Jan. 28, 1969 H. R. LEEDS ETAL 3,424,238

GLASSED HEAT EXCHANGER CONSTRUCTION

Filed May 8, 1967 Sheet 1 of 2

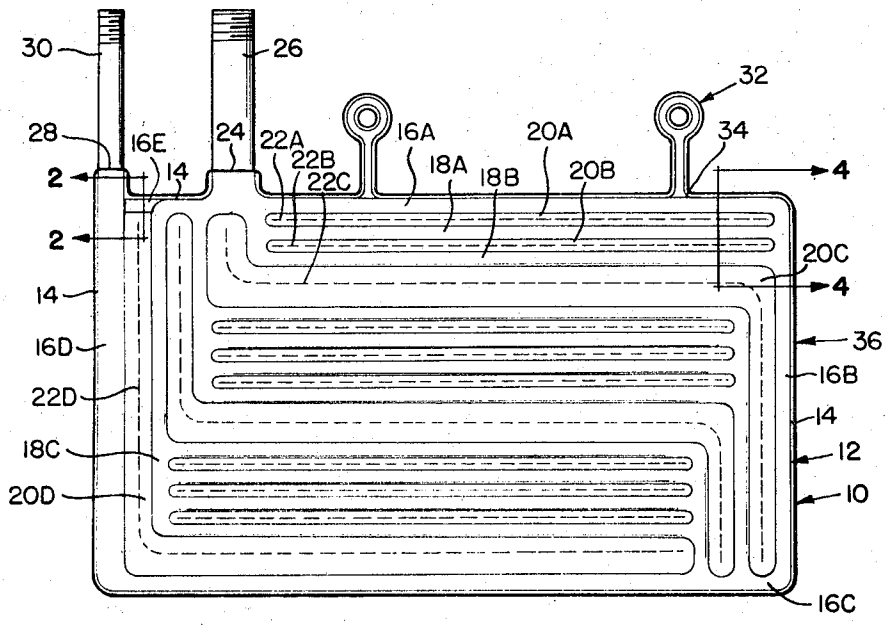


FIG. 1

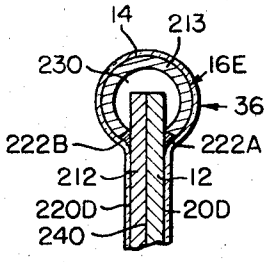


FIG. 2

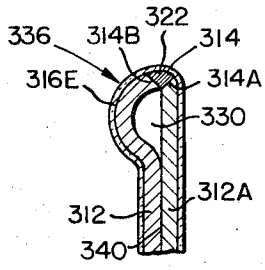


FIG. 3

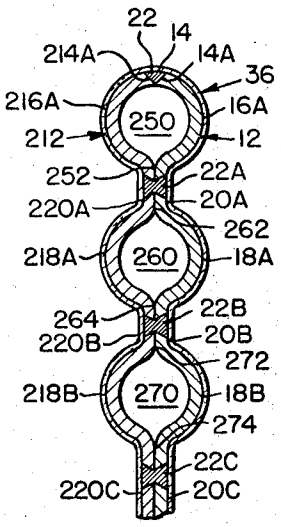


FIG. 4

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GLASSED HEAT EXCHANGER CONSTRUCTION

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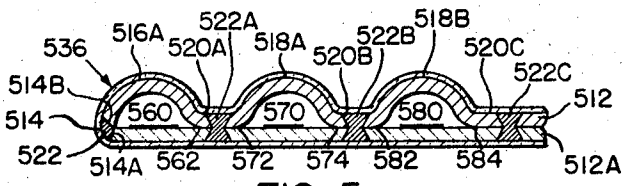


FIG. 5

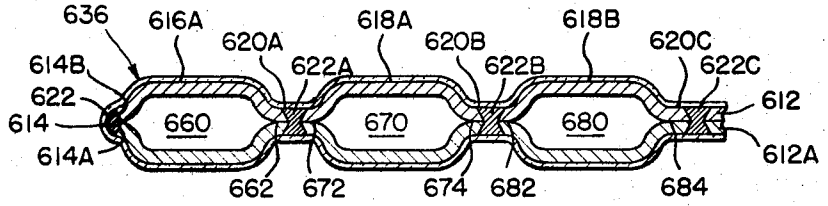


FIG. 6

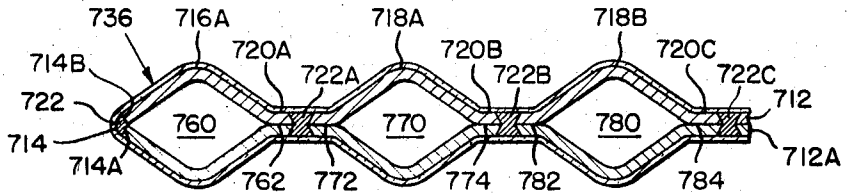


FIG. 7

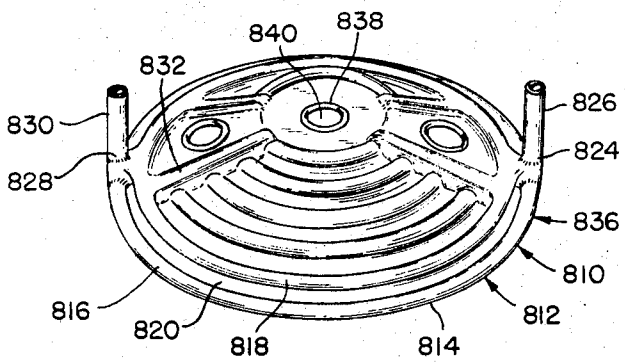


FIG. 8

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3,424,238

GLASSED HEAT EXCHANGER CONSTRUCTION

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U.S. Cl. 165—133 5 Claims
Int. Cl. F28f 19/02, 3/14

ABSTRACT OF THE DISCLOSURE

A heat exchanger is provided having two plates, at least one with a channel in one face, with an inlet and outlet, welded in face-to-face relation to enclose a circulation conduit therebetween for flow of a heat exchange fluid therethrough, and glassed exterior partially flat and partially arcuate surfaces. The edges of the plates are joined to form smoothly arcuate edge surfaces provided by arcuate protuberances set along the edges of the outer surface of at least one plate. The conduit between the joined plates passes along at least one arcuate edge of the joined plates.

Background of the invention

Heat exchangers, formed by welding together two metal plates so as to enclose a channel pressed or cut into their abutting faces and form a circulation conduit for heat exchange fluid, have long been known in the art. These heat exchangers, because of their ease and economy of manufacture and thus low cost, have found wide acceptance and use for heating and cooling liquids and gases, such as oils, metal plating baths, chemical reaction mixtures, etc. Such metal exchangers, however, when used to heat or cool corrosive or erosive materials, often have been subject to rapid attack by these materials. Further, in instances when, upon heating or cooling the materials, solids are deposited on the heat exchanger, the deposited solids often quickly and tenaciously cover and build up on the exchanger surfaces reducing their heat transfer capacity. To improve or restore heat transfer capacity, the solids coated exchanger either must be scrapped and replaced or removed from service and cleaned as by chipping or sand blasting, costly methods reducing the economies provided in the initial selection and use of these exchangers. Chemical methods to dissolve deposited solids are usually not usable, for such chemicals also often tend to attack and dissolve the metal plates of the exchanger.

Thus, it is an object of this invention to provide a heat exchanger which provides prolonged service in contact with corrosive and erosive materials and which is easy and economical to clean.

Attempts have been made to cure the foregoing difficulties by glass coating the prior art heat exchangers; however, glassing the prior art metal surfaces have been fraught with problems. For example, surface irregularities or sharp corners or edges of joined surfaces, such as are commonly present on prior art metal exchangers, prevent continuous coverage and bond with strongly adherent ceramic or glass coatings, or leave thin or weak spots in the protective coating which are prone to rapid spallation or fracture, etc.

Therefore, another object of this invention is to provide a glass or ceramic coated heat exchanger which has a uniform and continuous strongly adheernt protective coating substantially devoid of weak spots.

Methods for eliminating sharp edges and corners on heat exchanger surfaces to avoid thin or weak spots in the protective coating have been proposed, such as by machining the welded plate edges round, or welding to the plate edges round rods or tubes and then machining the welded surfaces smooth prior to glassing. However, machining

the joined plate edges round, for most useful plate thicknesses, produces a very narrow rounded edge with so low a convex radius of curvature as to approach a sharp edge. Such attempts, in substance, merely substitute one "edge" for two edges and thus provide no practical answer to glassing problems to provide a protective glassed coating of glass or ceramic. Welding a rod or tube along the plate edges and then machining the welds smooth, although apparently solving the "sharp edge and corner" problem, however, firstly, adds otherwise nonfunctional metal to the exchanger which surplusage metal acts as a nonuseful heat sink to decrease heat transfer capacity. Such necessary tube bending, welding and machining also substantially increases the cost of manufacture of the exchanger which detracts from the economies initially sought.

Yet another disadvantage, not solved by edge welding the plates together either with or without a rounded rod or tube, is the vexsome problem of heat buckling or stress relaxation buckling of the joined plates, respectively during or after glassing. This hitherto unsolved difficulty occurs especially along the metal flanges of the prior art exchanger which surround the exchanger plates and extend from the conduit portions to the edges of the joined plates. In making the prior art exchanger, the plates are usually seam welded in parallel lines and thus doubly sealed along flat portions around the conduit passages to trap between the adjacent welds interfacial gas pockets. In some prior art exchangers the plate edges are also welded. Thus, in prior art exchangers, in interfacial spaces between the seam weld and the open edge or edge weld, gases are trapped in enclosed pockets between the plates within which trapped gases expand, upon heating to the high glassing temperatures to buckle the plates and rupture the glass or ceramic coating. This phenomenon accounts for the high failure rates in glassing prior art plate exchangers, and occurs even if the welded plates were annealed prior to glassing to relieve welding strains.

Thus, another object of this invention is to provide a glassed heat exchanger with arcuate and flangeless edges and seam welds between which no gases are trapped in enclosed pockets.

In general, the higher the temperature employed the more the heat buckling and coating rupture problem is aggravated in glassing prior art plate heat exchangers. Thus, the best glassing materials which provide a desirable and improved resistance to erosion of exchanger coatings, such as the partially crystallized glasses or ceramics, could not be used successfully to coat prior art exchangers because very high glassing temperatures are required to fuse the glassing materials to the plates which almost invariably produce gas expanded heat buckling of the plates.

Therefore, a further object of this invention is to provide a heat exchanger that is coated with an erosion resisting partially crystallized glass.

Summary

It has now been found that a suitable glass or ceramic coated heat exchanger which achieves the foregoing objects is provided by the present invention. Broadly, in the present heat exchanger, two plates, in face-to-face relation, are joined together in fluid-tight seal along their edges with a smoothly rounded weld. At least one of the plates has a channel pressed or cut into its inner surface to form upon welding a conduit between the joined plates. The conduit communicates with the outside of the joined plates through an inlet and an outlet for the circulation of a heat exchange fluid therethrough. The joined plates are welded in fluid-tight engagement, such as by single seam welds, in such manner that any interior or interfacial spaces at the interfaces between the joined plates are not sealed from but rather communicate with the con-

duit, and thus do not tend to trap gases in enclosed pockets. The present joined plates have on at least one outer surface a smoothly rounded or arcuate bulge, protuberance or embossment adjacent to and extending from the welded edges of the plates, which bulge forms arcuate surfaces with the joined plate edges. The joined welded plates have a glass or ceramic coating which covers the outer surfaces, both flat and arcuate surfaces, of the joined plates so as to protect the outside of the present heat exchanger from corrosion and erosion otherwise incurred by contact of the exchanger with materials to be heated or cooled.

It will readily be seen that the present construction provides important advantages over prior art plate heat exchanger constructions. For example, all exterior surfaces of the joined plates are rounded or arcuate and smooth to a degree which completely avoids the "sharp edge or corner" problem often present in prior art constructions. Thus, by present construction, exchangers of this invention have smooth, flat and arcuate surfaces throughout, i.e. no sharp corners nor edges, which surfaces readily accept a continuous, uniform, strongly adherent glass or ceramic coating. The glass or ceramic surfaces of the present exchanger thus provided may be easily cleaned of adhering solids merely by wiping or by chemical dissolution of deposited solids. The present exchanger, also, by largely eliminating the prior art "edge flange" thereby eliminates most surplusage metal which acts as a heat sink to reduce heat transfer capacity. Yet further, the present exchanger, through largely eliminating the prior art flange, by placing at least a portion of the heat exchange conduit close to an edge of the exchanger and by making all internal or seam welds such that no deleterious enclosed gas pockets are formed, completely eliminates the plate buckling problem otherwise invariably present during the glassing of prior art exchangers. By such construction, the present exchanger offers the additional advantage of providing preferred embodiments having a glassed coating of a high temperature fusing glass or ceramic, such as partially crystallized glass, which coating is especially resistant to corrosion, erosion and abrasion.

Yet other desirable advantages and objects of the present invention will be evident from the following detailed explanation of embodiments of this invention when considered in connection with the accompaying drawings wherein:

FIG. 1 is a plan view of one embodiment of a glass or ceramic coated heat exchanger of this invention.

FIG. 2, a fragmentary view in section taken along line 2—2 of FIG. 1, shows a portion of the edges of the joined plates rounded with a welded "dummy" protuberance to form an easily glassed arcuate surface.

FIG. 3, a fragmentary view in section similar to that taken along line 2—2 of FIG. 1, differs somewhat from that shown in FIG. 2 and shows an embossed "dummy" edge protuberance on the outer surface of one of the joined plates.

FIG. 4 is a fragmentary view in section taken along line 4—4 of FIG. 1, showing a welded edge protuberance portion, interior portions of the circulation conduit, welded interior or intermediate protuberance portions and the arcuate surfaces formed thereby.

FIG. 5, a view in fragmentary cross section similar to that taken along line 4—4 of FIG. 1, shows another embodiment having embossed edge and interior protuberances that differ from those shown in FIG. 4 in that the protuberances are on one plate.

FIG. 6, a fragmentary cross sectional view similar to that taken along line 4—4 of FIG. 1 differing from that in FIG. 4, shows another embodiment of joined doubly embossed plates having somewhat elliptically shaped protuberances.

FIG. 7, a fragmentary view in section similar to that taken along line 4—4 of FIG. 1, differing somewhat from that in FIG. 4, shows another embodiment having doubly embossed somewhat rounded diamond shaped protuberances.

FIG. 8, in perspective view, is of a conical glass or ceramic coated plate heat exchanger of the invention.

Preferred embodiments

With regard to the embodiments shown in the drawings, in general, elements which have identical functions although varying in shape from figure to figure have been identified with numbers having the same last two digits.

Referring to FIG. 1 and to FIG. 4, a glass or ceramic coated heat exchanger of this invention, generally designated **10**, has a plate **12** with an outer periphery **14**. Plate **12** is joined by a smoothly rounded weld **22** to another plate **212** beneath it at peripheral edges **14A** and **214A**. Extending inward from periphery **14** are rounded protuberances **16A**, **16B**, **16C**, **16D** and **16E** of plate **12** which are smoothly joined to under plate **212** with aforesaid rounded weld **22** so as to oppose corresponding protuberances such as at **216A** of plate **212**. The joined edge protuberances form smoothly arcuate joined plate edge surfaces **14**. At the interface between plate **12** and under plate **212**, conduit portions such as those designated at **250**, **260**, and **270** are disposed along at least one edge of the joined plates adjacent to periphery **14**, generally following the pathway of peripheral protuberances, such as **16A** to **16D**, and follow the pathway of intermediate protuberances, such as those designated **18A**, **18B**, and **18C** on plate **12** and **218A**, **218B** and **218C** on plate **212**, in a tortuous and intercommunicating conduit pathway. Intermediate the adjacent protuberances on each plate and those corresponding conduit portions thereunder, where plate **12** and under plate **212** face and oppose one another, such as along the flattened areas **20A**, **20B**, **20C** and **20D** of plate **12** and corresponding areas **220A**, **220B**, **220C** and **220D** of plates **212**, plate **12** is joined and sealed to under plate **212** by seam welds, such as welds **22A**, **22B**, **22C** and **22D**. These single seam welds separate adjacent conduit portions, such as portions **250**, **260** and **270**, in a manner such that the gas spaces, such as spaces **252**, **262**, **264**, **272** and **274** located at the interface where the plates meet, always communicate with adjacent conduit portions, such as portions **250**, **260** and **270**. Thus, no enclosed gas pockets are formed by the present structure to trap gases. Therefore, vexsome plate buckling due to trapped gases expanding during the glassing process presents no problem.

The conduit in this embodiment extends from an inlet **24** having a fitted inlet nozzle **26** to an outlet **28** fitted with an outlet nozzle **30** in tortuous pathway for the circulation therethrough of a heat exchange fluid. Conveniently eyelet hangers **32** are provided in this embodiment, which are welded in smoothly rounded joints **34** to arcuate joined plate periphery **14**, for suspending the heat exchanger in a vessel whose contents are to be heated or cooled. Heat exchanger **10** has a continuous, uniform and strongly adherent glass or ceramic coating **36** which permits easy cleaning, which resists the accumulation of deposited solids during heating or cooling of substances and which coating resists corrosion and erosion of the heat exchanger surfaces.

At the joined plate edges between inlet **24** and outlet **28** is smoothly welded a "dummy" protuberance **16E**. Protuberance **16E** has no portion of conduit beneath it, giving rise to the term "dummy." Peripheral protuberance **16E** functions to provide an arcuate continuation of the accurate surfaces of protuberance **16D** with the arcuate surfaces of the shoulder of peripheral protuberance **16A** and corresponding protuberances of plate **212** along the joined periphery **14**. The present construction of exchanger **10**, by means of peripheral protuberances **16A** to **16D** of plate **12**, corresponding peripheral protuberances of underplate **212** and "dummy" peripheral protuberance **16E** extending about all joined plate edges at periphery

14, provides no sharp corners nor edges. Further, by means of intermediate arcuate protuberances such as 18A to 18C of plate 12, and the corresponding protuberances of plate 212, the present exchanger is smooth and/or rounded on all flat and arcuate surface portions to permit easy glassing, to afford exchanger 10 the uniform, strongly adherent easily glassed coating 36.

Glass or ceramic coating 36 may be fixed to exterior flat and arcuate metal surfaces of exchanger 10 by techniques well known in the glass enameling art. Coating 36 is a fused glass or ceramic, either amorphous or partially crystallized, and may be a composite of one or more glass or ceramic "ground coats" and one or more glass or ceramic "cover coats" fused together. Typical of the many useful glass or ceramic compositions and methods for fixing them to metal surfaces are those disclosed in U.S. Patents 2,882,187, 2,920,971, 3,051,589, 3,055,779 and 3,075,860.

Turning to FIG. 2, a "dummy" protuberance 16E is shown joining plate 12 to under plate 212 at outer surfaces 20D and 220D respectively. Protuberance 16E forms an arcuate surface with plates 12 and 212 by means of a rounded plate 213 welded to said plates by welds 222A and 222B respectively, whereby said arcuate surface forms a portion of arcuate periphery 14 of exchanger 10. The space 230 formed by plate 213 and welds 20D and 220D has no portion of conduit beneath it. However, space 230 and the interfacial space 240 formed between opposing interior faces of plates 12 and 212 are in communication with the adjacent portions of the conduit set under adjacent protuberance 18C of FIG. 1. Thus, no enclosed pockets are formed to trap gases by the present use of a dummy protuberance that is needed to provide an arcuate continuation of the rounded arcuate surfaces of periphery 14 of heat exchanger 10.

In FIG. 3, which shows another embodiment of a "dummy" protuberance, a plate 312 is joined in face-to-face relation to a plate 312A at their respective edges 314B and 314A. Plate 312 has an embossed dummy protuberance 316E, whereas plate 312A does not. Edge 314B, terminating protuberance 316E, and edge 314A are joined by a smoothly rounded fluid-tight weld 322 to form in combination with 316E a smoothly arcuate peripheral surface portion 314. Between plate 312A and protuberance 316E of plate 312 is formed a space 330 which however is not a portion of the circulation conduit in this embodiment. Nevertheless, in this construction space 330 and the interfacial space 340 communicating therewith, in turn communicate with that portion of the conduit adjacent thereto, such as the portion of conduit under protuberance 18C of FIG. 1, so that no closed pockets are formed to trap gases.

With regard to FIG. 5, plate 512 is in face-to-face relation with flat plate 512A such that their respective edges 514A and 514B, the peripheral protuberance 516A, the intermediate protuberances 518A, 518B, and the respective flattened portions 520A, 520B and 520C are aligned to oppose adjacent portions of plate 512A. Opposing edges 514B and 514A respectively of plates 512 and 512A are joined by an edge weld 522 to form in combination with edge protuberance 516A a smoothly arcuate plate periphery 514 in this exchanger. Plates 512 and 512A are also sealed and joined by seam welds at their opposing flattened portions at 520A by weld 522A, opposing portions at 520B by weld 522 B, and flattened opposing portions at 520C by weld 522C. Between end weld 522 and seam weld 522A and between protuberance 516A and its opposing flat portion of plate 512A, is defined a conduit portion 560. Between seam welds 522A and 522B and between protuberance 518A and the opposing inner face of plate 512A, is defined intermediate conduit portion 570. Between intermediate seam welds 522B and 522C and between corresponding intermediate protuberance 518B and the opposing portion of plate 512A, is defined conduit portion 580. An interfacial void 562, defined between plates 512 and 512A and between seam weld 522A and edge conduit portion 560, is in communication with adjacent conduit portion 560 to enclose no gas pockets. In similar fashion, the interfacial gas spaces 572 and 574 are in communication with adjacent conduit portion 570 to provide no enclosed gas pockets. Similarly, gas spaces 582 and 584 are in communication with adjacent conduit portion 580 to obviate trapping gases at the plate interface. Thus, joined plates 512 and 512A form surfaces which are in part smoothly arcuate and in part smoothly flattened, to provide plate surfaces which are easily glassed with no plate buckling and so coated with glass coating 536.

In FIG. 6, a plate 612 is in face-to-face relation with plate 612A, plate 612A being similar to the under plate 212 of FIG. 1, such that their respective peripheral edges 614B and 614A, their peripheral embossed protuberances such as 616A, their respective embossed intermediate protuberances such as 618A and 618B, and their flattened portions such as 620A, 620B and 620C, are aligned to oppose one another. Said protuberances have somewhat elliptically shaped arcuate surfaces. Opposing edges 614B and 614A are joined by a rounded, somewhat protruding edge weld 622 to form a smoothly arcuate plate somewhat extended periphery 614 in this exchanger. Such arcuate periphery differs somewhat from that shown in FIGS. 2 to 5 and 7 and is especially suited to embodiments where plates 612 and 612A are quite thick, say about 1/16" or greater. Plates 612 and 612A are also sealed and joined by seam welds at their flat opposing portions, such as at portion 620A by seam weld 622A, portion 620B by seam weld 622B, and at portion 620C by seam weld 622C. Between end weld 622 and seam weld 622A and between corresponding opposing protuberances 616A, is defined a conduit portion 660. Between seam welds 622A and 622B and between corresponding opposing protuberances 618A, is defined intermediate conduit portion 670. Between intermediate seam welds 622B and 622C and between intermediate corresponding opposing protuberances 618B, is defined conduit portion 680. An interfacial void 662, defined between plates 612 and 612A and between peripheral weld 622A and edge conduit portion 660, is in communication with adjacent conduit portion 660 to provide no deleterious gas pockets sealed from communication with the outside. In similar fashion, the interfacial gas spaces 672 and 674 are in communication with adjacent conduit portion 670 to provide no enclosed gas pockets. Similarly, interfacial gas spaces 682 and 684 are in communication with adjacent conduit portion 680 to trap no gases. Thus, by this construction, joined plates 612 and 612A form surfaces which are in part smoothly arcuate and in part smoothly flat, which surfaces of the plates are easily glassed with no plate buckling to provide continuous, strongly adherent glassed coating 636.

In similar fashion to FIGS. 4, 5 and 6, FIG. 7 shows a plate 712 aligned in face-to-face relation with plate 712A, similar to the under plate of FIG. 1, such that their respective edges 714B and 714A, their corresponding peripheral protuberances 716A, their corresponding intermediate protuberances 718A and 718B, and their flattened portions 720A, 720B and 720C oppose one another. Opposing edges 714B and 714A are joined by an edge weld 722 to form a smoothly arcuate plate periphery 714 of this glassed exchanger. Plates 712 and 712A are also sealed and joined by seam welds at their corresponding flattened portions 720A by seam weld 722A, at corresponding portions 722B by seam weld 722B, and at corresponding flattened portions 720C by seam weld 722C. Between end weld 722 and seam weld 722A and between corresponding edge protuberances 716A, is defined a peripheral conduit portion 760. Between seam welds 722A and 722B and between corresponding intermediate protuberances 718A, is defined an intermediate conduit portion 770. Between intermediate seam welds 722B and 722C and between protuberances 718B, is de-

fined a conduit portion **780**. An interfacial void **762**, defined between plates **712** and **712A** and between seam weld **722A** and edge conduit portion **760**, is in communication with adjacent conduit portion **760** to provide no enclosed gas pockets. In similar fashion the interfacial gas spaces **772** and **774** are in communication with adjacent intermediate conduit portion **770** to obviate enclosure and trapping of gas in pockets sealed from communication with the outside. Similarly, gas spaces **782** and **784** are in communication with adjacent conduit portion **780** to trap no gases. Thus, joined plates **712** and **712A** form surfaces which are in part smoothly arcuate and in part smoothly flat, which surfaces of the plates are easily glassed with no plate buckling to provide glass or ceramic coating **736**.

Turning to FIG. 8, a glass coated heat exchanger that may be used as a header for reaction vessels, the top plate **812** is joined to an under plate (not shown) by a smoothly rounded weld at its periphery **814**. Extending around periphery **814** is an edge protuberance **816** which forms a portion of the arcuate peripheral surface **814**, and has between plate **812** and the under plate a portion of a conduit beneath it enclosed by said joined plates. Interior to edge protuberance **816** are a plurality of intermediate protuberances **818** with flattened portions **820** therebetween. An inlet **824** provided with an inlet nipple **826** communicates with the conduit beneath protuberances **816** and **818**. An outlet **828**, provided with a nipple **830**, communicates with the conduit that follows a tortuous pathway beneath protuberances **816** and **818** such that a heat exchange fluid may circulate from inlet **824** through the conduit beneath said protuberances to outlet **828**.

In this embodiment, along the immediate flat portions between edge protuberance **816** and adjacent intermediate protuberance **818**, and between the plurality of intermediate adjacent protuberances **818**, the plates are seam welded to afford fluid-tight separation of conduit portions beneath such protuberances in such manner that interfacial spaces, which might otherwise be sealed to trap gases in enclosed pockets along the opposing joined flat portions **820**, according to this construction now communicate with adjacent conduit portions which are open to the outside through inlet **824** and outlet **828**. Intermediate protuberances **818** are joined to lateral protuberances **838** in smoothly arcuate surfaces to form manifolds with manifold conduit portions thereunder, which conduit portions communicate with those conduit portions beneath intermediate protuberances **818** and peripheral protuberance **816** to inlet **824** and outlet **828**. Between intermediate protuberance portions **818** and manifold portions **838** may be holes **840** through said joined plates to provide passages for ancillary processing equipment such as baffles, agitator shafts or electrical cables. Surrounding holes **840** and at the corresponding edges of the joined plates are "dummy" protuberances **842**, which protuberances provide smoothly arcuate edge surfaces for easy glassing. In cross section, such dummy protuberances may appear similar to that shown in FIGS. 2 or 3. Again, such protuberances **842** are smoothly welded to the joined plates as in FIGS. 2 or 3 such that all interfacial gas spaces between opposing joined plates are in communication with adjacent conduit portions, thus sealing in no gas pockets. The glass or ceramic coating **836** strongly adheres to and covers joined plate **812** and its under plate to protect the exchanger surfaces from corrosion and erosion.

The conical glass or ceramic coated heat exchanger shown in this embodiment also may be used as a separate unit set at the bottom of a reaction vessel, or suspended from the reactor top. Its smooth arcuate and flat surfaces are such as to afford upon glassing a coating of high temperature fusing glass or ceramic, such as partially crystallized glass. Its construction, by avoiding enclosure of gas pockets at the plate interfaces, avoids the plate buckling problems that are otherwise present during the glassing of prior art heat exchangers.

In this latter regard, it will readily be appreciated that embodiments of this invention may be constructed which have no seam welds. Slight leakage of circulation fluid between adjacent conduit portions across adjacent unwelded flat abutting portions at the joined plate interface presents no real problem to the successful use of such exchangers of the invention. Alternately, embodiments employing spot welds for reinforcement at diverse points between conduit portions are within the purview of this invention, or embodiments employing both single seam and spot welds may be constructed by these teachings and are useful for our purposes.

The foregoing embodiments of the invention are provided merely for illustration and of themselves do not define the invention. Although specific shapes, protuberances, embossments, spacings, welds, configurations, types of glass or ceramic coatings, locations and combinations of heat exchanger elements are shown or described, from the present teachings those knowledgeable in the art may readily make changes therein for their particular purposes and yet fall within the concept and scope of the invention as is defined by the appended claims to achieve the objects of this invention.

We claim:

1. A coated heat exchanger comprising

(a) two plates joined in face to face relation in imperfect contact to define interfacial gas spaces therebetween;

(b) a fluid tight weld joining said plates at their edges, said weld forming a smoothly rounded joint;

(c) a conduit formed by and following a pathway between said plates, said conduit being in communication with said interfacial gas spaces;

(d) an inlet outlet communicating with said conduit for the circulation therethrough of a heat exchange fluid;

(e) a smooth protuberance on the outer surface of at least one of said joined plates at least adjacent to and along all edges of said plate to form therewith arcuate surfaces for receiving a glassed coating; and

(f) a glassed coating fixed to and covering said joined plates.

2. A heat exchanger according to claim **1** wherein said protuberance follows a pathway intermediate said edges corresponding to the pathway of said conduit.

3. A heat exchanger according to claim **1** wherein each of said plates has said protuberance.

4. A heat exchanger according to claim **1** wherein said protuberance is an embossment.

5. A heat exchanger for use in contact with corrosive and erosive materials comprising

(a) a plate having one surface with an open channel, said channel following a pathway at least a portion of which is adjacent to and along at least one edge of said plate and said pathway communicating with the outside to form an inlet and outlet;

(b) another plate welded at the edges to said plate to define therebetween interfacial gas spaces, said welded plates having a smoothly rounded joint and being joined in fluid-tight engagement at said channel containing surface to enclose said channel to form a conduit in communication with said interfacial gas spaces and in communication with said inlet and outlet for the circulation of heat exchange fluid therethrough;

(c) a smoothly rounded protuberance on at least one outer surface of said welded plates adjacent to and extending from said welded edges to form therewith an arcuate surface for receiving a glassed coating; and

(d) a glassed coating fixed to and covering said poined plates whereby said plates are protected from said corrosive and erosive materials.

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U.S. Cl. X.R.

165—170