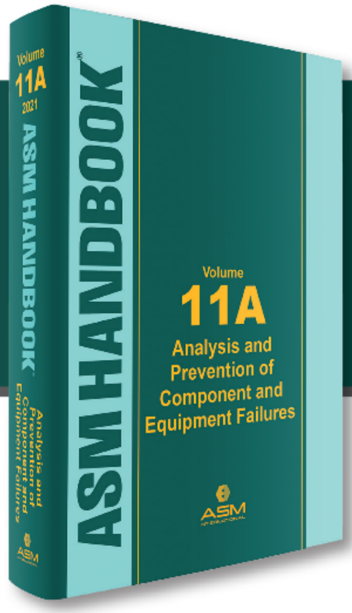

ASM HANDBOOK, VOLUME 11A:

ANALYSIS AND PREVENTION OF COMPONENT AND EQUIPMENT FAILURES

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Failure of Boilers and Related Equipment

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FAILURES IN BOILERS and other equipment taking place in power plants that use steam as the working fluid are discussed in this article. The discussion is mainly concerned with failures in Rankine cycle systems that use fossil fuels as the primary heat source. In a Rankine cycle system, the steam is generated in a boiler, followed by its expansion in the prime mover and condensation in the condenser; finally, it is fed into the boiler again. Although, many of the principles that apply to Rankine cycle systems also apply to systems using other steam cycles or to systems using working fluids other than steam.

Boilers/steam generators work on the principle of conversion of the chemical energy in fuel into thermal energy to generate steam or hot water. Power boilers using pulverized coal, fuel oil, or natural gas as the fuel are used in thermal power plants to produce steam for generation of electricity. They are very large in size and are operated at high pressure and temperature in order to produce high-pressure, high-temperature superheated steam for power generation.

The other category of boilers termed as the industrial, commercial, and institutional (ICI) boilers are relatively small in size and are used to cater to captive demand of steam or hot water for the intended application. Boilers installed in chemical industries, petrochemicals and refineries, food processing, paper, textile, and similar other industries belong to this category. Their main function is to provide steam, hot water, or electricity, depending on the nature of the requirement. Institutions and commercial establishments such as hospitals, schools, colleges, hotels, restaurants, and office buildings use boilers for generation of steam and/or hot water.

Likewise, there are boilers termed as heat-recovery steam generators (HRSGs) and kraft-recovery boilers. As the HRSG name indicates, the waste heat released by the exhaust gases or hot air from combustion processes of gas turbines, diesel engines, or other industrial processes is effectively used to produce hot water or steam to improve the process economy. The kraft-recovery boilers (also known as black-liquor-recovery boilers) produce steam that can be used in the kraft process to generate electricity or for heating purposes.

Most boiler/steam generator failures occur in pressurized components, such as the tubing, piping, headers, and pressure vessels that constitute the steam-generating portion of the system. With very few exceptions, failure of pressurized components is confined to relatively small-diameter tubing (such as the water-wall, superheater, reheater, and economizer tubes) making up the heat-transfer surfaces.

This article discusses the main types of failure that occur in steam-power-plant equipment, with major emphasis on the distinctive features of each type that enable the failure analyst to determine the cause of failure.

Power plants, by and large, make use of various nonrenewable sources of energy such as coal, natural gas, oil, and nuclear for electrical power generation, of which coal is the most common source. Approximately 40% of electricity produced worldwide is still from coal-based thermal power plants. With coal as the fuel, there are two distinct technologies used for power generation: subcritical and supercritical. Supercritical is that state of a substance in which there is no clear distinction between the liquid and gaseous phase (i.e., it behaves as a homogeneous fluid). Water reaches this state at a pressure greater than 22.1 MPa (3.2 ksi) and a temperature equal to 374.15 °C (705.50 °F). *Supercritical* is a generic term used in the power plant industry that also includes ultra-supercritical (USC) and advanced ultra-supercritical (A-USC) boiler technologies.

From a design point of view, the conventional or subcritical thermal power plants have a drum-type boiler wherein steam is separated from a nonhomogeneous mixture of water and steam before it is superheated and fed to the turbine. On the other hand, all supercritical boilers are of the once-through type, wherein the water and steam flow through the boiler circuitry only once. Figure 1 explains the basic difference between the functioning of a subcritical and a supercritical boiler.

For a fossil-fuel-based (such as the coal-based) thermal power plant, the operating steam temperature and pressure decide its efficiency. The operating temperature and pressure in cases of subcritical boilers are below 538 °C (1000 °F) and 22.1 MPa (3.2 ksi),

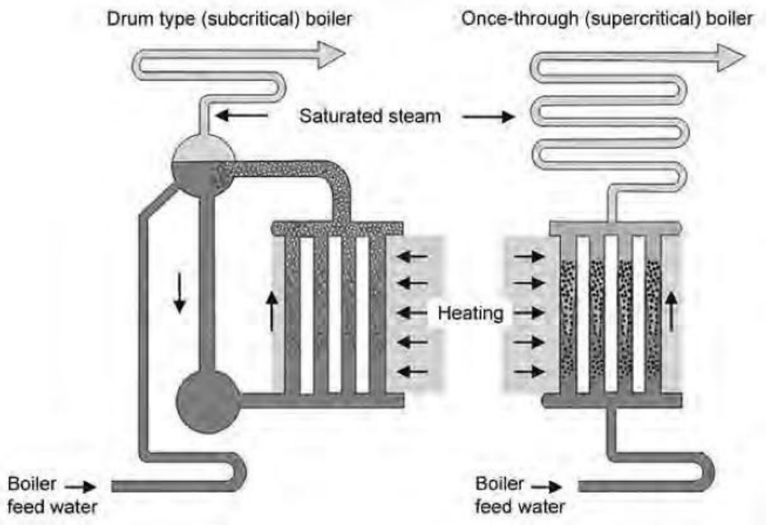

Fig. 1 Schematic showing difference in functioning of subcritical and supercritical boilers