June 23, 1970 S. L. GRAHAM ET AL 3,516,274

METHOD AND DEVICE FOR SHAPING METAL

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FIG. 1

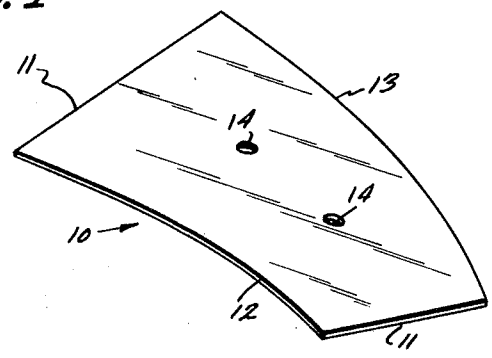


FIG. 2

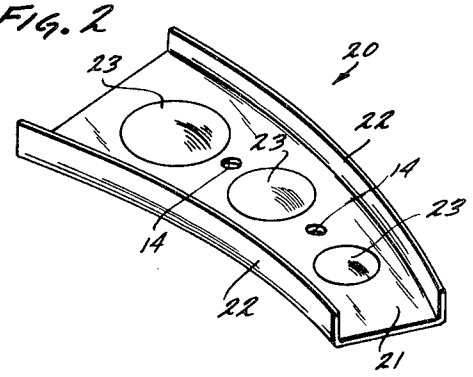


FIG. 4

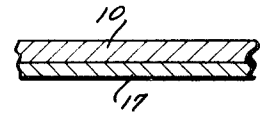
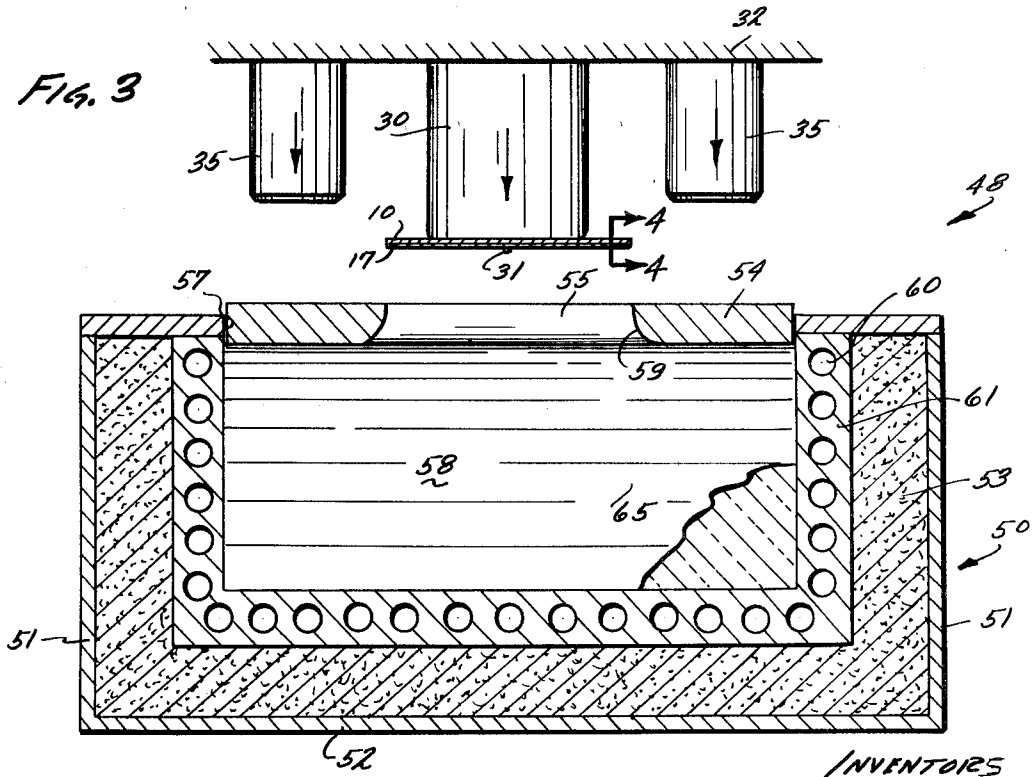


FIG. 3



INVENTORS
STANLEY LEWIS GRAHAM
MARVIN ROSENBERG
GILBERT EDWARD LEVASSEUR, SR.
WILLBURN LEWIS JONES
JEM YIN LEW
JOHN VAN HOESEN CHALLISS
BY Morgan, Walsh & Blackham
ATTORNEYS

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FIG. 5

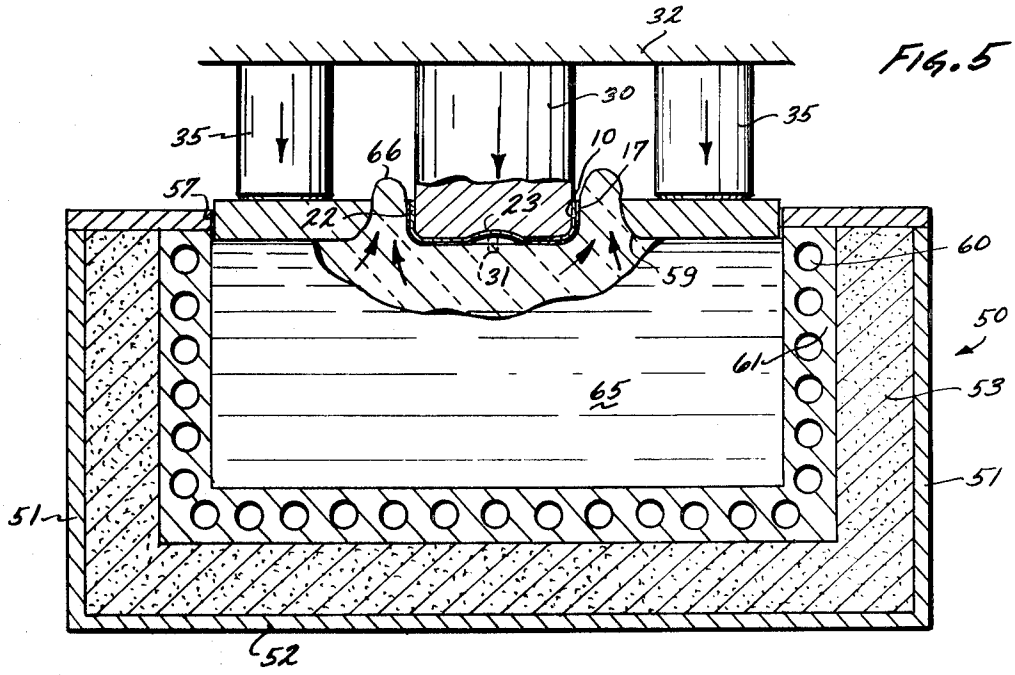
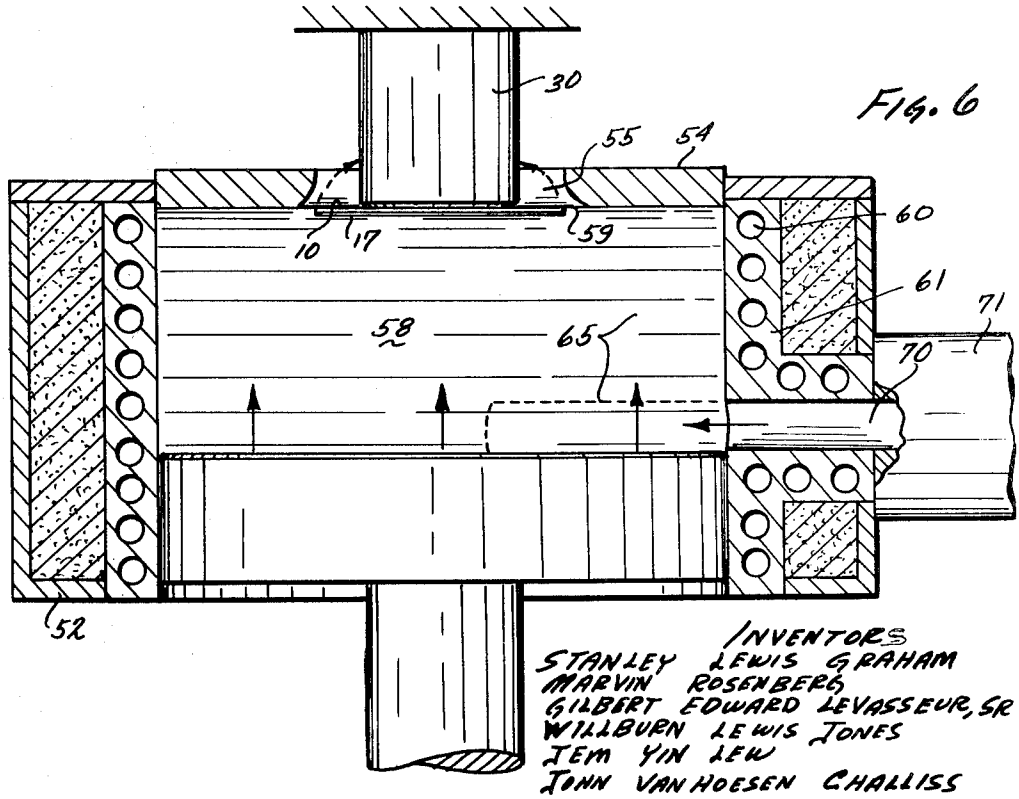


FIG. 6



INVENTORS
STANLEY LEWIS GRAHAM
MARVIN ROSENBERG
GILBERT EDWARD LEVASSEUR, SR
WILLBURN LEWIS JONES
JEM YIN LEW
JOHN VAN HOESEN CHALLISS

BY Darby, Walker & Blackburn
ATTORNEYS

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3,516,274

METHOD AND DEVICE FOR SHAPING METAL

Stanley Lewis Graham, 4530 W. 134th St., Hawthorne, Calif.; Marvin Rosenberg, 1540 9th St., Manhattan Beach, Calif.; Gilbert Edward Le Vasseur, Sr., 8924 Earhart Ave., Los Angeles, Calif.; Willburn Lewis Jones, 1830 W. El Segundo, Apt. 1, Gardena, Calif.; and Jem Yin Lew, 523 W. 120th St.; and John Van Hoesen Challiss, 323 S. Irving Blvd., both of Los Angeles, Calif.

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U.S. Cl. 72—57 15 Claims

ABSTRACT OF THE DISCLOSURE

Metal workpieces, such as titanium alloys, are formed at elevated temperatures by pressing the workpiece between a bed of semi-molten glass and a die. Such forming apparatus may have a container to house semi-molten glass, means for heating the glass, a die disposed above the container, and means for die pressing the metal into flowing contact with the glass.

BACKGROUND OF THE INVENTION

Present-day industry, especially the aircraft and space industries, has found an ever-increasing number of applications for new and exotic metal alloys. When such an alloy is subjected to forming operations at the proper elevated temperatures, internal stresses are substantially eliminated, yet the strength of the material is substantially retained. Engineering requirements typically call for elevated temperature-forming of exotic metals, such as titanium, at a range of temperatures, herein called the preferred forming temperature. Further, the forming operation or series of forming operations must be accomplished within a specified accumulated duration of time at the forming temperature. For example, solution treated titanium alloy 6Al–4V, comprising 90 parts titanium, 6 parts aluminum, and 4 parts vanadium, may be formed at 1200° F. for a period of time not to exceed 7 minutes at the designated temperature, or may be formed at 1100° F. for a period of time not to exceed 18 minutes at temperature. The values are merely representative and do not necessarily indicate the end limitations of the temperature-time curve for preferred forming. An acceptable finished product may be obtained by relatively short accumulated periods of heating at higher temperatures, or longer accumulated periods of heating at lower temperatures. Failure to remain within the periods of time, or by exceeding or failing to reach the prescribed temperature, results in unacceptable products.

Molten glass has been used as a lubricant in the extrusion of titanium. In forming sheet metal, it is well known to provide a counterdie having yieldingly deformable material which provides a bed upon which the workpiece rests and which distributes uniform pressure throughout the workpiece, as evidence by Galligan, 3,056,356; Palmer, 672,081; Walton, 2,317,868; Cannon, 385,905; and Swift, 383,081. None of these methods or structures has been particularly useful in forming the newer, high-temperature metals because, although exotic rubbers have been developed which are capable of withstanding surprisingly high temperatures, none of them has proven capable to date of forming metals at temperatures above several hundred degrees Fahrenheit.

When the application calls for relatively small gauge metal and relatively moderate curvatures, the metal may be formed at temperatures below the preferred forming temperature followed by heat treatment to relieve internal stresses according to well-known stress relief methods. When heavier gauged metals are used, or the shape desired has complex curvatures, the properties of the exotic metal, such as brittleness, prohibit full-forming operations at temperatures less than the preferred forming temperature. It is common practice to use a multiple-step process comprising partially forming the workpiece at relatively low temperatures followed by forcibly placing the partially formed workpiece between male and female die members which is then heated to the preferred forming temperature which will allow the workpiece to assume the configuration defined by the die members. Thereafter, the workpiece will usually be stress relieved at an elevated temperature for a designated minimum time period. The foregoing use of mating dies and application of heat is sometimes referred to as a hot-size press. Depending upon the metal used and the configuration desired, several incremental forming and hot-sizing operations may have to be performed. It is necessary to carry out the entire forming operation and obtain the final configuration within a predetermined accumulated time at forming temperature in order to obtain an acceptable product.

As described above, the presently used forming process for exotic metals requires mating male and female die members and associated heating equipment. The workpiece must be inserted and clamped between the die members followed by heating at an elevated temperature. Oftentimes it is necessary to repeat the forming and heating steps several times to obtain the final configuration. As used in the aircraft industry, the metal forming equipment must be very large to accommodate the workpiece being formed and much labor and time is expanded in carrying out each cycle of the forming and hot-sizing process. A further disadvantage of the above-described process arises due to the use of mating die parts which must be carefully aligned each time a part of differing configuration is to be produced. Still another disadvantage is the high cost of providing a metal counterdie shaped to the configuration of the desired part.

SUMMARY OF THE INVENTION

Therefore, it is a primary object of the present invention to provide a new and useful method and means for forming metal, particularly at high temperatures.

Another object of the present invention is to provide a means and method for forming metal which includes the use of a composition of glass in a viscous state as a counterdie.

A further object of the present invention is to provide a method and means for forming exotic metals, such as titanium and its alloys, in a single and continuous forming step in an environmental temperature which will relieve the exotic metal of internal stresses.

Still another object of the present invention is to provide a method and means for forming exotic metals adaptable to high production outputs of the article produced with relatively low tooling and labor uost.

According to the present invention, a new and useful method for forming metal utilizes a glass composition heated to a temperature greater than its softening point temperature, but less than its working point temperature and substantially equal to the predetermined forming temperature of the metal workpiece. When so heated, the viscosity of glass is such that the glass will be sufficiently viscous to support the metal workpiece, yet, under the influence of high pressure, it will flow as would a viscous liquid. The glass composition and metal workpiece are forced into flowing, yielding contact so as to cause the workpiece to deform into a desired configuration. Also, according to the present invention, a new and useful

means is provided for forming metal which includes a male die member, means for mounting the workpiece, a composition of glass in a viscous state, and means for forcing the workpiece and composition of glass into operative association with each other. Heating means are mounted with respect to the glass composition and the metal workpiece so as to maintain the glass and the metal workpiece at a temperature substantially equal to the forming temperature of the metal workpiece throughout the forming operation.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawings in which like reference characters refer to like elements in the several views.

IN THE DRAWINGS

FIG. 1 is a perspective view of a metal workpiece;

FIG. 2 is a perspective view of a metal workpiece which has been formed to a predetermined desired configuration;

FIG. 3 is a front elevational view in cross-section to show the construction of a container for confining a viscous glass composition and the relationship thereto of a male die member and metal workpiece prior to the initiation of the forming process;

FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 3 to show the relationship of the metal workpiece and a separating agent;

FIG. 5 is similar to FIG. 3 except that it shows the operative relationship of the metal workpiece and the viscous glass solution at the completion of the forming process; and

FIG. 6 shows an alternative embodiment of the invention wherein a piston for imparting compressive forces forms the bottom wall of the viscous glass container and it shows the operative relationship of the male die member and the metal workpiece with the viscous glass composition at a time immediately prior to the initial deformation of the metal workpiece.

Referring again to the drawings, in FIG. 1, a metal workpiece, generally designated **10**, is formed from a flat sheet stock and is pre-cut to give the desired dimensions after the forming process. The workpiece **10**, as shown, has been pre-cut with straight end edges **11**, side edge **12** having a complex curvature X, and side edge **13** having a complex curvature Y. Additionally, holes **14** are formed in workpiece **10** to facilitate the mounting of workpiece **10** onto a male die member.

FIG. 2 is illustrative of an article having a desired configuration produced by the process of the present invention as described below. As shown, the article of production, generally desginated **20**, has been formed having a flat base wall **21**, appending flanges **22**, and convex impressions **23** formed in the base wall **21**.

Referring to FIG. 3, the improvement in dies for shaping metal constituting a presently preferred embodiment of the invention, generally designated **48**, includes a male die member **30**, push rods **35**, a counterdie member **50**, and a viscous glass composition **65**, said embodiment being adapted to force the glass composition **65** and the metal workpiece **10** into yielding, flowing engagement.

DESCRIPTION OF PREFERRED EMBODIMENT

The counterdie member **50** includes a bottom wall **52**, upstanding side walls **51**, insulating material **53**, and heating elements **60** capable of heating the glass composition **65**, which fills the reservoir **58** defined by walls **51**, **52**, at a rate which will maintain the glass composition **65** in a viscous state. Top wall member **54** forms the upper wall of counterdie **50** and is slidably engageable

with the reservoir **58**. The gap **57** between the side walls **51** and top wall **54** is sufficiently small, or non-existent, to prevent undue extrusion or escape of glass composition **65** therethrough when said glass composition is subjected to working pressures which may be in the magnitude of 100,000 p.s.i.

Top wall member **54** receives the workpiece **10** through the opening defined by peripheral inner edge **55**. The opening corresponds to the dimensions of workpiece **10**, and, prior to forming of workpiece **10**, provides a gap **59** between the workpiece **10** and top wall **54** which substantially prohibits the flow of the viscous glass composition **65** therethrough. It is necessary to limit the flow only at pressures less than the yield pressure of the metai of workpiece **10**. It has been found in the practice of the invention that a gap of about .010 inch with typical titanium alloys and glass composition will provide easy working without an undesirable degree of glass loss.

The process of the invention may be practiced as follows: A workpiece **10** is mounted on male die member **30** by any suitable type of fastening means **31**, such as a pin inserted through hole **14** in the workpiece **10** and threadably engaging die member **30**. Reservoir **58** of counterdie **50** is then filled with a glass composition **65** of known properties which is heated to and maintained in a viscous state.

It is well known in the art that glass has no regular internal structure at relatively low temperature and that as its temperature increases, the viscosity decreases, and the glass eventually assumes the characteristics of a liquid. Glasses of different compositions have differing curves of decreasing viscosity with increasing temperature. A glass composition may be selected which will have desirable flow characteristics when heated to a temperature substantially equal to the forming temperature of the metal alloy of the workpiece **10**. The properties of glass are available in standard textbooks and various commercial publications, such as the Corning Glass Works Bulletin B–83, 1963. Commercially-produced glasses are available which have the same viscosity characteristics, for forming metals in accordance with the inventive process, in incremental steps of 25° F. throughout the range of 750° F. to 2500° F. Other glasses may be obtained with the desired characteristics at temperatures well in excess of 2500° F. In the practice of the invention by applicants' assignee, it has been observed that some contamination of the glass may occur in the normal manufacturing environment. This may cause some elevation in the viscosity-temperature curve of the glass. It is believed that a like change in the viscosity-temperature curve may be caused by repeated reheating of some glass compositions.

After the glass composition **65** is heated, the workpiece **10** is moved into engagement with the surface of glass composition **65** whereupon workpiece **10** will be heated to a temperature sufficient to relieve stresses therein created by deformation of the workpiece **10**. Prior to deformation of workpiece **10**, gap **59** is sufficiently small so as to limit the escape of glass composition **65** therethrough when glass composition **65** is subjected to pressure equal to less than the yield pressure of the workpiece **10**. Due to the flowing of the glass composition under pressure, equal pressure is exerted to all portions of workpiece **10**.

An increase in pressure within glass composition **65** will cause workpiece **10** to deform and permit a flow of glass **66** (FIG. 5) to escape through gap **59**. As will be appreciated by one skilled in the art, the degree and character of the forming of workpiece **10** will be a function of the shape of the male die member **30**, the magnitude of the pressure imparted to the workpiece **10**, the rate of flow of glass composition **65** through gap **59**, and the resilient properties of workpiece **10**. With sufficient control of the rate and direction of flow of glass composition **65**, the forming of workpiece **10** may

be accomplished with no, or very little, influence from the shape of male die member **30**.

It will be apparent that as glass composition **65** extrudes through gap **59**, the glass extrusions **66** will be rapidly cooled, become brittle, and will easily break off. Portions of workpiece **10** subject to contact with the cooled extrusions **66** may have glass adhering thereto. Further, when workpiece **10** is removed from counterdie **50** following the forming process, glass may adhere to exposed surfaces of workpiece **10**. Depending upon the material of workpiece **10**, such direct contact with either the molten glass or cooled glass may cause the parent material of workpiece **10** to become contaminated with the constituents of glass composition **65**. Current investigations of parting agents indicate that there are many potentially suitable, commercially available parting agents. In the practice of the invention, fairly satisfactory results have been obtained by use of a thin sheet of copper **17**. The parting agent **17** is shown affixed to the surface of workpiece **10** which is exposed to engagement with the glass composition **65**, thereby limiting contamination of the parent material of the workpiece. As the workpiece deforms, the sheet **17** deforms and flows with it. Care must be exercised to avoid undue thinning of the parting agent **17**, which can lead to a break in it, exposing the workpiece **10** to the glass **65**. Such contamination may be detrimental to some applications, such as certain uses of titanium alloys for aircraft or missile parts.

To initiate the forming process, male die member **30** and workpiece **10** mounted thereon, are moved downwardly toward counterdie **50**, thereby spatially disposing workpiece **10** and its associated parting agent **17** into contact engagement with viscous glass composition **65**. Simultaneously, push rods **35** are brought into contact with the upper surface of top wall member **54**. Arrows, FIG. 6, indicate the desired direction of deformation to be imparted to workpiece **10** which will result in the desired configuration of the article of production **20**.

Further downward movement of male die member **30** and of push rods **35** will impart an equal distance of downward movement to workpiece **10** and to top wall member **54**, thereby creating a uniform build-up of pressure in the viscous glass composition **65**. A corresponding uniform pressure is exerted over the entire surface of workpiece **10**. In the practice of the invention, it has been found that glass compositions having greater than an ideal viscosity may be used if movement of male die member **30** leads that of push rods **35** which allows gap **59** to increase and initiate the flow of glass composition **65** therethrough.

In FIG. 5, the male die member **30** and the counterdie member **50** are shown spatially disposed at the point when the pressure within the glass composition **65** has sufficiently exceeded the yield pressure of workpiece **10**, thereby bending the unsupported portions of workpiece **10** in the direction of arrows (FIG. 6). This allows the glass composition **65** to escape, as at **66**, through the gap **59**. The uniform pressure loading upon the surfaces of workpiece **10** has caused the workpiece **10** to assume the convex impression **23** and appending flanges **22**, as defined by the shape of the male die member **30**.

An alternative embodiment of the invention is shown in FIG. 6. Top wall member **54** is rigidly affixed to side walls **51**. The male die member **30** and the workpiece **10** are predisposed, prior to the deformation of workpiece **10**, within the opening formed in top wall **54**. Bottom wall **52** is slidably engageable with reservoir **58** and is designed to act as a piston for creating a build-up of pressure within glass composition **65**, thereby exerting pressure over the surface of workpiece **10** which causes forming thereof as described above. A further modification includes a feed passage **70** communicating with reservoir **58** and a source **71** if viscous glass composition **65**. The piston, or bottom wall **52**, and feed passage **70** may be designed for cooperative association so that the piston, during its compressive stroke, will close off feed passage **70** adn isolate the source **71** of viscous glass composition from the high working pressures created in reservoir **58** during the compressive stroke of piston, or bottom wall **52**. When the piston, or bottom wall **52**, is on a decompressive stroke, reservoir **58** and the source **71** of viscous glass composition will be in communication through feed passage **70** and the glass **65** in reservoir **58** will be replenished in a pre-heated state following each forming cycle. There is no need to interrupt the forming process to remove top wall **54**, add glass to reservoir **58**, and heat glass composition **65** to the desired temperature. Additionally, baffles or other modifications may be added to control and direct the flow of glass **65**, all of which will contribute to the final configuration of the workpiece **10**.

A further modification (not shown) may consist of transmitting heat by any conventional means into the male die member **30**, as well as upper wall **54**, which will assist in creating a more uniform temperature distribution in the glass composition **65** and the workpiece **10**.

Representative examples of a glass composition and metal workpiece that have been successfully used according to the invention are as follows:

(1) Corning Glass Works glass 0010, a clear potash soda lead, having a softening point at 1157° F. and a working point at 1705° F., was heated to 1350° F. which renders a viscosity of approximately 10^6 poises. The workpiece was a sheet of solution treated titanium alloy 8–1–1 having 90 parts titanium, 8 parts aluminum, 1 part molybdenum, 1 part vanadium, and minute traces of impurities. Alloy 8–1–1 has a recommended forming temperature of 1350° F. The sheet was shaped as shown in FIG. 1. The forming process was accomplished at a pressure of 100,000 p.s.i., resulting in a part as shown in FIG. 2.

(2) Corning glass 0010 was heated to 1225° F. The workpiece was solution treated titanium alloy 6–4 having 90 parts titanium, 6 parts aluminum, 4 parts vanadium, and minute traces of impurities. Alloy 6–4 has a forming temperature of 1225° F. The die-pressure was 100,000 p.s.i.

(3) Corning glass 7052, a borosilicate glass, may be heated to 1400° F. The workpiece is titanium alloy 5–2.5 having approximately 92 parts titanium, 5 parts aluminum, 2.5 parts tin, and minute amounts of carbon and other materials for the balance thereof. The die-pressure is approximately 100,000 p.s.i.

The invention and many of its attendant advantages will be understood by those skilled in the art from the foregoing description, and it will be apparent to them that various changes may be made in the form, construction and arrangement of parts, without departing from the spirit or scope of the invention or sacrificing all of its material advantages, the forms hereinbefore described being merely presently preferred embodiments thereof.

What is claimed is:

1. A process for forming metal work pieces, and the like, using liquid dies, which comprises:

placing a vitreous material in a female die;

heating the vitreous material in the die to an elevated temperature at which the metal workpiece can be worked and at which the vitreous material exhibits a pliant viscous property;

affixing the workpiece to a ram; and forcing the workpiece and the ram into the pliant vitreous material in said female die to cause said pliant vitreous material to exert a pressure against said workpiece and force it against the face of the ram.

2. A method as described in claim **1** wherein the glass composition is heated to the heat treating temperature of the metal of the workpiece.

3. A method as described in claim **1** which includes:

placing a separating agent between the surface of said

workpiece and said viscous glass prior to pressing said workpiece.

4. A method as described in claim 3 wherein:

(a) said workpiece is an alloy having 90 parts titanium, 8 parts aluminum, 1 part molybdenum, 1 part vanadium, and minute traces of impurities;

(b) said viscous glass composition is of a clear potash soda lead type having a softening point of about 1157° F. and a working point of about 1705° F. heated to about 1350° F.;

(c) said pressing is accomplished at about 100,000 pounds per square inch; and

(d) said separating agent is a thin sheet of copper.

5. Apparatus for forming workpieces and the like using liquid dies, comprising:

a heating element mounted in said female die for heating said vitreous material in said die to an elevated temperature at which the metal workpiece can be worked and at which the vitreous material exhibits a pliant viscous property;

die means mounted in cooperative relationship with said female die and in position for supporting the workpiece and serving to hold the workpiece against the pliant vitreous material in said female die to cause said pliant vitreous material to exert pressure on said workpiece and force it against the face of die means;

a piston having a head, said piston head forming the bottom wall of said container and being slidably mounted within the confines of the side walls of said container; and

means for reciprocating said piston head within said container.

6. An improvement in dies for the shaping of metal as described in claim 5 which includes:

conduit means for supplying viscous glass to the interior of said container.

7. An improvement in dies for the shaping of metal as described in claim 6 wherein: said conduit means is in communication with the interior of said container whereby movement of said piston during a compressive stroke seals off said conduit means.

8. Apparatus for forming workpieces and the like using liquid dies, comprising:

a female die in the form of a receptacle containing a quantity of vitreous material;

a heating element mounted in said female die for heating said vitreous material in said die to an elevated temperature at which the metal workpiece can be worked and at which the vitreous material exhibits a pliant viscous property; and

a ram mounted in cooperative relationship with said female die and in position in which it may be moved into said die, said ram supporting the workpiece and serving to force the workpiece into the pliant vitreous material in said female die to cause said pliant vitreous material to exert pressure said workpiece and force it against the face of said ram.

9. An improvement in dies for the shaping of metal as described in claim 8 which includes:

a parting agent removably affixed to the surfaces of the workpiece adjacent said glass.

10. An improvement in dies for the shaping of metal as described in claim 5 wherein:

(a) said ram comprises a top wall and is slidably mounted in said container; and including:

(b) means for pressing said upper wall on said glass composition.

11. An improvement in dies for the shaping of metal as described in claim 10 wherein: said die is mounted for pressing of said workpiece prior to movement of said top wall for pressing on said glass.

12. The process defined in claim 1 in which said vitreous material is glass.

13. The process defined in claim 1 in which said vitreous material is heated to a temperature range of the order of 1200° F.–1400° F.

14. The apparatus defined in claim 8 in which said vitreous material is glass.

15. The appaartus defined in claim 8 in which said heating element heats said vitreous material to a temperature range of the order of 1200° F.–1400° F.

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RICHARD J. HERBST, Primary Examiner

U.S. Cl. X.R.

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