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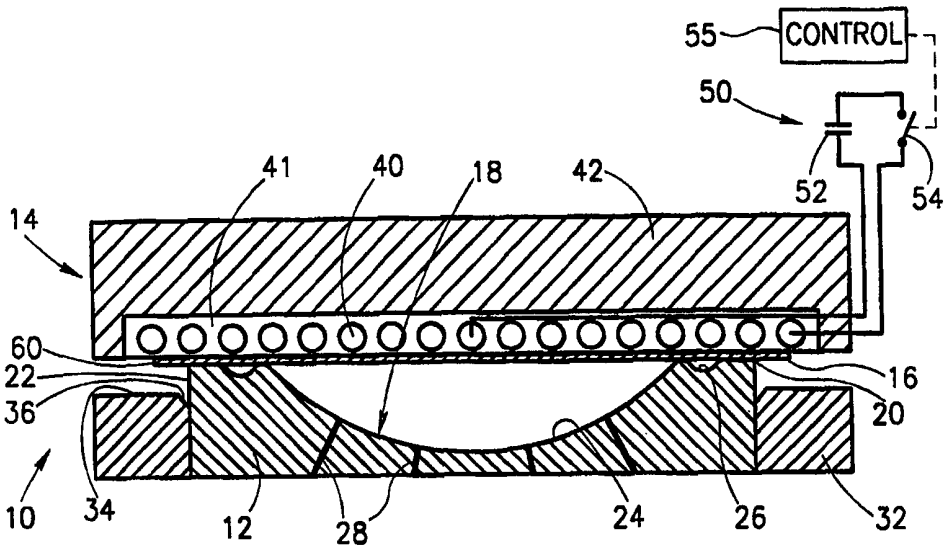

(57) Abstract

An electromagnetic forming apparatus for forming an essentially planar metal plate into a dish having a three–dimensional pattern, is provided. The apparatus comprises a mould having a forming surface with a contour corresponding to said three–dimensional pattern; a forming coil device; and an electric discharge circuitry for discharging a short and intense electric current pulse through the forming coil device to yield a pulsed magnetic forming (PMF) force for deforming said plate.

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APPARATUS AND METHOD FOR PULSED MAGNETIC FORMING OF A DISH FROM A PLANAR PLATE

FIELD OF THE INVENTION

The present invention is generally in the field of pulsed magnetic forming (PMF) and provides an apparatus and method for such forming. More particularly, the present invention relates to a PMF process forming of a dish from a planar plate.

BACKGROUND OF THE INVENTION

Metal objects can be formed to have a desired shape by a variety of processes. For example, metal in a liquid form, can be molded to have the desired final shape. However, such a process is applicable in certain specific cases and in addition requires the expense of a large amount of energy and complicated and costly installations for heating and cooling.

Metal has some pliability and accordingly metalwork pieces of one shape can at times be formed to have another shape. For example, a metal plate can be formed and cut to have a wide variety of desired shapes by using a mechanical press. Such pressing methods require a very costly and large installations required for achieving the necessary pressure for attaining the desired final object.

PMF is a process in which a metal workpiece or a portion thereof is put into a rapid motion by pulse magnetic fields which causes the workpiece to deform. One advantage of the PMF process is in that energy loss in this process is minimal and consequently there is no or very little heating of the workpiece. In addition, this process does not have the disadvantage of leaving tool marks, as is the case in a variety of other techniques. The PMF process uses a discharge capacitor or a bank of capacitors, a forming coil and often a field shaper, for creating an intense transient magnetic field. Very intense magnetic fields created in the PMF process, is a result of the rapid discharge of electric energy, stored in the capacitors, through the forming coil. The resulting eddy currents that are induced in the workpiece yields a magnetic repulsion between the workpiece and the forming coil, which cause the workpiece to deform.

A background on prior art apparatuses and methods for working of metal workpieces by the PMF process can be found in U.S. Patents 3,654,787, 3,961,739, 4,170,887, 4,531,393, 4,807,731, 5,353,617 and 5,442,846, and in PCT Application Publication No. WO 97/22426.

When forming a shaped metal object from a planar metal plate, it is necessary at times to both shape a plate to acquire a desired three-dimensional pattern and to trim the edges so as to define the boundaries of the shaped metal object.

It is an object of the invention to provide PMF forming apparatus and method for forming a metal plate into a dish having a desired three-dimensional pattern and shape.

GENERAL DESCRIPTION OF THE INVENTION

The present invention provides, by a first of its aspects, an electromagnetic forming apparatus for forming an essentially planar metal plate into a dish having a three-dimensional pattern. A typical non limiting example

of the invention is its application in the formation of a satellite dish from a planar plate.

In accordance with one embodiment, the apparatus comprises:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern, and having edges corresponding to boundaries of the dish, which edges are defined by side walls essentially perpendicular to the forming surface;

a forming coil device opposite and proximal to said forming surface, and extending peripheral to said edges; the plate being

accommodated between the forming coil and said forming surface; and

an electric discharge circuitry for discharging a short and intense electric current pulse through the forming coil device to yield a pulsed magnetic forming (PMF) force for deforming said plate.

In accordance with one embodiment of the invention, the forming coil comprises a single coil member. In accordance with another embodiment of the invention, the forming coil device comprises an array of two or more coil members. The coil members in a forming coil comprising two or more coil members are typically concentric. An apparatus in accordance with this embodiment comprises:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

a forming coil device opposite and proximal to said forming surface comprising two or more coil members; the plate being accommodated between the forming coil and said forming surface; and

an electric discharge circuitry, comprising two or more discharge circuitries, one associated with each coil member, for discharging short and intense electric current pulses through the coil members to yield pulsed magnetic forming (PMF) forces for deforming said plate.

In the case of a forming coil comprising two or more coil members, the discharge circuitries may be timed to discharge the current pulse through all coil members simultaneously; or advantageously, the discharge is timed in accordance with a predetermined discharge sequence. For example, in the case of several concentric coil members, the discharge sequence may be such so that it propagates from the central coils to the peripheral ones; in the reverse direction, namely from the peripheral ones towards the central ones; or in any other desired discharge sequence designed to obtain a certain three-dimensional pattern.

In accordance with another embodiment of the invention, the forming coil comprises one or more coil members which are displaceable along an axis essentially normal to a plane defined by the metal plate. The apparatus in accordance with this embodiment comprises:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

a forming coil device comprising one or more coil members, displaceable along an axis essentially normal to a plane defined by the metal plate;

an electric discharge circuitry, comprising two or more discharge circuitries, one associated with each coil member, for discharging short and intense electric current pulses through the coil members to yield pulsed magnetic forming (PMF) forces for deforming said plate.

The forming coil in the apparatus according to this embodiment typically comprises two or more coil members separately displaceable along said axis. The deformation of the plate may comprise two or more steps. In the first step, the plate is partially deformed by a PMF force and then the coil members are displaced to an axial position corresponding to the displacement of the plate after the initial deformation. Then a PMF pulse is discharged again

to further deform the plate, and this process may be repeated until the final shape has been attained.

In accordance with another embodiment of the invention, the forming coil device, which may comprise one or more coil members, has a size such that it covers only a portion of the plate to be deformed. An apparatus in accordance with this embodiment comprises:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

a forming coil device opposite and proximal to said forming surface, and comprising one or more coil members having a size such that it covers only a portion of the plate to be deformed, the one or more coil members being displaceable in plane parallel to that of the plate;

an electric discharge circuitry for discharging a short and intense electric current pulse through each of the one or more coil members to yield a pulsed magnetic forming (PMF) force for deforming said plate.

In accordance with this embodiment, the forming coil member is first positioned at an initial position, a PMF pulse is generated to partially deform the opposite portion of the plate and then the forming coil is moved to another position opposite another portion of the plate whuch is then deformed by another PMF pulse. These steps are repeated untill the entire plate has been deformed to assume said there-dimensional pattern.

The mold, in accordance with one embodiment, comprises one or more depressions which correspond to said three-dimensional pattern. Typically, in accordance with this embodiment, the mold has a central concave portion, defining and serving as a template for a central concave portion of the dish. During deformation in which portions of the plate rapidly move into the depression, gases, e.g. air, remaining in the mold can resist the movement and thus prevent the obtaining of the desired three-dimensional shape. Accordingly, by one embodiment, gas-release ducts are provided to allow egression of gasses

from the depression during this phase.. These may be connected to a vacuum source for removal of the gasses from the depression.

In accordance with another embodiment, the forming surface comprises bulges which define said three-dimensional pattern. In accordance with another embodiment of the invention, the forming surface comprises at least one depression and at least one bulge, which together define said three-dimensional pattern.

In accordance with another aspect the invention provides a method for electromagentic forming of a generally planar metal plate into a dish with a three-dimensional pattern. In accordance with one embodiment, the method comprises:

(a) providing a mold having a forming surface with a contour corresponding to said three-dimensional pattern, and having edges corresponding to boundaries of the dish, which edges are defined by side walls essentially perpendicular to the forming surface;

(b) placing the metal plate over the forming surface of the mold;

(c) providing a forming device coil connected to an electric discharge circuitry, and placing it over said metal plate, the forming coil extending beyond the edges of said forming surface; and

(d) discharging a short pulse of an intense electric current through said coil to shear the plate along said edges and forcing other portions of said plate to assume a shape defined by said mold, thus obtaining said dish.

In accordance with another embodiment the method comprises:

(a) providing a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

(b) placing the metal plate over the forming surface of the mold;

(c) providing a forming coil device, comprising two or more forming coil members each of which being connected to an electric circuitry, and placing the forming coil device over said metal plate;

(d) discharging a short pulse of an intense electric current through said two or more coil members to deform said metal plate;

(e) displacing said coil members along said axis to a position corresponding to the shape of the plate after the deformation and repeating step (d);

(f) repeating step (e) until attainment of said three-dimensional pattern.

In accordance with a further embodiment of the invention, the method comprises:

(a) providing a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

(b) placing the metal plate over the forming surface of the mold;

(c) providing a forming coil device which comprises one or more coil members having a size such that it covers only a portion of the plate to be deformed, the one or more coil members being displaceable in a plane parallel to that of the plate, and placing the forming coil device over said metal plate;

(d) discharging a short pulse of an intense electric current through said coil to deform portions of the plate opposite said forming coil device;

(e) laterally displacing said forming coil device and repeating step (d);

(f) repeating step (e) until said three-dimensional pattern has been attained.

The invention will now be illustrated by describing some non-limiting specific embodiments depicted in the annexed drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematical cross-section through a forming apparatus in accordance with an embodiment of the invention, prior to forming the metal plate.

Fig. 2 is a top elevation of the coil of the apparatus of Fig. 1.

Fig. 3 is a schematical representation of the forming process.

Fig. 4 is a cross-sectional view of a dish formed in the apparatus of Fig. 1 and by the illustrated process.

Fig. 5A is a schematical cross-section through a forming apparatus in accordance with another embodiment of the invention.

Fig. 5B shows the apparatus of Fig. 5A after formation of the dish.

Fig. 6 is a top elevation of a forming coil device in accordance with another embodiment of the invention comprising an array of three forming coil members.

Fig. 7 is a top elevation of a forming coil device in accordance with another embodiment of the invention, comprising three coil members each consisting of several coil winds.

Figs. 8A-8C are a schematical cross-section through a forming coil device in accordance with another embodiment of the invention a plurality (three in this specific embodiment) of coil members, each with a different, associated discharge circuitry. Figs. 8A-8C show the apparatus in different steps of the deformation process.

Figs. 9A-9C are schematical cross-sections through a forming apparatus in accordance with another embodiment of the invention with a plurality (three in this specific embodiment) of coil members, each separately displaceable in an axis normal to the plane defined by the plate. Figs. 9A-9C show the apparatus in different steps of the dish-forming process.

Figs. 10A and **10B** show an apparatus in accordance with another embodiment of the invention in an initial stage (Fig. 10A) and in a final forming stage (Fig. 10B) of the dish-forming process.

Fig. 11 shows another embodiment of an apparatus of the invention wherein the mold has a non-symmetrical shape.

Figs. 12A-12C are schematical cross-sections through an apparatus in accordance with the invention with a coil member displaceable in a plane parallel to that defined by the plate. Figs. 12A-12C show the apparatus in three consecutive steps of the dish-forming process.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Reference is first being made to Fig. 1 showing an apparatus generally designated **10**, comprising a mold **12**, a forming coil assembly **14** holding between them a metal plate **16**.

Mold **12** has a forming surface **18** of a generally circular shape with edges **20**, defined by upright side walls **22** with a central domed-shaped depression **24** and an annular groove **26**. As will be appreciated, the specific shape of the mold which defines the shape of the dish to be formed in the apparatus is an example only and it may assume also a variety of other shapes. By way of illustration, the mold may have an overall rectangular shape, may have different kinds of depressions for forming dishes with different three-dimensional patterns, etc. Thus the specific illustrated embodiment does not derogate from the generality of the invention as defined herein.

Formed in mold **12** are a plurality of ducts **28** leading from depression **24** to a vacuum source (not shown) which draws gas from the depression (represented by arrows **30** in Fig. 3).

Mold **12** is surrounded by an annular member **32** which has an upper surface **34**, below edge **20**, and having a chamfered inner portion **36** for receiving and holding sheared material waste (see below).

Coil assembly **14** consists of a coil **40**, embedded within space **41**, formed at the bottom of a supporting block **42**. Block **42** is preferably made of a non metallic substance. Coil **40** should be electrically insulated from surrounding metal objects, particularly metal plate **16**, for which purpose

space **41** may be filled by an electrically insulating material or alternatively coil **40** may be covered by an electrically insulating material.

Coil **40** is electrically connected to an electric discharge circuitry **50** comprising a capacitor battery **52** and a high current rapid discharge switch **54**, both as known *per se*. An example of such a discharge switch is a controlled vacuum discharger such as that disclosed in Israel Patent Application No. 119826 and its counterpart PCT Application No. PCT/IL97/00383. Switch **54** is controlled by a control circuitry **55**.

Metal plate **16** is generally planar and has boundaries such that it extends beyond edges **20** of mold **12**.

In operation, as illustrated in Fig. 3, switch **54** is closed, whereby electric current rapidly discharges through coil **40** yielding a pulsed magnetic force which forces a very rapid movement in portions of plate **16:** portions overlaying depression **24** and annular groove **26** are deformed to assume a three-dimensional pattern defined thereby and peripheral edge portions **60** of plate **16** are sheared over peripheral edges **20** of the mold **12**. Thus, a dish **62** as shown in Fig. 4, having a central concave depression **64** and a skirt **66** with an annular groove **68** is thereby formed. Such a dish is useful, for example, as an antenna, in particular such used in satellite communication. Annular member **32** can then be pushed upwards to allow disposal of sheared portion **60**.

Reference is now being made to Figs. 5A and 5B showing an apparatus generally designated **80** in accordance with another embodiment of the invention. The apparatus comprises a mold **82** and a forming coil assembly **84** holding between them a metal plate **86**, and comprises a discharge circuitry **88**. A major difference between apparatus **80** of Figs. 5A and 5B and apparatus **10** of Fig. 1 resides in that the mold, rather than being concave is convex. Otherwise, the operation of the apparatus is essentially the same as that described with reference to Figs. 1 and 3 with Fig. 5B illustrating the apparatus

after dish **90** has been formed from plate **86**. As the process is essentially the same as that described with reference to Figs. 1-3 the description will not be repeated again and the reader is referred to the description above.

Fig. 6 shows an apparatus in accordance with another embodiment of the invention. In this embodiment, forming coil device **100** consists of an array of three forming coil members **102, 104, 106**. Discharge circuitry **110** comprises a capacitor battery **112**, three high current rapid discharge switches **114, 116** and **118** under control of control unit **120**, each one associated with one of the coil members **102, 104** and **106**, respectively, and comprises resistors **122, 124** and **126**. Such a circuitry allows to independently discharge rapid current pulse through each of coil members **102, 104** and **106** in its desired sequence of operation. For example, in this case where the array consists of three concentric coil members, the discharge pattern may begin with current discharge through the central coil **102**, continued with a discharge through coil **104** and then finally through coil member **106**.

It should be appreciated, that an array of three coil members illustrated in Fig. 6 is but an example and the array may comprise any desired number of coil members, e.g. between two and ten.

As will also be appreciated, the electric discharge circuitry shown in Fig. 6 is but an example and a wide variety of different circuitries allowing to attain a sequential discharge through different coil members may be envisaged.

In Fig. 7, a forming coil device **130** in accordance with another embodiment of the invention is schematically illustrated. The forming coil device **130** comprises three coil members **132, 134** and **136**, each consisting of a plurality of coil winds. In this example each coil member has two coil winds, although as will be appreciated this is an example only and the number of winds in each coil member may be any desired number, typically between 2 and 20. The coil of each coil member is connected to a discharge/control circuitry **138**.

An apparatus in accordance with another embodiment of the invention is illustrated in Figs. 8A-8C. The apparatus is essentially similar in design to that illustrated in Fig. 1, with the major difference being in that the forming coil device **150**, comprises a plurality of coil members (three – **152, 154, 156**, are illustrated, although it will be appreciated that the forming coil device may comprise any other number of independent coil members). The forming coil device **150** is supported by supporting block **160**. Each of members **152, 154, 156** is connected to a corresponding discharge circuitry **162, 164** and **166**, all being under control of control unit **168**.

In this specific embodiment discharge circuitries **162, 164** and **166** are timed to discharge rapid and intense electric current pulse consecutively, starting from the central member **156** (Fig. 8A) and progressing laterally (represented by arrows **170**), to discharge through coil member **154** (Fig. 8B) and then finally in coil member **152** (Fig. 8C) yielding a dish **172** with a three-dimensional pattern defined by mold **174**.

An apparatus **180** in accordance with another embodiment of the invention is illustrated in Figs. 9A-9C. The apparatus comprises a mold **182** with a concavity **184** defining a three-dimensional pattern of the dish to be formed from plate **186** which is accommodated within peripheral supporting walls **188**.

Forming coil device **190**, comprises a plurality of coil members, three in this specific embodiment – **192, 194** and **196**. Each coil member is displaceable in an axis normal to the plane defined by the plate and is supported by an associated displaceable support block **202, 204** and **206**, respectively. Similarly as in the embodiment of Figs. 8A-8C, each coil member is connected to a respective discharge circuitry **212, 214** and **216** controlled by control unit **218**.

Fig. 9A illustrates the apparatus after an initial deformation accomplished by a PMF current discharge through coil member **196** and then sequentially through coil members **194** and **196**, whereby a partial deformed

plate **186'**, as can be seen in Fig. 9B. Then the coil members are axially displaced towards the deformed plate **186'**, so that each will be in a position more proximal to the plate and then a PMF pulse is again sequentially discharged through different coil members, similarly as before. By such repeated sequence, the plate becomes fully deformed yielding dish **224** (Fig. 9C).

Figs. 10A and 10B show an apparatus generally designated **230** in accordance with another embodiment of the invention. This apparatus comprises a mold **232** with a concavity **234** and supporting plate **236**. Forming coil device generally designated **240** comprises a plurality of coil members, three – **242, 244** and **246**, being shown in this specific embodiment, supported by a supporting block **250**. The different members are spatially arranged such that they generally follow a contour corresponding to that of concavity **234**. The deformation in this case is achieved by a sequential discharge of a PMF current through one or more of coil members and then displacing the entire block with the coil members in an axial direction represented by arrow **252** until a final deforming plate **236** to yield dish **254**.

Fig. 11 illustrates an apparatus **260** which is essentially similar to the embodiment of Fig. 10A but here, rather than a symmetrical concavity **254**, concavity **264** in mold **262** is non symmetrical. Accordingly, the spatial position of each of coil members **272, 274** and **276**, supported by support block **280**, have a general spatial position corresponding to the contour of concavity **264**.

In Figs. 10A, 10B and 11, the electric circuitries have been omitted for the sake of simplicity of description.

Reference is now being made to Figs. 12A-12C illustrating an apparatus **290** in accordance with another embodiment of the invention. The apparatus comprises a mold **292** with a concavity **294** and a supporting block **296** accommodating a forming coil device **298**. The forming coil device

accommodates a coil **300**, is horizontally displaceable as represented by arrows **302**. It should be noted that in principle forming coil device **298** may also be displaceable along an axis normal to the plane of the sheet.

The forming coil device is placed over one portion of plate **304**, a PMF current is passed through the coil (a discharge circuitry not shown) and then the coil device is moved to another position, the PMF current is discharged again, displaced again and so forth until the entire plate is deformed to yield dish **306**.

CLAIMS:

1. An electromagnetic forming apparatus for forming an essentially planar metal plate into a dish having a three-dimensional pattern, the apparatus comprising:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern, and having edges corresponding to boundaries of the dish, which edges are defined by side walls essentially perpendicular to the forming surface;

a forming coil device opposite and proximal to said forming surface, and extending peripheral to said edges; the plate accommodated between the forming coil and said forming surface; and

an electric discharge circuitry for discharging a short and intense electric current pulse through the forming coil device to yield a pulsed magnetic forming (PMF) force for deforming said plate.

2. An apparatus according to Claim 1, wherein said forming surface comprises one or more depressions corresponding to said three-dimensional pattern.

3. An apparatus according to Claim 2, wherein the forming surface of the mold, has a central concave portion, defining and serving as a template for a central concave portion of the dish.

4. An apparatus according to Claim 3, wherein the central depression is provided with ducts for release of gasses.

5. An apparatus according to Claim 4, wherein said ducts are connected to a vacuum source for the removal of gasses from the depression.

6. An apparatus according to Claim 1, wherein said forming surface comprises bulges defining said three-dimensional patterns.

7. An apparatus according to Claim 1, wherein said forming surface comprises at least one depression and at least one bulge, defining said three-dimensional patterns.

8. An apparatus according to any one of the preceding claims for forming a dish having a central concave portion and a peripheral skirt.

9. An apparatus according to Claim 8, wherein the forming surface has contours for forming a peripheral annular groove in the skirt portion of the dish.

10. An apparatus according to Claim 9, wherein the forming coil device comprises two or more coil members, each one associated with a separate electric discharge circuitry.

11. An apparatus according to any one of the preceding claims, wherein the coil device has one or more forming coil members displaceable along an axis essentially normal to a plane defined by the metal plate.

12. An apparatus according to Claim 11, wherein the coil device comprises two or more members, being separately displaceable along said axis.

13. An apparatus according to Claim 12, wherein after deformation of the plate the coil members are displaced to a position corresponding to the shape of the plate after the deformation.

14. An apparatus according to Claim 12 or 13, wherein the coil members are concentric.

15. An apparatus according to any one of the previous claims, wherein the forming coil device comprises coil members comprising two or more coils packed together.

16. An electromagnetic forming apparatus for forming an essentially planar metal plate into a dish having a three-dimensional pattern, the apparatus comprising:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

a forming coil device opposite and proximal to said forming surface comprising two or more coil members; the plate being accommodated between the forming coil and said forming surface; and

an electric discharge circuitry, comprising two or more discharge circuitries, one associated with each coil member, for discharging short and intense electric current pulses through the coil members to yield pulsed magnetic forming (PMF) forces for deforming said plate.

17. An apparatus according to Claim 16, wherein the electric discharge through each coil member by its associated unit is according to a predetermined discharge sequence.

18. An apparatus according to Claim 16 or 17, wherein each member is displaceable along an axis essentially normal to a plane defined by the metal plate.

19. An apparatus according to Claim 18, wherein each of said member is separately displaceable along said axis.

20. An apparatus according to Claim 19, wherein after deformation of the plate the coil members are displaced to a position corresponding to the shape of the plate after the deformation.

21. An apparatus according to any one of Claims 16-20, wherein the coil members are concentric.

22. An apparatus according to any one of Claims 16-21, wherein said device comprises coil members comprising two or more coils packed together.

23. An electromagnetic forming apparatus for forming an essentially planar metal plate into a dish having a three-dimensional pattern, the apparatus comprising:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

a forming coil device comprising one or more coil members, displaceable along an axis essentially normal to a plane defined by the metal plate;

an electric discharge circuitry, comprising two or more discharge circuitries, one associated with each coil member, for discharging short and intense electric current pulses through the coil members to yield pulsed magnetic forming (PMF) forces for deforming said plate.

24. An apparatus according to Claim 23, wherein the forming coil comprises an array of two or more coil members separately displaceable along said axis.

25. An apparatus according to Claim 23, wherein the electric discharge through each coil member by its associated unit is according to a predetermined discharge sequence.

26. An apparatus according to Claim 23 or 24, wherein after deformation of the plate the coil members are displaced to a position corresponding to the shape of the plate after the deformation.

27. An apparatus according to any one of Claims 23-25, wherein the coil members are concentric.

28. An electromagnetic forming apparatus for forming an essentially planar metal plate into a dish having a three-dimensional pattern, the apparatus comprising:

a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

a forming coil device opposite and proximal to said forming surface, and comprising one or more coil members having a size such that it covers only a portion of the plate to be deformed, the one or more coil members being displaceable in plane parallel to that of the plate;

an electric discharge circuitry for discharging a short and intense electric current pulse through each of the one or more coil members to yield a pulsed magnetic forming (PMF) force for deforming said plate.

29. A method for electromagnetic forming of a generally planar metal plate into a dish with a three-dimensional pattern, comprising:

(a) providing a mold having a forming surface with a contour corresponding to said three-dimensional pattern, and having edges corresponding to boundaries of the dish, which edges are defined by side walls essentially perpendicular to the forming surface;

(b) placing the metal plate over the forming surface of the mold;

(c) providing a forming device coil connected to an electric discharge circuitry, and placing it over said metal plate, the forming coil extending beyond the edges of said forming surface; and

(d) discharging a short pulse of an intense electric current through said coil to shear the plate along said edges and forcing other portions of said plate to assume a shape defined by said mold, thus obtaining said dish.

30. A method according to Claim 29, wherein the forming surface of the mold has a central concave depression defining and serving as a template for a central concave portion of the dish.

31. A method according to Claim 30, comprising removal of gasses from said depression.

32. A method according to Claim 31, comprising removal of gasses from said depression by means of a vacuum source.

33. A method according to any one of Claims 31or 32, wherein the dish is formed with a generally planar skirt portion.

34. A method according to Claim 33, wherein the skirt portion is formed with an annular groove.

35. A method of electromagnetic forming of a generally planar metal plate into a dish with a three-dimensional pattern, comprising:

(a) providing a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

(b) placing the metal plate over the forming surface of the mold;

(c) providing a forming coil device, comprising two or more forming coil members each of which being connected to an electric circuitry, and placing the forming coil device over said metal plate;

(d) discharging a short pulse of an intense electric current through said two or more coil members to deform said metal plate;

(e) displacing said coil members along said axis to a position corresponding to the shape of the plate after the deformation and repeating step (d);

(f) repeating step (e) until attainment of said three-dimensional pattern.

36. A method for electromagnetic forming of a generally planar metal plate into a dish with a three-dimensional pattern, comprising:

(a) providing a mold having a forming surface with a contour corresponding to said three-dimensional pattern;

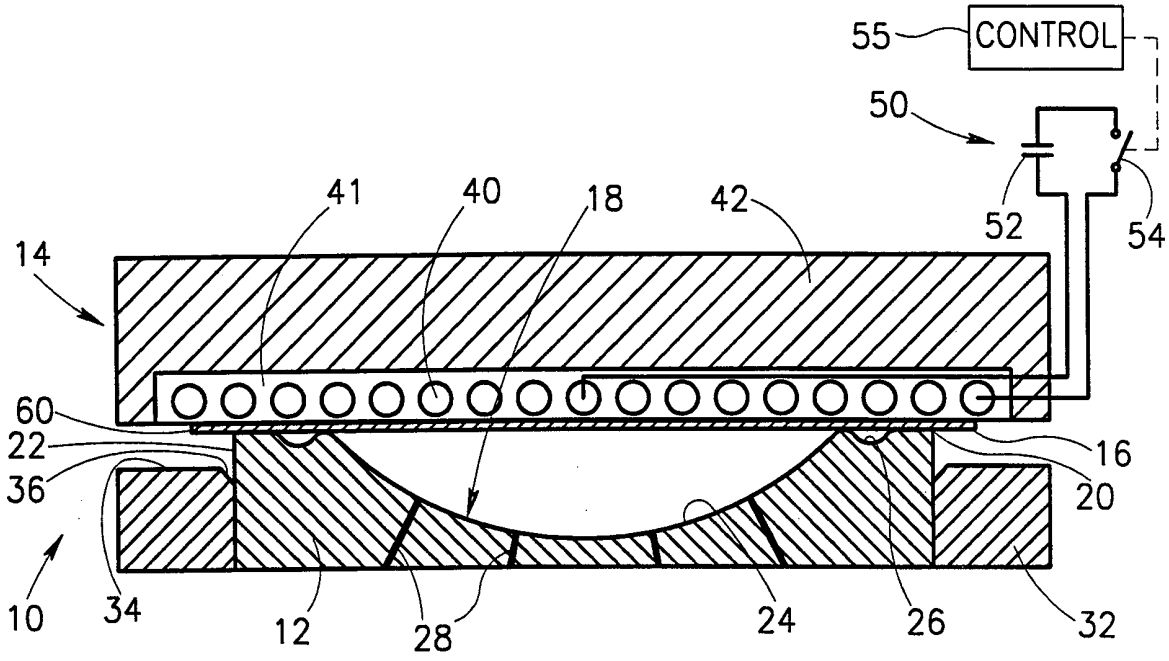
(b) placing the metal plate over the forming surface of the mold;

(c) providing a forming coil device which comprises one or more coil members having a size such that it covers only a portion of the plate to be deformed, the one or more coil members being displaceable in a plane parallel to that of the plate, and placing the forming coil device over said metal plate;

(d) discharging a short pulse of an intense electric current through said coil to deform portions of the plate opposite said forming coil device;

(e) laterally displacing said forming coil device and repeating step (d);

(f) repeating step (e) until said three-dimensional pattern has been attained.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CONTROL
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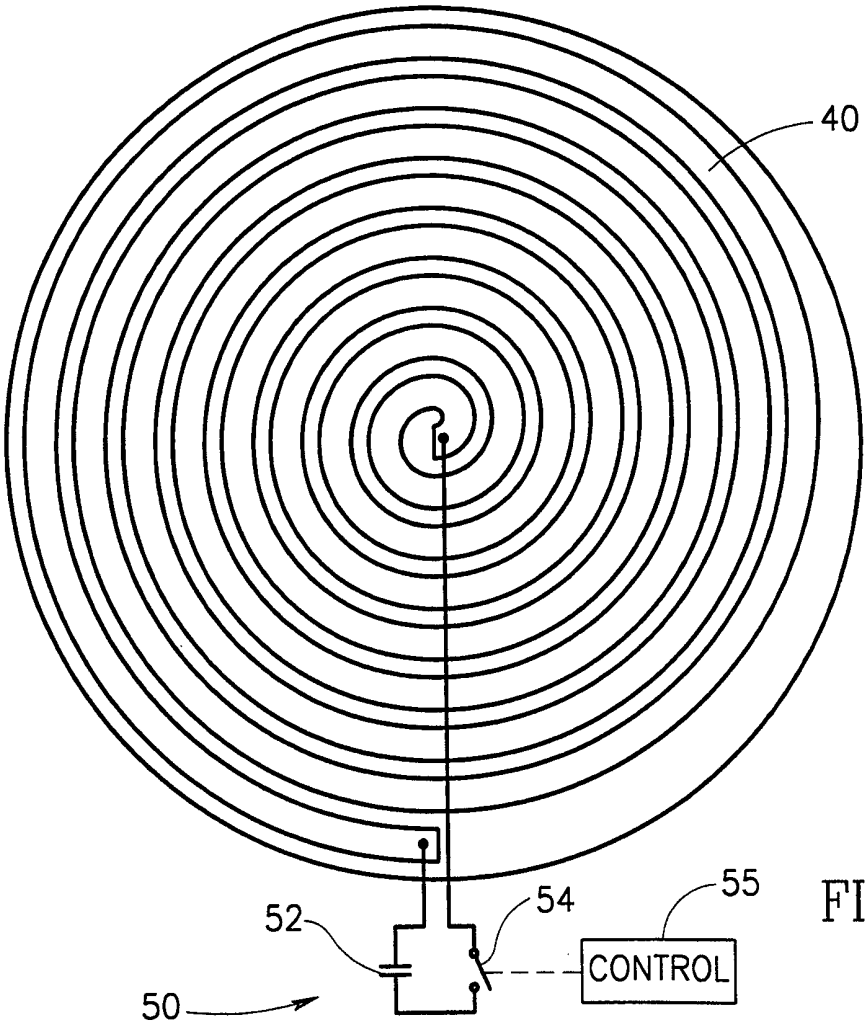
FIG.1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CONTROL
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FIG.2

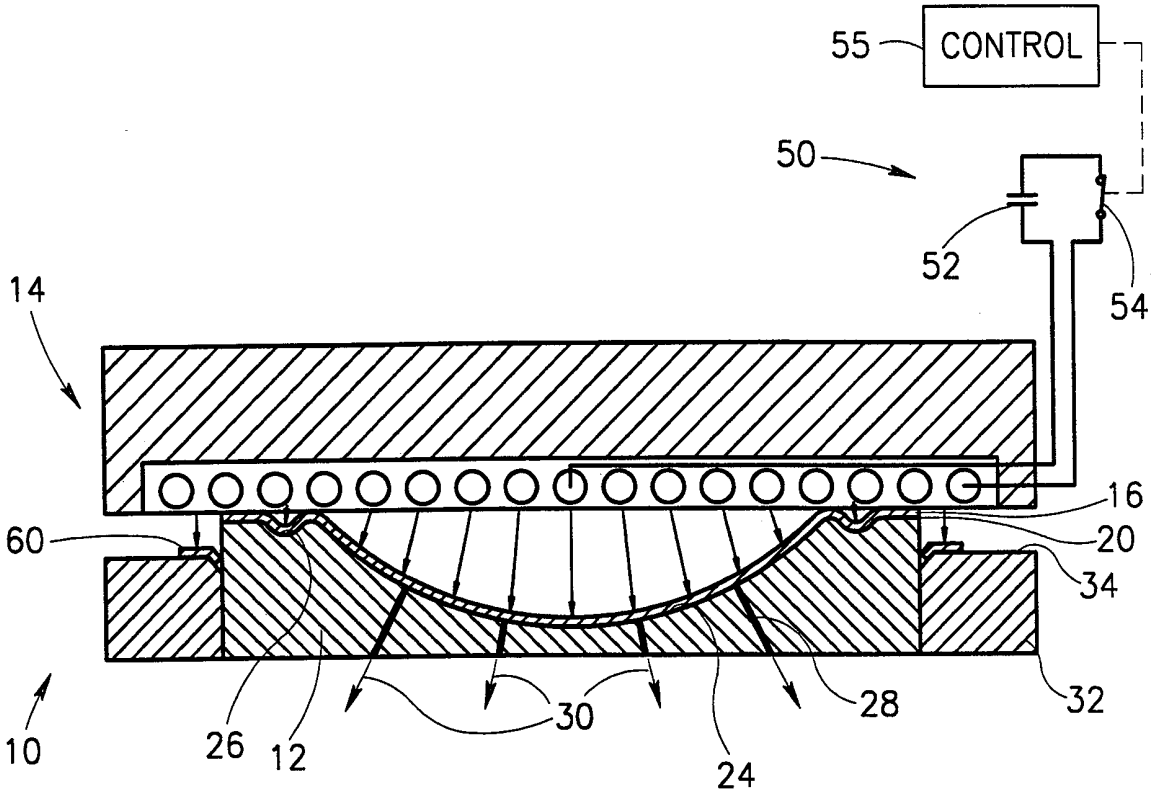


FIG.3

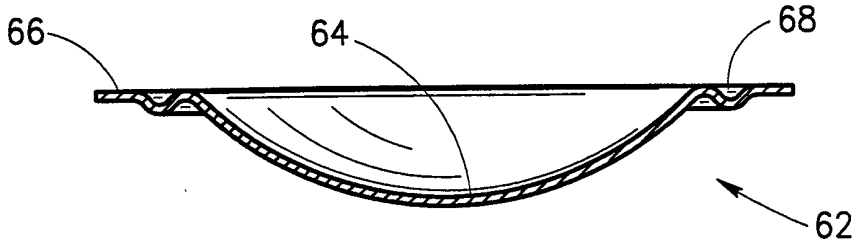


FIG.4

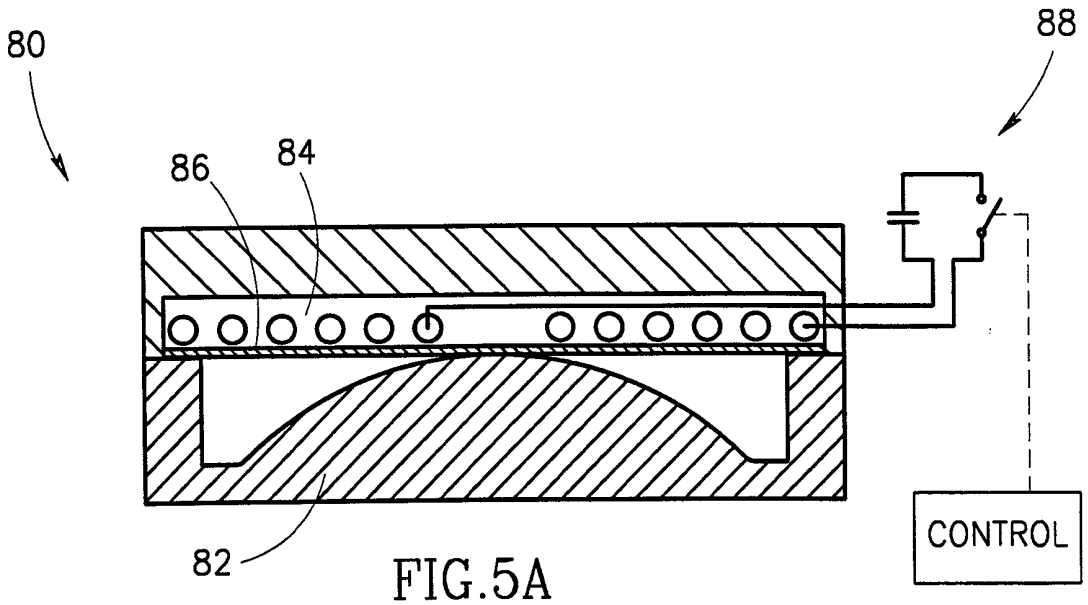


FIG.5A

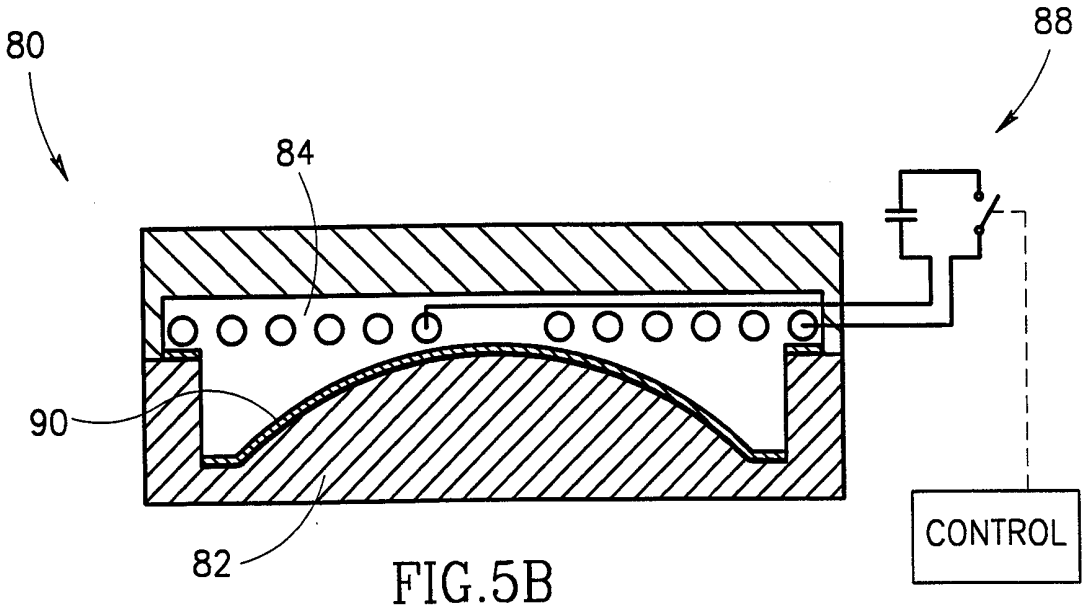
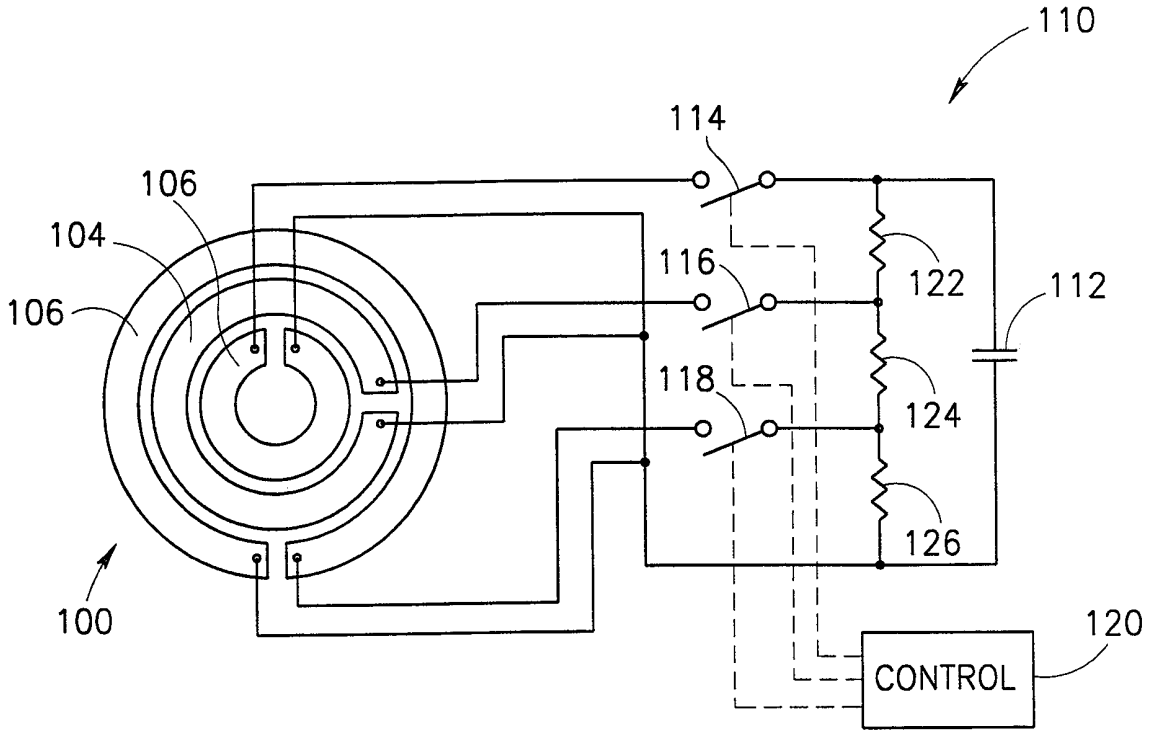


FIG.5B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CONTROL

FIG.6

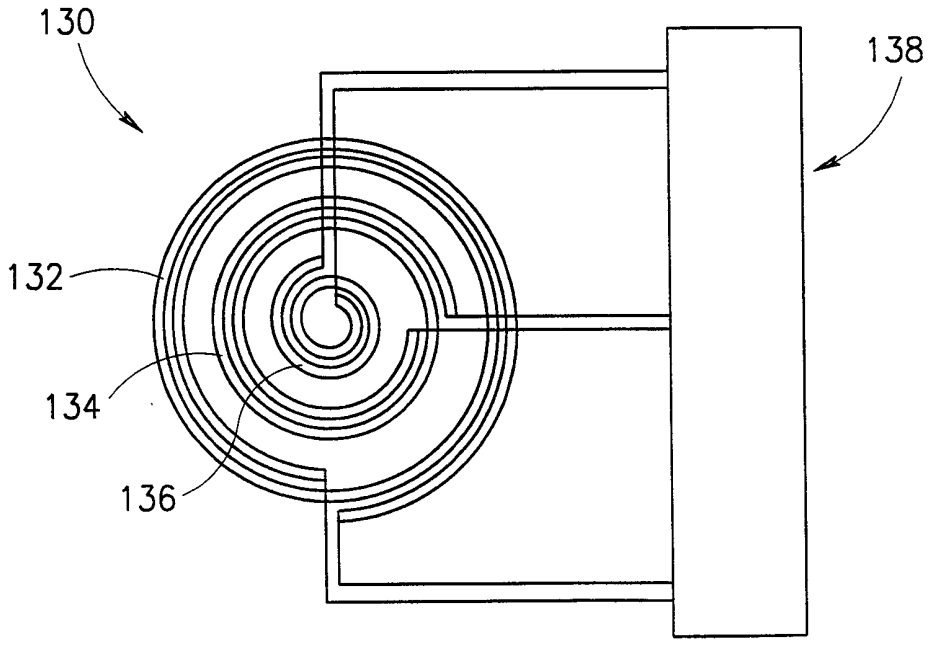
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FIG.7

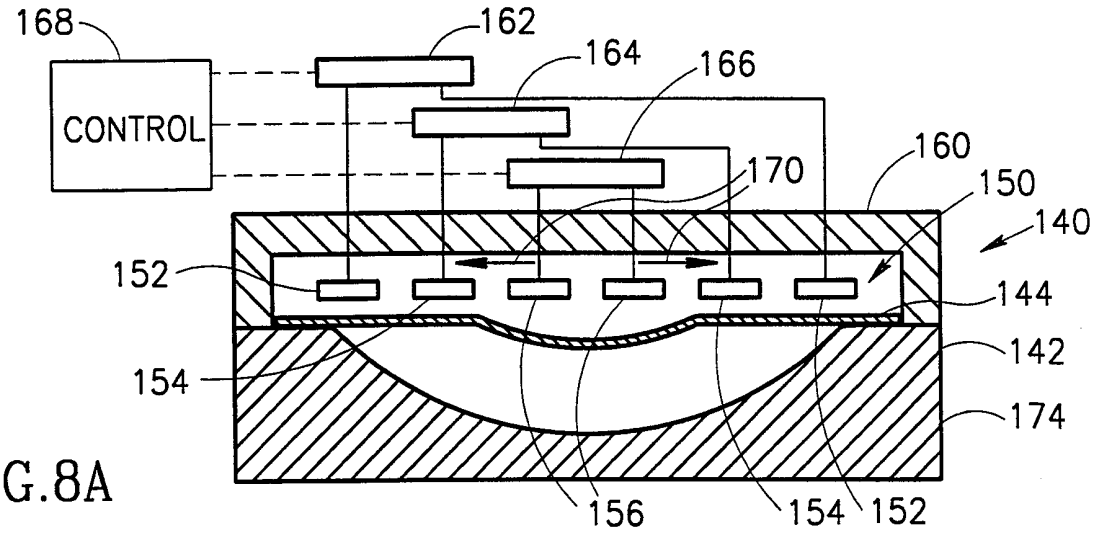

FIG.8A

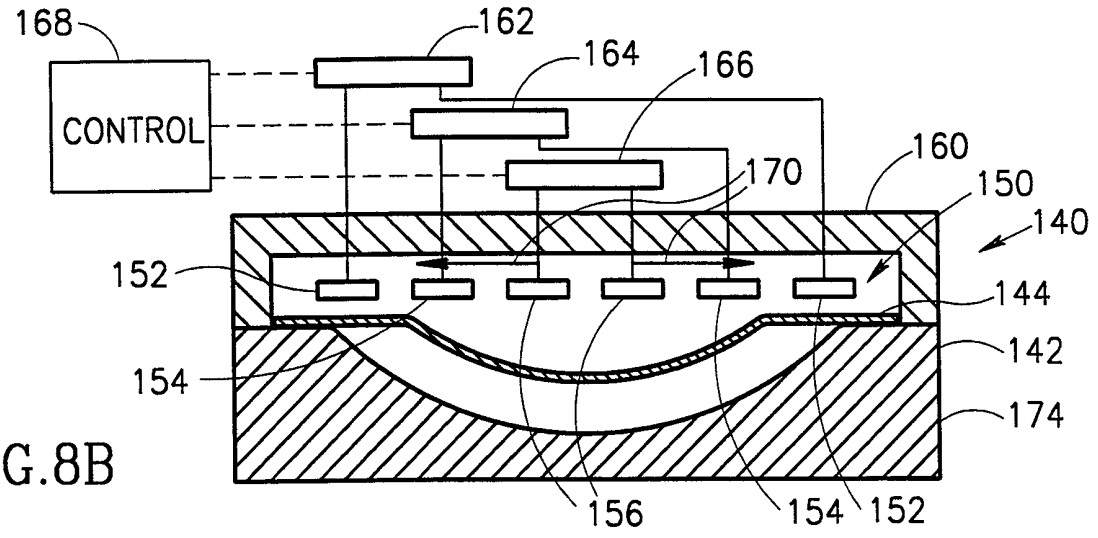

FIG.8B

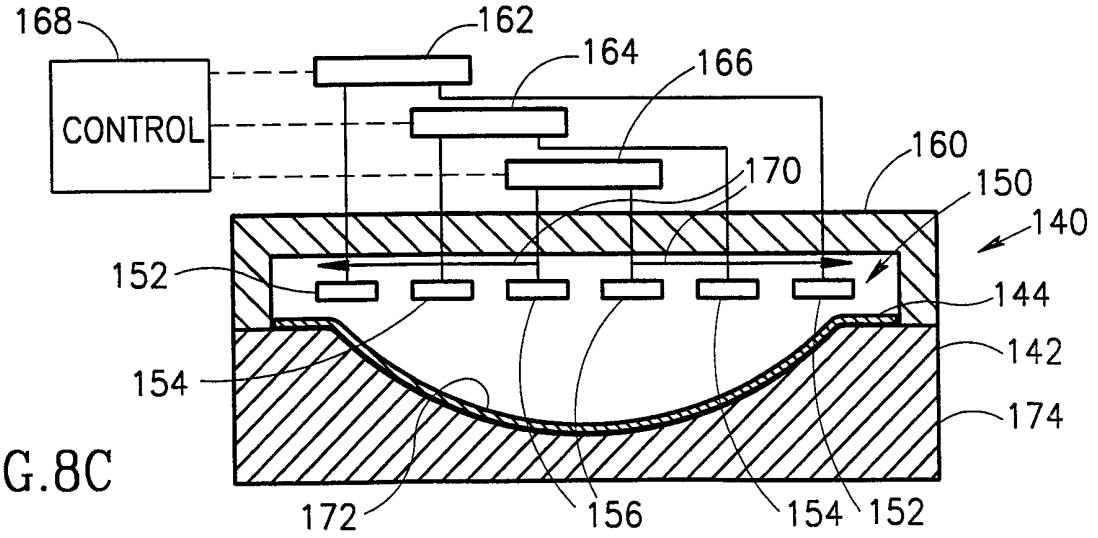

FIG.8C

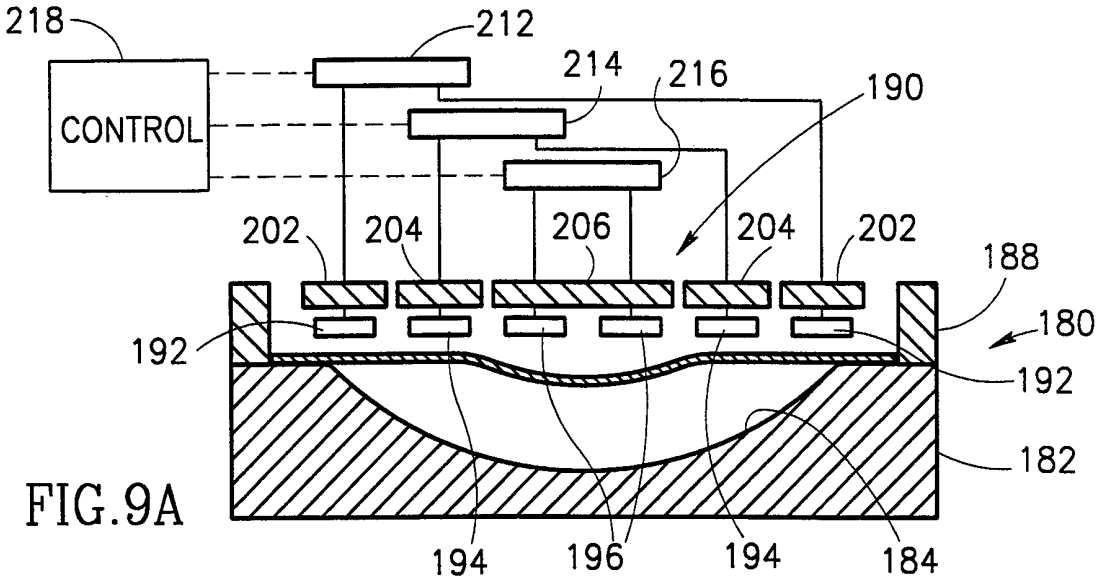

FIG.9A

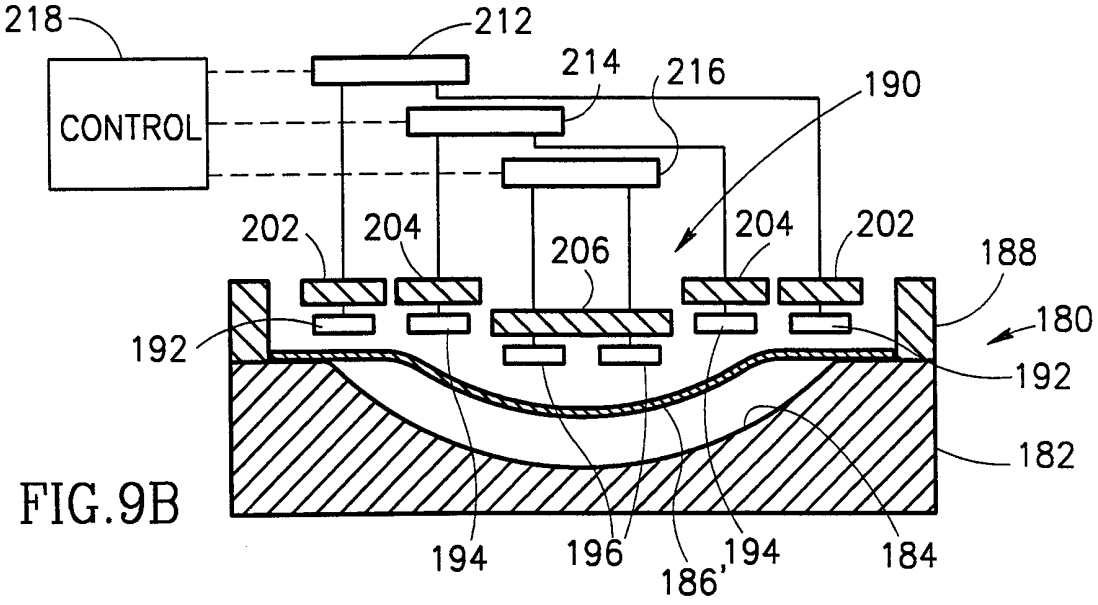

FIG.9B

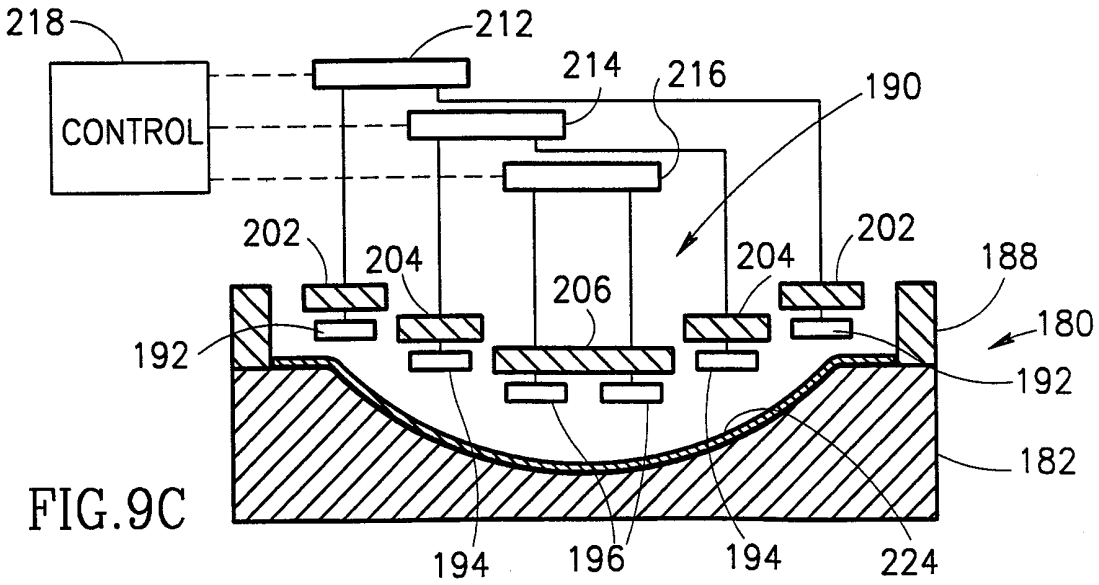

FIG.9C

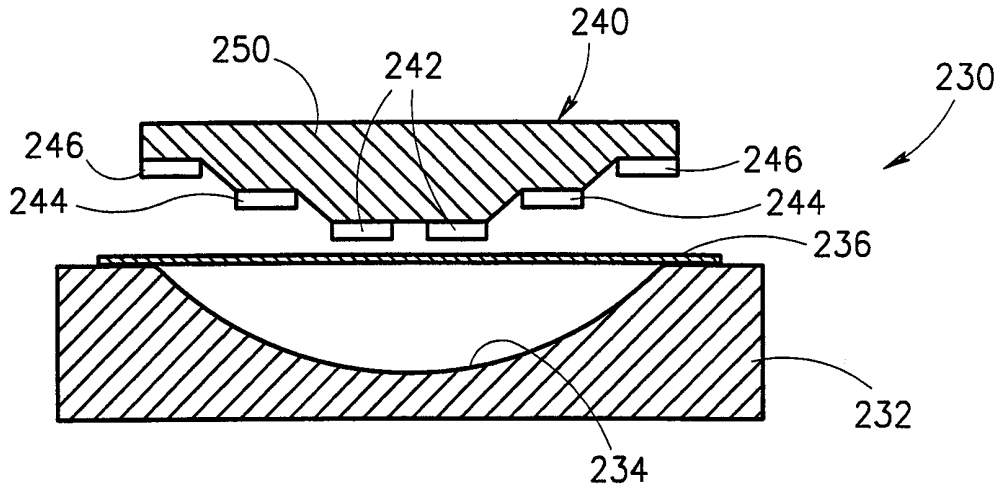

FIG.10A

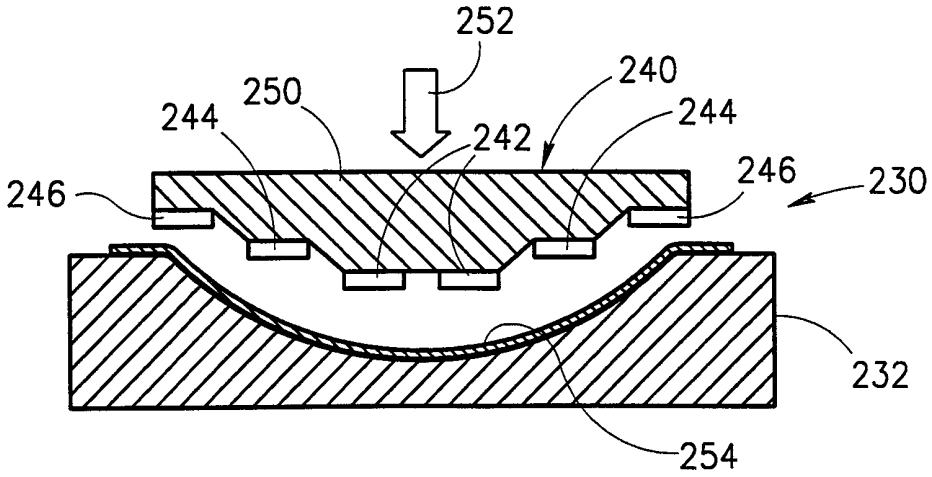

FIG.10B

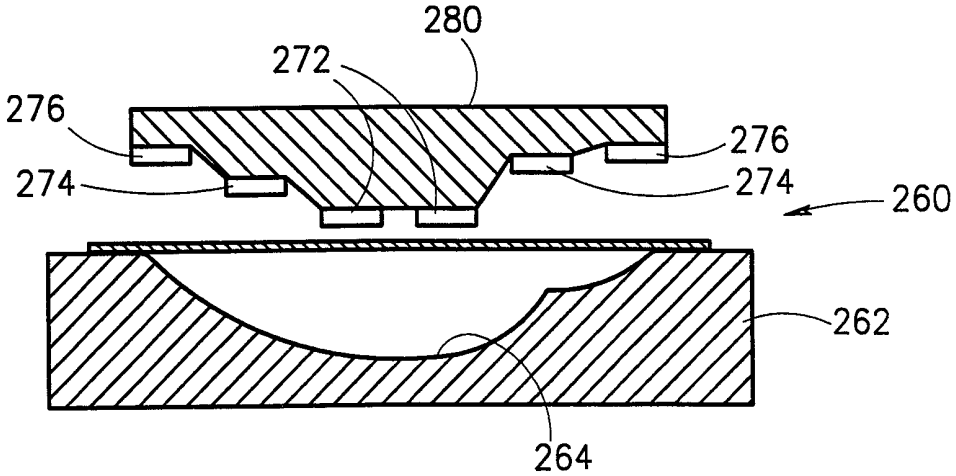

FIG.11

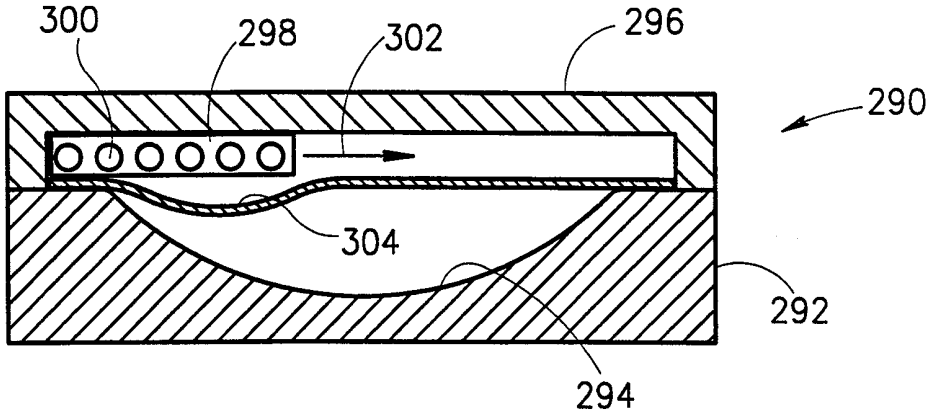

FIG.12A

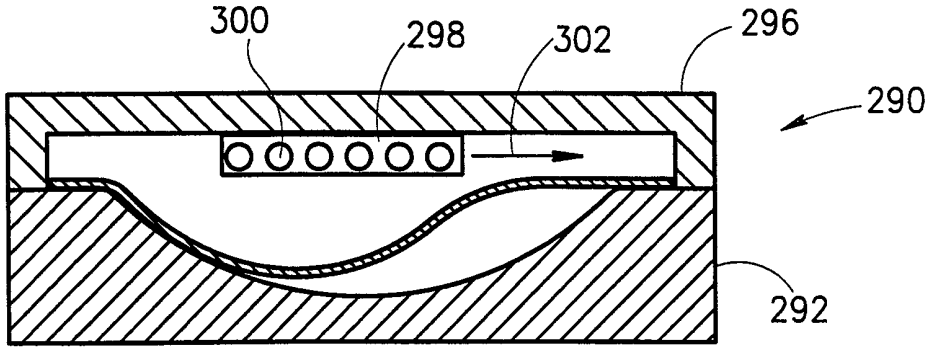

FIG.12B

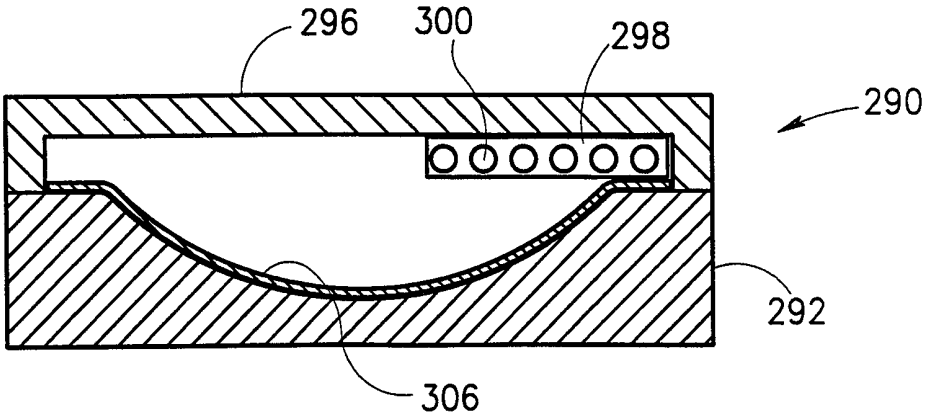

FIG.12C