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AL LT LV MK RO SI(30) Priority: **10.06.1997 US 872318**(71) Applicant: **KOMAX SYSTEMS, INC.****Wilmington, CA 90744 (US)**(72) Inventor: **King, Leonard Tony****Long Beach, California 90807 (US)**(74) Representative: **Driver, Virginia Rozanne et al****Page White & Farrer****54 Doughty Street****London WC1N 2LS (GB)**(54) **Static mixer-heat exchanger**

(57) A device for effecting transfer from a first fluid medium to a second fluid medium and for enhancing mixing and uniform distribution of the second fluid medium within the confines of a conduit. The device includes providing a core pipe (31,47,55) for receiving the first fluid medium and a series of helically wound tubes

(32-38,48,54) in fluid communication with the core pipe (31,47,55) along the longitudinal axis of the conduit. The second fluid passes within the conduit and is mixed by virtue of the static mixing effect of the helically wound tubes (32-38,48,54) and engages in heat transfer as a result of the intimate contact between the second fluid, the core pipe and the helically wound tubes.

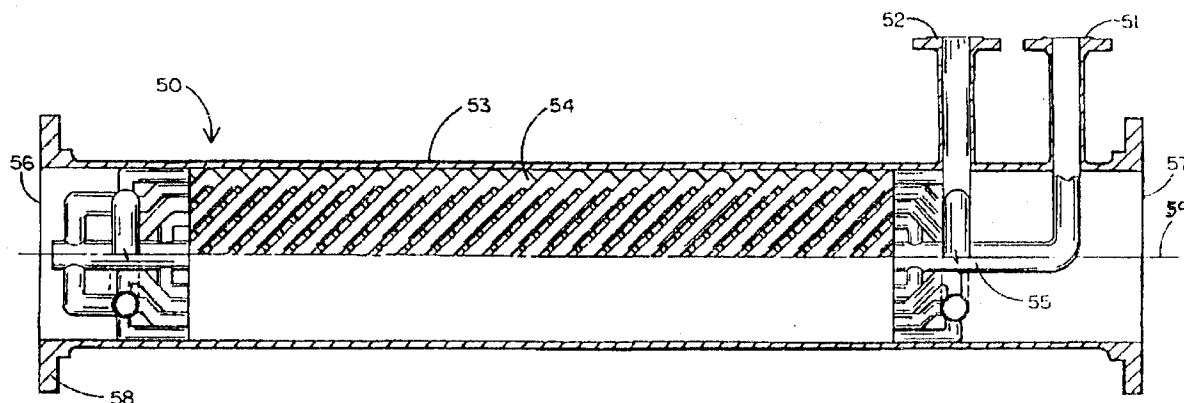


FIG. 5a

EP 0 884 549 A2

DescriptionTECHNICAL FIELD OF THE INVENTION

5 The present invention is directed to a device for effecting heat transfer from a first fluid medium to a second fluid medium and for enhancing mixing and uniform distribution of the second fluid medium within the confines of a conduit.

BACKGROUND OF THE INVENTION

10 It is notoriously well known in the processing of fluid streams to employ static mixers and heat exchangers as enhancements in promoting product uniformity and adjusting product temperature. Mixers can contain active elements such as paddles and rotors although it is quite common to provide static elements whereby the turbulent flow of the fluids in and around these elements enhance fluid mixing without the need for moving parts which inherently add to the cost of the mixing operation both in terms of power requirements and labor intensive maintenance procedures.

15 Many static mixers rely on a mixing element configurations which presents a set of interstices to the product flow. Elements of this type divide a fluid stream along the mixing path and recombine locally created substreams into a more homogeneous mixture.

It is further common to contain within a conduit a series of tubes or pipes to effect heat transfer between a product stream and a fluid medium contained within tubes in contact with the flow of fluid product.

20 It has long been known that reduction of the internal film coefficient of the moving fluid product as it contacts the tubes or pipes of a conventional tube and shell heat exchanger is advantageous for reduction of the internal film coefficient enhances heat transfer. In this regard, reference is made to FIG. 1 showing a conventional tube and shell heat exchanger 10. In this configuration, product enters orifice 13 at the upstream end of the heat exchanger and exits at orifice 14. Heat transfer medium enters the heat exchanger at orifice 16 and travels in a counterflow direction within

25 the heat exchanger to exit at orifice 15. Devices such as metal strip 17 are frequently installed in the tubes or pipes of such conventional tube and shell heat exchangers in order to enhance the internal film coefficient at its inside tube wall. Such devices can be twisted strips of metal or static or motionless mixers. As noted, the major resistance to heat transfer is due to what is called the film coefficient at the inside wall of the tubes where the product velocity is low. The cooling or heating medium flows over the outside of the tubes in area 12. It has been determined that the improvement

30 in heat transfer obtained by tube inserts for laminar flow applications is usually in the range of 2 to 5 times. However, the use of such devices significantly increases the pressure drop experienced and thus one using such expedients must pay a price.

FIG. 2 shows yet another conventional device employed as both a heat exchanger and static mixer. Device 20 relies upon a different design concept than the conventional tube and shell heat exchanger of FIG. 1 in that the product of interest is introduced within conduit 23 at upstream end 21 while the cooling/heating medium is contained within

35 tubes 24. It is further noted that the linear tube structure shown as element 11 of FIG. 1 is replaced by tube structure 24 in the form of a static mixer built of tubing instead of sheet metal. However, it has been determined that the device shown in FIG. 2 does not provide a good utilization of the exchanger shell available volume, less, in fact, than the conventional tube and shell heat exchanger.

40 It is thus an object of the present invention to provide a device in which a moving fluid product is both mixed and subject to heat transfer as a result of its contact with a fluid medium employed for that purpose.

It is a further object of the present invention to accomplish the above-referenced objects while, at the same time, improving the efficiency of such a device dramatically as compared to devices offered for this purpose commercially. These and further objects of the present invention will become more readily apparent when considering the following

45 disclosure and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a prior art depiction, in cutaway plan view, of a conventional tube and shell heat exchanger.

50 FIG. 2 is a perspective cutaway view of a modified tube and shell heat exchanger which represents the current state of the art.

FIGs. 3A to 3C depict, in plan view, the step-by-step construction of the presently configured invention.

FIG. 4 is a cutaway plan view depicting employment of the structure shown in FIG. 3 within a conduit for accomplishing the goals of the present invention.

55 FIG. 5 is a cutaway plan view depicting in more detail than as shown in FIG. 4 the structure of the present invention as its preferred embodiment.

FIG. 6 is a further cutaway plan view of yet another embodiment of the present invention.

BRIEF DESCRIPTION OF THE INVENTION

The present invention is directed to a device for effecting heat transfer from a first fluid medium to a second fluid medium and for enhancing mixing and uniform distribution of the second fluid medium within the confines of a conduit. The device comprises a conduit having a cross section and longitudinal axis. An inlet for introduction of the first fluid is provided within the conduit and an outlet for passing the first fluid from the conduit is further provided. A core pipe is located at the approximate longitudinal axis of the conduit, the conduit having an upstream opening for receiving the second fluid and a downstream opening for passing the second fluid from it.

A series of tubes are provided. Each of the tubes is in fluid communication with the first fluid inlet and outlet, the series of tubes comprising at least two tubes, each of which are helically wound around the core pipe and each of which are configured to carry the first fluid medium.

DETAILED DESCRIPTION OF THE INVENTION

As noted previously, the present invention is directed to a device for effecting heat transfer from a first fluid medium to a second fluid medium and for enhancing mixing and uniform distribution of the second fluid medium within the confines of a conduit. This can perhaps best be visualized by referring to FIG. 4. Device 40 is shown as consisting of conduit 41 having a cross section and longitudinal axis 42. The conduit is provided with an inlet 43 for introduction of the first fluid within conduit 41 and an outlet 44 for passing the first fluid from the conduit. The conduit further is provided with inlet 45 for the introduction of the fluid product as well as downstream exit 46 for passing the product fluid from conduit 41.

Referring further to FIG. 4, the device is provided with core pipe 47 which is depicted as element 31 in FIG. 3. As shown, the core pipe is located approximately at longitudinal axis 42. The device is further provided with a series of tubes which, for the sake of simplicity, are not shown within FIG. 4 but which are contained in area 48. As will be discussed in more detail, these tubes are helically wound around core pipe 47 and each are configured to carry the first fluid medium.

In operating the device of FIG. 4, it is noted that the heating or cooling medium enters at 43 at the upper lefthand flange and flows via an outer jacket 49 to the output end of the conduit where it enters core tube 47. The medium flows in core pipe 47 through the center of the conduit and to the end of the winding assembly where the product to be heated or cooled enters at 45 to flow over the outer surface of the tube assembly contained within area 48. Appropriate tube connections take the first fluid from the core tube and distribute it to the winding assembly. This first fluid flows through an inlet to the pipe and on to the tube assembly where another set of tube connections at the downstream end of the winding assembly join the pipe providing for first fluid exit at 44. In the embodiment shown in FIG. 4, the downstream end of core pipe 47 is plugged and rests against retainer cross 50 welded or otherwise connected to the conduit housing. Retainer cross 50 prevents the tube assembly from extrusion out of the housing by forces produced by pressure drop across the tube assembly. As per standard practice, flanges are provided at the extremities of the conduit so that the tube assembly can be disconnected to allow the entire structure to be removed as required for inspection, cleaning and repair.

The tube windings to be contained within area 48 of FIG. 4 will now be described in some detail.

The addition of multiple and consecutive helically wound layers of tubing upon core pipe 31 is shown in consecutive FIGs. 3A through 3C. Specifically, FIG. 3A shows a single tube 32 wound in a helical fashion about core pipe 31. Additional windings are shown in FIG. 3B wherein tubes 32, 33 and 34 are shown wound about core tube 31 each bearing the same sign. Finally, FIG. 3C depicts core tube 31 having tube windings 32, 33 and 34 of one sign and tubes 35, 36, 37 and 38 also helically wound about core tube 31 of an opposite sign.

FIG. 3C shows the preferred manner in which the various series of tubes are wound about a core pipe. Specifically, as noted, each of the tubes being helically wound about the core tube are wound at equal and uniform angles to the longitudinal axis of the conduit/pipe. In addition, each of the tubes is composed of a series of helical turns, each turn being approximately 45° to the longitudinal axis. As such, where each of the tubes are of a helical sign opposite to an adjacent tube, interstices are created between adjacent tubes of approximately 90°.

FIG 5A depicts the present invention in somewhat more detail than that shown in FIG. 4. Structure 50 is comprised of conduit 53 having flanged end connectors 58. In this depiction, which is shown as an end view in FIG. 5B, a first fluid medium is introduced at port 51 and travels countercurrent to the flow of the second fluid entering conduit 53 at 56 and exiting the conduit at end 57. As such, the first fluid exits device 50 at 52, thus completing its countercurrent path.

The first fluid, which acts as a heat transfer medium, is introduced to core pipe 55 whereupon the first fluid branches out into a series of helically wound tubes 54, each of which being ideally wound about core pipe 55 in a series of helical turns each of which being approximately 45° to longitudinal axis 59 so that adjacent tubes create consistent 90° interstices as an enhancement to the fluid mixing of the second fluid medium passing within conduit 53. When the helical turns of the windings are selected to be uniformly 45° to the longitudinal axis of core pipe the number of interstices per

unit volume remains constant. This will provide maximum utilization of the volume in terms of mixing divisions for a given pressure drop.

As yet a further embodiment, reference is made to FIG. 6 wherein device 60 consisting of conduit 61 having edge flanges 69 is shown both in plan view in FIG. 6A and as an end view in FIG. 6B. In this embodiment, first fluid acting as a heat transfer medium is introduced through inlet 64 and exits from the system at outlet 65. As in FIG. 4, the first fluid proceeds to fill annular space 62 contiguous to the inner wall of conduit 61. In order to improve the heat transfer coefficient, a number of baffles 63 are provided in annular space 62. The present embodiment differs from those previously described in that first heat transfer fluid introduced via inlet 64 proceeds only through helically wound tube 68 and not core pipe 70. In fact, core pipe 70 acts only as a mandrel upon which helically wound tubing 68 is applied.

In appreciation of the example which follows, the recited terms have indicated meanings:

L = overall length of mixer/reactor

d_c = outside diameter of core pipe

P_n = pitch of one turn of tube layer $n = \Pi/\sqrt{2} (R+1)$

N_n = number of turns per start in layer $n = L/P_n$

Total length of one tube start of layer $n = L\Pi/2^{0.5}$ for all starts in all layers

D = ID of mixer housing

$L_T = nL/\sqrt{2}$

d_t = tubing diameter of the winding

S_n = number of starts in layer $n = (R + n)$

$R = d_c/d_t$

As noted previously, as a preferred design goal, all helical windings are configured to intersect each other at an angle of 90° (45° to the longitudinal axis of the core pipe). To accomplish this, the number of tubing starts must be increased as layers are added.

As a further design goal it is desirable to minimize the ratio R as this minimizes the number of starts per layer of windings and minimizes the number of end connections to the starts at the input and output ends of the parallel connected tubes. The ratio R and d_t determine the pitch of each start. For example, the pitch of each layer starting from layer number 1:

$$PL_1 = (\Pi/\sqrt{2})(R+1)d_t$$

$$PL_2 = (\Pi/\sqrt{2})(R+2)d_t$$

$$PL_3 = (\Pi/\sqrt{2})(R+3)d_t$$

... etc. and the number of starts for each layer will be (R+1) for the first layer, (R+2) for the second layer, (R+3) for the third one and so on.

Noting that in most instances, the present invention will involve values of R within the range of 1 to 3. With this in mind, the following calculations were made.

	Layer 1	Values for R = 1		Values for R = 2		Values for R = 3	
		Pitch	Starts	Pitch	Starts	Pitch	Starts
5	1	$4.44d_t$	2	$6.66d_t$	3	$8.88d_t$	4
	2	$6.66d_t$	3	$8.88d_t$	4	$11.10d_t$	5
10	3	$8.88d_t$	4	$11.10d_t$	5	$13.33d_t$	6
	4	$11.10d_t$	5	$13.33d_t$	6	$15.55d_t$	7
	5	$13.33d_t$	6	$15.55d_t$	7	$17.77d_t$	8
15		Total starts = 20 Tube surface area = $140L_t d_t$ Outside Dia. = $11d_t$ Shell area = $\pi 11d_t L$ Shell vol. = $\pi (11d_t)^2 L$		Total starts = 25 Tube surface area = $175L_t d_t$ Outside Dia. = $12d_t$ Shell area = $\pi 12d_t L$ Shell vol. = $\pi (12d_t)^2 L$		Total starts = 30 Tube surface area = $210L_t d_t$ Outside Dia. = $13d_t$ Shell area = $\pi 13d_t L$ Shell vol. =	
20		$\pi (13d_t)^2 L$ Area/vol. = $0.46/d_t$		Area/vol. = $0.47/d_t$		Area/vol. = $0.47/d_t$	
	Comp. with pitch ¹ shell & tube exchanger	54 tube $1\frac{1}{4}$ " ∇ pitch Area/vol. = $0.39/d_t$		64 tube $1\frac{1}{4}$ " ∇ pitch Area/vol. = $0.39/d_t$		78 tube $1\frac{1}{4}$ " ∇ Area/vol. = $0.39/d_t$	
25							

¹ 78 tube $1\frac{1}{4}$ " ∇ pitch means compare with a conventional shell and tube exchanger with 78 tubes on a triangular $1\frac{1}{4}$ inch pitch where $d_t = 1.0$ ". Assuming a wall thickness of 0.065 inches, values taken from Chemical Engineering Handbook, 3rd Ed.

In the above-recited examples, it was assumed that all tubes were 1.00" in diameter with a wall thickness of 0.065". In practicing the present invention, the surface area per unit volume advantage over conventional shell and tube units is approximately 20%. The area per unit volume advantage is 24% for tube wall thickness of 0.078 inches. In addition, the present invention provides a static mixing system created by the helical windings of the tubes which will typically provide a heat transfer factor of two to five times for a net total heat transfer improvement of three to ten times that of a standard shell and tube exchanger.

In addition to the heat exchange area increase provided by the helical windings there is yet another advantage. The static mixer effect is achieved at the tube external surfaces which is known to enhance heat transfer by a significant factor of three or more. This is achieved without the manufacturing complication and cost of installing mixing elements in tubes.

While the principles of this invention have been discussed above in connection with several alternative embodiments, it should be understood that numerous other applications of the principles may be found by those of ordinary skill in this art. Accordingly, the invention is not limited to the specific exemplary applications described above but may be employed in any situation in which a fluid is intended to be mixed and undergo simultaneous heat transfer.

Claims

1. A device for effecting heat transfer from a first fluid medium to a second fluid medium and for enhancing mixing and uniform distribution of said second fluid medium within the confines of a conduit said device comprising a conduit having a cross section and longitudinal axis, an inlet for introduction of said first fluid within said conduit, an outlet for passing said first fluid from said conduit, a core pipe located at the approximate longitudinal axis of said conduit, said conduit having an upstream opening for receiving said second fluid and a downstream opening for passing said second fluid, a series of tubes, each of which being in fluid communication with said first fluid inlet and outlet, said series of tubes comprising at least two tubes, each of which being helically wound about said core pipe and each of which being configured to carry said first fluid medium.

2. The device of claim 1 wherein each of said tubes being helically wound about said core tube are wound at equal and uniform angles to said longitudinal axis so that interstices created by said helically wound tubes are substantially constant along the length of said core pipe.

5 3. The device of claim 2 wherein each of said tubes is composed of a series of helical turns, each turn being approximately 45° to said longitudinal axis.

10 4. The device of claim 2 wherein each of said tubes are of a helical sign opposite to the sign of said tubes adjacent thereto.

5. The device of claim 4 wherein each of said tubes is composed of a series of helical turns, each turn being approximately 45° to said longitudinal axis so that each turn of a tube forms an interstice with a turn of an adjacent tube of approximately 90°.

15 6. The device of claim 1 wherein said first fluid is directed pass through said core pipe as well as through said series of tubes.

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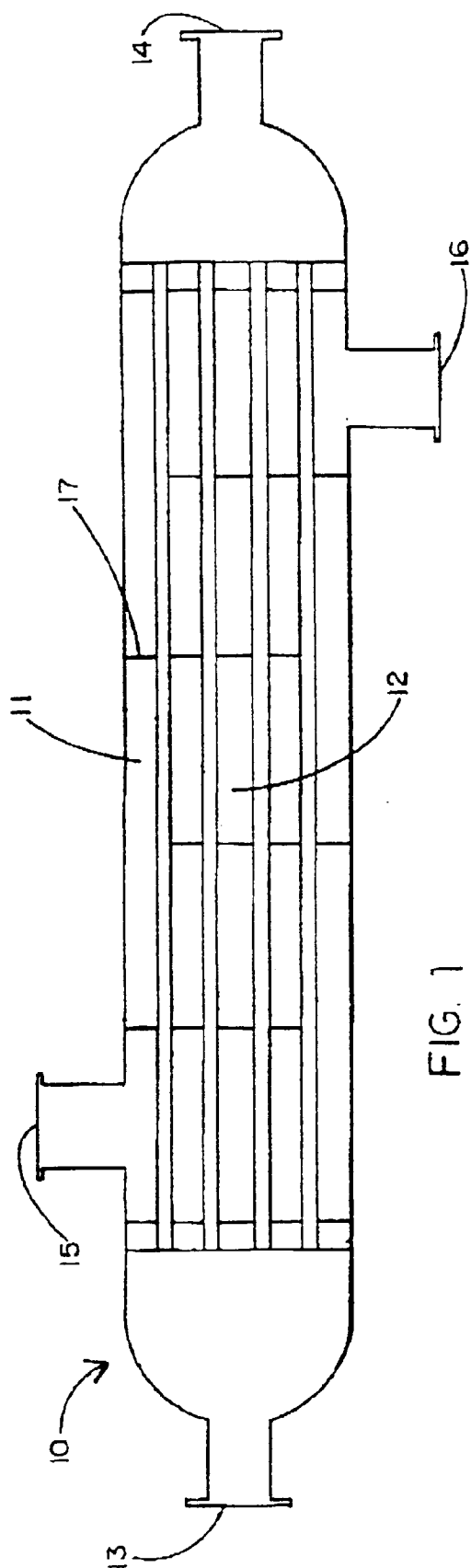


FIG. 1
PRIOR ART

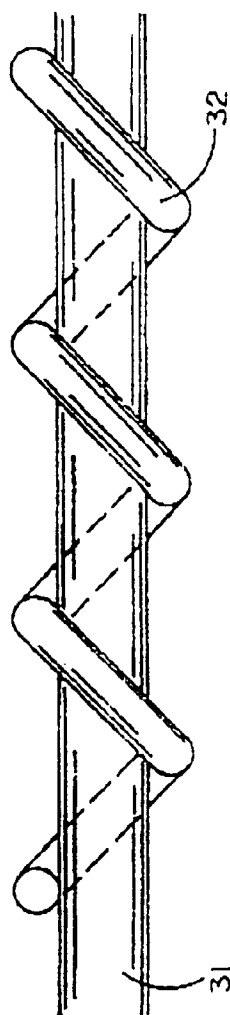
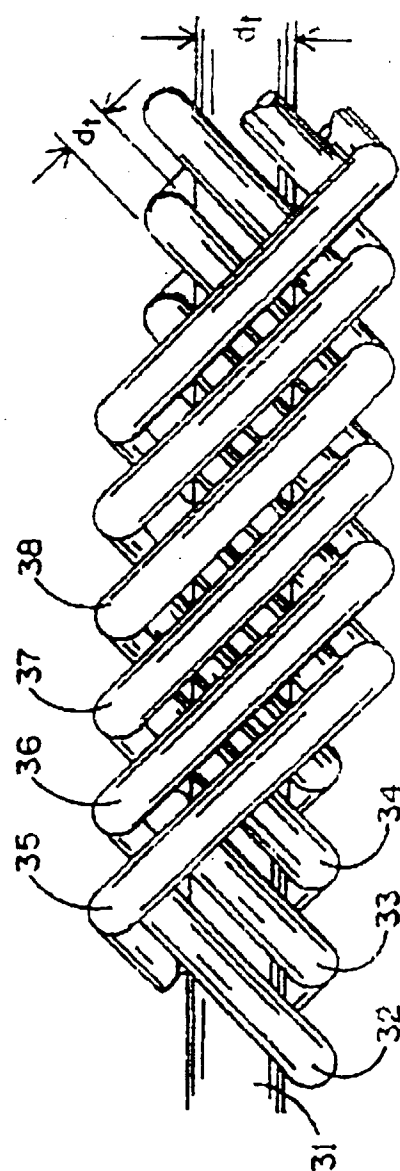
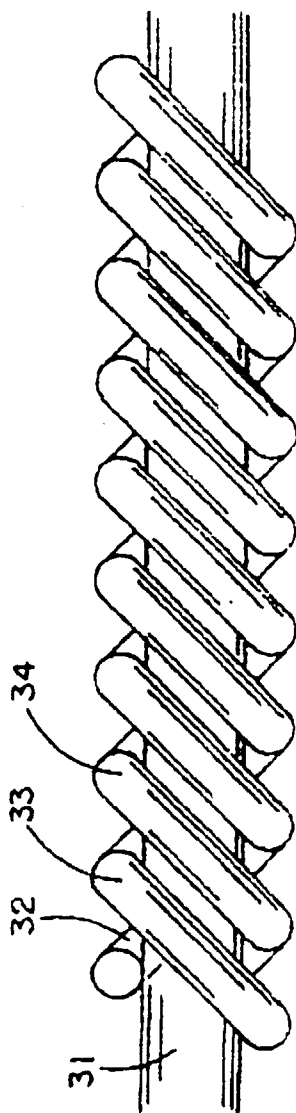
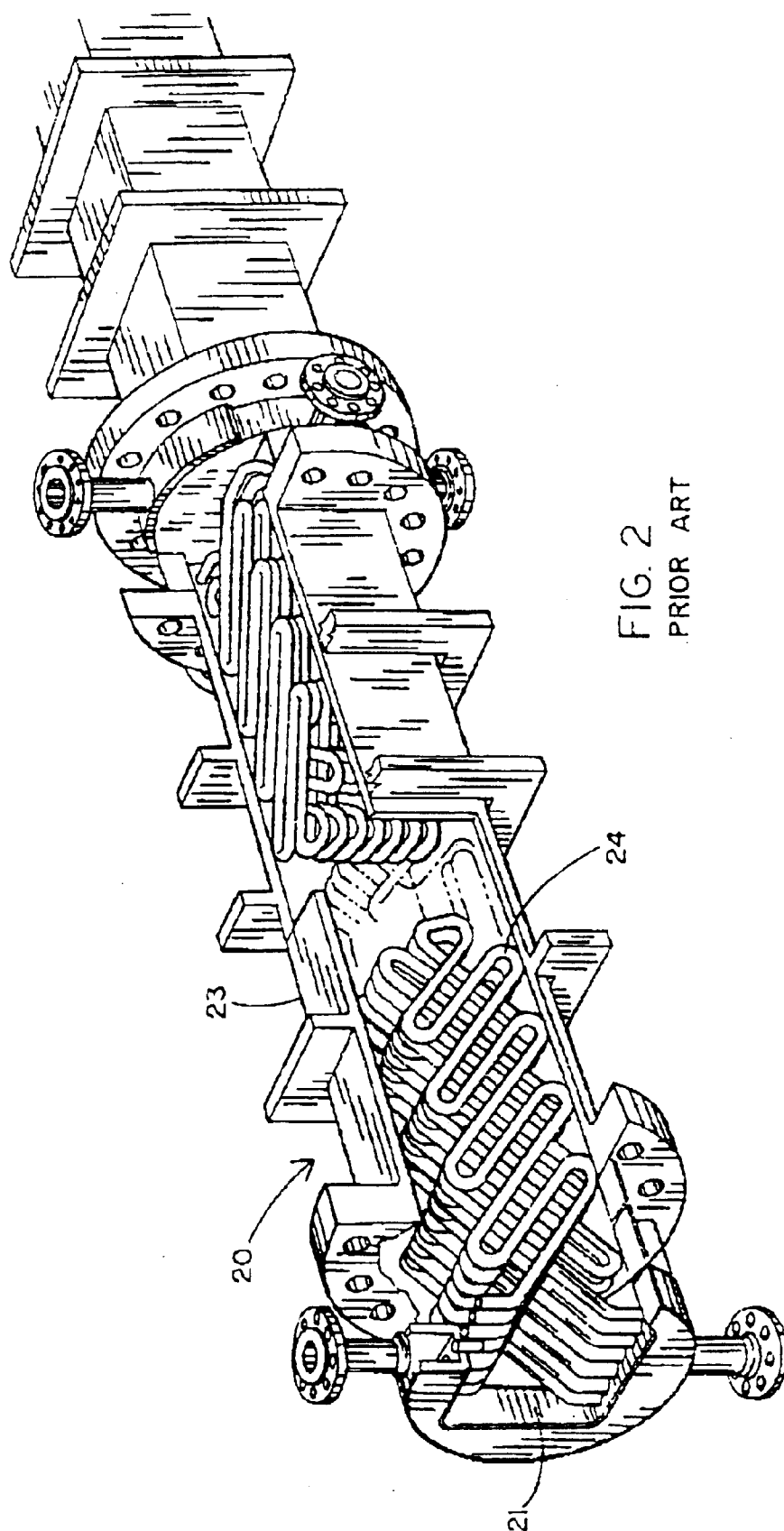


FIG. 3a





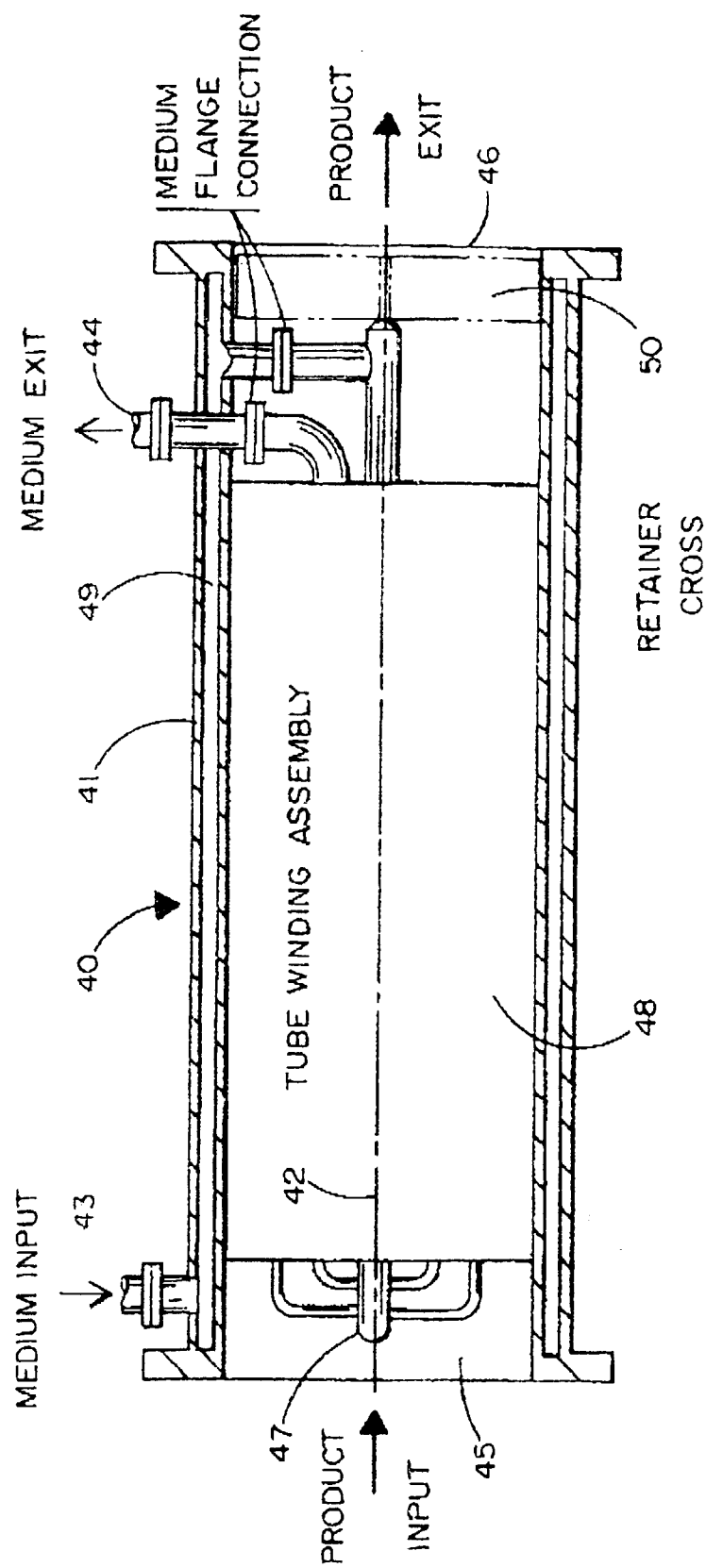


FIG. 4

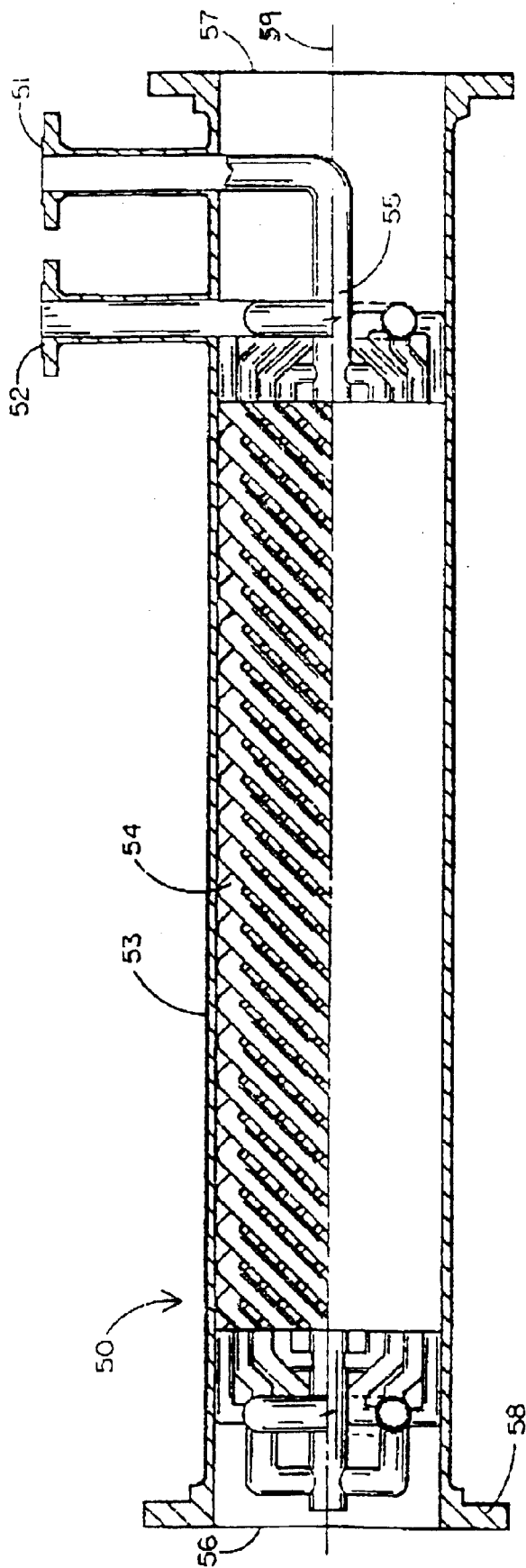


FIG. 5a

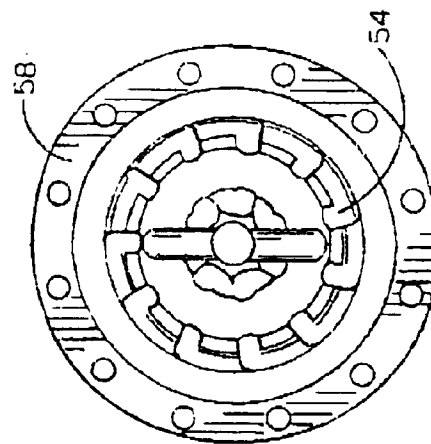


FIG. 5b

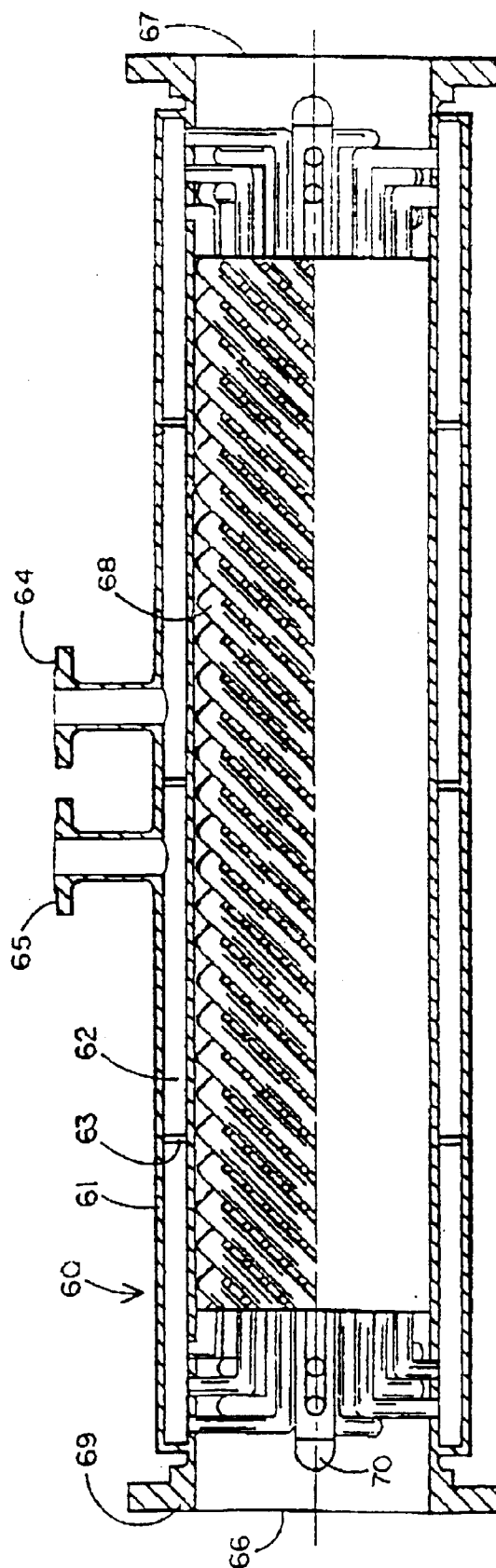


FIG. 6a

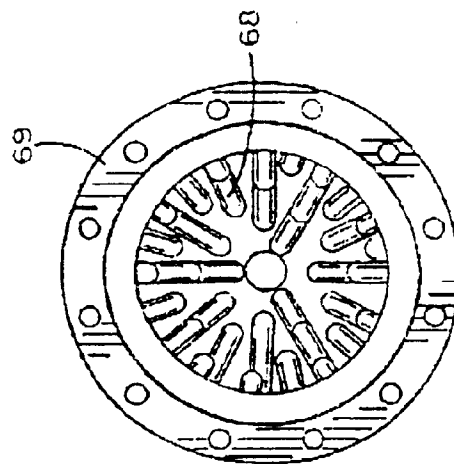


FIG. 6b