This invention relates to a new article of manufacture in the form of a slab or plate of almost any formable substance composed of two thinner sheets or plates, one of which is smooth, the other so arranged as to surface as to act to space, stiffened and aid in joining the composite sheet to another or to an adjacent member. The purpose of the invention is economy; economy of material, of weight, of fabricating time and in the nature of the machinery of fabrication, of labor and of heat necessary in making the joint and lastly by making possible structures of superior rigidity without encroachment upon space interior to the walls of the structure.

A plate so made will approximate the stiffness of a solid sheet of similar dimensions against some stresses and even exceed it in others, despite a weight ratio of solid to composite of not less than five to one. For some purposes this ratio may even be exceeded although the tensile strength of the composite sheet, as compared with the solid plate will remain in the approximate ratio of the areas of metal in the contrasted cross sections. Modern design, however, rarely needs to concern itself with strength per se. It seems invariably true that a structure sufficiently stiff for its purpose is strong enough under all its working conditions.

Costs of material and fabrication aside, light structure has so infinite a scope in progressive design as to demand the utmost attention to its device, especially in the transportation fields. Material made under the instruction of this invention would substitute for solid section of similar depth, eliminate necessity for much auxiliary structure, yet maintain the low weight desirable both for better function and cost reduction.

Aerial craft daily advance in importance as a class of manufacture so any simplifying factor in design is of interest.

Ship building, at the moment is seriously hampered by shortage of steel on the one hand and by the lack of facilities for fabricating heavy plate on the other.

Our national facilities, however, have been of late years vastly expanded as to light gauge sheet and a surplus of machines for fabricating light gauge metal actually exists without prospect of employment in the present situation.

While ship construction based on composite plate of this type would be unconventional it might be helpful in enabling existing machine equipment to manipulate vital material to a vital purpose at less cost, with less material, with less energy, human and otherwise and with a more competent end result.

While the initial statement of this application "this invention relates to a new article of manufacture" is technically correct it would be equally true to say it outlines a design system whereby simple structures may be quickly made with a minimum of material and energy.

In the accompanying drawings:

Figure 1 is a perspective, sectional view of one form of the invention.

Figure 2 is a perspective view of an adjoining strip.

Figure 3 is a section on line 1—3 of Figure 2.

Figure 4 is a section on line 4—4 of Figure 2.

Figure 5 is a sectional view showing the manner of joining two elements of the type shown in Figure 1.

Figure 6 is a perspective, sectional detail.

Figure 7 is a plan view of a modified form of the invention.

Figure 8 is a section on line 5—8 of Figure 7.

Figure 9 is a plan view, with certain parts broken away, showing another modification.

Figure 10 is a section on line 9—10 of Figure 9.

Figures 11, 12 and 13 are sectional views of further modifications.

Figure 14 is a sectional view, illustrating one method of securing a structural element to the article of the present invention.

Figures 15 and 16 are plan and sectional views of another modification.

Figure 17 is a sectional view of a modified form of joint between two adjacent sections, and

Figure 18 is a diagrammatic view showing a preferred method of welding adjacent sections.

In a preferred form of fabrication, two sheets of material 10, 11 of similar dimensions and character are taken. One sheet 10 is left smooth, the other embossed, as at 12 to suitable depth and pattern to provide the desired thickness of the composite plate when superimposed upon the smooth sheet. The two are then welded together at the points of contact 13, becoming a single unit which thereafter may be treated precisely as a solid sheet might be. The weld 13 may be a zone of spot welding in the form of a series of circumferential spots around the opening 14, formed, for instance, by a series of projections, or the weld 13 may be a continuous line formed by a hollow cylindrical electrode welding around the periphery of the opening 14. To become specific for the sake of clarity let us take two similar sheets of steel of a thickness easily produced by a continuous rolling mill, leave one sheet alone but on six inch centres
in staggered but symmetrical arrangement pierce half inch holes 14 and draw down angularly walled cups —two patty pans—from the zone surrounding each hole, the depth of the cup to depend upon the final thickness of assembly desired.

Such pans or depressions 15 can be drawn down, where a central hole 4 exists, without materially distorting the surrounding metal so the external dimensions will not be affected and the two sheets can be superimposed with edge parallel to edge. The welding 15 takes place about the pierced bottom of each patty pan 15, by any of the methods suggested above.

While joints may be fewer in a structure built from this composite sheet since longer lengths of thin material can be rolled, handled and welded together than possible with the heavy solid plate, the joining of composite sheets in a manner to assure fluid tightness and at the same time avoid weakness at the joint is part of the problem and of this invention. One method, as indicated in Figures 2–5, employs a backing strip 20 for the interstices formed between the sizes or shapes as laid up, the depressions or pans 15 in the embossed sheet being divided in halves along the backed edges, these halves lacking depth as compared with the other depressions 15 in the sheet area by the thickness of the metal of the backing strip 20 in order to nest in reinforcing pockets 21 in the strip, similar in all form respects to the embossments 15–18 used on the stay sheet except for the inter-pocket channelling 22. Thus the backing strip presents a continuous smooth surface when in place immediately behind and in contact with the smooth surfaces while the pockets 21 in the strip embrace the half embossments 16 leaving the edges drawing them tight together.

Projection welding spots 23 are formed at the mouth of these pockets and along the flange 28 of the channel portions. These spots may be in the form of fine edged rings 23 swaged by pressure from the neighboring metal. By the use of supporting electrodes it is possible to weld the backing strip 20 to the embossed sheet 11 at the projection welding spots 23 to weld the smooth sheet joint between sheets and to the face 25 of the backing strip channel portions 22, securing a smooth joint for a face or skin 10 of the structure and ample reinforcement for the embossed face, notwithstanding the fact that the backing strip 20 is completely enclosed within the walls of the composite elements. Projections similar to those shown at 23 may be employed at the contact surface of the sheets to be joined. The smooth plates 10 and the embossed plates 11 are welded with their ends butted at the lines of division contact.

Apart from the direct economy of primary material the use of light sections of metal aid the welding characteristics making for speed and the use of less electric current or gas. The backing strip helps in making welds and at no time does spot welding have to be attempted through double thickness. The embossment of the half cups 16 by the double thickness backing strip relieves the weld of much of any strain which may later be imposed and assures the true positioning of adjacent plates each to each prior to welding.

It is not essential for facing and backing sheets to be similar in gauge or analysis. Dissimilar thicknesses and analyses may be used in accordance with ordinary welding practice. Thus a stainless steel may be used for the smooth surface 10 matched with a cheaper grade for the stay sheet 11.

It should be observed the shallow edge cups may be halved along the edge of a plate or quartered, as at 18', at the corners, and it is important in order that the reinforcement may be at its full value for these divisions to be accurate. In special cases it may be advisable to use cups alone without attached channels to complete the joint, inserting the channels separately. The centre spacings of embossments used should in any case be accurate within ordinary limits and it may be found useful, for some service to carry indications of the centres through the smooth plate so a gun welder may be properly located from the smooth side.

In forming the joint of the type shown in Figure 5, a pair of composite plates of the type shown in Figure 1 are first prefabricated, by welding the embossments 15 to the smooth sheets 10, along lines 18, but leaving the bottoms of the embossments 16 and 16' spaced from the sheet 10 as indicated at 27, a distance equal to the thickness of the metal in the channel member 20. Because of the inherent spring of the metal in the composite plates, the sheets 10 and 11 may be separated slightly along their edges and the channel member 20 inserted by compressed axial and rotational movement about its longitudinal axis so that the edge embossments 16 and 16' are positioned within the pockets 21 of the backing strip 20. The next plate may then be joined by similarly spreading the plates 10 and 11 along their edges and positioning the half-embossments within the unoccupied halves of the pockets 21.

The dimension of the spaces 27 between the bottoms of the half or quarter embossments 16 and 16' is such that the bottom 25 of the jointing cups 21 are pinched between the smooth plates and the embossments, under the inherent springiness of the metal. Also, the projections 32 somewhat spread apart the embossed sheets and the smooth sheets which subjects the projections to the spring pressure of the metal.

This spring contact is most useful in following up the weld when welding current raises the projections 23 to welding heat, which occurs after the parts have been assembled as just described.

In forming the welded joint between the composite plates assembled in this manner, a central electrode contacts the bottom 25 of the channel 20 through the opening at the center of the half or quarter embossments, as well as the periphery of the embossments 16, 16'. Heavy spring follow-up is preferably used to assure ample pressure at the projections and along the flanges of the channel. This operation may leave the edges of the smooth plates 10 slightly apart, but in firm contact against the bottom surface 25 of the channel. Thereafter, these edges are electrically or otherwise welded together to secure full tightness and to anchor the edges of the plates 10 to the surface 28 of the strip. Being of light gauge, the metal is swiftly brought to welding temperature and a completely supported joint is made.

It will be understood that, when the composite plates are assembled, a pair of adjacent quarter embossments 16' at the corners will be disposed adjacent to each other and preferably opposite to a half embossment 16 on the edge of the next composite plate so that the lines of junction between the plates may be staggered and discontinuous.

For some purposes the flat bottomed, pierced cup can be replaced by a single conical embossment as indicated at 30 in Figures 7 and 8, the apex 31 of the cone becoming a projection spot.
This is especially desirable where very thin metal is to be used and where the depth of the section is small, and also in some bends where close pitched reinforcement is desirable. Pitch and centre distances of embossments are entirely a matter of material and conditions.

There is merit in double welding, i.e. along both inner and outer sheet junctions but the process is slower and in the main the seam weld along the inner seam is unnecessary.

The shot welding of the reinforcing cups should in any case be retained.

Sections of composite sheet may have other than parallel sides. For example as indicated in Fig. 11 a tapered wing might be built by using graded depths and pitches for the embossments. Sections having more than two plane surfaces may similarly be constructed.

In general the embossment in the form of a truncated right cone having a circular base will be found completely adequate but special conditions may arise wherein an elliptically based embossment, as indicated at 40, 41, in Figures 15 and 16 will prove advantageous in searching for the ultimate economy of weight.

Staggered pitch in symmetrical pattern may be less efficient than a pitch arrangement patterned to meet the loading conditions. Staggered overall thickness may have place in transition of zones of section. Such matters are in the province of design and in no way depart from the spirit of the invention.

Figures 7 and 8 illustrate an unpierced cone type of embossment in which the apex 31 of the cone 30—being thinned in the draw provides its own welding projection.

Figures 9 and 10 indicate the method of using double embossment to produce a double faced smooth plate.

Smooth plates 33, 34 are welded to the ends of downwardly and upwardly projecting cones 35, 36 respectively, pressed from the intermediate embossed sheet 37, the latter acting as a stiffening member for the two smooth plates. As indicated in Figure 9, the cones are preferably staggered, but any other arrangement may be adapted, depending upon the use to which the composite plate is to be put.

In Figure 11 a diagrammatic representation of a tapered structure is given showing change in depth and pitch of the cups 38 both as demanded by optimum design considerations and by the practical conditions governing the relation of diameter to depth of draw. A curved surface is represented by Figure 13. Its purpose is to indicate the use of chordal flats 44 between the pitch of the embossments 46. This advantage in stability comes from delaying the welding operation until after the desired bend in the smooth plate is established. While Figure 13 shows cones for embossments, the spherical embossment 47 shown in Figure 13 is often preferred. Moreover the spherical embossments are of particular utility in tapered sections, as shown in Figures 11 and 12.

The advantages of the use of the present invention in connection with the curved sections will be apparent when consideration is given to the difficulties encountered in bending solid plates of substantial thickness. Operations of this type require heavy machine tools and the expenditure of considerable power. With a composite sheet in accordance with the present invention, similar results may be accomplished quite readily by bending each of the elements of the plate, before the sealing operation is performed. The resulting product is exceptionally stable and stiff, since the chordal sections or flats 45 act as straight brace members and restrain bending.

Figures 11 and 12 has numerous advantages over corresponding solid plates, particularly from the point of view of initial manufacture, since it is a difficult task to roll out or machine down a solid plate to a variable thickness.

Figure 14 indicates a preferred method of attaching a composite sheet to structural members, such as bulb angles and the like. The embossed plate 11" is apertured at 50, 51 for the reception of clamping bolt assemblies 52 and for the foot electrode 53 of a welding apparatus, the upper electrode 54 being positioned to engage the flange 55 of the bulb angle.

Figures 17 and 18 illustrate modified joints between adjacent composite plates. The smooth plates 10a have their marginal portions 56 disposed on downwardly inclined planes and their edges 58 turned upwardly, thereby providing marginal chamfers 60 for the reception of roller electrodes 61, 62, adapted to function in the manner fully described in my co-bending application for patent, Serial Number 388,653. Welding current flows from one electrode through the upturned edge 58 of the embossed plate, through the two flanges of the smooth plates 10a, then through the other edge 59 and finally to the other electrode. Since the metal is relatively thin, the roller electrodes 61, 62 may be moved along the joint quite rapidly, to provide a continuous welded seam.

If desired, the opposite, smooth face may be welded, as indicated at 63.

The flanges 57 of the smooth plates 10a may extend a substantial distance beyond the embossed plates, as indicated at 64, to serve as a reinforcement.

In some cases it may be desirable to reinforce the smooth skin sheet against local puncture. This can be done by filling the space between the sheets with a setting compound, including cement or plaster. The filler may be inserted in unit form or poured in plastic condition. Preferably, however, jointings are left free of compound so that the back strip can be inserted and the welding operations performed. In some cases, the plastic material can be inserted after the whole structure is completed. Resonance is greatly reduced by the use of such material, and the sound-proofing qualities greatly increased.

While this specification deals with a single plate and its relation to adjacent plates or other members and so defines a unit of construction the development of the system opens up fields of design hitherto untouched.

It would for instance be feasible and economical to fabricate a ship's hull in such a manner with only a minimum of other framing, since the general stiffness and resistance to torsion would approximate that to be expected if plates of similar solid thickness were to be employed. A wall depth of say three inches using 11 gauge plate would only weigh the same as the same area of 1/4 inch solid plate—a thickness much too light to be used without close framing. The total weight of such a hull would approximate one-fourth of that of normal conventional construction, and fabrication facilities could be found almost anywhere in the U. S. A. Production of suitable sheets could be effected on continuous mills and the handling would be lighter so avoid-
ing much of the difficulty of craneage supply. For equivalent lines the effective hull space would be much greater.

In aircraft work avoidance of the myriad rivet holes would make for simpler, cheaper and more aerodynamically efficient general arrangements of plane elements.

The cost of composite plate is almost directly as the weight if material alone is considered, since the fabricating cost of the embossed member is very small with proper equipment. If handling machine overheads and assembly work are included the potential saving over solid metal is large. Contrasted with equivalent structure characteristics obtained with solid plate and contributory framing the economy is striking.

The use of the terms "welding" and "welding" used throughout this specification must not be taken to preclude the use of other methods of firm attachment under other circumstances and with other materials. Thus brazing in controlled atmosphere furnaces would be satisfactory so far as the junction between the plates is concerned, equally so silver soldering with or without atmosphere control. With non-ferrous metals, soft soldering would be adequate for many purposes.

Even castings bored between surfaces to achieve the generic form of spaced plates connected by a multiplicity of right cones would provide the stiffness demanded at with economy of weight.

Although the invention has been described with considerable particularity, it must be understood that it is not limited to the details of construction described above and shown in the accompanying drawings, but includes all modifications coming within the scope of the appended claims and their equivalents.

I claim:

1. In combination, a plurality of composite plates and means for joining the same together in edge to edge relation, each plate comprising a substantially smooth sheet and a sheet having a plurality of tapering embossments formed therein in symmetrical, staggered relation and welded to the smooth sheet, and a plurality of similarly tapered half embossments along the edges of the embossed sheets, each plate comprising a member having a tapering pocket embracing the two half embossments of two adjacent plates and a welded connection between the member and the smooth sheet of each plate.

2. In combination, a plurality of composite plates and means for joining the same together in edge to edge relation, each plate comprising a substantially smooth sheet and a sheet having a plurality of embossments formed therein in symmetrical, staggered relation and welded to the smooth sheet, and a plurality of half embossments along the edges of the embossed sheet with the ends thereof spaced from the smooth sheet, said means for joining the composite plates together comprising a channel member having pockets embracing the two half embossments of two adjacent plates and a welded connection between the half embossments, the pockets in the channel member and the smooth sheets of each plate.

3. In combination, a plurality of composite plates and means for joining the same together in edge to edge relation, each plate comprising a substantially smooth sheet and a sheet having a plurality of embossments formed therein in symmetrical, staggered relation and welded to the smooth sheet, and a plurality of half embossments along the edges of the embossed sheet and quarter embossments at the corners thereof, said means for joining the composite plates together comprising a member having a plurality of pockets embracing two adjacent mating half embossments of the member and two adjacent plates and four quarter embossments at the corner of four adjacent plates, and welded connections between the embossments, the pockets in the member and the smooth sheets of each plate.

4. In combination, a plurality of composite plates, means joining the same together in edge to edge relation, each plate comprising a substantially smooth sheet and a sheet having a plurality of substantially conical embossments formed therein in symmetrical staggered relation and welded to the smooth sheet and a plurality of half embossments at the edges of the embossed sheet and quarter embossments at the corners thereof, said means for joining the composite plates together comprising a member having a plurality of pockets, certain of which embrace two adjacent mating half embossments of two adjacent plates, and others of which embrace one half embossment of one plate and two quarter embossments at the corners of two adjacent plates, and welded connections between the embossments, the pockets in the member and the smooth sheets of each plate.

5. A slab-like composite plate adapted to be assembled permanently with other plates of similar construction and matching edges, and means for securing the plates together, each of said plates comprising a smooth sheet welded to an embossed sheet, the depth of the embossments plus the thickness of the smooth sheet aggregating the thickness of the plate, the margins of the plate being defined in part by edge embossments projecting from the embossed sheet and being of less depth than the space between the sheets, thereby providing a space between the edge embossments and the smooth sheet to permit the insertion of said means for securing the plates together, the last-mentioned means comprising a member disposed entirely within the thickness of the plates and interposed in part between the edge embossments and the smooth sheets, spanning the lines of junction between adjacent plates and embracing the edge embossments and drawing the same together, and a welded connection between the edge embossments, the member, and the edges of the smooth sheets.

6. In combination, a plurality of composite plates and means for joining them together in edge to edge relation, said plates each comprising a smooth sheet and a sheet having a plurality of integral, spaced embossments welded to the smooth sheet, said joining means comprising a member disposed completely within the thickness of the plates, spanning the edges thereof and joined to the embossments on the edges of the embossed sheets and to the smooth sheets by welding.

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