Chapter 10

Coal-Ash Corrosion

Locations

Coal-ash corrosion is a high-temperature, liquid-phase corrosion phenomenon that occurs on metals whose surface temperatures are in the range of 1050 to 1350°F (566 to 732°C). It is usually confined to superheater and reheater sections of the boiler.

General Description

Coal-ash corrosion may occur when the fuel supply or fuel type is changed, resulting in production of an aggressive ash.

During coal combustion, minerals in the coal are exposed to high temperatures, causing release of volatile alkali compounds and sulfur oxides. Coal-ash corrosion occurs when fly ash deposits on metal surfaces where temperatures range from 1050 to 1350°F (566 to 732°C). With time, the volatile alkali compounds and sulfur compounds condense on the fly ash and react with it to form complex alkali sulfates such as $K_3Fe(SO_4)_3$ and $Na_3Fe(SO_4)_3$ at the metal/deposit interface. The molten slag fluxes the protective iron oxide covering of the tube, exposing the metal beneath to accelerated oxidation.

Reduction of wall thickness by this corrosion mechanism effectively increases stresses through the thinned wall. These increased stresses, coupled with high metal temperatures, may lead to final failure by stress rupture.

Critical Factors

The critical factors causing coal-ash corrosion include the use of a coal that produces an aggressive ash, and conditions that produce metal temperatures in the range of 1050 to 1350°F (566 to 732°C).

Identification

Coal-ash corrosion is identified by slag buildup on the tube wall and the associated metal loss. Austenitic stainless steel tubes may exhibit a pockmarked surface appearance. Low-alloy carbon steel tubes typically show a pair of flat zones of metal loss that are located on both sides of the leading face of the tube at orientations of 30 to 45°. Corroded surfaces have a grooved or roughened appearance (Fig. 10.1).

Usually, if corrosion occurs, it will be greatest in tubes having the highest steam temperatures. The highest corrosion rates are generally found on the outlet tubes of radiant superheater or reheater platens.

The corrosion rate is a nonlinear function of temperature, reaching a maximum between 1250 and 1350°F (677 and 732°C). At higher temperatures, the corrosion rate decreases rapidly because of thermal decomposition of the corrosives (Fig. 10.2).

Corrosion is almost always associated with a sintered or slag-type deposit that is strongly bonded to the metal surface. This deposit consists of three distinct layers (Fig. 10.3). The outer layer is a bulky layer of porous

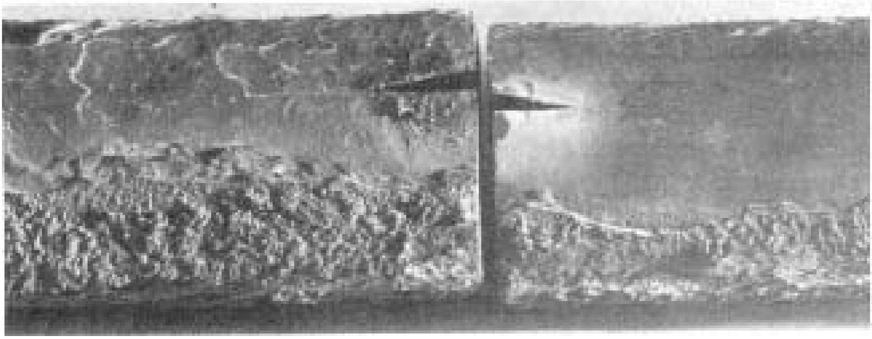

Figure 10.1 Superheater tube (ASME SA-213, grade T22) that ruptured due to thinning by coal-ash corrosion. *(Reprinted with permission of* American Society for Metals Handbook, *vol. 10, 8th ed., Metals Park, Ohio, 1975, p. 537.)*

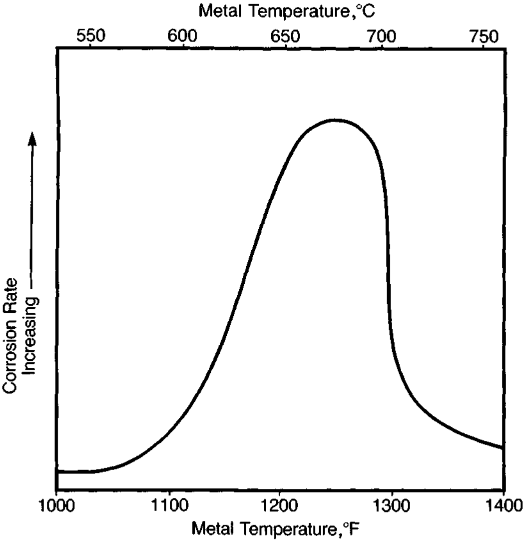

Figure 10.2 Nonlinear relationship between temperature and corrosion rate.

fly ash; the intermediate layer consists of whitish, water-soluble alkali sulfates, which are responsible for the corrosive attack. This layer is typically 1⁄32 to 1⁄4 in. (0.79 to 6.35 mm) thick; a thin inner layer is composed of glassy black iron oxides and sulfides at the metal surface. This layer is seldom thicker than 1⁄8 in. (3.2 mm).

Ultrasonic thickness measurements taken at angles of 30 to 45° on both sides of the leading face of the tube should indicate whether significant metal loss has occurred.

Coal-ash corrosion can occur with any bituminous coal but is more probable with coals containing more than 3½% sulfur and ¼% chlorine.

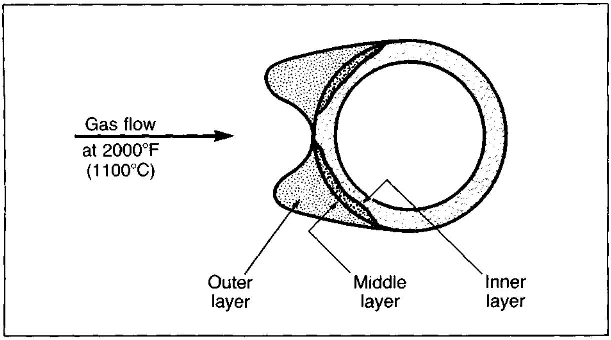

Figure 10.3 Layers of deposit associated with coal-ash corrosion.

Elimination

Generally, a chemical analysis of fuel and ash deposits is recommended to determine what corrosive constituents may be present. A determination of ash-fusion temperatures may also prove valuable.

If corrosion is known to have occurred, ultrasonic thickness surveys are useful for determining the extent and severity of the attack. If corrosion is not severe, economic solutions may include periodic tube replacement, specification of thicker tube walls, use of thermal spray coatings, or pad welding. The use of stainless steel shields over affected areas has extended tube life.

Where coal-ash corrosion is severe, cladding of tubes with a resistant alloy may be required. To date, fuel additives have not been economically successful in combating coal-ash corrosion.

In view of the critical factors that govern this form of corrosion, it may be valuable to blend coals to reduce the percentage of corrosive constituents, and to lower metal temperatures. Methods of lowering metal temperature include lowering steam temperatures, periodic cleaning of drainable superheater and reheater sections to prevent buildup of internal scale, and redesign of affected areas to reduce heat-transfer rates.

CASE HISTORY 10.1

Industry:	Utility
Specimen Location:	Secondary-superheater outlet
Specimen Orientation:	Vertical
Years in Service:	21
Water-Treatment Program:	All volatile treatment
Drum Pressure:	2500 psi (17.2 MPa)
Steam Temperature:	1050°F (566°C)
Tube Specifications:	2⅛ in. (5.4 cm) outer diameter, austenitic (SS321) stainless steel
Fuel:	Eastern coal, 10% ash, 7% S

The boiler from which the tubes illustrated in Figs. 10.4 and 10.5 were removed had experienced chronic corrosion problems in the outlet pendants of the secondary superheater. Ten separate failures had occurred over a 3-year period. The boiler was operated continuously.

The tube submitted for analysis had not failed, but had sustained a 1-in.-wide (2.5-cm-wide) band of severe corrosion along one side of its external surface. Measurement indicated a reduction in tube-wall thickness of 0.085 in. (2.2 mm).

Figure 10.4 Contour of external surface in corroded zone. Note pockmarked surface appearance characteristic of attack on stainless steel.

Figure 10.5 Transverse profile of tube showing metal loss.

Microstructural examinations revealed solidified eutectics of slag covering the external surface in the corroded zone. Chemical analysis of material covering the corroded region revealed large amounts of iron, sulfur, and potassium, as well as components of fly ash.

Evidence from visual, microstructural, and chemical analyses identified the wastage as coal-ash corrosion resulting from the formation of complex alkali sulfates at the metal surface.