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WASTE HEAT UTILIZATION TECHNOLOGIES FOR INDUSTRIAL BOILER PLANTS

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Abstract: This article explores modern technological approaches for utilizing waste heat energy generated during the operation of industrial boiler plants. By recovering significant amounts of thermal energy typically lost in thermodynamic processes, it is possible to improve energy efficiency and reuse waste heat as a secondary energy source. Various heat recovery technologies are analyzed, including heat exchangers, regenerative boilers, waste heat recovery power generation (WHRPG) based on the Rankine cycle, and absorption chillers. Scientific studies indicate that reusing waste heat can reduce fuel consumption in industrial boiler plants by 10–30% and significantly cut emissions of harmful gases into the environment.

Keywords: waste heat, industrial boiler, regeneration, heat exchanger, energy efficiency

Introduction

Improving energy efficiency and reducing emissions are among the most critical challenges in the energy sector. In many industrial facilities, especially in metallurgy, chemical, oil and gas, and thermal supply sectors, boilers produce substantial waste heat (i.e., unused high-temperature exhaust gases, steam, air, or fluids) during operations. This energy is usually lost to the environment or dissipated through cooling devices.

Scientific studies (Liu et al., 2021; Zhang et al., 2020) show that using special technologies to recover this heat can significantly reduce energy consumption, improve system efficiency, and limit environmental damage. This paper presents a technical analysis of waste heat recovery technologies and their practical applications.

Main Content

1 Sources of Waste Heat

In industrial boiler plants, waste heat originates from:

Flue gases: typically at 150–300°C
Cooled steam or water: typically 70–120°C
Combustion inefficiencies and energy losses

These sources contain substantial unused thermal energy that can be regenerated using advanced technologies.

2 Waste Heat Recovery Technologies

a) Heat Exchangers

Heat exchangers transfer waste heat to working media (e.g., water, air). Common types include:

Tubular heat exchangers
Plate heat exchangers
Regenerative rotary heat exchangers

Studies show that efficient heat exchangers can convert 20–25% of waste heat into useful thermal energy (Chen et al., 2019).

b) Waste Heat Recovery Power Generation (WHRPG)

WHRPG systems generate electricity from waste heat using the Rankine cycle:

Evaporation of working fluid by waste gases

Steam drives a turbine

Turbine rotates a generator to produce electricity

These systems are widely applied in cement, steel, and petrochemical industries.

c) Absorption Chillers

High-temperature waste heat can be used in absorption cooling systems to produce chilled water for buildings or industrial processes. Studies (Wang et al., 2022) indicate that such systems can reduce total energy consumption by 10–15% in industrial boiler applications.

Energy Efficiency and Environmental Benefits

Recovering waste heat leads to:

10–30% reduction in lost thermal energy

3–8% improvement in boiler efficiency

Decreased emissions of SO_2, NO_x, and CO_2

Reduced fuel consumption and increased economic gain

For example, waste heat recovery systems implemented in China have reduced CO_2 emissions by up to 100,000 tons annually (Zhou et al., 2021).

Conclusion

Industrial boilers produce significant waste heat during operation. Efficient reuse of this thermal energy significantly improves boiler system performance. Technologies such as heat exchangers, WHRPG systems, and absorption chillers not only save energy but also minimize negative environmental impacts. Continued research on implementing, optimizing, and automating these technologies offers substantial economic and ecological benefits.

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