This invention relates to apparatus and methods for forming sheet metal and, while not limited thereby, relates particularly to metal forming using presses and to the hot forming and sizing of titanium metal.

The forming of sheet metal is generally accomplished with presses having male and female dies which press a sheet metal workpiece into the desired shape. After forming some metals, particularly titanium and many of its alloys, the part must be held to the formed shape at elevated temperatures (hot sizing) such as 1000° F, for a period of at least several minutes or it tends to revert to its original shape and becomes warped. The operation or spring back occurs immediately after forming pressure is removed. The spring back is believed to be due to the fact that the yield and ultimate strengths of titanium are almost equal so that large stresses are locked into the formed part. Hot sizing relieves these stresses so that the formed shape is retained. The problem of hot sizing depends on the severity of forming the thickness of the workpiece, the particular titanium alloy used and other factors; usually, however, a period of between five and ten minutes is sufficient for titanium.

One method of forming and hot sizing titanium is to keep the formed workpiece between the male and female forming dies for the required period of several minutes or more. However, the waste of press usage and operator time is considerable inasmuch as forming without hot sizing can be accomplished in about fifteen seconds, while hot sizing generally requires many times as much time. Increased production can be obtained by providing additional presses, operators, and sets of dies, but the cost especially of additional precision matching die sets is very high. The cost of dies could be reduced considerably by operating the Guerin Process which utilizes a single die and a thick rubber mat to prevent the actual workpiece about the die. However, the rubber mats cannot be used at high temperatures. Furthermore, only limited precision is obtainable inasmuch as the rubber mats do not exert uniform high pressure against the portion of the workpiece against the side of the die. Even if expensive dies were eliminated, the cost of lining up a press and operator for five to ten minutes for each part is prohibitive.

A forming apparatus and method which enabled forming and hot sizing of titanium with a minimum of equipment and at high production rates would be of great utility.

While titanium parts are usually formed at elevated temperature, they sometimes may be formed at room temperature and then clamped in shape and hot sized. However, the effort required to clamp a part which has already partially sprung back is considerable. Furthermore, where severe forming is employed, and in the forming of many of the more brittle alloys of titanium, forming must be performed at elevated temperatures to prevent tearing. Accordingly, it is generally desirable to initially form titanium parts at elevated temperatures. Many of the materials besides titanium alloys are somewhat brittle and are preferably shaped at elevated temperatures, for example, tungsten, many of the nickel alloys, and many of the stainless steels, although they generally do not require hot sizing. Apparatus which enabled the forming of materials at elevated temperatures using a single die or form block would substantially facilitate the production of sheet metal parts, not only at titanium, but of many of the other high strength metals which are difficult to form.

Accordingly, one object of the present invention is to provide apparatus and methods for enabling metal forming in a more efficient and economical manner than heretofore.

Another object is to provide for the rapid and economical forming and hot sizing of titanium sheet metals.

Still another object is to provide for the hot forming of sheet metal parts in a more efficient and economical manner than heretofore.

Yet another object is to provide apparatus for the forming of sheet metal parts without precision matching dies.

A still further object is to provide a system for enabling the efficient handling, forming and heat treating of metal in the production of formed metal parts.

The foregoing and other objects are attained by forming apparatus including a press which forms sheet metal workpieces about a die or form block. The press includes a base upon which is placed a large sheet of ductile metal, or diaphragm, with a titanium sheet metal workpiece on top of it and a form block on top of the titanium workpiece. The press includes a head which pushes the periphery of the diaphragm against the base to form a fluid-tight chamber between the base and diaphragm. A high pressure fluid, generally a gas, is admitted into this chamber and it applies pressure against the diaphragm. The diaphragm forms itself and the titanium workpiece about the form block, which is supported or backed up by the head, thereby forming the workpiece to the required shape. The diaphragm only is also formed into indentations provided in the side of the form block to keep the diaphragm blocked thereon, the workpiece having insufficient width to extend to the indentations. The head of the press is lifted and the form block, workpiece and diaphragm are removed as a single unit for conveying to an oven where hot sizing occurs. Finally, the diaphragm is stripped away, allowing the workpiece to come off and the die to be re-used.

The diaphragm is composed of a ductile material such as low carbon steel or iron. It serves to form a fluid tight chamber to the pressurized fluid which forms it and the workpiece about the form block. After forming over the block, the diaphragm holds the workpiece tightly against the block and prevents the workpiece from springing back toward its original flat form. During hot sizing, which typically requires five to ten minutes for titanium, the only equipment which must be used is an oven and the form block. The press, which typically forms the workpiece and diaphragm in about fifteen seconds, can therefore be used for high production, in connection with a large number of form blocks which may be of different shapes to form different parts.

Various embodiments of the forming press may be used. In one of these, a fluid such as molten salt is held in the base of the press below the sheet metal diaphragm. After the head grips the periphery of the diaphragm, a ram pushes the form block down against the workpiece and diaphragm, and moves them into the fluid. The fluid cannot escape and therefore deforms the diaphragm and workpiece about the form block. In still another embodiment wherein no ram is used, steam is utilized as the pressurizing fluid, the steam being created by injecting a quantity of water into the volume between the base and the diaphragm, the base having been heated to at least several hundred degrees Fahrenheit.

The forming press is generally one element of a complete forming system which includes an oven, apparatus for stripping the diaphragm from the form block, and conveyor apparatus for moving material through the system.
The foregoing and other features of the invention will be more readily understood from the following detailed description and claims taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a pictorial illustration of a complete forming system constructed in accordance with the invention;

FIG. 2 is a perspective view, with parts broken away, of a forming press constructed in accordance with the invention;

FIG. 3 is a sectional perspective view of a portion of one embodiment of a press which utilizes a liquid forming medium and a ram which forces the form block and diaphragm into the liquid;

FIG. 4 is a sectional view of an assembly consisting of a diaphragm and workpiece formed about a composite form block by a press of the invention;

FIG. 5 is a partial sectional view of another embodiment of the press which utilizes a pressurized gas to form a diaphragm and workpiece about a form block;

FIG. 6 is a partial, sectional view of still another embodiment of a press wherein water injected into the heated base of the press turns into a steam pressurizing medium;

FIG. 7 is a perspective view of a press mechanism for use with presses of the type shown in FIGURES 5 and 6, wherein a pressurized fluid is utilized for forming; and

FIG. 8 is a sectional view of a diaphragm-removing machine wherein strips press 10 is located from the form block and workpiece after forming and hot sizing.

Reference is now made to FIG. 1 which illustrates a complete forming system comprising a press 10 for forming metal about form blocks, an oven 12 for hot sizing the formed metal, a disassembly machine 14 for removing the workpiece from around the form blocks, and a conveyor system 16 for transporting the material and form blocks between various work stations or zones. A strip 18 of ductile material such as 1020 steel extends from a supply reel 20 past a loading table at an assembly zone 22 and through the press 10. At the assembly zone 22 a titanium sheet metal workpiece 24 is placed on the strip, and a die or form block 26 is placed on the titanium workpiece. The strip 18 includes perforations 28 formed along each side, which are engaged by a motor-driven sprocket wheel 30 to advance the strip toward a forming zone in which the press 10 is located.

The press 10 generally comprises a first platen or base 32 over which the strip 18 passes, and a second platen or head 34 which is movable down onto the strip to press it against the base. In the press, a portion of the strip referred to as a diaphragm 19 is forced against the form block 26 and that strip portion and the workpiece resting thereon are formed about the form block. The head 34 is then lifted and the strip advanced to a severing zone where a shear machine 36 severs a strip section including the portion serving as a diaphragm which is formed about a workpiece and form block. Severing can also be done before the strip reaches the press so that the diaphragm 19 is separate from the strip during forming. Also, if desired, discrete diaphragm pieces can be used initially.

The diaphragm, workpiece, and form block assembly 38 is carried by the conveyor system 16 to the oven 12 for hot sizing. Hot sizing consists of rigidly maintaining the titanium workpiece in its formed shape at an elevated temperature for a period of about five to ten minutes, to relieve the stresses produced by forming. Without hot sizing the titanium tends to revert to its unformed shape and an accurately formed part is not obtained. While hot sizing is usually accomplished at a temperature of about 1,000 degrees F. for pure titanium, other temperatures are required for various of its alloys. For example, 6-aluminum-4-vanadium titanium, which is a very high strength type, is generally hot sized at temperatures of about 1200° F.

After passage through the oven, the assembly 38 is carried to the disassembly machine 14 for removal of the diaphragm from about the workpiece and form block. After the diaphragm is removed, the form block and the workpiece are lifted from the block. If the shape of the formed part includes a portion which would prevent its removal from the block, the block is usually made so as to be disassemblable. After removing the workpiece, the block 26 is moved by the conveyor system to the assembly zone 22 for reuse.

Reference is now made to FIG. 2 which shows the complete forming press with a form block workpiece and diaphragm, immediately prior to forming, and to FIG. 3 which shows details of the press during the forming of a part. The press comprises a lower support 50 set in a floor and an upper support 52 hinged at 54 to the lower support. The unhinged side 56 of the upper support is raised and lowered by the vertical movement of a beam assembly 58, which is raised and lowered by a hydraulic cylinder 60. When the beam assembly lowers the upper support 52, a latch 62 pivotally mounted to the upper support is rotated so that a latch keeper 64 locks the unhinged side 56 of the upper support tightly against the lower support 50. A base 66 mounted on the lower support and a head 68 fixed to the upper head support grip the material to be formed. A ram 70 slidably mounted within the head 68 is moved up and down by a hydraulic cylinder assembly 73 fixed to the upper support support 52.

The base 66 is formed as a shallow cup with a rim and a shaped rim and a cavity. The cavity holds a liquid forming medium 75 which presses the diaphragm and workpiece about the form block, as will be described below. Electric heating elements 80 imbedded in the base and connected to an electricity source (not shown) heat the liquid to enable metal forming at elevated temperatures.

In order to form a workpiece, the upper support 52 is raised so that there is a wide space between the head 68 and base 66 while the ram 70 is maintained in an upward position. A portion of the sheet metal strip 18 serving as the diaphragm 19, on which is located a workpiece 24 and form block 26, is then moved between the head and base. The head 68 is lowered and locked in place by operating the hydraulic cylinder 60 of the beam assembly, so that a ring-shaped area 72 of the diaphragm is gripped between the head and base.

Although the keeper 64 holds the base 66 and head 68 together, the gripping pressure on the diaphragm is not easily controlled thereby. Gripping pressure is maintained by a ring-shaped hydraulic bladder 74 disposed between the head 68 and diaphragm. The bladder and its operation are described in the copending patent application entitled, Variable Pressure Drawpress and Method, Ser. No. 321,472, filed Nov. 5, 1963. The bladder comprises two thin, ring-shaped sheets of steel welded together along two concentric circles to form a ring-shaped bladder. Oil or gas pumped into the bladder under pressure through conduit 76 causes its slight expansion and it exerts pressure against the head 68 and diaphragm 19.

After the diaphragm 19 is tightly gripped between head and base, the ram 70 is forced down by the hydraulic cylinder assembly 72. Downward movement of the ram pushes the form block, workpiece and center of the diaphragm into the liquid 78. Inasmuch as the liquid is substantially incompressible, large pressure is exerted by the liquid on the surface of the diaphragm which it contacts. The pressure is exerted uniformly over the diaphragm, causing the unsupported areas thereof to marginal protruberances 75 are provided on the ram to increase displacement of fluid. In deforming, the diaphragm 19 pushes the workpiece 24 about the form block 26. Inasmuch as the liquid applies pressure uniformly, the workpiece is accurately formed about the form block, including the sides thereof. The form block 26 includes indentations or recesses 82 in its side. The workpiece 24 is not wide enough to extend to the recesses, but the diaphragm 19...
is formed into them. The formation of the diaphragm into the recesses prevents the accidental removal of the diaphragm and workpiece from the form block during subsequent handling and hot sizing.

After forming, the ram 70 is raised, pressure in the bladder 74 removed, and the head 68 lifted to allow for the removal of the assembly consisting of the form block 56 with the workpiece 24 and the diaphragm 19 formed thereof. The formed assembly 38 is lifted from the press and conveyed to the shear machine 36 while another form block, workpiece and diaphragm portion of the strip are placed in the press.

After being severed, the assembly 38 is conveyed to the oven 12. Formed parts of titanium must be hot sized at temperatures of about 1,000° F. for pure titanium to about 1300° F. for some of its commonly used alloys, for periods of about 5 to 10 minutes. Accordingly, the portion of the conveyor system running through the oven completes a trip therethrough in about 5 to 10 minutes. After passage through the oven, the assembly is conveyed to the disassembly machine 14.

The disassembly machine, best illustrated in FIG. 8, comprises a base 54 for holding the periphery of the diaphragm, and a head 86 which can be clamped against the base by supports (not shown). A ram 88 having a yieldable head 89, of rubber or the like, is slidable mounted on the base. The disassembly or stripping of the diaphragm 19 from the form block 26 is accomplished by raising the head 86 and placing the assembly in the machine with a peripheral area of the diaphragm on the rim of the base. The head 86 is lowered so that it clamps the diaphragm 19 tightly against the base. The ram 88 is then raised to deform the diaphragm so that the portions lying in the form block indentations 82 are spread apart. The ram 88 is lowered, the head 86 is raised, and the form block and workpiece are removed from the machine. Where the workpiece is not formed into any indentations of the form block, it can then be slipped off the form block in a finished condition. The form block is then returned to the assembly zone 22 for reuse. Of course, many variations of the illustrated disassembly machine may be employed. For example, pressured air may be admitted beneath the diaphragm 19 to push it upward instead of using a ram.

The press illustrated in FIGS. 2 and 3 is only one of many types of presses which can be used for forming in accordance with the methods of this invention. Another type of press, illustrated in the partial view of FIG. 5, includes a base 90 and head 92, the figure showing a workpiece 94 and diaphragm 96 formed in a cavity 102 of the head and about a form block 98 therein. Heating elements 100 in the base and head maintain the press at elevated temperatures for hot forming. A bladder 104, similar to the bladder 74 previously described, is disposed between the head and diaphragm, the bladder receiving pressure fluid through a conduit 106 to enable gripping of the diaphragm with controlled pressure. To enable tighter gripping of the diaphragm, a series of concentric serrations 108 are formed on the base on the peripheral portion thereof which is normally opposite the bladder 104. The serrations provide several fine contacts of large area contacts, and enable the serrations to press into the diaphragm and hold it tightly in a fluid tight seal. A conduit 110 formed in the base carries a gaseous fluid which performs the forming.

Forming is accomplished by first separating the head and base and placing on the base the originally flat diaphragm 96 with a workpiece 94 and form block 98 thereon. The head and base are then clamped together and the bladder 108 is pressurized to hold the diaphragm and to form a fluidtight chamber between the diaphragm and the base. Then gaseous fluid is released from a dry nitrogen source 112 and allowed to flow through the conduit 110 and into the volume between the diaphragm 96 and base 90.

The large pressure on the underside 95 of the diaphragm 96 and the lack of support on its upper surface 97, except at the form block, results in the stretching and deformation of the diaphragm about the form block 98. Generally, forming pressures about 2,000 p.s.i. are used, although thicker pieces which are formed with thicker diaphragms may require pressures of 5,000 p.s.i. As the diaphragm 96 deforms, it presses the workpiece 94 about the form block and the workpiece attains the shape of the block. When the diaphragm approaches the head, air trapped in the cavity 102 is expelled through bleed holes 114 extending through the head. Spiral grooves 118 are formed in the head, each groove connecting with a bleed hole to allow for the escape of air trapped in the cavities as the diaphragm is completely formed and seats against the head. After forming, pressure is relieved in the chamber between the base and diaphragm, and in the bladder 104. The base 90 and head 92 are separated to allow for the removal of the assembly comprising the diaphragm 96, workpiece 94 and form block 98, and the assembly is conveyed to the oven for hot sizing.

In forming the diaphragm to the shape shown in FIG. 5, the diaphragm must stretch as it bends over the corner or edge 116 of the form block 98. Much of the bending force is a result of upward tension transmitted by the unsupported diaphragm regions which readily deform. Accordingly, the portions of the diaphragm near the indentations 120 in the block do not curve inwardly until the last stages of forming; the workpiece and diaphragm are accurately formed about the edge 116 even if it is sharp, and forming is accomplished with a minimum of wrinkling.

The diaphragm 96 must be thick enough to retain the fluid forming pressure and to retain the formed workpiece 94 against spring back. The diaphragm is aided in resisting workpiece spring back by reason of flange portion 117 of the diaphragm extending away from the form block 98. Workpiece spring back tends to push the flanges outwardly and they resist such forces very efficiently.

A complete press apparatus for moving the base 90 and head 92 of the press and clamping them together is shown in FIG. 7. The press comprises column supports 122, a support plate 124 rigidly fixed thereto, and the press head 92 fixed to the plate. A press bed 126 is supported on the cross beams 128 extending between the columns, and two lifting wedges 130 are slideably mounted on the bed. The wedges 130 and 132 support the base 90 of the press and serve to raise and lower it.

The base 90 is raised when the wedges 130 and 132 are moved together and lowered when they are moved apart. Connecting rods 134 and 136, fixed to the wedges 130 and 132 respectively, are engaged with a drive screw 141. The drive screw has right hand threads formed on the screw portion 140 engaged with the rod 134 and left hand threads formed on the portion 142 engaged with the rod 136. An electrically driven gearhead motor 144 selectively rotates the screw 141 in a first direction to move the wedges apart and lower the base 90, and in a second direction to move the wedges together and raise the base. Brackets 146 support the screw under the bed, and slots 148 formed in the bed enable movement of the rods there along.

The forming of a diaphragm and workpiece about a form block with the press of FIG. 7 is accomplished by rotating the screw 141 in a direction which separates the wedges and lowers the base 90. The diaphragm, workpiece and block are inserted between the base and head, and the screw is then driven in a direction to move the wedges together and raise the base so that the periphery of the diaphragm is clamped between the base 90 and head 92. The rest of the forming process is as described hereinbefore in connection with the press mechanism of FIG. 5.
The type of press which employs a pressured fluid between the base and diaphragm to form the workpiece about a stationary form block may derive the pressured forming fluid in a number of ways. One method, described hereinbefore in connection with the press of FIG. 5, is to open a valve and allow gas from a high pressure gas supply to flow between the diaphragm and the base, another method is to inject water or other fluid into the area between the base and diaphragm and allow the resulting steam to serve as the pressurizing fluid. The press illustrated in FIG. 6 uses water injection onto a heated base to obtain steam.

In the press of FIG. 6, the diaphragm 150, upon which lies a workpiece 152 and form block 154, is supported at its periphery between a press head 156 and base 158. A bladder 160 similar to the bladder 74 described in connection with the press of FIG. 3 applies controllable gripping pressure. A series of heater elements 170 disposed in the head and base are connected to an electric source (not shown) to heat the press. The base 158 includes a pocket 162 formed near the periphery thereof. A conduit 164 leading to the pocket carries water from a water tank 166 to a pump 168 and then to the pocket. Pressured fluid between the base 158 and diaphragm 150 for forming the diaphragm is obtained by operating the pump 168 to force a quantity of water into the pocket. The heated base 158 converts the water into steam under high pressure, and the steam serves as the pressurizing medium to form the diaphragm and workpiece about the form block. A valve 172 allows the steam to escape after the forming operation is completed and before the pressure in the bladder 160 is relieved and the head 156 and 158 are separated. The valve 172 can also be set as a relief valve to allow excess steam to escape where the maximum steam pressure required at the temperature of which the base is heated is greater than the pressure required for the forming operation. However, in many applications the maximum steam pressure is equal to the required forming pressure; for example, at 700°F, the maximum steam pressure is 3,100 p.s.i.g. and at that temperature and pressure the volume is 0.0753 cubic feet per pound. Accordingly, in hot forming at 700°F and 3,100 p.s.i.g. a relief valve operation is required, and at sufficient pressure is obtained by pumping into the pocket, two gallons of water for each cubic foot of volume to be attained between the base 158 and diaphragm 150 after forming.

The form block about which the diaphragm and workpiece are shaped may be a single block of metal where the formed part is of a shape which is easily removed from the block. In this case, the diaphragm is stripped away and the formed workpiece is slipped off. However, where the formed part lies within an indentation in the side of the form block, a block which is collapsible, as illustrated in the partial, sectional view of FIG. 4, generally must be used. The formed block 170 of the assembly of FIG. 4 comprises two block sections 172 and 174 and a wedge block section 176 between them. Pins 178 extending through aligned holes in all three sections of the block serve to hold them together. The workpiece 180 is designed to be formed partially into the indentations 182 in the side of the block.

In order to remove the workpiece 180, the diaphragm 184 is first removed as by the disassembly machine of FIG. 8. Then the pins 178 are withdrawn from the holes in the block sections, the wedge 176 is removed and the block sections 172 and 174 are removed. The block is, of course, re-assembled prior to re-use.

In the manufacture of titanium parts wherein diaphragms are used for retaining the shape of the workpiece during hot forming, the form block can be reused only about once every 5 to 10 minutes, since the passage through the oven requires 5 to 10 minutes. During the intervening time, form blocks for shaping other parts can be used instead of providing many form blocks for the same part. Accordingly, for low production runs, which are typical for titanium parts, the forming press can be used constantly by providing many different form blocks for the various titanium parts needed and reusing each block only once every 5 to 10 minutes. It should also be noted that where small parts are to be formed, several form blocks and base blanks can be placed on one diaphragm to form and hot size several parts simultaneously.

The use of a diaphragm formed about the workpiece to hold it in shape during hot sizing is useful not only in connection with the presses described above, but also in connection with other presses. For example, in typical presses using mating male and female dies, a diaphragm can be placed between the workpiece and one of the dies. After forming, the male and female dies are separated and the die to which the workpiece and the diaphragm are held (usually, though not necessarily, the male die, by means of indentations in the sides of the die) is transferred to an oven for hot sizing. As another example, the diaphragm may be used in connection with the Guerin Process involving forming by rubber mats over a form block. In both of the above examples, the diaphragm does not serve as a means to retain pressured forming fluid, but primarily as a clamping means to hold the workpiece in shape.

Although the diaphragm has been shown to be useful in retaining a separate workpiece in shape during hot sizing, it may also be used as the workpiece itself. The diaphragm is then used to retain a pressed fluid during forming. The form block, which may be a single block of metal where there are no side indentations, is removed after forming. The peripheral portions of the diaphragm are removed in a blanking press or the like, and the center of the diaphragm becomes the formed part.

While particular embodiments of the methods and apparatus for forming parts in accordance with the invention have been illustrated and described in detail, it will be understood by those skilled in the art that many variations and modifications therein may be made without departing from the teachings of the invention. Accordingly, the invention is not limited to the particular embodiments shown, but only by a just interpretation of the following claims.

I claim:
1. A system for hot forming and sizing titanium sheet metal into desired shapes on form blocks, comprising: a generally closed loop conveyor system including an assembly zone, a forming zone, a sizing zone, a severing zone, and a disassembly zone; a supply reel carrying an elongate strip of deformable, shape retaining sheet metal adjacent said assembly zone and adapted to feed said sheet metal to a loading table at said assembly zone to receive a sheet of titanium and a form block; means to remove said sheet metal outwardly sufficiently to locate said titanium and form block at said forming zone; means at said forming zone to apply heat to said titanium and sheet metal to raise said titanium to a suitable forming temperature, and to deform said titanium to a suitable forming temperature, and to deform said titanium around said form block, and to deform said sheet metal around said titanium and form block in gripping and shape holding relation; said means to move said sheet metal being adapted to move the strip outwardly to locate the formed material at said severing zone; means at said severing zone to sever the formed portion of said sheet metal from the succeeding portion of said strip; conveyor means to transfer said formed portion together with said titanium and form block outwardly to and through said sizing zone to the disassembly zone;
means at said sizing zone to maintain said formed portion, titanium, and form block at a predetermined elevated temperature for a predetermined period of time; means at said disassembly zone to forcefully separate said sheet metal, titanium, and form block; and conveyor means to transfer said form block to a position adjacent said assembly zone.

2. A system as defined in claim 1 wherein:
said strip of sheet metal is provided with sprocket holes along at least one margin thereof; and said means to move said strip of sheet metal onwardly comprises at least one power driven rotatable sprocket adapted to engage said sprocket holes.

3. A system for hot forming and sizing titanium sheet metal into desired shapes on form blocks, comprising:

- a loading table to receive a portion of a strip of sheet metal in horizontal position for assembly with a sheet of titanium and a form block;
- a supply reel carrying an elongate strip of deformable, shape retaining sheet metal adjacent said loading table and adapted to feed successive portions of said strip thereto;
- a hot forming press adapted to receive an assembly of sheet metal, titanium, and form block from said loading table and apply heat and pressure thereto to deform said titanium and sheet metal around said form block with the sheet metal clamping the titanium tightly about said form block;
- means to sever the deformed portion of said sheet metal from the succeeding portion of said strip;
- an oven adapted to receive said assembly and maintain it at a predetermined elevated temperature for a predetermined period of time; and
- disassembly means to forcefully separate said sheet metal, titanium, and form block from each other.

4. A system for hot forming on a form block a sheet metal workpiece of a material which tends to creep and deform during a short period of time after the forming operation, and for maintaining said workpiece in its formed shape during the creep period, comprising:

- a form block;

- a piece of deformable, shape retaining sheet metal; said sheet metal and form block being adapted to receive between them a workpiece to be formed;

- a hot forming press adapted to receive the assembly of sheet metal, workpiece, and form block and apply heat thereto to raise the workpiece to the desired forming temperature, and adapted to apply pressure to deform said workpiece and sheet metal around said form block with the sheet metal clamping the workpiece tightly about said form block;

- an oven adapted to receive said assembly and maintain it at a predetermined elevated temperature for a predetermined period of time; and

- disassembly means to forcefully separate said sheet metal, workpiece, and form block from each other.

5. A system as defined in claim 4 wherein:
said press comprises a head and a base formed to define between them a cavity surrounded by marginal clamping formations;
said cavity is adapted to receive the assembly of sheet metal, workpiece, and form block;
said marginal clamping formations are relatively movable toward each other to clamp between them a corresponding marginal area of said sheet metal surrounding and spaced from said workpiece and form block;
said sheet metal serves as a diaphragm extending across said cavity; and
means to apply fluid under pressure to the face of said sheet metal remote from the workpiece and form block to deform the workpiece and the corresponding portion of said sheet metal tightly about said form block.

6. A method of hot forming a sheet metal workpiece of a material which tends to creep and deform during a short period of time after the forming operation, and maintaining said workpiece in its formed shape during the creep period, comprising:

- assembling said workpiece between a form block and a piece of deformable, shape retaining sheet metal;

- raising said workpiece to the desired forming temperature;

- deforming said workpiece about the form block to its desired final shape;

- deforming at least a portion of said sheet metal about said workpiece into clamping relation with said workpiece and form block; and

- maintaining said workpiece tightly clamped on the form block by means of the constrictive force of said sheet metal while maintaining the assembly at an elevated temperature during the creep period of said workpiece.

7. A method as defined in claim 6 including:

- subsequently restraining marginal portions of said sheet metal and applying pressure to the side thereof remote from said workpiece to peel the sheet metal away from said workpiece and release the latter from the form block.

8. Apparatus for deforming a sheet metal workpiece to a desired final shape, comprising:

- a head and base having complementary marginal clamping formations and defining between them a generally central cavity;

- a diaphragm of permanently deformable sheet metal having an area greater than that of the cavity to provide a peripheral portion to be gripped between the clamping formations and divide the cavity into a forming zone and a pressure fluid zone;

- said clamping formations being movable into sealing relation with said diaphragm;

- a form block adapted to be placed in the forming zone with a workpiece between it and the diaphragm; and

- means to apply fluid under pressure in the pressure fluid zone against said diaphragm to stretch and deform it around the workpiece and form block to deform the workpiece into its desired final shape and to remain in gripping engagement therewith.

9. A method of maintaining the shape of a formed workpiece of a material which tends to creep and deform during a short period of time after the forming operation, comprising:

- deforming a piece of deformable but shape retaining sheet metal about a formed workpiece mounted on a form block; and

- retaining the deformed piece of sheet metal in clamping relation to the workpiece and form block throughout the creep period.

10. A device for clamping on a form block a workpiece of sheet metal having the characteristic of creeping and deforming for a short period of time after the forming operation, said device comprising:

- a unitary sheet of metal shaped to encompass and conform to the shape of the workpiece;

- said sheet of metal being fitted tightly on the workpiece to retain it in tight engagement with the form block;

- the resistance of said sheet of metal to deformation being greater than the deforming force of said workpiece.

11. A device as defined in claim 10 wherein:
said sheet of metal has an integral flange extending laterally in the general plane of said workpiece to increase the resistance of said sheet of metal to deformation by said workpiece.

12. An apparatus for forming a sheet metal workpiece comprising:

- a head and a base relatively movable toward each other, said head and base having corresponding peripheral clamping portions;
a central ram disposed within said head and movable toward said base, said ram having marginal protuberances extending toward said base;

a diaphragm of a formable sheet metal extending across said head and base and gripped between said clamping formations;

a form block adapted to be placed on said diaphragm beneath said ram with said workpiece arranged between said form block and said diaphragm;

a cavity formed in said base;

a substantially incompressible liquid disposed in said cavity; and

means to force said ram toward said diaphragm to reduce the volume of said cavity and displace said liquid, for forming said diaphragm around said workpiece and form block.

13. Apparatus for forming a sheet metal workpiece comprising:

a head and base relatively movable toward each other and having complementary peripheral clamping formations;

a cavity formed in said head to receive a workpiece and form block;

a diaphragm of deformable sheet metal extending across said head and base and adapted to be gripped by said clamping formations;

a form block adapted to be placed in said cavity with said workpiece between it and said diaphragm; and

means to force fluid under pressure between said base and said diaphragm to deform said diaphragm around said workpiece and form block.

14. Apparatus for forming a sheet metal workpiece comprising:

a head and base relatively movable toward each other and having complementary peripheral clamping formations;

a cavity formed in said head to receive a workpiece and a form block;

a diaphragm of deformable sheet metal extending across said head and base and adapted to be gripped by said clamping formations;

a form block adapted to be placed in said cavity with said workpiece between it and said diaphragm;

a pocket formed in said base to receive vaporizable liquid;

means to maintain said base at an elevated temperature sufficient to vaporize said liquid; and

means to inject a quantity of liquid into said pocket for vaporizing it and applying pressure to said diaphragm to deform it around said workpiece and form block.

15. Apparatus for forming a sheet metal workpiece comprising:

a head and base relatively movable toward each other and having complementary peripheral clamping formations;

a cavity formed in said head to receive a workpiece and a form block;

a diaphragm of deformable sheet metal extending across said head and base and gripped by said clamping formation;

a form block adapted to be placed in said cavity with said workpiece between it and said diaphragm;

means to inject a liquid between said base and the side of said diaphragm remote from said workpiece and form block; and

means to maintain said base at an elevated temperature sufficient to vaporize said liquid.

16. Apparatus for forming sheet metal comprising:

a head and a base;

means for moving said head and base together;

peripheral gripping means formed on said head and base for holding the periphery of a sheet metal diaphragm between them and for forming a fluid-tight chamber between said base and a surface of said diaphragm facing said base to hold a pressurizing medium there-in; and

a form block disposed against said head, said block having an outer surface portion substantially facing said base and having side portions, and including indentations formed in said side portions for enabling the secure holding of a sheet metal portion formed about said block.

17. Apparatus for forming metal comprising:

a base;

a head including a cavity formed therein;

means for moving said base and head together; a diaphragm of ductile sheet metal disposed between said base and head;

a die disposed within said cavity and adjacent said diaphragm;

means for gripping the periphery of said diaphragm between said base and head; and

means for applying a pressure against the side of said diaphragm facing said base for permanently forming said diaphragm to the shape of said die.

18. Apparatus for forming a diaphragm about a form block comprising:

a base;

a head including a cavity therein;

means for moving said base and head together;

means for gripping the periphery of said diaphragm between said base and head and for forming a fluid-tight chamber between said base and a surface of said diaphragm facing said base, for retaining a liquid pressurizing medium therein; and

a ram means movable within said cavity and against a form block disposed within the cavity in said head, for pushing said form block against said diaphragm while maintaining said diaphragm tightly gripped by said means for gripping.

19. Apparatus for forming metal comprising:

a head and base;

gripping means for gripping a diaphragm between said head and base to form a chamber between said diaphragm and said base;

means for heating said base to a predetermined temperature; and

conduit means for carrying a fluid into said chamber while gripping said diaphragm, the saturation vapor pressure of said fluid at said predetermined temperature being of the order of magnitude of at least hundreds of pounds per square inch.

20. A forming system comprising:

a male die means, said die means having an indented side surface for enabling its retention of metal formed about the die;

press means for forming a workpiece and a diaphragm of ductile material about said die;

oven means for maintaining said die, with said diaphragm and workpiece formed thereabout, at an elevated temperature; and

means for removing said diaphragm from said workpiece and die.

21. A method for forming a sheet workpiece comprising:

maintaining a die having an indented portion against one surface of said workpiece;

maintaining a diaphragm of ductile material having a greater area than said workpiece against a surface of said workpiece opposite said die;

forming said diaphragm to the shape of said die with said workpiece between said die and diaphragm, and forming outer portions of said diaphragm into said indented portion of said die and in direct contact with said die;

maintaining said workpiece at elevated temperatures while sandwiched between said diaphragm and die;
removing said diaphragm from about said workpiece; and
removing said workpiece from said die.

22. A method for forming and hot sizing a sheet metal workpiece comprising:
5 maintaining said workpiece between a die and a diaphragm of ductile material;
applying forming pressure on the side of said diaphragm opposite said workpiece to form said diaphragm and workpiece to the shape of said die;
removing said forming pressure from about said diaphragm;
maintaining said die with said diaphragm and workpiece thereagainst at an elevated temperature;
removing said diaphragm from about said workpiece; and
removing said workpiece from said die.

23. A method for forming and hot sizing a sheet metal workpiece as defined in claim 22:
10 wherein said diaphragm has a greater area than said workpiece, said die includes indented side portions positioned for receiving portions of said diaphragm which do not cover said workpiece, and including the step of forming said diaphragm into said indented side portions.

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