CLAIMS

1. A zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device, comprising:

a waste heat collection pipeline system, a plurality of waste heat recovery devices (9) arranged in groups, and a waste heat return pipeline system, wherein

the waste heat collection pipeline system is configured to lead out a working medium having waste heat from a waste heat source of the ethylene device and distribute the working medium to the plurality of waste heat recovery devices (9), the plurality of waste heat recovery devices (9) are configured to heat combustion-supporting air of a bottom burner of an ethylene cracking furnace through the waste heat, and the waste heat return pipeline system is configured to transport the working medium that has undergone waste heat recovery and utilization back to the waste heat source;

the waste heat collection pipeline system is provided with flow control elements in stages, and flow rates in pipelines are distributed differentially through the flow control elements to allow flow rates in the groups of waste heat recovery devices (9) to be distributed evenly;

the plurality of waste heat recovery devices (9) are arranged in groups, each of the groups comprises at least two waste heat recovery devices (9), and the plurality of waste heat recovery devices (9) are connected in parallel and operate independently;

the waste heat collection pipeline system comprises a collection master pipe (16), collection main pipes (7) and collection branch pipes (12);

the waste heat return pipeline system comprises a return master pipe (5), return main pipes (8) and return branch pipes (13);

the collection master pipe (16) is configured to lead out the working medium having waste heat from the waste heat source, the working medium is transported to the groups of waste heat recovery devices (9) through the collection main pipes (7), and is further transported to each of the waste heat recovery devices (9) in a group through corresponding ones of the collection branch pipes (12);

the working medium that has undergone waste heat recovery and utilization by each of

the waste heat recovery devices (9) in the group is returned, through corresponding ones of the return branch pipes (13), to a corresponding one of the return main pipes (8) corresponding to the waste heat recovery devices (9) in the group, and further returned to the waste heat source through the return master pipe (5); and

the collection master pipe (16) is provided with a master pipe flow control element (17), each of the collection main pipes (7) is provided with a main pipe flow control element (6), and each of the collection branch pipes (12) is provided with a branch pipe flow control element (11); and

the flow rates in the groups of waste heat recovery devices (9) are evenly distributed, and pressure drops of the waste heat recovery and utilization system satisfy the following conditions:

$$\begin{cases} \dfrac{\Delta P_a}{\Delta P_t} \in [0.01, 0.1] \\ \dfrac{\Delta P_b}{\Delta P_t} \in [0.01, 0.1] \\ \dfrac{\Delta P_c}{\Delta P_t} \in [0.8, 0.98] \\ \Delta P_a + \Delta P_b + \Delta P_c = \Delta P_t \end{cases}$$

$$\Delta P_{g1} + \Delta P_{j1} + \Delta P_{z1} = \Delta P_{g2} + \Delta P_{j2} + \Delta P_{z2} = \ldots = \Delta P_{gn} + \Delta P_{jn} + \Delta P_{zn}$$

wherein ΔP_t represents a total pressure drop of the waste heat recovery system, ΔP_a represents a total pressure drop of the collection master pipe (16), the return master pipe (5) and the master pipe flow control element (17), ΔP_b represents a total pressure drop of the collection main pipes (7), the return main pipes (8) and the main pipe flow control elements (6), and ΔP_c represents a total pressure drop of the waste heat recovery devices (9), the collection branch pipes (12), the return branch pipes (13) and the branch pipe flow control elements (11); and n represents the number of the groups of waste heat recovery devices (9), ΔP_{gi} represents a total pressure drop of a corresponding one of the collection main pipes (7) and a corresponding one of the return main pipes (8) corresponding to the waste heat recovery devices (9) in group i, ΔP_{ji} represents a total pressure drop of the waste heat recovery devices (9) in group i and corresponding ones of the branch pipe flow control elements (11) corresponding to the waste heat recovery devices (9) in group i, and ΔP_{zi} represents a total

pressure drop of corresponding ones of the collection branch pipes (12) and corresponding ones of the return branch pipes (13) corresponding to the waste heat recovery devices (9) in group i, wherein i=1, 2, 3,..., n.

2. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 1, wherein operating parameters of the master pipe flow control element (17), the main pipe flow control elements (6), or the branch pipe flow control elements (11) conform to the following relationship:

$$q = \mu A\sqrt{2\Delta P\rho}$$

wherein q represents the flow rate, μ represents the flow coefficient, A represents the area of a flow control element, ΔP represents the pressure loss, and ρ represents the density of the waste heat source.

3. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 2, wherein the number of the waste heat recovery devices (9) in each of the groups is 8 to 10.

4. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 1, wherein the waste heat collection pipeline system is provided with a desuperheating pressure-balance device, and the desuperheating pressure-balance device comprises a pressure sensor (15), a temperature sensor (20), a regulating valve (19), desuperheating water (14) and a desuperheater (18), wherein

the pressure sensor (15) and the temperature sensor (20) are configured to monitor a temperature signal and a pressure signal of the waste heat collection pipeline system, the regulating valve (19) is configured to perform opening degree adjustment based on the temperature signal and the pressure signal to control a flow rate of the desuperheating water (14), and the desuperheater (18) is configured to spray the desuperheating water (14) to cool the waste heat source and further maintain a stable pressure in the waste heat collection pipeline system.

5. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 1, wherein each of the waste heat recovery devices (9) comprises an air inlet (28), an air outlet (32), a connection air duct (21),

a water inlet assembly (24), a water outlet assembly (26) and a heat exchange element (30), wherein

the water inlet assembly (24) is connected to the waste heat collection pipeline system for introducing the working medium having waste heat, the water outlet assembly (26) is connected to the waste heat return pipeline system for returning the working medium that has undergone the waste heat recovery and utilization, the air inlet (28) is configured to introduce cold air, the heat exchange element (30) is configured to exchange heat between the working medium having waste heat and the cold air, and the air outlet (32) is connected to the connection air duct (21) for transporting preheated air.

6. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 5, wherein

each of the waste heat recovery devices (9) further comprises an online self-cleaning device (25), which comprises a blow pipeline (34) and blow nozzles (33), each of the blow nozzles (33) is a fan-shaped atomizing nozzle with a spraying angle ranging from 60 degrees to 120 degrees, and the blow nozzles are arranged opposite to each other in two layers;

a blow medium is transported to the blow nozzles (33) through the blow pipeline (34) to clean the waste heat recovery device (9); and

the blow medium is compressed air or low-pressure steam.

7. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 5 or 6, wherein the heat exchange element (30) is a circular or elliptical finned tube bundle.

8. The zero-power-consumption self-adaptive distributed waste heat recovery and utilization system for an ethylene device according to claim 7, wherein a spoiler assembly (35) is provided in the finned tube bundle.