Chapter

21

Materials Deficiency

Locations

Materials deficiencies described in this chapter result from the inadvertent use of unalloyed steel in locations where alloyed steels are specified. Steam-cooled components, such as superheater and reheater tubes, are usually the areas of a boiler system that are affected.

General Description

With the possible exception of cast irons, the most commonly used industrial metal is unalloyed, plain carbon steel. Alloyed steels are used sparingly because of their expense. Most industrial and utility boilers use plain carbon steel in tubes that carry boiler water or a mixture of boiler water and steam. Low-alloy steels containing small amounts of chromium and molybdenum are commonly specified for steam-carrying tubes such as those in reheaters and superheaters because of the high temperatures at which these tubes operate. Chromium and molybdenum are added to retard the thermal degradation that occurs at these higher temperatures in unalloyed steel. Chromium is generally added in amounts of ¼ to 2¼% to retard rapid, high-temperature oxidation of the metal and to enhance creep resistance. Molybdenum is added in amounts of ¼ to 1% to increase creep resistance of the metal.

Critical Factors

The critical factors in materials deficiency are scaling temperature and susceptibility to creep. The *scaling temperature* is the temperature at which metals begin thermal oxidation at an accelerated rate (Fig. 21.1). Table 2.1 lists the steels commonly used in boiler tubes and their respective scaling temperatures.

Creep resistance is also a function of alloy content. Additions of chromium and molybdenum increase creep resistance.

Material deficiency occurs when a metal is used in an environment that exceeds the metal's thermal stability. Typically, this involves the use of unalloyed carbon steel in high-temperature superheater or reheater sections where normal operating temperatures would require the use of low-alloy steels.

Identification

Superheater and reheater tubes that exhibit excessive scaling and/or thick-walled ruptures (creep rupture) are suspect. Although low-alloy steels may exhibit these conditions if overheating has been severe, plain carbon steel will reach the same condition at lower metal temperatures. This makes plain carbon steel more susceptible to this type of failure in typical superheater and reheater environments. An examination of material specifications for the superheater or reheater sections will disclose the type of steel specified.

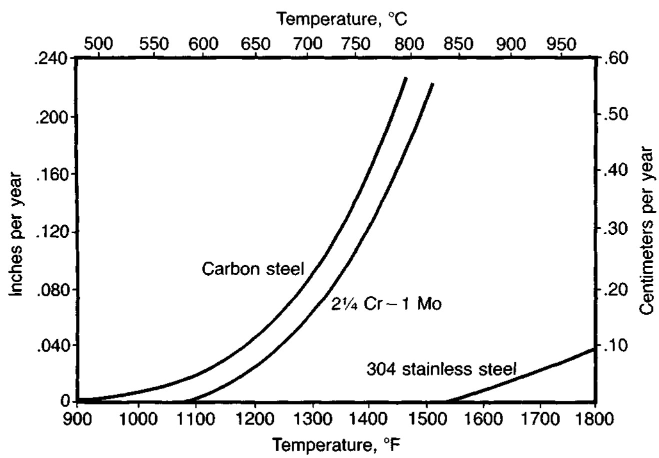

Figure 21.1 Approximate thermal oxidation (scaling) rates of carbon, low-alloy, and stainless steels in air.

It is difficult to identify positively tube metallurgy in the field. A section of the suspect tube should be submitted for alloy identification.

Elimination

The primary responsibility for prevention of misapplied material rests with the boiler manufacturer, boiler constructor, and purchaser of the boiler. Elimination requires close adherence to effective quality control procedures, beginning with equipment design and carrying through to equipment installation.

Cautions

Thermal-degradation failure (excessive scaling, creep rupture) of superheater and reheater tubes may occur both in properly specified and installed low-alloy steels, and in misapplied plain carbon steel tubes. Therefore, the occurrence of a thermal-degradation failure is not proof that a material has been incorrectly used in an application. If failures of this type occur in properly operating superheater or reheater sections, it is appropriate to suspect possible misapplication of materials.

Related Problems

See also Chap. 2, "Long-Term Overheating."

CASE HISTORY 21.1

Industry:	Pulp and paper
Specimen Location:	Secondary superheater, first pass
Specimen Orientation:	Vertical
Years in Service:	1½
Water-Treatment Program:	Coordinated phosphate
Drum Pressure:	1400 psi (9.7 MPa)
Tube Specifications:	2¾ in. (7.0 cm) outer diameter, carbon steel
Fuel:	Bark

The tube illustrated in Fig. 21.2 ruptured in service in a bark-fired boiler. Three similar failures had occurred over the previous year in this section of the superheater. The boiler is operated continuously except for semiannual maintenance outages.

Figure 21.2 Part of a thick-walled rupture in a superheater tube.

The rupture edges are thick, and have a chisellike contour. The external surface is covered with a barklike encrustation of thermally decomposed metal. The internal surface is smooth and free of deposits and corrosion products.

Microstructural examinations of the metal revealed the presence of graphite and spheroidized iron carbides in the tube wall at all locations. Intergranular oxidation, as well as thick layers of iron oxide (thermally decomposed metal), was also observed at all surfaces.

The tube had been operated above the scaling temperature [approximately 1000 to 1050°F (538 to 566°C) for plain carbon steel] for this metal over a long period. Previous failures, the first of which occurred a year after start-up of the boiler, indicate a possible imbalance between heat flux and coolant flow rate in this superheater section. However, failure is improbable had the tubes been fabricated from low-alloy steel (SA-213 T22).

CASE HISTORY 21.2

Industry:	Utility
Specimen Location:	Reheater
Specimen Orientation:	Vertical
Years in Service:	20
Water-Treatment Program:	Coordinated phosphate
Drum Pressure:	2875 psi (19.8 MPa)
Tube Specifications:	2¼ in. (5.7 cm) outer diameter, carbon steel
Fuel:	Coal

The thick-walled rupture shown in Fig. 21.3 is one of many similar failures that occurred sporadically in this section of the boiler. The boiler is presently base-loaded, but had been in peaking service previously.

The external surfaces are covered with thick layers of black iron oxide (thermally deteriorated metal) overlaid with light-colored deposits. The internal surface is also covered with thick layers of iron oxide.

Microstructural examinations of the metal revealed a dense population of graphite nodules and spheroidal iron carbides in the tube wall. Intergranular oxidation was apparent at all surfaces.

The failure of this tube is a direct result of operation in an environment that exceeded the thermal stability of the metal. A low-alloy steel tube (SA-213 T22) that had been butt-welded to the ruptured tube did not fail and had sustained only mild thermal deterioration.

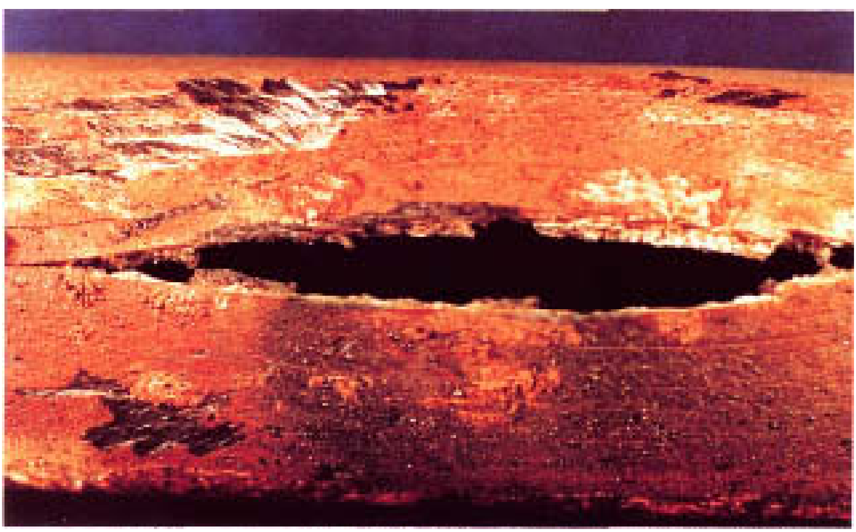

Figure 21.3 Thick-walled rupture in a reheater tube. Note fissures on external surface aligned with the rupture.