Steam Generation

The greatest use of high-temperature water and steam is in electrical power generation. Historically, fossil fuels (i.e., wood, coal, gas, and oil) were used almost exclusively to heat water and make steam until the introduction of nuclear power steam generators in the second part of the 20th century. The two types of power plants are different in many ways; however, they share a reliance on technically advanced water treatment and control for successful operation.

Treatment of Boiler Feedwater Make-up

Boiler feedwater and feedwater make-up must be softened and deaerated in accordance with specific requirements for boilers operating in different temperature and pressure ranges. Low-hardness salts to prevent scaling in the system and deaeration to prevent corrosion of steel are the goals.

A number of lime-softening treatments were used in the past, but these have given way to more sophisticated treatments. Probably the most common for boilers operating at pressures from 2.8 to 4.0 MPa (400 to 600 psig) is zeolite (silicate) softening. In this treatment, a sodium salt of a long-chain polymeric organic molecule constitutes the ion-exchange bed. As the feedwater passes through the bed, sodium ions are exchanged for the calcium and magnesium ions that create the water hardness. Other cations are also exchanged. The water then exits from the zeolite bed softened and at a higher pH than it entered. The beds are regenerated intermittently with sodium chloride (NaCl) solution to backwash the hardness salts and reform the sodium salt.

For purer water quality, the water may be totally demineralized by mixed beds of polymeric resins, which in turn exchange hydrogen ions for all cations and hydroxyl ions for all anions, effectively producing pure water (H₂O) from a raw water stream. Such highly purified waters are required for boilers operating above ~6 MPa (900 psig) and for all nuclear boilers (to avoid creating radioactive water-borne salts).

Softened, high-purity water is at its most corrosive, being still saturated with dissolved oxygen (DO) and having no hardness that could even hope to slow down attack. Many plant problems arise from inappropriately using boiler feedwater at this stage in processing, under the impression that it is “the best water in the plant.” So it will be, but only after further treatment.

Usually, the first step in removal of DO is the comparatively inexpensive thermo-mechanical deaeration. The boiler feedwater is preheated and then flashed in a deaerator to remove any free carbon dioxide (CO₂) and most of the DO. Then, the last traces of DO are chemically scavenged with sodium sulfite (Na₂SO₃) that reacts with oxygen to form sodium sulfate (Na₂SO₄). If this solid precipitate is undesirable, the treatment by Na₂SO₃ may be replaced with hydrazine (N₂H₄), which forms water and gaseous nitrogen in the presence of oxygen.

Both sulfite and hydrazine are available in catalyzed form to promote more rapid reaction rates. A boiler designed to be operated with a catalyzed oxygen scavenger must never be operated on the uncatalyzed grades, or severe corrosion will be encountered in the economizers (feedwater pre-heaters) or even the steam drum.

A final step in boiler feedwater treatment consists of pH adjustment as a further aid to corrosion control. Usually, the pH is adjusted to a range of 10 to 11 with trisodium phosphate (Na₃PO₄) (or combinations of caustic with sufficient mono- or disodium phosphate [Na₂HPO₄] to form trisodium phosphate upon inadvertent evaporation of the water). This “coordinated phosphate” treatment is intended to prevent the environmental cracking of steel by free sodium hydroxide (NaOH) (caustic embrittlement, a catastrophic form of corrosion). Caustic carry-over with the steam can present severe corrosion problems.

Nuclear plant requirements are such that “zero-solids” treatment is required, precluding the addition of sodium salts and necessitating the use of ammonium hydroxide (NH₄OH) for pH adjustment.