Sept. 11, 1962 L. H. GRENELL 3,053,514

SHEET METAL FABRICATIONS

Original Filed Nov. 18, 1949 2 Sheets-Sheet 1

Fig. 1

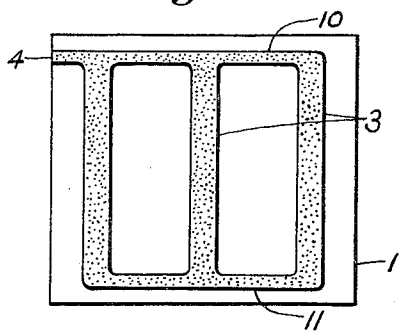


Fig. 2

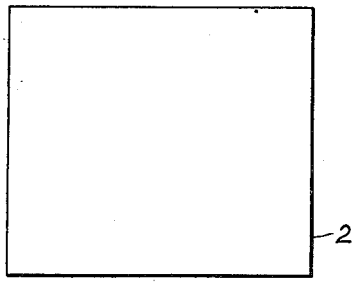


Fig. 6

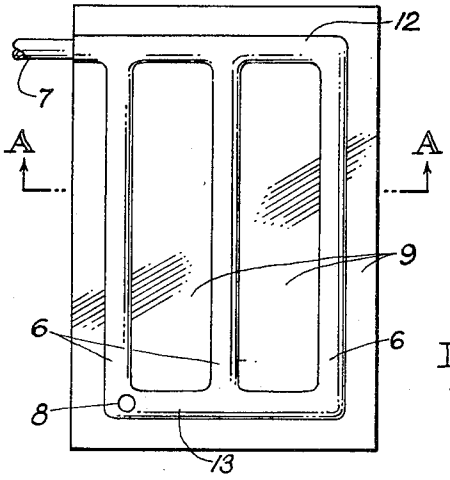


Fig. 3

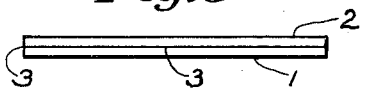


Fig. 4

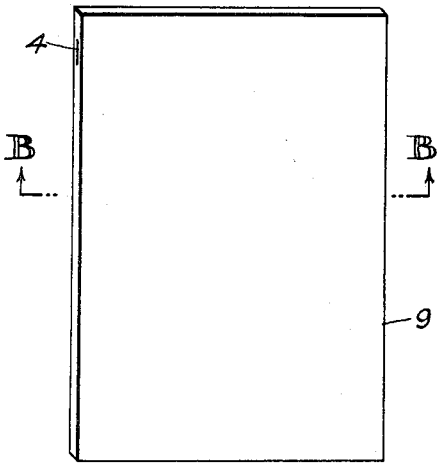


Fig. 5

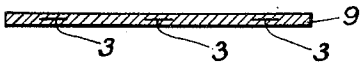
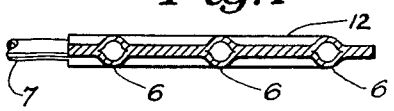


Fig. 7



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SHEET METAL FABRICATIONS

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Fig. 8



Fig. 9

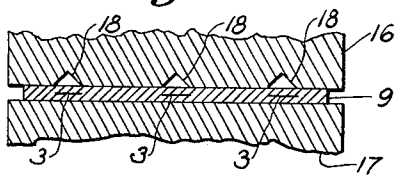


Fig. 10



Fig. 11

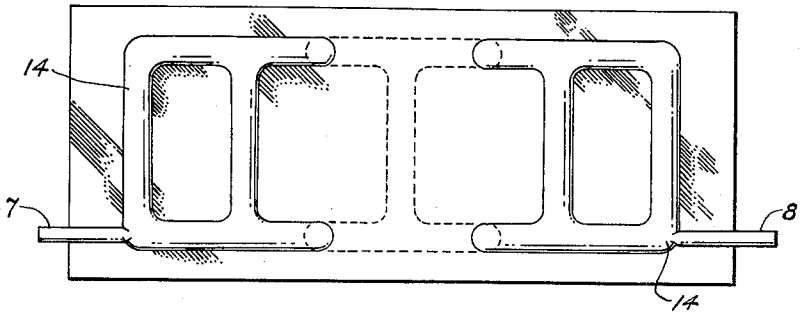
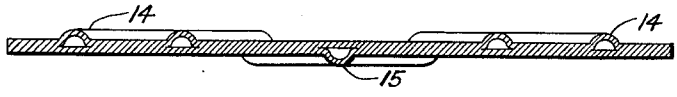


Fig. 12



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3,053,514

SHEET METAL FABRICATIONS

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Original application Nov. 18, 1949, Ser. No. 128,116, now Patent No. 2,690,002, dated Sept. 28, 1954. Divided and this application Aug. 30, 1954, Ser. No. 452,910
Claims priority, application Canada Feb. 18, 1953
7 Claims. (Cl. 257—256)

This invention relates to the manufacture of sheet metal fabrications and in particular to structural members, heat exchangers, fluid containers, and the like made of sheet metal and to a method of making the same. This applicaion is a division of co-pending application, Serial No. 128,116, filed November 18, 1949, now U.S. Patent No. 2,690,002, granted September 28, 1954, and the process of forming sheet metal fabrications set forth herein is described and claimed in said copending application.

Structural members for some uses must have at least one flat or smooth surface, for instance, when used as airplane fuselage, wing, or tail surfaces, box car walls, and the like, and it has been customary to utilize two metal sheets face to face, one flat and one indented, riveted, spot-welded, or brazed together. In such composite members, the ribs or bulges of the indented sheet strengthen and stiffen the flat sheet and thereby reinforce the member. In the art of making refrigerator evaporators, radiant heaters, and the like, such heat exchange devices in general are composed of a plurality of tubes or chambers adapted to serve as a conduit for the fluid of the heat exchange system and have been constructed heretofore of relatively thin gauge sheet metal by a method which involves indenting channels or grooves in the metal sheeting in a pattern designed to provide after assembly interconnecting passageways. Two of the sheets are then arranged face to face in superposed relation and joined together by brazing or spot-welding along predetermined lines to provide the desired fluid passageways between the sheets. Another method for making heat exchange devices, disclosed in U.S. Patent 1,779,911 issued to Little, October 28, 1930, consists briefly in superposing two sheets of metal, sealing the edges of the sheets by welding, joining the inner faces of the sheets at spaced intervals by spot-welding, and then introducing fluid pressure through a hole in one of the sheets to expand and separate the sheets between the spot-welds.

Now, the brazing, riveting and spot-welding methods utilized in producing such fabrications have attendant disadvantages. For instance, when the sheets are joined by brazing, one must employ a brazing alloy and an extra processing step of inserting and adequately positioning the brazing strip is required. Further, the brazed joint is not always mechanically perfect and the sheets may separate when stress is applied. Likewise any strengthening of the tube or rib walls due to working is lost owing to the annealing effect obtained at the brazing temperature. The spot-welding and riveting techniques are not adapted for complete sealing of the sheets between the ribs or fluid passageways, particularly when the ribs or passages are formed by long ducts following either straight, or serpentine, tortuous or other intricate paths. With such structures, voids are often found present between the sheets at points other than the intended ribs or passageways, resulting in possible lower strength in the case of structural members, and in leaks in the case of heat exchangers, and otherwise detract from the efficiency of such fabrications. Further the course-grained cast structure of the spot-welds tends to weaken the fabrication at these points. Likewise, the spot-welding procedure is not in general well suited for alloys of high electrical conductivity and in many instances the surfaces of the sheets

tend to adhere to the spot-welding electroder marring the sheets and requiring frequent cleaning of the electrodes.

The advantages which may become apparent from the detail description hereinafter, are accomplished in accordance with this invention by a combination of processing steps including sandwiching a pattern of a non-bonding or separation material between two sheets of metal, forming a single layer of metal between the areas covered by the separation material by pressure welding, and applying a fluid pressure on the inner surfaces held apart by the separation material to expand the metal in these areas. Any desired processing may be employed intermediate the aforenamed steps provided such processing does not interfere with the functioning of said steps. The diameter, length, and positioning of the cavities formed within the sheet by the fluid pressure and the resulting bulges or ribs on the surface depend mainly upon the pattern dimensions and design in which the separation material is originally applied and complex and intricately shaped reinforcing ribs or conduits are thus readily formed by applying the desired pattern. No voids exist between adjacent passageways or ribs, since the metal of the sheets intermediate the passageways are forged or pressure welded into one layer of metal of substantially uniform composition.

Having described in the foregoing in a general way the nature and substance of this invention, there follows a more detailed description of preferred embodiments thereof with reference to the accompanying drawing in which:

FIGURE 1 is a plan view illustrating a sheet of metal coated with a pattern of separation material,

FIGURE 2 is a plan view illustrating a sheet of metal to be superposed on the coated sheet of FIGURE 1,

FIGURE 3 is an end view illustrating the metal sheets of FIGURES 1 and 2 after assembly,

FIGURE 4 is a perspective view illustrating the assemby of FIGURE 3 after hot rolling,

FIGURE 5 is an enlarged sectional view illustrating the metal sheet at B—B of FIGURE 4,

FIGURE 6 is a plan view illustrating reinforced metal sheeting suitable for use as a heat exchanger,

FIGURE 7 is a sectional view taken at A—A in FIGURE 6,

FIGURE 8 is a sectional view illustrating another embodiment, in which the sheet has ribs only on one surface,

FIGURE 9 is a sectional view illustrating a metal sheet held in a die,

FIGURE 10 is a sectional view illustrating a sheet formed in accordance with this invention,

FIGURE 11 is a plan view illustrating another embodiment, in which the ribs are on one surface of the sheet in one area and on the opposite surface in another area, and

FIGURE 12 is a cross-sectional view of the sheet of FIGURE 11.

Referring first to FIGURES 1 and 2, for the manufacture of a heat exchange device, sheets **1** and **2** of metal, 0.070 inch thick and composed of 92% to 94% copper, 2.05% to 2.60% iron, 0.025% phosphorus, 0.05% lead, with the balance zinc, are first degreased by immersion in an organic solvent bath, such as naphtha or white gasoline, at room temperature and then wiped free of solvent. The sheets are then cleaned in an acid bath containing approximately 1 part by volume of 68% nitric acid, 1 part by volume of 95% sulphuric acid, and 1 part by volume of water at room temperature. Such treatment is designed to remove any oxide film on the metal. The sheets are then rinsed thoroughly in cold water and subsequently in hot water, and air dried at room temperature. The clean surface of the sheet is desirable in order to secure good bonding in the subsequent hot rolling operation.

A separation or weld-preventing material **3**, consisting of a mixture of graphite in water glass, is then applied in a thin layer to selected areas on the face of sheet **1** according to a predetermined pattern. Such separation material may be sprayed through a masking die, painted through a stencil, squeezed through a silk screen, or applied in any other suitable manner. For instance, if the separation material **3** is to be applied through a silk screen to the selected area, graphite in the ratio of about three to four kilograms to three liters of water glass solution is satisfactory. A thinner more fluid mixture is, of course, used if the separation material is to be applied by painting or spraying on the selected areas.

The elongation of the metal during subsequent rolling must be allowed for in the shape and dimension of the pattern of separation material originally applied to the sheet. For instance, the strip and pattern is lengthened in the direction of rolling in substantially inverse proportion to the change in thickness of the assembly. Pattern lines, **10** and **11**, that run perpendicular to the direction of rolling are, therefore, increased in width, as indicated at **12** and **13**, in substantially inverse proportion to the change in thickness of the assembly. Pattern lines **3** that run in the direction of rolling are not changed appreciably in width as indicated at **6**, FIGURE 6. Thus, if one wishes a conduit running perpendicular to the direction of rolling one inch in diameter and the assembly thickness during the rolling operation is reduced to one-half the original thickness, then the pattern lines running perpendicular to the direction of rolling must be made only about one-half inch wide. The thickness of the layer of separation material decreases in direct proportion with the decrease in thickness of the assembly during rolling due to the spreading or elongation of the material during the rolling operation. The thickness of the layer of separation material after rolling should be sufficient to prevent bonding of the metal except where such bonding is desired thereby insuring a discontinuity of bonding within and between the subsequently welded metal sheets as indicated by the numeral **3** in FIGURES 5 and 9.

As can be clearly seen in FIGURE 1, pattern lines **3**, **4** and **10** define a continuous pattern which in the resultant bonding and expansion of the metal sheets provides a corresponding pattern of tubular passages having continuous axes which upon traversal define a tortuous outline through the welded structure.

After the pattern of separation material **3** has been applied to sheet **1**, the sheet **2** is placed on sheet **1** with the separation material **3** between them, FIGURE 3. If sheet **2** is permitted to move freely in frictional contact with the separation material on sheet **1** prior to the subsequent hot roll operation, the pattern is likely to be damaged or distorted so that the desired conduit system will not be obtained. The sheets are therefore fastened together to avoid obliteration of the pattern, by any suitable means, such as heli-arc welding the edges, tacking the edges together by spot-welding, or by crimping the edges, or the like.

The assembly is then placed in a furnace and heated to about 900° C. To prevent oxidation of the inner faces of the sheets **1** and **2**, the edges of the assembly may be completely sealed as by welding or the like, or an inert or reducing atmosphere may be employed in the furnace if desired. The temperature of 900° C. is about 160° C. below the melting point of the alloy and is sufficiently high to effect pressure welding of the two sheets of metal in the hot rolling step to be described hereinafter. The exact temperature to be used for pressure welding is, of course, dependent upon the melting point of the particular metal or alloy utilized and should be relatively close thereto.

Inasmuch as each sheet of the metal, **1** and **2**, is 0.070 inch thick and the layer of separation material **3** is only about 0.002 to 0.005 inch thick, the assembly, FIGURE 3, is about 0.14 inch thick which for the specific assembly employed is the thinnest dimension thereof. As soon as the assembly has reached a temperature of about 900° C. it is hot rolled in one pass to a thickness of about 0.070 inch and is then cleaned with acid, washed and dried as described in the foregoing treatment of sheets **1** and **2**. It is desirable to hot roll to a reduction of thickness of at least 35% in order to insure welding of the sheets, and a reduction of approximately 50% in one pass is preferable as is described in the foregoing. The welded sheet is then cold rolled to a finish gauge of about 0.048 inch thickness, is then annealed at a temperature of 750° C. for one half hour to remove the hardening effect of the cold rolling, and is then cleaned by acid, washing, and drying treatments as described hereinbefore. The cold rolling step is carried out in order to accurately control the thinness of the sheet. If sufficient accuracy in gauge for the particular use can be obtained by hot rolling, the entire reduction can be carried out by hot rolling, and the cold rolling and annealing treatments referred to in the foregoing may be omitted. The strength of the sheet formed by the hot rolling step is appreciably greater than that of the cast structure obtained with spot-welding techniques. The cast structure formed by spot-welding contains appreciably larger grains than the sheet prior to such welding, whereas the sheet formed by the hot rolling step has a grain size substantially uniform throughout the sheet.

In applying the separation material **3** to sheet **1**, a portion is extended to the edge of the sheet at **4**. The unbonded edge **4** of sheet **9**, FIGURE 4, is then pried open mechanically, and a copper tube is inserted into the opening and silver soldered, brazed, or threaded therein. The free end of the copper tube **7** is attached to an hydraulic pump by any suitable means such as a sleeve and nut, and about 250 to 300 pounds per square inch fluid pressure is applied to expand the metal in the unwelded inner portions of the sheet containing the separation material. Only sufficient pressure need be applied to bulge the metal in these areas to an extent sufficient to provide the desired cavities or conduit indicated at **6**, **12** and **13**, FIGURES 6 and 7. As will be understood in the art the amount of fluid pressure necessary will vary with the gauge, temper, and composition of the metal used. If desired, to produce very sharp, intricate conduit patterns, the sheet **9** prior to application of the pressure may be placed in a die whose faces are recessed in accordance with the desired conduit pattern. During the application of the fluid pressure, the conduit walls **6**, **12**, and **13** within the die are reduced in thickness about 0.001 to 0.002 inch from the original thickness of about 0.024 inch on each side of the separation material prior to application of the fluid pressure, and appear as bulges on the surfaces of the sheet. The cavity walls are thus strengthened by the work-hardening effected by expansion of the metal.

When no die is used, the metal expands with little or no thinning of the cavity wall and the cavity is formed upon applying the fluid pressure merely by further separation or opening up of the metal in the separation material areas with a resultant decrease of sheet length or width, or both, depending on the design and dimension of the cavities. However, the sheet may be so held in a die, during application of the fluid pressure, that the length or width does not decrease and the expansion is accomplished by a thinning of the cavity wall, as in the foregoing.

In some instance it may be desirable to have the heat exchange device in a shape other than a relatively flat sheet, for instance, a U-shaped device may be desired, such as is used to partially surround the ice cube or freezing compartment of a refrigerator. For such purposes the sheet **9** can be bent into the desired shape either before or after the fluid pressure has been applied to form the conduit within the sheet. If the bending is done after

the conduits have been formed, the conduit pattern should be so designed as to permit such bending and care should be observed in such deforming operations to avoid closing off desired passageways. A hole such as illustrated at **8**, FIGURE 6, may be drilled into the conduit and a copper tube partially inserted therein and silver soldered or brazed thereto which copper tube may then serve along with copper tube **7** to provide an entrance and exit for the heat exchange medium. The conduit **6**, **12**, and **13**, FIGURE 6, corresponds substantially to the pattern of separation material **3**, FIGURE 1.

While the foregoing specific embodiment is described with particular reference to a heat exchanger, it will be understood that the expanded sheet **9**, FIGURE 6, is relatively strong and rigid due to the ribs formed by the conduit **6**, **12**, and **13** and minus the inlet and outlet, **7** and **8**, can be used to advantage as a sheet metal structural member. If a structural member having only longitudinal reinforcing ribs is desired, the ends of the sheet may be cut off for a sufficient distance to remove the transverse conduits, or headers, **12** and **13**. The cavities in the sheet whether they be ultimately utilized for the sheet strengthening effected by their walls or as fluid conduit, or both, may as pointed out hereinbefore have practically and desired design, the design being controlled by the pattern of separation material.

For some uses, it may be desirable to have the bulges formed by the cavities all on one side of the sheet instead of on both surfaces. An embodiment illustrating such construction is shown in section in FIGURE 8, in which the conduit **6** and **12** forms bulges on only the top surface of the sheet. Such construction, which is well adapted for structural members having a flat or smooth face, can be obtained, for instance, if one sheet is sufficiently thicker than the other that all expansion occurs on the thin sheet surface when the fluid pressure is applied. For example, the bottom sheet **1** utilized may be ten times as thick as the sheet **2** and the pattern applied, the sheets assembled and hot rolled until pressure welded, and the fluid pressure applied, etc., as described in the foregoing embodiment, the final thickness of the device being greater, of course, due to the greater thickness of the bottom sheet. Such construction, as is illustrated in FIGURE 8, may also be obtained by inserting the rolled sheet **9** containing the separation material **3** in a die having one face recessed to conform to the conduit pattern and the other face unrecessed. Upon applying fluid pressure on the unwelded inner surfaces of sheet **9** one surface of the sheet is prevented from expanding by the unrecessed face of the die, whereas the other surface of the sheet expands into the recesses in the other face of the die. For some uses as in structural members, a semicircular bulge or rib may not be as desirable as some other shape. The contour of the expanded surface may be controlled by providing the recesses in the die face with the desired contour. For instance, FIGURE 9 illustrates an embodiment for forming an angular contour instead of the semicircular contour shown for the ribs in FIGURE 8. The unexpanded sheet **9** containing separation material **3** is held between the unrecessed die plate **17** and the die plate **16** having angular shaped recesses **18** in its inner face positioned over the separation material **3** within the sheet **9**. Upon applying the fluid pressure, as described hereinbefore, the surface of the sheet expands forming angular contoured ribs **19**, FIGURE 10. In some instances it may be desirable to have the bulges forming the conduit partly on one side of the sheet and on the opposite side of the sheet in other areas. Such an embodiment is illustrated in FIGURES 11 and 12, where it may be seen that the conduit is formed by expansion of the top surface towards the ends of the sheet, and by expansion of the bottom surface near the center of the sheet. Here again such construction is accomplished by inserting the sheet **9** in a die whose faces are recessed in accordance with the pattern to permit the desired expansion of the top surface near the ends of the sheet **9** forming bulge **14** and of the bottom surface at the center forming bulge **15**. The conduit thus lies above the plane of the sheet at the end portions and below the plane of the sheet at the center portion. Where the sheet is to be shaped, for instance into a U-shape to fit about the ice-cube compartment of a refrigerator, it may be highly desirable to permit bulging of only one surface in various areas of the sheet in accordance with the practice illustrated in the foregoing.

While in the foregoing a specific rolling, annealing, and cleaning sequence is described, it will be understood that various rolling, annealing and cleaning techniques, trimming, tacking the sheets together, shaping and other such operations may be employed in accordance with this invention between the step of applying the separation material and the step of applying the fluid pressure, depending upon the prevailing practice and the physical characteristics desired in the finished product. For instance, the hot and cold rolling may be carried out in a number of steps depending upon the economics of the situation and available rolling equipment, or the cold rolling or annealing, or both, may be omitted entirely. Whereas, the pressure weld is accomplished by hot rolling the assembly in accordance with the preferred practice set forth herein, it is to be understood that some metal sheeting may be pressure welded merely by applying sufficient pressure at room temperature and that such pressure welding technique may be utilized in accordance with this invention. Regardless, however, of the intermediate processing used, it is necessary that the metal of the sheets be suitably joined to form one substantially uniform layer at all superposed points not held apart by the separation material prior to application of the fluid pressure.

The process is well suited for continuous operation. For example, the patterns of the separation material may be applied successively to the surface of a strip of metal being unwound from a coil, a second strip of metal being unwound from another coil may be superposed on the pattern-coated strip, and the strips then tacked together by spot-welding, edge crimping, or the like and fed continuously through a heating furnace and hot rolling mill. After the rolling and other such processing has been completed, the pressure welded strip containing the separation material is then expanded by applying fluid pressure as described above to the internal metal surfaces coated with separation material.

Any suitable separation material may be employed, its chief function being to prevent bonding of the coated surfaces during the welding operation. For instance, in addition to the graphite water glass mixture set forth in the foregoing, other inorganic ingredients and mixtures may be employed such as zinc oxide, kieselguhr or other diatomaceous earths, flint, talc, powdered quartz, clays, and the like and mixtures thereof with each other and with graphite and water glass or the like. The separation material used must, of course, be so compounded as to flow or elongate with the metal and retain uniformly sufficient thickness to prevent bonding where not desired. Likewise, although the embodiment is described in the foregoing with particular reference to copper base alloys, the process of this invention is applicable to other metal sheeting, for example, aluminum, magnesium, steel, and the like adapted to be pressure welded. As will be apparent from the foregoing, the process of this invention permits the fabrication of a sheet of metal provided with internal ducts or internal passageways of substantially any desired design or pattern which cavitied sheet of metal with appropriate conduit pattern is adapted for use as a lower cost, more efficient heat exchange device than is obtainable with prior processes. Relatively thick low cost sheet stock may be employed since the desired cavity wall thinness is obtained by the thinning action resulting from the pressure welding step and the thinning of the

metal in the immediate area upon which the fluid pressure is applied. In prior methods, in which the cavity wall was stamped or drawn, the sheet stock used had to be substantially of the thinness desired in the cavity wall. Likewise, the process permits the manufacture of cavitied sheet metal well suited for strong light weight structural members and other uses. It is to be understood that the embodiment of the present invention as shown and described is only illustrative and that many changes may be made therein without departing from the spirit and scope of the invention as set forth in the following claims.

The word "sheet" is used in the appended claims to define a piece of metal which is very thin in relation to its length and breadth.

Having thus described the invention, what is claimed and desired to secure by Letters Patent is:

1. A wrought substantially uniformly worked blank of sheet metal adapted for the manufacture of hollow articles by fluid pressure inflation comprising a single body of ductile metal having a substantially homogeneous internal wrought grain structure and further having intermediate its thinnest dimension an area of separation which is discontinuous in all planes parallel with said thinnest dimension and extends in a plane normal to said thinnest dimension said area of separation comprising a planar stratum of separation material disposed within the confines of the interior of the sheet in a pattern corresponding in plan to a predetermined conduit configuration generable from said sheet by fluid pressure distention, said material extending at least adjacent to an exterior surface of said sheet at at least one place to adapt said blank to the formation of an entry to said stratum and said material having a plurality of interconnected portions, at least one of which extends substantially in said normal plane but having its extreme ends or any extensions in the direction thereof terminating short of all external surfaces of said sheet.

2. The blank of claim 1 in which at least some of the portions of the area of separation material extend tortuously and are interconnected to be continuous in the normal plane.

3. A fluid container or the like comprising a single sheet of rolled metal of substantially uniform reduction and substantially homogeneous internal wrought grain structure throughout and embracing in the body of said sheet a cavity the peripheral edges of which except for an elongated inlet are spaced from the periphery of the sheet, said inlet being extended to communicate with said cavity in a direction substantially different than the direction of at least one portion of said peripheral edges of said cavity adjacent said inlets, and said cavity having walls distended to project beyond the surfaces of the unseparated portion of said sheet.

4. A fluid container from a hollow sheet fabrication comprising a sheet of metal having a substantially homogeneous internal wrought grain structure and further having a continuous cavity internal thereof forming bulges on the surface of said sheet in accordance with a predetermined pattern of separation in a plurality of directions in the body of the sheet with at least one wall of said cavity having a thickness substantially less than the thickness of said sheet, said sheet between said cavitated portions forming an integral structural support, and said

cavity forming a chamber for a fluid and having at least one elongated portion extending laterally across said sheet but having its extreme ends or any extensions in the direction thereof terminating short of the edges and all external surfaces of said sheet and having at least one elongated portion extending longitudinally in said sheet but having its extreme ends or any extensions in the direction thereof terminating short of the edges and all externals surfaces of said sheet, and the area of said member being greater than the area of said cavity.

5. A single solid sheet of metal having a substantially homogeneous internal wrought grain structure and containing a continuous and tortuous pattern of communicating elongated tubular cavities within the body of said sheet with at least one of said elongated cavities having its extreme ends and any extensions thereof in the direction of its elongation terminated inwardly of all external surfaces of said sheet.

6. A single solid sheet of metal having a substantially homogeneous internal wrought grain structure and containing a continuous and tortuous pattern of elongated tubular cavities within the body of said sheet, said pattern of tubular cavities comprising a first tubular cavity elongated in one direction and a second tubular cavity elongated in a direction substantially different than said first tubular cavity and having its extreme ends and any extensions thereof in said different direction terminated inwardly of all external surfaces of said sheet, said first tubular cavity and said second tubular cavity being in communicating relationship with each other.

7. A single solid sheet of metal having a substantially homogeneous internal wrought grain structure and containing a continuous and tortuous pattern of elongated tubular cavities within the body of said sheet, said pattern of tubular cavities comprising at least two spaced tubular cavities elongated in one direction and at least one other tubular cavity elongated in a direction substantially different than said spaced tubular cavities and having its extreme ends and any extensions thereof in said different direction terminated inwardly of all external surfaces of said sheet, said other tubular cavity interconnecting said spaced tubular cavities and being in communicating relationship therewith.

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