Serial Number 309,742

Filing Date 8 Oct 1981

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(1)

AD D008971

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LEVEL II

U.S. DEPARTMENT OF THE NAVY
Office of Naval Research
Assistant Chief for Patents
Arlington, Virginia 22217

Fluidized Bed Heat Exchanger/Freezer.

Patent Application, *Filed 8 Oct 81,

3/18/75

Navy Case 65,361

FLUIDIZED BED HEAT EXCHANGER/FREEZER

BACKGROUND OF THE INVENTION

This invention relates to heat exchangers and particularly to the use of a fluidized bed heat exchanger.

Indirect contact heat exchangers of various types are used to transfer heat from one fluid to another where direct contact and mixing or contamination of the heating or cooling fluid and the heated or cooled fluid cannot be permitted. Indirect contact heat exchangers generally use metallic walls to separate the two fluids. In order to promote rapid transfer of heat the two fluids are pumped through the heat exchanger to attain forced convection with turbulent flow. Turbulent flow causes relatively rapid mixing of the cooled or heated layer of liquid at the interface between the metallic wall and the fluid. The fluid often contains material which adheres to the metallic wall and impedes heat flow and/or forms a surface coating beneath which corrosive attack can occur.

Enhancement of turbulence to promote rapid mixing is effected in some heat exchangers by pumping the fluid through tortuous passages of small diameter so that the distance between the boundary layer and the center of the fluid stream is small. As a consequence, the pumping losses are increased. Further, cleaning of the tortuous paths must be conducted periodically to keep the walls of the heat exchanger free of adhering deposits commonly referred to as foulants or scalants. These deposits may be inorganic or organic in nature and may also be of biological origin. Their removal is necessary to maintain the heat exchanger design capacity and may require shut down of equipment.

In prior devices which use particles in heat exchange tubes for cleaning and/or maximizing heat transport qualities, the particles are passed through the entire system and are not maintained in a fluidized bed. In these devices, external separators or traps are required for recovery and reuse of the cleaning particles. In prior devices which continually recirculate particles, the flow phenomena which enhances heat transfer (i.e., turbulence) is not maximized, and may require translation of particle motion in a tangential direction to promote cleaning and/or mixing action.

The present invention is of the type used in the system discussed in U.S. Patent Application Serial No. filed 1981, together herewith.

SUMMARY OF THE INVENTION

The purpose of this invention is to enhance heat transfer in a vertically oriented tubed heat exchanger. Heat transfer is enhanced by two mechanisms; (1) highly turbulent mixing of the fluid so that the boundary layer adjacent to the tube wall rapidly mixes with the fluid bulk stream and (2) constant impinging of particles on the tube wall causes subsequent removal, by peening action, of adherent material which would otherwise impede heat transfer.

It is a primary object of this invention to provide a heat exchanger using a fluidized bed in which recirculation of beads or particles occurs totally within the heat exchanger itself; does not require the use of external separators or traps for recovery and reuse of the cleaning particles, and does not require any translation of particle direction to impart tangential motion for promoting cleaning or mixing action. The fluidized bed particles respond to the drag forces exerted by the process fluid and to one another and the heat exchanger wall in a random manner on a particulate scale, but in a predictable manner on a macro scale. In addition, the present invention uses gentler abrasive action of particles in a vertically oriented tube without requiring a scheme for recirculating the abrasive particles through an erosion prone pump.

The device of the invention is a fluidized bed heat exchanger which has a vertically oriented tube by which a quantity of particles of inert material are contained so that when the fluid is introduced at the bottom of the tube, the particles are displaced in an upward direction and distribute themselves along the length of the vertical tube. The distribution is maintained in a predetermined manner wherein the drag forces imposed on the particles by the upward flowing fluid are balanced by the downward force of gravity. The vertical tube is surrounded by a chamber which contains the heating or cooling medium. The lower portion of the bed containing tube is provided with screens or orifices to prevent loss of bed material when a shutdown occurs. An expansion chamber is provided at the upper end of the tube in order to reduce fluid velocities to less than that necessary to produce lifting drag forces on the particles. Circulation of the particles occurs totally within the heat exchanger.

The invention will be further explained with reference to the accompanying drawings, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a vertical section of preferred embodiment suitable for carrying out the invention, at rest, with the particle bed unfluidized.

Fig. 2 shows the device of Fig. 1 in operation, with the particle bed fluidized.

Fig. 3 is a partial vertical section showing a multi-orifice plate or screen particle bed retainer.

Fig. 4 is a partial vertical section showing a U-tube type of particle bed retainer.

Fig. 5 is a vertical section illustration of a folded U-tube retainer system.

Fig. 6 is a vertical section diagram of a multi-tube embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The fluidized bed heat exchanger/freezer, shown in Figs. 1 and 2, consists of a vertically oriented tube 10 in which is located a bed of uniformly sized beads or particles 12. The particles 12 are retained in the tube 10 by a ball check valve 14, or other means as hereinafter described, at the bottom of the fluidized bed tube.

Fluid forced into the fluid inlet 16 lifts the ball check valve 14 and causes the particles 12 to rise under the influence of drag force on the individual particles, causing them to rise and distribute themselves along the length of the tube 10 when the fluid velocity is maintained by an external pumping system, not shown. To prevent particles from being carried out of the tube 10 a particle trap 17 of enlarged cross sectional area is provided which causes the fluid velocity to drop below that necessary to lift the particles, and the particles fall back into the tube 10. The process fluid flows out through fluid outlet 18. The action of the particles 12 in the fluid flowing through the tube is such that the normally parabolic velocity profile across the tube is flattened and thorough mixing occurs between the fluid in the center of the tube and the fluid at the fluid-tube wall boundary. In addition, because the motion of particles 12 is erratic, impact on the tube walls occurs causing disruption of the fluid-wall boundary layer and a peening or hammering effect great enough to dislodge adherent components on the tube wall. Particle trap 17 provided at the top of the fluidized bed tube can also be provided with a screen 19 or other deflector means in addition to the enlarged cross-section to further impede the escape of particles from tube 10 into fluid outlet 18.

Figs. 1 and 2 show a concentric heating/cooling chamber 20 surrounding the fluidized bed tube 10 and extending over substantially that portion of tube 10 wherein the fluidized particles are active. The heating/cooling chamber 20 serves to conduct the heating or cooling fluid through inlet 22 into the chamber 20 about tube 10 and thence to an outlet 24. By appropriate arrangement of flow piping, not shown, and the provision of suitable particle traps similar to those used in the central tube 10, the heating/cooling fluid can also be provided with a fluidized bed to improve the heat transfer and cleanliness of the heat exchange surface on the outside of fluidized bed tube 10.

Other means, besides a ball check valve 14, for retaining the bed of particles 12 within tube 10 are shown in Figs. 3, 4 and 5. In Fig. 3, an orifice plate or screen 31 is used at the bottom of tube 10 to retain particles 12. Fig. 4 shows the use of a U-shaped inlet section 41 which will trap particles 12. Fig. 5 shows a folded U-tube retainer system where a process fluid inlet tube 51 passes from the top down through the center of the tube 10, to an area just short of the bottom of the tube which is closed. The fluid then rises through tube 10, particle bed 12, and trap 17, and passes out through outlet 52.

In this invention the heat transfer coefficient is high as compared to other shell and tube configurations with low fluid velocities, and the heat transfer coefficient is maintained at a high level over time due to the continuous cleansing action of the fluidized bed particles, whereby fouling, plating, scaling or freezing constituents in the processed fluid are knocked off the heat exchange surface and are carried away by the process fluid. The nature of this cleansing action is such that little, if any, erosion of the particles or the tube wall occurs. Further, the need for scraping or other mechanical or chemical cleaning is obviated.

Turbulent mixing coupled with impact of the bed material (i.e., beads or particles) on the heat exchanger walls causes a thorough mixing of the process fluid and also removes adhering foulants and scalants from the tube walls by peening action and fluid-wall boundary layer disruption.

Use of the present heat exchanger system to obtain high heat transfer coefficients provides an alternative method to; the use of high velocity fluid flow to ensure turbulent mixing of the boundary and bulk streams; the use of scraped surfaces to remove the boundary layer and any adherent materials; the periodic shutdown and cleaning to remove heat flow impeding scalants or foulants;

the periodic use of "pigs", elastic plugs or balls to mechanically brush foulants off; or, the periodic cleaning by chemicals such as may preferentially react with the fouling or scaling material on the heat exchanger surface.

Multiple tubes having fluidized beds may be used in parallel in a tube and sheet configuration with a common vessel, as shown in Fig. 6 and described below, wherein the heating or cooling fluid id directed to flow past and around the fluidized bed tubes. The multiple tube arrangement is provided with a particle trap at the upper end of the tubes, as shown, and with either screens, orifices, U-tubes or ball check valves, as previously described, to retain the individual particle beds whenever process fluid flow through the tubes is disrupted. Otherwise, the particles will fall into the common delivery pipe or inlet header and be lost.

The multi-tube fluidized bed heat exchanger arranged as shown in Fig. 6 includes a single outer heating/cooling chamber shell 61 fitted with several fluidized bed tubes 10 connected to common inlet 63 and a common outlet 65.

In this arrangement process fluid enters the plurality of tubes 10 via inlet 63, passes through the tubes and their respective particle traps 17 to a common outlet 65. The heating/cooling fluid enters the common chamber 61 via inlet 67 and is drawn off via outlet 68.

Fluidized bed heat exchanger designs are dependent upon process heating, heated fluid properties, and geometric constraints. In general, design alternatives include: particles whose diameter ranges from one fifth to one twentieth of the fluidized bed tube diameter; or spheroidal, cylindrical or prism shape particles with specific gravities greater than that of the process fluid in which they are used; and particles made of material which resists corrosion and erosion effects in the ambient thermal and chemical environment. The fluidized bed tube can be made of metal with characteristics suited to resist corrosion and erosion and with high thermal conductivity. In addition, the surface finish of the tube need be no smoother than that found in commercially fabricated tubing.

ABSTRACT

A fluidized bed heat exchanger having a vertically oriented tube through which a quantity of particles of inert material contained therein are displaced when fluid is introduced at the bottom of the tube; the particles are displaced in an upward direction and distribute themselves along the length of the vertical tube, and distribution is maintained in a predetermined manner wherein the drag forces imposed on the particles by the upward flowing fluid are balanced by the downward force of gravity. The vertical tube is surrounded by a chamber which contains a heating or cooling medium. The lower portion of the bed containing tube is provided with means to prevent loss of bed material when a shutdown occurs, and an expansion chamber is provided at the upper end of the tube to reduce fluid velocities to less than that necessary to produce lifting drag forces on the particles.

TITLE: FLUIDIZED BED HEAT
EXCHANGER/FREEZER
INVENTOR: ROBERT S. CHAPLER
ATTY: J. M. ST. AMAND N.C.- 65,361
SHEET 1 OF 3

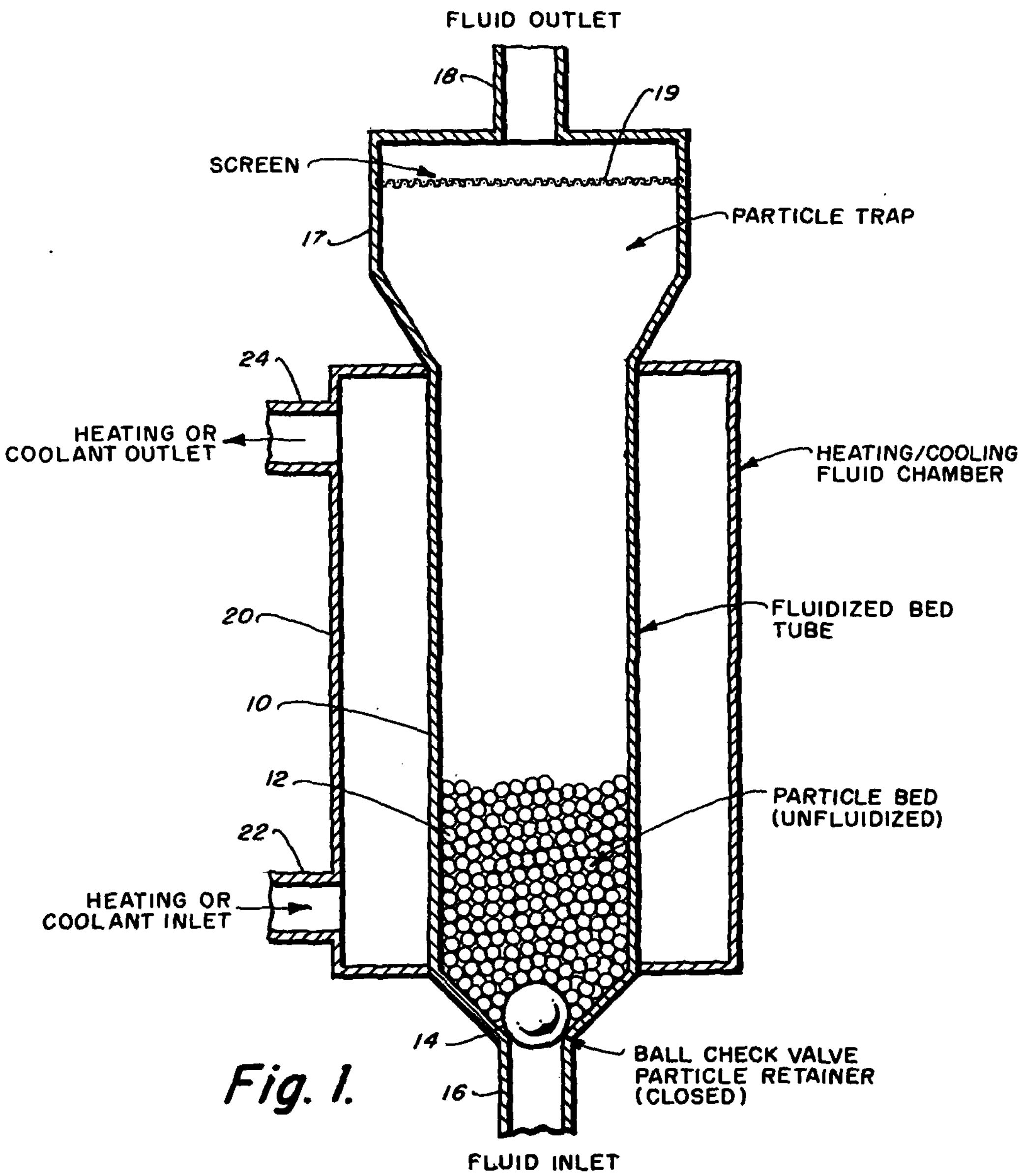

Fig. 1.

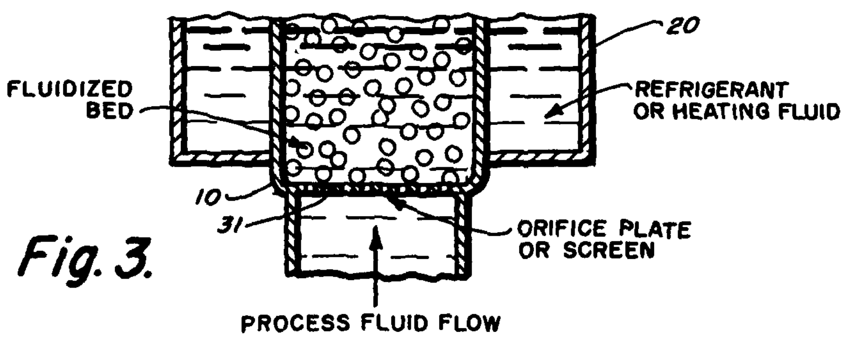

Fig. 3.

TITLE: FLUIDIZED BED HEAT EXCHANGER/FREEZER
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SHEET 2 OF 3

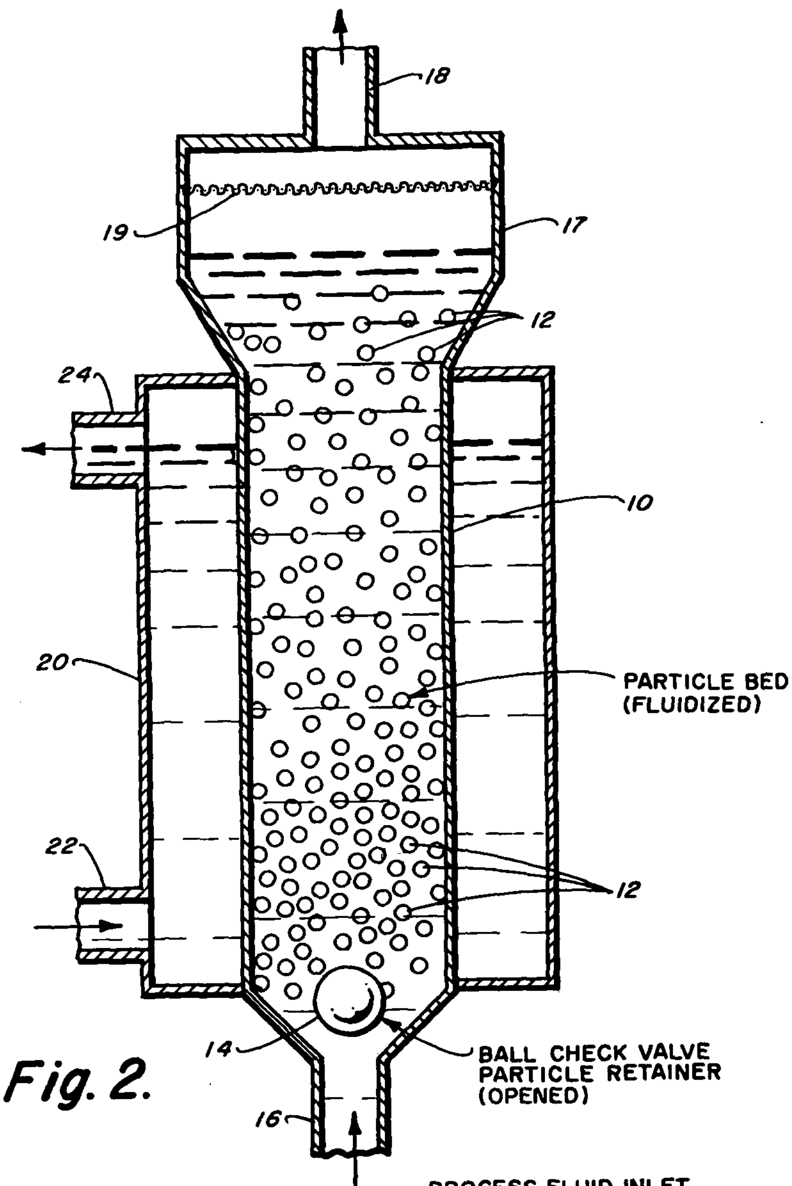

Fig. 2.

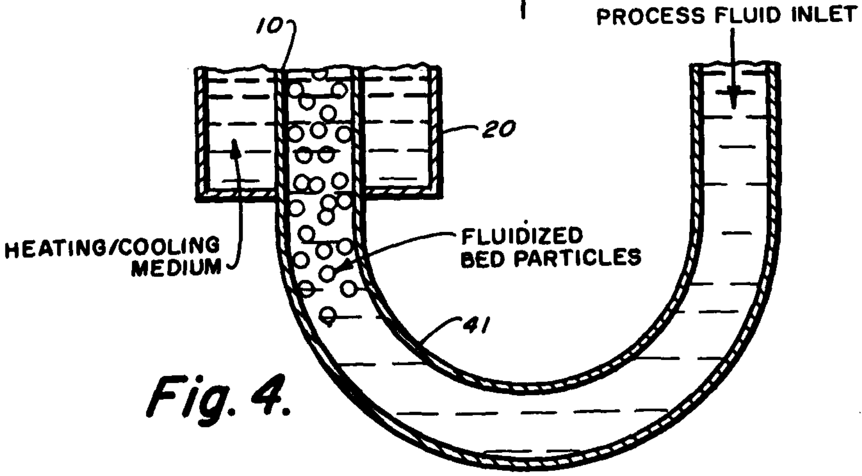

Fig. 4.

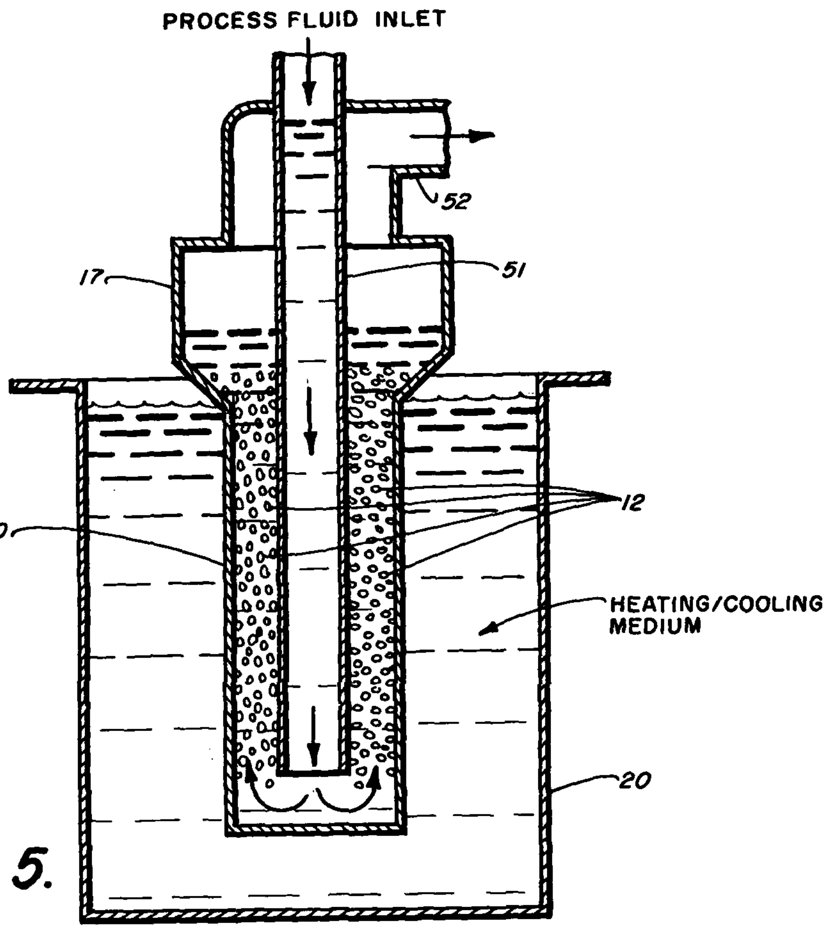
PROCESS FLUID INLET
52
17
51
12
10
HEATING/COOLING
MEDIUM
20

Fig. 5.

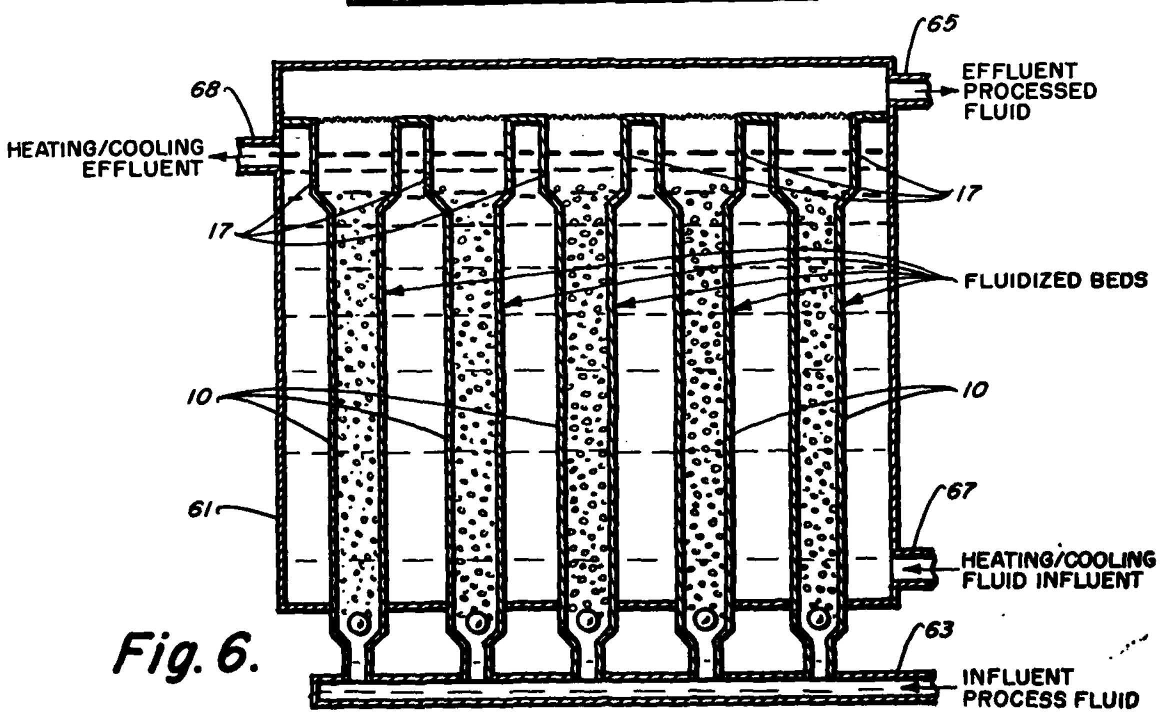
65
EFFLUENT
PROCESSED
FLUID
68
HEATING/COOLING
EFFLUENT
17
17
FLUIDIZED BEDS
10
10
61
67
HEATING/COOLING
FLUID INFLUENT
63
INFLUENT
PROCESS FLUID

Fig. 6.