Jan. 19, 1971 D. J. ROTH 3,555,866

ELECTROPNEUMATIC AND ELECTROHYDRAULIC RE-FORMING OF TUBING AND THE LIKE

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FIG. 1

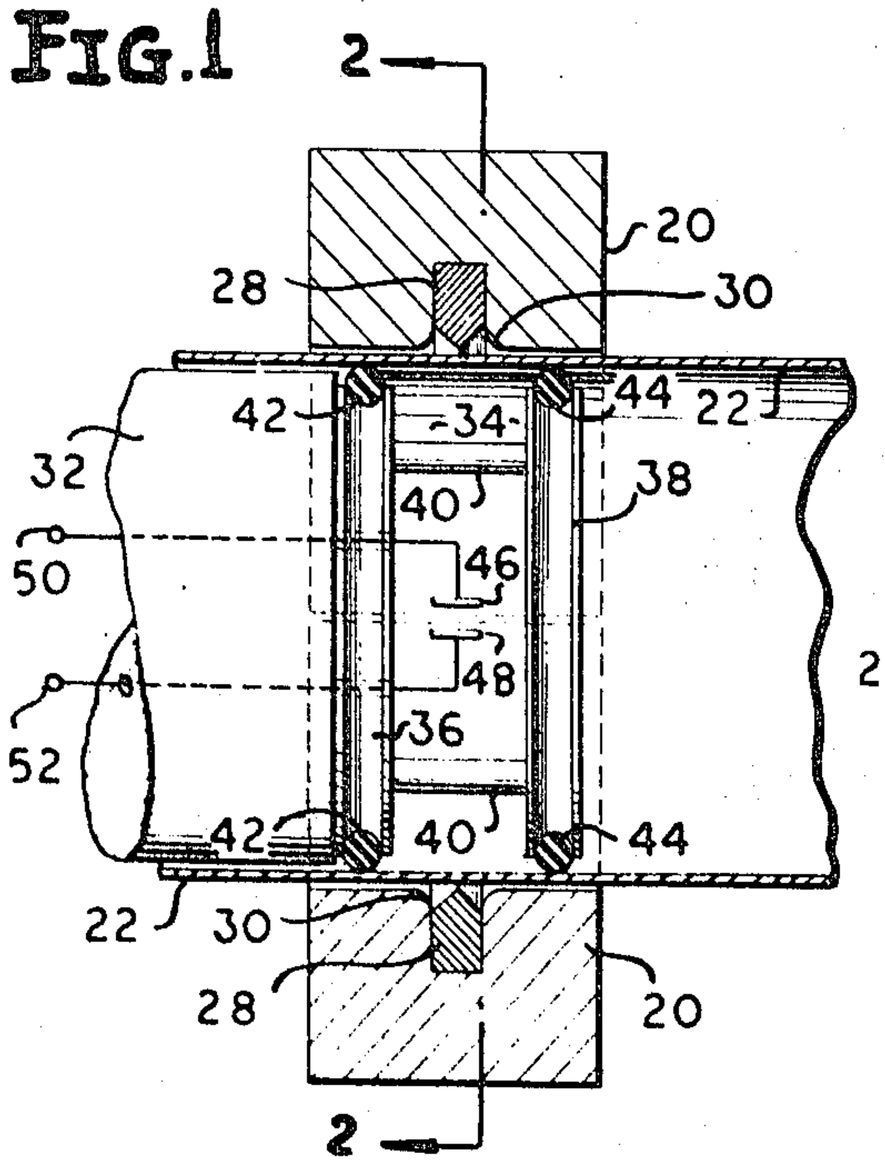

FIG. 2

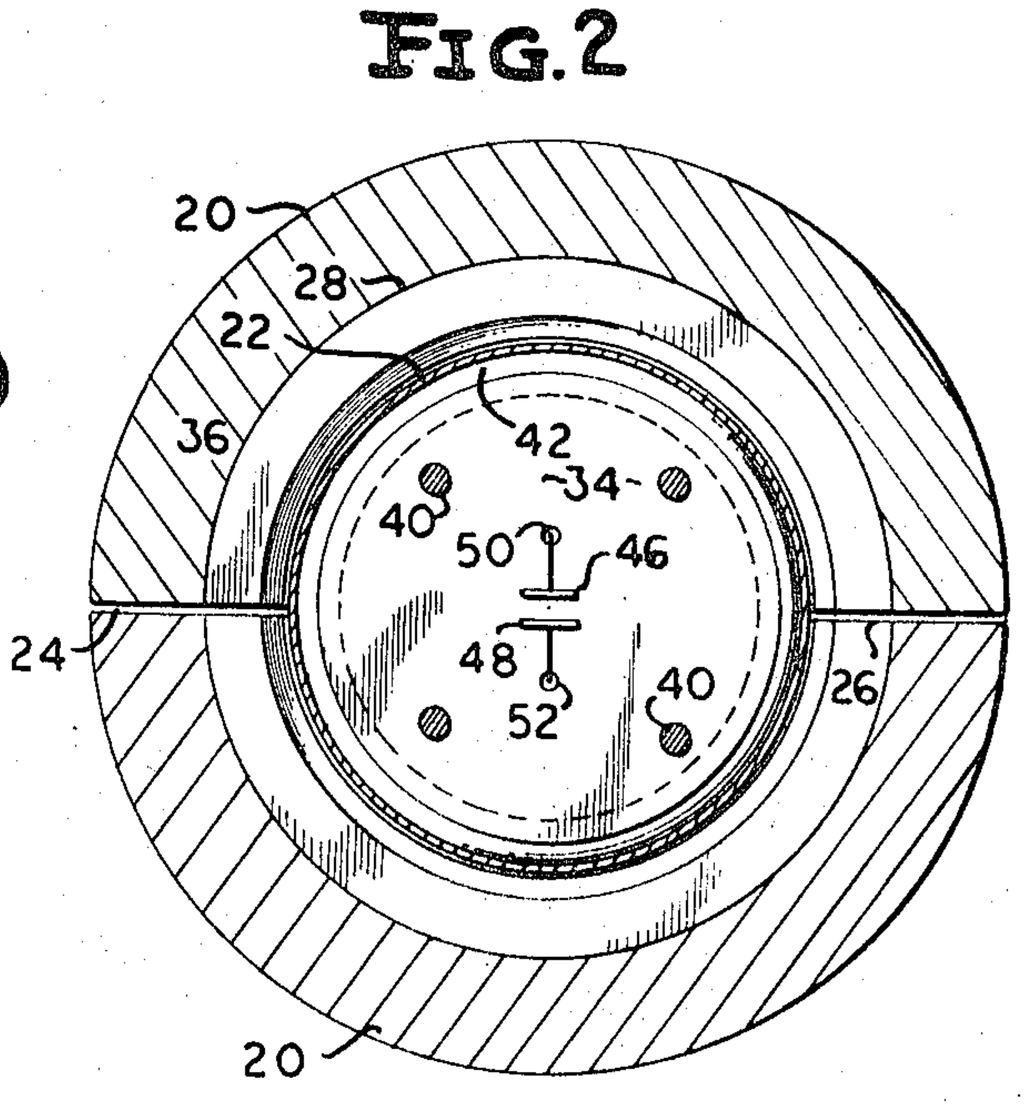

FIG. 3

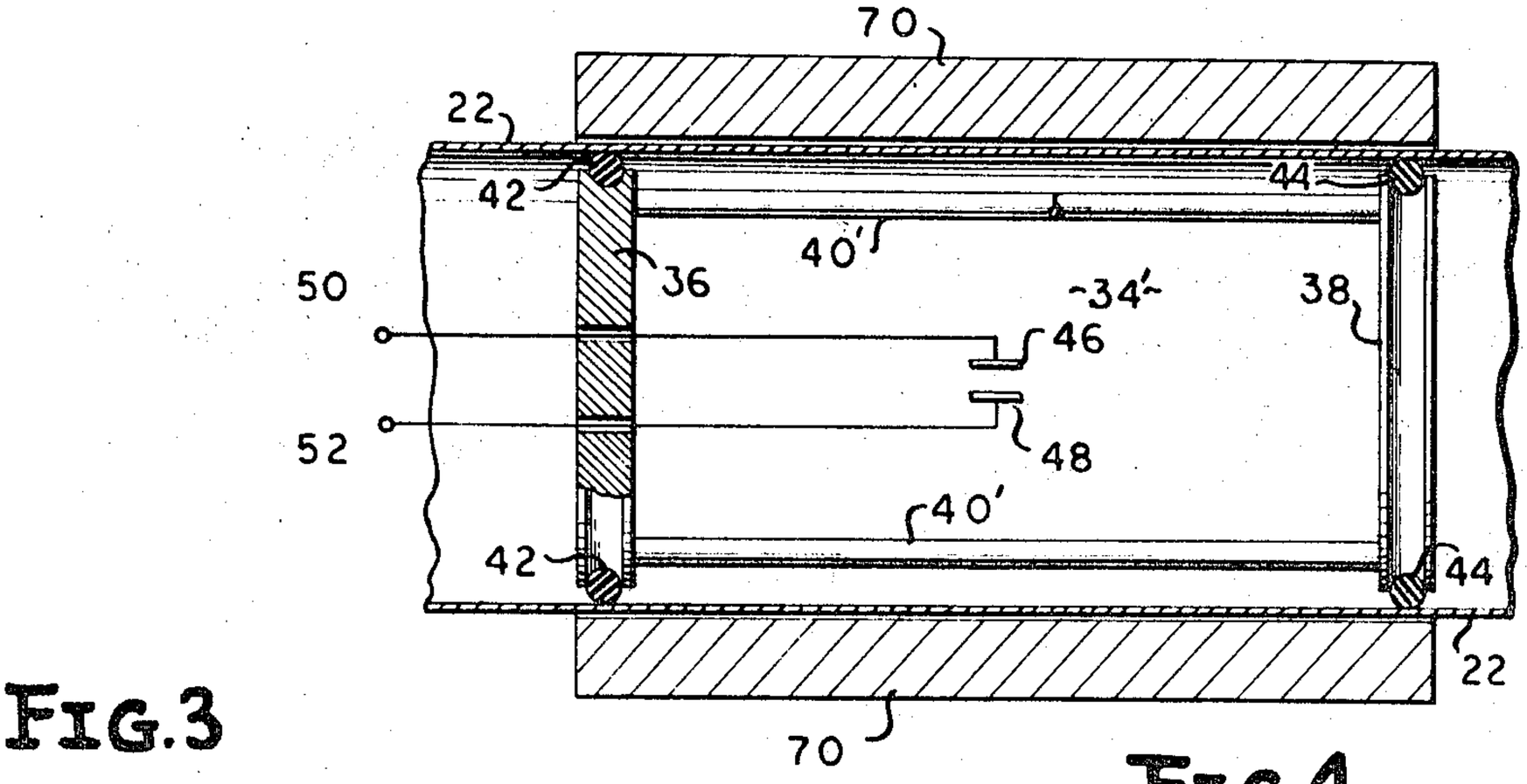

FIG. 4

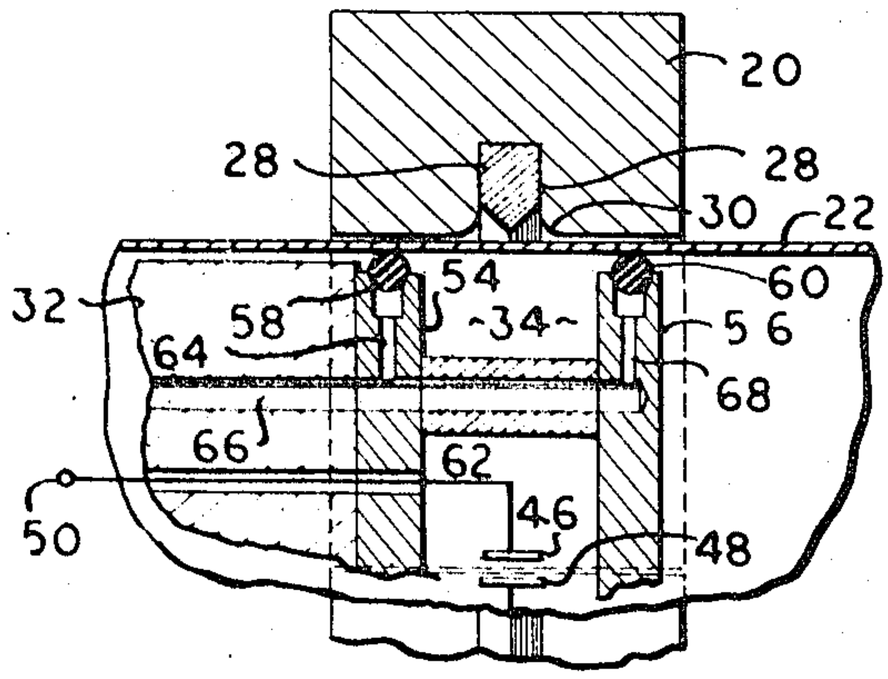

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FIG.5

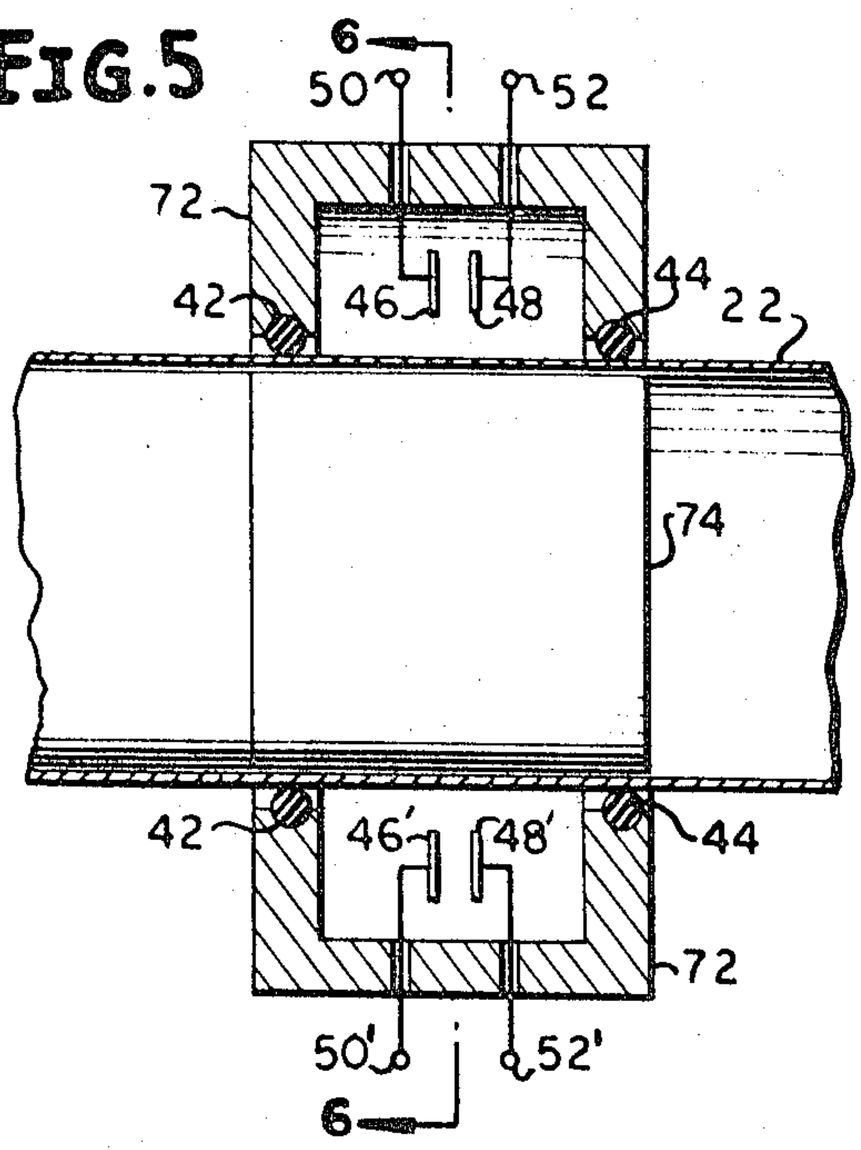
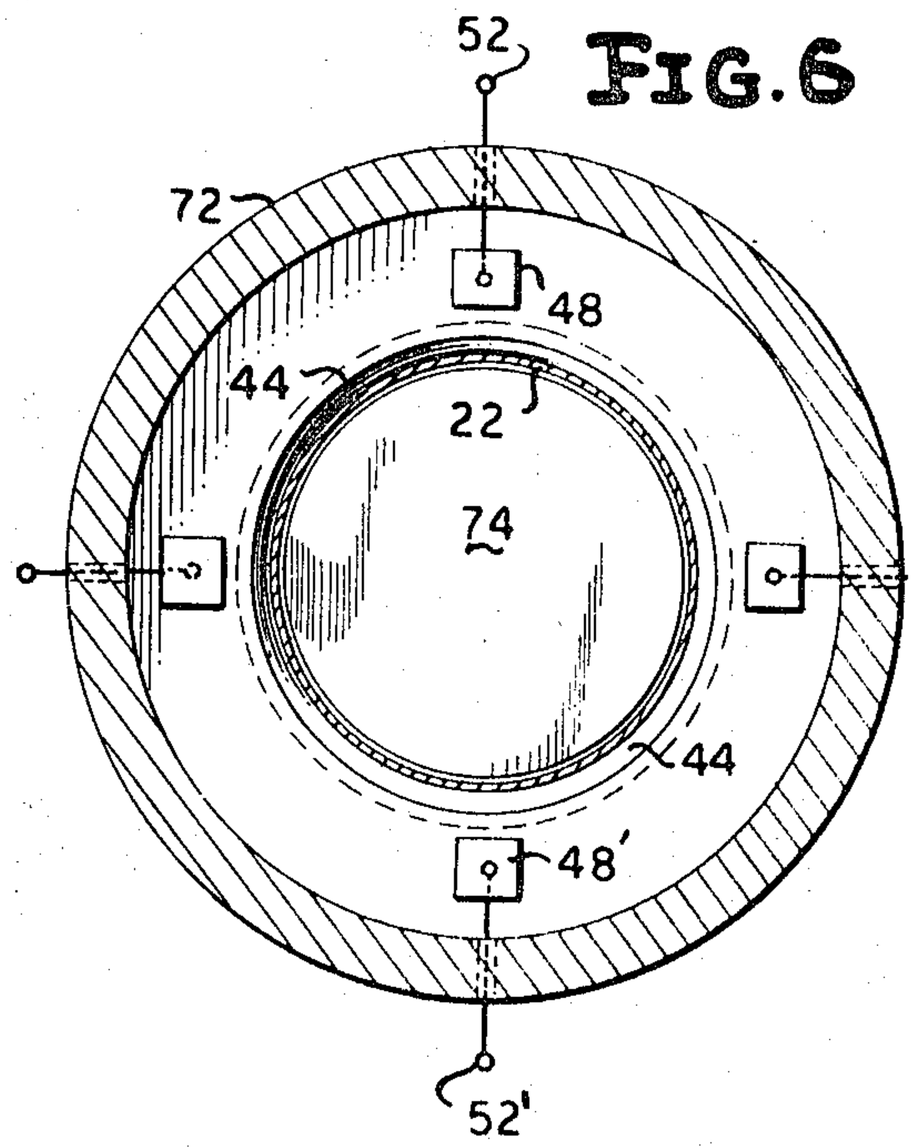
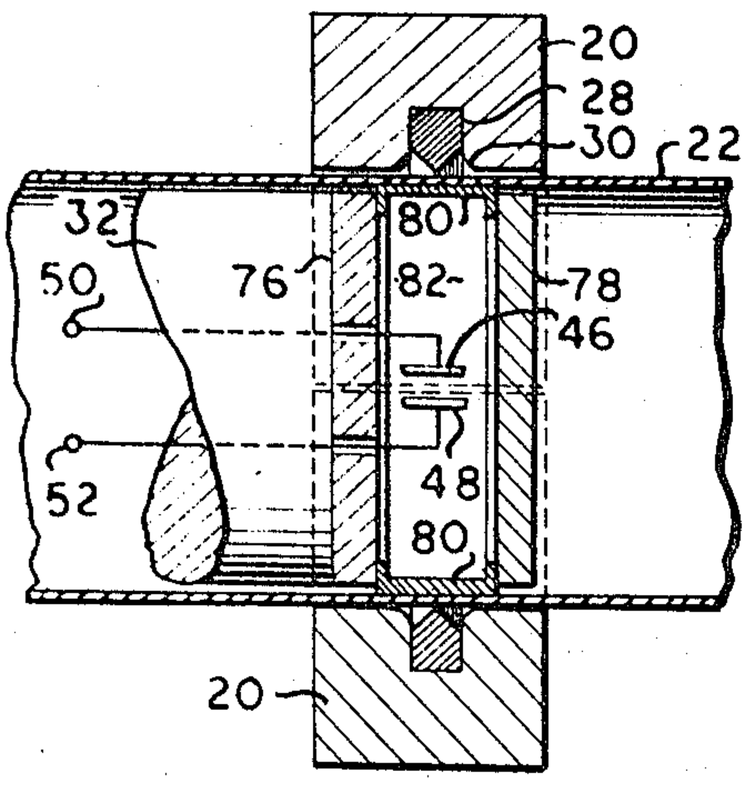


FIG.6





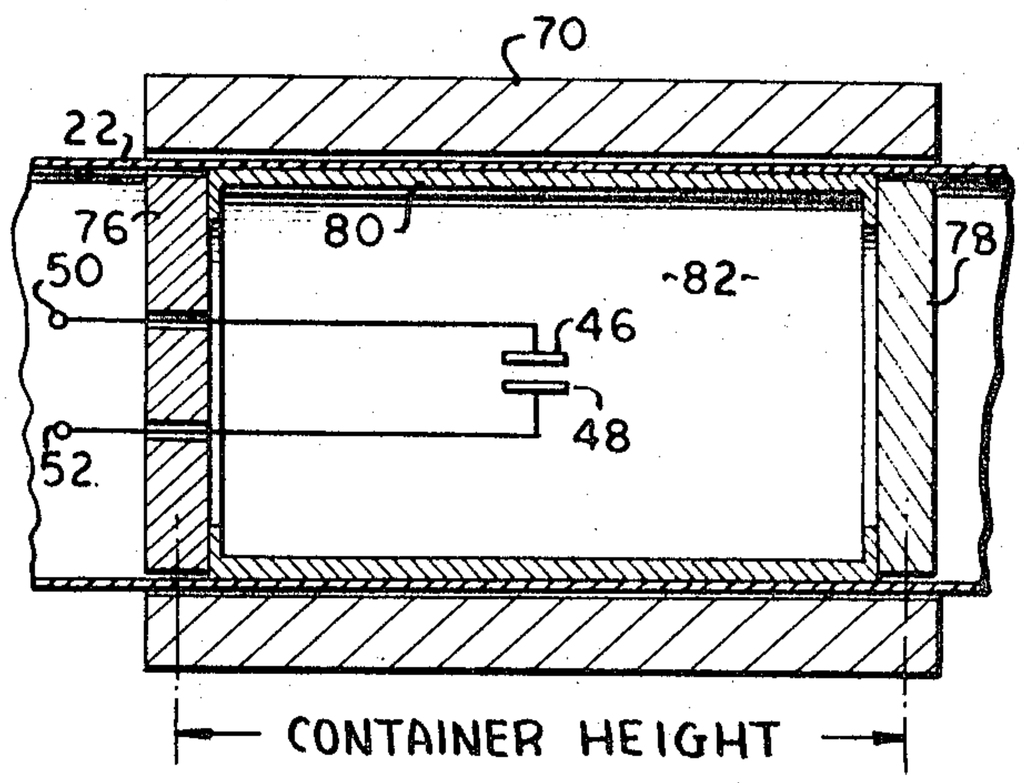


FIG.7

FIG.9

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FIG. 8

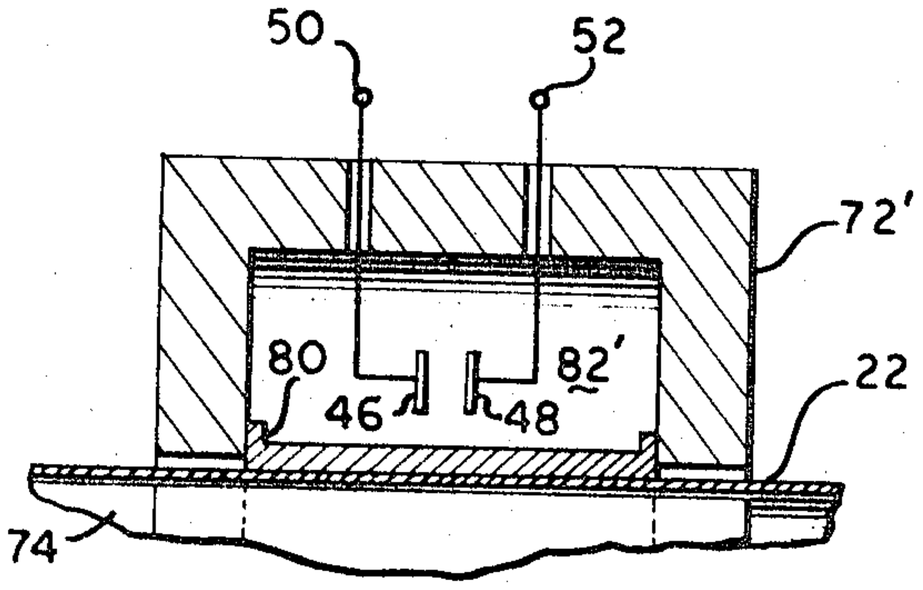


FIG. 10

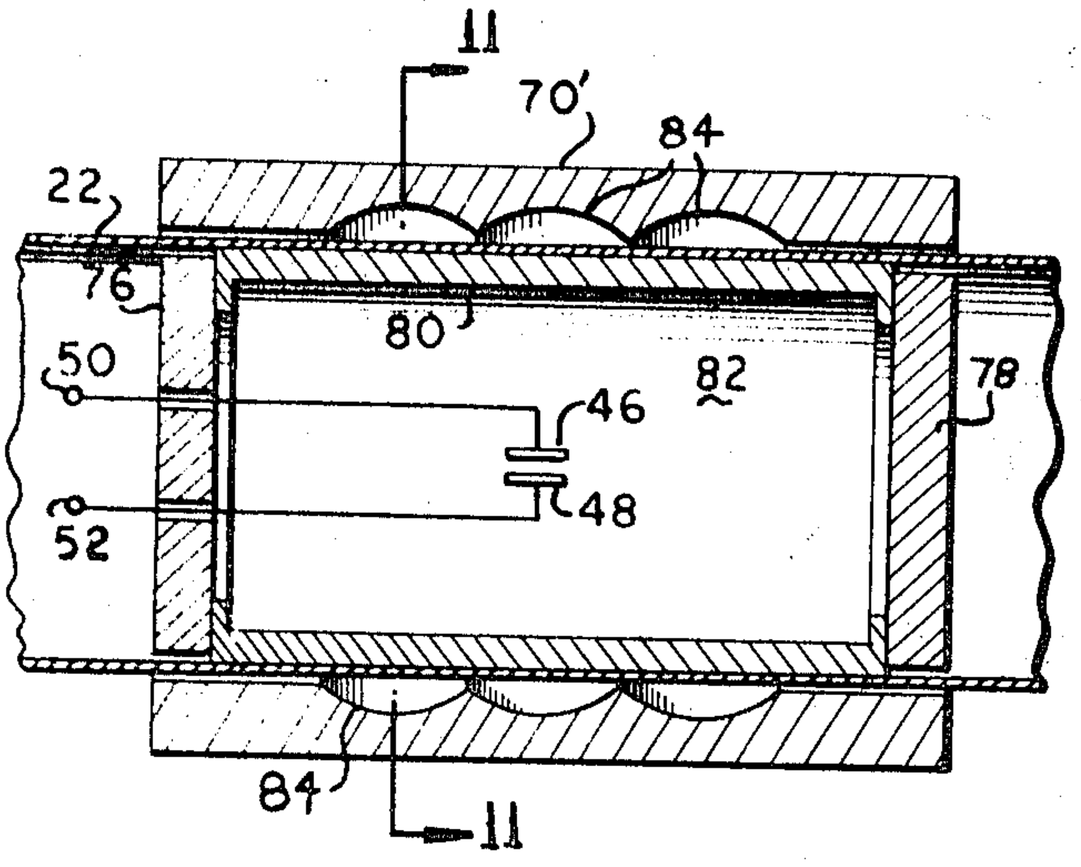
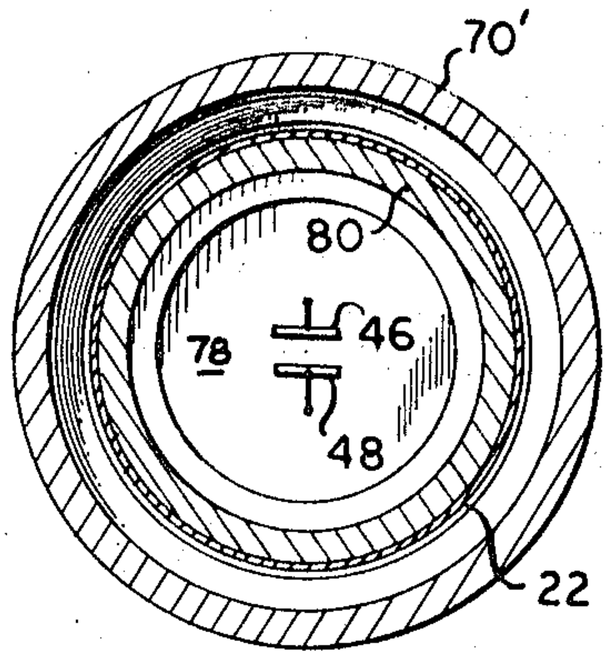


FIG. 11



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ELECTROPNEUMATIC AND ELECTROHYDRAULIC RE-FORMING OF TUBING AND THE LIKE

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Original application Mar. 19, 1965, Ser. No. 441,017. Divided and this application July 3, 1969, Ser. No. 839,002

Int. Cl. B21d *26/12*

U.S. Cl. 72—56 21 Claims

ABSTRACT OF THE DISCLOSURE

Disclosed herein are apparatus and method for the electropneumatic and electrohydraulic re-forming and the like of members such as, for examples, container bodies and the like. The force generated for performing the re-forming is created through the application of electrical energy to a pair of electrodes positioned within a chamber to provide an electrical discharge within such chamber. The electrical discharge creates a plasma bubble between the electrodes and such bubble continues to grow as continued power is supplied to the electrodes. Also disclosed are apparatus and method for severing and flanging members using similarly developed force. The force so created drives the wall of the member or workpiece against an adjacent die to perform the desired operation or operations.

This application is a divisional of my copending commonly assigned application Ser. No. 441,017, filed Mar. 19, 1965.

This invention relates to re-forming means and more specifically to apparatus and methods for performing re-forming by the employment of an arc discharge in an electropneumatic or electrohydraulic medium.

Heretofore, in operations relating to the fabrication of containers possessing thin walls, the initial step in the fabrication of the container is to sever a portion from stock material. This portion, known as a blank, is then advanced to means which form the blank in the desired configuration. The operations of cutting or severing, flanging, reshaping and/or re-forming were accomplished at relatively slow speeds and each operation was performed individually. If the fabrication of containers, whether they be of metal, plastic, paper or any combination of these materials, is to be truly successful, then the operation must be performed at high speed, with economies of operation, and the fabrication must be easily controlled.

The principles of the invention are applied to the operation of re-forming or reshaping a container body. It will be understood that throughout the specification reshaping and re-forming are synonymous and will be used interchangeably. The re-forming operation could be performed before or after a severing and flanging operation. If it is desired, the re-forming operation could be performed by a continuous operation without the necessity of halting the containers while traveling through the fabrication process.

It is a further object of the present invention to provide a means for performing operations on container bodies and tubes by causing a spark discharge in a fluid medium to displace the body according to a predetermined configuration.

Although a number of operations are shown and described which may be performed on container bodies, the principle of the invention relates to, in one embodiment, positioning a length of cylindrically formed material within a restraining means and severing a portion of the material, which severing takes place radially and completely about the periphery of the container. The container edge may also be flanged simultaneously with the severing operation. The container body is positioned within a circular die and supported about the inside periphery of the die is a cutting or severing knife. Within the die, a chamber is formed which houses a pair of electrodes. The chamber may house any one of a number of fluids, such as air, water or oil of high dielectric constant, etc. When a power supply capable of causing a discharge to take place between the electrodes is applied to connecting leads, the force created by the discharge is transmitted through the fluid to the inside wall of the container. At the point where the cutting knife meets the container, a severing operation will result. The cutting knife is beveled which permits the rapidly moving severed container edge to continue on into the beveled area (a void between the side of the severing knife and the die) to then result in a flanging operation. Due to the elasticity of the material, a certain amount of flanging may take place just prior to the complete severing of the cylindrical wall of the container. The energies which force the wall of the container against the severing-flanging die are created by the discharging of the high current spark across the spark gap. A plasma bubble is formed in the spark gap and continues to grow as continued power is supplied to the electrodes. This expansion, in one embodiment, forces the elastomeric material out very rapidly against the tubing causing the desired operation on the tubing. This force occurs within microseconds so that a very rapid severing and flanging rate may be maintained.

In addition to the possible severing and flanging operation mentioned above, a re-forming operation is performed. In the reforming operation, the severing knife die is replaced with a re-forming die in which the spark discharge causes the container wall to be violently forced against the re-forming die to result in a forming or re-forming operation.

Various modifications are anticipated, one of which would be the positioning of the severing knife or die within the container, with the severing and re-forming operations accomplished by driving the container wall inwardly. In addition, various combinations of severing, re-forming, or flanging may be accomplished by positioning the elements of the invention in the desired manner.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in conjunction with the accompanying drawings in which:

FIG. 1 is a cross-sectional side elevation view showing a cylindrical member in position for severing and flanging;

FIG. 2 is a sectional view taken on the line **2—2** of FIG. 1;

FIG. 3 is a fragmentary view of a modification of the form of the invention illustrated in the FIG. 1;

FIG. 4 is a cross-sectional view showing one form of the re-former and a cylindrical body in position for re-forming;

FIG. 5 is a cross-sectional side elevation view similar to the view of the FIG. 1 and illustrating a modified form of the invention wherein the electrodes are disposed about the container body;

FIG. 6 is a sectional view taken on the line **6—6** of FIG. 5;

FIG. 7 is a sectional side elevation view similar to the view of the FIG. 1 and illustrating a modified form of the invention;

FIG. 8 is a fragmentary view of a modified form of the invention shown in the FIG. 1;

FIG. 9 is a sectional view similar to the view of the

FIG. 4 and illustrating a modified form of the container re-former or reshaper and a container body in position to be re-formed or reshaped;

FIG. 10 is a sectional view similar to the view of the FIG. 9 but illustrating a type of embossing die wherein undulations are formed in the container wall to result in a reshaping or re-forming of the tube or container body; and

FIG. 11 is a sectional view taken on the line **11—11** of the FIG. 10.

It may be noted at this point, that the apparatus shown in the FIGS. 1 through 6 is best suited for performing operations with the spark discharge being in an atmosphere of air or other gas. These embodiments may be termed electropneumatic. The apparatus shown in the FIGS. 7 through 11 are best suited for operations wherein the chamber enclosing the spark discharge area contains a liquid. These embodiments may be termed electrohydraulic. However, it will be understood that either a gas or liquid may be employed in any of the apparatus illustrated in the figures.

With reference to the FIGS. 1 and 2, a cylindrical die **20** surrounds a cylindrical tube or container body **22**. The die **20** is split at **24** and **26** to facilitate the removal of a severed and flanged container body by separating the die **20**, which separation means are not shown.

Supported within the die **20** and directed inwardly is a severing knife **28** having its severing surface substantially perpendicular to the container body **22**. The container body **22** fills substantially all the area within the inside of the die **20** and may or may not lightly engage the die **20** in the absence of a severing operation. It will be noted that the severing surface or point of the severing knife **28** extends to a point substantially in line with the inside periphery of the die **20**. Formed next to the severing knife **28** and on the die **20** is a flanging radius **30** which controls the shape of the flange formed on the edge of the container body **22** when the container body **22** is driven against the severing knife **28** and severed. By varying the flanging radius **30**, on the die **20**, a great variety of shapes and sizes of flanges may be derived. By reducing the flanging radius **30** to substantially zero, then little or at best a very small radius would be formed on the container body **22**. It will be intuitively clear that a certain area must be provided next to the severing knife **28** to permit the knife **28** to completely penetrate the wall of the container body **22**, if such is desired.

In FIGS. 1 and 2, a horn extension **32** of slightly lesser diameter than the container body **22**, supports the means within the die **20** to cause the severing and flanging operation. A gas chamber **34** is formed between a sealing plate **36**, which is rigidly connected to the horn extension **32** and a second sealing plate **38** which is held in place by a plurality of spacers **40**. Thus, the chamber **34** is formed in the area between the sealing plates **36** and **38**. The chamber **34** is substantially sealed between the sealing plates **36** and **38** and the container body **22** by a pair of low friction seals (such as the familiar O-ring) **42** and **44**, respectively. The horn extension **32** would be movable and would normally place the chamber **34** in a position within the area toward which the severing knife **28** is directed.

Supported by any suitable means, not shown, are a pair of electrodes **46** and **48** which are coupled to a power supply, not shown, by the conductors **50** and **52**, respectively. The force which does the mechanical work of severing and/or flanging a container body **22** is created by discharging a high power spark across the electrodes **46** and **48**. A plasma bubble is formed in the spark gap between the electrodes **46** and **48** and continuous to grow as additional power is applied to the electrodes by the power supply, not shown. The spark discharge causes heating and vaporization of some of the fluid and expansion of this vapor along with gases entrapped within the fluid. The bubble thus generated displaces the fluid which in turn

provides the force for subsequent operation. Thus, a cylindrical body such as a container body **22** would be thrown outwardly and against the severing knife **28** and into and about the flanging radius **30**. The die **20** would then be opened by any conventional means and the severed portion of the cylindrical body **22** would be removed and the remaining portion of the cylindrical body **22** would be advanced to the point where another severing and/or flanging operation is desired.

Spark discharges between a pair of electrodes, such as the electrodes **46** and **48** in the FIG. 1, are well known in the art and do not need to be explained in detail with reference to the invention.

The FIG. 3 shows a modification of the chamber sealing means of the FIG. 1. As the FIG. 1 employs a pair of O-rings **42** and **44**, the apparatus of the FIG. 3 employs inflatable members. The chamber **34** is formed by the sealing plates **54** and **56**. About their peripheries and engaging the inner circumference of a container body **22** are the inflatable tubes or members **58** and **60**, positioned respectively upon the sealing plates **54** and **56**. The sealing plate **54** is connected to the horn extension **32** (in a manner similar to that shown in the FIG. 1) and the second sealing plate **56** is supported by a spacer **62** which is rigidly coupled to the sealing plate **54**. Communicating with and within the sealing plate **54**, is a passage **64** which connects with a source of pressure within a tube such as the air supply tube **66**. The tube **60** communicates with the air supply tube **66** through a passage **68**. The electrodes **46** and **48** are substantially identical to those shown in the FIG. 1.

In the embodiment of the FIG. 3, the tubes **58** and **60** would be deflated during positioning of a container body or cylindrical tube **22** and upon the container body **22** reaching the point at which it is desired to sever and/or flange the body **22**, a source of pressure would be supplied to the air supply tube **66** which would inflate the tubes **58** and **60** and engage the inside circumference of the container body **22** to effect a seal formed within the chamber area **34** defined by the sealing plates **54** and **56** and the inner circumference of the container body **22**. When an appropriate source of potential is applied to cause a discharge between the electrodes **46** and **48**, the container body **22** would be abruptly driven against the servering knife **28** and the flanging radius **30** to result in a complete severing and flanging of the container body **22**.

During certain operations, the container body or cylindrical tube **22**, whether metal, plastic, paper or any combination of these materials, may become distorted and require a re-forming or reshaping of the cylindrical body. Accordingly, such a means is provided by the embodiment of the FIG. 4 wherein like elements are designated in a manner similar to those of the FIG. 1. The sealing plates **36** and **38** are positioned a greater distance apart than those of the FIG. 1 as shown by the designation **40'**. The sealing members **42** and **44** are positioned entirely about the sealing plates **36** and **38**, respectively, and form a chamber **34'** within the area enclosed by the sealing plates **36** and **38**, the seals **42** and **44**, and the inside circumferrence of a container body or cylindrical tube **22**.

As shown in the FIG. 4, a re-forming or reshaping die **70**, of cylindrical shape, completely surrounds the container body **22** and a proximity thereto. When a discharge is effected between the electrodes **46** and **48**, the gas within the chamber **34'** would be heated and the confined air, would produce a very high gas pressure due to its thermal expansion. This energy, would force the container body **22** against the re-forming die **70** to result in a reshaping or reforming of the body.

In the FIG. 4, it will be noted that the re-forming die **70** is positioned externally to the member to be shaped. In the embodiment shown in the FIGS. 5 and 6, the re-forming die is positioned within the body and the dis-

charge is caused between pairs of electrodes within a chamber formed about the body.

The apparatus of the FIGS. 5 and 6, will perform a re-forming or reshaping operation by directing the reshaping energy inwardly toward the center of the container body **22**. A U-shaped channel **72** is cylindrical with the open portion of the U directed inwardly toward similar configurations of the channel. A re-forming die **74** is positioned within the cylindrical U-shaped channel **72** but is of slightly lesser diameter than the diameter of the area within the body **72**. A container body **22** is positioned between the outer extremities of the re-forming die **74** and the inner circumference of the U-shaped channel **72**. A pair of sealing members **42** and **44** are positioned within the notches of the projecting members of the U-shaped channel **72** and are in engagement with the outer circumference of the container body **22**. The seals or O-rings **42** and **44** are of a low friction material to permit sliding engagement between the container body **22** and the seals **42** and **44**.

A plurality of pairs of electrodes **46** and **48**, having electrical leads **50** and **52** coupled, respectively, thereto, are positioned about the chamber formed within the U-shaped member **72** and in the particular embodiment shown and described, four such pairs of electrodes are shown; however, it will be understood that any number of pairs of electrodes may be provided according to the requirements of the operation to be performed.

Thus, with a container body or cylindrical tube **22** in the position shown in the FIG. 5, a substantially sealed and closed chamber is formed within the U-shaped member **72** and the container body **22**. Upon the application of a suitable power source to the conductors **50** and **52**, a discharge will be caused to occur between the electrodes **46** and **48** and its resulting thermal expansion of the gases within the chamber, will force the walls of the container body **22** inwardly against the reforming die **74** to result in a re-forming or reshaping operation.

Whereas the FIGS. 1 through 6 disclose embodiments of the invention wherein the chamber would contain an atmosphere such as air, the embodiments shown in the FIGS. 7 through 11 are known as electrohydraulic forming means and would employ a fluid within the chamber such as water, and oil of high electric constant, or other suitable material. The fluid is contained within the chamber by an elastomeric material to be hereinafter described.

One form of this embodiment is shown in the FIG. 7. The die **20** and the severing knife **28** surround the container body **22** as in the FIG. 1. The horn extension **32** supports a first sealing plate **76** to the left of the severing knife **28** and a second sealing plate **78** to the right of the severing knife **28**. It is not necessary that the knife **28** be centered between the sealing plates **76** and **78** but may ben anywhere in line with a chamber **82** and about an elastomeric material **80**. The elastomeric material **80** of circular configuration is hollow and joins the sealing plates **76** and **78**. The outside circumference of the elastomeric material **80** may or may not loosely engage the container body **22** and may be secured to the sealing plates **76** and **78** in any suitable manner. A fluid chamber **82** is now formed within the confines of the elastomeric material **80**. A pair of electrodes **46** and **48** are positioned within the fluid chamber **82** and have connecting electrical leads **50** and **52** coupled respectively, thereto. The force which performs the mechanical work to cause severing and/or flanging of a container body **22** in the FIG. 7, is created by discharging a high voltage spark across the electrodes **46** and **48**. A plasma body or bubble is formed in the spark gap between the electrodes and continues to grow as continued power is applied to the electrodes **46** and **48**. This forces the elastomeric material **80** out very rapidly against the body or tubing **22**, causing the tubing **22** to expand against the die to result in a severing and flanging operation.

In the FIG. 8, a reforming apparatus is shown which employe a fluid chamber **82'** which completely surrounds the container body **22** to be re-formed. Whereas the embodiment in the FIG. 5 discloses the electropneumatic arrangement is shown in the FIG. 8, A U-shaped channel **72'** is of circular configuration and completely surrounds the container body **22** and the re-forming die **74**. The elastomeric material **80** provides a seal to contain the fluid within the chamber **82'**. Upon the application of a suitable voltage to the conductors **50** and **52**, the resulting discharge between electrodes **46** and **48** will force the elastomeric material **80** against the container body **22** to result in a re-forming or re-shaping operation.

In the FIG. 9, a re-forming or reshaping apparatus is shown which directs its forces outwardly, unlike the embodiment of the FIG. 8 which directs its reshaping forces inwardly. The sealing plates **76** and **78** are positioned a greater distance apart than that in the FIG. 7 so that reshaping may take place over a greater distance, which expanse is not required in a severing operation to which the apparatus of the FIG. 7 is directed. The elastomeric material **80** joins the sealing plates **76** and **78** and may be in intimate contact, loose contact or not in contact at all with the container body **22**. Arranged circumferentially about the container body **22** is a re-forming die **70**, similar to that shown in the FIG. 4. Upon the application of a suitable voltage, the spark discharge between the electrodes **46** and **48** will cause the material **80** to be driven outwardly and force the container body **22** against the inner wall of the re-forming die **70**, to result in a reshaping of the container body **22**.

The elastomeric material **80** may be of any suitable construction such as rubber, plastic, etc., and need be deformable by pressure within the chambers **82** and **82'**. It is sufficiently resilient and yielding to transmit any pressure waves caused by the spark discharge between the electrodes **46** and **48** to the container body **22**. The amplitude and duration of the electrical supply coupled to the conductors **50** and **52** may be controlled by any suitable control means. In addition, capacitors may be utilized to assure the correct energy charge applied to the electrodes **46** and **48**. The control then, will include suitable means for applying the appropriate voltage to the capacitor, suitable impedance means in the capacitor and spark gap circuit to vary the time constant of the circuit, and thereby control the discharge rate. In addition, suitable means would be provided to control the time intervals between successive energizations of the electrodes.

The FIGS. 10 and 11 illustrate reshaping or re-forming means and are similar to the illustration of the FIG. 9 except that instead of a smooth die **70**, the die **70'** of the FIG. 10 has formed about its inner wall a plurality of undulations **84**. When a spark discharge appears across the spark gap formed by the electrodes **46** and **48**, the resulting outward movement of the elastomeric material **80** drives the container body **22** into the undulations **84** which result in rings or beads about the circumference of the container **22**, which beads provided added strength and esthetic appeal. It will be understood that any number of undulations **84** may be provided and that the undulations **84** may be of any suitable geometric shape in which it is possible to form the container wall **22** without a severing or parting of the material. Further, it will be readily understood that reshaping may take many different forms and that the dies **70'** may be conical, square, triangular, etc., or any combination of these geometric figures. As the container material **22** or tube is advanced through or about the dies so formed, excitation of the electrical energy will cause the elastomeric membrane **80** to drive the container body **22** into engagement with the conforming die.

Thus, there has been described a means for severing, flanging, reshaping or re-forming cylindrical containers

by the use of the electrical energy created through a spark discharge across a pair of electrodes. In the first embodiment, either of the operations may be performed within a chamber containing a gas such as air. In other embodiments, the chamber may, as well as a gas, contain water or an oil which will transfer the force resulting from the electrical discharge between the electrodes **46** and **48** to cause the desired operation to the container wall. It will be understood that severing and/or flanging and/or re-forming may be performed either simultaneously, separately, or in any useful combination, as desired. For example, a re-forming operation may precede or follow a severing operation and severing and flanging may be performed substantially simultaneously. It may be an advantage to do all the operations simultaneously.

Thus, the present invention may be embodied in other specific forms without departing from the spirit and the essential characteristics of the invention. The present embodiments are, therefore, to be considered in all respects as illustrative.

I claim:

1. Tubular body forming means comprising a re-forming die, means defining a fluid filled closed chamber about said die on the outside thereof and permitting the insertion of a generally tubular body to be re-formed between said re-forming die and said means defining a fluid filled chamber, and means causing an electrical spark discharge within the fluid in said chamber for establishing a plasma bubble within said fluid to force said body inwardly against said re-forming die.

2. Tubular body forming means according to claim **1** wherein said chamber is provided with a resilient member having one and an another side adapted to contact said body with said one side and said fluid with said other side.

3. Tubular body forming means according to claim **1** wherein said fluid is a gas.

4. Tubular body forming means according to claim **3** wherein said gas is air.

5. Tubular body forming means according to claim **2** wherein said fluid is a liquid.

6. Tubular body forming means according to claim **1** wherein said fluid directly contacts said body.

7. Tubular body forming means according to claim **1** wherein said body is a continuously moving tube or container body, and said die is of substantially uniform cross section.

8. Tubular body forming means comprising a continuous channel substantially U-shaped in radial cross section, said continuous channel having an opening therein defining the open end of said U for allowing a tubular body to be positioned adjacent the channel opposite said open end of said U and also defining a fluid filled chamber therewithin, a re-forming die positioned within the opening of said channel but permitting the insertion of said body about the re-forming die and within the opening of said channel, and means for causing the electrical discharge in the fluid within said chamber for establishing a plasma bubble within said fluid to force the body against said re-forming die.

9. The combination as defined in claim **8** wherein said substantially U-shaped, continuous channel is circular and defines said opening as a circular opening.

10. A tubular body forming means comprising a continuous channel substantially U-shaped in radial cross section for accommodating a tubular body having an opening therein and in addition, defining a fluid filled chamber within said U-shaped channel, a re-forming die positioned within the opening of said channel but permitting the insertion of a body over said re-forming die and between said re-forming die and said opening of said channel, means projecting from each extension forming the ends of the substantially U-shaped channel for effecting a seal of said chamber to a tubular body which is to be re-formed, and means for causing an electrical discharge within the fluid in said chamber for establishing a plasma bubble within said fluid to force said body against said re-forming die.

11. The combination as defined in claim **10** wherein said means for causing an electrical discharge includes pairs of electrodes spaced within the fluid-filled chamber defined by said channel.

12. The combination as defined in claim **10** wherein said means for effecting a seal include resilient means of O-ring construction.

13. Tubular body forming means comprising a continuous channel substantially U-shaped in radial cross section and having an opening therein and, in addition, defining a fluid filled chamber within the extending legs of said channel, a re-forming die positioned within the opening of said channel but permitting the insertion of a body over said re-forming die, deformable means extending across and joining the extending legs of said substantially U-shaped channel and in engagement with a body when present, and means for causing an electrical discharge within the fluid within said chamber for establishing a plasma bubble within said fluid to force said deformable member inwardly against the body and into engagement with said re-forming die.

14. The combination as defined in claim **13** wherein said deformable member is resilient.

15. The combination as defined in claim **13** wherein said fluid is water.

16. The method of re-forming a tubular body comprising the steps of inserting a tubular body to be re-formed over a re-forming die, supporting a fluid filled channel defining a chamber surrounding and about the die and body on the outside thereof, and causing an electrical discharge within the fluid in said chamber for establishing a plasma bubble within the fluid to drive the body inwardly against the re-forming die.

17. The method of claim **16** including placing said body in direct contact with said fluid.

18. The method of claim **16** including continuously moving said body over said die.

19. Tubular body forming means comprising a re-forming die of substantially uniform cross section, means defining a fluid filled chamber adjacent said die and permitting insertion of a tubular workpiece between said re-forming die and said means defining a fluid filled chamber, means causing an electrical spark discharge within said fluid in said chamber for establishing a plasma bubble within said fluid to force said workpiece against said re-forming die, and means for continuously moving said tubular workpiece across said die in a direction perpendicular to said cross section.

20. Tubular body forming means according to claim **19** wherein said chamber is positioned within said die.

21. Tubular body forming means according to claim **19** wherein said chamber is positioned about said die on the outside thereof.

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