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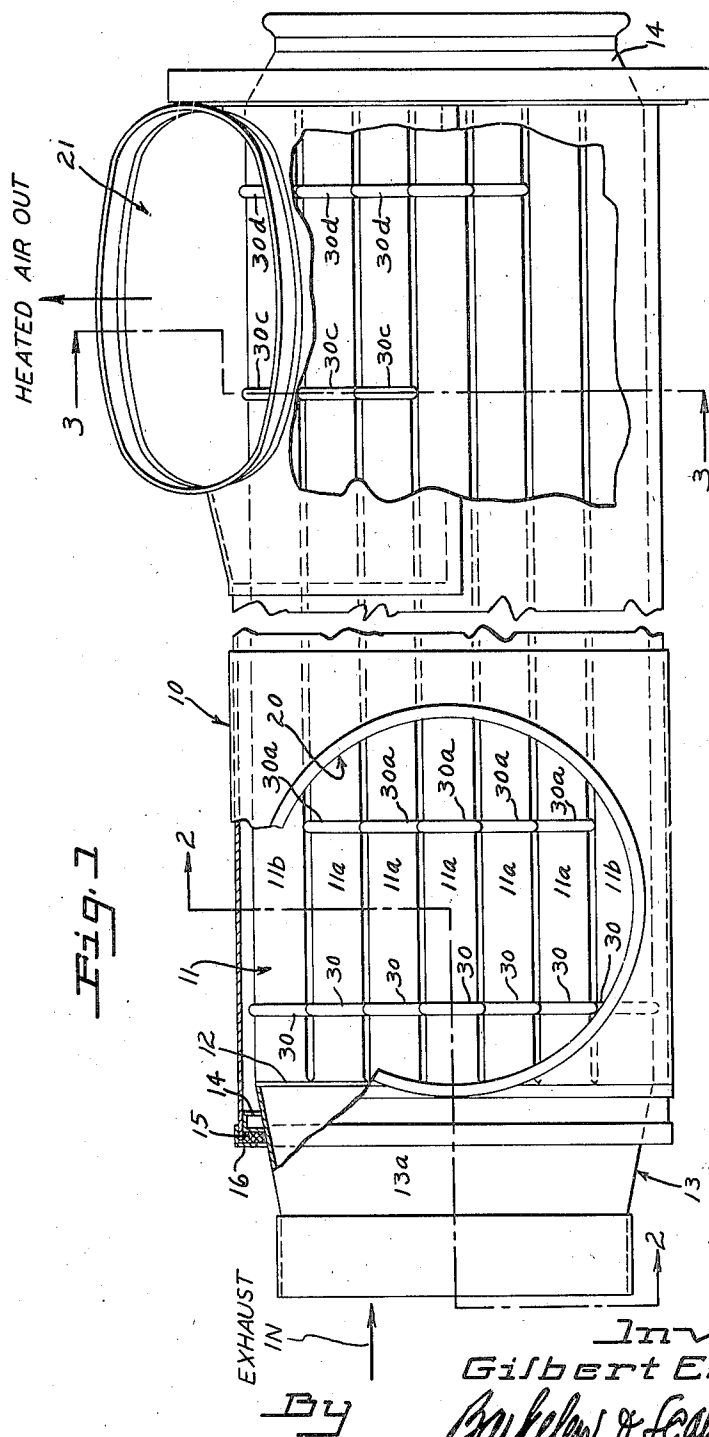
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2,388,721

HEAT EXCHANGER

Filed June 16, 1943

3 Sheets-Sheet 1



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Fig. 2

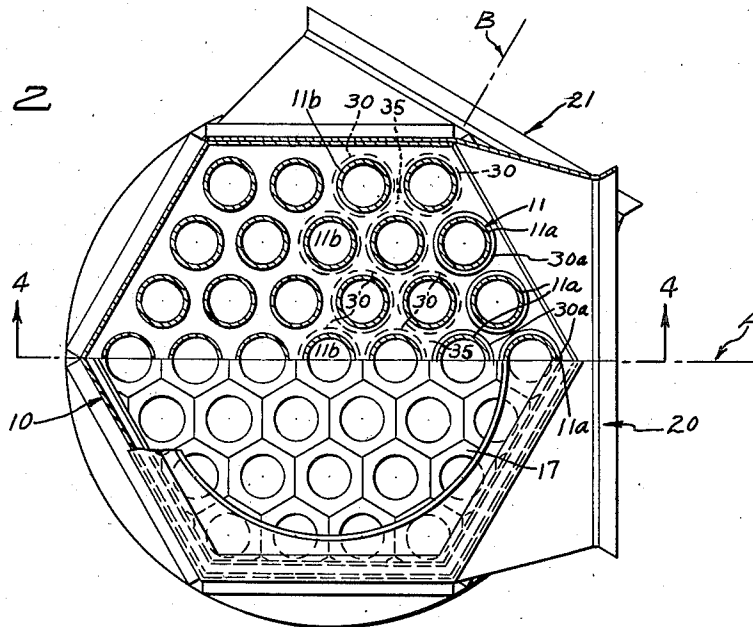
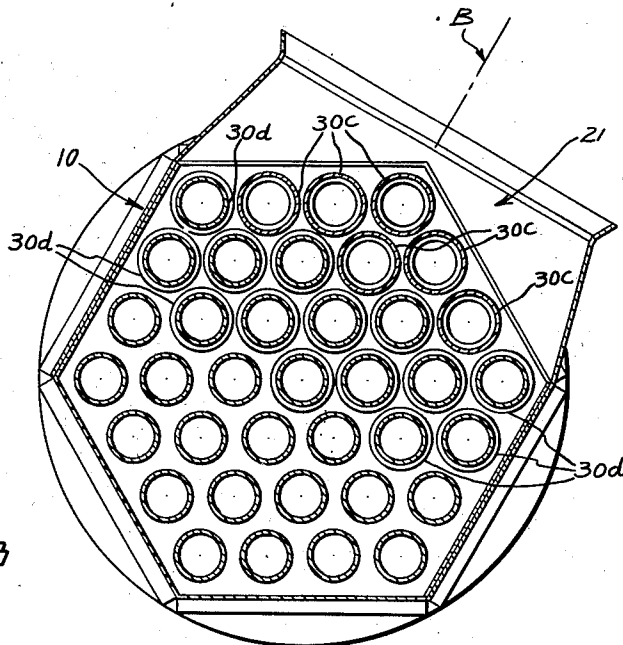


Fig. 3



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Fig. 5

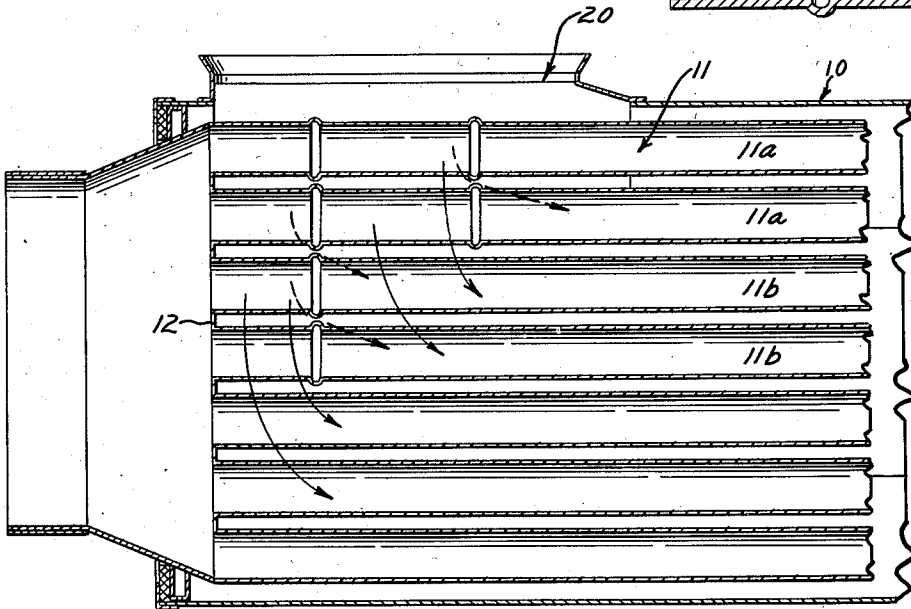
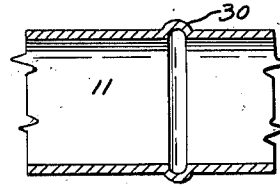


Fig. 4

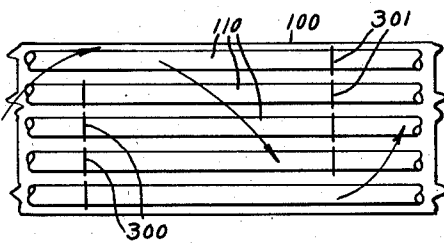


Fig. 6

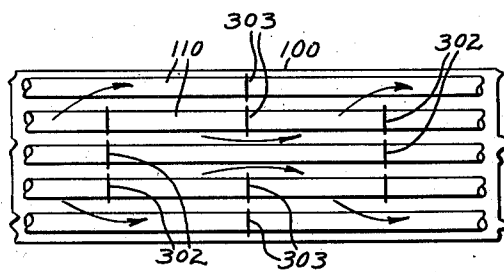


Fig. 7

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UNITED STATES PATENT OFFICE

2,388,721

HEAT EXCHANGER

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1 Claim. (Cl. 257—236)

The problem presented by the demand for heat exchangers adapted particularly to use in aircraft for such purposes as de-icing and cabin heating, has not to my knowledge been heretofore satisfactorily solved. The requirements, in a heater which may be used for such purposes, are particularly severe. The heat exchanger must have, in proportion to its size and weight, a relatively large heat exchanging capacity, and it must also have great dependability and long life without failure due to burning out or other causes. For instance, a typical set of specifications for an exchanger to be used for the purpose of heating air from the exhaust of a 400 H. P. engine include the following requirements: 4000 lbs. of air per hour are required to be heated from -5° F. to 300° F., with an extraction of 285,000 B. t. u. from the exhaust gases; the pressure drop through the exchanger of both the exhaust gases and air to be not more than approximately 4" of water, and the heat exchanger to weigh not more than approximately 50 lbs.

The heat exchanger described in the following specifications and shown in the accompanying drawings is illustrative of my invention which solves the problem posed by requirement specifications such as outlined above. And it also has maximum dependability and long life, as will be pointed out.

In the accompanying drawings:

Fig. 1 is a fragmentary side elevation, with parts broken away and shown in section, of a typical form of my heat exchanger;

Fig. 2 is a half-section and half-end-elevation taken as indicated by line 2—2 on Fig. 1;

Fig. 3 is a cross section taken as indicated by line 3—3 on Fig. 1;

Fig. 4 is a longitudinal section taken as indicated by line 4—4 on Fig. 2;

Fig. 5 is a fragmentary sectional detail showing the formation of a tube, and

Figs. 6 and 7 are diagrams illustrating typical variant uses of the baffle formations shown in the other figures.

Heat exchangers of the general type shown in the drawings are well known. That is, heat exchangers embodying an assembly of longitudinal tubes extending between two tube sheets at the ends of a casing, one of the fluids passing through the tubes and the other fluid flowing through the casing between inlet and outlet ports which are located in the side walls of the casing at or near the ends. My invention is generally applicable to any heat exchanger of the general type employing a tube assembly and in which the fluid flow

external of the tubes is either in a general longitudinal or general transverse direction.

In the drawings numeral 10 designates an elongated casing shell of hexagonal section, through which the assembly of longitudinal tubes 11 extends. The ends of the tubes are set in tube sheets 12 which are joined to induction and eduction fittings 13 and 14 in a manner which will be briefly described. The inner parts of fittings 13 and 14 (such as the part 13a of fitting 13) are tapered and are mounted in shell 10 in a mounting ring 14 which fits the taper, and are sealed by gasket 15 which is held against ring 14 by an external flanged ring 16. Ring 16 may be secured to shell 10 in any suitable manner. Ring 14 need not be secured to shell 10; it may be supported against the gasket by its fit on the tapered part 13a.

The tube sheet 12 can be made in any suitable manner, but is preferably made by expanding and flanging the ends of tubes 11 to form hexagonal head flanges such as are shown at 17 in Fig. 2; these head flanges being welded or brazed together to form the continuous tube sheet which is welded or brazed at its periphery to the hexagonal tapered part 13a of, for instance, fitting 13. The structure at eduction fitting 14 may be the same as at fitting 13.

As shown in the drawings, the several tubes, of which there are 37 in this particular design, are arranged in spaced relation in a hexagonal pattern. In the particular design (which is one which fully and overly satisfies the particular illustrative requirements set out before) these tubes are of 1" outside diameter, with walls .035" thick, of stainless steel, and approximately 33" long. The other dimensions of the other parts of the whole exchanger are shown proportionately in the drawings.

As shown in Figs. 1 and 4 of the drawings, the inlet for the hot exhaust gases is at the left hand end of the shell, the hot gases passing through tubes 11 from left to right in those figures. The lateral inlet opening 20 for cold air, in this particular design, is located in the side of the shell at or near the left hand end, on a transverse axis A, and the lateral outlet opening 21 for heated air is located on a transverse axis B in the side of the shell at or near the right hand end. As shown in the drawings, the axes of these air openings are located at an angle of 60° to each other. As will be pointed out later, it is one of the features of my invention that the air openings may be located on the shell in any desired angular relation, or longitudinal relation, to each other

to suit the location of the air connections most conveniently.

One of the most common reasons for inefficiency and burning out of heaters of the general type under discussion has been the unequal distribution of fluid flow through the shell and around the longitudinal tubes. In a heater where the general flow is longitudinal or mainly so (which is the type of heater shown here as an illustration of the invention) it is mainly unequal lateral distribution of the general longitudinal flow which causes the difficulties. Unequal distribution, and unequal velocities of flow, have resulted in relative overheating of some parts of the structure, with resultant inefficiency of heat transfer and pronounced tendencies to burn out. These tendencies have in the past been partially cured by placement of transversely extending baffle sheets across the tubes at or near the lateral fluid openings; but while such baffles may be arranged to attain a fairly uniform distribution of fluid flow around the tubes, they do not wholly solve the problem. The spaced tubes pass through the baffles and may be brazed or welded to them; but the heat transfer at the surface of the baffles is not as high as it is at the surface of the tubes themselves, and efficiency is lost. Furthermore the tube and baffle structure is not easy to make.

My improved structure provides a transverse baffle formation which is formed of the material of the tubes themselves, which is easy and inexpensive to manufacture, which provides a baffle surface which is in full effect the external surfaces of the individual tubes themselves, and which provides a baffle structure that can be assembled to give any desired placement and transverse extent of the baffles to effect a highly uniform distribution of the fluid flow around the tubes. Further, as will be pointed out, my baffle formation provides compensation for unequal expansions and contractions of the several tubes; and performs its distributive functions without any mutual contacts between the tubes, or of the tubes with any baffle element, and thus, while allowing relative differential expansive movements, involves no contacts where relative movement will in time wear the tube walls through. The primary element of my baffle structure is a local external enlargement of each individual tube, that enlargement being preferably made as a ring-shaped formation surrounding the tube, and also preferably made by locally expanding the tube wall into such an annular bead as is shown in detail at 30 in Fig. 5. The bead thus preferably made has substantially the same wall thickness as the tube proper and is completely out of contact with adjacent beads so that each bead is completely physically free, and so that heat transfer through the tube wall at the bead is substantially the same as the heat transfer through the remainder of the wall of the tube.

As shown in Fig. 1, the arrangement in a heater of the type shown may preferably be such that there is more than one formation array of such beads arranged in transverse planes extending across the tubes 11 at the air intake 20, that is within the projected area of intake 20. Thus, as shown in Fig. 1, there is one such transverse formation of beads 30 extending across the area of inlet opening 20 adjacent the left hand edge of the opening, and another transverse formation of beads 30a extending across the tubes and across inlet opening 20 nearer the right hand edge of opening 20. As shown in Fig. 4 the left hand formation of beads 30 extends deeper into

the nest of tubes than does the right hand formation of beads 30a. (I am using the term "deeper" in the sense of a direction inward into the nest of tubes along the axis of inlet opening 20.) The relative depths to which the bead formations extend may be varied. As shown in Fig. 4 the left hand formation extends inwardly to the tube, or row of tubes, at the center of the tube formation, while the right hand bead formation only extends inwardly as far as two tubes or rows of tubes. The half section in Fig. 2 also shows the relationship. The tubes which are specifically designated by numerals 11a are the only ones which are provided with both beads 30 and beads 30a, the beads 30a being shown in full lines in Fig. 2; while tubes such as those designated specifically as 11b are provided only with the beads 30 which are shown in dotted lines.

The beads in each formation are preferably of such diameters, with relation to the spacings of the tubes, that the beads do not quite contact each other. For instance, using tubes of 1" diameter on spacings of approximately $1\frac{1}{4}$ " the external bead diameter may be typically $1\frac{1}{8}$ ", leaving $\frac{1}{8}$ " spacings between adjacent beads. (Figs. 2, 3 and 4 show these spacings. In Fig. 1 the spacings are fore-shortened due to the aspect in which the tube assembly is seen in that figure.) It is preferable that adjacent beads do not actually contact each other, but that there be an appreciable spacing between them at their closest points of approach so as to allow free space for air flow between the beads at those points, to prevent local overheating and to avoid local contacts. In any case, whether the beads actually contact each other or not, it is seen from Fig. 2 that the baffles which are formed by the bead formations are not solid or continuous but that the formations are interspersed with fluid flow passages between beads, such passages being designated 35 in Fig. 2. The final result is that the bead formations guide and enforce main distributed transverse flows of air such as are indicated by the solid line arrows in Fig. 4, past the inner edges of the bead formations, and also allow a secondary minor distributed flow through the bead formations, such as indicated by the dotted lines in Fig. 4. The final total result is a very even transverse distribution of flow from inlet 20 across the whole cross section of the tube assembly, and a consequent high efficiency of heat transfer and prevention of localized overheating of any part of the structure.

The same type of baffle formations may also be utilized at outlet 21, to transversely guide and distribute the fluid flow as it approaches and passes out through the outlet. Figs. 1 and 3 show the arrangement at the outlet, consisting of a shallower formation made up of beads 30c and a deeper formation made up of beads 30d. Without further detailed explanation, it will be seen from Figs. 1 and 3 that these two bead formations bear substantially the same relation to outlet 21 as the bead formations 30 and 30a bear to the inlet 20. The resultant distributed paths of flow at the outlet are thus made to be the same with relation to the outlet as they are to the inlet. Depending upon varying conditions, including the general design of the heat exchanger, the baffle formation of beads may be utilized only at the inlet or at the outlet, or at both inlet and outlet as circumstances require. And, as will be readily understood there may be only one, or any number of spaced baffle formations at the inlet or outlet, as circumstances require.

As has been previously noted, the heat transfer efficiency of my heat exchanger is exceptionally high in an apparatus of minimum size and weight. The life of the apparatus, its non-liability to local overheating and burning out, are also exceptionally high. And the structure is easy and inexpensive to manufacture and assemble. Tubes provided with the swelled beads and tubes without the swelled beads may be manufactured in quantity and kept in stock; and the locations and extents of the baffle formations are then merely matters of assembly of selected tubes. And another advantage may be remarked. Due to the fact that the location of the baffle formations depends merely upon the selection and assembly of appropriate tubes, the structure lends itself readily to efficient manufacture of heat exchangers in which the relative angular or longitudinal locations of the lateral inlet and outlet may be made to suit any locations of the connecting conduits. For instance, in the drawings the inlet and outlet are shown at a relative angle of 60°. The baffle arrangement for any other relative angular arrangement may be made up simply by proper selection and arrangement of the tubes.

Another important feature of my baffle structure, and one of the main reasons for the long life of a heat exchanger equipped with my invention, is the fact that differential tube expansions and contractions are provided for and that the tubes, including the beads, are completely free of any contact where destructive wear would take place. This feature is of high importance in any service where, as in the illustration given, the structure, including the tubes, is subjected to wide temperature ranges and excessive vibration. Under large temperature changes, such as are encountered in aircraft service, the distortions due to heat expansion and contraction are large. The tubes are subjected to unequal expansion and contraction stresses. The arch forms of the beads provide a substantial accommodation for differential longitudinal expansions and contractions. And, the tubes being free of any physical contacts throughout their lengths, the differential movements of the tubes causes no wear.

The baffle formations which I have described may also be used in situations and structures other than those particularly set out herein as illustrative of use of the invention. The exchanger designed particularly for aircraft use is

only typical; my invention is useful in any exchanger which embodies a set of heat transfer tubes. And, furthermore, the baffle structure may be used on a tube set for purposes other than that of causing distributed flow at inlet or outlet. Its more broadly expressed function is to cause directed and distributed flow of fluid over a set of tubes; and that function may be employed, by suitable arrangement of the baffle formations, to direct fluid flow over the tubes in various manners. For instance, the baffle formation may be used to guide fluid flow transversely across a set of tubes from an inlet at one side to an outlet which is transversely opposite. Or it may be used to guide a flow which is generally longitudinal of the tubes into a zig-zag path from one side of the casing to the other. The diagrams of Figs. 6 and 7 illustrate such typical uses. In those figures an assembly of tubes 110 is shown in a shell 100. Baffle elements are indicated diagrammatically. The flow of fluid around the tubes is generally longitudinal. In Fig. 6 baffle formations of tube enlargements 300 and 301, extending across the shell interior from opposite sides, guide the flow in a zig-zag path. In Fig. 7, alternating baffle formations of tube enlargements 302 located centrally, and of tube enlargements 303 located in annular formation near the shell wall, guide the flow as indicated.

I claim:

In a heat exchanger, the combination of an elongate external casing having inlet and outlet openings for one fluid near its opposite ends so that the fluid flows longitudinally in the casing between said openings, said inlet and outlet openings entering a side of the casing on axes transverse of the casing and tube lengths, an assembly of laterally spaced tubes extending longitudinally through the casing to carry the other fluid, and a baffle formation extending in a plane transverse of the tube lengths within the projected area of one of said openings, said baffle formation being composed of localized external enlargements of the walls of a contiguous tube group comprising less than the whole number of tubes, the several localized enlargements lying in said transverse plane and co-operatively forming a baffle restriction of the inter-tube passages over a baffle area in said plane which is less than the total area occupied by the whole tube assembly and which lies at that side of the casing which the opening enters.

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