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Industrial Combustion Boilers

HIGHLIGHTS

- **PROCESS AND TECHNOLOGY STATUS** – Combustion boilers are widely used to generate steam for industrial applications and power generation. While all kinds of energy sources - fossil fuels, biomass, nuclear and solar energy, electricity - can be used to generate heat and steam, the scope of this brief is limited to combustion boilers using fossil fuels and biomass. Boilers can be grouped into two broad categories: *water-tube boilers* and *fire-tube boilers*. In the *water-tube boilers,* tubes containing water are heated by combustion gases that flow outside the tubes, while in the *fire-tube boilers* hot combustion gases flow inside the tubes and water flows outside. Key design parameters to determine the boiler size and power are the output steam mass flow rate, pressure and temperature. Since the first boilers were used in the 18th century, the design of boilers has evolved so as to increase efficiency as well as steam pressure and temperature. In the United States, the energy consumption of industrial boilers accounts for 37% of total energy use in the industrial sector. In the industrialised countries, more than 50% of the industrial boilers use natural gas as the primary fuel and about 76% of the total boiler population is older than 30 years. Boiler sales in 2002 amounted to 1/6 of the total sales in 1967.
- **PERFORMANCE AND COSTS** – The power of a boiler is determined by the required steam mass flow rate, pressure and temperature. The amount of input fuel depends on the fuel energy content and on the overall energy efficiency. New boilers running on coal, oil, natural gas and biomass can reach efficiencies of 85%, 80%, 75% and 70% respectively. Boiler efficiency can be improved by preventing and/or recovering heat loss. The construction of a large industrial steam generator can take between 22 and 48 months depending on the scope and framework. A boiler's annual availability ranges between 86% and 94% including planned outage. Unplanned outages are typically very small or non-existing. The costs of steam generation are usually referred to as a system cost covering the entire boiler life cycle. For a full-load steam system (86%-94% utilization), the fuel cost accounts for 96% of the total life-cycle cost while investment, operating and maintenance costs usually account for 3% and 1%, respectively. The cost structure clearly demonstrates that the energy efficiency is the main cost driver.
- **POTENTIAL AND BARRIERS** – Technology improvements for boilers focus on efficiency and low-cost design while giving increasingly more attention to air pollutant emissions. In the industrialized countries, specific emission standards exist or are being implemented for carbon monoxide, hydrogen chloride, mercury, particulate matter, selected metals (arsenic, beryllium, cadmium, chromium, lead, manganese, nickel and selenium) as well as greenhouse gases such as CO_2 and for SO_2 and NO_x. Emission standards depend on the primary fuel type, boiler size, load factor, and become more demanding over time. In the European Union, the directive 2001/80/EC of the European Parliament on the limitation of emissions of certain air pollutants from large combustion plants defines maximum emission levels for SO_2, NOx and dust, based on fuel type (solid, liquid, gaseous), input capacity (MW_{th}) and the year in which the operating license was requested. In some industrial applications, steam boilers based on renewable energy (biomass, solar energy) are becoming market competitors for the conventional fossil fuels-based boilers.

PROCESS AND TECHNOLOGY STATUS – A combustion boiler (or steam generator) consists of a fossil fuels or biomass burner and a heat-transfer system to boil water and generate steam. Steam generators also include systems and components for pressure control, heat recovery, steam delivery and distribution, condensate drainage, and separation of oxygen and non-condensable gases. [1] ■ **Fire-tube Boilers and Water-tube Boilers** – In the fire-tube boilers, hot combustion gases flow inside tubes immersed in a pressure vessel containing boiling water. In water-tube boilers, the boiling water flows inside tubes and hot combustion gases flow on the shell side. Fire-tube boilers were first developed in the 18th century. In the current designs, the technology of choice is the water-tube design which is more suited to high-pressure steam generation as small tubes can withstand high pressure better and are less vulnerable to fracturing and failure.[1] ■ **Saturated, Superheated and Supercritical Steam** – Steam pressure and temperature are the key parameters that characterize the boiler performance. *Saturated steam* is steam at saturation (i.e. boiling) temperature for a given pressure (water-steam equilibrium). If further heat is provided and the steam temperature rises above the saturation temperature at a given pressure, then the steam is referred to as *superheated steam*. (e.g. steam at T > 100°C, P= 1 bar). *Supercritical steam* [1] is steam at a pressure and temperature above the water critical point (i.e. 374.15 °C, 218.3 atm) where changes of phase (boiling) no longer occur. Steam in supercritical conditions is often used in power generation.

Boilers account for a significant share of industrial energy consumption and are the key components in power generation and industrial plants [9]. Quantitative information on the importance of boilers from the energy and industrial point of view in industrialised and emerging countries, can be obtained from a 2005 study by the US Energy and Environmental Analysis Inc. (EEA, [2]).

[1] A supercritical fluid is a fluid at a temperature (T) and pressure (P) above its critical point. Close to the critical point, small changes in T and P result in large changes in density, allowing key fluid properties to be "tuned". Supercritical fluids are used in industrial applications and power generation

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