

Dec. 29, 1953

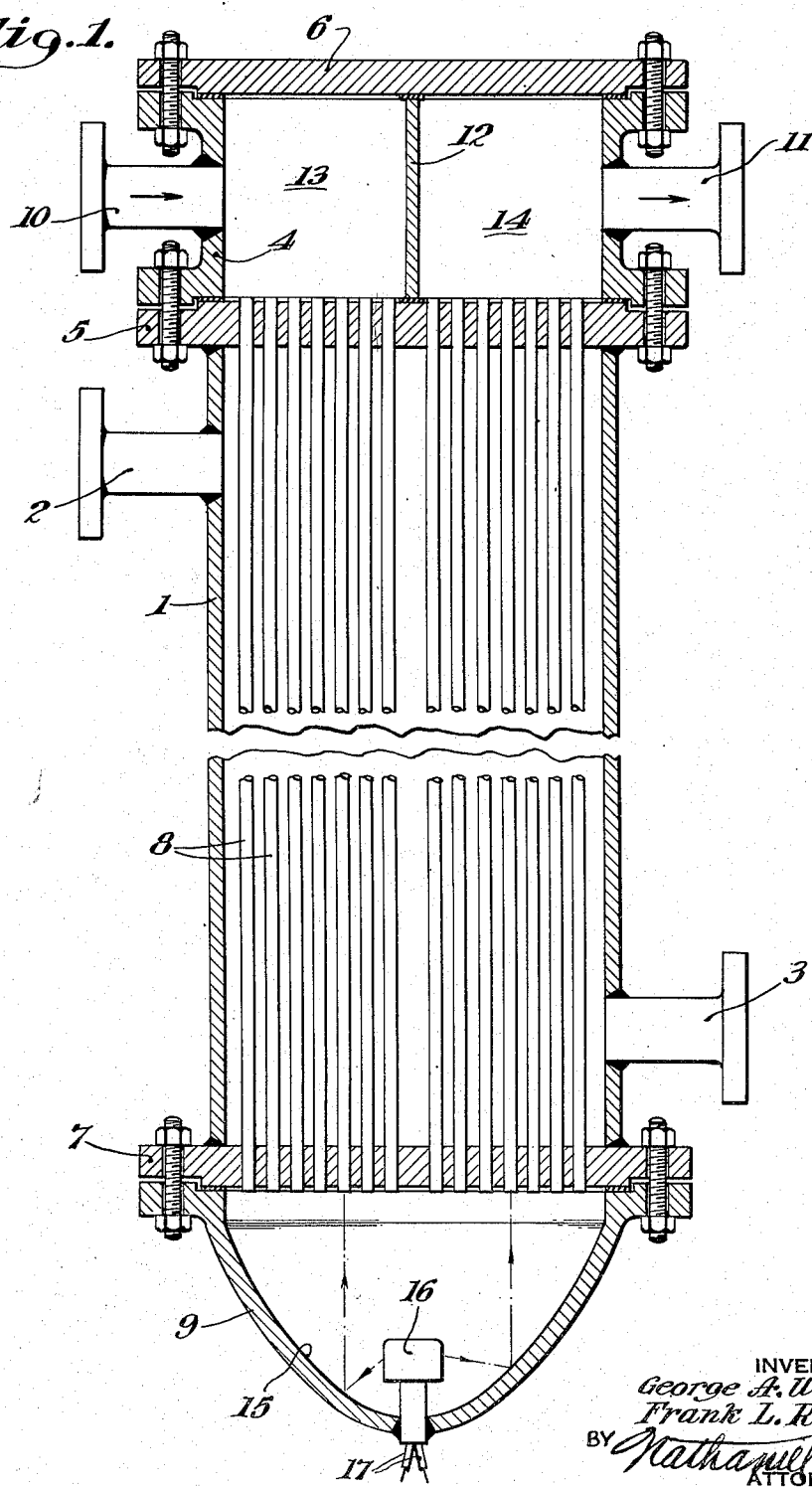
G. A. WORN ET AL
METHOD AND APPARATUS EMPLOYING SONIC
WAVES IN HEAT EXCHANGE

2,664,274

Filed Dec. 22, 1951

2 Sheets-Sheet 1

Fig. 1.



INVENTORS
*George A. Worn &
Frank L. Rubin*
BY *Nathaniel Ely*
ATTORNEY

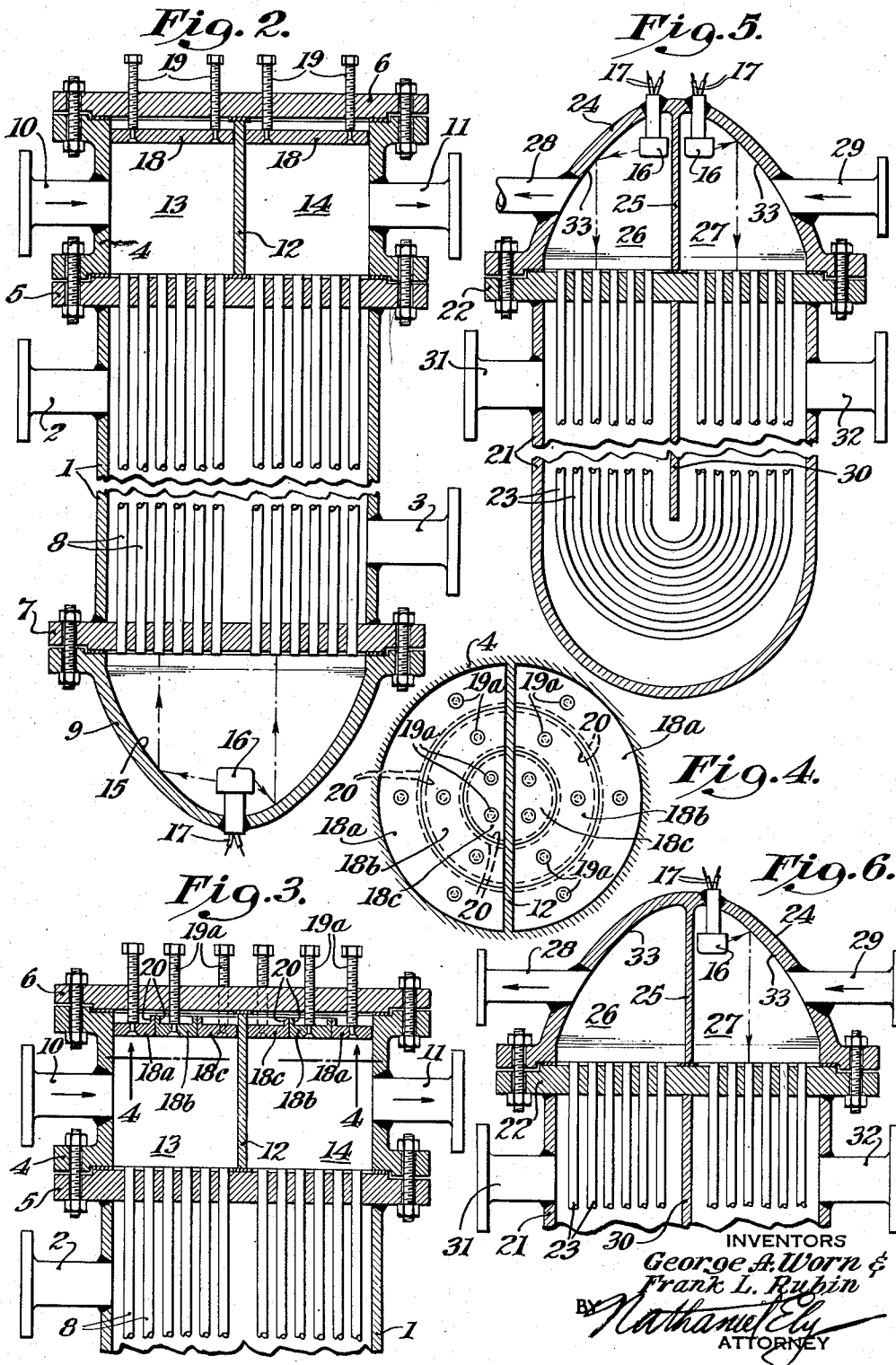
Dec. 29, 1953

G. A. WORN ET AL
METHOD AND APPARATUS EMPLOYING SONIC
WAVES IN HEAT EXCHANGE

2,664,274

Filed Dec. 22, 1951

2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,664,274

METHOD AND APPARATUS EMPLOYING
SONIC WAVES IN HEAT EXCHANGE

George A. Worn, Greenwich, Conn., and Frank
L. Rubin, Brooklyn, N. Y., assignors to The
Lummus Company, New York, N. Y., a corpo-
ration of Delaware

Application December 22, 1951, Serial No. 262,948

9 Claims. (Cl. 257-73)

This invention relates to improvements in indirect heat transfer wherein the transfer is effected between two fluids separated by a heat-conducting wall. More particularly, the invention is concerned with effecting contact of at least one of the fluids with said wall in a manner to increase the efficiency of the heat transfer.

Important objects of the invention are, to provide for said improved contact and increased efficiency of heat transfer by producing waves of the nature of sound waves in the fluid; to provide for production and direction of said waves in a manner to obtain the maximum desired result with a minimum input of power; to provide for the production of said waves in a manner to avoid vibration of an exchanger structure in which the heat transfer is effected; to provide for employment of the principle of resonance to reinforce the waves and further increase the heat transfer efficiency; and to provide for satisfactory production and utilization of the waves in the tube-side fluid of an exchanger wherein one of the fluids is conducted through a bundle of tubes.

Other objects of the invention will appear from the following description taken with the accompanying drawings.

In the drawings:

Fig. 1 is a longitudinal section of a heat exchanger equipped for conducting the heat transfer according to the invention.

Fig. 2 is a view similar to Fig. 1 showing the heat exchanger modified for employing the principle of resonance.

Fig. 3 is a sectional view of an end portion of the heat exchanger showing another modification thereof for employing the principle of resonance.

Fig. 4 is a section on the line 4-4 of Fig. 3.

Fig. 5 is a view similar to Fig. 1 showing a heat exchanger of the U-tube type equipped for conducting the heat transfer according to the invention.

Fig. 6 is a sectional view of an end portion of a heat exchanger of the type shown in Fig. 5 showing a modification thereof.

The structure of the exchanger illustrated in Fig. 1 includes a shell which may be cylindrical or of other suitable form and has nozzles 2 and 3 for passing fluid through it. At one end of the shell there is a channel or header formed by an annular member 4, a tube sheet 5 and a cover plate 6. As shown, the tube sheet 5 is welded to the shell, the annular member is bolted to the tube sheet, and the cover plate is bolted to the annular member with gaskets between the bolted

members. These structural details may be modified, however. At the opposite end of the shell a tube sheet 7 is welded or otherwise suitably secured to the shell and a bundle of substantially parallel tubes 8 within the shell are connected at their opposite ends to the tube sheets 5 and 7, respectively. A channel member 9 is bolted or otherwise suitably secured over the outer face of the tube sheet 7, with a gasket interposed. The exchanger is shown as vertical but it may be otherwise disposed. The upper channel has an inlet nozzle 10 and an outlet nozzle 11 and a pass partition 12 dividing the channel into two compartments 13 and 14. Nozzle 10 opens into the compartment 13 and nozzle 11 opens from the compartment 14. One half of the tubes open from the compartment 13 and the other half open into the compartment 14. The lower channel forms a single chamber with which all of the tubes communicate. The tube bundle may be substantially circular in cross section.

The channel member 9 is cup-shaped and has a smooth inner surface 15 which is paraboloidal, or substantially so. This surface faces the tube sheet 7, is coaxial with the tube bundle and its projected area is sufficient to take in the projected area of the adjacent end of the bundle. At the focus of the paraboloid of said surface, or approximately so, there is disposed a device 16 for initiating sonic waves in the fluid within the lower channel. This device may be of any suitable character. For example, it may be an electrically or mechanically operated vibrator or a wind instrument. As an electrically operated vibrator it may be of the piezo-electric type employing a transducer of quartz, ceramic or other suitable material. The device is shown as provided with a tubular supporting stem projecting through an aperture in the member 9 and secured therein. Wires 17 are shown extending into the stem to supply electric current for operating the device. In the operation of the heat exchanger, the shell-side fluid is circulated through the shell, via the nozzles 2 and 3, to surround the tubes of the bundle and, if desired, suitable baffles, not shown, for the fluid may be employed within the shell. The tube-side fluid is passed through the nozzle 10, the channel compartment 13 and one group of the tubes 8 to the lower channel. Thence, it is passed through the other group of tubes, the channel compartment 14 and the outlet nozzle 11. While said fluids are being passed through the exchanger, the device 16 is continuously operated to initiate waves of the nature of sound waves in the tube-side fluid within the

3

channel. Some of these waves will be propagated directly into the fluid within the tubes. Others will pass to the surface 15 to be subjected to distributed substantially parallel reflection into the fluid within all of the tubes of the bundle to cause a molecular agitation of the fluid and assist heat transfer by bringing a greater number of molecules of the fluid into contact with the tube wall and by repetition of said contact. Another purpose of the agitation is to prevent a film of the fluid from forming on the tube wall and prevent deposit of solid matter, both of which reduce heat exchange efficiency.

Waves of sonic, ultrasonic or subsonic frequency may be employed for said purposes depending upon the character of the tube-side fluid, its operating temperature and other factors. Hereinafter in the specification and claims the term "sonic" is intended to include waves of any frequency which are of the nature of sound waves. The invention particularly contemplates the use of a tube-side fluid in gaseous state such as vapors or gases of various kinds. However, liquid may be used.

The invention further provides for mounting of a vibrator device for producing the waves in a position spaced from all parts of the heat exchanger, as shown in the drawing, to avoid transmission of the vibrations to the heat exchanger structure and possible damage thereof. The location of said device in the return channel of the exchanger is also particularly advantageous for the reason that it enables a single device and a single reflector to propagate the waves through all of the tubes of the bundle. The location of the device also renders it conveniently accessible by unbolting and removing the channel member 9.

The invention also comprehends employment of the principle of resonance whereby the waves passing through the tubes from the reflector 15, or directly from the device 16 may be reinforced by reflected, or echo, waves passing in the opposite direction. For that purpose, the channel cover 6 may be so spaced from the tubes, with reference to the wave length as to reflect the waves in the required phase relation to the original waves to effect reinforcement of the latter and further increase the heat transfer efficiency of the contact of the medium within the tubes. Fig. 2 shows provision for obtaining resonance from different wave lengths. Within each of the channel compartments 13 and 14 there is a plate 18 having an area substantially equal to the cross section of the respective compartment. Each plate is adjustable toward and from the tubes by screws 19. These are in screw-threaded connection with the channel cover 6 and have swivel connections with the plate 18. The plates 18 serve as reflecting surfaces for the waves coming from the tubes and may be adjusted a proper distance from the tubes to establish resonance relation between the reflected waves and the oncoming waves to reinforce the latter. The term "resonance" used in the specification and claims is to be understood as applying to the reinforcement of waves of any suitable frequency according to the principle of resonance and as not limited to waves of sonic frequency.

Provision for more flexible adjustment of wave reflection is shown in Figs. 3 and 4. There, in each of the compartments there is a number of reflecting plates which are individually adjustable. In the present instance, there are three of these plates, designated 18a, 18b and 18c in each

4

compartment. Plates 18a and 18b are segmental in form and plate 18c is semicircular. All of the plates are shown as concentric and screws 19a are provided to adjust them individually toward and from the tubes, as in the case of the plates 18 of Fig. 2. The plates 18a, 18b and 18c have flanges 20 upon their back faces to avoid a gap when one of the plates is adjusted a substantial distance farther than an adjacent plate. Of course, the shape and number of the plates may be varied to suit conditions such as variations in the tube layout and in the shape of the channel compartments. The plates may also be adjusted by means other than the screws.

Fig. 5 shows an adaptation of the invention to a heat exchanger having U-tubes. The exchanger structure shown includes a shell 21 closed at one end having a tube sheet 22 welded or otherwise suitably secured to its opposite end. A bundle of U-tubes 23 have their ends secured in the tube sheet and opening into a channel defined by a member 24 bolted or otherwise suitably secured to the tube sheet. A pass partition 25 divides the interior of the channel member into two compartments 26 and 27 and one leg of the tubes opens into one of said compartments and the other into the other compartment. The member 24 has nozzles 28 and 29 opening into the compartments 26 and 27 respectively, to circulate fluid through the tubes. The shell 21 has a longitudinal partition 30 extending from the tube sheet 22 and between the legs of the tubes. At opposite sides of the partition the shell has nozzles 31 and 32, for circulating fluid through the shell and around the outer surfaces of the tubes.

The channel member 24 has two internal reflecting surfaces 33 within the respective channel compartments and facing the tubes. Each of the surfaces forms approximately half of a paraboloid and the two surfaces together form approximately a complete paraboloid. At opposite sides of the pass partition 25 two devices similar to the device 16 of Fig. 1, and similarly designated, are mounted in the region of the focus of the paraboloid to initiate sonic waves which are reflected by the surfaces 33 substantially in parallel into both legs of all of the tubes of the bundle. Thereby, as described in connection with Fig. 1, a molecular agitation of the fluid within the tubes will be caused and the heat exchange efficiency will be increased. In Fig. 6 only one of the devices 16 is employed to initiate the waves. Said device is disposed in one of the channel compartments. In some cases a single device will be sufficient to send the waves through the U-tubes. As in the case of the operation of the exchanger shown in Figs. 1 and 2 the use of a tube-side fluid in gaseous state is particularly contemplated but liquid may be used.

It is, of course, to be understood that the present disclosure of the invention is merely illustrative and in nowise limiting and that the invention comprehends such modifications as will fall within the scope of the claims.

We claim:

1. In the operation of a heat exchanger having a group of substantially parallel tubes and means including a channel chamber at one end of the tubes to pass a fluid through the tubes and in which there is provision for contact of other fluid with the exterior of said tubes in indirect heat exchange relation with the first-mentioned fluid, the improvement comprising initiating sonic waves in the tube-side fluid within a region with-

5

in said chamber small in comparison with the chamber and spaced from the tubes longitudinally of the latter, and reflecting said waves within said chamber predominantly longitudinally of the tubes and into the latter to increase the heat transfer efficiency of the contact of the tube-side fluid with the inner walls of the tubes.

2. In the operation of a heat exchanger according to claim 1, the improvement claimed therein wherein said waves are of ultrasonic frequency.

3. In the operation of a heat exchanger according to claim 1, the improvement claimed therein wherein the tube-side fluid is in a gaseous state.

4. In the operation of a heat exchanger according to claim 1, the improvement claimed therein wherein the said waves are of ultrasonic frequency and the tube-side fluid is in a gaseous state.

5. In the operation of a heat exchanger having a group of substantially parallel tubes and means including a channel chamber at one end of the tubes to pass a fluid through the tubes and in which there is provision for contact of other fluid with the exterior of said tubes in indirect heat exchange relation with the first-mentioned fluid, the improvement comprising initiating sonic waves in the tube-side fluid in said chamber at a point surrounded by said fluid and clear of the chamber walls and spaced from the tubes, and directing said waves within said chamber predominantly longitudinally of the tubes and into the latter to increase the heat exchange efficiency of the contact of the tube-side fluid with the inner walls of the tubes.

6. In the operation of a heat exchanger having a group of substantially parallel tubes and means including a channel chamber at one end of the group and a channel chamber at the opposite end of the group to pass a fluid through the tubes, and in which there is provision for contact of other fluid with the exterior of said tubes in indirect heat exchange relation with the first-mentioned fluid, the improvement comprising initiating sonic waves within the tube-side fluid in one of said chambers at a point surrounded by said fluid and clear of the chamber walls and spaced from the tubes, directing the waves in said chamber predominantly longitudinally of the tubes and into the latter for advance therethrough to increase the heat exchange efficiency of the contact of the tube-side fluid with the inner walls of the tubes, within the other of said chambers, reflecting said waves reversely into the tubes, and adjusting said reflection to produce resonance of the reflected waves with the waves advanced through the tubes.

7. In a heat exchanger having a group of substantially parallel tubes, means including a channel chamber at one end of the tubes for passing a fluid through the tubes, and in which there is provision for contact of other fluid with the exterior of said tubes in indirect heat exchange relation with the first-mentioned fluid, the improve-

6

ment comprising a device within said chamber operable to initiate sonic waves in the tube-side fluid at a point clear of the walls of said chamber and spaced from the tubes longitudinally of the latter, the area of said device projected longitudinally of the tubes being small as compared with that of said chamber and that of the group of tubes, and reflecting means within the chamber formed and disposed to reflect said waves predominantly longitudinally of the tubes and into the latter, to increase the heat transfer efficiency of the contact of the tube-side fluid with the inner walls of the tubes.

8. In a heat exchanger according to claim 7, the improvement claimed in said claim wherein said reflecting means has a paraboloidal surface facing said end of the tubes and said wave-initiating device is located in the region of the focus of said surface.

9. In a heat exchanger having a group of substantially parallel tubes and means including a channel chamber at one end of the group and a channel chamber at the opposite end of the group to pass a fluid through the tubes, and in which there is provision for contact of other fluid with the exterior of said tubes in indirect heat exchange relation with the first-mentioned fluid, the improvement comprising a device within one of said chambers operable to initiate sonic waves in the tube-side fluid at a point clear of the walls of said chamber and spaced from the tubes longitudinally of the latter, the area of said device projected longitudinally of the tubes being small as compared with that of said chamber and that of the group of tubes, reflecting means within said chamber formed and disposed to reflect said waves predominantly longitudinally of the tubes into the latter for passage therethrough, to increase the heat transfer efficiency of the tube-side fluid with the inner walls of the tubes, reflecting means in the other of said chambers disposed to receive said waves transmitted through the tubes and reflect them back through the tubes, and means to adjust the second-mentioned reflecting means toward and from the tubes to produce resonance of the waves reflected thereby with the oncoming waves.

GEORGE A. WORN.
FRANK L. RUBIN.

References Cited in the file of this patent UNITED STATES PATENTS

Number	Name	Date
1,570,781	Ruben	Jan. 26, 1926
1,834,875	Schaafhausen	Dec. 1, 1931
1,982,341	Hitchcock	Nov. 27, 1934
2,351,163	Thomas	June 13, 1944
2,489,944	Worn et al.	Nov. 29, 1949
2,514,797	Robinson	July 11, 1950
2,523,174	Worn	Sept. 19, 1950

FOREIGN PATENTS

Number	Country	Date
532,144	Great Britain	Jan. 17, 1941