HEAT EXCHANGER CONTROL SCHEME

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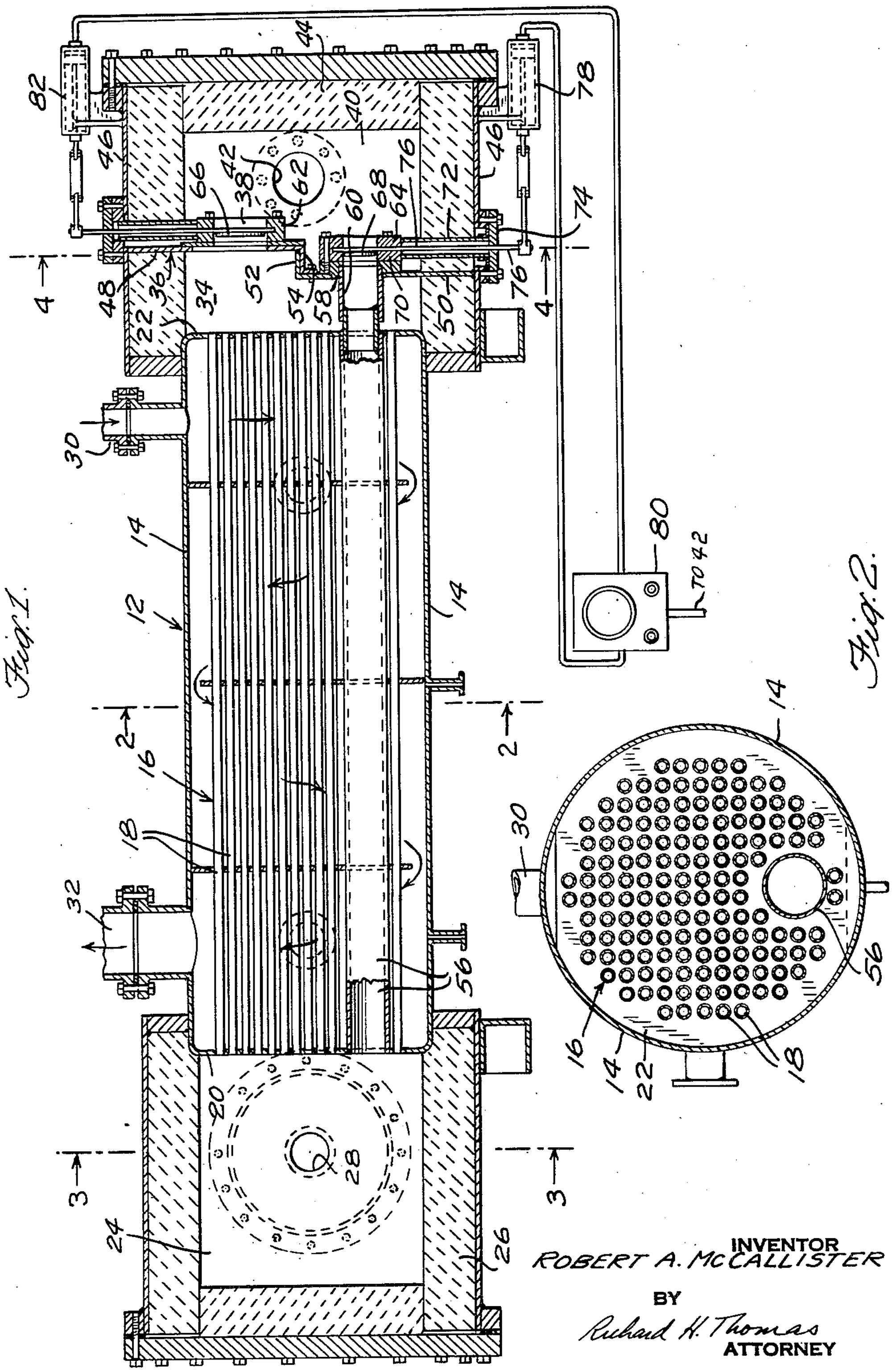

INVENTOR
ROBERT A. McCALLISTER
BY
Richard H. Thomas
ATTORNEY

Aug. 10, 1965 R. A. McCALLISTER 3,199,577

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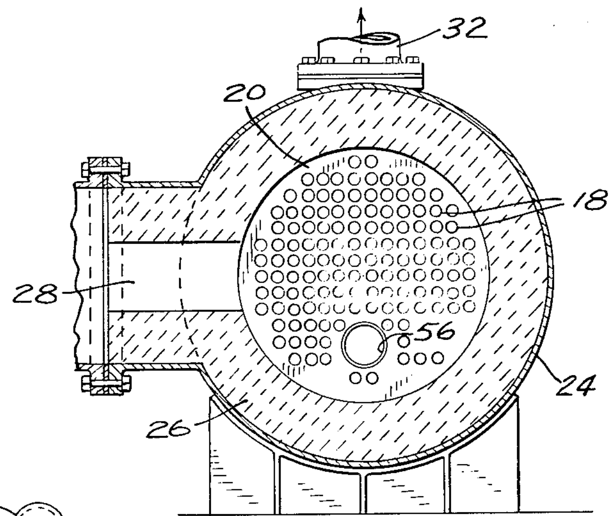
Fig. 3.



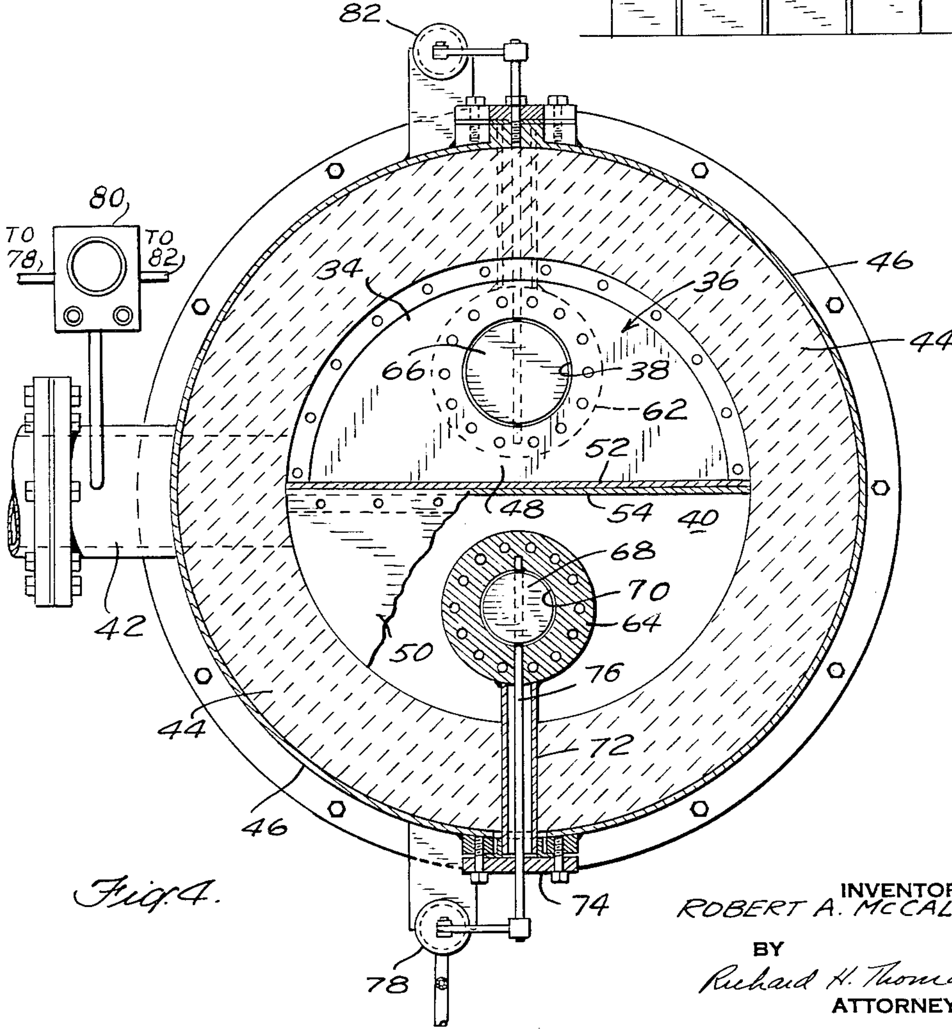


Fig. 4.

INVENTOR
ROBERT A. McCALLISTER

BY
Richard H. Thomas
ATTORNEY

United States Patent Office

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HEAT EXCHANGER CONTROL SCHEME

Robert A. McCallister, Hackensack, N.J., assignor to Foster Wheeler Corporation, New York, N.Y., a corporation of New York

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This invention relates to a control arrangement for a heat exchanger, and in particular to a control device for maintaining a constant set of conditions at the exit of a heat exchanger using an internal by-pass control.

In a typical fire tube, waste heat boiler for chemical and refinery processes, hot process gas is cooled by flowing it through heat exchanger tubes. Steam may be generated on the shell side of the heat exchanger.

In these processes, it is necessary to control the temperature of the process gas leaving the exchanger because of requirements of subsequent processing steps. Using a control arrangement on the steam side of the heat exchanger, it is extremely difficult to control the exit gas temperature, so that it becomes necessary to place the control device on the process gas side of the exchanger.

The simplest control device is to by-pass the heat exchanger tubes with hot gas so that following the exchanger a cooled stream of process gas will be mixed with a hot stream of process gas to yield the desired exit temperature. In such an arrangement, it is necessary that some hot gas always be bypassed so that the required corrections can be made either as the exit gas temperature becomes too high or as it becomes too low.

In addition, a fire tube boiler of this type must be designed to allow for a decrease in heat transfer efficiency with time in service because of fouling of the exchanger surfaces. Further, it is quite common for a considerable over-design to exist in such a unit because of the uncertainty of heat transfer data. The system for controlling the exit temperature for such a unit must take these factors into account and be flexible enough to handle substantial performance changes with time.

One common practice is to use a shell and tube heat exchanger having an external by-pass and controls. In many applications, the hot gas by-pass stream operates at temperatures in excess of 1100° F., requiring either a special costly steel alloy line, or internal insulation to permit the use of a carbon steel line. The use of an internally insulated line is feasible, but presents design complications and problems which lead to extensive maintenace during operation. For instance, internal insulation presents difficulties in designing for thermal expansion and in making turns in the line.

It has been proposed to provide an internal by-pass consisting of a large diameter line within the heat exchanger shell and parallel to the gas tubes. The line and the by-pass control for the line is located in the boiling liquid portion of the exchanger and, as a result, will operate at a relatively low temperature of about 450° F., the same temperature as that for the carbon steel heat exchanger tubes.

However, the single controlled internal by-pass also presents certain problems. For instance, it is customary that the heat exchanger tubes and by-pass tube exit in a common mixing chamber within the heat exchanger. Low pressure drop design generally less than 2.0 p.si. requires that a butterfly or diaphragm-type control valve be used in the by-pass, and it is characteristic of this type of control valve that optimum control occurs when the valve is 60% open.

When the control valve in the by-pass is required to take corrective action, it is evident that the valve must over-correct. For instance, if it is necessary to by-pass more hot gas, to achieve a higher exit gas temperature, the by-pass valve will open. At the same time, the gas flow through the exchanger tubes will decrease, lowering the pressure drop across the tube bundle. This results in a reduced pressure drop available for the control valve, which must still further open to reduce its pressure drop.

Two conditions are then possible. One is where the valve must over-correct to such an extent that the range of the control instrument is substantially reduced, seriously reducing the effectiveness of the system. The second condition is that the over-correction required may lead to a less stable system requiring a longer period of time to attain a steady state condition after a process change or upset.

It has now been found that, in accordance with the invention, these conditions and disadvantages can be overcome by the use of a partition plate within the heat exchanger in the mixing chamber thereof, or by the use of a collector positioned at the exit of the heat exchanger tubes, designed to collect only the gas flowing through the heat exchanger tubes. The collector exits through an outlet to the mixing chamber where the cool gas is mixed with the by-pass hot gas, and a control valve is disposed in this outlet passageway, which may be either automatically controlled or manually controlled.

In general, the collector control valve is adjusted to ensure that the by-pass valve operates in an area of good controlability regardless of the operating conditions, or changes in the system hydraulic characteristics. The collector valve may also be used as a dampening device imposing a pressure drop across the tube bundle and reducing the system instability.

For instance, it may be desired to by-pass significantly less gas and lower the exit gas temperature of the process gas stream a substantial amount, perhaps as a result of a reduced efficiency in heat-transfer in the exchanger between the process gas stream and the boiling liquid, or perhaps as a result of a change in operating conditions or system hydraulic characteristics. This is accomplished by closing the by-pass control valve.

To maintain the control valve in an area of optimum control and to achieve rapidly a steady state condition, the collector control valve is opened a specified amount. This accommodates for the increased pressure drop across the heat exchanger caused by the increased flow through the heat exchanger tubes, and reduces the extent to which the by-pass control valve must be closed.

These and other advantages and the invention will become apparent upon further consideration of the following detailed description with reference to the accompanying drawings, in which:

FIGURE 1 represents a section elevation view of a heat exchanger in accordance with the invention;

FIGURE 2 is a section view taken along line 2—2 of FIG. 1;

FIGURE 3 is a section view taken along line 3—3 of FIG. 1; and

FIGURE 4 is an enlarged section view taken along line 4—4 of FIG. 1.

Referring to FIGS. 1 and 2, there is illustrated a heat exchanger 12 of the tube-and-shell type consisting of a cylindrical shell 14 in which a tube bundle 16 having rows of tubes 18 is disposed. The tubes of the tube bundle are supported at their ends by tube sheets 20 and 22, forming the inlet and outlet ends of the heat exchanger shell.

On the gas side of the inlet tube sheet 20, FIGS. 1 and 3, the heat exchanger is provided with an inlet header 24. The header is lined with a refractory 26 adapted to withstand a high temperature and is provided with an inlet opening 28. On the shell side of the heat exchanger a suitable liquid such as water is disposed around the tube bundle. Water is fed to the shell through a downcomer 30 and is circulated around the tube bundle receiving heat from the hot process gas, steam exiting from the shell through riser 32.

After the gas passes through the tubes 18 of the tube bundle, it enters a collection chamber 34 defined by the tube sheet 22 and a partition plate 36 disposed in approximately parallel relation with the tube sheet 22. From the collection chamber 34 the hot gas passes through the partition wall 36 through opening 38 into outlet header chamber 40 and through outlet 42. As with the inlet header, the outlet header is lined with a refractory 44. The structure of the partition wall is also shown in FIG. 4.

Although many different arrangements are within the scope of the invention, in the embodiment illustrated, the collection chamber 34 and outlet header 40 are defined by a single vessel casing or wall structure 46 through which the partition wall 36 is adapted to extend. The partition wall itself consists of removable semi-circular upper and lower plate members 48 and 50 having cooperating mating lugs 52 and 54 by which they are joined together.

In accordance with the invention, a by-pass line 56 of much larger diameter than the tubes 18 is provided supported within the boiling liquid by and between the tube sheet 20 and the tube sheet 22. Because of the greater fluid flow capacity of the by-pass tube per heat transfer surface, and other mechanisms associated with the use of a larger diameter tube, the heat transfer from the by-pass line is less than that for a number of heat exchanger tubes 18 handling the same flow. An opening 58 is provided in the lower partition plate member 50 and a sleeve arrangement 60 is provided bringing the by-pass line into communication with the opening 58 preventing the diffusion of by-pass gas into the collection chamber 34. As shown, the sleeve 60 is adapted to accommodate for relative expansion or movement between the tube sheet 22 and the partition plate member 50.

Valve casings 62 and 64 and butterfly valves 66 and 68 are disposed at and across the openings 38 and 58, respectively, in the upper and lower plate members to control the flow from the collection chamber and by-pass line respectively to the mixing chamber or outlet header chamber 40. The temperature of the gas exiting from the heat exchanger in outlet 42 is controlled by synchronous operation of the butterfly valves.

Essentially, the valve casings comprise washer-like flange members, 70 FIG. 4, secured by bolts or like means to the partition plate members with the openings therein aligned with the partition plate openings. A tubular stem 72 is adapted to extend radially from each valve flange casing through the vessel wall 46 and a sealing plate 74 located on the outside of the heat exchanger and aligned with the tubular stem. The butterfly valve, located in the valve flange casing, is actuated from the outside by a control rod 76 extending from the valve through the tubular stem and sealing plate to the outside.

The diaphragm or butterfly-type control valve illustrated in FIGS. 1 and 4 has optimum control when the valve is approximately 60% open. The principal purpose of the valve 66 between the collection chamber 34 and the outlet header chamber 40 is to impose or superimpose a pressure drop across the heat exchanger tube bundle 18. During operation, when the control valve 68 for the by-pass is required to take corrective action, that is, to increase or decrease the flow through the by-pass line and to increase or decrease the exit gas temperature, it will either open or close from its 60% open position. If the by-pass control valve opens to allow a greater amount of gas to by-pass the tube bundle, a reduction in pressure drop will occur across the tube bundle. Accordingly, the valve 66 or second control valve is closed to increase the pressure drop across the tube bundle permitting the by-pass control valve 68 to be returned approximately or closer to its 60% open or optimum control position. If a lesser flow through the by-pass is required, the reverse situation will develop.

It is apparent that the arrangement prevents over-correcting by the by-pass control valve 68 and results in a stable condition being arrived at in a shorter period of time.

As previously indicated, the second valve between the collection chamber and the outlet header chamber may be automatically controlled or manually controlled. Preferably, the by-pass valve 68 is automatically controlled by the control arrangement 78, FIG. 1, schematically illustrated. If it is desired to control both valves automatically, a temperature recorder and control means 80, suitably linked to the outlet gas temperature, may be associated with a second control arrangement 82.

Although the invention has been described with reference to a specific embodiment, it is apparent that variations may be made without departing from the scope and spirit of the invention as defined in the following claims.

What is claimed is:

1. A heat exchanger unit of the type designed for a low pressure drop therethrough comprising:
  - a shell;
  - a tube bundle supported and disposed therein;
  - inlet and outlet headers at opposite ends of the heat exchanger and in fluid communication with the tubes of said tube bundle;
  - means defining a collection chamber in flow communication with said tubes adjacent the outlet header and arranged to collect the fluid passing through said tube bundle, said means having an opening therein in fluid communication with said outlet header;
  - a first butterfly-type valve disposed in said opening;
  - a by-pass line disposed within said shell extending between said inlet and outlet headers and by-passing said collection chamber, said by-pass line being of larger diameter than the tubes of said tube bundle and having a lower heat flow rate from the fluid per unit of flow;
  - a second butterfly-type valve disposed in said by-pass line;
  - first adjusting means for opening and closing said first butterfly-type valve; and
  - second adjusting means for opening and closing said second butterfly-type valve.

2. A heat exchanger according to claim 1 further including means by which said second adjusting means is automatically actuated in response to a variance in outlet header temperature.

3. A heat exchanger according to claim 2 wherein said first adjusting means is also automatically controlled depending upon the temperature of the outlet header.

4. A heat exchanger according to claim 1 wherein the pressure drop across the inlet and outlet headers is less than 2 p.s.i.

References Cited by the Examiner

UNITED STATES PATENTS

447,285	3/91	Alberger	165—101
1,311,809	7/19	Giesler	236—34.5
1,320,755	11/19	Grikscheit.	
1,918,966	7/33	Harkness	165—134 X
2,498,637	2/50	Bay	165—35
2,814,446	11/57	Phillips et al.	236—13
2,951,685	9/60	Bliss et al.	165—34 X

FOREIGN PATENTS

261,196	11/26	Great Britain.	

ROBERT A. O'LEARY, *Primary Examiner.*

ALDEN D. STEWART, CHARLES SUKALO, *Examiners.*