NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

April 5, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,360,972

Corporate Source : Marshall Space Flight Center

Supplementary
Corporate Source : ____________

NASA Patent Case No.: XMF-03793

G Parker
Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

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N71-24833

Jan. 2, 1968 R. J. SCHWINGHAMER ET AL **3,360,972**

MAGNETOMOTIVE METAL WORKING DEVICE

Filed May 4, 1965 4 Sheets-Sheet 1

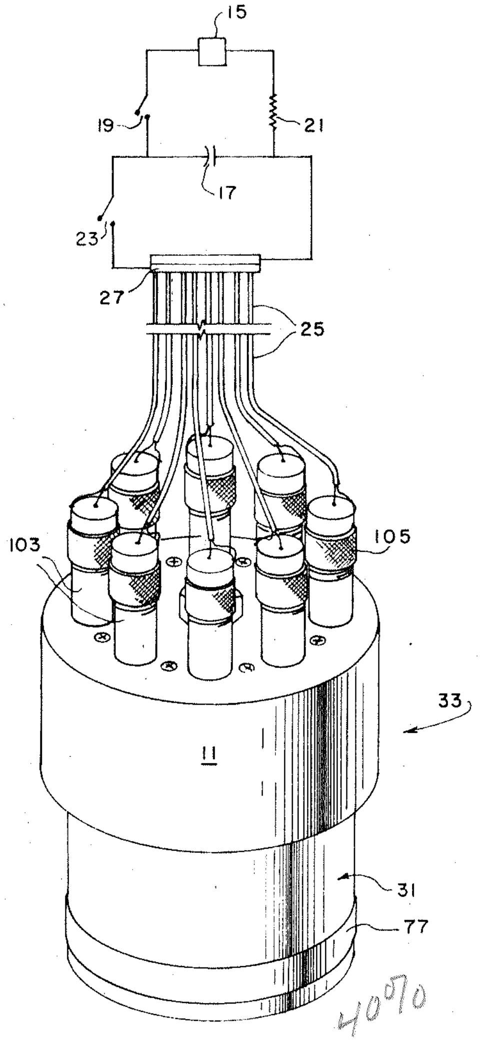

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FIG. 1

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MAGNETOMOTIVE METAL WORKING DEVICE

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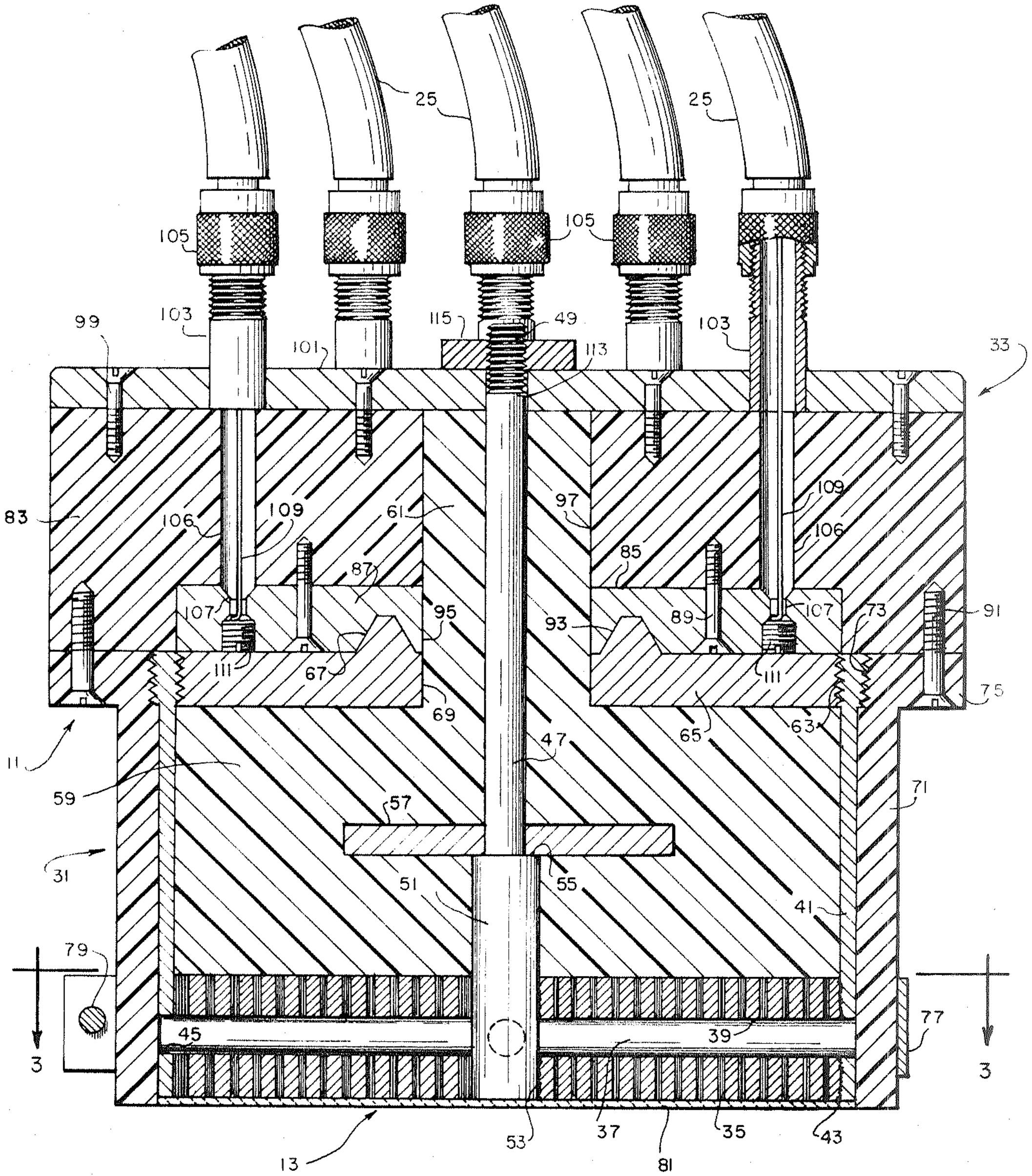

FIG. 2

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MAGNETOMOTIVE METAL WORKING DEVICE

Filed May 4, 1965 4 Sheets-Sheet 3

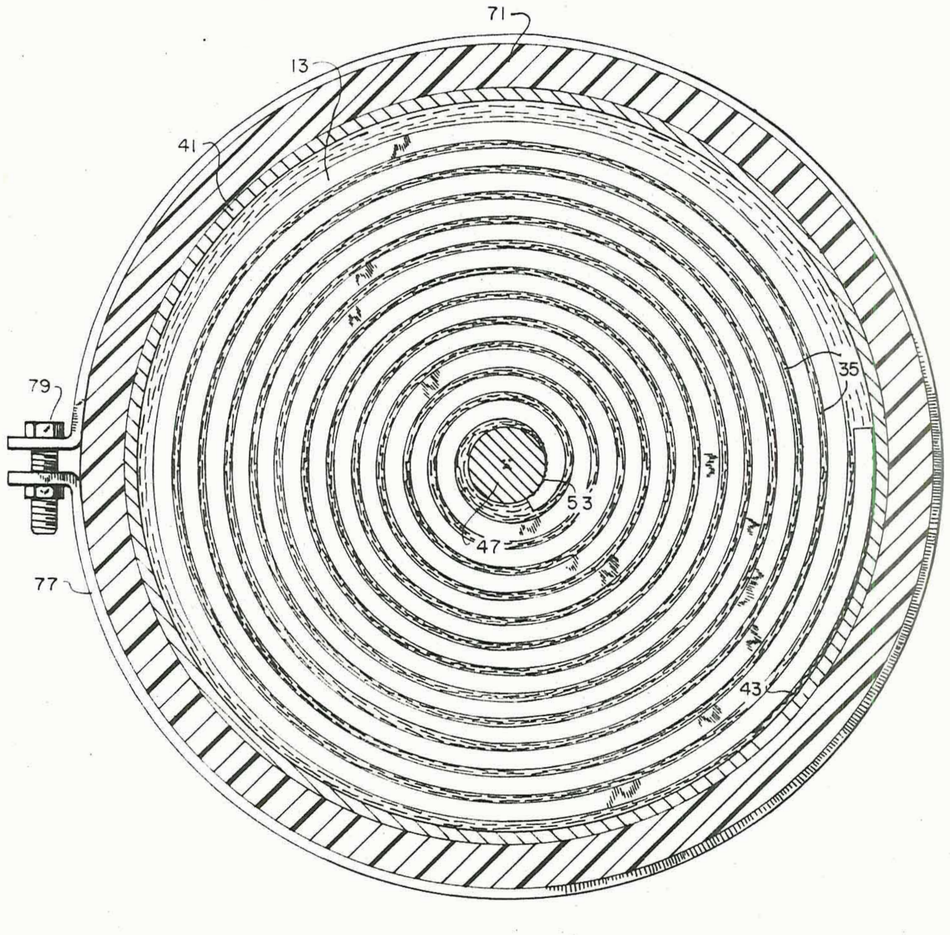

FIG. 3

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MAGNETOMOTIVE METAL WORKING DEVICE

Filed May 4, 1965 4 Sheets-Sheet 4

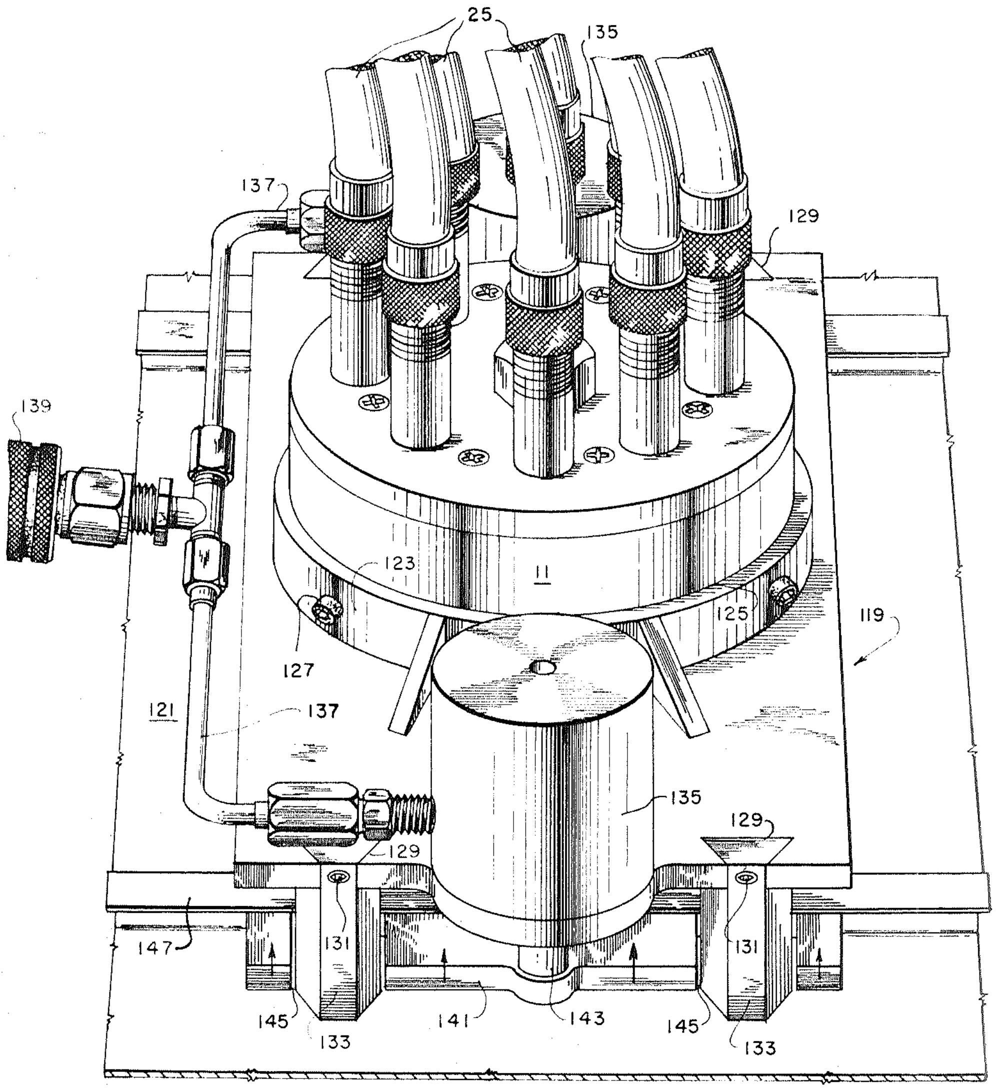

FIG. 4

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Patented Jan. 2, 1968

3,360,972

MAGNETOMOTIVE METAL WORKING DEVICE

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Filed May 4, 1965, Ser. No. 453,225
20 Claims. (Cl. 72—56)

ABSTRACT OF THE DISCLOSURE

A magnetomotive metal working portable "hammer" unit having a reinforced flat spiral coil at one end electrically connected to a pair of abutting metallic electrical contact plates with an insulation block separating the coil and the contact plates. The coil, insulation block and contact plates are housed in a shell of insulating material. The various components of the "hammer" are clamped together by an axial bolt extending from the center of the coil to the opposite end of the "hammer." Relatively long transmission lines connect the "hammer" to a power supply and electrical energy within the "hammer" passes through the contact blocks, coil and axial bolt.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to the field of metal working and particularly to a device for manipulating metallic material by the use of an intense transient magnetic field.

In recent years particularly, much effort has been devoted to seeking better tools and techniques for working sheet and plate metals to the shapes required. This working of metal to desired shapes, curves and contours involves a variety of operations such as sizing, blanking, flaring, stress removal and other operations which are well known in the art. Among the newly developed tools and techniques for performing metal working operations are those related to the sphere of activity known as electromagnetic forming or magnetomotive forming (MMF). This mode of manipulating metal is based on the creation, by electrical discharge, of an intense magnetic field about a shaped conductor, such as a coil, disposed adjacent the metal workpiece. An induced current is thus caused to flow in the workpiece in a direction opposite to that flowing in the coil. The field associated with this induced current reacts against the magnetic field around the coil producing intense forces between the coil and the metallic workpiece. If the coil has a degree of structural or inertial rigidity greater than the workpiece, a yielding of the workpiece under the magnetic forces will occur.

Working of metal with electromagnetic forces has several intrinsic and important advantages. The isostatic forces are distributed relatively uniformly through the material which is being manipulated, effecting a "natural" reshaping without causing appreciable change in the grain structure of the material. Very high strain rates may be achieved, affording heretofore impossible accomplishments in the forming of hardened materials. Surface marring of the workpiece, a bothersome aspect of more conventional forming techniques, can be avoided in magnetomotive forming. The entire operation is clean, dry, and easy to execute, and may be performed with apparatus essentially free of moving parts.

Although prior art devices and methods for magnetomotive forming offer inherent advantages in comparison to more conventional practices, relatively few tools suitable for specific job situations and applications have been introduced. Many times it is impractical or impossible to bring the workpiece to the metal forming equipment. For example, in the fabrication of large metallic structures, such as rocket vehicles, sizing, blanking, and stress removal operations are frequently required, and the great size and weight of the components prohibit movement and application of the components to the forming equipment. Therefore, a fully portable device is needed which not only can be readily moved into proximity to the workpiece but which can be applied directly to the particular workpiece area that is to be manipulated.

One particular metal working job which has heretofore been extremely difficult, if not impossible, is that of removing distortion from fabricated metallic components of rocket vehicles. Such distortion may occur during processing and handling of the components, and frequently results from the necessity of welding certain fittings into the components thus causing localized shrinking of the material. This type of distortion, unless removed, is often so severe as to render entirely useless a component costing many thousands of dollars.

Taking cognizance of the present state of the metal forming art, it has been found that in many instances the distortion of these rocket components can be satisfactorily removed only with a portable magnetomotive "hammer" embodying the present invention. It will become apparent that the present invention affords the capability of performing a wide range of other metal working operations.

Portable magnetomotive devices previously proposed suffer from a number of serious drawbacks. The magnetic coils incorporated in these devices have deteriorated quite rapidly, even after relatively few applications. The quantity of energy delivered by previous devices was deficient, variable and unpredictable from one discharge to the next. Electrical arcing from the metal housing of these devices to the workpiece was often intolerable because of the attendant danger and marring of the workpiece. These objectionable features of previous devices have been found to be largely attributable to certain defects relating to the structural systems employed therein, including the selection and arrangement of materials and the manner of effecting internal electrical contacts.

Therefore, it is a general object of the present invention to provide a compact, lightweight and highly portable magnetomotive metal working device which is durable, dependable and efficient, and capable of performing a wide range of tasks.

A more specific object of the present invention is to provide an electromagnetic metal working device which may be easily carried appreciable distances from its power source and applied directly to a workpiece area requiring manipulation, and successfully perform the required manipulation without the aid of dies or similar tooling, although such backup tooling can be resorted to, if desired.

A further object of the invention is to provide a magnetomotive "hammer" incorporating a unique structural system which imparts the necessary rigidity to the electromagnetic coil of the "hammer" and assures a constant and positive electrical contact between the coil and the transmission lines extending between the "hammer" and its power source.

Another object of the invention is to provide a magnetomotive "hammer" which repeatedly delivers an adequate and precisely predictable amount of energy useful and controllable for metal working operations.

Briefly, the invention comprises a portable, compact, and lightweight "hammer" unit which is connected to an electric power supply through relatively long transmission lines. The "hammer" unit includes a multi-turn coil mounted at one end of a housing shell. The turns of the coil are separated by insulating material and the entire coil is strengthened by incorporating therein a medium for interlocking the turns. Electrical contact from the center turn of the coil is through a heavy bolt extending axially through the "hammer" from the coil center. Electrical contact from the outer turn of the coil is through a metallic element connected to the outer turn of the coil at one end and to a metallic contact block at the other end.

The space between the coil and the contact block, not occupied by the axial bolt, is filled with an insulating material such as Teflon. Bearing upon the first contact block is a second contact element which is connected to one conductor of each of the transmission lines going to the power supply. The second conductor of each of the transmission lines is connected, as by connecting studs, to a metallic plate which constitutes the top element of the "hammer" unit, with an insulating material separating this top plate from the second contact element. All of the elements of the "hammer" unit are firmly clamped together by the axial bolt which receives a nut at its upper end that bears on the top plate. This structural system insures a rigid coil and a constant and positive electrical contact from the coil to the transmission lines.

To prevent possible arcing between the "hammer" and the workpiece the "hammer" unit is encased in a shell of insulating material.

According to one aspect of the invention, the "hammer" unit is equipped with a device for clamping the "hammer" unit to the workpiece thereby eliminating the necessity of manually holding the "hammer" against the workpiece.

FIGURE 1 is a schematic perspective view of a magnetomotive metal working device including a diagram of a circuit for supplying and controlling electrical energy for the metal working device.

FIGURE 2 is a cross sectional view of the metal working device of FIGURE 1.

FIGURE 3 is a cross sectional view taken along line 3—3 of FIGURE 2.

FIGURE 4 is a perspective view of the metal working device equipped with an apparatus for clamping it to a workpiece.

Referring now to FIGURE 1, therein is shown a magnetomotive metal working "hammer" unit **11**, a principal component of which is a flat spiral coil **13** (FIGURE 2). A system is provided for supplying and controlling pulses of electrical energy so as to produce a varying magnetic field of high intensity about the coil. This system includes a high-voltage source **15** for charging a capacitor bank **17**. Connected in series with the voltage source **15** are switch **19** and a current limiting resistor **21**. A switching means **23**, such as an ignitron, is connected in series with the capacitor bank. The electrical energy system is connected to the "hammer" **11** by a plurality of transmission lines **25**, preferably coaxial cables, which enter the electrical energy system through a connector box **27**. It is desirable that the transmission lines **25** be quite long, extending about 45 feet in one embodiment, so that the "hammer" unit, which is very light and easily carried, may be taken a substantial distance from the power supply to the location of the workpiece. In order to use long transmission lines without impairing the efficiency of the electrical circuit, it is essential that a near optimum inductance ratio exist between the coil inductance and the inductance in the circuitry external to the coil. This ordinarily means that the coil should have a relatively large number of turns and have a moderately high inductance relative to the external circuitry. In addition, it is desirable for the electrical impulse to be delivered over a relatively longer period of time, when long transmission lines are used. To minimize the inductance of the transmission lines, specially constructed coaxial cables may be used in which the inner conductor comprises a metallic sheath surrounding a polyethylene insulating core, and the outer conductor comprises a metallic sheath surrounding a polyethylene insulator separating the two conducting elements.

Referring to FIGURE 2, the "hammer" unit **11** comprises two distinct subunits designated as a coil assembly **31** and a shell assembly **33**, the latter being mounted atop the former. The coil assembly **31** includes the coil **13** which is wound from a fairly thin and narrow strip of electrical conducting material such as beryllium copper. In one embodiment of the invention the coil constituted approximately 14 turns wound from a 3/16" x 1½" x 210" strip of Berylco "25." To assure electrical insulation between the turns of the coil, a strip of special insulating material **35** such as Mylar is interposed between the coil turns.

In the design of the coil **13**, somewhat conflicting requirements are evidenced. First, it is essential that the coil be structurally rigid to withstand the intense magnetic pressures exerted between it and the workpiece. It is apparent that these pressures tend to cause a displacement of "shucking out" of the coil turns from their coplanar positions. Therefore, from the standpoint of giving rigidity to the coil and of minimizing the resistance of the coil winding, the use of a coil conductor of relatively large cross sectional dimensions would be indicated. However, it is beneficial in some respects to use a coil conductor of rather narrow and thin cross section in order to give the finished coil a compact diameter and thickness while at the same time permitting a sufficient number of coil turns to produce an adequate magnetic field density. To satisfy the objects of structural rigidity as well as compactness of the coil, a relatively thin and narrow conductor is used but with a strengthening system comprising high-strength, nonconductive rods **37** extending radially at 90° intervals from the center of the coil, these rods being disposed in passageways **39** passing through the coil turns to thereby interlock the coil turns and prevent any of them from "shucking out."

Two alternative solutions also apply. The coil conductor can have milled slots which, while equally spaced, occur at random in the finished coil. The potting material fills these slots during vacuum potting, thereby providing a strong conductor retaining force. The other alternative provides for retaining force by virtue of polyurethane potting material which covers the conductors and the Mylar insulating material on the face of the coil. The Mylar is deliberately left slightly short to facilitate the forming of the polyurethane "end plate" so-to-speak.

The coil **13** is housed within a cylindrical electrically conducting element **41** with the bottom surface of the coil positioned substantially flush with the lower end of the element **41**. An electrical connection **43** is made, as by brazing, between the outer turn of the coil **13** and the inner surface of the conducting element **41**. To strengthen the connection between the coil **13** and the element **41** the rods **37** extend through holes **45** of the element **41** and terminate flush with the outer surface thereof.

Electrical contact from the center of the coil **13** is through a relatively large bolt **47** which extends axially through the "hammer" **11** and has a threaded upper end **49**. The bolt **47** has a lower portion **51** of a diameter approximately the same as the inside diameter of the inner turn of the coil **13** into which the portion **51** is inserted and connected at **53** as by brazing. About midway between the upper and lower ends of the cylindrical element **41**, the diameter of the bolt **47** changes, forming a shoulder **55**. A retaining ring **57** encircles the bolt **47** and bears on the shoulder **55**. This ring prevents "pulling in" of the coil center conductors.

From the upper surface of the coil **13** to its threaded upper end **49**, the bolt **47** is embedded in a block of insulating material **59**, such as Teflon. This insulating block bears on the upper surface of the coil **13** and substantially fills the cylindrical element **41** and includes a portion **61** of reduced diameter which rises above the cylindrical element **41** and terminates at the threaded end **49** of the bolt **47**. Although the insulating block **59** may be preformed in separate pieces and applied to the bolt **47** and retaining ring **57**, it is preferable that the block be cast in one piece around the bolt and retaining ring **57** thereby producing an integral and more rigid assembly.

At the upper end of the cylindrical element **41** are internal threads **63** for threadedly engaging an electrically conducting contact block **65**. The contact block **65** has a concentrically disposed buttress **67**, and a central hole **69** through which the portion **61** of the insulating block **59** passes.

For completing the housing of the "hammer," an insulating shell **71**, with Teflon again being a very suitable material, covers the entire external surface of the cylindrical element **41**. This is extremely important, and prevents arcing to the workpiece due to induced voltages. The shell **71** and the cylindrical element **41** are threadedly joined at **73**. At its upper end the shell **71** has a laterally projecting circumferential flange **75**. To further strengthen and rigidify the "hammer" in the coil region a stainless steel clamp band **77** provided with a clamp bolt **79** is applied around the shell **71** opposite the coil **13**. Induction losses are fare less in stainless steel than in good electrical conductors.

All surfaces of every turn of the coil **13**, except those surfaces electrically connected to the bolt **47** and the cylindrical element **41**, are covered with insulating potting **81**. This is assured by vacuum potting the coil, and during the potting process the potting material flows between the coil turns and around the insulating strip **35** as well as the strengthening rods **37**.

The coil potting process is preferably performed after the other components of the coil assembly **31** have been assembled so that the potting **81** will also flow into engagement with adjacent surfaces of the bolt **47**, insulating block **59**, cylindrical element **41** and the shell **71**. This causes the coil to be bonded to the adjacent elements and therefore more integrated and firmly set in the assembly. A good material for potting the coil is one produced by Product Research Corporation under the designation "PRC 1538 with Metal Primer PR–1531." The potting **81** serves as an excellent insulator and also has a reasonably high tensile and shear strength thus increasing the overall rigidity of the coil.

The shell assembly **33** is mounted on the coil assembly **31** and comprises an insulating block **83** having a recess **85** therein which receives a "hot" contact plate **87**. Connection between insulating block **83** and the conductor plate **87** is through screw **89**. The periphery of the insulating block **83** coincides with the periphery of the flange **75** and connecting screws **91** extend through the flange **75** into the insulating block **83**. The "hot" contact plate **87** is coextensive with the contact block **65** and is provided with a circular groove **93** which mates with the buttress **67** of the contact block. Aligned holes **95** and **97** in the contact plate **87** and the insulating block **83**, respectively, are occupied by the portion **61** of the insulating block **59**.

Covering the top of the insulating block **83** and joined thereto by screws **99** is a metallic ground plate **101**. Integral with the ground plate **101** are connecting studs **103**, each having a threaded end engaging a threaded connector sleeve **105** of a coaxial cable **25**. Each of the connecting studs **103** is axially aligned with a passage **106** through the insulating block **83** and with an aperture **107** in the contact plate **87** thus permitting an inner conductor **109** of each coaxial cable **25** to extend to and be clamped by a set screw **111** in the contact plate **87**.

The axial bolt **47** passes through a hole **113** in the center of the ground plate **101** and receives a nut **115** which bears on the ground plate **101**. The necessary torque is applied to the nut **115** to bind and pull together the coil assembly **31** and the shell assembly **33**. All of the components of the "hammer" are thus firmly bound and clamped into a very rigid, compact unit. The electrical circuit within the "hammer" unit **11** is through conductors **109**, contact plate **87**, contact block **65**, cylindrical element **41**, coil **13**, bolt **47**, nut **115**, ground plate **101**, studs **103** and sleeves **105**. The ground plate **101**, contact plate **87**, contact block **65** and the cylindrical element **41** are preferably made of a soft metal such as brass.

To avoid a defect of previous devices a multiplicity of contact screws or simple, but poorly performing flat contacting surfaces, are not depended on for conducting current, but rather contact is through the broad area of the contact block **65** and buttress **67**, and the contact plate **87**, with mating groove **93**. Positive electrical contact between these elements is assured due to the compressive force exerted thereon through the axial bolt **47** and the retaining ring **57**. The pressure fit of the circular buttress **67** into the mating groove **93** further enhances the rigidity of the joint between the shell assembly **33** and the coil assembly **31** as well as the electrical contact between the contact block **65** and the contact plate **87**.

The unique structural arrangement of the "hammer" described above imparts the necessary rigidity to the "hammer" and its coil to give durability to the device. Moreover, the quantity of the metal working energy delivered by the "hammer" is adequate, controllable, repeatable and predictable due to the above described means of providing constant and positive electrical contact and conduction within the "hammer."

The occurance of electrical arcing between the housing of the "hammer" unit and the workpiece is eliminated in the present invention. Previous devices utilized all metal housings around the coil and when the coil was applied to the workpiece a danger existed of arcing from the housing to the workpiece and into the coil since there was a difference of potential between the housing and the coil conductor. Even though the coil was well insulated, eddy currents generated from the coil into the metal housing sometimes arced from the housing into the workpiece. As indicated previously herein, this arcing from the housing to the workpiece is extremely objectionable not only as a safety hazard but because it facilitates complete coil breakdown and surface marring of the workpiece and undesirable loss of energy. If the coil is fabricated using only plastic or epoxies, the resulting structure is entirely inadequate with regard to burst strength at high energy levels. In the present invention arcing from the housing to the workpiece is eliminated by the provision of an insulating exterior for the "hammer."

As shown in FIGURE 4, the "hammer" may be equipped with a quick release clamping device **119** for holding the "hammer" unit to a workpiece **121**, thereby eliminating the necessity of manually holding the "hammer" against the workpiece. The clamping device includes a frame **123** having an opening **125** therein encircling the "hammer" and being releasably secured to the "hammer" by set screws **127**. At opposite ends of the frame **123** are dovetail grooves **129** in which are releasably fixed by set screws **131** guides **133**. Mounted on the frame **123** between grooves **129** are cylinders **135** each containing a piston (not shown) which may be operated, pneumatically, for example, with air pressure being supplied through tubes **137** and **139**.

The piston actuates a clamping bar **141** through a rod **143**. The clamping bar **141** engages and slides along the guides **133** through slots **145**.

The clamp device **119** may be used to position the "hammer" unit **11** between projections, such as stiffening tees **147** of the workpiece **121**. Components of the clamp device are easily removable from the frame **123** which may be more or less normally secured to the "hammer" **11** and used to facilitate handling of the "hammer" during operation when the clamp device is not used.

It is apparent from the above that by employing the teachings of the present invention a greatly improved magnetomotive metal working device may be produced than has heretofore been obtainable. It is also apparent that the invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

What is claimed is:

1. A magnetomotive metal working device comprising:
   (a) a hammer unit, said hammer unit comprising:
      (1) a coil conductor having a plurality of coplanar spiral turns disposed adjacent one end of said hammer unit;
      (2) a pair of abutting electrical contact elements electrically connected to said coil conductor;
      (3) solid insulating means disposed between said coil conductor and said pair of contact elements;
      (4) means for clamping said coil conductor, insulating means and contact elements together to form a rigid assembly;
      (5) said clamping means comprising a bolt extending axially of said hammer unit and having one end thereof connected to said coil;
   (b) a high-voltage source;
   (c) means for connecting said high-voltage source to said hammer unit.

2. The device of claim 1 including means for strengthening said coil, said strengthening means including means passing transversely through said turns to interlock said turns in said coplanar relation.

3. The device of claim 1 wherein said connecting means comprises a plurality of substantially coextending coaxial cables.

4. The device of claim 1 wherein said hammer unit comprises an exterior insulating shell in the region of said coil conductor.

5. The device of claim 1 including quick release means for holding said hammer unit to a workpiece.

6. A portable hammer unit for electromagnetic metal working comprising:
   (a) a conducting coil having a plurality of coplanar spiral turns;
   (b) a pair of abutting metallic plate elements electrically connected to said conducting coil;
   (c) a block of insulating material disposed between said coil and said pair of plate elements;
   (d) means for clamping said conducting coil, insulating block and plate elements together to form a rigid assembly;
   (e) said coil, insulating block and contact plates having a common axis.

7. The hammer unit of claim 6 wherein said clamping means comprises a bolt disposed along said common axis.

8. The hammer unit of claim 6 wherein 6 wherein said abutment of said pair of plate elements includes a mating rib and groove engagement.

9. The hammer unit of claim 6 wherein said plate elements are made of a soft metal.

10. A portable hammer for electromagnetic metal working comprising:
   (a) a housing;
   (b) a conducting coil having a plurality of turns mounted within said housing adjacent one end thereof;
   (c) means for delivering electrical current through said coil;
   (d) said means including a pair of metallic contact elements within said housing with each of said elements having a contact surface abutting a contact surface of the other element;
   (e) means extending through said contact elements for clamping said contact elements together thereby assuring a constant and positive electrical conduction through said contact elements;
   (f) said clamping means extending through said contact elements comprising a bolt extending axially of said housing and having one end thereof connected to said coil.

11. A portable hammer as defined in claim 10 including means releasably secured to said hammer for releasably holding said hammer to a workpiece.

12. A portable hammer as defined in claim 10 wherein said housing includes an insulating exterior shell in the region of said coil.

13. A portable hammer as defined in claim 10 wherein said turns of said coil are coplanar with strengthening means passing transversely through said turns to interlock said turns in said coplanar relation.

14. A portable hammer for magnetomotive metal working comprising:
   (a) a coil assembly and a shell assembly;
   (b) said coil assembly comprising:
      (1) a tubular housing element;
      (2) a conducting coil having a plurality of coplanar spiral turns with insulating means disposed between said turns;
      (3) said coil being mounted adjacent one end of said housing element;
      (4) a bolt extending axially of said housing element and having one end thereof connected to said coil;
      (5) a contact block joined to said housing element adjacent the end thereof opposite said coil;
      (6) a conducting element extending between said coil and said contact block;
      (7) insulating means contained within said housing element and extending between said coil and said contact block;
   (c) said shell assembly comprising:
      (1) a contact plate abutting said contact block of said coil assembly;
      (2) a ground plate overlying said contact plate;
      (3) an insulating element separating said contact plate and said ground plate;
   (d) said bolt of said coil assembly extending through said coil assembly and said shell assembly;
   (e) means including and associated with said bolt for clamping said coil assembly and said shell assembly together into a rigid, compact unit.

15. A portable hammer as defined in claim 14 wherein said coil and contact block of said coil assembly have a common axis which axis is common with an axis of said shell assembly and wherein said bolt is disposed along said axis.

16. An electromagnetic metal working device comprising:
   (a) a portable hammer;
   (b) a high-voltage source for supplying electrical energy to said hammer;
   (c) means including a transmission line for connecting said power supply to said hammer;
   (d) said hammer comprising:
      (1) a conducting coil having a plurality of coplanar spiral turns with insulating means disposed between said turns;
      (2) means passing transversely through said coil turns to interlock said turns in said coplanar relation;
      (3) a tubular conducting element;
      (4) said coil being mounted within and adjacent one end of said tubular conducting element with the outer turn of said coil being electrically connected to said element;
      (5) a bolt having a portion thereof axially disposed within said tubular element with one end of said bolt being connected to the innermost turn of said coil;

(6) said portion of said bolt within said cylindrical element bearing a laterally projecting retaining element;

(7) a metallic contact block electrically connected to said tubular element adjacent the end thereof opposite said coil;

(8) solid insulating material contained within said tubular element and extending between and abutting said coil and said contact block;

(9) said retaining ring and the portion of said bolt bearing said retaining ring being embedded in said insulating material;

(10) a metallic contact plate having a contact surface abutting the surface of said contact block;

(11) said contact block and said contact plate having aligned central holes therethrough through which passes said bolt;

(12) means for electrically connecting said bolt and said contact plate to said transmission line;

(13) means including said bolt for clamping said coil, insulating material, contact block and contact plate together to form a rigid unit;

(14) an insulating shell substantially covering the external surface of said tubular element.

17. The device as defined in claim **16** wherein a clamp band surrounds said shell in the region thereof opposite said coil.

18. The device as defined in claim **16** wherein said transmission line has a minimum length of 12 feet whereby said hammer may be carried and operated an appreciable distance from said high-voltage source.

19. The device as defined in claim **16** wherein said cylindrical element, contact block and contact plate are made of a soft metal.

20. The device as defined in claim **16** including means comprising a potting material for binding together the turns of said coil and for binding said coil to said tubular conducting element and said insulating shell.

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