have long passed challenges to chemists at industrial and utility power plants. While corrosion has caused the greatest concern in the past, interest has focused increasingly on fouling because of cooling system operation at high temperatures and heat transfer rates, longer periods between cleanings and increased recycling of both water and waste water.

The essence of cooling water systems consists of plant heat exchange components and the water that passes through them to remove heat from process fluids. Treatment begins with an understanding of the design characteristics of the cooling system itself. Basic types are once through closed-recirculating (non-evaporative) and open-circulating (evaporative) systems. The principles of problem solving are essentially the same for all three.

Removing suspended solids with Clarifiers, Softeners, Filters

High-rate solids-contact clarifiers are widely used to remove suspended solids in makeup water. Clarifier effluent containing less than 10 ppm suspended solids is generally sufficient to eliminate source-water turbidity and is a factor limiting the cycling-up of the cooling system. Lime / Soda softening will reduce the levels of calcium, silica and magnesium as well as suspended solids. Silica is most often limiting as more than 125 - 150 ppm will result in silica deposits on heat exchangers. Softening will also help to prevent calcium sulfate scaling.

In practice, 5-15 cycles of concentration (COC) are attained in cooling systems using make-up treatment only. With the addition of sidestream softening and / or filtration, the ratio of makeup to blowdown volumes may be increased more efficiently at the high concentrations of the recirculating cooling water than at the front end of the system.

Side stream filtration is used either along or in conjunction with makeup treatment. Coagulants are not usually necessary because no more than 25 - 50% of the solids need be removed to establish the desired level of suspended solids in the loop. Benefits are significant when slug feeding of biocides results in periodic suspended-solids excursions and when entrapment of airborne dust is a problem.

High rate clarifiers may allow much greater CDC when applied to a cooling tower sidestream. They are most often selected as warm process softeners. Although the reactions entailed in softening may be inhibited by antiscalants and dispersants, the problem of off set by locating the sidestream softener on the warm side of the heat exchangers where the elevated temperatures improve the kinetics and equilibria of softening and silica-absorption reactions. Side stream clarification and softening will permit nearly zero blowdown operation, where dissolved salts are removed only by wind drift of mists from the cooling towers.

Control of Water Chemistry

Close, continuous water-chemistry monitoring is fundamental to optimizing cycle water chemistry in power plants. On a broader scale, detailed water and steam analysis are key to ensuring cycle chemistry conformance with recommendations of equipment manufacturers and EPRI guidelines-both of which are designed to maximize steam generator and turbine reliability.

Thus the heightened, continuous concern with trace-level impurities throughout the cycle has led to generation of enormous amounts of data requiring management and interpretation. Supplementing this concern is the need to provide for chemistry control during periods of reduced staff coverage when large loads switch predominate.

As a result, plant chemists have turned to computers assigning to them a growing role in : (1) data management to evaluate plant-chemistry status daily and even hourly (2) data storage to provide historical comparisons and meet regulatory requirements and (3) data retrieval to reveal chemistry trends and identify developing adverse conditions. If computers are not used for monitoring atleast gauges and controllers should be installed in the system for proper monitoring of water conditions.

Instrumentation and Control

In high pressure boilers, the treatment system must be monitored on a regular basis for the purposes of (1) controlling the entry of contaminants into the steam / water cycle and (2) detecting if treatment equipment (filters, demineralisers etc.) is functioning properly. Critical operating parameters of makeup water effluent are listed in Table below along with recommended testing frequencies.

Conductivity and pH measurements are the basic operating parameters of steamcycle chemistry, indicating overall content of dissolved (and ionized) impurity and acidity / alkalinity, respectively. If these parameters are controlled properly the remaining parameters shown in the tables can be managed more easily.

Tables

Sl. No	Type of Fuel/Furnace	Unburnt Carbon Percentage (W/W in Residue)	
		Furnace	Fly Ash
1.	Travelling Grate Furnace - Coal Firing	10 - 20	8 - 15
2.	Dry Bottom Furnaces - Bituminous Coal Firing	2 - 8	1 - 5
3.	Dry Bottom Furnaces - Brown Coal / Lignite Firing	2 - 6	1 - 5

4.	Circulating fluidised bed furnaces - Biomass Firing	-	6 - 12
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