United States Patent

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[54] **SHEET METAL WELDING MACHINE**
4 Claims, 7 Drawing Figs.

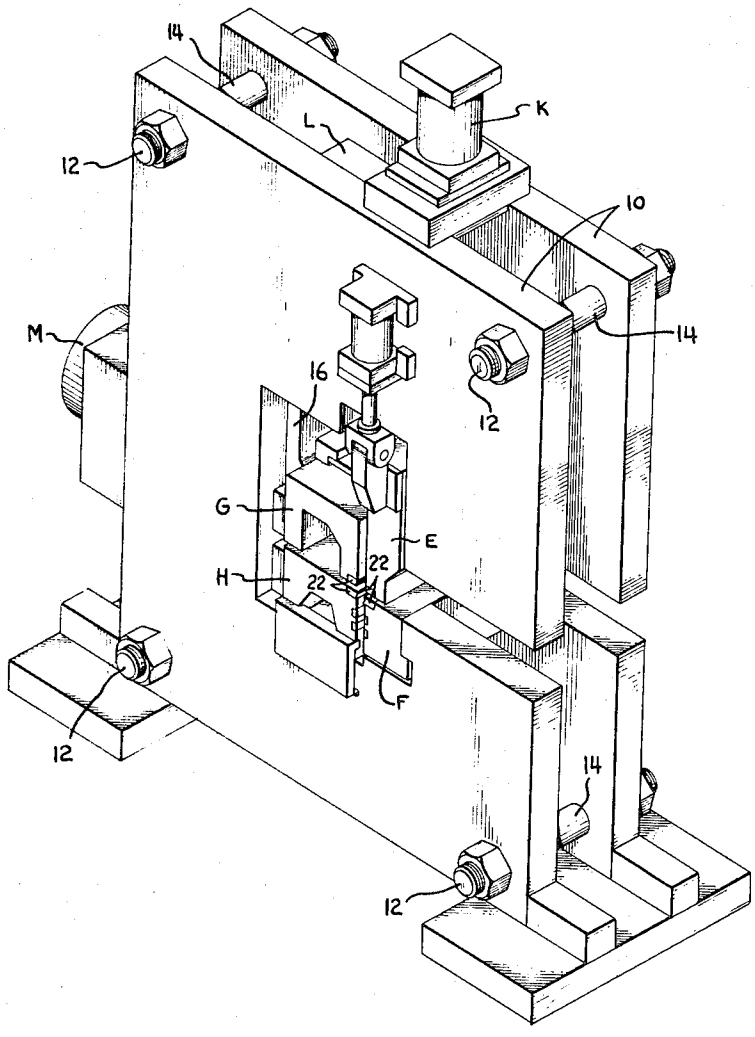
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[51] **Int. Cl.** **B23k 1/00,** B23k 37/04
[50] **Field of Search** 228/3, 3.5, 4, 5; 219/78, 101

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ABSTRACT: A heated fusion-bonding sheet metal press having a pair of stationary C-shaped metal frames arranged parallel to one another. Disposed between the two frames is a movable second C-shaped metal frame. Die holders associated with the stationary frames and movable frame are mounted for vertical movement. Heating means associated with the die holders raise the temperature of the sheet metal to below its fusion temperature.



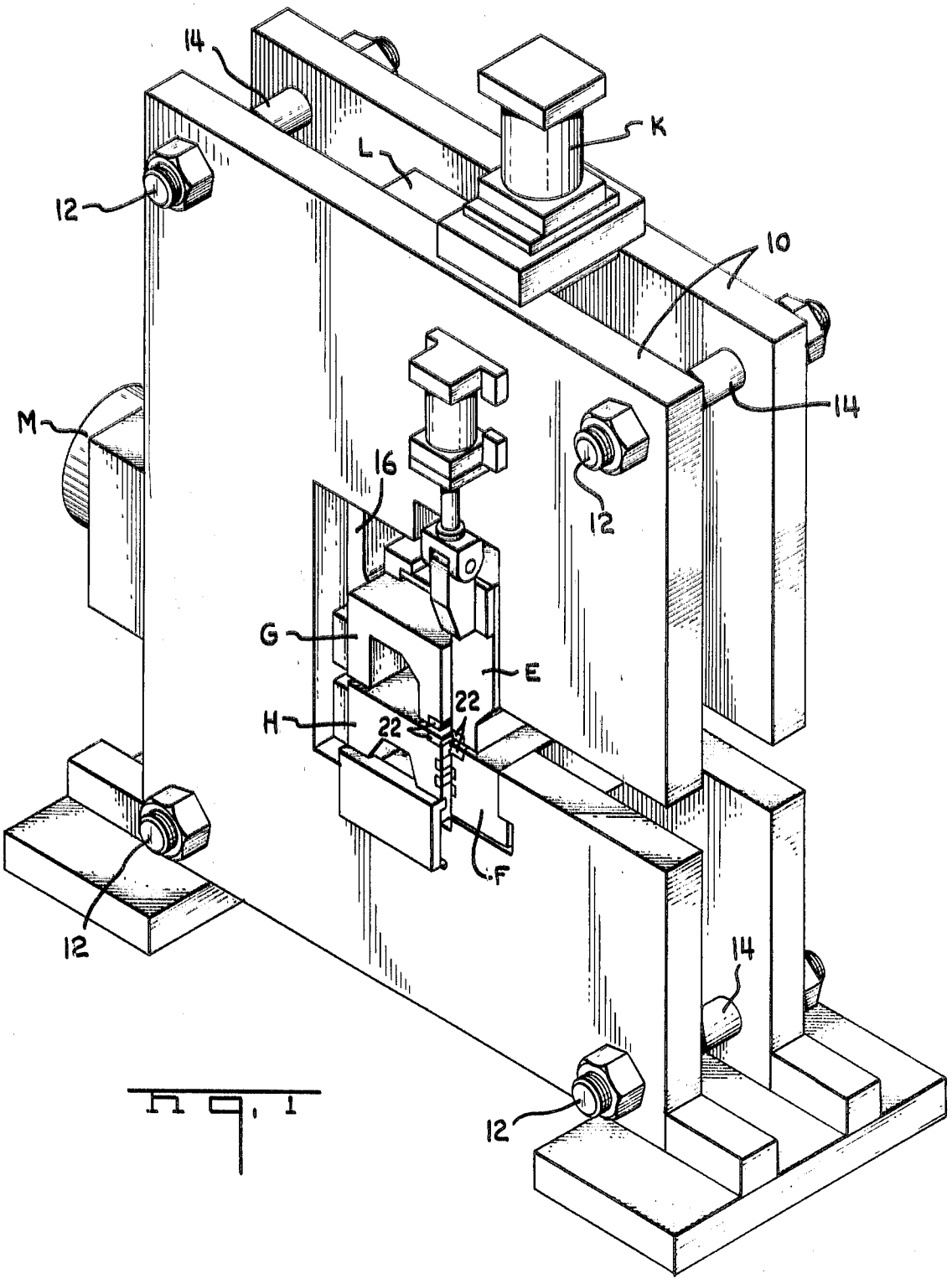
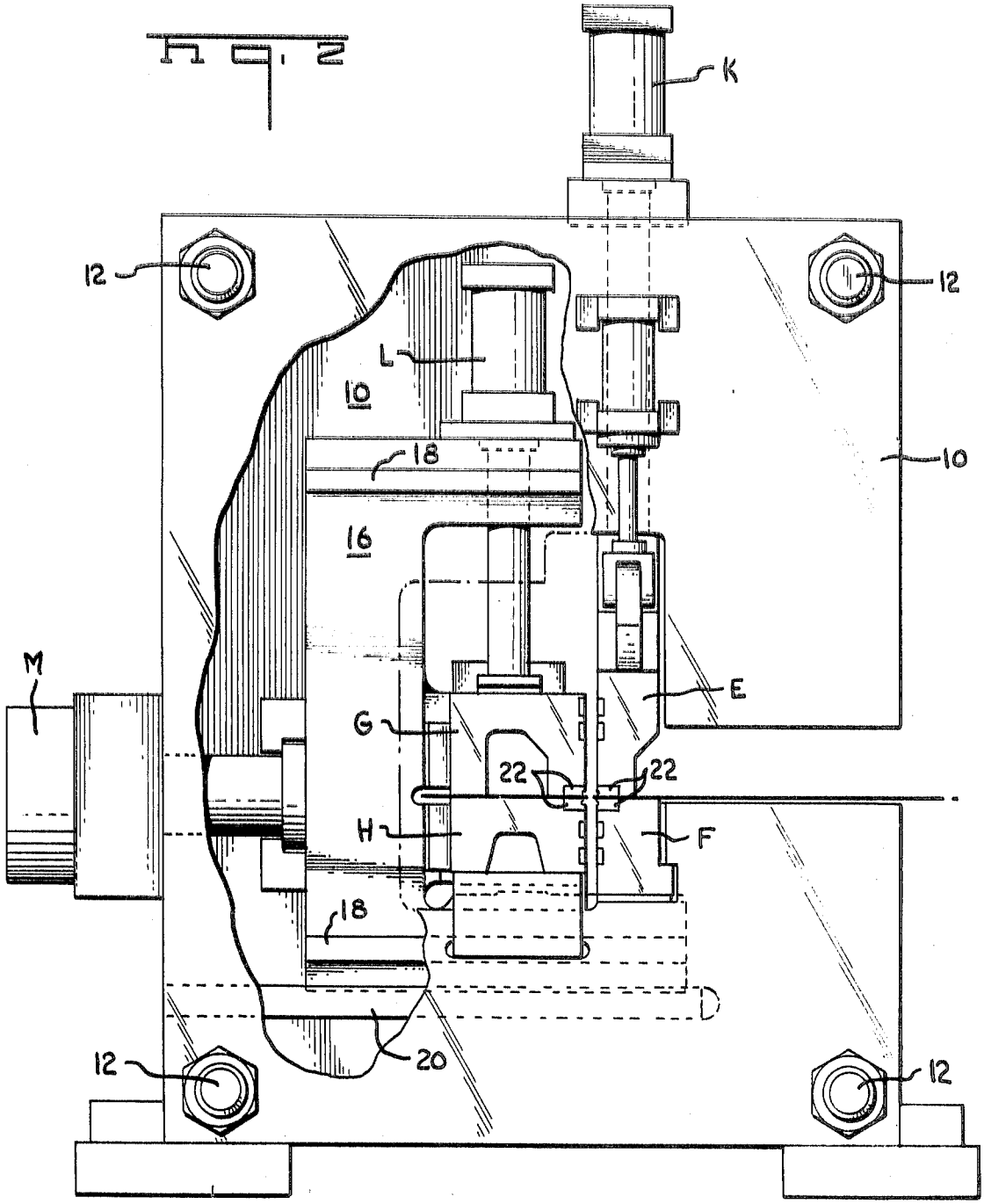
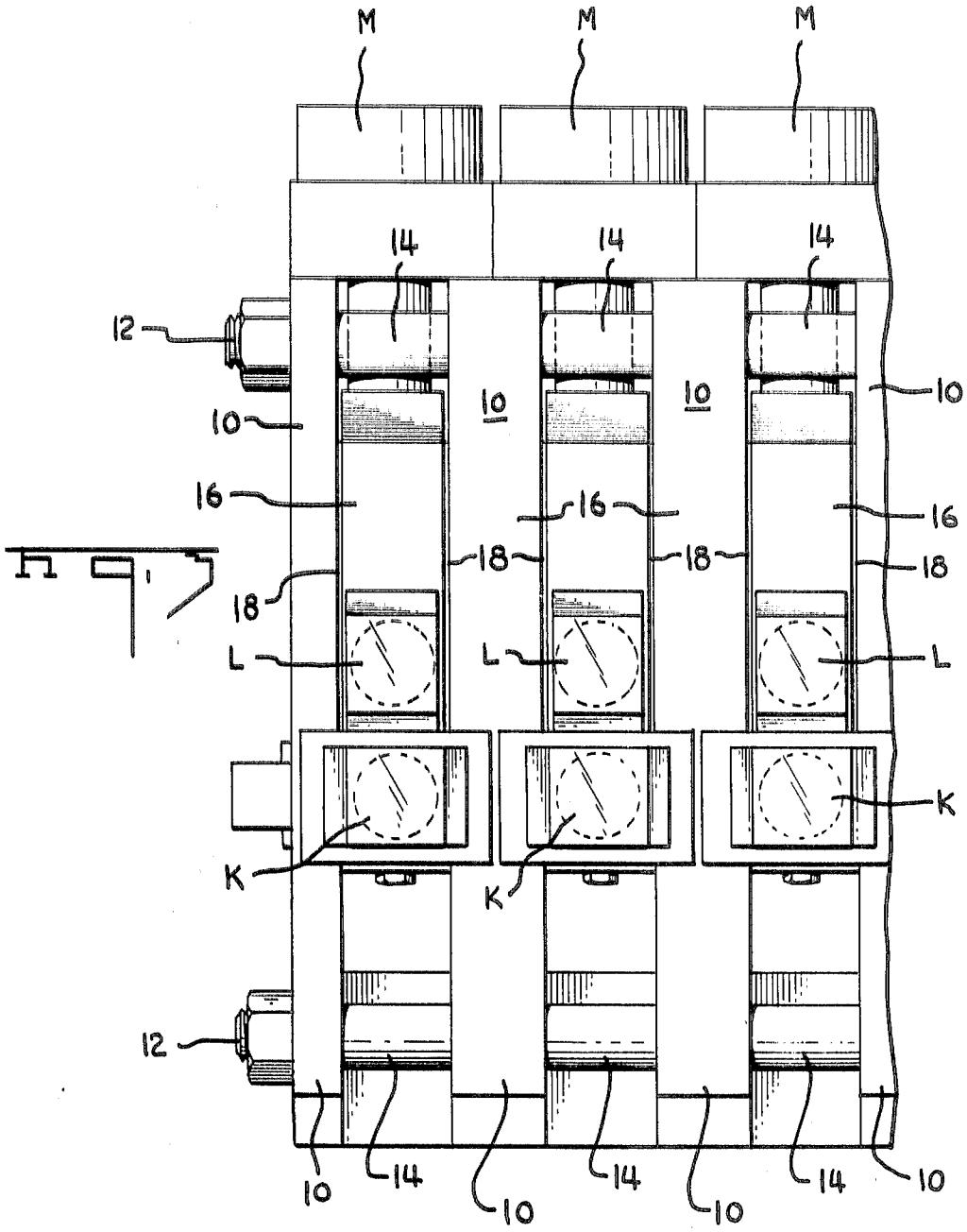


FIG. 1

FIG. 2




M
M
M
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16
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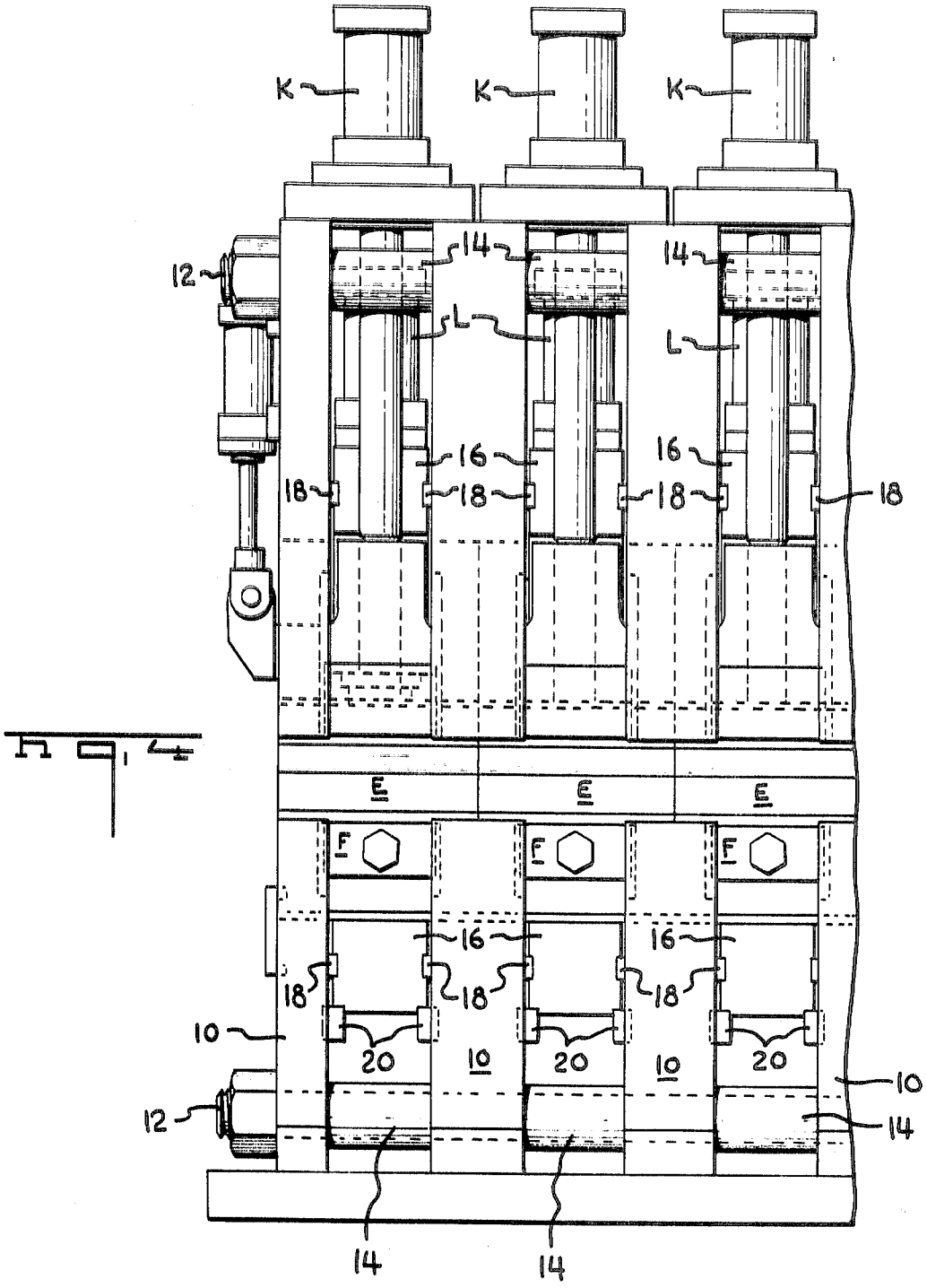

K
K
K
12
14
14
L
L
16
16
18
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18
18
E
E
E
F
F
F
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16
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FIG. 4

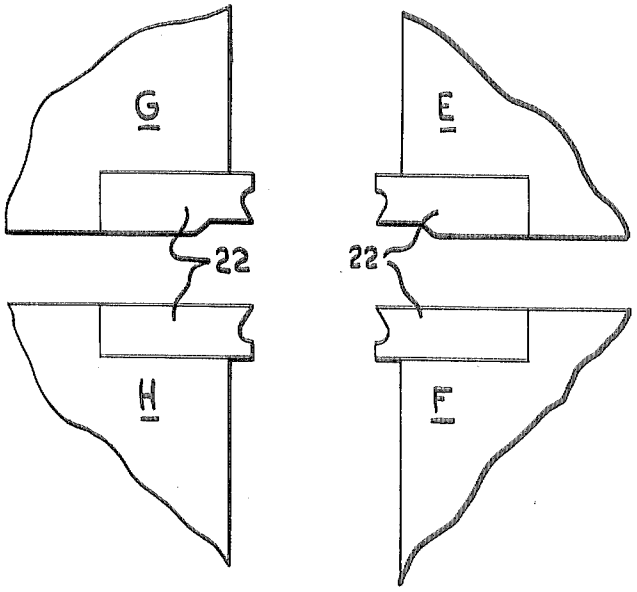


FIG. 5

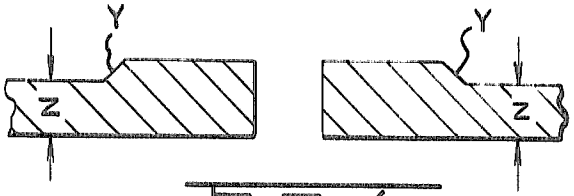


FIG. 6

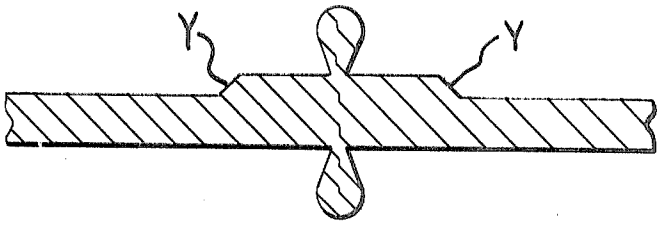


FIG. 7

SHEET METAL WELDING MACHINE

BACKGROUND

About 20 years ago a relatively simple method was developed for welding together nonferrous materials, particularly aluminum and copper. According to this method, two sections or bars of metal are made to flow together at room temperature by merely applying sufficient pressure at the juncture thereof, with no heat applied to bring about a weld. Although this method has been known and practiced for sometime, it has been limited to the softer aluminum alloys and to parts having small cross-sectional areas (usually less than 0.5 square inch of cross-sectional area).

The aforementioned rather simple cold welding process, while suitable for the softer aluminum alloys and members of small cross-sectional areas, is not suitable for higher strength aluminum and magnesium alloys or for aluminum and magnesium members having a large cross-sectional area.

Many of these high strength alloys are far too brittle, particularly those of large cross-sectional area, to permit the extreme distortion and deformation necessary for cold pressure welding. This has presented a particularly troublesome problem, not only in nonheat treatable high strength alloys, such as aluminum alloys (for example those containing 0.3 percent silicon, 0.4 percent iron, 0.1 percent copper, 0.05 percent manganese, 4.5 percent to 5.6 percent magnesium, 0.05 percent to 0.2 percent chromium, 0.1 percent zinc, remainder aluminum and especially the high strength heat treatable aluminum alloys such as those which have the standard designations 2014, 2017, 6061, 7075, 2024, 5056) and magnesium alloys (such as those containing:

1. 3.0 percent aluminum, 0.45 percent manganese, 1 percent zinc, remainder magnesium;

2. 5.7 percent zinc, 0.55 percent zirconium, remainder magnesium;)

and in alloys of similar metallurgical characteristics.

Moreover, it has been practically impossible to obtain strong ductile welds in these alloys without postweld heat treatment. Such postweld heat treatment is cumbersome and impractical, and gives rise to undue distortion of the components. Even where postweld heat treatment has been possible, difficulties have been encountered in the form of weld cracking and low ductility. This problem is particularly acute in the aircraft and allied industries where large quantities of both high strength aluminum and magnesium alloys, and also aluminum and magnesium alloys having large cross-sectional areas are utilized.

In response to these needs, a novel process for welding aluminum and magnesium alloys was developed a few years ago, and according to this process high strength aluminum and magnesium alloys and/or aluminum and magnesium alloys of large cross-sectional area may be successfully welded together by quickly heating the sections to be joined to a temperature within the range of 200° F. and 600° F., and immediately thereafter welding the heated components together under the influence of high pressures.

For certain of these alloys elevated temperatures in excess of 600° F. can also be used satisfactorily to obtain high joint strengths. For example, in the case of the magnesium base alloy containing 5.7 percent zinc and 0.55 percent zirconium, joints with 100 percent joint efficiency have been produced with heating temperatures of 650° F., and in the case of the magnesium base alloy containing 3.0 percent aluminum, 0.45 percent manganese, and 1.0 percent zinc, joint efficiencies in excess of 100 percent have been obtained by using heat temperatures of 650° F.

In this process the optimum temperature range varies from one alloy to another depending on the metallurgical characteristics of each alloy. The upper temperature limit being that temperature which during the welding time and forge cycle will not be sufficiently high to overage or partially anneal the parent metal. Although this process is applicable to any

temper of any aluminum alloy, some advantage may be expected in the case of the heat treatable alloys by welding them in the solution heat treated condition and subjecting them to an aging and stabilizing treatment after welding which has a tendency to improve the homogeneous nature of the weld and to relieve any stresses introduced during the welding operation.

A number of high strength aluminum alloys are known in the metallurgical arts, and although the teachings of this invention are believed to be applicable to all such high strength alloys, this disclosure is especially concerned with those aluminum alloys that have the following standard designations (see "Standards for Aluminum Mill Products," Eighth Edition, issued Sept., 1965 by the Aluminum Association):

2011,	2014,	2017,	2117,	2018,	2618,	2219,
2024,	2025,	3003,	5052,	5252,	5652,	5154,
5254,	5454,	5155,	5056,	5356,	5456,	5257,
5457,	5557,	5657,	5086,	6101,	6201,	6003,
6011,	6151,	6951,	6053,	6253,	6061,	6062,
6262,	6063,	6463,	6066,	7001,	7039,	7072,
7075,	7076,	7277,	7178,	2218,	7079,	5083

The disclosure of this invention is also applicable to the high strength magnesium alloys and specifically the following magnesium alloys:

a. 3.0 percent aluminum, 1.0 percent zinc, remainder magnesium (Az31B);

b. 6.5 percent aluminum, 1.0 percent zinc, remainder magnesium;

c. 5.7 percent zinc, 0.55 percent zirconium, remainder magnesium (zK60A alloy);

d. 3 percent aluminum, 0.45 percent manganese, 1.0 percent zinc, remainder magnesium.

These high strength alloys are presently of the greatest commercial interest.

There are three main requisites for this improved process. These are as follows:

1. A clean surface must be prepared which is as free of oxide and absorbed gases, films, and foreign particles as possible.

2. The ends to be butt welded must be heated sufficiently to permit the required plastic flow to occur in the welding operation. The surface condition must not be altered during the heating since this would prevent a good weld from being formed. Heating must be controlled below overaging recrystallization and annealing temperatures.

3. Sufficient upset must be obtained to permit a bond to be formed between the two members. Upset must be sufficient to allow an increase of interface area of two to four times that of the original mating surfaces. This stretching of the cleaned interfaces is an essential and critical factor for successful welding.

It is essential that the surface condition of the area to be welded be carefully cleaned prior to welding by either machining and/or physical means. The use of files, wire brushes, dry machining, etc., have been found satisfactory. Unless such cleaning treatments are employed, there is a considerable risk that a faulty weld will result because of the presence of deleterious oxides, grease, adsorbed films, moisture, or other objectionable foreign matter.

One of the novel aspects and requirements of this method is the amount of upset required. Specifically, it is not the amount of material that is upset, but an adequate increase in the area of the mating interface which is required. The initial area of the interface is defined as the cross-sectional area of the pieces to be butt welded. The final area of the interface is defined as the area of the total interface (or weld) after upset has taken place.

In order to obtain a strong weld, the final area of the interface must be at least two to four times the initial area. Larger

values can be used, but the additional upset is unnecessary and is wasteful of material.

The temperature of between 200° F. and 600° F. must be carefully controlled as to time, since if high strength alloys are heated for too long a time at these temperatures an undesirable decrease in the strength of the alloy occurs. The exact time during which welded sections can be heated within the specified temperature range, of course, depends upon the original strength and temper of the alloy and the amount of loss in strength which can be tolerated. When heating temperatures of about 500° F. are employed, it is generally preferable to maintain this temperature for less than a minute, although longer times are permissible under certain circumstances. Since the optimum time, the optimum temperature, and the optimum amount of upset for a given cross section are interdependent rather than independent factors, it will be appreciated by those skilled in the art that the optimum combination of conditions in order to obtain the best possible product will sometimes require a limited amount of experimentation within the range of temperatures, times, amount of upset, and pressure herein specified.

FIELD OF THE INVENTION

Basically the present invention involves a device for carrying out the above-described improved process and our device mainly encompasses means for two flat aluminum plates between sets of dies, means for raising the plates to a predetermined temperature and then means for forcing the longitudinal edges of the plates together with sufficient pressure so that the resultant "upset" of the material will cause a weld between the two pieces without melting or heating to a degree that would seriously reduce the properties of the material. By welding consecutive pieces together it is possible to form a continuous sheet of metal material of any desired length. The width is limited only by the economics of machine cost. Not only can flat material be produced but the plates being put together may have stiffening ribs or any other desired contour that may be required for a particular application.

THE DRAWINGS

The present invention will be better understood by reference to the attached drawings wherein:

FIG. **1** is an isometric view of a single module comprising three sections in accordance with this invention;

FIG. **2** is an end view of the module shown in FIG. **1**;

FIG. **3** is a fragmentary plan view of a multiple module unit in accordance with this invention;

FIG. **4** is a fragmentary front view of a multiple module unit in accordance with this invention;

FIG. **5** is an enlarged fragmentary view of the die holders in accordance with this invention;

FIG. **6** and FIG. **7** are enlarged fragmentary views showing metal sections before and after being worked on by the machine of this invention.

Referring now to the drawings, it will be seen that the press in accordance with this invention consists of a plurality of stationary C-frames **10** that are arranged parallel to each other in a spaced-apart manner. These stationary frames **10** are supported and held in position by large bolts **12** that pass through spacers **14**. The spacers **14** serve to align all of the stationary frames **10** and to hold them an equal distance apart.

Between each pair of stationary frames **10** there is mounted a movable C-frame **16**. Between the stationary frames **10** and the moving frame **16** are interposed bronze sliding surfaces **18** to facilitate movement of the movable frame **16**. The stationary frames **10** are also provided with supports **20** upon which the moving frames **16** may slide.

This arrangement of the interconnected stationary frames **10** results in a modular type of machine which may be made any desired length by simply bolting together the desired number of stationary frames **10** and movable frames **16**.

Into the above-described assembly are inserted four die holders. Two of the die holders, E, and F, are mounted one above the other and are attached to the stationary frames **10**. The other two die holders G and H are mounted one above the other and are attached to each movable frame **16**. The upper die holders G and E are movable in a vertical direction by means of hydraulic cylinders L and K respectively. Die holders G and H are mounted so that they move with the movable frame **16** in a lateral direction when the hydraulic cylinder M, which is a high-pressure forging cylinder, moves the movable frame **16**. Die holder F is stationary.

The cylinders K that move the upper die holder E are mounted on or between stationary frames **10**. The cylinders L that move the top die holder G are each preferably mounted on the upper portion of the movable C-frame **16**.

The purpose of the moving two top die holders G and E is to clamp the material to be worked upon when the dies are down so that the material will not slip when the lateral forge-welding operation occurs. When the dies are in the "up" position the material to be worked upon can be freely moved into and out of the machine.

There is preferably one high-pressure forging cylinder M for each movable frame **16**. These cylinders M are mounted on the stationary frames **10** and all of the cylinders M work in unison so as to act on the movable frames **16** and move the die holders G and H in the direction of dies E and F, thus causing the pieces of metal to be welded to come into contact. Contact pressure is applied to cause "upset" of the material which will be forged welded together.

Stated in another way, one piece of material which is to be welded is clamped between the die holders G and H. The other piece of material to be welded is clamped between die holders E and F. At this point in the operation the two sets of die holders are separated rather far apart in a lateral direction. Heat is now applied to the two pieces of material that are in the dies. The heat may be applied in any desired manner. For instance, one means of heating is to employ resistance-heating elements in the die. As soon as the material has attained the desired temperature, cylinders M are activated, which moves the movable frames **16**. This in turn causes die holders G and H to move toward die holders E and F. The four die holders have of course previously been arranged in the machine so that they clamp the material to be welded in perfect alignment. As the dies G and H move laterally they bring the edges of the material to be welded together. The welding takes place when sufficient upsetting has been performed on the material to be welded.

A multiplicity of forging die shapes **22** can be either machined into or attached to die holders E, F, G and H. Specific die shapes **22** are shown in FIG. **5**. A weld made with such a die on two pieces of material (such as the pieces shown in FIG. **6**) might have the final appearance indicated in FIG. **7**. This arrangement of the dies causes the flash material resulting from the upsetting that occurs during the welding process to be at the minimum. This of course means a minimum amount of scrap in the process. Furthermore, the arrangement permits the removal of the scrap to be easily carried out either manually or by automatic machines.

Some advantage in machine design and an extra margin of safety in the joint areas can be obtained by using thicker metal sections in the weld area as illustrated in FIG. **7**. Other variations of this configuration have also proven desirable in machine design and operation.

Our machine is ideally suited for the fabrication of a wide range of nonferrous metal products and is particularly well suited to those alloys recited earlier, wherein previously it has been impossible to obtain high joint strengths in large cross-sectional areas of materials to be joined. For example, our machine is ideally suited for the fabrication of large panels for aircraft and transportation applications. Utilizing the advantages of our machine it is now possible to fabricate large panels by starting with a plurality of small extruded panels **10** and joining them together to form one continuous panel with

properties at the joint interface equivalent to those of the parent material and in a wide range of high strength alloys. Using a similar type of joint design, longitudinal seam welds and welds of headers can be made for a range of chemical tank applications which were previously difficult or impossible in the high strength alloys mentioned above.

Another specific application of this invention is the production of high strength, lightweight, weldable aluminum armor plate. In the past it has been difficult or impossible for military applications to utilize the highest strength and consequently most desirable aluminum alloys for armor plate applications, because it has been impossible to arc weld these alloys in the fabrication process and field repair. Consequently substantial portions of armor plate used of aluminum in recent years has consisted of alloys such as 5083, 7039, and 5454, which are in a medium strength range with ultimate tensile strength of the order of 40,000 to 50,000 pounds per square inch, and which have fairly good ballistic characteristics, and also have excellent arc welding capabilities. It would, however, be much more desirable to utilize higher strength aluminum alloys such as 2024, 7075–T6, 7186–T6, etc. By utilizing the machine of the present invention a plurality of small panels could be fitted together in side-by-side relationship to form an armor plate section of a vehicle. These small panels would be cut from high strength armor plate aluminum alloys (e.g. #7178T6) which have the best ballistic characteristics which are non-weldable by normal techniques. Then, by using the machine of the present invention such high strength panels (such as 7186—T6) could be forge welded to strips of more weldable alloys (such as 7005 or 7039—T6 or any other weldable alloy such as 5083 or 5086). After this forge-welding operation is completed, then the unit will consist of the main body comprising 7079–T6 alloy with a narrow strip **22** of arc-weldable alloy approximately 1 to 2 inches in width around the edge which then makes the plate easy to field fabricate and arc weld in the final assembly of the vehicle. Thus for the major portion of the armored vehicle the maximum protection is obtained for ballistic characteristics and yet the unit itself also possesses good weldability at the edge areas where joints are needed and good, although not the very best ballistic characteristics are likewise obtained at the joint areas.

In cases where it appears desirable to utilize a composite sheet material for armor plate to give the best ballistic characteristics with regard to penetration and shattering of the material upon impact, by utilizing the machine of this invention it is possible to lay several sheets together to form a composite as required before actually forge welding the weldable strip about the outer edge. In this manner sandwiched panels of different materials and alloys can readily be prepared and made into a homogenous structure by the forge welded ring around the outside of the part.

If it were desirable to obtain equivalent ballistic characteristics at the joint areas to the main plate then the portion which is forge welded to the plate proper can be made of greater thickness to compensate for the ballistic properties of the weldable strips. In this manner, armored vehicles can be built, either of the same weight as at the present time but with improved ballistic properties or lighter weight equipment can be fabricated with the same ballistic characteristics resulting in higher speed and longer range equipment.

The present invention is also particularly suited for the fabrication of structurally reinforced panels. There have been a number of commercial and industrial applications where it has been desirable to obtain extruded shapes and structural panels of greater width than is possible in existing extrusion presses. For example, using even the largest aluminum extrusion presses in existence today, the maximum width which can be obtained in an extruded panel is somewhat less than 30 inches and in most cases does not exceed 24 inches in width. Thus, for example, in the fabrication of wing panels for aircraft, floor decking for transportation equipment, building panels and like products, the design and use of these products is limited to the size of extrusions which can be produced. As a result, for example, in the aircraft industry, it has been necessary to take large area plates of aluminum 3 or 4 inches in thickness or greater and approximately 7 to 8 feet in width and machine out of this plate a structurally reinforced section which would end up with a thickness of the plate material of the order of three-fourths inch and integral with this plate stiffening members in the form of tees or angles which give the plate the necessary rigidity strength and structural properties.

By utilizing the machine of the present invention it is possible to make such panels of even greater width than those already manufactured from plate and also eliminate the machining operation by starting with extruded panels in the high strength alloys required, such as 7075–T6, 2014, or 2024 alloys. These standard extrusion panels need only be approximately 1 foot in width from a standard extrusion press, consequently, not limiting itself to the capacity of the maximum large extrusion presses of which there are only a few available. These extruded planks can then be forge welded together by using the machine of this invention to produce a panel which is essentially as good as the one-piece panel fabricated and machined at great expense from a large plate. Since the weld properties are similar to those of the parent material and since there is substantially no limitation to the width of plate which can be made in this manner, this allows a capability of producing large aluminum structurally integral stiffened panels, for architectural applications, transportation equipment applications, and military applications which are not possible by any other process and yet possess the inherent properties of a unit panel sculptured out of plate. For example, applications of this method of manufacturing panels can be utilized for fabricating sections of dump trailer side panels and floor sheets, van trailer floor sheets of high strength alloys which will be light in weight and of the highest strength alloys, wing panels for aircraft, skin sections for missiles and floor panels for architectural and structural applications.

The present invention is also quite useful in connection with fabricating aluminum or magnesium stock of extreme width and in a wide variety of high strength alloys. The present method of manufacturing aluminum plate and sheet limits the size of the sheet which can be made to the width of the largest rolling mill, which is approximately 110 inches in width. In applications where plates of greater width than this is required, particularly in a high strength alloy, it has not been possible to produce them on existing plant equipment. However, by utilizing the machine of the present invention, several plates can be taken and forge welded together in such a manner as to produce properties at the joint area which are equivalent in practically all respects to the properties of the parent material and as a result of this invention makes it possible to produce and market plate products which are considerably wider than is presently possible with existing equipment. Applications of this type are particularly valuable in the aerospace industry as well as for other commercial applications.

Such large plate sections have also been limited to the maximum billet size available to the rolling mill and here again this can be extended to substantially larger sizes both of length and width by utilizing the instant machine and still maintain the excellent properties and characteristics of the parent material in the joint areas. Furthermore, such large plate sections need not start from rolled plate but might also be fabricated from extruded sections as indicated above and possibly on a more economical basis, depending somewhat upon the gage and width.

The teachings of this invention, while being particularly applicable to high strength aluminum and magnesium alloys and aluminum and magnesium alloys of large cross-sectional area, are also equally applicable to certain other alloys, and particularly to the alloys of titanium, zirconium, beryllium, and certain alloy steels.

While we have described what we consider to be the most advantageous embodiments of this invention, it is evident that various modifications can be made in the specific procedures set forth without departing from the purview of this invention.

What we claim is:

1. A press for joining two sections of metal comprising:

a. at least one pair of stationary C-shaped metal plate frames,

b. the members of each pair of stationary C-shaped metal plate frames being arranged parallel to each other in a spaced-apart manner,

c. a laterally movable C-shaped metal frame mounted between each pair of stationary C-shaped metal plate frames,

d. a first pair of die holders associated with each pair of stationary C-shaped metal plate frames, said die holders being mounted for movement in a vertical direction,

e. a second pair of die holders associated with said laterally movable C-shaped metal frame, said die holders being mounted for movement in a vertical direction,

f. said die holders being associated with means to heat the material being worked onto a maximum temperature below the fusion temperature of the metal sections to be joined.

2. A press according to claim 1 wherein said stationary C-shaped metal plate frames are spaced apart with bolts and spacers.

3. A press according to claim 1 wherein a surface is positioned immediately below each laterally movable C-shaped metal frame which surface connects said stationary C-shaped metal plate frame so that the movable C-shaped metal frame can slide laterally in relation to said stationary C-shaped metal plate.

4. A press according to claim 1 wherein there are a plurality of pairs of stationary C-frames arranged in a parallel side-by-side relationship.