Nov. 1, 1955 J. R. GIER, JR 2,722,048

METHOD OF MAKING HEAT EXCHANGERS

Original Filed April 8, 1950 2 Sheets-Sheet 1

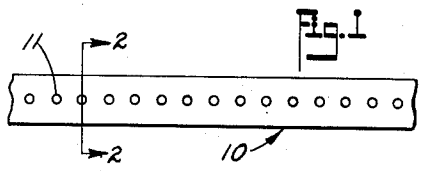


Fig. 1

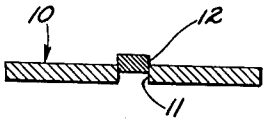


Fig. 2

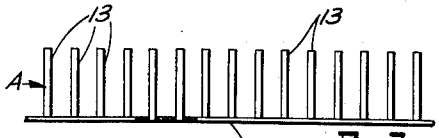


Fig. 3

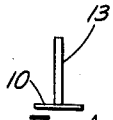


Fig. 4

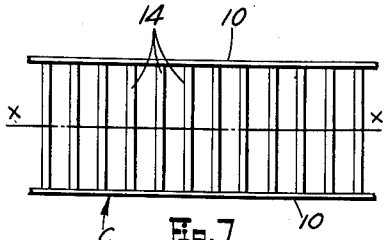


Fig. 7

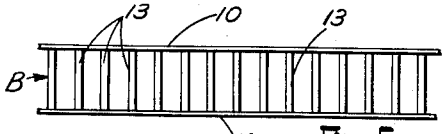


Fig. 5

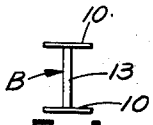


Fig. 6

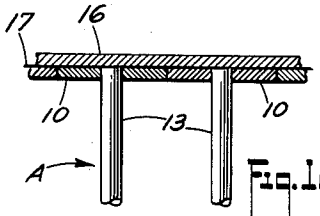


Fig. 10

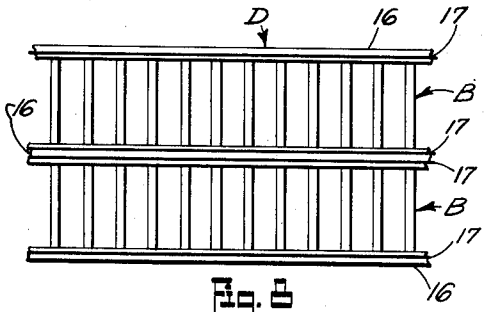


Fig. 8

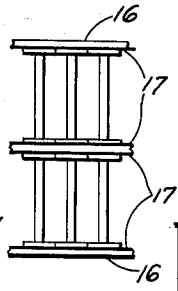


Fig. 9

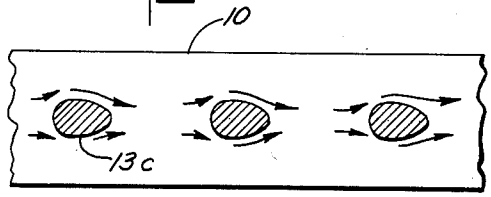


Fig. 12

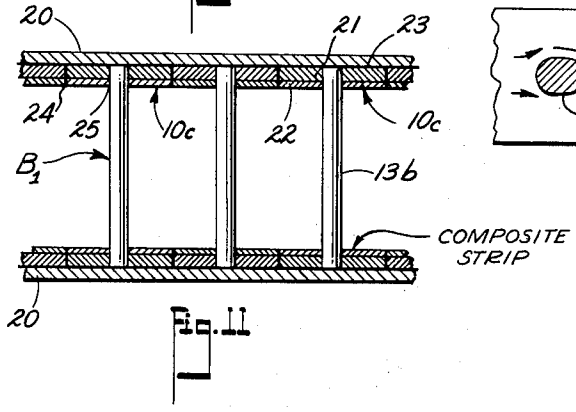


Fig. 11

INVENTOR.
JOHN R. GIER, JR.

BY

Richey & Watts

ATTORNEYS

Nov. 1, 1955 J. R. GIER, JR 2,722,048

METHOD OF MAKING HEAT EXCHANGERS

Original Filed April 8, 1950 2 Sheets-Sheet 2

Fig. 13

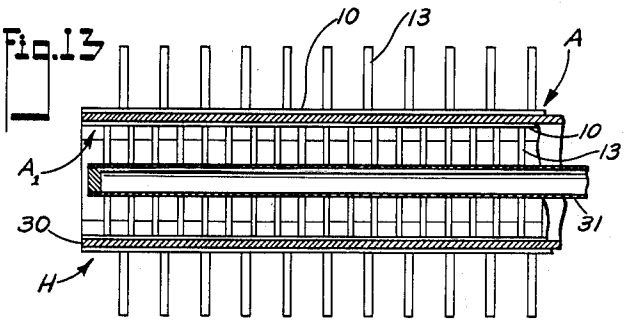


Fig. 14

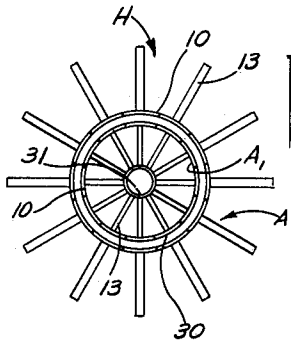


Fig. 15

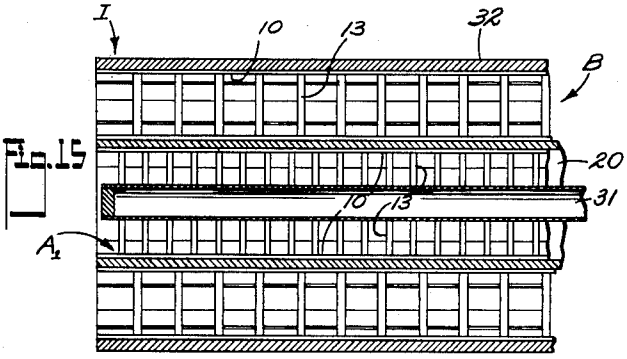


Fig. 16

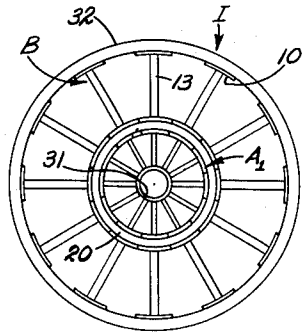


Fig. 17

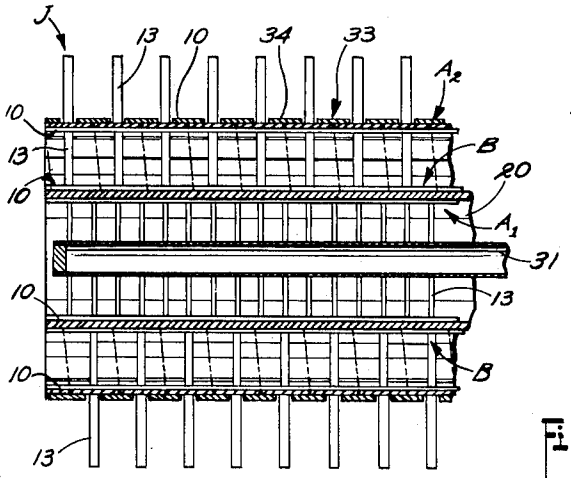
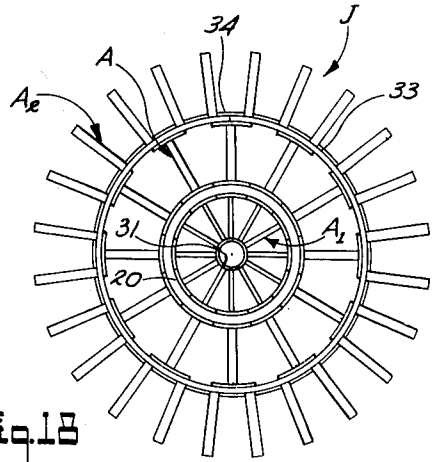


Fig. 18



INVENTOR.
JOHN R. GIER, JR.

BY

Richey & Watts
ATTORNEYS

United States Patent Office 2,722,048 Patented Nov. 1, 1955

2,722,048

METHOD OF MAKING HEAT EXCHANGERS

John R. Gier, Jr., Cleveland, Ohio

Original application April 8, 1950, Serial No. 154,843. Divided and this application August 10, 1951, Serial No. 241,329

3 Claims. (Cl. 29—157.3)

This invention relates to methods for making heat exchangers having the pin-type of extended surface, a feature of the invention being that it facilitates the commercial manufacture and assembly of the efficient and effective pin-type heat exchange units. This application is a division of my co-pending application Serial No. 154,843, filed April 8, 1950, now abandoned.

It has been determined by calculations and demonstrated by laboratory experiments that of all the means known for extending the surface of plates or tubes comprising the fluid passage wall, the most effective and efficient employs a plurality of wire-like pins or filaments extending generally perpendicular to the plates or tubes at their points of attachment thereto and disposed transversely to the fluid flow.

For example, when employed in connection with heat exchangers of the plate-type, the pin method of extending the surface would ideally involve the endwise mounting of a plurality of wire-like pins perpendicular to and between adjacent plates. The size of the wire and the spacing of the pins are chosen to produce an optimum heat transfer coefficient for a given rate of fluid flow between the plates. Similarly the pins may be formed between concentric tubes or may extend from both surfaces of a single tube, each pin being generally radially disposed. Although calculations and experiments have shown heat exchangers of this type to be the most efficient known, to my knowledge the pin-type of extended surface has found very little use outside of laboratories because of the difficulties heretofore encountered in their commercial manufacture and fabrication. It will be recognized that production of a large commercial-type heat exchange unit may involve the bonding of literally millions of wires or pins to the fluid separating surfaces because the heat transfer coefficient increases as the pins become more numerous per unit area and smaller in perimeter which dictates the use of many small pins.

It is a principal object of the invention to facilitate the economic and commercial fabrication of a heat exchanger which has a maximum rate of heat transfer for unit volume. As mentioned, the pin-type of extended surface represents the optimum construction and in accordance with the invention I am able to commercially fabricate pin-type heat exchangers more rapidly and economically than heretofore thought possible.

Briefly, an important feature of the invention involves the method of manufacture of a basic heat exchange element or strip which is formed by partially punching one or more rows of small recesses in an elongated metal strip and pressing pins or wire into the holes to form a subassembly or element. The elongated metal strip retains the pins temporarily until the final assembly wherein a plurality of the strips are arrayed side-by-side upon a supporting surface such as a plate or a tube, brazing material is applied in any suitable manner known in the brazing art, and the assembly is passed through a continuous brazing furnace with the parts held together so that a unitary heat exchange member results. Thus,

an extended surface of radial pins is produced, the cost of fabrication of which is economically and commercially practical and competitive. In some instances both ends of the pins will be pressed into apertures in elongated strips and the resulting ladder-like unit will be brazed between two plates or tubes to provide an envelope which affords the most effective heat transfer action known.

Other objects of the invention refer to methods whereby various types and styles of heat exchangers may be economically fabricated from the basic elements just described.

For example, tubular heat exchange units may be formed by arranging the basic strips or elements in longitudinal rows about the inner or outer periphery of solid tubes and furnace brazing them in position, employing suitable means to initially hold them in place. The subassembly or elements just described can thus be seen to offer the designer a wide range of readily fabricated constructions, all of which have the highly efficient pin-type extended surface.

Another object of the invention is the economical and commercial production of a heat exchanger assembly of the type wherein the exposed surface is formed of material that is difficult to braze, such as stainless steel. For example, I contemplate that a corrosion resistant assembly can be commercially produced wherein the pins may be formed of stainless steel wire or clad wire resistance-welded to strips of stainless steel, the strips being clad on their outer surfaces with a readily-brazed material such as copper or low carbon steel. These composite strips may in turn be furnace-brazed to or between plates or tubes likewise formed of a readily-brazed material, and after the brazing operation, all the surfaces exposed to fluid flow are formed of a corrosion-resistant metal. Yet this assembly is readily completed by the high-production, economical, furnace brazing process in ordinary commercial equipment without the use of special fluxes.

To summarize, the following list gives the aforesaid described advantages and features of the invention, plus other features that have not been described in detail.

The subassemblies may be made automatically by machine at low cost, employing applicant's methods.

The subassemblies are easily assembled in envelope for brazing.

The brazing metal is easily applied in the process.

The assemblies are formed with parallel surfaces that promote spreading of brazing metal to the joints.

The brazing metal may be well protected against corrosive attack.

The manner in which these objects, features, and advantages may be attained in practice will be apparent from the following detailed description of the preferred methods embodying the invention.

In the drawings:

Fig. 1 is a plan view of one of the strips forming part of a heat exchanger element or subassembly;

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

Figs. 3 and 4 show a completed element having a single strip base;

Figs. 5 and 6 show an element having a double strip base;

Fig. 7 shows a prelimnary operation of an alternate method of forming the strip shown in Fig. 3;

Figs. 8 and 9 show the plate-type heat exchanger including the elements shown in Figs. 5 and 6;

Fig. 10 is an enlarged fragmentary section of a plate-type heat exchanger;

Fig. 11 is an enlarged fragmentary section of a plate-type heat exchanger produced by furnace brazing, but

having the exposed surfaces made of a material that is difficult to braze;

Fig. 12 is a fragmentary view of an element showing how the pins may be of air foil section;

Figs. 13 and 14 show a tubular heat exchanger wherein the elements are arranged longitudinally of the tube;

Figs. 15 and 16 show a double tube heat exchanger with longitudinal elements; and,

Figs. 17 and 18 show a double tube heat exchanger with an outer extended surface formed by wrapping helical strips about the ends of the pins.

As seen in Figs. 1 to 4 a heat exchange strip or subassembly A of the pin type is fabricated by forming an elongated strip of metal **10** and punching therein a series of depressions **11**. As best seen in Fig. 2, I prefer to punch the strip so that a slug **12** is partially separated from the strip which simultaneously provides a pocket **11** for reception of the end of a pin. A plurality of pins **13** preferably formed of wire stock are cut to length and successively pressed into pockets **11**, the pins being of substantially the same diameter as the punch that formed the pockets. By applying the proper degree of pressure to the pins and strips while holding the pins from bending, the pins may be made to complete the punching operation whereupon they eject the slugs **12**. The pin punching operation may be continued to the extent that, as seen in Figure 3, the ends of the pins are positioned flush with the face of the strip opposite from the face at which they entered during the punching operation. Preferably the pins are held so as to be guided or restrained from bending, and the strips **10** backed up against buckling during the pressing of the pins and strips together. The force of the strip gripping the slug is transferred to the end portion of each pin as it ejects the slug, thereby retaining the pins for handling prior to subsequent assembly operations. It will be understood that a subassembly such as A may also be produced by endwise welding of the pins to flat strips, although this operation is difficult with high-conductivity metals such as aluminum or copper, and the method outlined above is preferred. The joint area is usually considerably less than the section of the pins so maximum strength is not attained. Also, there is usually some flash which catches dirt and increases turbulence. I contemplate that some of the disadvantages of butt-welded pins may be overcome by subsequently furnace brazing the pin joints.

Another method of forming single back strips is indicated in Fig. 7. Here, longer pins **14** are joined end-to-end to spaced strips **10** and the assembly severed along a line such as *x*—*x* to produce two heat exchange strips.

In some designs it is required that a double strip assembly be produced as shown at B in Figs. 5 and 6. Here two strips **10** are joined to opposite ends of the rows of pins **13**, substantially as described in connection with the fabrication of element A.

As seen in Figs. 8 to 10, elements B lend themselves to formation of a plate or envelope-type heat exchanger D. The elements B are arranged in rows between sheets or plates **16**. In order to facilitate the furnace brazing operation, brazing metal and flux material **17**, if flux is needed, is placed in the joints between the strips in the associated plates. The parts are held into engagement by suitable means for applying pressure thereto and the entire assembly is heated above the melting point of the brazing material in a suitable furnace, preferably in a reducing atmosphere which causes the brazing material to flow and to bond all the joints without the use of flux. Thus, the parts are permanently assembled with a good thermal and mechanical bond and the most efficient known plate-type heat exchanger is produced by an economical, practical, fabricating process.

It will be understood that the nature of the brazing material **17** may be adjusted for the service intended and, as known in the brazing art, it may be a copper base alloy, silver solder or the like. Flux may be included if necessary, or the material may be applied as a metallic paint or a separate coating of powdered metal so long as just enough material is provided to produce a perfect joint. These remarks also apply to other brazing operations to be described and will not be repeated.

In applications where corrosive fluids are exceedingly high temperatures are to be handled by a heat exchanger, it is desirable that area subject to attack and oxidation are formed of a highly corrosive-resistant metal, such as stainless steels or other alloys. In this case, applicant first makes a construction shown in Fig. 11 wherein a plurality of double-backed elements B_1 are arranged in rows between plates **20**, it being understood that the same construction may be applied to the tubular type of heat exchanger. The elements B_1 are of such construction in that the pins **13***b* are either pre-clad with or formed of a material that is not readily furnace brazed, such as stainless steel, and the backing or strip elements **10***c* are formed of composite or clad construction, there being aligned apertures through strips **21** and **22** to receive the pins. The backing elements or strips are formed to comprise a strip **21** of readily-brazed material (such as ordinary steel) bonded to a strip **22** of material that is difficult to braze (such as stainless or any other high-chrome alloy steel). The silver solder, copper or other brazing material is shown at **23** and is placed between the rows of elements B_1 and the plates or envelopes **20**, the latter of which may be likewise made of readily-brazed material such as ordinary steel.

For example, assume that stainless steel pins are to be attached to base strips clad with stainless steel. The following procedure is recommended:

(1) Insert pins into composite base strip as shown in Fig. 11.

(2) Braze pins to base strips in a special furnace having a pure, dry hydrogen atmosphere capable of preventing oxidation of the metal. The brazing material might be a copper base material, or pure copper, or Colmonoy No. 6, or other metal suited to the intended service. The pin strips could be brazed by passing them through a furnace similar to those used for bright strand annealing of stainless steel wire or strip.

(3) After the pins are thus brazed to their base strips, these strips can be assembled into the heat exchanger and brazed in place by ordinary practice. This is possible because the final assembly brazing involves the joining of easily-brazed metals.

During the final brazing of the assembly, with the parts properly held in place, the brazing material firmly joins all the parts and flows by capillary action into all unbonded joints including those between the strips **10***c* and the plates **20** and between the edges of the composite strips **10***c*. As a result of this construction all surfaces exposed to the corrosive action of fluids within the envelope may be made of a material difficult to braze, such as stainless steel, without departing from commercial fabrication practice, except as noted below.

If it were desired to build a heat exchanger for use at extremely high temperatures where it was necessary to employ only materials of construction, such as solid stainless steel, that are difficult to braze, then the general procedure would be to fabricate the pin elements and assembly in the manner described for easily-brazed metals as shown in Fig. 8 but a special brazing procedure would be required to make the joints.

This special brazing of the entire heat exchanger unit envelope could best be accomplished in a bell-type furnace containing a pure, dry hydrogen atmosphere, or lacking this, a special box or retort could be used in any suitable furnace to contain the assembly to be brazed and maintain the required protective atmosphere.

The pins **13** in the various heat exchange assemblies described will necessarily produce a certain amount of turbulence in the fluid stream and in some cases it may

be desirable to facilitate flow past the pins with some reduction in turbulence. As seen in Fig. 12 this may be accomplished by forming strips, either of the single or double-backed construction, which have pins **13***c* configured with an air foil cross-section. This configuration may be imparted to the wire stock forming the pins or (in the case of single row pins) may be produced by suitable dies or by toothed wheels or the like, either during or subsequent to the strip assembling operation. By a similar method, I contemplate impressing peripheral fins or threads on the pins to extend their surface. Of course, the axis of the air foil section will be formed so that it is oriented with respect to the flow depending upon the design of the unit.

In some designs, tubular fluid conductors having pin-type extended surfaces are indicated. According to my invention, I contemplate means for making a novel and economically produced tubular heat exchanger unit.

For example, a tubular heat exchanger such as shown at H in Figs. 13 and 14 may be produced by assembling the strips longitudinally of the tube. In this construction a plurality of strip elements A and A_1 are disposed circumferentially about and longitudinally of a solid tube **30**, there being, of course, suitable brazing material applied as described and the entire assembly joined in the usual brazing furnace.

A preliminary assembly of the outer strips A may be obtained by winding them with wire or by a preliminary spot-welding operation. In assembling the inner strips A_1 into tube **30** two apparently incompatable requirements are encountered. These are:

(1) There should be clearance to permit ready insertion of the strips.

(2) There should be a tight fit between the strips and tube **30** to insure good brazing.

I contemplate that these requirements can both be met by employing a center tube **31** as a mandrel for locating the strips A_1 within the tube **30**. For example, ⅓ to ½ of the strips might be assembled in tube **30**, the mandrel tube **31** inserted, and the remainder of the strips slid into place. One end of the tube **31** may be plugged and the other connected to a source of liquid under pressure, thereby expanding tube **31** past its yield point to a larger diameter sufficient to permanently close the clearances between the strips and both tubes. Alternately a rod with an enlarged head may be pushed or drawn through tube **31** to expand the latter for the purpose described.

In some designs a multiple pass or double tube construction is required such as the assembly shown at I in Figs. 15 and 16. Here the inner surface of a solid tube **20** may be extended by a plurality of rows of single strip units A_1 (assembled with an expandable tube **31** as described), and in addition an outer tube **32** of solid construction may be provided between which are furnace brazed the double-type elements longitudinally arranged as at B. The outer tube **32** may be compressed against strips B by forcing them through a suitable die or by a swaging operation. Alternately, the outer tube **32** may be hydrostatically sealed at its ends and compressed to provide the desirable close-brazing fit between strips B and the associated tubes. Thus, a double-pass, highly-efficient tube is formed by a process that is both economical and dependable.

The tubular unit J shown in Figs. 17 and 18 is likewise a double-pass assembly, but has the additional feature that the outer surface of the outer tube is also extended. Here, longitudinal rows of double strip elements B are formed and arranged exteriorly of a solid tube **20** as are rows of single strip element A_1 arranged interiorly along the tube, the central mandrel tube **31** being useful for this assembly as described. The elements A are suitably held in place on the exterior of tube **20** by wiring or preliminary welding or brazing and thereafter a long, continuous single strip element A_2 is wrapped around the outer ends of pins **13** forming a part of the element A. In order to prevent leakage between the edges of strips A_2 I prefer to wind a lap strip **34** across the joints before brazing. Thus, the base **10** of the outer element A_2 forms an outer tube **33**, the net result being the multiple-extended surface, double-pass unit described. The tube formed by outer elements A_2 will be compressed by the tension of wound strips A_2 sufficiently to close all clearances at strips A in order to insure perfect brazing. In order to supply brazing metal to the ends of the pins of strips A, the inner surface of strip A_2 may be coated with brazing metal or the pins may be disposed at the joints between the edges of strip A_2 whereby brazing metal flows to the pin ends by capillary action.

Of course the relative size and proportioning of the elements depends upon the nature and function of the heat exchanger or structural element. For heat exchanger application, for example, typical proportions and sizes may range from pins or legs of .025" diameter, ⅛" long and spaced .060" apart to pins ⅛" in diameter, ¾" long and spaced 5/16" apart. Obviously, still larger elements may be produced by the method of this invention.

The term "brazed," or "brazing" as employed herein and in the claims is intended to include the employment of bonding processes wherein a metal or alloy of lower melting point than the base metals is caused to flow between and bond the parts upon application of heat high enough to melt the bonding material but not the base structure.

I contemplate the term "metal that is difficult to braze" refers to metals having stable oxides, that is, oxides that have a low dissociation pressure. Chromium and its alloys, for example, fall within this group. Conversely, the expression "readily-brazed metal" refers to a metal or alloy having oxides of a high dissociation pressure. Copper, iron, steel, etc. are examples of metals that fall within this group.

Having completed a detailed description of my invention so that others skilled in the art may practice the same, it will be apparent that other forms thereof may be provided without departing from the essence of the invention as defined in the appended claims.

What is claimed is:

1. The method of making a structural element comprising cold punching a piece of thin sheet metal with a tool from one face at a plurality of spaced areas so as to partially eject slugs of the metal from the opposite face at said areas, respectively, and thereby form depressions in said one face at said areas, respectively, and then with the piece in unheated condition, and in the internally stressed condition resulting from said punching operation, and with unheated small diameter wire pins to be fastened to the piece, each of which is substantially the same diameter as the punch at at least one end, punching and completing ejecting the slugs by said ends of the pins, respectively, and thereby effecting resilient pressure engagement between the wall of each aperture formed by the pin punching operation and the peripheral wall of said one end of its associated pin for holding its associated pin in place temporarily, arranging said piece upon, and with said opposite face in face to face relation with, a metal wall member, and then concurrently brazing said pins to the piece and said opposite face of the piece in face to face relation to said wall member.

2. The method of making a structural element comprising cold punching each of a pair of pieces of thin sheet metal with a tool from one face of each at a plurality of spaced areas so as to partially eject slugs of the metal from the opposite face of each at said areas, respectively, and thereby form depressions in said one face of each at said areas, respectively, and then, with the pieces in unheated condition, and in the internally stressed

condition resulting from said punching operation, and with unheated small diameter wire pins to be fastened to the pieces, each of which pins is substantially the same diameter as the punch at its ends, punching and completing ejecting the slugs from the pieces by opposite ends, respectively, of the pins, and thereby effecting resilient pressure engagement between the wall of each aperture formed by the pin punching operation and the engaged peripheral wall of its associated pin for holding its associated pin in place temporarily, arranging said pieces between, and with their said opposite faces in face to face relation with, a pair of metal wall members, respectively, and then concurrently brazing said pins to the pieces and said opposite faces of the pieces in face to face relation to their associated wall members.

3. The method of making a structural element comprising cold punching a piece of thin sheet metal with a tool from one face at a plurality of spaced areas so as to partially eject slugs of the metal from the opposite face at said areas, respectively, and thereby form depressions in said one face at said areas, respectively, and then with the piece in unheated condition, and in the internally stressed condition resulting from said punching operation, and with unheated small diameter wire pins to be fastened to the piece, each of which is substantially the same diameter as the punch at at least one end, punching and completing ejecting the slugs by said ends of the pins, respectively, by causing the pins to enter the depressions and punch through the sheet metal from the entering surface a distance such as to dispose their entering surfaces substantially flush with the opposite surface of the sheet metal, and thereby effecting resilient pressure engagement between the wall of each aperture formed by the pin punching operation and the peripheral wall of said one end of its associated pin for holding its associated pin in place temporarily, and then brazing said pins to the piece.

References Cited in the file of this patent

UNITED STATES PATENTS

513,655	Schoen	Jan. 30, 1894
1,478,998	Howard	Jan. 1, 1924
1,500,560	Henderson	July 8, 1924
2,181,927	Townsend	Dec. 5, 1939
2,350,875	Carney	June 6, 1944
2,505,619	Holm	Apr. 25, 1950
2,537,797	Simpelaar	Jan. 9, 1951
2,595,457	Holm	May 6, 1952
2,632,633	Hammond	Mar. 24, 1953