(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 777 098 A2

# (12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**04.06.1997 Bulletin 1997/23**

(51) Int Cl.[6]: **F28F 9/02**

(21) Application number: **96308593.1**

(22) Date of filing: **28.11.1996**

(84) Designated Contracting States:
**AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE**

(30) Priority: **28.11.1995 US 563644**

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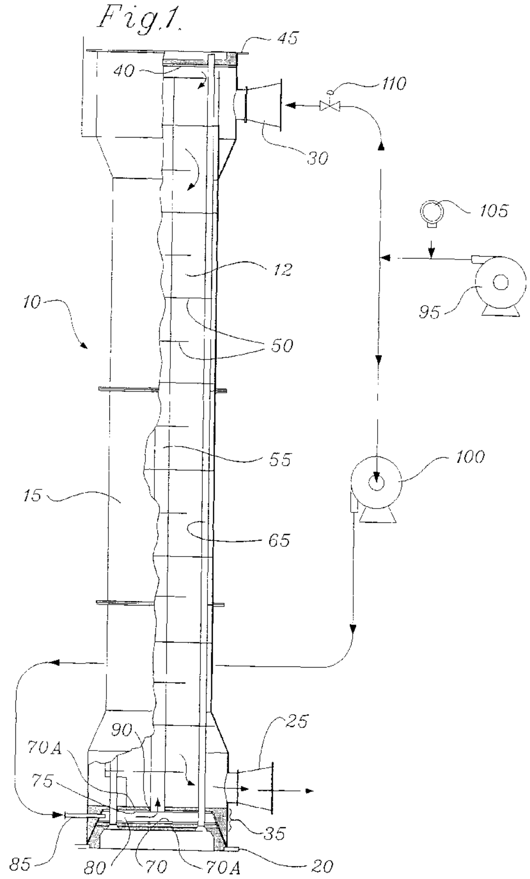
## (54) Improved heat exchanger for use in high temperature applications

(57) A heat exchanger (10) achieves a more uniform internal temperature gradient within its sections during normal operation as well as subsequent to an unexpected power shutdown. Internal fouling (65) of tubes containing the process gas and entrained solids is reduced. An external shell (15) is utilized which is insulated on its inner surface and optionally provided with cooling medium flowing within the shell wall. A double bottom tube sheet (35) enclosing a secondary cooling medium chamber (80) is also provided. The top of the process gas tube (65) is preferably enclosed within a shielded chamber (140) to facilitate a thermal gradient proximate thereto. A ferrule (145) is similarly affixed to the bottom of the process gas tube (65) at the point where it passes through the double bottom tube sheet (35). Cooling medium flow is diverted and passed directly into the cooling chamber (80) of the double bottom tube sheet (35). Cooling medium from the double bottom tube sheet (35) is then vented to the top of the heat exchanger (10) to a point adjacent the top tube sheet (40). A secondary blower (100) for propulsion of the cooling medium is provided in line with the normal flow of cooling medium from the primary blower (95). Under unexpected shutdown conditions, the primary blower operation is discontinued and the secondary blower continues its propulsion of cooling medium through the double bottom tube sheet (35) and the main cooling medium chamber (12).

*Fig.1.*

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**Description**

The present invention relates to a heat exchanger particularly adapted for use in high temperature applications. More specifically, the invention relates to a heat exchanger which is intended to be utilized in the carbon black industry in which significantly high temperatures are encountered. The device incorporates several features which are intended to facilitate a uniform thermal gradient within the exchanger and avoid catastrophic meltdown during an unanticipated power termination.

Heat exchangers are typically used for preheating air or other gases to higher temperatures by utilizing the heat from the basic industrial process with which the heat exchanger is associated. One particular type of heat exchanger is a gas-to-gas heat exchanger which utilizes process off-gases from combustion of fuels or other materials to preheat air or other gases to higher temperatures for use in other aspects of the industrial process. In this manner, energy is conserved through the recovery of the process gas heat which would otherwise be expelled into the atmosphere and wasted.

Heat exchangers are typically designed for use within particular temperature ranges. The temperature of operation determines the type of materials utilized in the construction of the heat exchanger as well as the physical orientation of the components incorporated therein. In general, the carbon black industry utilizes relatively high operating temperatures which necessitate specific design features in the heat exchangers associated therewith. During the carbon black manufacturing process, a liquid feedstock is sprayed within a reactor on a high temperature flame which cracks the feedstock and produces the carbon black as a finely dispersed solid entrained within reactor off-gases. These finely entrained solids are typically separated from the reactor off-gases through the use of bag filters. Unfortunately, bag filters are unable to withstand the operating temperatures at which the carbon black feedstock is cracked into the solid material. In this situation, the reactor off-gases containing the dispersed carbon black solids must be cooled to a temperature which is more acceptable to the bag filters. Typically, reactor process gases emerge at a temperature between 1100°C and 1200°C. The heat exchanger is therefore utilized to reduce the temperature of the process gas through the use of heat exchange with a cooling medium which stores or recoups the heat energy contained in the process gas. This cooling medium may then be transported or utilized in situ for the recovery of the heat energy.

Typically, the heat exchanger is arranged such that the process gas flows upwardly through a generally cylindrical shell of the heat exchanger within which a series of tubes have been longitudinally arranged. The process gases flow through the tubes which are surrounded by the cooling medium. The heat from the process gases is passed through the walls of the longitudinal tubes to the surrounding cooling medium which is circulated through the length of the heat exchanger. The tubes are connected at the top and bottom to tube sheets which receive and restrain the ends of the tubes and also serve, along with the shell, as a barrier between the internal portion of the heat exchanger containing the cooling medium, the environment and the process gases. The bottom tube sheet, which provides the interface between the reactor where the feedstock is cracked and the cooling portion of the heat exchanger, is therefore exposed to the most significant heat degradation as well as the highest operating temperatures. Various inventions have been proposed for the particularized cooling of the tube sheet and the heat exchanget generally in this region, including Marburger, United States Patent No. 4,585,057, issued April 29, 1986, and German Published Specification No. DE 4404068 CI, published August 17, 1995. Marburger discloses a cooled tube sheet inlet for a heat exchanger which provides a cooling chamber particularly disposed adjacent the tube sheet which contains a series of inlet tubes passing therethrough.

Other prior art devices, most notably those manufactured by American Schack, of Pittsburgh, Pennsylvania, and Schmidtsche Heissdampf-Gesellschaft in Kassel, Germany, have utilized multiple wall or double bottom tube sheets which contain a space for a cooling medium within the supporting structure for the cooling tubes. SHG utilizes a series of parallel ovoid tubes to form the bottom tube sheet into which the cooling tubes are mounted.

The cooling of the bottom tube sheet is of particular importance as the impingement of the high temperature process gas upon this structure, and most notably upon the welded juncture between the cooling tubes and the tube sheet, causes particularized fatigue and failures at this point. Catastrophic failure mostly occurs, however, in situations in which the manufacturing facility experiences an unexpected power shut-down or termination. These situations are a particular application of the present invention, but have also served as a catalyst for several cooling methodologies directed at the lower portion of the heat exchanger module. As previously stated, the process gas is transferred from a reactor, typically located upstream of the heat exchanger, upwardly and through the heat exchanger during its normal operation. The heat exchanger is therefore subjected to significantly higher temperatures at its lower portion as compared to the upper portion. With the development of high temperature processes, especially in the carbon black industry, increasingly specialized materials and cooling methodologies have been utilized to maintain operating temperatures which are within the structural capabilities of the materials utilized in construction as well as the welded junctures between the various metal components. Prior art designs, however, have utilized either gas or liquid cooling media passing through the heat exchangers to facilitate the heat transfer. In double tube bottom applications, the cooling medium is also passed through the interstitial space of the double bottom to provide particularized cooling at this specific location. During a scheduled termination of operation, the process gas flow is gradually reduced and eventually terminated and the heat exchanger unit is permitted to cool to an ambient temperature under continued flow of the cooling medium. This permits a gradual and stable reduction of temperature, especially at the lower portions of the heat exchanger unit.

The various pump or propulsion systems for the cooling medium through the heat exchanger unit are typically tied to the electrical or other power systems of the operating plant as a whole. During an unscheduled or emergency termination of operation or power to the manufacturing unit, the flow of the cooling medium is terminated contemporaneously with the discontinuance of the process gas generation. However, residual process gases contained within the reactor and heat exchanger at the time of power termination remain trapped within the reactor and the heat exchanger. As the cooling medium has terminated its flow through the cooling medium spaces, the reactor and heat exchanger are required to soak in the heat contained within the entrained residual process gases, effectively raising the entire structural system to the operating temperature of the process gases. These temperatures are considerably higher than the temperatures for which the structural materials which make up the heat exchanger are designed. The effect of this soaking is even more critical with respect to the welded junctures between the cooling tubes and the bottom tube sheet. Once the heat exchanger is soaked in the process gas heat to the extent that the strength limit of the construction materials is reached, a failure, typically at the welded juncture between the tubes and the tube sheet, causes the commingling of the process gases with the cooling medium. In the event that the cooling medium is air, or other media which supports combustion, the sudden exposure of the process gas containing a variety of combustible hydrocarbon materials and the cooling medium which supports the combustion of those materials, causes a catastrophic failure, typically including fire and explosion. This also causes the permanent destruction of the heat exchanger.

Other failures are attributable to clogging or fouling of the interior portions of the heat exchanger by deposition of the carbon black solids entrained in the process gas over time on the interior portions of the heat exchanger. This fouling may cause failures both independent of and connected to the catastrophic failures described earlier, but are more typically caused by variations in cooling tempcratures at specialized locations within the heat exchanger construction.

What is lacking in the art, therefore, is a heat exchanger which provides both a more uniform distribution of temperature gradients as well as a construction methodology which maintains an operating temperature gradient within the heat exchanger even in the event of a sudden unexpected power loss, such that catastrophic failure of the heat exchanger is averted.

An improved heat exchanger is disclosed which utilizes a series of devices to achieve a more uniform temperature gradient within the body of the heat exchanger as well as provide means for maintaining the temperature gradient within the heat exchanger subsequent to an unexpected power shutdown, such that the structural integrity of the heat exchanger is maintained. Additionally, the present invention reduces the internal fouling of the tubes containing the process gas and entrained carbon black solids.

A heat exchanger is provided which incorporates an external shell which is preferably insulated by a refractory or other insulating material on its inner surface. Alternatively, a slip stream of cooling medium may be passed through the shell wall. The shell is generally cylindrical in nature and is adapted to contain a plurality of process gas tubes which are longitudinally disposed within said shell and extend substantially entirely therethrough. The tubes are substantially surrounded in their entirety by a cooling medium chamber which directs the flow of the cooling medium along the external surface of said process gas tubes to facilitate the transfer of heat energy from within said process gas tube to said cooling medium. The process gas tubes are suitably connected at the top and bottom by mounting means, also referred to as tube sheets. The mounting means are adapted to receive and restrain the process gas tubes proximal to the top and bottom ends of said tubes. The tube sheets are further adapted to enclose the cooling medium chamber formed by the external shell.

The bottom tube sheet is itself constructed of a top and a bottom which enclose a secondary cooling medium space and which top, bottom and cooling medium space form what is known in the art as a double bottom tube sheet. The double bottom tube sheet is provided with means for ingress and egress of the cooling medium, with egress preferably being in communication with the cooling medium chamber of the heat exchanger as a whole.

The process gas tubes are mounted at the top end in the top or upper tube sheet but are preferably affixed thereto through the utilization of an expansion joint which permits relative movement between said process gas tubes and said top tube sheet while maintaining a structural sealing relationship therebetween. Said expansion joint is preferably enclosed within a shield chamber formed by a shield encircling said expansion joint and an upper portion of the substantially formed process gas tubes. These shield chambers may be utilized on some or all of the process gas tubes, but are preferably utilized on said process gas tubes which are proximal to the cooling medium inlet which is generally disposed at the top of said cooling medium chamber.

A shield or ferrule is similarly preferably affixed to the bottom of said process gas tube at the point where it passes through and is received and restrained by said double bottom tube sheet. Unlike the teaching of the prior art, the ferrule utilized in the present invention extends substantially completely through said double bottom tube sheet such that the portion of the process gas tube exposed to the cooling medium within the double bottom tube sheet is entirely shielded thereby. Said shielding of the process gas tubing, as well as the insulation of the shell as a whole, facilitate the maintenance of a uniform, gradual thermal gradient with the various sections of the heat exchanger.

The heat exchanger further incorporates the utilization of a secondary means for propulsion of the cooling medium through the double bottom tube sheet as well as the heat exchanger as a whole. The propulsion means is preferably a blower for the preferred cooling medium which is air. The secondary blower is disposed in line with the normal flow of cooling medium through the heat exchanger and is adapted such that it provides no drag on the normal flow of cooling medium. The flow of cooling medium, under normal operating conditions, is generally arranged such that the majority of the cooling medium flows into the heat exchanger at a top inlet port, is directed downwardly through the body of the heat exchanger in a sinuous pattern through the use of baffle plates contained within the cooling medium chamber of the heat exchanger, and passes outward from the heat exchanger through an outlet port which is preferably at the lower portion of the longitudinal length of the heat exchanger. A slip stream of the normal cooling medium flow is diverted and passed directly into the cooling chamber of the double bottom tube sheet. This cooling medium from the double bottom tube sheet is then preferably vented through a tube which is positioned longitudinally within the heat exchanger and parallel to the process gas tubes and which also extends substantially the length of the heat exchanger. This tube is mounted such that a fluid interconnection exists between it and the cooling medium chamber of the double bottom tube sheet, permitting the passage of cooling medium from the double bottom tube sheet upwardly substantially through the entire length of the cooling medium chamber of the heat exchanger as a whole. This cooling medium tube, however, terminates short of the top tube sheet and directs the flow of the cooling medium into the cooling medium chamber of the heat exchanger such that it is incorporated within the normal inlet flow of cooling medium. Under unexpected shutdown conditions, the primary blower operation is discontinued and a pressure sensitive valve is closed isolating the primary blower from the remainder of the system to prevent backflow leakage of cooling medium out of the heat exchanger system. The secondary blower, which is powered by an alternative power source which is not dependent upon the primary electrical power and is preferably powered by a diesel motor or diesel electric generator, thus continues its propulsion of cooling medium through the double bottom tube sheet and upwardly through the cooling medium tube and thence through the cooling medium chamber of the heat exchanger as a whole. The operation and arrangement of the secondary blower and the diversion of the cooling medium through the double bottom tube sheet and into the heat exchanger cooling medium chamber thus permits the heat exchanger to maintain an operating temperature gradient within its various sections even during unexpected power termination. This permits the structural integrity of the heat exchanger to be maintained within acceptable temperature limits, during such time as the process gas is permitted to soak in the heat exchanger.

These and other advantages and features of the present invention will be more fully understood with reference to the presently preferred embodiments thereof and to the appended drawings.

Figure 1 is a side elevational view, partially in section, of the heat exchanger, including a diagrammatic view of the cooling medium propulsion system affixed thereto.

Figure 2 is a side elevational view, partially in section, of a second embodiment of the heat exchanger.

Figure 3 is a side sectional view of a portion of a third embodiment of the heat exchanger.

Figure 3A is an enlarged view of a portion of the embodiment shown in Figure 3.

Figure 4 is a side sectional view of the inlet port and top tube sheet region of the heat exchanger of Figure 3.

Referring now to Figure 1, the heat exchanger 10 is provided having an exterior shell 15 which surrounds the entire interior portion of the heat exchanger 10. The shell 15 serves to structurally support the length of the heat exchanger 10 and is generally cylindrical in orientation and may be of unitary or segmental construction. Shell 15 is generally adapted to enclose the interior components of the heat exchanger 10 as well as provide a lateral boundary for main cooling medium chamber 12. Heat exchanger 10 is preferably adapted to be mounted atop a plenum chamber and is provided with plenum mounting flange 20 for the purpose of joining the two together and providing an enclosed chamber. Heat exchanger 10 is thus adapted to receive process gases which are forced in a unitary direction through heat exchanger 10.

Heat exchanger 10 is provided with cooling medium outlet port 25 and cooling medium inlet port 30 for the passage of a cooling medium, which is preferably air, through the main cooling medium chamber 12. Main cooling medium chamber 12 is defined by the space enclosed by exterior shell 15, top tube sheet 40 and a bottom tube sheet, which is preferably double bottom tube sheet 35. Heat exchanger 10 is further provided with outlet mounting flange 45 so as to sealably connect heat exchanger 10 with appropriate process gas transfer means, which are not displayed, for eventual passage into a bag filter for removal of the entrained carbon black solids from the process gas. A series of baffles 50 are provided within the main cooling medium chamber to force the cooling medium into a sinuous path through main cooling medium chamber 12 to maximize the utilization of the surface area of the interior of heat exchanger 10 which is encountered by the cooling medium. This is intended to facilitate the heat transfer from the process gas to the cooling medium.

A series of process gas tubes 65 are mounted longitudinally internally to shell 15 in a regular parallel pattern such that the process gas tubes permit the process gas to move longitudinally in a relatively direct path through heat exchanger 10, while the cooling medium is bathed over the external surface of process gas tubes 65 in main cooling medium chamber 12 as directed by baffles 50. Process gas tubes 65 are arranged in such a fashion so as to maximize the throughput of process gas while achieving the desired temperature reduction from the inlet to the outlet of the heat exchanger 10.

Process gas tubes 65 are mounted in and restrained by top tube sheet 40 and double bottom tube sheet 35 and provide a fluid interconnection between the two ends of heat exchanger 10. Conical entry ports of the process gas tubes 65 at the double bottom tube sheet end are optionally provided, as may be more clearly seen with reference to Figure 3, to facilitate process gas entry into process gas tubes 65. Tube sleeves 148, as more specifically shown with reference to Figure 3A, are welded to double bottom tube sheet 35 at both lower bottom tube sheet 70 and upper bottom tube sheet 75 which form the boundary layers of double bottom tube sheet 35. Process gas tubes 65 are welded to the bottom end of the tube sleeves 148. Lower bottom tube sheet 70 and upper bottom tube sheet 75 form bottom tube sheet cooling medium chamber 80 which contains a separate yet related reservoir of cooling medium, as will be discussed subsequently in more detail. A cooling medium transfer tube 55 is adapted to provide a fluid interconnection between bottom tube sheet cooling medium chamber 80 and main cooling medium chamber 12.

Heat exchanger 10 is arranged such that plenum mounting flange 20 supports lower bottom tube sheet 70 and upper bottom tube sheet 75 forming double bottom tube sheet 35. Process gas tubes 65 are mounted within and are restrained by double bottom tube sheet 35 and the combination of all process gas tubes 65, which is alternatively referred to as the tube bundle, provide the sole exhaust path for the process gas from the reactor. As the process gas with the entrained carbon black solid material exits from the reactor, it is forced into the process gas tubes 65 which then transfer the process gas and carbon black material longitudinally upwardly through the heat exchanger 10. All the process gas tubes 65 are arranged generally parallel to each other in a spaced-apart orientation.

Double bottom tube sheet 35 is adapted to receive a separate reservoir of cooling medium to provide exceptional heat reduction at the point of impingement of the process gas upon lower bottom tube sheet. Particularized cooling is necessary at this point because of the significantly high temperatures to which this material is exposed. A ceramic heat barrier 70A is optionally mounted upon either or both of lower bottom tube sheet 70 and upper bottom tube sheet 75 for the purpose of reducing the effects of said high temperature impingement of process gas, while cooling medium within bottom tube sheet cooling medium chamber 80 serves to reduce the internal temperature of the double bottom tube sheet 35. Of particular note is the susceptibility of the welded joinder between process gas tubes 65 and double bottom tube sheet 35 to degradation from exposure to this significantly high temperature.

Cooling medium is typically passed into the heat exchanger 10 through cooling medium inlet port 30. Cooling medium inlet port 30 provides fluid interconnection between an exterior source of cooling medium and the main cooling medium chamber 12. The majority of the cooling medium enters main cooling medium chamber through cooling medium inlet port 30 and is directed over a series of baffles 50 which are adapted to maximize the utilization of the surface area of the interior of heat exchanger 10 which is exposed to the cooling medium so as to create a uniform temperature gradient between the inlet and outlet portions of heat exchanger 10.

The cooling medium is provided to cooling medium inlet port 30 by main blower 95 in an embodiment which utilizes air as a cooling medium. In an embodiment which uses another fluid or liquid as the cooling medium, a more appropriate drive mechanism must be selected which is well known to those skilled in the art. Main blower 95 is typically electrically connected and driven through the main power supply of the plant and is conventionally arranged to provide a continuous flow of cooling medium into cooling medium inlet port 30.

A slip stream of the output of main blower 95 is diverted for entry into bottom tube sheet cooling medium chamber 80 through bottom tube sheet inlet port 85. A secondary blower 100 is placed in line between main blower 95 and bottom tube sheet inlet port 85 and is specifically adapted such that it places no drag on the flow of cooling medium from main blower 95 to bottom tube sheet inlet port 85. Secondary blower 100 is necessarily powered by a power supply which is independent of the main electrical source of power for main blower 95 and is specifically adapted to continue operation in the event of an emergency power failure. Preferably a diesel electric power generation system or a similar prime mover is utilized and is preferably operated even during conventional operation of heat exchanger 10 under normal operating conditions. Any power generation system known to those skilled in the art may be utilized as well. This includes various stored and natural energy sources such as solar power or wind turbine generation. In the preferred embodiment, it is specifically intended that no delay or interruption be encountered in the flow of cooling medium into double tube sheet cooling medium chamber 80 in the event of a sudden or emergency loss of electrical power and flow of cooling medium through main blower 95. An alternative embodiment is also provided in which secondary blower 100 is activated through the detection of loss of cooling medium output from main blower 95 by main blower pressure sensor 105 and that the activation of main blower pressure sensor 105 initiates the flow of cooling medium through secondary blower 100. In either embodiment, the activation of main blower pressure sensor 105, which senses a loss of cooling medium flow from main blower 95, closes cooling medium inlet port valve 110 to prevent the loss of backflow leakage of cooling medium through the inactive portions of the cooling medium flow path during emergency operation.

During both normal and emergency operation, the output of either main blower 95 combined with secondary blower 100, or secondary blower 100 by itself, is passed into bottom tube sheet inlet port 85 which provides fluid communication from both of main blower 95 and secondary blower 100 with bottom tube sheet cooling medium chamber 80. Bottom tube sheet cooling medium chamber 80 provides cooling medium to the lowest portions of process gas tubes 65 surrounded by tube sleeves 148 which are disposed within double bottom tube sheet 35 and further provides additional cooling for the portions of process gas tubes 65 which are directly impinged by the high temperature process gases. The cooling medium is forced from bottom tube sheet cooling medium chamber 80 through bottom tube sheet outlet port 90 which is in fluid connection with cooling medium transport tube 55. Cooling medium transport tube 55 is provided as a conduit for cooling medium between bottom tube sheet cooling medium chamber 80 and the uppermost portion of main cooling medium chamber 12. Cooling medium transfer tube 55 is arranged parallel to process gas tubes 65 and extends longitudinally along the central axis of shell 15. Cooling medium which enters cooling medium transfer tube 55 from bottom tube sheet cooling medium chamber 80 is exhausted at the top of main cooling medium chamber 12 through transfer tube outlet port 60 at a point adjacent to the uppermost surface of main cooling medium chamber 12 formed by top tube sheet 40.

In providing a uniform temperature gradient, it is desirous to avoid the direct impingement of high temperature process gases within the process tubes to the coolest portions of the cooling medium within main cooling medium chamber 12. Similarly, it is desirous to avoid the direct impingement of the relatively cool, fresh cooling medium entering main cooling medium chamber 12 at cooling medium inlet port 30 upon process gas tubes 65, as will be discussed in further detail with further reference to Figure 3. As a result, the cooling medium transferred through cooling medium transfer tube 55 from bottom tube sheet cooling medium chamber 80 is utilized to warm the cooling medium, which is of relatively low temperature, as it enters heat exchanger 10 through cooling medium inlet port 30 during normal operation.

Referring now to Figure 2, an alternative embodiment is provided for the ingress of cooling medium into main cooling medium chamber 12. It is, however, to be specifically noted that the alternative embodiment shown in Figure 2 as well as those shown in Figures 3 and 4 are to be considered interchangeable with the first embodiment shown in Figure 1. Additionally, the elements of the three embodiments may be combined in any fashion such that a heat exchanger may be constructed using any or all of the various elements which comprise the embodiments described herein.

Referring again to Figure 2, a heat exchanger 10 is again provided with a shell 15. Shell 15 defines a main cooling medium chamber 12, which is further defined by top tube sheet 40 and double bottom tube sheet 35. Baffles 50 are again provided to induce the cooling medium entering main cooling medium chamber 12 into a sinuous path which maximizes the surface area interaction of the cooling medium with the process gas tubes 65. In this embodiment, cooling medium inlet port 30A is disposed at the lower portion of shell 15 as is a cooling medium outlet port which is not displayed in the Figure. Cooling medium enters through cooling medium inlet port 30A, as described with reference to Figure 1, but enters from cooling medium inlet port 30A to a cooling medium inlet plenum 112, which surrounds main cooling medium chamber 12 rather than directly to main cooling medium chamber 12. In this embodiment, shell 15 is comprised of two shell walls, being outer shell wall 115 and inner shell wall 120, which are spaced apart from each other forming cooling medium inlet plenum 112. Cooling medium inlet plenum 112 extends substantially along the entire length of shell 15 and is adapted to permit the flow of cooling medium from cooling medium inlet port 30A circumferentially and upwardly around main cooling medium chamber 12 between outer shell wall 115 and inner shell wall 120. The cooling medium then passes through main cooling medium chamber inlet 123 and into main cooling medium chamber 12 where it acts in a manner similar to that as described with respect to Figure 1. The cooling medium inlet plenum 112 serves to provide a forced cooled insulating barrier between main cooling medium 12 and the ambient air external to heat exchanger 10. This reduces the temperature differential between main cooling medium chamber 12 and outer shell wall 115 which provides structural support for the heat exchanger 10 as a whole. While this reduces operationally induced fatigue or failure of the structural components, it also provides warmer cooling medium entering cooling medium chamber 123. This arrangement also reduces the direct impingement of relatively cold cooling medium on process gas tubes 65 adjacent top tube sheet 40, thereby reducing fouling tendency inside the process gas tubes 65.

Referring now to Figure 3, a third embodiment is provided which utilizes a refractory or other insulating material as shell insulation 125. The shell insulation 125 provides an insulating function for the hot process gas tubes 65, cooling medium chamber 12, and the ambient air external to heat exchanger 10 in a more passive arrangement which retains the cooling medium inlet port 30 at the top portion of the main cooling medium chamber 12.

An expansion joint 130 is illustrated in Figure 3 which is utilized to join the process gas tube 65 to top tube sheet 40 in a manner such that relative movement is possible therebetween. Because of differential thermal expansion of the various components of the heat exchanger, including the process gas tube 65 and the shell 15, it is necessary to permit relative movement between the process gas tube 65 and the remainder of the heat exchanger. Similarly, as will be discussed later, certain operational conditions cause differential thermal expansion between the various process gas tubes 65 in and of themselves which necessitates the use of these expansion joints. It is to be specifically noted that the use of the expansion joints is applicable to each of the embodiments and is, in fact, preferred for any installation of the heat exchanger described herein.

A process gas tube shield 135, which is circumferentially mounted adjacent the uppermost portion of process gas tube 65, is adapted to form process gas tube chamber 140 around the uppermost end of process gas tube 65. The boundaries of process gas tube chamber 140 not formed by process gas tube shield 135 are formed by top tube sheet 40 and top baffle 50A. Process gas tube chamber 140 is utilized as an insulating heat barrier between the heating tube 65 and the cooling medium 12, as will be explained herein.

During the passage of process gases through process gas tube 65, certain fouling of process gas tube 65 may occur. During the combustion of the feedstock in the reactor, certain oil-based by-products, as well as unreacted feedstock, passes along with the carbon black solids into the process gas through heat exchanger 10. Furthermore, water quenching of the feedstock reaction introduces moisture as a component to the process gas. As the process gas with its entrained carbon black solids passes through process gas tube 65, any sudden downward change in temperature will cause the condensation of the water or oil portion of the process gas. The condensed liquid then adheres to the interior surface of process gas tube 65 and provides a trap for both the oils and carbon black solids also contained in the process gas. Over time, a build-up of this material can occur on the interior wall of process gas tube 65. This build-up also serves as a heat sink for the passing process gas and further exacerbates the original temperature differential which created the fouling. After a certain period of time, complete blockage of process gas tube 65 may occur, which discontinues the flow of process gas therethrough. At this point, the entire process gas tube 65 is reduced to a temperature which is much lower than the adjacent process gas tubes 65, further disturbing the uniform temperature gradient achieved within the normal operation of the heat exchanger 10 on a systematic basis. It is therefore desirous to not only reduce fouling but also to reduce the conditions of temperature differential which are the primary cause of localized fouling. The avoidance of abrupt localized temperature changes is the basis for the process gas tube chamber 140 in the embodiment shown with respect to Figure 3.

With particular reference to Figure 3 and process gas tube chamber 140, it is desirous to utilize process gas tube chamber 140 wherever necessary to shield process gas tube 65 in an area where relatively cold cooling medium will directly impinge thereupon. Process gas tube chamber 140 may be utilized in connection with all process gas tubes 65 in a heat exchanger 10 or only a portion thereof adjacent to cooling medium inlet port 30, as necessary. Irrespective of their arrangement, process gas tube chambers 140 servo to provide a more gradual temperature gradient between the relatively warm process gas tube 65 and the surrounding cooling medium.

Referring now to Figures 3 and 3A, a similar concept underlies the application of ferrule 145 at the lower portion of process gas tube 65. Ferrule 145 is disposed circumferentially adjacent the lower portion of process gas tube 65 within double bottom tube sheet 35. Ferrule 145 is optionally filled with ceramic ferrule tiller 147 in the interstitial space between ferrule 145 and process gas tube 65. Ferrule 145 together with ferrule filler 147 is adapted to create a heat barrier between the hot process gas and the bottom section of the process gas tube 65 to keep the process gas tube 65 cooler and stronger to withstand the mechanical load at the joint with the double bottom tube sheet 35. These are optionally applied to those process gas tubes 65 adjacent to bottom tube sheet inlet port 85 but are preferably utilized on all of the process gas tubes 65 because of the otherwise relatively high temperature of all of the process gas tubes 65 within the bottom tube sheet cooling medium chamber as compared to the cooling medium therein. This arrangement provides multiple heat barriers between the hot process gas and the double tube sheet cooling medium, to effectively cool the upper bottom tube sheet 75 and the lower bottom tube sheet 70, respectively.

Referring now to Figure 4, the third embodiment of Figure 3 is shown in more detail, more particularly at the top portion of main cooling medium chamber 12. Cooling medium transfer tube 55 provides a conduit for cooling medium from bottom tube sheet cooling medium chamber 80 upwardly to the top portion of main cooling medium chamber 12. Transfer tube plenum baffle 153 is provided which serves as a partial barrier between top tube sheet 40 and the majority of main cooling medium chamber 12, forming transfer tube plenum 150. Transfer tube plenum baffle 153 is provided with a series of holes through which process gas tubes 65 are passed. These holes are slightly oversized, forming a transfer tube plenum orifice 155 circumferentially surrounding each process gas tube 65. These permit the passage of cooling medium from transfer tube plenum 150 into main cooling medium chamber 12 as shown by the arrows of Figure 4. As also shown in Figure 4, the cooling medium which passes upwardly through cooling medium transfer tube 55 is dispersed throughout transfer tube plenum 150 and flows through transfer tube plenum orifices 155 to commingle with cooling medium entering main cooling medium chamber 12 through cooling medium inlet port 30. This arrangement serves to provide, as previously stated, a warmer cooling medium in the space immediately adjacent the cooling medium inlet port 30, warming the upper portions of process gas tubes 65 to reduce fouling and clogging.

## Claims

**1.** A heat exchanger of the type having

an exterior shell,
a cooling medium chamber within said shell having a cooling medium inlet and outlet piercing said shell, and

at least one process gas conduit extending through said cooling medium chamber such that thermal energy passes between cooling medium in said cooling medium chamber and process gas within said at least one process gas conduit,
the heat exchanger comprising:

a) thermal insulation means mounted adjacent said exterior shell for reducing the transfer of thermal energy from said cooling medium chamber to said exterior shell; and
b) shield means mounted adjacent a portion of at least one of said at least one process gas conduit creating a heat barrier between said at least one process gas conduit, a process gas conduit chamber formed by said shield means, and said cooling medium surrounding said at least one process gas conduit and said shield means.

**2.** A heat exchanger as claimed in Claim 1, wherein said thermal insulation means further comprises a cooling medium inlet plenum, said plenum being in fluid communication with an inlet port which permits cooling medium flow therethrough from without the exterior shell to said cooling medium chamber.

**3.** A heat exchanger as claimed in either Claim 1 or Claim 2, wherein said exterior shell further comprises an exterior wall and an interior wall which form a space therebetween.

**4.** A heat exchanger as claimed in any preceding Claim, further comprising a cooling medium chamber top, said shield means being affixed thereto and extending circumferentially outwardly therefrom along said at least one process gas conduit.

**5.** A heat exchanger as claimed in Claim 4, further comprising an expansion joint slidably affixing said at least one process gas conduit and said cooling medium chamber top, permitting relative movement therebetween.

**6.** A heat exchanger as claimed in either Claim 4 or Claim 5, further comprising a cooling medium chamber plenum adjacent said top of said cooling medium chamber and interior thereto.

**7.** A heat exchanger as claimed in any preceding Claim, wherein said shield means forms at least one of said process gas conduit chambers.

**8.** A heat exchanger as claimed in any preceding Claim, further comprising a series of baffles mounted internally to said cooling medium chamber in a spaced apart orientation, such that said cooling medium flows thereby in a nonlinear direction.

**9.** A heat exchanger as claimed in any preceding Claim, further comprising an inlet adapted to provide fluid communication between said cooling medium chamber from without said exterior shell.

**10.** A heat exchanger as claimed in any preceding Claim, further comprising a ferrule mounted within said at least one process gas conduit.

**11.** A heat exchanger as claimed in any preceding Claim further comprising

c) a cooling medium chamber bottom, mounted proximate to an entry point of said at least one process gas conduit to said cooling medium chamber;
d) a secondary cooling medium chamber within said cooling medium chamber bottom;
e) primary cooling medium propulsion means for the introduction of said cooling medium into said secondary cooling medium chamber;
f) secondary cooling medium propulsion means for the introduction of said cooling medium into said secondary cooling medium chamber, adapted to introduce cooling medium into said secondary cooling medium during such time as said primary cooling medium propulsion means is inoperative;
g) fluid communication means for introducing said cooling medium from said secondary cooling medium chamber to said cooling medium

chamber;

12. A heat exchanger as claimed in Claim 11 as dependent on Claim 10, wherein said at least one process gas conduit passes through said secondary cooling medium chamber, said ferrule being mounted within said at least one process gas conduit at a point proximate to said secondary cooling medium chamber.

13. A heat exchanger as claimed in either Claim 11 or Claim 12, wherein said cooling medium chamber bottom further comprises an upper sheet and a lower sheet which form said secondary cooling medium chamber within said shell.

14. A heat exchanger as claimed in any of either Claims 11 to 13, further comprising an outlet port which is adapted to provide fluid communication from said secondary cooling medium chamber to without said shell.

15. A heat exchanger as claimed in any of either Claims 11 to 14, wherein said at least one process gas conduit is mounted such that cooling medium chamber bottom is pierced thereby.

16. A heat exchanger as claimed in Claim 15, further comprising a tube sleeve mounted adjacent to and spaced apart from said at least one process gas conduit within said secondary cooling medium chamber.

17. A heat exchanger as claimed in any of either Claims 11 to 16, wherein said fluid communication means for introducing said cooling medium from said secondary cooling medium chamber to said cooling medium chamber further comprises a transfer tube extending therebetween.

18. A heat exchanger as claimed any of either Claims 11 to 17, further comprising a sensor adapted to detect a cessation of operation of said primary cooling medium propulsion means.

19. A heat exchanger as claimed in Claim 18, wherein said secondary cooling medium propulsion means is engaged upon detection of cessation of operation of said primary cooling medium propulsion means by said sensor.

Fig.1.

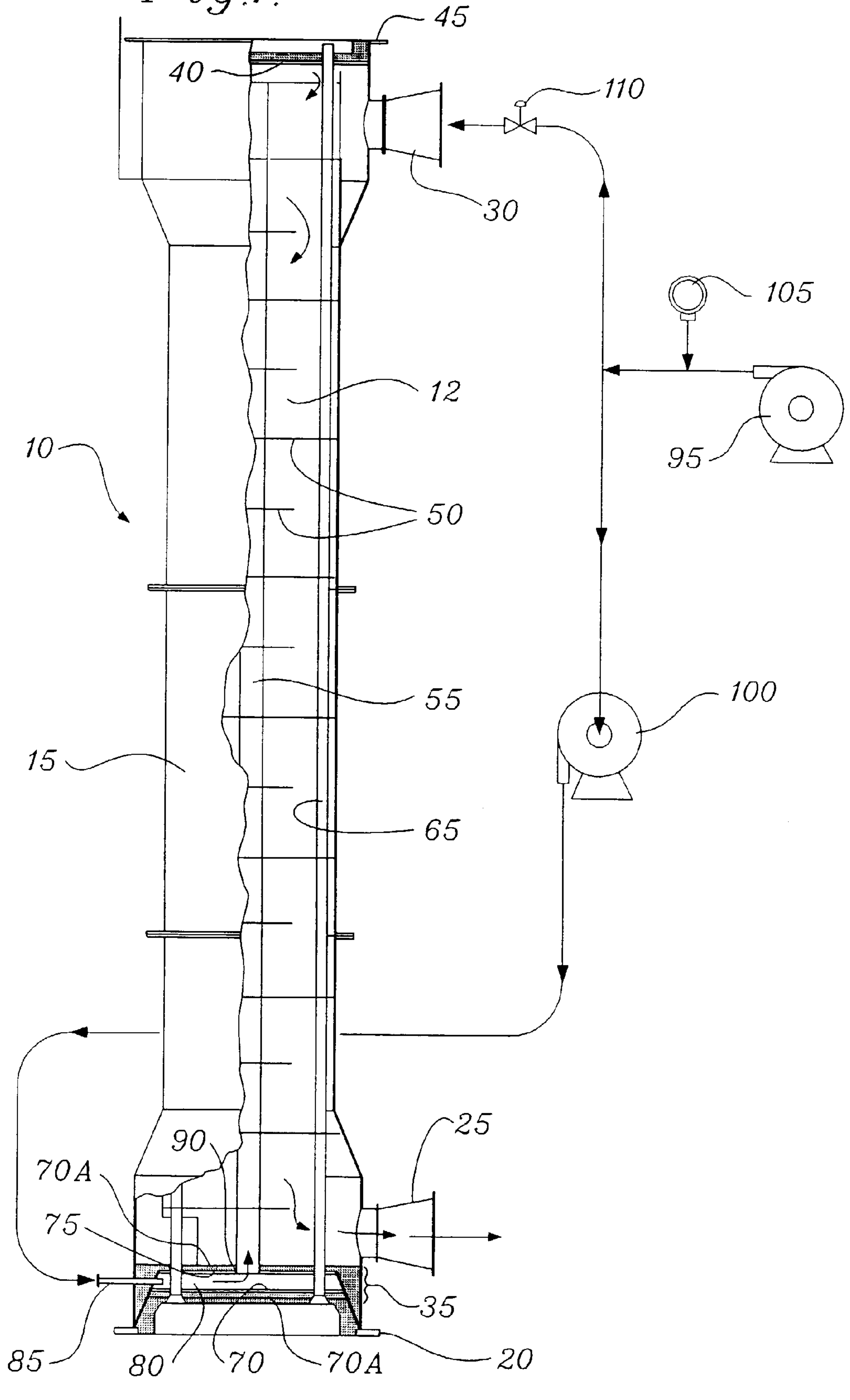
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Fig.2.

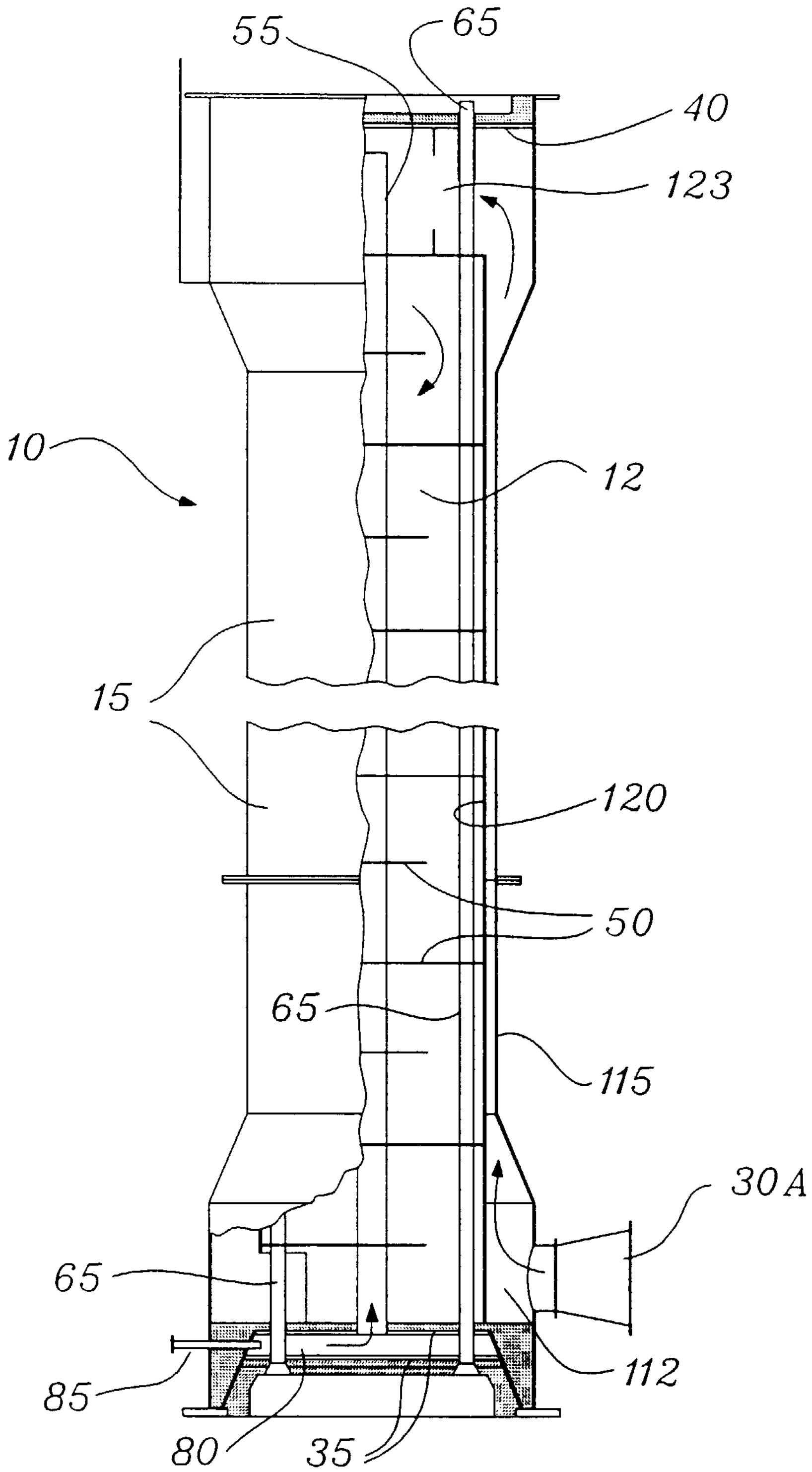

*Fig.3.*

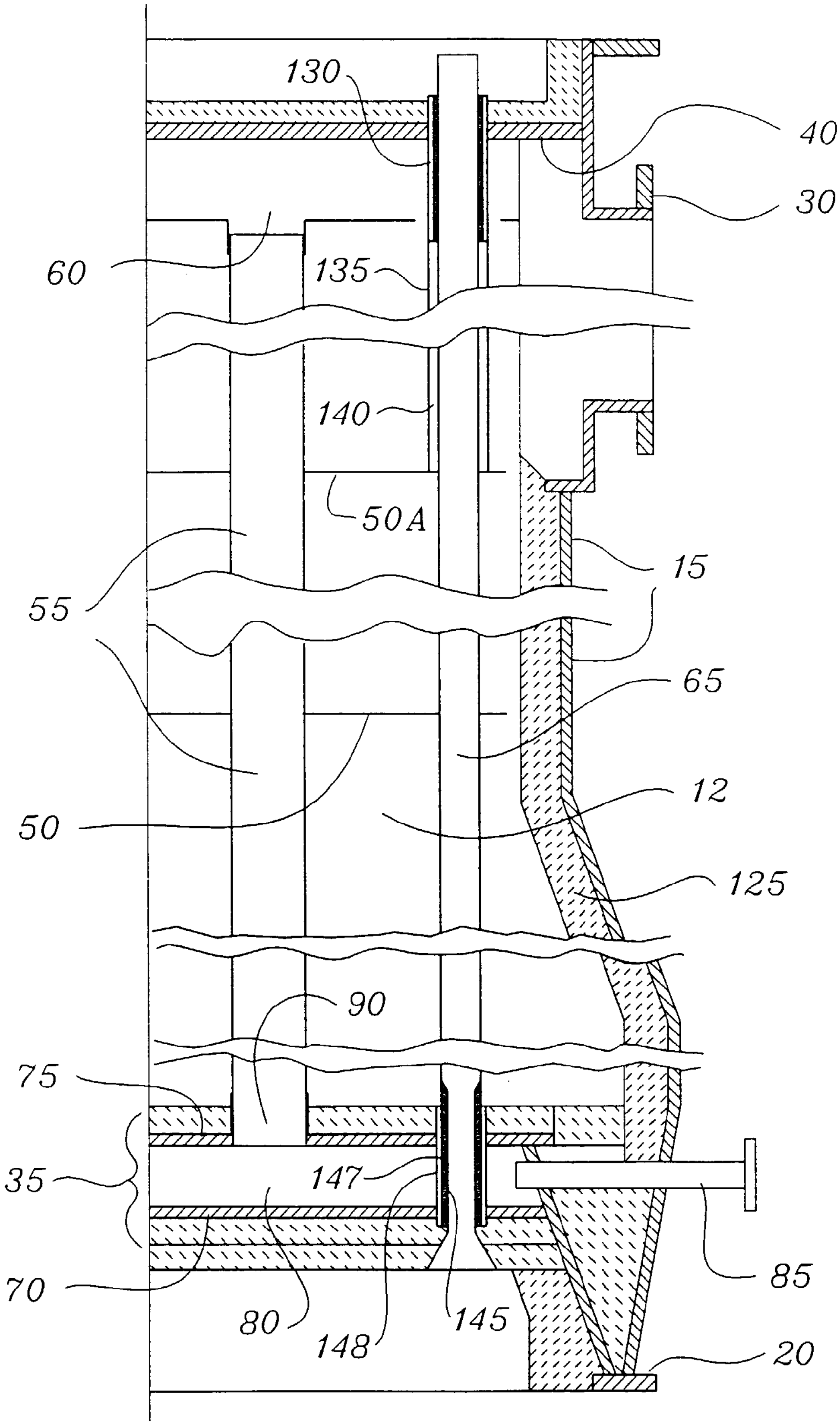
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Fig.3A.

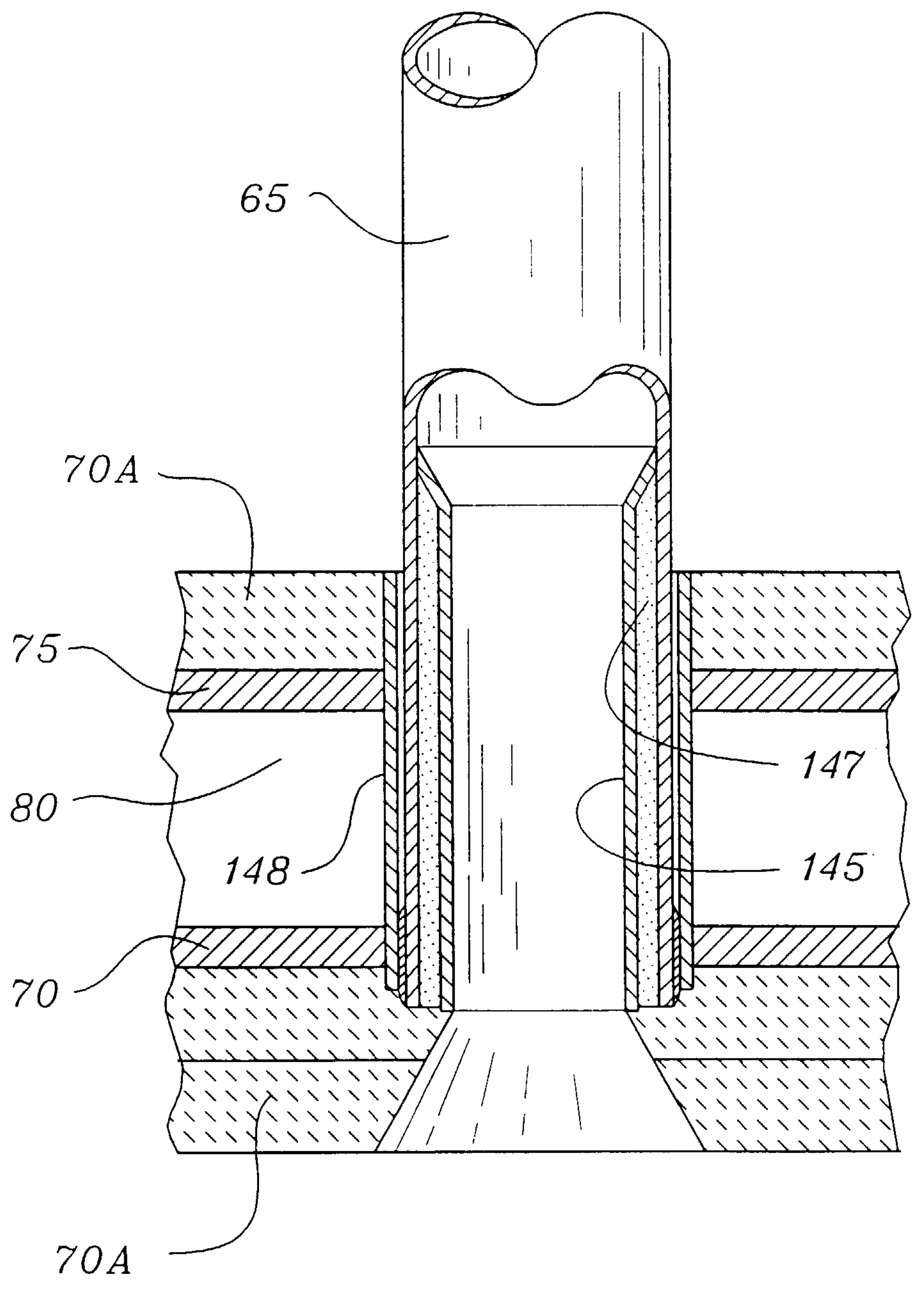

Fig.4.