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[54] **PROCESS GAS COOLER**

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[51] **Int. Cl.**[2] **F28D 7/04**

[58] **Field of Search** 122/32, 34; 165/160, 163, 165/145

[56] **References Cited**

UNITED STATES PATENTS

2,283,832	5/1942	Thomas	122/32 X
2,946,570	7/1960	West	165/161 X
3,672,444	6/1972	Lowe	122/32
3,690,374	9/1972	Vollhardt	165/63

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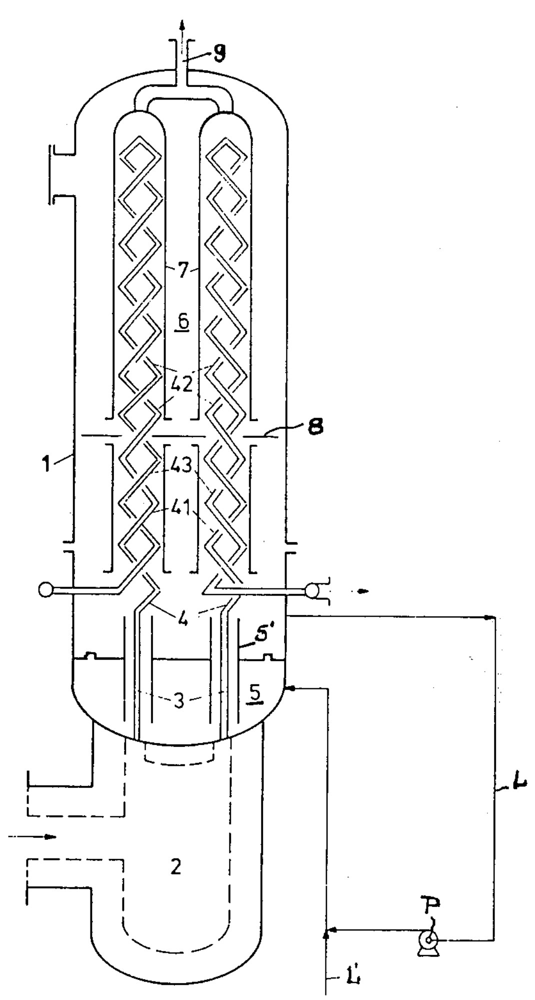
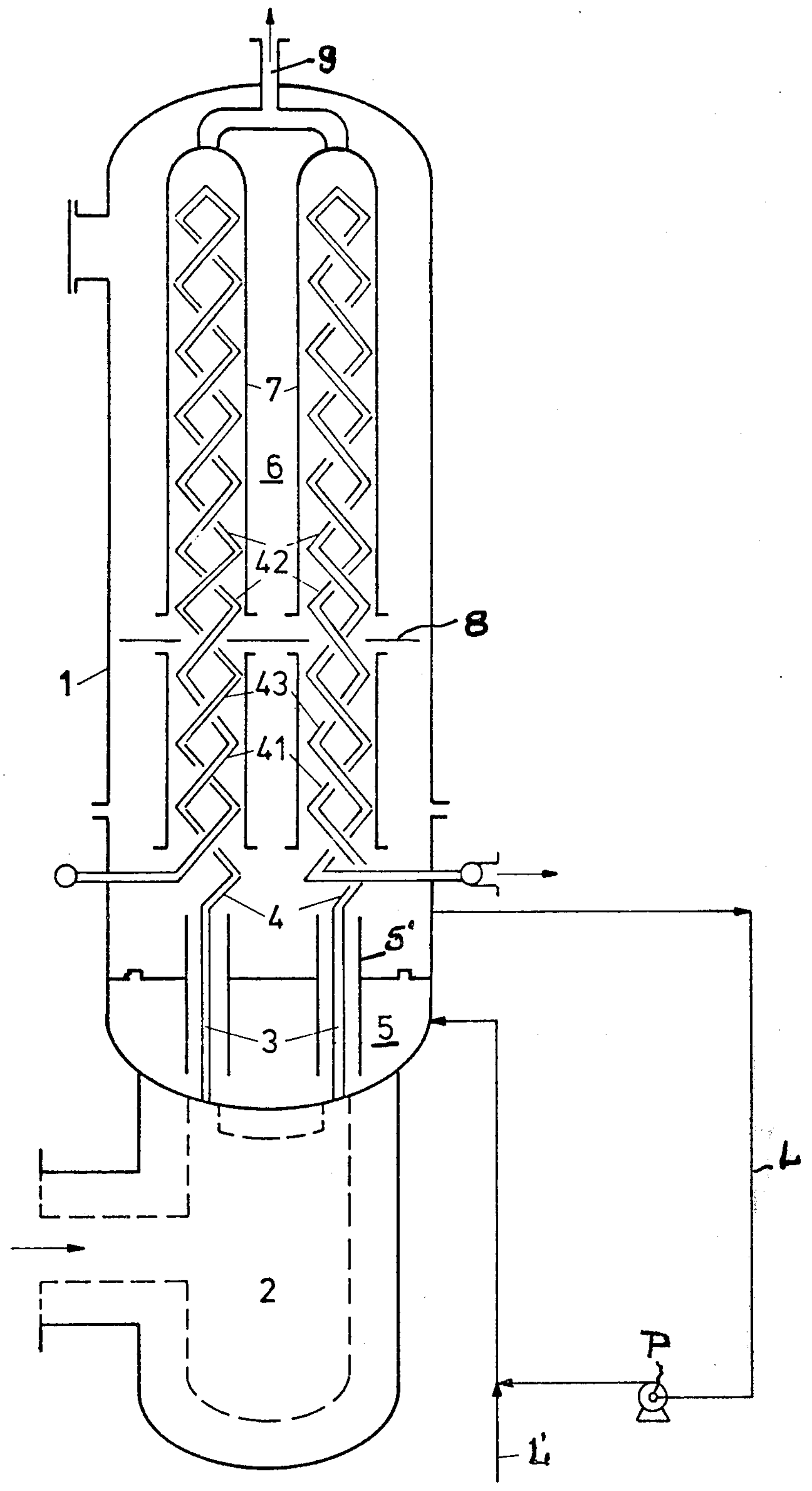
[57] **ABSTRACT**

A cooler for process gas of temperatures in excess of 750° C in which the gas passes through tubes, the cooling length of which is subdivided into three sections. The sections comprise; first, a hot or inlet section where the tubes are surrounded by a vaporizing liquid; secondly, a medium temperature or intermediate section where the tubes are arranged in a steam space and cooled by the saturated steam produced; and, thirdly, a cool discharge section where the tubes are surrounded by the vaporizing liquid. The tubes are of inverted U-shape and preferably are of serpentine form where one arm of the U has portions overlapping the other arm for greater heat exchange. Vaporizing liquid is recirculated, added to, and cooled by feedwater.

7 Claims, 1 Drawing Figure

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PROCESS GAS COOLER

BACKGROUND OF THE INVENTION

Process gas coolers are preferably used in the chemical industries where process gas streams at high temperatures are required to be cooled before further processing while the heat content of the process gas is intended to be utilized for generating steam.

Process gas coolers employed for the service described above are expected to lower the temperature of the gas stream to the desired final level while the heat to be dissipated for this purpose shall be transferred at the same time to boiler feedwater for generating superheated steam at elevated temparture. It is known that such superheated steam can advantageously be employed in steam turbines for transformation into kinetic energy.

Process gas streams at temperatures in excess of **1,000°** C and pressures of **20** atm. abs. and more are obtained, for example, in chemical processes and must be cooled, for example, to **300°** C and less prior to further processing. Because the chemical processes generally require steam, and/or steam production is credited to the final product price, the hot process gas streams shall be subjected to profitable cooling. Process gas coolers are provided, for example, downstream of steam reforming reactors or partial oxidation reactors, said coolers receiving the hot gas at temperatures of about **1,000°** C or **1,400°** C. After intensive cooling through vaporization of boiler feedwater, the process gas leaves the cooler at temperatures of approximately **350°** C or **200°** C. The entire heat available at the high temperature level is utilized for generating saturated steam only. No superheated steam is generated.

Another item of equipment to serve as superheater would be needed in a chemical plant where superheated steam is intended to be generated downstream of a reactor from which hot process gas is obtained. Because of the required temperature difference, the hot process gas would have to be admitted from the process gas cooler to the superheater at an elevated temperature of, for example, **550°** C. This high temperature level would impose considerable stresses upon the interconnecting piping, particularly where high operating pressures are involved. It would not be possible to apply an efficient temperature difference in favor of the heat exchange area because the gas temperature between process gas cooler and superheater would be subject to an upper limit depending on the strength of the materials of construction. The use of brick-lined piping in this area would involve considerable additional expense and difficulties of physical arrangement including the inevitable mechanical problems.

The technological status of the art implies designing a cooling system for lowering the temperature of a hot fluid in that this system comprises a space substantially filled with liquid cooling fluid, the hot fluid passing across said space after being split up into a multitutde of streams with the aid of guide walls. Boiler feedwater preheaters, for example, are known from ammonia synthesis plants, where the hot synthesis gas is sent through the tubes while a cross-flow stream of boiler feedwater passes across the shell side of the preheater. In this case, the preheater is entirely filled with liquid cooling fluid.

A waste heat boiler as normally employed in partial oxidation plants using the Shell process may be cited as

another example of a cooling system whose outer space is entirely filled with vaporizing cooling fluid. In this system, boiler water is admitted to the outer space of the cooler at any suitable point while a steam/water mixture is withdrawn at the top of the cooler for being sent to a boiler steam drum.

Referring to the partial oxidation process of Texaco, which, similar to the Shell process, yields a process gas at **1,200°** C to **1,500°** C, it is common practice to employ waste heat boilers that are filled to **70%** with boiling water while the space above the liquid level is used for separating steam and water. The tubes carrying the hot process gas are arranged for being permanently covered with boiling water.

From a thermodynamic point of view, this design of heat exchange facilities is unfavorable because the hot fluid which is at a high temperature level is used for the preheating and vaporization of cooling liquid at relatively moderate temperatures only. The inherent energy of the hot fluid is utilized to a moderate extent only.

A typical arrangement may be cited for exemplification:

A chemical process is assumed to yield a gas stream at **1,500°** C, said gas stream being admitted for cooling to a tubular waste heat boiler while saturated steam at **20** atm. abs. and **211°** C is generated at the same time. The high temperature level of more than **1,000°** C is used for generating saturated steam only. However, saturated steam has only a limited field of application. The loss of energy would be lower if the cooling fluid were not only heated and vaporized but were superheated to **500°** C. Steam generating will, indeed, drop with the quantity of heat transferred being held constant, but the volume of efficient thermal energy received by the cooling fluid will rise. When the superheated steam at an elevated temperature level is expanded in a turbine it will perform more work than a saturated steam generated through the same quantity of heat and will require less cooling water in the condenser.

On the other hand, superheating the cooling fluid is subject to limitation by the attainable heat resistance of those materials of construction that may be used for fabricating the partition walls between the hot and cold fluids. At high inlet temperatures of the hot fluid, this implies that the individual streams after the hot gas inlet are in any case required to pass through liquid cooling fluid. A good heat transfer on the liquid side and a poor heat transfer on the hot gas side combine to attain sufficiently low partition wall temperatures. On the other hand, the heat exchange zone receiving hot gas whose temperature has already been substantially lowered should be provided for the vaporization of cooling fluid. This is necessary because a positive motive temperature gradient is required for transferring the heat to the cooling fluid, and the cooling fluid temperature in the vaporizing zone is lower than in the superheating zone. In addition, the design should be based on utilizing high heat transfer rates in the area of small motive temperature gradients in order to reduce the necessary heat transfer areas.

SUMMARY OF THE INVENTION

The present invention relates to a process gas cooler with liquid and steam spaces for generating superheated steam through heat exchange with hot gas at temperatures in excess of 750° C, said hot gas passing through a number of hot gas tubes.

The object of the present invention is to eliminate the disadvantages described above with reference to the cooling of hot gases and to achieve the maximum possible utilization of heat, i.e., a high rate of heat transfer to the cooling fluid.

According to this invention, the problem is solved by subdividing the cooling length of the hot gas tubes in the process gas cooler into three sections and, consequently, three temperature ranges, the hot section and the cool section being surrounded by vaporizing liquid, the section of the medium temperature range being arranged in the steam space so that it is inevitably cooled by the saturated steam produced, the liquid level constituting the boundary zone between successive tube sections.

The subdivision according to the present invention provides for first routing the hot gas across a zone of liquid cooling fluid, then across a zone of cooling fluid to be superheated and subsequently again across a zone of liquid cooling fluid, the hot gas being heat-exchanged against the cooling fluid in each zone. In the zones of liquid cooling fluid, the latter can be preheated and vaporized. The temperature zone of the cooling fluid to be superheated is located between the two zones of the liquid cooling fluid or, more precisely, in the area where the motive temperature gradients are sufficient and where these conditions ensure partition wall temperatures that are compatible with material strengths while leaving sufficient flexibility for selecting the shape of the partition walls. This design also permits solving heat transfer problems where both a considerable temperature difference and marked pressure differences between hot gas and cooling fluid are involved. Referring to the foregoing observations, it may be added that the level of the temperatures involved requires to be visualized in conjunction with the materials of construction that are available.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE is a schematic view of a process gas cooler in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The hot process gas penetrates into process gas cooler vessel **1** through a bricklined inlet housing **2** at a temperature of **1,400**° C and at any pressure up to **120** atm g. The gas leaves this housing and passes through the bottom of vessel **1** through several tubes **3** which continue into zig zag or serpentine tube coils **4**, which are U-shaped, the inlet and outlet sections of which cross each other as shown. The outlet ends of the tubes **3** extend from the side of the cooler vessel **1** in the vicinity of their gas inlet points. The cooled process gas is collected in a header (not shown).

Those tube sections or lengths **41, 43,** that carry the gas of the highest temperature level and those carrying the gas of the lowest available temperature in the cooler are surrounded by boiling water of, for example, **254**°C at **43.5** atm. abs. This water is picked up by a

pump P and recycled through a pipeline L, boiler feedwater of a lower temperature level from line L′ being admixed to suppress boiling before the water is admitted to a chamber **5** in the lower part of the vessel which is filled with water. The chamber **5** accommodates the inlet ends of the tube coils **3** where the temperature is naturally at its highest level. The water in the chamber **5** is heated to boiling or near boiling temperature before it penetrates through pipes **5′** into the cooler vessel **1.** Steam space **6** above the water level **8** is of substantial volume and may be over half that of the vessel **1,** and is filled with saturated steam, except for coils **42** arranged within their jackets **7.** Saturated steam passes upwards around these coils and the associated jackets and is superheated along this route. Superheated steam passes from the jackets **7** at the top of the vessel through a common outlet pipe **9.**

The drawing is only a schematic representation of the system according to this invention. It is essential, however, that the gas be subject to a marked temperature drop in the two zones of boiling water and in the superheating zone. To achieve this temperature drop, the gas tubes in these zones are shaped, for example, in the form of serpentine coils, helices or other means or configurations enlarging the heat exchange area.

It might be expedient to provide for a larger heating area in the second vaporization zone as compared to that of the first. This can be achieved, for example, by modifying the shape of the gas carrying tubes to shorten the gas route of the first pass as compared to that of the second pass through the zone of liquid cooling fluid, for example by providing spirals or helices that have a steeper pitch.

What we claim is:

1. Process gas cooler comprising:

A. an upright closed vessel,

B. inverted U-shaped tubes extending substantially throughout the length of the vessel and each having an inlet for hot process gas at one end portion of the vessel and an outlet from said vessel in the general region of the inlet,

C. means for maintaining a quantity of liquid in said vessel for partially filling the vessel and for providing a substantial steam space above the liquid level and so that substantial portions of each tube are below and above the liquid level, whereby the cooling length of each hot gas tube is subdivided into three sections, namely an upward gas flowing section adjacent the inlet below the liquid level constituting the hot section, an upward and downward gas flowing section above the liquid level and arranged in the steam space constituting the medium temperature section, and the downward gas flowing section adjacent the outlet below the liquid level constituting the cool section,

D. jacket means for the hot gas tubes, and

E. means for venting the jacket means to the outside of the vessel.

2. Process gas cooler as claimed in claim **1,** in which each hot gas tube is of serpentine form providing a series of lateral portions successively extending in opposite directions and the corresponding lateral portions of the legs of the U overlapping each other.

3. Process gas cooler as claimed in claim **2,** in which said liquid means comprises a pipeline extending from the lower portion of the vessel to an area near the bottom, pump means in said pipeline, and means to introduce feed-water to said line.

4. Process gas cooler as claimed in claim **3**, comprising means to form a separate liquid chamber at the bottom of said vessel at the tube inlet end, and to which said pipeline extends, and means providing communication between said chamber and the interior of the vessel thereabove.

5. A process gas cooler for cooling a process gas stream from a high temperature while using the heat content thus removed from the process gas stream for generating superheated steam from added feedwater, comprising:

A. an upright closed vessel,

B. at least one inverted U-shaped tube extending vertically throughout the length of the vessel, the tube having an inlet means for receiving a hot process gas stream and having an outlet means for giving out a cooled process gas stream,

C. means for maintaining a quantity of liquid in a lower part of the vessel by partially filling the vessel with the feedwater to a predetermined liquid level, whereby the vessel is divided into a substantial liquid space below the liquid level and a substantial steam space above the liquid level, and whereby three sections, namely, first, an upward gas flowing section of the tube adjacent the input means and situated below the liquid level to constitute a hot section of the tube, second, an upward and downward gas flowing section of the tube situated above the liquid level to constitute a medium temperature section of the tube, and third, a downward gas flowing section of the tube adjacent the outlet means and situated below the liquid level to constitute a cool section of the tube,

D. a jacket means surrounding the medium temperature section of the tube above the liquid level, the jacket means having a bottom and an upper portion, the jacket being in open communication with the steam space at the bottom of the jacket means, and, above the point of open communication, the jacket means preventing passage of steam from the steam space to the inside of the jacket means and vice versa, and

E. means for venting the upper portion of the jacket means to the outside of the vessel for withdrawal of superheated steam.

6. A cooler according to claim **5** wherein the at least one inverted U-shaped tube comprises a plurality of such tubes.

7. A cooler according to claim **5** wherein the temperature of the uncooled process gas is above **750°C**.

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