

# MULTI-MODE WASTE-HEAT RECOVERY DEVICE FOR POT-FURNACE COOLING WATER JACKET

## TECHNICAL FIELD

**[1]** The invention relates to the technical field of waste-heat recovery and utilization, particularly to a multi-mode waste-heat recovery device for the cooling water jacket of a pot furnace.

## BACKGROUND ART

**[2]** The pot furnace is a commonly used high-temperature heating device in industries such as metallurgy and chemicals. During operation, the furnace reaches very high temperatures and must be continuously cooled by a water jacket installed outside the furnace shell to ensure safe operation. This process produces a large amount of medium- to low-temperature cooling water (typically 60–90 °C). This water carries substantial thermal energy; if it is directly discharged or merely cooled by a cooling tower for recirculation, significant energy is wasted and thermal pollution to the environment is introduced.

**[3]** At present, the utilization of waste heat from pot-furnace water-jacket cooling is relatively single-purposed and insufficient. Common practices include:

**[4]** Simple cooling circulation: the high-temperature cooling water is only cooled by the cooling tower and pumped back to the water jacket. This approach wastes the embedded waste heat completely, without any energy recovery.

**[5]** Single-mode utilization: some plants attempt waste-heat recovery but typically for a single purpose (e.g., only space heating in winter or only domestic hot water). However, plant energy needs are diverse and seasonal. In the non-heating season, the heating system is idle, leaving waste heat unutilized; likewise, demand for domestic hot water is intermittent. Such single-mode systems lack adaptability and lead to low utilization rates, failing to maximize energy recovery.

**[6]** Lack of integration and switching capability: existing technologies lack a system that highly integrates multiple waste-heat utilization paths—such as power generation, refrigeration, space heating, and hot-water supply—and, more importantly, lack a reliable and flexible switching scheme among these modes. They cannot intelligently allocate waste heat according to seasonal changes and real-time energy demand.

**[7]** Therefore, the main problem in the prior art is that the waste heat of a pot-furnace cooling water jacket has not been comprehensively and cascade-utilized; recovery modes are rigid and single, energy-utilization efficiency is low, and they cannot adapt to diversified and changing energy demands in factories. The present invention aims to overcome these shortcomings.

## **SUMMARY OF THE INVENTION**

**[8]** To address the above deficiencies, the invention provides a multi-mode waste-heat recovery device for a pot-furnace cooling water jacket. By means of an integrated system design and automatic mode switching, the device realizes cascaded and on-demand allocation of waste heat, significantly improving energy-recovery efficiency and reducing waste.

**[9]** The device includes a pot-furnace cooling water jacket, a cooling tower, a first water-to-water heat exchanger, a second water-to-water heat exchanger, a waste-heat power-generation boiler, a refrigeration unit, a space-heating system, and a circulating cooling-water pump set. The outlet of the cooling water jacket connects to the hot-side inlet of the first heat exchanger. The hot-side outlet of the first heat exchanger splits into a first branch connected to the cooling tower and a second branch connected in parallel—via an intelligent electrically-actuated valve set—to the hot-side inlet of the second heat exchanger, the inlet of the waste-heat power-generation boiler, the inlet of the refrigeration unit, and the inlet of the space-heating system.

**[10]** The system further includes an intelligent control system composed of a PLC controller, temperature sensors, flow sensors, and a human–machine interface, used to automatically control valve states according to preset programs or real-time requirements.

**[11]** The hot-side outlet of the second heat exchanger, the outlet of the waste-heat power-generation boiler, the outlet of the refrigeration unit, and the outlet of the space-heating system are collected via piping and connected back to the hot-side circuit of the first heat exchanger or to the inlet of the circulating cooling-water pump set. The outlet of the cooling tower connects to the inlet of the pump set, whose outlet connects to the inlet of the pot-furnace cooling water jacket.

**[12]** Compared with the prior art, the invention offers the following advantages: it innovatively integrates multiple waste-heat utilization paths—power generation, refrigeration, space heating, and domestic hot-water preparation—into one system. Through switching of the intelligent electrically-actuated valve set, the most economic utilization mode can be flexibly selected according to seasons and actual plant needs, thereby achieving cascaded and on-demand energy utilization and greatly improving overall energy-use efficiency. Industrial-grade intelligent valves are adopted as actuators together with redundancy design and fail-safe modes, enabling precise automatic control and ensuring reliability under harsh industrial environments. The system supports remote monitoring, fault diagnostics, and energy-efficiency analysis, which improves operating efficiency and maintenance convenience. The device fully utilizes otherwise wasted low-grade heat, converting it into high-value electricity, cooling, warm air, and hot water, directly reducing external energy purchases with a short investment payback period and significant economic benefits.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[13]** Fig. 1 is a schematic diagram of the multi-mode waste-heat recovery device.

## DETAILED DESCRIPTION

**[14]** One embodiment of the multi-mode waste-heat recovery device for a pot-furnace cooling water jacket is shown in Fig.1. The device comprises a pot-furnace cooling water jacket (1), a cooling tower (2), a first water-to-water heat exchanger (3), a second water-to-water heat exchanger (4), a waste-heat power-generation boiler (5), a refrigeration unit (6), a space-heating system (7), and a circulating cooling-water pump set (8). The intelligent electrically-actuated valve set consists of multiple intelligent valves (G1, G2, G3, G4), including:

**[15]** Intelligent electric ball valve G1: installed on the pipeline leading to the waste-heat power-generation boiler (5) for on/off control of power-generation service;

**[16]** Control valve G2: installed on the pipeline leading to the refrigeration unit (6) to regulate cooling output as required;

**[17]** Control valve G3: installed on the pipeline leading to the space-heating system (7) to dynamically control heat supply according to heating demand;

**[18]** Control valve G4: installed on the pipeline leading to the hot-side inlet of the second water-to-water heat exchanger (4) to precisely control the heat-exchange flow for domestic hot water.

**[19]** Connections among components are as follows: the high-temperature outlet water (about 60–90 °C) from the pot-furnace cooling water jacket (1) is delivered to the hot-side inlet of the first water-to-water heat exchanger (3) for initial cooling.

The cooled water exits the hot-side outlet of the first heat exchanger (3), where the pipeline splits into two branches. Branch 1 connects to the inlet of the cooling tower (2). Branch 2 is connected in parallel to four target devices, each pipeline equipped with an intelligent valve: G1 controls flow to the waste-heat power-generation boiler (5); G2 controls flow to the refrigeration unit (6); G3 controls flow to the space-heating system (7); and G4 controls flow to the hot-side inlet of the second water-to-water heat exchanger (4).

**[20]** The hot-side outlet of the second water-to-water heat exchanger (4), the outlet of the waste-heat power-generation boiler (5), the outlet of the refrigeration unit (6), and the outlet of the space-heating system (7) converge and return either to the hot-side loop of the first water-to-water heat exchanger (3) or to the inlet of the circulating cooling-water pump set (8). The outlet of the cooling tower (2) is connected to the inlet of the pump set (8), which pressurizes water and feeds it back to the inlet of the pot-furnace cooling water jacket (1) to complete the cycle.

**[21]** The cold-side inlet of the second water-to-water heat exchanger (4) is connected to a municipal water source, and its cold-side outlet can be connected to end-uses such as bathhouses and canteens for domestic hot water.

**[22]** The intelligent control system comprises a PLC controller, temperature sensors (installed on key pipelines and at device inlets and outlets), flow sensors (installed on each branch), and a human-machine interface (touch screen). Operators may select preset operating modes (e.g., summer cooling mode, winter heating mode, daily mode) via the interface or define custom modes. Based on the selected mode and real-time sensor data (temperature and flow), the system automatically controls the open/close state and opening degree of each intelligent valve to achieve automatic allocation and precise control of waste-heat utilization.

**[23]** Summer cooling mode: when the system detects an ambient temperature above 28 °C, valve G3 is closed and valves G1, G2, and G4 are opened. After passing through the first water-to-water heat exchanger (3), a portion of the high-temperature cooling water flows to the refrigeration unit (6) (e.g., a lithium-bromide absorption chiller) to generate cooling for workshops or offices; another portion flows to the waste-heat power-generation boiler (5) for power generation; another portion flows to the second water-to-water heat exchanger (4) to supply hot water for bathhouses and canteens. The cooled water returns to the system.

**[24]** Winter heating mode: when the system detects an ambient temperature below 15 °C, valve G2 is closed and valves G1, G3, and G4 are opened. A portion of the high-temperature cooling water flows to the space-heating system (7) (e.g., radiators) to provide building heating; another portion flows to the waste-heat power-generation boiler (5) for power generation; another portion flows to the second water-to-water heat exchanger (4) to provide domestic hot water. The cooled water returns to the system.

**[25]** Daily mode: based on historical data and real-time demand forecasting, valves G2 and G3 are closed while valves G1 and G4 are opened. A portion of the high-temperature cooling water flows to the waste-heat power-generation boiler (5), where steam drives a turbo-generator to convert heat into electricity; another portion flows to the second water-to-water heat exchanger (4) to supply domestic hot water.

**[26]** The above embodiments are merely illustrative to enable those skilled in the art to understand and implement the invention. Various modifications will be apparent to those skilled in the art. The general principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention.