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Keinanen et al.

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[54] **APPARATUS FOR ELECTROHYDRAULIC PRESSURE ARC CONTROL**

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[51] **Int. Cl.** **B21d 26/12**
[58] **Field of Search** 72/56, 60, 63; 29/421

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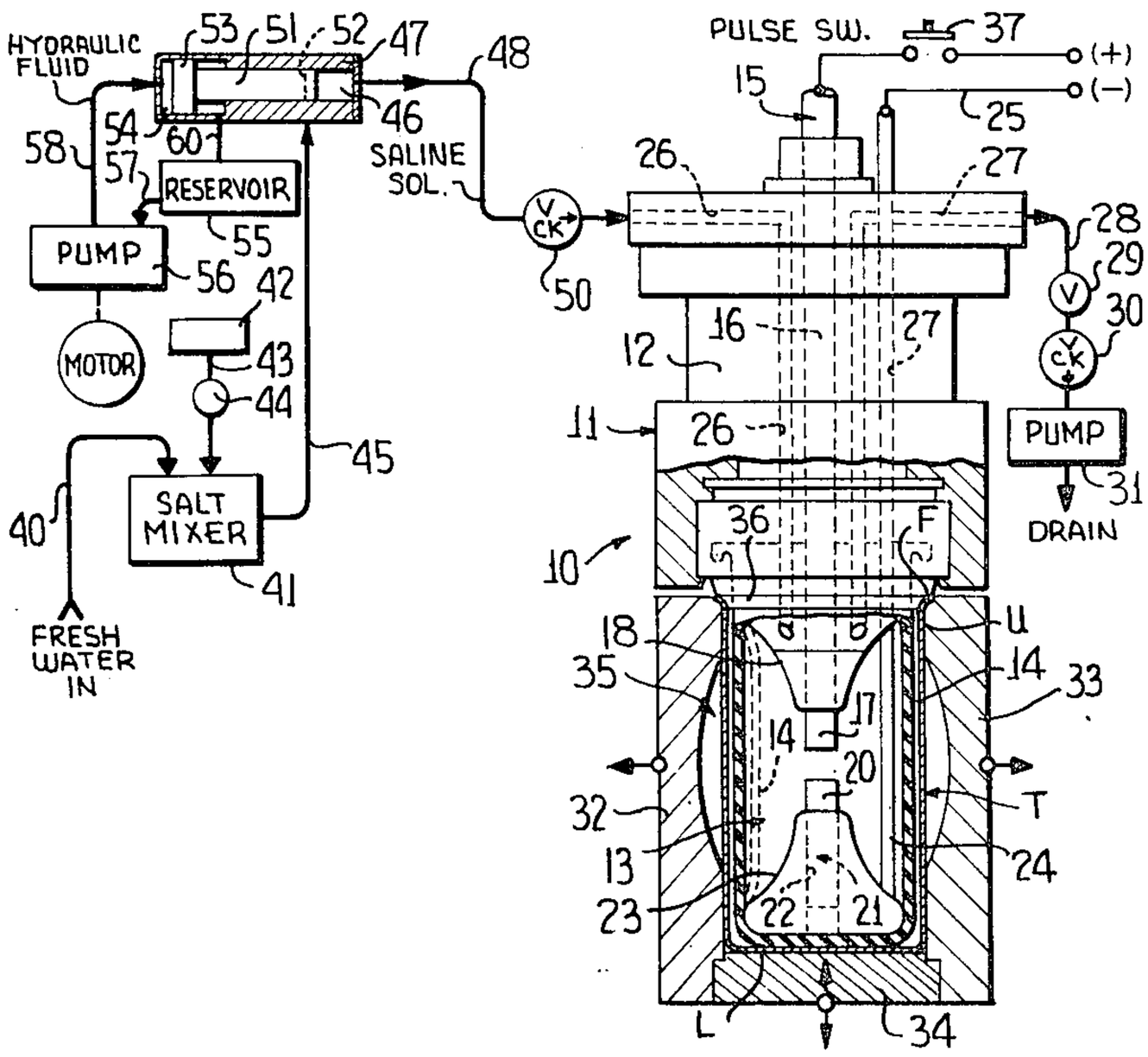
[57] **ABSTRACT**

This disclosure relates to an apparatus for preventing erroneous arcing during electrohydraulic pressure reforming of tubular elements, and includes a flexible electrohydraulic chamber wherein is supported a plurality of electrodes, means are provided for introducing a fluid medium into the chamber and for preventing erroneous arcing during the discharge of electrical energy across the electrode gap by pressurizing the fluid medium between 300–3,000 p.s.i., and preferably between 600–800 p.s.i.

4 Claims, 2 Drawing Figures



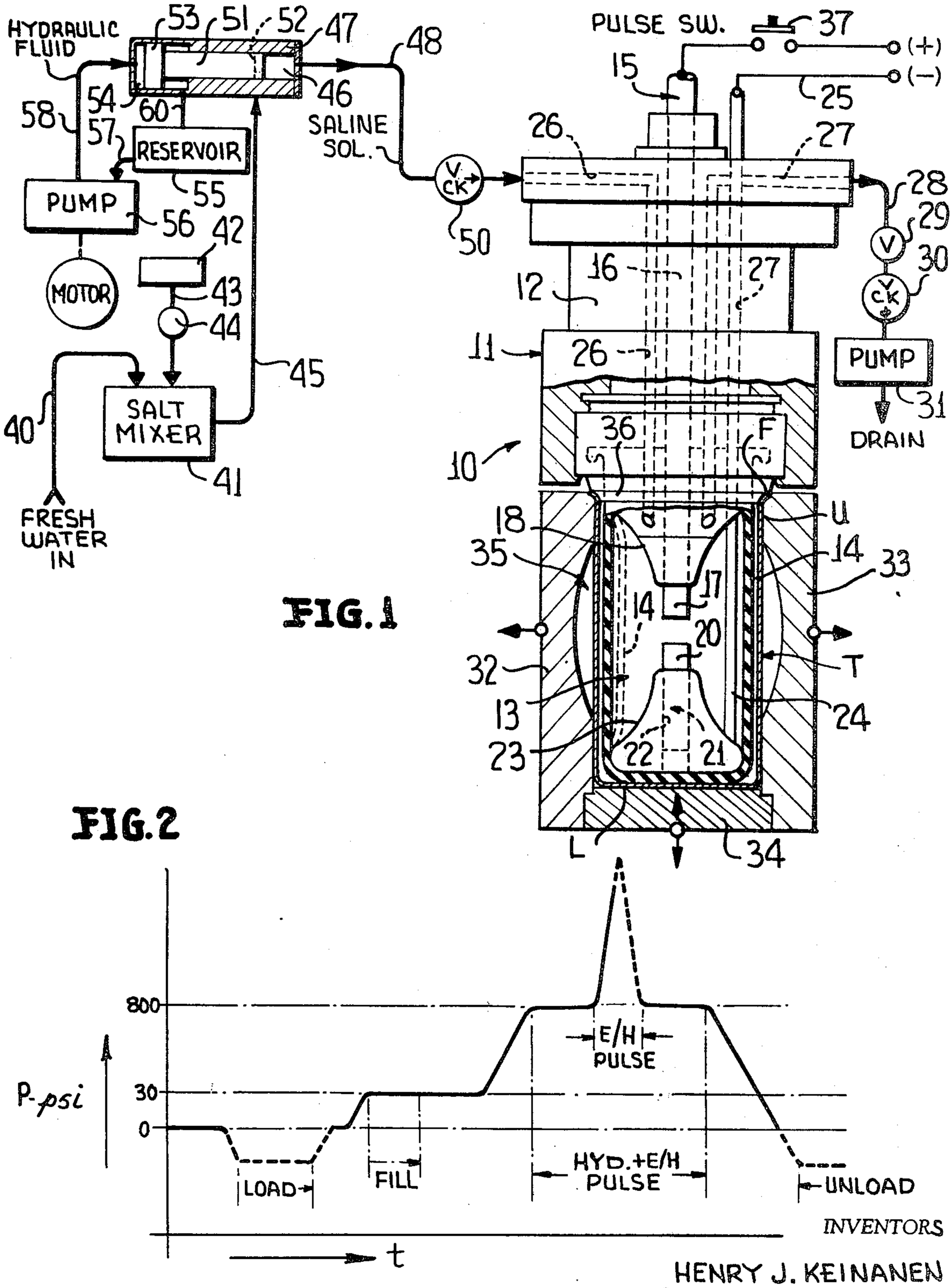


FIG. 1

FIG. 2

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APPARATUS FOR ELECTROHYDRAULIC PRESSURE ARC CONTROL

During experiments conducted with electrohydraulic energy transfer devices and particularly electrohydraulic energy transfer devices of the type utilizing a cage structure, inconsistent forming of the workpieces has been noted when the voltage amplitude exceeded a particular value. The workpieces under consideration were can bodies which were positioned in a split mold and internally of which was positioned the flexible chamber and its associated cage structure supporting the electrodes in axially aligned, spaced relationship. Since the can bodies are of the type closed at one end, it is necessary to support the electrode more closely positioned to the closed end by means of one or more metallic rods or pillars, and to obtain symmetrical forming of the can bodies it is necessary to achieve repetitive discharging across the electrode-electrode gap and to prevent erroneous arcing from one electrode to the pillar or pillars supporting the other electrode. When such erroneous electrode-pillar arcing takes place the electrode-electrode discharge is correspondingly reduced and consistency of forming is prevented.

Various parameters were changed in an effort to prevent such erroneous electrode-pillar arcing including changing the conductivity of the fluid medium in the chamber, the addition of anti-foaming agents, and improved chamber purging after each discharging operation, all without success. The electrode-pillar arcing could only be controlled by reducing the electrode-electrode gap (spark gap), but this resulted in rapid deterioration of the functioning of other portions of the system, such as premature electrode erosion and poorer operating efficiency caused by proportionately higher losses elsewhere in the system (switch, etc.).

These disadvantages and particularly the erroneous electrode-pillar arcing were unexpectedly eliminated when it was unobviously discovered that pressurizing the fluid medium in the electrohydraulic chamber to a certain degree would tolerate larger electrode gaps while avoiding electrode-pillar arcing at higher operating voltages than realizable with only atmospheric pressure in the chamber. The life of the electrodes and associated insulation was also increased. Prior to pressurizing the fluid medium it was found that arcing more often than not was initiated under and near the end of the insulator covering the "cold" (ground) electrode, and the "bubble" thus established caused rapid deterioration of the insulator and a corresponding increase in the number of errant arc discharges to the pillars. Thus, by increasing the pressure of the fluid medium in the chamber the increased life of the insulator assures a reduction in the number of electrode-pillar arc discharges.

The increase in pressure of the fluid medium expectedly made the fluid more difficult to ionize. Initially this was not considered to be detrimental, and has since indeed proved beneficial by materially reducing the burning of switch contacts due to arcing when a switch between a stored source of electrical energy (capacitor or inductor) is continuously closed. The burning of the switch contacts upon closing has been found to be much less than expected, and this is attributed to the comparatively slow rate of current increase in the circuit as limited by the "slow" ionization of the pressurized fluid medium in the electrohydraulic chamber.

It is therefore a primary object of this invention to provide a novel apparatus which not only prevents erroneous electrode-pillar arcing during pressure reforming operations and thus increases the electrode and insulator life of the apparatus, but also increases the over-all efficiency of the system by reducing the burning of switch contacts upon the closing thereof to effect the electrical discharge across the electrodes.

A further object of this invention is to provide a novel apparatus of the type heretofore set forth wherein the fluid medium in the electrohydraulic chamber is pressurized between 300–3,000 p.s.i., and preferably between 600–800 p.s.i.

Still another object of this invention is to provide a novel apparatus including each of the elements heretofore set forth wherein the pressurizing means is a hydraulic cylinder, a double-ended piston is positioned in the cylinder and defines a pair of fluid chambers therewith, means are provided for introducing the fluid medium into one of the chambers which is in turn connected to the electrohydraulic chamber, and means for introducing a pressurized fluid in the other chamber whereby the fluid medium in the electrohydraulic chamber is pressurized within the latter-noted range thereby advantageously permitting the use of a noncorrosive operating fluid to pressurize the fluid medium which is preferably though not necessarily a low concentration saline solution.

A further object of this invention is to provide a novel apparatus wherein the electrodes are positioned within the electrohydraulic chamber in axially opposed spaced relationship with one of the electrodes being suspended by one or more suspension pillars thereby enabling the electrohydraulic pressure forming of can bodies or similar tubular elements having at least one closed end.

With the above and other objects in view that will hereinafter appear, the nature of the invention will be more clearly understood by reference to the following detailed description, the appended claimed subject matter, and the several views illustrated in the accompanying drawing.

IN THE DRAWING:

FIG. 1 is a schematic view of an apparatus constructed in accordance with this invention, and illustrates a flexible electrohydraulic chamber in which is housed a pair of coaxial electrodes, means for introducing a pressurized fluid medium into the chamber, and means for discharging electrical energy across the electrode-electrode gap to conform a can body to the configuration of a cavity defined by a split mold.

FIG. 2 is a diagram of time versus the pressure of the fluid medium, and graphically illustrates the initiation of the electrical energy discharged when the fluid medium has been pressurized to 800 p.s.i.

A novel apparatus for preventing erroneous electrode-pillar arcing during an electrohydraulic pressure reforming operation is illustrated in FIG. 1 of the drawing, and is generally designated by the reference numeral 10. The apparatus 10 includes an electrohydraulic transducer 11 which includes an upper rigid supporting portion 12 and a lower flexible electro-hydrau-

lic reforming chamber 13 defined by a flexible bag-like element 14. An electrode 15 which is suitably insulated projects downwardly through a bore 16 of the supporting portion 12 and terminates in a noninsulated end portion 17 projecting outwardly of a reflector 18 which is suitably supported by the supporting portion 12. A noninsulated end portion 20 of another electrode 21 is positioned in axial aligned spaced relationship to the electrode end portion 17. The electrode 21 is conventionally secured in a bore 22 of a electrically conductive metallic reflector 23 which is in turn suspendingly supported by a plurality of electrically conductive metallic suspension rods or pillars 24, only one of which is illustrated and is shown connected to ground by a conductor 25. The upper end portion of the pillar 24 which passes through the supporting portion 12 is likewise suitably insulated. Further details of the specific construction of the electrohydraulic transducer 11 which are considered unnecessary for an understanding of this invention are disclosed in commonly assigned application Ser. No. 762,523, entitled Electrohydraulic Transducers, filed on Sept. 25, 1968 in the names of Donald J. Roth and Carl A. Pesce now U.S. Pat. No. 3,593,551.

A passage 26 is provided in the supporting portion 12 and the reflector 18 for introducing a fluid medium, which is preferably a low (4 percent) concentration saline solution, into the chamber 13 prior to a discharging operation. A passage 27 is likewise provided in the supporting portion 12 and the reflector 18 for purging the chamber 13 after a discharging operation by means of a conduit 28, a valve 29, a check valve 30 and a pump 31 connected to a suitable drain.

The supporting portion 12 is preferably mounted in a stationary position and three die bodies 32 through 34 which form a die cavity 35 are closed as shown to position a tubular element T, such as a metallic, plastic, paper or similar container having a closed lower end L and an upper open end U in external telescopic relationship to the chamber means 13 and internal telescopic relationship to the cavity 35.

The mold bodies 32, 33 are of a semi-annular configuration and when closed they define an annular cavity which is closed at its lower end by the die body 34 which is of a circular configuration. The upper open end of the cavity 35 is closed by an annular shoulder 36 which cooperates with shoulders (unnumbered) of the dies 32, 33 to clamp a flange F of the tubular element T therebetween.

The tubular element T is positioned in the manner illustrated in FIG. 1 by being first supported on the die body 34 when the latter is positioned beneath the bag-like element 14 a sufficient distance to position the tubular element T thereon in coaxial relationship to the chamber 13. The mold bodies 32, 33 are in their open positions to the left and right respectively of that illustrated. Thereafter conventional means (not shown), such as a fluid motor or a cam and cam follower are actuated to move the die body 34 upwardly until the flange F contacts the shoulder 36. Thereafter conventional means of the type associated with the die body 34 are operated to move the die bodies 32, 33 to the closed position shown in FIG. 1 at which time the chamber 13 can be filled with the fluid medium through the passage 26 incident to an electrohydraulic reforming operation upon the closing of a switch 37 connected between the positive side of the stored high energy source and the electrode 15.

Assuming that the fluid medium is a low concentration saline solution, fresh water at line pressure is conducted by a conduit 40 to a tank 41 to which is also added saline by gravity from a brine tank 42, a conduit 43 and a valve 44. The fluid medium is thereafter conducted from the tank 41 via a conduit 45 to a chamber 46 of a fluid isolator or intensifier 47 having an outlet connected to the passage 26 by a conduit 48 and a check valve 50. The intensifier 47 functions as the means to pressurize the fluid medium in the chamber 13 and expand the bag-like element 14 radially outwardly to bring the tubular element T in conformity with the cavity 35 prior to an electrical discharge across the end portions 17, 20 of the electrodes 15, 21, respectively.

The intensifier 47 houses a double-ended piston 51, one end 52 of which in part defines the chamber 46 and another end 53 positioned in a chamber 54. Hydraulic fluid, such as oil, is conducted from a reservoir 55 to a motor driven pump 56 by conduit 57. The pump 56 conducts the oil or similar hydraulic fluid to the power side of the piston 51 into the chamber 54 through a conduit 58 which moves the piston 51 to the right as viewed in FIG. 1 thereby pressurizing the interior of the chamber 13. During the left-to-right movement of the piston 51 hydraulic fluid in the chamber 54 to the right of the piston head 53 is conducted to the reservoir 55 by a conduit 60.

Assuming that the apparatus 10 has been loaded in the manner heretofore described an that the chamber 13 and the die bodies 32 through 34 are in the positions shown in FIG. 1, the bag-like element 14 of the chamber 13 is filled by line pressure (30 p.s.i., as indicated in FIG. 2) from the tank 41, the conduit 45, the chamber 46, the conduit 48, the check valve 50, and the passage 26. At this time the piston 51 is in its leftmost position at which point the end face 52 thereof is just to the left of the port (not shown) connecting the conduit 45 to the chamber 46. During this initial filling stage the valve 29 is closed.

The pump 56 is then operated automatically or manually by starting the motor which conducts the hydraulic fluid from the reservoir 55 and delivers the same over the flow path heretofore described to the chamber 54 thereby causing the piston 51 to move from left-to-right at which point the end face 52 moves from the phantom outline position to and beyond the solid outline position closing the port from the conduit 45 and pressurizing the interior of the chamber 13 to between 300–3,000 p.s.i., but preferably between 600–800 p.s.i. During this increase in the pressure of the fluid medium, which in FIG. 2 is shown to terminate at 800 p.s.i., the bag-like membrane 14 is progressively expanded radially outwardly and forces the tubular element T to the configuration of the cavity 35. However, if the surface of the cavity 35 is provided with minute details the exterior of the tubular element T will not intimately conform thereto under the relatively low pressure of 800 p.s.i., and details will not be completely and accurately transferred to the exterior surface of the tubular element even though the latter is now permanently contoured to the general configuration of the cavity 35.

The pressure of the fluid medium within the chamber **13** is momentarily appreciably increased (upwardly to 30,000 p.s.i.) by closing the switch **37** which causes the electrical energy stored in a capacitor or inductor to be rapidly discharged across the end portion **17, 20** of the electrodes **15, 21**, respectively. This discharge causes a rapidly expanding plasma bubble at the electrode-electrode gap, and the interaction of the expanding bubble and the nearly incompressible fluid medium surrounding it causes a mechanical pressure or shock wave which moves outwardly through the fluid medium and the bag-like element **14** to expand the same further and force the tubular element T into intimate relationship with the cavity **35**. Due to the initial high pressure of the fluid medium (800 p.s.i.) electrode-pillar arcing is virtually precluded and the burning of the switch **37** and its contacts (unnumbered) is likewise materially reduced.

After the tubular element T has been reformed the valve **29** is opened and the pump **31** is operated to reduce the pressure in the chamber **13** and remove the fluid medium therefrom. During the operation of the pump **31** the port from the conduit **45** into the chamber **46** remains closed and any remaining fluid medium in the chamber **46**, the conduit **48** and the passage **26** eventually flows by gravity and/or the action of the pump **31** into the chamber **13**. The pump **31** is operated to reduce the pressure of the fluid medium in the chamber **13** below atmospheric pressure at which time the bag-like element **14** progressively collapses radially inwardly to generally the phantom-outline position thereof which facilitates the removal of the reformed tubular element upon the opening of the die bodies **32, 33** and the lowering of the die body **34**.

The piston **51** is thereafter returned from its rightmost position to its leftmost position by, for example, reversing the drive of the motor to withdraw hydraulic fluid through the conduit **58** and establish a higher pressure on the right-hand side of the piston **53** to return the piston **51** to the left at which time the port from the conduit **45** is again opened to initiate another operation upon the closing of the valve **29**.

While preferred forms and arrangements of parts have been shown in illustrating the invention, it is to be clearly understood that various changes in details and arrangement of parts may be made without departing from the spirit and scope of the invention as defined in the appended claimed subject matter.

We claim:

1. Apparatus for preventing erroneous arcing during electrohydraulic pressure reforming of tubular elements comprising a split mold defining a cavity, flexible chamber means in said cavity, means supporting a plurality of electrodes in said chamber means, means for introducing a fluid medium into said chamber means, means for discharging electrical current across said electrodes, means for pressurizing the fluid medium in said chamber means, prior to the operation of said discharge means, between 300–3,000 p.s.i. to prevent erroneous discharge of the current between one of said electrodes and said supporting means, and means for removing the fluid medium from said chamber means to collapse the latter whereby a reformed tubular element is readily removable from its normal external telescopic relationship relative to said chamber means.

2. Apparatus for preventing erroneous arcing during electrohydraulic pressure reforming of tubular elements comprising a split mold defining a cavity, flexible chamber means in said cavity, means supporting a plurality of electrodes in said chamber means, means for introducing a fluid medium into said chamber means, means for discharging electrical current across said electrodes, means for pressurizing the fluid medium in said chamber means, prior to the operation of said discharge means, between 600–800 p.s.i. to prevent erroneous discharge of the current between one of said electrodes and said supporting means, and means for removing the fluid medium from said chamber means to collapse the latter whereby a reformed tubular element is readily removable from its normal external telescopic relationship relative to said chamber means.

3. Apparatus for preventing erroneous arcing during electrohydraulic pressure reforming of tubular elements comprising a split mold defining a cavity, flexible chamber means in said cavity, means supporting a plurality of electrodes in said chamber means, means for introducing a fluid medium into said chamber means, means for discharging electrical current across said electrodes, means for pressurizing the fluid medium in said chamber means, prior to the operation of said discharge means, between 300–3,000 p.s.i. to prevent erroneous discharge of the current between one of said electrodes and said supporting means, said pressurizing means is a hydraulic cylinder, a double-ended piston in said cylinder defining a pair of fluid chambers, means for introducing the fluid medium into one of said chambers, said one chamber being connected to said chamber means, means for introducing a pressurized fluid in the other chamber whereby said fluid medium in said chamber means is pressurized within the latter-noted range, and means for removing the fluid medium from said chamber means to collapse the latter whereby a reformed tubular element is readily removable from its normal external telescopic relationship relative to said chamber means.

4. Apparatus for preventing erroneous arcing during electrohydraulic pressure reforming of tubular elements comprising a split mold defining a cavity, flexible chamber means in said cavity, means supporting a plurality of electrodes in said chamber means, means for introducing a fluid medium into said chamber means, means for discharging electrical current across said electrodes, means for pressurizing the fluid medium in said chamber means, prior to the operation of said discharge means, between 300–3,000 p.s.i. to prevent erroneous discharge of the current between one of said electrodes and said supporting means, said supporting means includes an electrically conductive suspension rod for supporting one of said electrodes, said electrodes are supported in axially opposed relationship, and means for removing the fluid medium from said chamber means to collapse the latter whereby a reformed tubular element is readily removable from its normal telescopic relationship relative to said chamber means.

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