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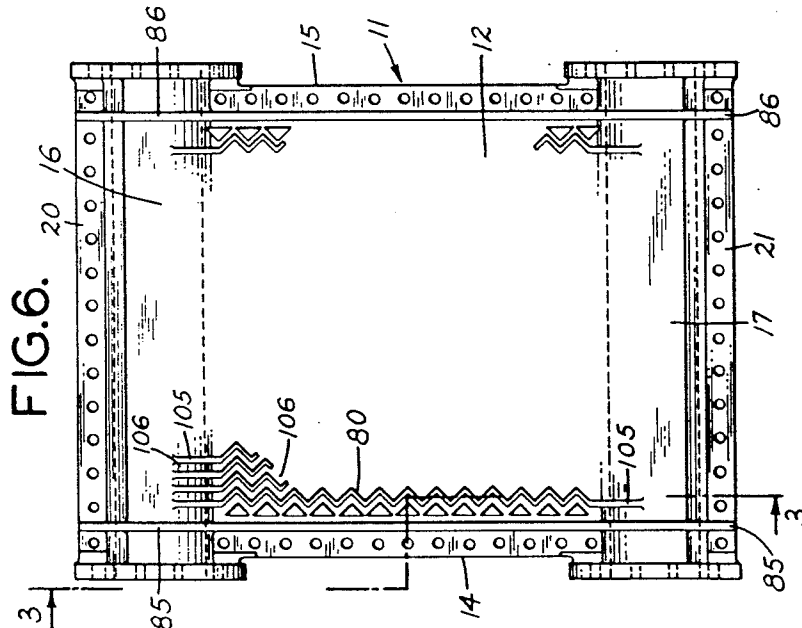
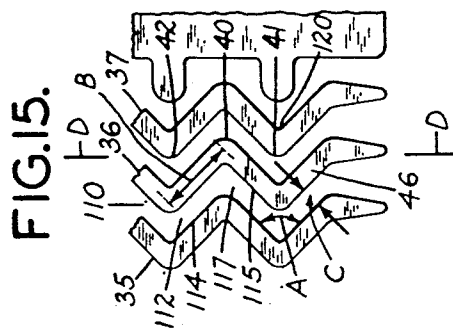
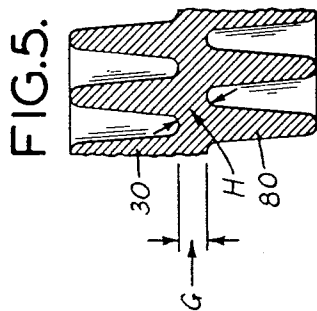
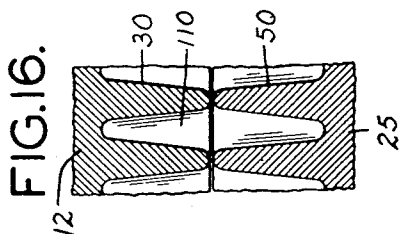
B. M. CARTER

2,566,928

HEAT EXCHANGE APPARATUS

Filed Dec. 10, 1947

3 Sheets-Sheet 2



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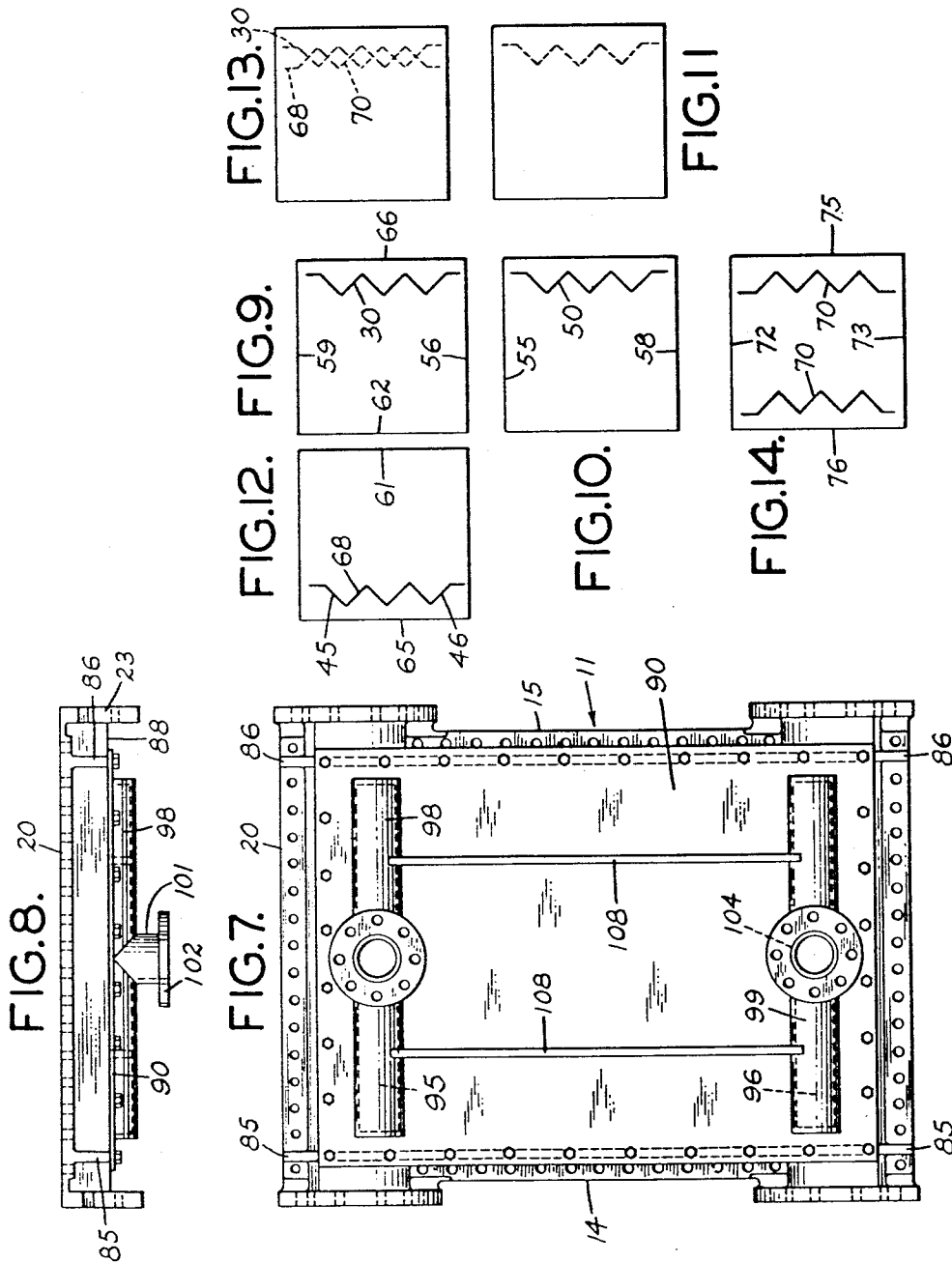
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UNITED STATES PATENT OFFICE

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HEAT EXCHANGE APPARATUS

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Application December 10, 1947, Serial No. 790,735

9 Claims. (Cl. 257-245)

1 This invention relates to heat exchangers, and particularly to cooling apparatus, adapted for use in the manufacture of e. g. sulfuric acid, of the type in which the acid or other fluid to be cooled is flowed in the form of a ribbon or thick sheet between relatively closely arranged metallic heat transfer walls which are externally cooled by a cooling medium such as water.

In acid cooling apparatus of the kind to which this invention relates, it is important to maintain turbulence and to effect a complete breaking up or thorough mixture of all portions of the acid layer or ribbon being cooled in order to prevent the formation of a central core of relatively uncooled acid interiorly of the acid ribbon as the latter flows between the externally water-cooled side walls of the cooler. In order to provide for the foregoing, in prior apparatus, design has been such as to space the acid passage side walls rather close together, thus restricting the thickness of the acid layer or ribbon. Further, the area of heat transfer metal in contact with the acid is relatively fixed. These factors limit the capacity of a unit of given rectilinear dimensions.

A principal object of my invention is to increase the capacity of coolers of the type indicated and thereby decrease the number of units required for installation. With reference to a cooler unit or cell of given rectangular dimensions, the invention aims to provide constructions the design of which affords increased metal surface areas with which acid to be cooled and cooling medium are in contact, increased heat transfer from the acid to the metal, supply of heat to the metal in quantity equivalent to the maximum conductivity of the particular metal employed, and increased heat transfer from the metal to the cooling medium, and at the same time provide structural aspects which are needed to prevent core formation. By so doing, I am enabled to substantially increase the quantity of acid flowing between the acid confining walls and correspondingly increase the capacity of a cooler unit of given rectilinear dimensions.

The invention, its objects and advantages may be understood from the following description taken in connection with the accompanying drawings, in which

Fig. 1 is an elevation of the inside face of the rear side plate or casting of a preferred cooling unit of the invention, Fig. 1 being taken looking in the direction of the arrows of line 1-1 of Fig. 2;

Fig. 2 is a half plan view of the top of the side

2 plate or casting of Fig. 1, and a half horizontal section taken on the line 2-2 of Fig. 1, and also shows fragmentally in horizontal section a portion of a front side wall plate not shown in Fig. 1;

Fig. 3 is a partial end elevation and a partial vertical section taken on the lines 3-3 of Figs. 1 and 6; Fig. 3 also showing partly in elevation and partly in vertical section an outer cover plate not shown in Figs. 1, 2 or 6;

Fig. 4 is an end elevation of the front side plate or casting of the preferred cooling unit, shown without the outer cover plate indicated in Fig. 3;

Fig. 5 is a detail section taken on the line 5-5 of Fig. 1;

Fig. 6 is an elevation of the outside face of the rear side plate or casting of Fig. 1, Fig. 6 being taken looking in the direction of the arrows of line 6-6 of Fig. 2;

Fig. 7 is an elevation the same as Fig. 6 except that in Fig. 7 an outer cover plate is shown bolted in place;

Fig. 8 is a top plan view of Fig. 7;

Figs. 9-14 are diagrammatic sketches hereafter discussed;

Fig. 15 is an enlarged detail of the extreme lower right-hand corner of the ribwork of Fig. 1; and

Fig. 16 is an enlarged detail of a portion of Fig. 2.

Referring particularly to Figs. 1-4, the cooler unit comprises vertically disposed front and rear side plates 10 and 11 preferably made of cast iron. Rear plate or casting 11, the inner or acid side of which is shown in elevation in Fig. 1, comprises a preferably planar side wall section 12 bounded on either vertical side edge by outwardly extending flanges 14 and 15. The upper horizontal edge of wall section 12 terminates in an upper half-header portion 16, and the lower horizontal edge of section 12 merges with lower half-header portion 17. The upper and lower header portions are each provided with vertical flanges 20 and 21 which are coplanar with side flanges 14 and 15. On each end of each half-header section is a semicircular flange 23. From a comparison of Figs. 3 and 4, it will be seen that the general construction of front side plate or casting 10 is similar to that of rear plate 11, front plate 10 including a preferably planar side wall section 25 (shown by dotted lines in Fig. 4) and upper and lower header portions 27 and 28. Flanges 14, 15, 20, and 21, and the matching flanges on front plate 10, are drilled as at 29 to accommodate bolts by means of which front

and rear side plates 10 and 11 may be attached together to form a unitary structure which comprises spaced apart side wall sections, an upper horizontal header for inflow of acid to be cooled, and a lower outlet header for discharge of liquid from the unit. The flanges on the ends of the half-header portions afford means for connecting the unit shown to other cooling units or to suitable acid inlet and outlet pipes.

One of the major features of the invention which make it possible to space the side wall sections relatively far apart, and thereby largely increase the capacity of the unit of given rectangular dimensions, and at the same time maintain the turbulence and effect complete breaking up and thorough mixture of all portions of the acid being cooled in order to prevent the formation of a central quiescent core of relatively uncooled acid, is the provision on the inner face (the acid side) of wall section 12 of inwardly projecting ribs indicated in general by numeral 30. Such ribs, when viewed in elevation as in Fig. 1, may take various forms in accordance with different modifications of the invention. Usually these ribs are cast integrally on the acid side of the wall section and lie in planes which are disposed preferably at a right angle to the general vertical plane of side wall section 12.

In the embodiment of the invention shown, the ribs 30 appear in elevation, Fig. 1, as a series of corrugations of general Z-shaped configuration. Preferably each of ribs 30 is cast on the inner face (acid side) of wall section 12 so that the entire rib edge, remote from the inner face of planar wall section 12, lies in a vertical plane which passes thru the longitudinal axes of the upper and lower headers. This construction may be observed from Fig. 3 which shows that the innermost edges of all of ribs 30 and the inner faces of top and bottom flanges 20 and 21 and of side flanges 14 and 15 all lie in a common plane which includes the longitudinal axes of the upper and lower headers when the unit is assembled.

Fig. 15, an enlarged detail of the lower right corner of Fig. 1, shows three adjacent ribs 35, 36 and 37. The wave-like configuration of the ribs, when seen in elevation as in Figs. 1 and 15, may vary substantially. For example, the angle A (Fig. 15) may be acute or obtuse, but in order to obtain good commercial results, angle A ordinarily lies within the range of 75-105°, and is preferably about 90°. Leg length, distance B Fig. 15, of a single wave or corrugation of a rib 30 may likewise vary to a considerable extent. The spacing apart of ribs 30, distance C, is subject to substantial variation, but should be such as to provide a relatively narrow channel between two adjacent ribs. Further, in the more desirable forms of the invention when angle A is about 90°, spacing-apart distance C and leg length B are so chosen and correlated that (1) straight line (linear) travel of an acid particle thru a channel is not substantially more than spacing apart distance C, and (2) the apex, e. g. 40 of rib 36, Fig. 15, of a convex surface of a rib extends at least to and preferably just beyond a vertical plane which is disposed at a right angle to the vertical plane of wall section 12 and which passes thru the apices 41 and 42 of the adjacent convex surfaces of the adjacent rib 37, the vertical trace of such a plane being represented by the line D-D of Fig. 15. This arrangement prevents uninterrupted straight-line downflow of acid between two adjacent ribs, e. g. 36 and 37.

An important feature of all forms of the invention in which ribs 30 are wave-like or corrugated (when viewed in elevation as in Fig. 1) is that the design of each rib 30 is preferably such that the terminal slopes 45 and 46 of a given rib are disposed in angular relation, preferably at right angles. Thus, ribs 30 are formed so that an individual rib is made up of a plurality of complete wave lengths, and because of this arrangement the courses of the terminal slopes of such rib are relatively at right angles. It will be observed that the portions of the structure of Fig. 1 above and below a horizontal median line and that the portions of the structure of Figure 1 to the right and left of a vertical median line are symmetrical. The reason for the foregoing construction hereinafter appears.

The inner face (acid side) of side wall section 25 of front side plate 10 is provided with ribs 50 (Fig. 2) similar in elevational wave-like configuration to ribs 30. In one form of the invention both the front and rear plates 10 and 11 are cast in molds which are identical throughout. Alternatively, the front plate 10 may be cast in a mold which may be the same as the mold used for casting the rear plate 11 except that the mold employed for casting the front plate 10 is made so that the elevational configuration of the ribs 50 as cast on the inner side (acid side) of the front side wall section 25 are mirror patterns of the ribs 30 on the inner side of the rear wall section 12. For convenience of discussion, these two forms may be hereinafter referred to as "identical patterns" and "mirror patterns."

The invention provides cooler units or cells which may have one of two distinctly different modifications of rib arrangements within the acid space. As previously observed, the cooler unit is assembled by bolting a front and rear plate together at corresponding flanges. The relation between identical and mirror rib patterns and the differences between the internal rib arrangement of heat exchange units which may be made by using a pair of identical pattern rib side walls or a pair of mirror pattern rib side walls may be understood from a consideration of Figs. 9-14.

Figs. 9-13 diagrammatically illustrate assembly of two different internal rib arrangements of two forms of coolers both of which may be made from two castings having identical rib patterns. Fig. 9 represents an elevation of the inside of a rear side wall section the same as side wall section 12 of Fig. 1. Fig. 10 represents an elevation of the ribbed inside of a wall section which in all respects is identical with the wall section of Figs. 1 and 9. It will be seen that when the casting of Fig. 10 is turned up out of the plane of the paper and rotated 180° about edge 55 so that the inside of the Fig. 10 casting is placed in abutting relation with the inside of the casting of Fig. 9, and so that edge 55 of Fig. 10 coincides with edge 56 of Fig. 9, and so that edge 58 of Fig. 10 coincides with edge 59 of Fig. 9, the cooler construction thus formed is such that corresponding ribs 30 and 50 abut (except for the thickness of the gasket between the bottom and side flanges) and are exactly coextensive. The resulting "coextensively ribbed" cooler unit or cell appears in front elevation as shown in Fig. 11 of which the dotted line indicates a generally Z-shaped partition made up by the abutting and coextensive ribs 30 and 50 and extending across the acid space of the unit.

Fig. 12 represents an elevation of the ribbed inside of a wall section which again in all respects

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is identical with the wall sections of Figs. 1 and 9. If the wall section of Fig. 12 is turned up out of the plane of the paper and rotated 180° about edge 61 so that the inner faces of the wall sections of Figs. 12 and 9 abut, and so that edge 61 of Fig. 12 coincides with edge 62 of Fig. 9 and so that edge 65 of Fig. 12 coincides with edge 66 of Fig. 9, the cooler construction thus formed when viewed in front elevation will appear as in Fig. 13. From the latter it will be noted that a rib 68 of Fig. 12 abuts a corresponding rib 30 of Fig. 13 at spaced intervals, but that such abutment of corresponding ribs is in criss-cross preferably right-angled relation, thus forming a "criss-cross ribbed" cooler unit.

Figs. 9, 14, 11 and 13 illustrate assembly of two different internal rib arrangements of two different cooler units which may be made from castings having mirror rib patterns. As before, Fig. 9 represents an elevation of the inside of a rear side wall section the same as side wall section 12 of Fig. 1. Fig. 14 indicates in elevation the inside of a casting which may be the same in all other respects as the Fig. 9 casting except that in Fig. 14 the ribs 70 are mirror patterns of the ribs 30 of Fig. 9. If the wall section of Fig. 14 is turned up out of the plane of the paper and rotated 180° so that the inner faces of the wall sections of Figs. 9 and 14 abut and so that edge 72 of Fig. 14 coincides with edge 56 of Fig. 9 and so that edge 73 of Fig. 14 coincides with edge 59 of Fig. 9, the resulting unit when viewed in front elevation will appear as in Fig. 13 giving a construction the same as previously described relative to Fig. 13, i. e. a rib 70 of Fig. 14 abuts a rib 30 of Fig. 13 at spaced intervals but such abutment of corresponding ribs is in criss-cross right-angled relation.

Assume that the mirror pattern castings of Figs. 9 and 14 were placed side by side, i. e. so that the casting of Fig. 14 is placed in a position the same as that of Fig. 12. If the inside of a Fig. 14 casting is then turned over 180° into abutting relation with the inside of a Fig. 9 casting so that edge 75 of Fig. 14 coincides with edge 62 of Fig. 9 and so that edge 76 of Fig. 14 coincides with edge 66 of Fig. 9, the resulting construction with respect to rib arrangement will be the same as shown in Fig. 11 in which corresponding ribs on the opposite sides of the unit abut and form coextensive partitions across the cooler unit.

Fig. 11 represents one preferred modification of internal rib arrangement in which corresponding inwardly projecting ribs on the rear and front wall sections abut, are coextensive, and form partitions extending across the acid space of the cooler, particularly as shown fragmentally in Fig. 2. Fig. 13 represents a second preferred internal rib arrangement in which corresponding ribs on the front and rear wall sections abut at spaced intervals but in criss-cross right-angled relation. From an inspection of Figs. 9-14 it will be seen that the terminal slopes (e. g. 45 and 46, Fig. 12) of all of the ribs shown in the several figures are relatively at right angles. While in all forms of cooler units within the scope of these improvements the angular terminal slope arrangement described is not controlling, in accordance with the invention, it has been determined that when internal ribs are designed so that the terminal slopes or portions of each rib are oppositely disposed preferably at right angles, it is possible to assemble a unit in either of the modifications shown in Figs. 11 and 13 regardless of whether the internal ribs of op-

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posed wall sections are of identical or mirror patterns. Thus, this right-angled terminal slope feature of the invention affords the outstanding manufacturing advantage that front and rear plates or castings 10 and 11 may be made in molds which in all respects are identical, and yet the two different forms of internal rib arrangements, as illustrated in Figs. 11 and 13, may be made by assembling in the manner discussed in connection with Figs. 9-13. In the manufacture of some cooler units it may be desirable to have some parts, other than the wall sections 12 and 25, of non-corresponding form or configuration in which instance it may be necessary to use for the manufacture of a single unit two different molds and provide internal ribs of mirror patterns. However, even with these changes, by designing the ribs so that the terminal slopes of each are oppositely disposed, it is still possible to make cooler units having the two different internal rib arrangements illustrated in Figs. 11 and 13 by assembling mirror pattern castings as above described in connection with Figs. 9 and 14.

A further important feature of the invention comprises construction by means of which the transfer of heat from the metal confining walls of the acid space to the fluid used as a cooling medium is greatly increased. To this end, the outside (water side) of each of the side wall sections 12 and 25 is provided with outwardly projecting ribs, such ribs 80 of rear wall section 12 being shown in section in Figs. 2 and 3 and in elevation in Fig. 6. As shown best by comparison of Figs. 1 and 6, the elevational configuration of inside ribs 30 and of outside ribs 80 is preferably the same except that the convex and concave portions of the outer ribs 80 when viewed as in the elevation of Fig. 6 are disposed in reverse relation to the corresponding portions of inner ribs 30 seen in Fig. 1. As shown particularly in the enlarged detail of Fig. 5, the outer ribs 80 and the inner ribs 30 are preferably arranged in a staggered form, which is such that an inside rib 30 and an outside rib 80 may be considered as being in a coextensive but offset relationship. This construction adds strength to the wall structure by affording a minimum thickness of wall metal, distance H, which is always greater than a distance G which represents the thickness of the metal side wall proper.

Referring to Figs. 3, 6, 7 and 8, the outside of rear side plate or casting 11 is provided near its vertical edges with flanges 85 and 86 which extend the full vertical length of the plate 12 and which project outwardly on the outside (water side) face of wall section 12 a distance such that the outer vertical edge of each of flanges 85 and 86 is flush with the outermost circumferences or bosses (as at 88, Figs. 3 and 8) of upper and lower header portions 16 and 17. The outer ribs 80 of rear wall section 12 likewise project outwardly from the water side of wall section 12 a similar distance, that is, the construction is such that the outer vertical edges of flanges 85 and 86, the outer vertical edges of the outside wall ribs 80, and the bosses of upper and lower header portions 16 and 17 all lie in a common vertical plane. This arrangement facilitates attachment of a cover plate 90, Figs. 3 and 7, which in conjunction with flanges 85 and 86 and the water side of side wall section 12 forms a water or other cooling fluid chamber on the backside of rear side plate 11. Fig. 6 shows a rear elevational view of rear side plate 11 without the cover plate 90 attached, while Figs. 7

and 8 show the cover plate in place. Plate 90 is rectangular and is drilled at its edges to facilitate bolting of the plate into water-tight relation to the outer vertical edges of flanges 85 and 86 and to the bosses of upper and lower headers 16 and 17. Thus as shown in Fig. 3, it will be seen that the inner face of cover plate 90 abuts the outer vertical edges of the outer wave-like ribs 80 of Fig. 6.

Plate 90, near its upper and lower edges, is provided with rectangular slots 95 and 96 which, as shown particularly in Fig. 3, are positioned adjacent the outside surfaces of the upper and lower header portions 16 and 17. Welded to the edges of slots 95 and 96 are the edges of semi-circular closed-ended conduits 98 and 99, slots 95 and 96 and associated conduits 98 and 99 extending substantially the width of cover plate 90. Upper conduit 98, Figs. 3, 7 and 8, is provided with a centrally disposed inlet pipe 101 flanged as at 102 for connection to a cooling medium feed line. Lower conduit 99 is provided with a similar flanged outlet pipe 104. It is noted that the upper and lower ends of each outside rib 80 (Fig. 6) are provided with vertical extensions 105 the outer ends and edges of which merge into and become flush with the bosses of upper and lower header portions 16 and 17. Since these extensions terminate within the areas bounded by the slots 95 and 96, it will be seen that each channel 106 between each pair of adjacent ribs 80 is in direct communication with upper and lower conduits 98 and 99. Ribs 108 afford strengthening for cover plate 90.

It will be understood that the construction providing a cooling medium chamber on the outside of front side plate 10 is the same as above described in connection with rear side plate 11.

In connection with the operation of the apparatus described, e. g. for cooling sulfuric acid, it will be noted (Fig. 1) that the upper end of each channel between two adjacent ribs 30 opens into the upper header, and the lower end of such channel discharges into the lower header. In this embodiment of the invention, the coextensive relationship of corresponding ribs on the rear and front wall sections 25 and 12 is illustrated particularly in the section of Fig. 2 and the detail of Fig. 16 which shows that corresponding rear and front ribs form substantially unbroken partitions extending transversely of the cooler unit, and that any two adjacent partitions form a channel 110 which in horizontal section is elongated transversely of the cooler unit. Each of these channels provides for a ribbon or stream of acid to be cooled disposed at a right angle to the sides of the cooler and having a horizontal cross-sectional area corresponding with the horizontal cross-sectional area of the channel.

As more clearly shown in the detail of Fig. 15, ribs 30 are constructed preferably to provide a plurality of sharply inclined reversely extending surfaces against which the acid in a channel 110 impinges. After the acid flows downwardly in one portion 112 of a channel 110, an abrupt change in the direction of flow produced by the sharp concave turn of rib 36 causes the relatively sluggish skins of acid particles, formerly in contact with opposing faces of the ribs, and the faster moving central core of acid, which was not in direct contact with the surface of either rib, to be vigorously churned up and thoroughly mixed. As the acid flows to the end of the lower and oppositely inclined portion 117 of channel 110, a similar though oppositely disposed turbu-

lence and mixing of the acid is effected. It will be observed that the ribs are provided with a plurality of convex surfaces 40 and a plurality of concave surfaces 120 connected by short inclined surfaces. Thus, the acid between two adjacent ribs is projected successively across each passage from one rib to the adjacent rib. It will be understood that the shorter the lineal or straight line length of the inclined surfaces, the greater will be the turbulence of the acid flowing between two adjacent ribs, the most satisfactory results being obtained when the length of inclined portions 112 and 117 are such as to limit straight line linear travel of an acid particle to a distance not substantially longer than the thickness C of each channel 110. Also, it will be recalled that the ribs are formed and spaced so that the apex of the convex surface of one rib projects at least to and preferably thru a vertical plane which is disposed at a right angle to the vertical plane of the wall section and which passes thru the apices of the adjacent convex surfaces of the adjacent rib as mentioned in connection with Fig. 15. This construction prevents an uninterrupted vertical descent of any liquid directly from the upper header to the lower header, and also prevents the passage of liquid particles between adjacent ribs without causing such particles to be repeatedly projected from contact with one rib to contact with another. Further, it will be observed that the wave-like course or undulation of a ribbon of acid, flowing downwardly in a channel 110 formed by two adjacent ribs 30 and the two corresponding ribs 80 on the front wall section, lies in a general plane disposed at right angles to the rear and front side wall sections 12 and 23 of the cooler unit.

A principal function of inner ribs 30 and 50 on the rear and front wall sections is to largely increase, within a minimum space, the amount of metal heat-conducting surfaces exposed to the acid being cooled. As will be observed from Figs. 2 and 16, the inwardly projecting ribs greatly multiply the extent of metal heat-conducting surface in contact with acid as compared with prior constructions which comprise only side walls which may be of corrugated configuration in transverse vertical cross-section, but do not contain the inwardly projecting ribs. In cooler units of the latter type which do not include inwardly projecting ribs, in order to provide reasonably satisfactory turbulence, core breaking, and acid mixing as the acid flows down between the outer cooler walls, it is necessary that the side walls be positioned close together. This limits the total area of the acid passageway between the upper header and the acid space of the cooler unit as defined by the closely spaced side walls, and correspondingly limits the capacity of a unit of given rectangular dimensions. In accordance with this invention, provision of the inner ribs 30 and 50 projecting into the body of acid in the cooler unit affords such a greater increase of metal cooling surface in contact with acid as to make it possible, in the case of use of cast iron, to space apart the side walls distances equal to 6 to 8 times the spacing permissible in similar but non-ribbed cooler units. The combined result of the use of the inwardly projecting ribs and the much farther apart spacing of the side walls is that the total area of the several channels 110 as shown on Figs. 2 and 16 is greatly increased as compared with the total area of the passageway between the upper header and the interior of the cooler in constructions in which the inwardly

projecting ribs are not provided and in which the absence of such ribs requires close spacing of side wall sections.

The advantages afforded by the invention will be appreciated from a comparison of a specific "coextensively ribbed" embodiment of Figs. 1-8 and 11 and a typical prior art acid cooler having corrugated side wall sections but not provided with inwardly projecting ribs. In both instances, assume rectangular elevational dimensions of about 3 feet square. In the prior art apparatus, having corrugated side wall sections but no inwardly projecting ribs, in order to obtain reasonably satisfactory turbulence, core breaking, and acid mixing as the acid flows down between the outer corrugated cooler walls, the side walls should be spaced about $\frac{1}{2}$ inch apart. Thus, the ribbon of acid flowing from the upper header into the acid space between the side walls has a width of $\frac{1}{2}$ inch and a length of 36 inches, giving a total horizontal cross-sectional area of 18 square inches. The combined areas of the corrugated side walls have an acid contact surface, between the upper and lower headers, of about 21-23 square feet. In the invention embodiment being discussed, the front and rear side wall sections are provided with say 25 coextensive inwardly projecting ribs affording downflow thru the cooler of 26 acid ribbons disposed at a right angle to the vertical side wall sections 12 and 25. Assume, as practice of the present invention has shown easily permissible, that each of ribs 30 and 53 (Fig. 16) projects inwardly from side walls 12 and 25 a distance of 2 inches, the spacing apart of adjacent ribs being such that the average width of a channel 110 is $\frac{1}{2}$ inch. Accordingly, there are passed downwardly thru the cooler 26 ribbons of acid each having a horizontal cross-sectional area of 2 square inches, giving a total horizontal cross-sectional area of acid in the cooler of 52 square inches. Further, the rib design illustrated and dimensions mentioned in connection with Fig. 16 afford about 86 square feet of internal metal surfaces between the headers in contact with the acid. Hence, in this specific embodiment of the invention, the total horizontal cross-sectional area of the several acid ribbons of 52 square inches and an acid contact surface of about 86 square feet substantially exceed the 18 square inches and 22-23 square feet values of the prior art apparatus, and the capacity of a cooler unit of the same rectangular dimensions is increased about 2.5 times the capacity of the prior art cooler.

The outstanding advantage demonstrated above is attributable to the provision of the inwardly projecting ribs which permit a substantial farther spacing apart of cooler side wall sections 12 and 25. This spacing apart, while indicated as 4 inches in the specific embodiment discussed, is limited only by the conductivity of the metal used and the ability of the apparatus to remove quickly from the metal the heat transferred thereto from the acid. In accordance with this invention, removal of heat from the metal in contact with the hot acid is greatly enhanced and speeded up by the provision of the particularly constructed outside water chambers. In practice, inlet pipe 101 and flange 102 (Fig. 8) are connected to a water supply, and water is run into top conduit 98 and thence into each of the channels 106 between outside ribs 80. Since these ribs 80 are preferably of the same configuration as the inner ribs 30, and since the water cooling medium is less viscous and more mixable than the acid being cooled, it is

readily possible to remove from the acid confining walls as much or more heat than can be taken up from the acid. Further, since the water chambers are closed by the cover plates 90, water may be passed thru the outside jackets under pressure and at any rate which may be found desirable under the particular circumstances of operation. Because of the great rapidity with which heat may be removed by the outside water jacket construction described, side walls 12 and 25 (Fig. 16) may be spaced even substantially farther apart than instanced in the above specific example. Accordingly, the overall construction of the cooler unit described is such that the only capacity limiting factor of major importance is the conductivity of the metal employed.

In the cooler of the "criss-crossed ribs" modification of Fig. 13, the set of acid channels formed by the inwardly projecting ribs on the front casting of the unit criss-cross and are disposed in right angular relationship to the set of acid channels formed by the inwardly projecting ribs on the rear casting of the unit. In use, the cooler of the Fig. 13 modification functions generally similarly to the unit of Figs. 1-8 and 11. However, in the embodiment of Fig. 13 it will be understood that, except where inwardly projecting corresponding ribs of the front and rear castings actually abut (in angular criss-cross relation), the set of acid channels formed by the ribs on the front casting of the unit are in angularly disposed but open communication with the set of acid channels formed by the ribs of the rear casting of the unit. Thus, during the downflow of acid thru the unit, in addition to the undulations and resultant acid mixing caused by the set of the inwardly projecting ribs on the rear casting, and the inwardly projecting but criss-cross related ribs on the front casting, there is a constant interflow of acid particles from the acid channels of one set of ribs to the acid channels of the other set of ribs. It will be appreciated that this crossflow of acid particles from one set of channels on one half of the unit to a criss-cross related set of channels on the other half of the unit provides a still greater degree of turbulence, core breaking and acid mixing than described above in connection with Figs. 1-8 and 11. In the cooling of some highly corrosive liquids, wear and tear on the inner edges of the criss-crossed ribs of the Fig. 13 embodiment may be excessive, in which instance the "coextensively ribbed" embodiment of Fig. 11 would probably be preferred.

Although the coolers of the invention have been described as being constructed of cast iron, other metals such as stainless steel, aluminum, etc. may be employed.

I claim:

1. Heat exchange apparatus comprising a pair of spaced apart side wall sections, a plurality of inwardly projecting relatively Z-shaped ribs attached to the inner face of each of said sections, a plurality of outwardly projecting relatively Z-shaped ribs attached to the outer face of each of said sections, said inner ribs of both sections being so formed that at least a plurality of portions of the inner edges of corresponding inner ribs on opposed sections substantially abut, to thereby provide between said sections a plurality of restricted passageways thru which a fluid is adapted to flow, each of said inner ribs of both sections comprising angular, sharply formed convex and concave portions connected by short inclined portions, said inclined and convex and

concave portions being so associated and arranged as to cause fluid within a channel between two adjacent inner ribs on the same section to be projected successively across the channel from one rib to the adjacent rib, said inner ribs being spaced so that the apex of each convex surface of a rib extends at least to a plane which is disposed at a right angle to the planes of the side wall sections and which passes thru the apices of the adjacent convex surfaces of the adjacent rib on the same section; the outer ribs of each of said sections being disposed in co-extensive but offset relation to the inner ribs on a common section, said wall sections being of substantially identical construction.

2. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each wall section, means for connecting said side plates to form a unitary structure, a plurality of inwardly projecting relatively Z-shaped ribs attached to the inner face of each of said sections, a plurality of outwardly projecting relatively Z-shaped ribs attached to the outer face of each of said sections, the terminal slopes of each of said inner ribs adjacent said header portions being disposed at substantially right angles to each other, said inner ribs of both sections being so formed that the inner edges of corresponding inner ribs on opposed sections substantially abut throughout their length and thereby provide between said sections a plurality of restricted passageways thru which a fluid is adapted to flow, each of said inner ribs of both sections comprising angular, sharply formed convex and concave portions connected by short inclined portions, said inclined and convex and concave portions being so associated and arranged as to cause fluid within a channel between two adjacent inner ribs on the same section to be projected successively across the channel from one rib to the adjacent rib, said inner ribs being spaced so that the apex of each convex surface of a rib extends at least to a plane which is disposed at a right angle to the planes of the side wall sections and which passes thru the apices of the adjacent convex surfaces of the adjacent rib on the same section; the outer ribs of each of said sections being disposed in coextensive but offset relation to the inner ribs on a common section, said plates and wall sections being of substantially identical construction.

3. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each wall section, means for connecting said side plates to form a unitary structure, a plurality of inwardly projecting relatively Z-shaped ribs attached to the inner face of each of said sections, a plurality of outwardly projecting relatively Z-shaped ribs attached to the outer face of each of said sections, the terminal slopes of each of said inner ribs adjacent said header portions being disposed at substantially right angles to each other, said inner ribs of both sections being so formed that portions of the inner edges of corresponding inner ribs on opposed sections substantially abut in right-angular criss-cross relation to thereby provide between said sections a plurality of restricted passageways thru which a fluid is adapted to flow, each of said inner ribs of both sections comprising angular, sharply formed convex and concave portions connected by short inclined portions, said inclined and convex and concave portions being so associated and ar-

ranged as to cause fluid within a channel between two adjacent inner ribs on the same section to be projected successively across the channel from one rib to the adjacent rib, said inner ribs being spaced so that the apex of each convex surface of a rib extends at least to a plane which is disposed at a right angle to the planes of the side wall sections and which passes thru the apices of the adjacent convex surfaces of the adjacent rib on the same section; the outer ribs of each of said sections being disposed in co-extensive but offset relation to the inner ribs on a common section, said plates and wall sections being of substantially identical construction.

4. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each section, means for connecting said plates to form a unitary structure having headers at said opposite edges, a plurality of inwardly projecting wave-like ribs attached to the inner face of each of said sections, each of said ribs being disposed at substantially right angles to the longitudinal axes of the headers and also lying substantially in the same plane as the headers, said inner ribs of both sections being formed so that at least a plurality of portions of the inner edges of corresponding inner ribs on opposed sections substantially abut, thereby to provide between said sections a plurality of restricted passageways connecting said headers and lying generally parallel to said inner ribs, a plurality of outwardly projecting wave-like ribs attached to the outer face of each of said sections, the outer ribs of each of said sections being disposed in co-extensive but offset relation to the inner ribs on a common section, and means for flowing fluid medium thru the channels formed by the outer ribs on the outer face of each section.

5. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each section, means for connecting said plates to form a unitary structure having headers at said opposite edges, a plurality of inwardly projecting ribs attached to the inner face of each of said sections, each of said ribs being disposed at substantially right angles to the longitudinal axes of the headers and also lying substantially in the same plane as the headers, said inner ribs of both sections being formed so that portions of the inner edges of corresponding inner ribs on one section substantially abut, in criss-cross relation, portions of the inner edges of the ribs on the other section, thereby to provide between said sections a plurality of restricted passageways connecting said headers and lying generally parallel to said inner ribs, a plurality of outwardly projecting ribs attached to the outer face of each of said sections, the outer ribs of each of said sections being disposed in co-extensive but offset relation to the inner ribs on a common section, and means for flowing fluid medium thru the channels formed by the outer ribs on the outer face of each section.

6. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each section, means for connecting said plates to form a unitary structure having headers at said opposite edges, a plurality of inwardly projecting relatively Z-shaped ribs attached to the inner face of each of said sections, each of said ribs being disposed at substantially right angles to the longitudinal axes of the headers and also

lying substantially in the same plane as the headers, the terminal slopes of each of said inner ribs adjacent said opposite edges being angularly disposed with respect to each other, said inner ribs of both sections being formed so that at least a plurality of portions of the inner edges of corresponding inner ribs on opposed sections substantially abut, thereby to provide between said sections a plurality of restricted passageways connecting said headers and lying generally parallel to said inner ribs, a plurality of outwardly projecting relatively Z-shaped ribs attached to the outer face of each of said sections, the outer ribs of each of said sections being disposed in co-extensive but offset relation to the inner ribs on a common section, said plates and wall sections being of substantially identical construction, and means for flowing fluid medium thru the channels formed by the outer ribs on the outer face of each section.

7. Heat exchange apparatus comprising a pair of spaced apart substantially planar side wall sections, a header portion adjacent opposite edges of each wall section, said header portions forming a header adjacent opposite edges of said sections, a plurality of inwardly projecting wave-like ribs attached to the inner face of each of said sections, a plurality of outwardly projecting wave-like ribs attached to the outer face of each of said sections, said inner ribs of both sections being so formed that at least a plurality of portions of the inner edges of corresponding inner ribs on opposed sections substantially abut, to thereby provide between said sections a plurality of restricted passageways thru which a fluid is adapted to flow, each of said inner ribs of both sections comprising relatively angular and sharply formed convex and concave portions connected by relatively short inclined portions, said inclined and convex and concave portions being so associated and arranged as to cause fluid within a channel between two adjacent inner ribs on the same section to be projected successively across the channel from one rib to the adjacent rib, said inner ribs being spaced so that the apex of each convex surface of a rib extends at least to a plane which is disposed at a right angle to the planes of the side wall sections and which passes thru the apices of the adjacent convex surfaces of the adjacent rib on the same section; the outer ribs of each of said sections being disposed in coextensive but offset relation to the inner ribs on a common section.

8. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each wall section, means for connecting said side plates to form a unitary structure, a plurality of inwardly projecting relatively Z-shaped ribs attached to the inner face of each of said sections, a plurality of outwardly projecting relatively Z-shaped ribs attached to the outer face of each of said sections, the terminal slopes of each of said inner ribs adjacent said header portions being disposed at substantially right angles to each other, said inner ribs of both sections being so formed that the inner edges of corresponding inner ribs on opposed sections substantially abut throughout their length and thereby provide between said sections a plurality of restricted

passageways thru which a fluid is adapted to flow, each of said inner ribs of both sections comprising angular, sharply formed convex and concave portions connected by short inclined portions, said inclined and convex and concave portions being so associated and arranged as to cause fluid within a channel between two adjacent inner ribs on the same section to be projected successively across the channel from one rib to the adjacent rib, said inner ribs being spaced so that the apex of each convex surface of a rib extends at least to a plane which is disposed at a right angle to the planes of the side wall sections and which passes thru the apices of the adjacent convex surfaces of the adjacent rib on the same section; the outer ribs of each of said sections being disposed in coextensive but offset relation to the inner ribs on a common section.

9. Heat exchange apparatus comprising front and rear side plates each having a side wall section, a header portion adjacent opposite edges of each section, means for connecting said plates to form a unitary structure having headers at said opposite edges, a plurality of inwardly projecting wave-like ribs attached to the inner face of each of said sections, each of said ribs being disposed at substantially right angles to the longitudinal axes of the headers and also lying substantially in the same plane as the headers, the terminal slopes of each of said inner ribs adjacent said opposite edges being oppositely disposed with respect to each other, said inner ribs of both sections being formed so that at least a plurality of portions of the inner edges of corresponding inner ribs on opposed sections substantially abut, thereby to provide between said sections a plurality of restricted passageways connecting said headers and lying generally parallel to said inner ribs, a plurality of outwardly projecting wave-like ribs attached to the outer face of each of said sections, the outer ribs of each of said sections being disposed in co-extensive but offset relation to the inner ribs on a common section, and means for flowing fluid medium thru the channels formed by the outer ribs on the outer face of each section.

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