Dec. 5, 1944. G. E. CLANCY 2,364,130

HEAT EXCHANGE APPARATUS

Filed March 2, 1942

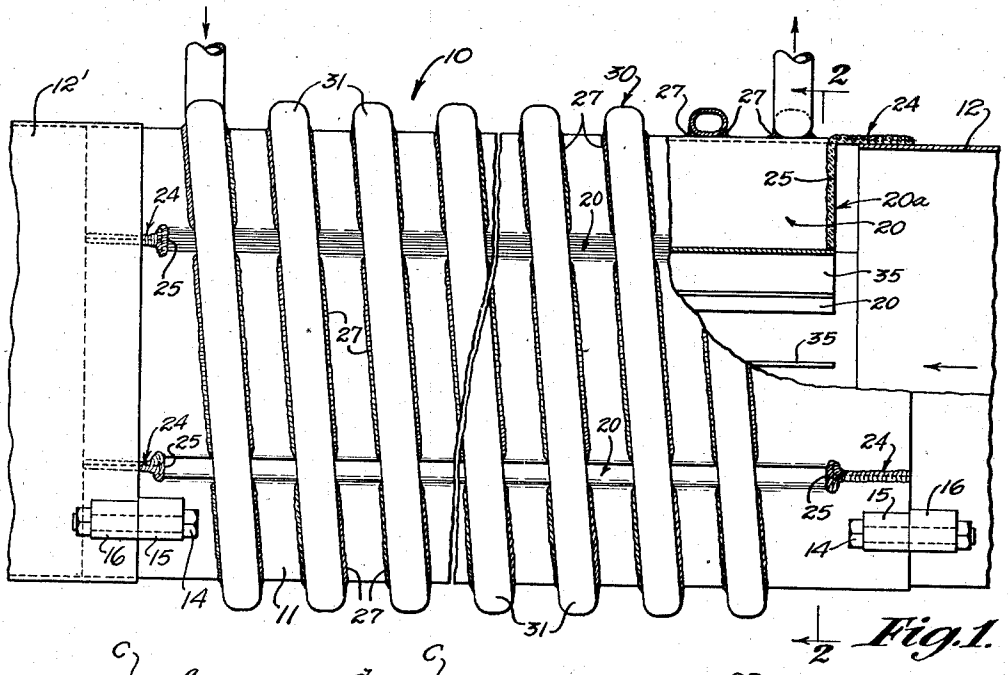


Fig. 1.

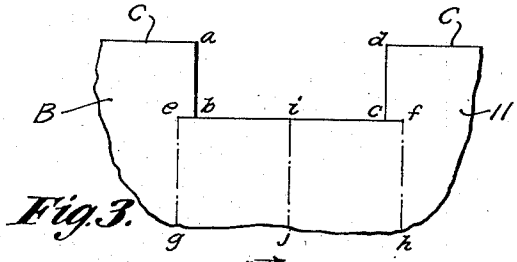


Fig. 3.

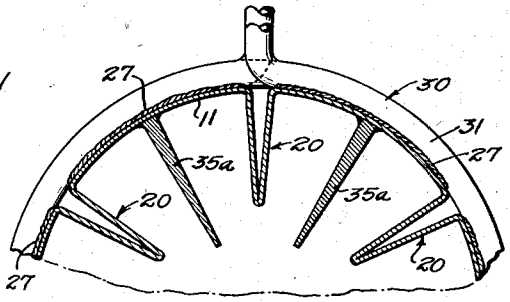


Fig. 4.

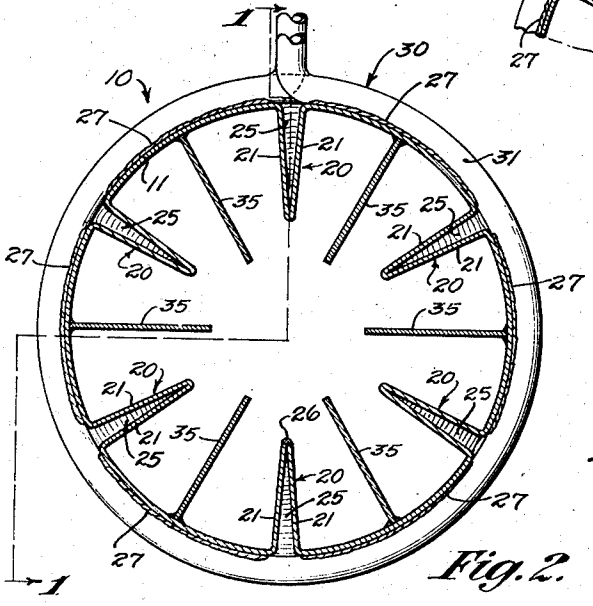


Fig. 2.

Inventor
Gilbert E. Clancy.

Barhelew & Scantlebury

Attorneys.

Patented Dec. 5, 1944 2,364,130

UNITED STATES PATENT OFFICE

2,364,130

HEAT EXCHANGE APPARATUS

Gilbert E. Clancy, Los Angeles, Calif., assignor to Drayer & Hanson, Incorporated, Los Angeles, Calif., a corporation of California

Application March 2, 1942, Serial No. 432,959

1 Claim. (Cl. 257—241)

This invention relates generally to heat exchange apparatus, and more particularly to fluid heaters and boilers designed to utilize the waste heat of exhaust gases of an aircraft or other internal combustion engine, though not necessarily limited thereto.

Aircraft of modern design are commonly equipped with cabin heating systems and with water heaters, and may have use for steam as a medium for driving the turbines of generators and the like. Heat exchangers designed to derive the heat for such typical needs from the exhaust gases of the engine have been incorporated directly in the exhaust pipe. The exhaust pipe of a large aircraft may be, for instance, about 9'' in diameter, and the exhaust gases flowing through the pipe will range in temperature between 1200° and 1700° F. Under such conditions, the heat exchanger may, if properly designed, derive sufficient heat for all these needs from the exhaust gases, though prior efforts to provide suitable apparatus of the class mentioned have realized but little success owing to failure to recognize or to provide satisfactory solutions for certain inherent problems immediately presented. Among these problems are the provision of a structure which will not be liable to fracture under the severe expansive forces incident either to the high temperature ranges involved in operation, or to freezing up while the plane is on the ground; the provision of a structure which will not burn out if it should become dry; the provision of a heat exchange arrangement yielding a sufficiently high rate of heat transfer between the exhaust gases and the fluid to be heated; and finally, the provision of a construction which does not set up objectionable turbulence in the exhaust gases, nor in any other way materially increase the back pressure in the exhaust pipe.

The general object of the present invention is to provide a simple, rugged and relatively inexpensive waste heat heater or boiler which overcomes all of the above mentioned problems.

With this general object in view, I now proceed to a detailed description of one present preferred illustrative embodiment of the invention, reference being had to the accompanying drawing, in which:

Fig. 1 is an elevation, with parts broken away, of a boiler in accordance with the present invention indicated as made up in an exhaust pipe such as that of an aircraft engine, the broken away portion at the right-hand end of the view being in accordance with the broken line 1—1 of Fig. 2;

Fig. 2 is a transverse section taken on line 2—2 of Fig. 1;

Fig. 3 is a fragmentary view showing a portion of the metal blank of which the shell of the boiler is formed prior to formation of the radial indentations; and

Fig. 4 is a detail similar to a portion of Fig. 2, but showing a modification.

The boiler of the present invention, designated generally by numeral 10, embodies a tubular shell or sleeve 11, formed typically and preferably of 18 gauge sheet steel, adapted to be made up as a section of a conduit carrying hot gases, such as the exhaust pipe of an aircraft engine. Thus, as here typically illustrated, the sleeve 11 is shown as receiving within its right hand end the end portion of exhaust pipe section 12, understood to lead from the exhaust manifold of an aircraft engine, and as received at its left hand end within the end portion of exhaust pipe section 12', understood to discharge to atmosphere. Sleeve 11 is secured to the exhaust pipe section 12 and 12' in any suitable manner, as for instance by means of screws 14 passing through perforated lugs 15 and 16 (see Fig. 1).

The sleeve 11 is formed with a plurality of longitudinally extending expansion joints, permitting necessary radial expansion and contraction of the sleeve with all temperature changes to which the boiler is subjected. In the present preferred embodiment of the invention, these expansion joints are in the form of a plurality of annularly spaced longitudinally extending indentations 20, bent inwardly substantially radially from the metal of the sleeve, and extending substantially from end to end of the sleeve in directions parallel to its central longitudinal axis. As best shown in Fig. 2, each such indentation is defined by two longitudinally extending wall portions 21 forming a reentrant angle of for instance about two or three degrees (the drawing shows the angle somewhat exaggerated), affording substantial freedom for radial and circumferential contraction or expansion. The indentations 20 may extend inwardly within the sleeve typically and preferably to a distance substantially half its radius.

Indentations 20 terminate just short of the connections of the sleeve 11 with the exhaust pipe, as indicated at 20a (Fig. 1), and the end portions of the sleeve, outwardly of the ends of the indentations, are closed to permit the effect-

ing of a proper closure with the exhaust pipe. The manner of accomplishing this closure will be apparent from a consideration of Fig. 3, which is a detail showing a fragmentary end portion of the initially flat rectangular blank from which the sleeve will be understood to be formed. In Fig. 3, B designates the fragmentary portion of the blank, and letter C an edge which is eventually to become one end of the sleeve. Edge C is formed with a plurality of rectangular notches such as *abcd*, one for each of the indentations **20** (but one such notch appearing in Fig. 3), and it will of course be understood that the edge of the blank opposite to edge C will be formed with corresponding notches of the same kind. The metal is severed for a short distance beyond points *b* and *c*, to form a straight edge *ebcf*. The metal is then bent inwardly along longitudinal crease lines *eg* and *fh*, being at the same time folded in the reverse direction at crease line *ij* to form the apex of the indentation. Thus the areas represented by *egji* and *fhji* will form the two walls **21** of the indentation. In this operation, edges *ab* and *cd* are butted against one another, and they are then welded together, as indicated at **24** in Fig. 1. The openings then left at the ends of the wall members **21** (between the edges represented by *ei* and *fi* in Fig. 3) are closed by welding, as indicated at **25** in Figs. 1 and 2.

In the particular embodiment of the invention here disclosed, the sleeve or shell **11** is, as stated, formed from a rectangular blank, so that a longitudinal seam is necessarily provided. This may conveniently be located at the apex of one of the indentations **20**, and the seam closed by welding, as indicated at **26** in Fig. 2.

Mounted on the sleeve **11** is a coil **30** comprising a number of spaced turns of steel tubing **31**, preferably and here shown as flattened somewhat, so as to increase the area of contact with the sleeve. This tubing is welded along each of its edges to the sleeve **11**, as indicated at **27**, so as to reduce materially the resistance to flow of heat from the sleeve to the tubing. However, as will be evident from the drawing, the weld-integration of the tubing to the sleeve is discontinuous, being interrupted wherever the tubing bridges across an indentation **20**.

The end of the coil at the downstream end of the sleeve **11** is connected to the supply of water or other liquid to be heated or evaporated, and the other end of the coil is of course connected to whatever is to be supplied with the hot water, steam, etc.

The "hydraulic radius" of the sleeve is reduced, and the pick-up of heat from the exhaust gases correspondingly augmented, by the use of radially disposed longitudinally extending fins **35** here illustratively shown as welded to the interior surface of the sleeve. These fins **35** are positioned in parallelism with the central longitudinal axis of the sleeve, so as to avoid setting up turbulence in the exhaust gases flowing through the sleeve, as well as the creation of back pressure on the engine, and they are preferably and here shown as extending about two thirds of the distance from the wall of the sleeve to its center, the fins being here shown as uniformly spaced between the radial heat expansion indentations **20**.

The boiler as thus described has many unique advantages. Considered first from the standpoint of heat transfer, the following features are to be noted. The radial fins **35**, as well as the radial indentations **20**, reach deeply into the exhaust gases flowing through the sleeve, reducing greatly the "hydraulic radius," and hence increasing correspondingly the quantity of heat absorbed and conveyed to the sleeve. This heat then flows into the coil **30** tightly wrapped about the sleeve, the conduction from the sleeve to the coil being augmented substantially by the weld connections **27**. The described weld-integration of the tubing **30** to the sections of the sleeve **11** between indentations **20** greatly increases the rate of heat transfer from the sleeve into the coil. The flattening of the tubing, with one of its flat sides in contact with the sleeve, substantially increases the area of contact between the sleeve and the coil, and hence further materially increases the rate of heat transfer. Moreover, the flattening of the tubing reduces its hydraulic radius, and hence increases the rate of heat transfer from the tubing to the water or other liquid contained therein, as will be evident to those skilled in the art.

The indentations **20** and the fins **35** both function as heat intercepting and conducting fins, being designed to absorb a substantial quantity of heat from the gases and to convey heat at a rapid rate to the sleeve **11**. Fig. 4 shows a modification, in which the fins **35***a* are tapered in thickness, being thickest at their butt ends, that is, at point of juncture with the sleeve. Since all portions of the fins absorb heat from the hot gas, and since the heat intercepted by the fins flows outwardly toward the sleeve, the quantity of heat carried by the fins necessarily increases in the same direction, with some tendency to overheat the outer portions of the fins. The described thickening of the fins toward their butt ends accommodates this increased heat flow.

The coil of the boiler as described cannot burn out even though operated dry. This follows from the fact that the heat radiation surface of the coil, arranged on the outside of the shell, is equal to or greater than the radiation surface of the sleeve, and so long as the sleeve itself does not burn out, it is impossible to convey sufficient heat from the sleeve to the coil to burn out the latter.

Neither the sleeve nor the coil is subject to fracture under the rather substantial expansive forces arising either from the extreme heat to which the apparatus is subjected, or from possible freezing of water in the coil. The described expansive joints in the sleeve allow it to expand or to contract radially and circumferentially, or to twist somewhat about its longitudinal axis to accommodate itself to any stresses placed upon it under any contemplated service conditions. The coil has been described as weld-integrated to the sleeve, but with a necessary break in the weld line whenever the tubing bridges across an expansion joint. This results in a structure having some capability for yielding torsionally about its central longitudinal axis with any torsional stress that may be set up owing to differential rates of expansion or contraction between the sleeve and the coil. The structure as described is capable of expanding, contracting, or working or giving in any required direction, with any stress placed upon it owing to high heat, rapid temperature changes, or freezing up, all possibility of fracture resulting from any temperature conditions which will be experienced under service conditions having been eliminated.

The flattening of the tubing of which the coil is composed safeguards against bursting of the coil upon freezing up. Thus, since the cross-

sectional area of a round tube is greater than that of a flattened tube, if water left in the coil should freeze, and therefore expand, the effect will be merely to force the flattened tubing to assume a more rounded shape, such change of shape being sufficient to provide the increased volume required.

The disposition of the indentations **20** and fins **35** in planes parallel to the sleeve is of importance in avoiding turbulence of the exhaust gases, and hence back pressure on the engine.

In brief summary, the boiler of the present invention has the important features of exceptionally high rate of heat transfer from exhaust gases to the liquid to be heated, avoidance of all possibility of fracture of the structure under any temperature condition which may be experienced in practical service, impossibility of burning out the coil, even if dry, and substantially complete avoidance of increasing the back pressure on the engine.

Certain of the advantageous features of structure and operation which have been described apply to heat exchangers in general as well as to boilers, and apply also whether the high temperature fluid or the low temperature fluid flows through the inner sleeve. For instance, the provision of the expansion and contraction joints **20** takes care of the stresses which would otherwise be set up by differential expansions or contractions in such a structure where one member (the inner member here) carries fluid at one temperature, and the other member (the outer member here) in metallic contact or metallically bonded with the first member, carries a fluid at another temperature. In any such circumstances the expansion joints **20** accommodate differential contractions and expansions and also materially increase the heat conducting surface.

In the specific illustrative form which has been described the spiral tube form of one of the fluid carrying members allows free expansion and contraction of that member with the longitudinal changes of dimension of the other member which is here shown as tubular; while the expansion joints **20** in the latter member accommodate that member to the lateral or circumferential contractions and expansions of the first mentioned or spiral member.

It is of course to be understood that the drawing, and description are to be considered as merely illustrative of the invention in one of its possible practical forms, and that various changes in design, structure and arrangement may be made without departing from the spirit and scope of the invention or of the appended claim.

I claim:

In heat exchange apparatus, the combination of a fluid carrying member having a heat conductive, fluid confining wall of general tubular formation, said wall including a plurality of circumferentially spaced and longitudinally extending open indentations which project inwardly, from the inner surface of those portions of the wall which lie between the indentations, into the interior of the tubular member to form internal hollow heat conductive fins, said indentations being externally open to the surrounding atmosphere at their outer edges and forming fluid confining portions of the wall which also provide for circumferential contraction and expansion; means connected with an end of the tubular member for feeding a fluid exclusively through the interior of said member, the interiors of the open indentations being isolated from the fluid feed; and another fluid carrying member composed of a helically coiled tube with longitudinally spaced turns closely surrounding the indented tubular wall, physically and heat-conductively integrated with the wall between the circumferentially spaced indentations, and bridging their outer openings.

GILBERT E. CLANCY.