July 13, 1948. E. G. BAILEY ET AL 2,444,908

FLUID HEAT EXCHANGE INSTALLATION

Original Filed Jan. 9, 1943 7 Sheets-Sheet 1

Fig. 1

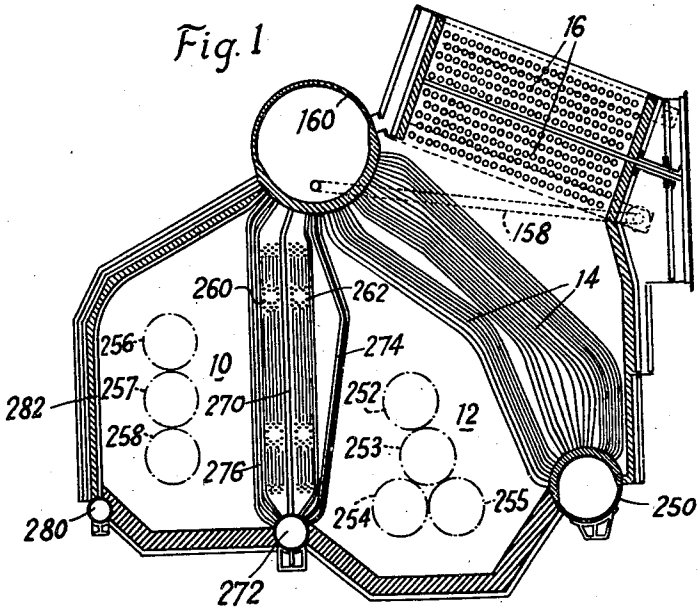


Fig. 2

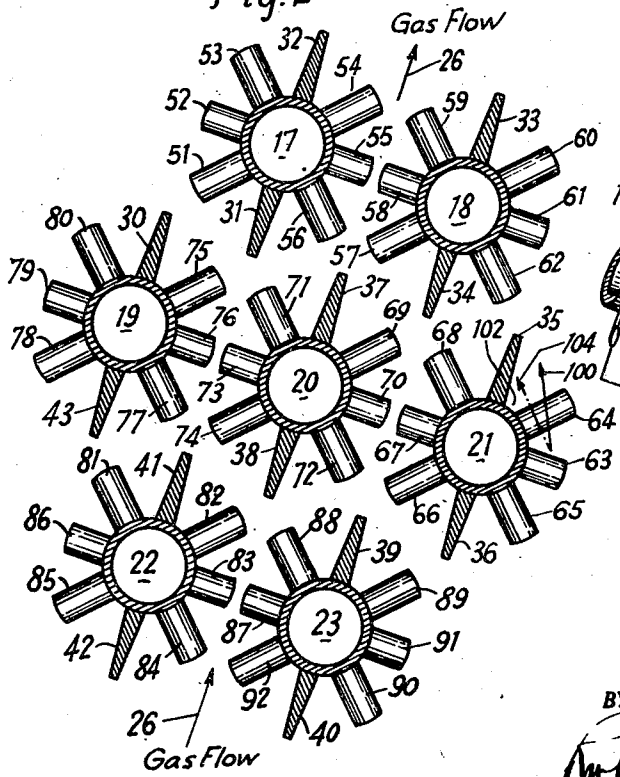
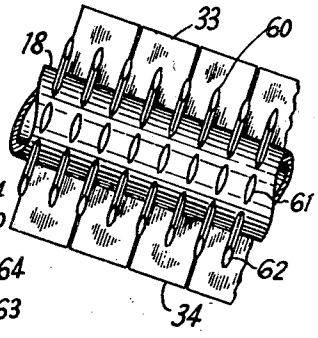


Fig. 3



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FLUID HEAT EXCHANGE INSTALLATION

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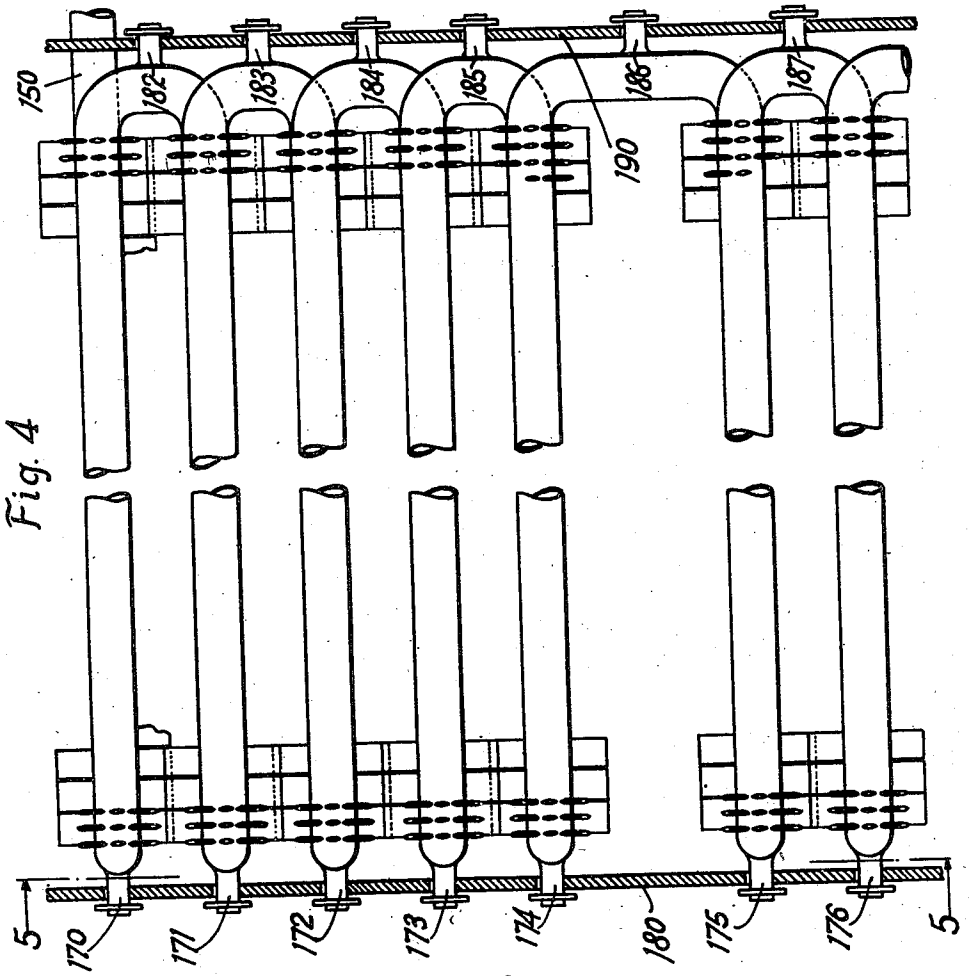

Fig. 4

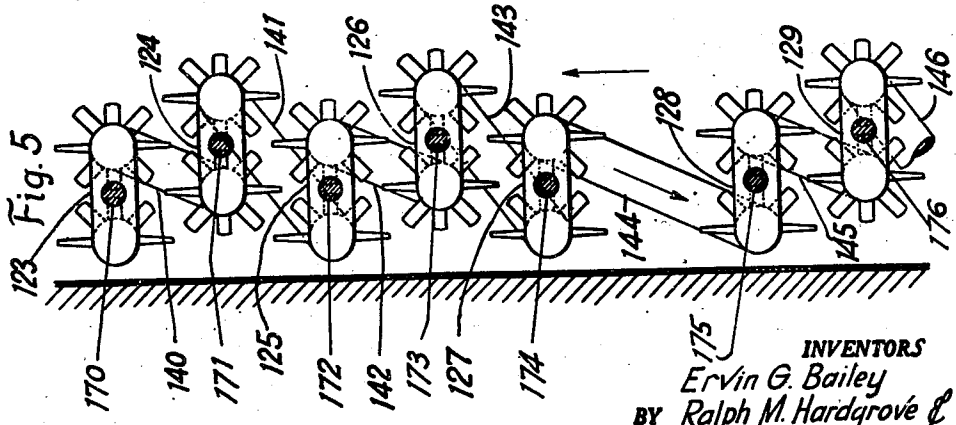

Fig. 5

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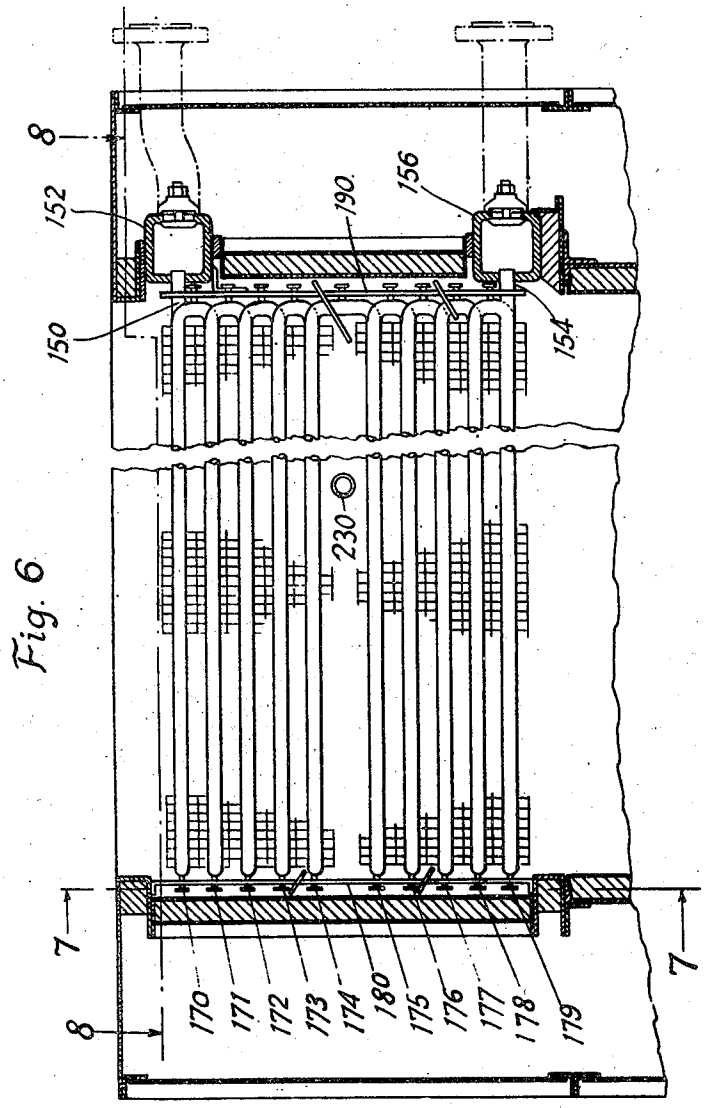

Fig. 6

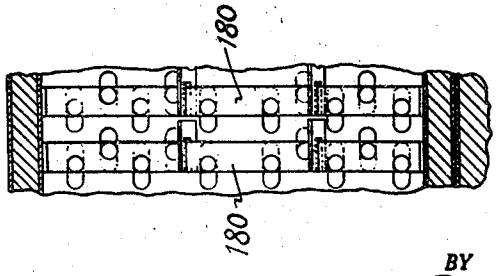

Fig. 7

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FLUID HEAT EXCHANGE INSTALLATION

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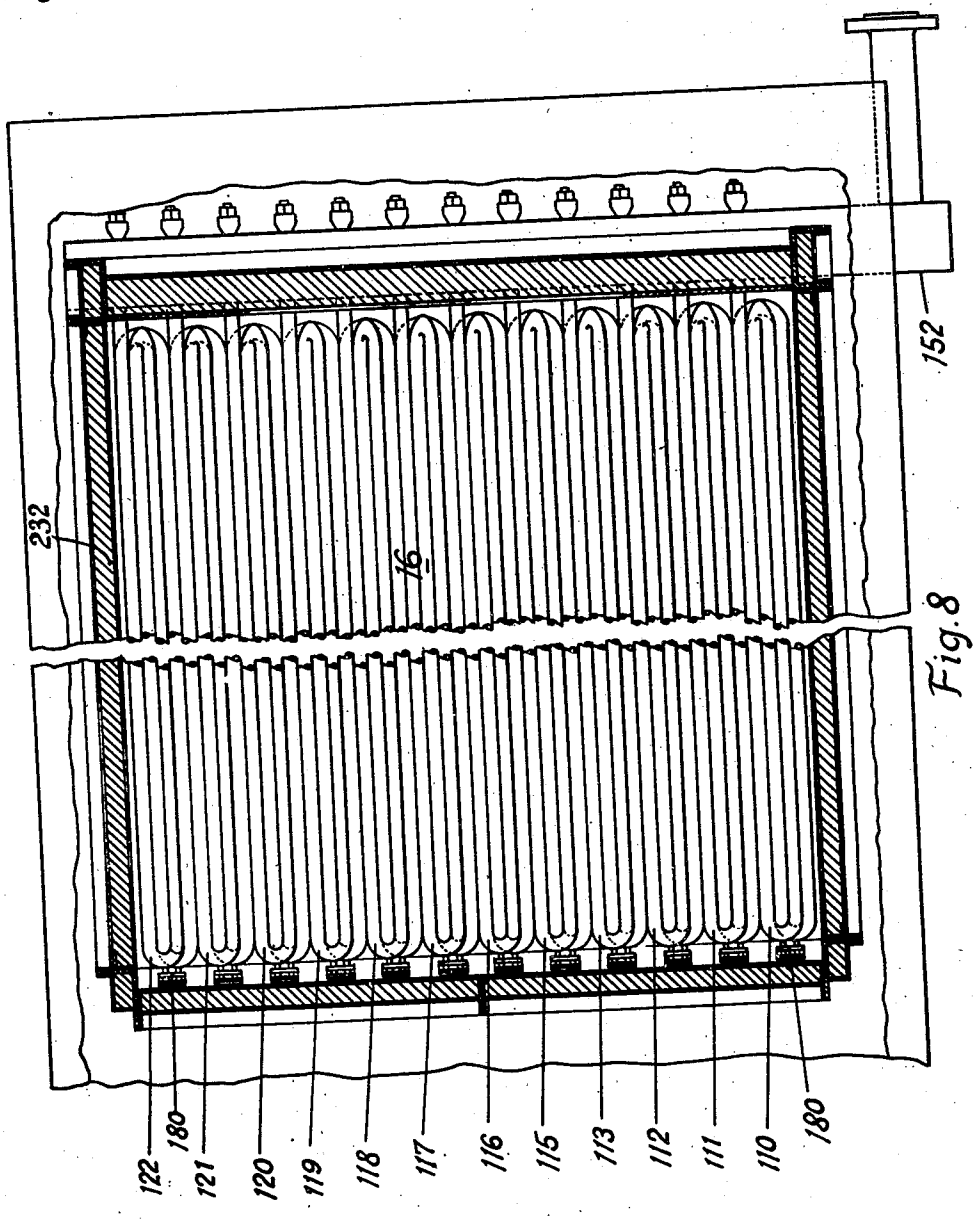

Fig. 8

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FLUID HEAT EXCHANGE INSTALLATION

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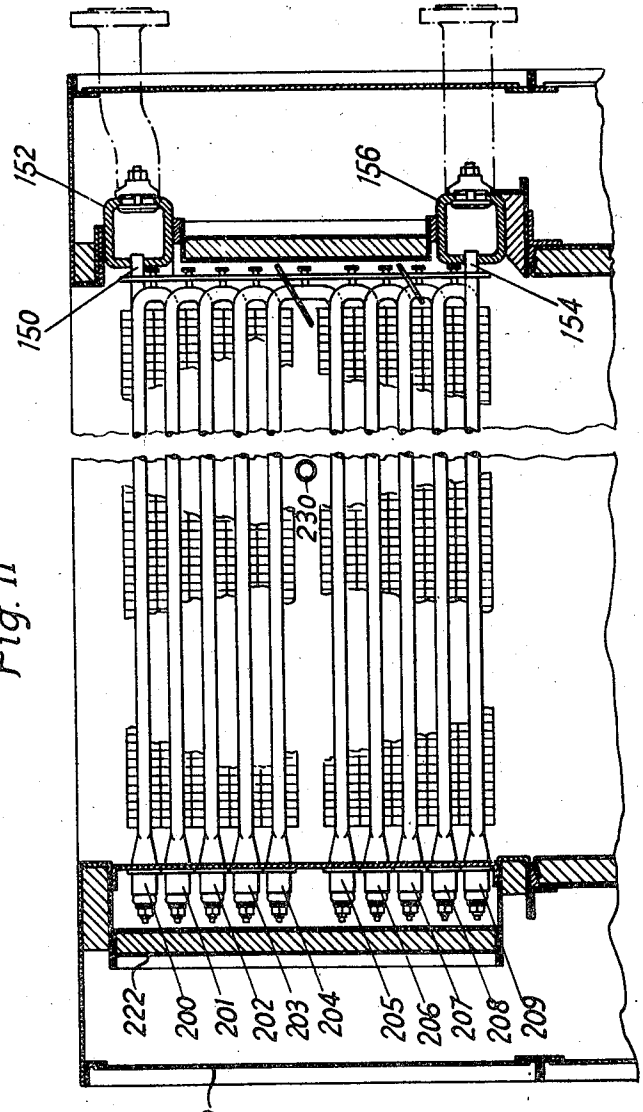

Fig. 11

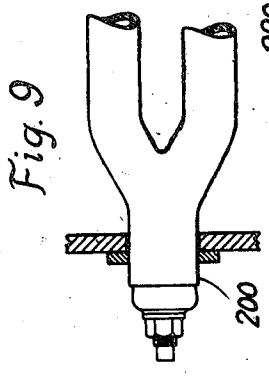

Fig. 9

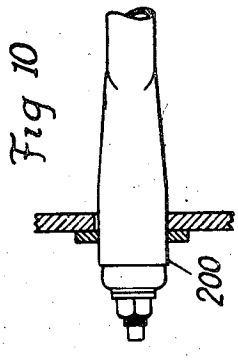

Fig. 10

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FLUID HEAT EXCHANGE INSTALLATION

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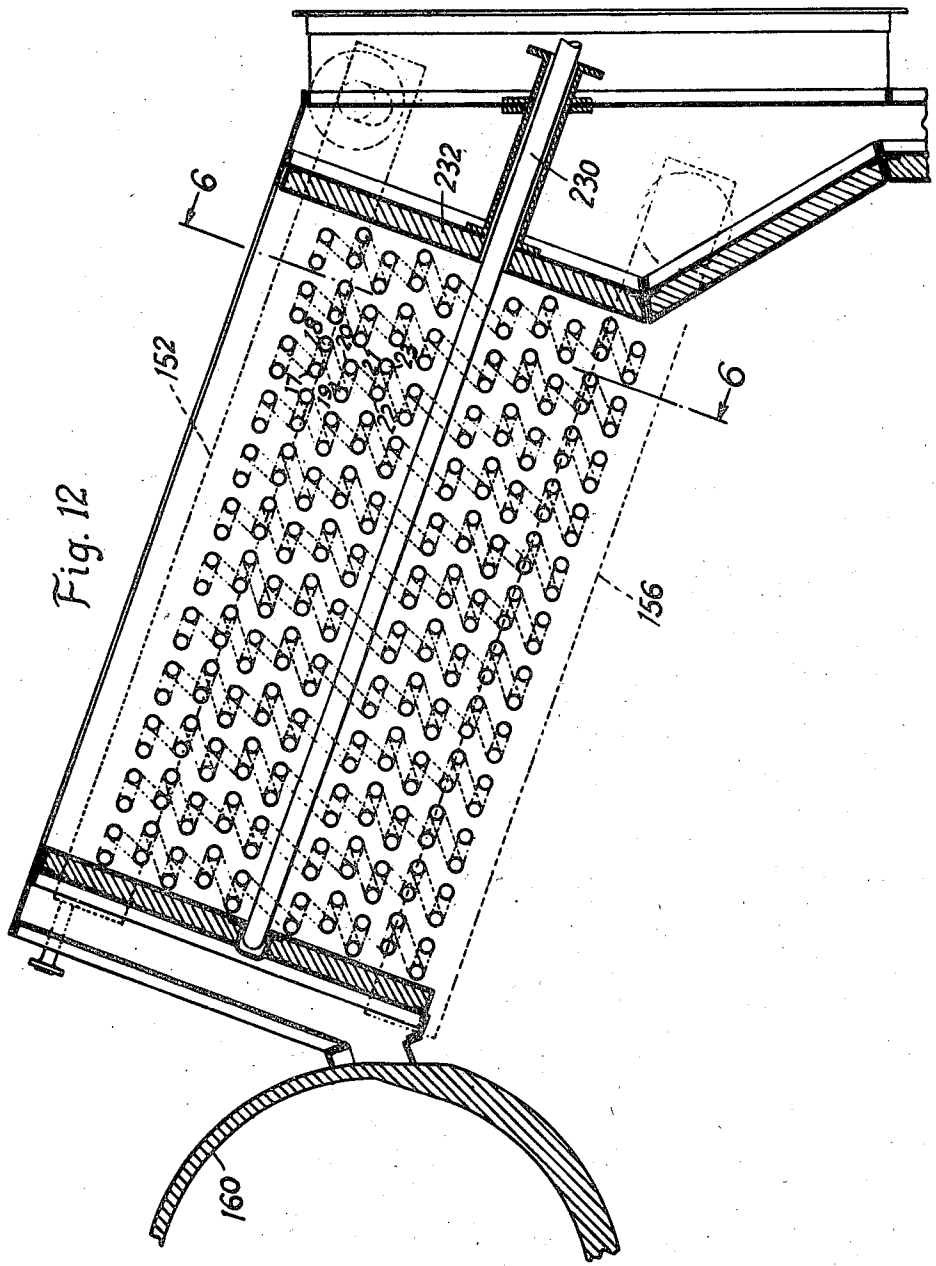

Fig. 12

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FLUID HEAT EXCHANGE INSTALLATION

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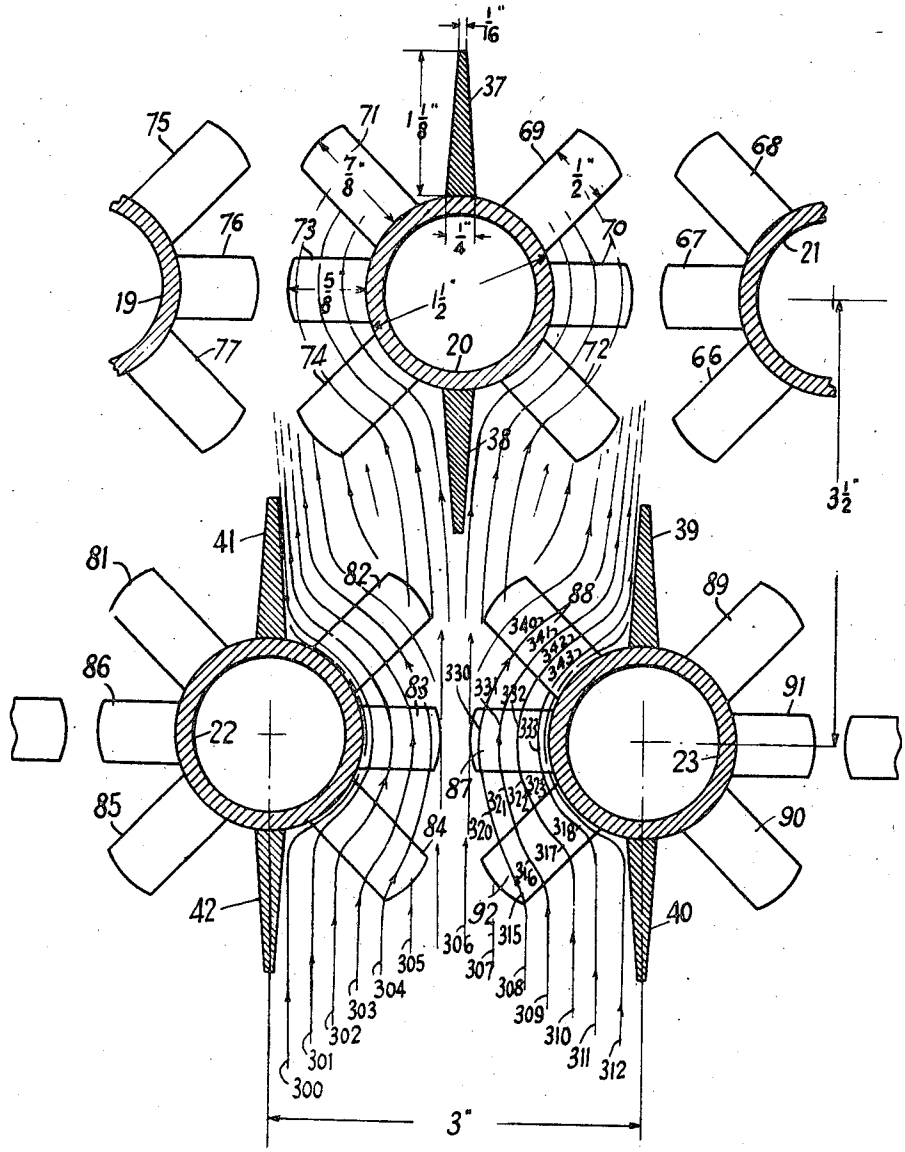
Fig. 13



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Patented July 13, 1948 2,444,908

UNITED STATES PATENT OFFICE

2,444,908

FLUID HEAT EXCHANGE INSTALLATION

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Continuation of application Serial No. 471,856, January 9, 1943. This application June 6, 1946, Serial No. 674,786

6 Claims. (Cl. 257—262)

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This invention is concerned with improvements in fluid heat exchange installations of the convection type and, more specifically, the invention relates to such installations including a bank of spaced metallic tubes with extended surface elements such as oval metallic studs or flat studs secured to the tubes in good heat exchange relationship and extending from the tubes into the path of the flow of a heat exchange fluid across the bank of tubes.

In heat exchange installations of this type, and particularly in economizers employing furnace gases as the heating medium, the efficiency and effectiveness of the installation depend upon several factors. One of these, of course, is the ratio of the area of metal surface exposed to the heating gases to the surface exposed to the fluid to be heated, and among other factors are the thermal conductivity of the metal, and the effectiveness with which the exterior metal surface is swept by the hot gases.

Among other objects of the invention is the provision of a boiler economizer which forms a light weight heat exchange unit of high heat absorptive capacity and which can be fabricated from standard shapes of readily available material. It is readily adapted for operative disposition in gas passes of different widths and lengths; its ratio of effective heating surface to occupied space is high; and it has a high ratio of heating surface to net weight.

Another factor that determines the effectiveness of the pertinent heat exchange installations is the inherent draft loss, or resistance to flow, of the tubes and their extended surface elements. It is a further object of the invention to provide an economizer with extended surface elements so constructed and arranged on the tubes that, for certain thermal results, there is a relatively low draft loss.

The particular manner in which the different types of extended surface elements are constructed and arranged will be specifically described in the following specification which deals with a preferred embodiment of the invention, and the description will have reference to the accompanying drawings in which that embodiment is illustrated.

In the drawings:

Fig. 1 is a vertical section of a steam generating unit in connection with which the illustrative economizer is employed;

Fig. 2 is a sectional view of some of the economizer tubes, showing particularly the construction and arrangement of the extended surface elements secured to the tubes;

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Fig. 3 is a side elevation of one of the economizer tubes with its extended surface elements;

Fig. 4 is an elevation showing the arrangement and connections of some of the economizer tubes;

Fig. 5 is a view in the nature of an end elevation from a plane indicated by the line 5—5 in Fig. 4, looking in the direction of the arrows;

Fig. 6 is a longitudinal vertical section of the economizer on the line 6—6 of Fig. 12;

Fig. 7 is a partial end view in the nature of an elevation from the plane indicated by the section line 7—7 of Fig. 6;

Fig. 8 is a plan of the illustrative economizer from a plane indicated by the section line 8—8 of Fig. 6;

Figs. 9 and 10 are detail views indicating a modified type of U-bend affording tube access connections;

Fig. 11 is a longitudinal vertical section of an economizer employing such tube access connections as those indicated in Figs. 9 and 10;

Fig. 12 is a transverse vertical section of the economizer on a much larger scale than the corresponding section of Fig. 1; and

Fig. 13 is a detail view showing the tube and stud construction on an enlarged scale.

In the steam generating installation indicated in Fig. 1 of the drawings, furnace gases pass from one or both furnaces 10 and 12 across a bank of steam generating tubes 14 and then over the tubes of the economizer 16. The economizer tubes are arranged and constructed with two different types of extended surface elements in the manner indicated more particularly in Fig. 2 of the drawings. In this view, the general direction of gas flow (as indicated by the arrows 26) is over the tubes 17–23, and some of their extended surface elements are secured to the tubes on diametrically opposite sides thereof as clearly shown. They are indicated as longitudinally arranged elements 30—43 extending from the tubes in the general direction of gas flow. In section, these elements taper away from the tubes and they are secured to the latter in slightly spaced relationship as indicated in Fig. 3.

Secured to the tubes 17–23 and extending substantially radially therefrom at positions between the diametrically opposite flat studs are the extended surface oval studs 51–82. These studs are of a section particularly adapted for effective heat transfer conditions and the rows of studs arranged in positions nearest the flat

stud segments 30—43 are effective to cause not only a greater amount of flowing gases to scrub the upper flat stud segments 30, 32, 33, 35, and 37, etc., but also to increase the surface or area of the flat studs swept by flowing gases.

It has been found that due to the fact that the pressure drop of a gas flowing diagonally across a tube or other heat absorbing member is greater than when the same gas flow takes place in a direction normal to the axis of the tube or member, there is a corrective modification in the direction of an unconfined flow directed diagonally toward the tubular member, and such an alteration in the flow of the heating gas is beneficially utilized in the construction of the present economizer to effect better overall heat absorption.

With respect to the above it might be said that the invention utilizes the directive effect of the heat transfer members (oval studs) arranged obliquely with respect to the approaching gas stream to distribute the heating gas flow in more effective relation to subsequent heat exchange members mounted on the same tube or on a subsequent tube.

Gas flow through a bank of superposed staggered tubes occurs with a laterally stratified stream so that if extended heat absorbing elements (studs) are extended obliquely from the tube wall with respect to the approaching gas stream, the above described flow deflection results in more uniform gas stream conditions to give more uniform heat transfer. With this condition the angularly arranged studs would have a dual function in that they effect a more uniform gas stream condition while presenting an additional extent of metallic heat absorption surface to the hot gases.

By way of explanation, if it be assumed that the arrow 100 (Fig. 2) indicates the general direction of the flow of gases past the upper right hand quarter of the tube 21 when no studs corresponding to studs 64 are present, then when these studs are added the gases approaching the studs in the direction of the arrow 100 will be deflected toward the flat stud and tube pocket 102. Such deflection is intended to be indicated by a comparison of the relative positions of the arrows 100 and 104. Thus, the gases are rendered more effective in the transfer of heat to the fluid within the tubes because the gases scrub or contact greater portions of the lateral surfaces of the upper flat studs 30, 32, 33, 35, 37, etc. This correlation of surface elements causes a substantial improvement in heat transfer conditions by the attainment of higher rates of heat transfer with a given area of tubes and their extended surfaces, while keeping draft loss within allowable limits.

The gas flow conditions over a bank of tubes constructed in accordance with the invention may be considered as more clearly indicated in Fig. 13 of the drawings. In this figure the tubes 22 and 23 may be considered as the tubes initially contacted by gases flowing in the direction indicated by the arrows 300—312. On one side, the gases first engage the oblique heating surface of a row of studs 92, and the effect upon the gas flow is to deflect it toward a normal to a plane including the longitudinal axes of the studs. This action is indicated by comparison of the flow lines 308—312 to the flow lines 315—318.

The gases after leaving the studs 92, engage the leading surface of edges of the row of studs 87 in the direction indicated by the flow lines 320—323. Here, again, the gases are deflected

toward a normal to a plane including the longitudinal axes of the studs as indicated by comparison of the flow lines 330—333 to the flow lines 320—323. In this latter instance the gases are deflected toward the upper surface or quadrant of the tube, and, in this way, greater metal gas contact along the surface of the tube will be obtained. This effect is increased by the action of the long studs 88 to again deflect the gas flow toward the tube and toward the roots of the extended surface elements 39. Similar action takes place along each side of all tubes in the arrangement shown.

When the tubes of the Fig. 13 arrangement are on 3" centers, the tubes are of 1½" outside diameter. The diametrically opposed upper and lower extended surface elements 37—42 are preferably about 1⅛" long in the radial direction and about ⅛" thick at their apexes. The middle studs are ⅝" long and the intermediate studs, such as studs 69, 71, 72, 74, are appreciably longer (¼") than the studs 70 and 73 so that they project over substantially the entire length of the latter. The surfaces of the entire studs are thereby contacted by the greater portion of the gases flowing upward between the short lateral studs such as those indicated at 76 and 73.

The use of the illustrative economizer permits the reduction of the extent of tube surface and that, for a given performance, makes a material saving in the metal to be employed. Its use also combines a maximum of gas swept surface and a maximum of thermal performance, with a minimum of weight, minimum of space occupied, and minimum of gas flow resistance. In marine installations, and particularly in naval vessels, it is most important that any component of the steam generator be of minimum weight and space requirement for a given performance, and the illustrative economizer has met with very favorable reception because of its corresponding attributes. In comparative tests with competive economizers, the ilustrative economizer has been shown to have an 18% higher transfer rate for the same mass flow. These tests have also shown that, by the use of the illustrative economizer, competitive performance is notably improved at no increase in gas resistance.

The economizer is shown in Figs. 1, 4, 6, and 12 as including a bank of convector tubes associated with a steam generator of the marine type. Adjacent economizer tubes in the same horizontal plane are connected by return bends such as those indicated by 110—113 and 115—129 in Figs. 5 and 8, and vertically adjacent pairs of such return bend tubes are connected by such inclined return bends as those indicated at 140—146 in Fig. 5 to form what may be termed a circuit. In the economizer shown in the drawings, each circuit receives its fluid through an inlet tube such as that shown at 150 in Fig. 11. This inlet tube is connected to an inlet header 152, and the liquid heated in the circuit flows downwardly through the associated tubes and their return bend connections to the outlet tube 154, and thence to the outlet header 156. From that header the heated liquid flows through a tubular connection including such as that shown in 153 in Fig. 1 to the steam and water drum 160 of the boiler.

The economizer tubes are supported by projections at their ends as shown in the construction illustrated in Figs. 4 and 6.

The projections 170—179 extend through openings in an upright plate or bar 180 at one

side of the installation and the projections 182—187 similarly extend through openings in bars or plates 190 at the other side of the installation. In the construction indicated in Fig. 11, the return bends at one side of the installation involve access fittings 200—208, one of which is shown in plan in Fig. 9, and in elevation in Fig. 10. When such fittings are employed, access may be had to two of the economizer tubes connected by any one of such fittings by removal of the outer casing sections 220 and the inner casing section 222.

Fig. 12 of the drawings additionally indicates a soot blower including the rotatable tube 230 extending through the bank of economizer tubes and one of the casing sections 222 at one side of the economizer. This soot blower is appropriately connected with a source of steam and with means by which the soot blower is periodically operated.

The marine steam generator indicated in Fig. 1 includes a lower water drum 250 directly connected to the steam and water drum 160 by the bank of steam generating tubes 14. The tubes of this bank extend across the gas outlet of the furnace 12 which may be operated independently of the furnace 10 by the burners 252—256. When the steam is superheated, the furnace 10 is fired by the burners 256—258 so that the furnace gases pass across the tubes of the superheater sections 260 and 262. The superheater sections are preferably supported by large diameter tubes 270 directly connecting the water space of the steam and water drum 160 to the auxiliary lower drum 272. These drums are also directly connected by the steam generating tubes 274 and 276.

At the other side of the furnace 10 there is a lower header 280 directly connected to the water space of the drum 160 by the steam generating wall tubes 282.

Although the invention has been described with reference to the details of a preferred embodiment associated in a particular manner with a steam generator, it is to be appreciated that the invention is not limited to all the details of that construction or arrangement of elements. The invention is rather to be considered of a scope comparable with the scope of the subjoined claims.

This application is a continuation of our parent application Serial No. 471,856, filed January 9, 1943, now abandoned.

We claim:

1. A convector including a bank of spaced tubes extending transversely of a flow of an external heat exchange fluid, a primary set of closely adjacent and aligned fin-like extended surface elements secured to each tube in two longitudinal rows at diametrically opposite sides of the tubes with said elements extending generally in the direction of gas flow and having their major transverse axes disposed longitudinally of the tubes, a second set of extended surface elements in the form of studs of thin or flattened cross section secured to opposite sides of the tubes between the opposite rows of elements of the first set, the elements of said second set having their major transverse axes disposed transversely to the wide faces of the elements of the primary set, a third set of oblique extended surface elements constructed and arranged similarly to the elements of the second set, the elements of the third set being longer radially of the tube than the elements of the second set and secured to the downflow quadrants of the tubes between the first and second sets of elements, and means for effecting a flow of fluid through the tubes.

2. A convector including a bank of spaced tubes extending transversely of a flow of furnace gases, a first set of extended surface elements in the form of closely adjacent solid studs of elongated cross section secured to each tube in two longitudinal rows at diametrically opposite sides of the tube with some of said elements extending generally radially of the tubes and in the direction of gas flow, a second set of extended surface elements in the form of solid studs of elongated cross section secured to opposite sides of the tubes between the opposite rows of elements of the first set, a third set of obliquely arranged solid studs longer than those of the second set and extending from the downstream (furnace gas side) quadrants of the tubes, the studs of the third set being closely spaced in rows longitudinally of the tubes and disposed between the studs of the first and second sets with their major transverse axes disposed transversely to the wide faces of the first studs, the projected area of the studs of the second or third set per unit of tube length taken transversely of gas flow being less than the lateral projected area of the studs of the first set, means for effecting a flow of fluid through the tubes, and a source of furnace gases for heating the fluid within the tubes, the studs of the second and third sets being also arranged in circumferent rows with unobstructed gas flow paths therebetween up to the first set of studs.

3. In fluid heat exchange apparatus, a plurality of spaced tubes disposed transversely of a flow of a heat exchange fluid, each tube having a plurality of closely spaced studs of elongated cross section aligned in a row on the downflow side of the tube, said studs being arranged with their major transverse axes disposed longitudinally of the tube, a plurality of closely spaced side studs of elongated cross section secured to opposite sides of the tubes and arranged with their major transverse axes transversely related to the wide faces of the first studs, sets of oblique studs similar in construction and arrangement to said side studs, the oblique studs being longer than the side studs and secured to the downflow quadrants of the tubes between the rows of side studs and the row of first studs and in circumferent rows with the side studs, the projected area of the side studs or oblique studs per unit of tube length taken transversely of gas flow being less than the lateral projected area of the first studs, means for connecting the tubes for a flow of fluid therethrough, and means providing for the flow of a heating fluid over the tubes and their studs.

4. A convector including a bank of spaced tubes extending transversely of gas flow, a first set of extended surface elements in the form of closely adjacent solid studs of elongated cross section secured to each tube in two longitudinal rows at diametrically opposite sides of the tubes with said elements on one side of the tube extending generally in the direction of gas flow, a second set of extended surface elements in the form of solid side studs of elongated cross section secured in rows to opposite sides of the tubes with each row between the opposite rows of elements of the first set, the side studs extending from the tubes in a direction substantially normal to the general direction of gas flow, a third set of

obliquely arranged solid studs longer than those of the second set and extending substantially radially from the downstream and upstream (furnace gas side) quadrants of the tubes, the studs of the second and third sets being similarly closely spaced longitudinally of the tubes and disposed in the same circumferent rows with their major transverse axes transversely related to the wide flat faces of the first studs, the studs of the second and third sets being spaced more widely than the studs of the first set so that the projected area of the second and third sets per unit tube length taken transversely of gas flow is much less than the lateral projected area of the first set, means for effecting a flow of fluid through the tubes, and a source of furnace gases for heating the fluid within the tubes, the gas flow paths around the tubes and between the rows of studs being unobstructed up to the studs of the first set.

5. A convector including a bank of spaced tubes extending transversely of a flow of an external heat exchange fluid, a primary set of closely adjacent extended surface elements of elongated cross section secured centrally to each tube in a longitudinal row on the downflow side thereof with said elements extending generally in the direction of gas flow and having their major transverse axes disposed longitudinally of the tubes, a second set of extended surface elements in the form of studs secured to opposite sides of the tubes and extending transversely of gas flow, a third set of oblique extended surface elements constructed and arranged similarly to the elements of the second set, the elements of the third set being longer radially of the tube than the elements of the second set and secured to the downflow quadrants of the tubes between the first and second sets of elements, the projected area of either of the second or third set

of elements per unit of tube length taken transversely of gas flow being less than the lateral projected area of the first set of elements, and means for effecting a flow of fluid through the tubes.

6. In a fluid heater, a bank of spaced tubes disposed in staggered arrangement transversely of gas flow, closely spaced studs of elongated cross section disposed in a longitudinal row on the downstream side of each tube, a longitudinal row of side studs of elongated cross section radially shorter than the first studs and disposed on opposite sides of each tube transversely of gas flow, and opposite longitudinal rows of oblique studs of elongated cross section secured to each tube between the rows of the first and side studs, the side and oblique studs being arranged with their major transverse dimensions in circumferent rows transversely related to the wide faces of the first studs, the spacing of said circumferent rows longitudinally of each tube being so much greater than the spacing of the first studs that the projected area of the side and oblique stud rows per unit of tube length taken transversely of gas flow is much less than the lateral projected area of the first studs.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
833,486	Sager	Oct. 16, 1906
1,870,670	Brown	Aug. 9, 1932
2,120,125	Cassidy et al.	June 7, 1938