United States Patent

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[31] 9446/68

[54] **DEVICE FOR FORMING WORKPIECES HYDROELECTRICALLY**
7 Claims, 3 Drawing Figs.

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[51] Int. Cl. B21d 26/12
[50] Field of Search .... 72/56; 29/421 E; 340/12; 313/35, 171, 232, 345, 353, 355; 315/111

[56] References Cited
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3,200,626	8/1965	Callender	72/56
3,228,221	1/1966	Zernow et al.	72/56
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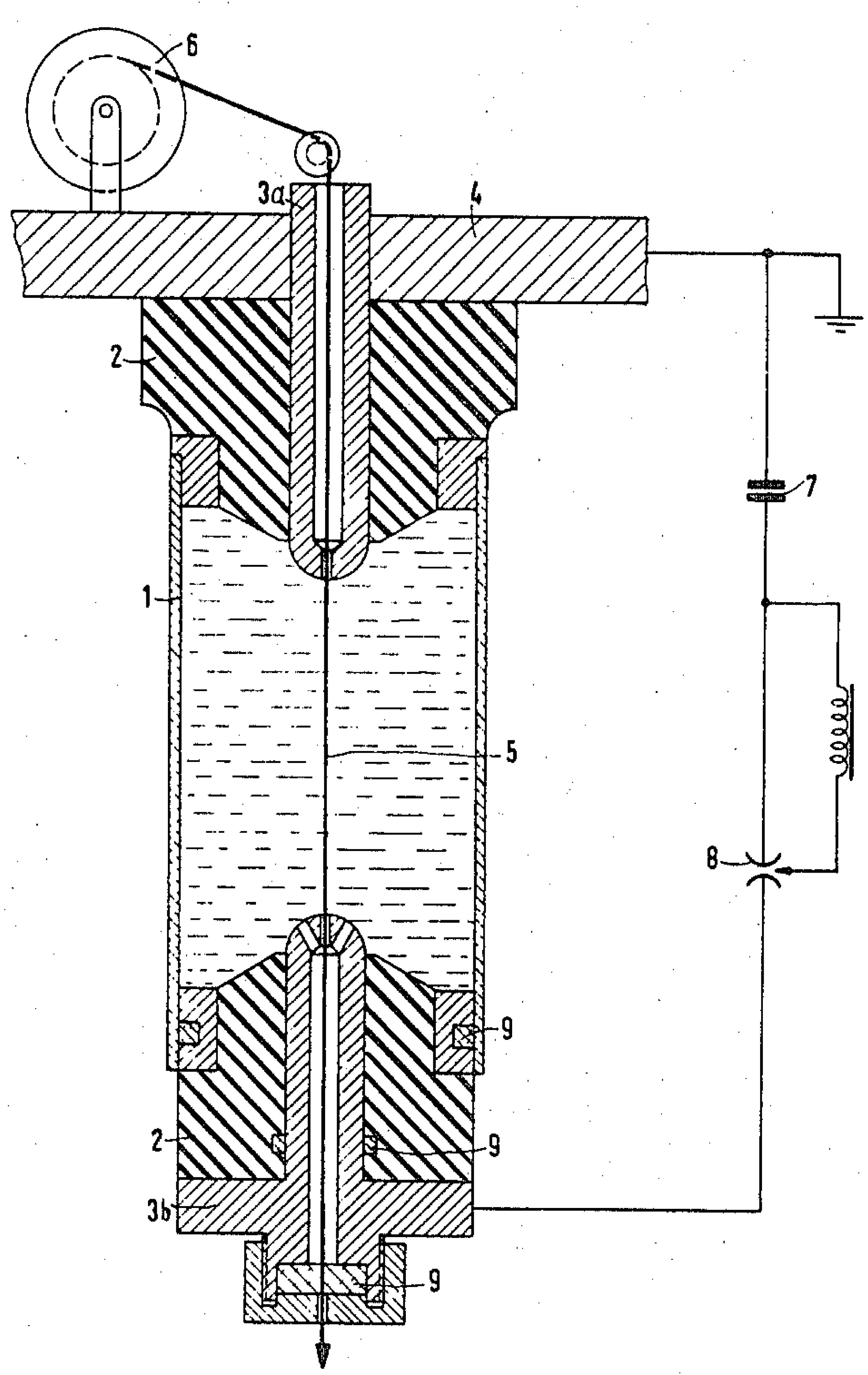
ABSTRACT: A device for forming workpieces by pressure waves generated in a liquid by an undersurface spark discharge has two electrodes immersed in the liquid. The electrodes are mutually separated so as to define a spark gap. A capacitor battery is connected across the electrodes and an ignitor is suspended between the electrodes. The ignitor is made up of a carrier threaded of nonconductive material surrounded by a sheath of conductive material.



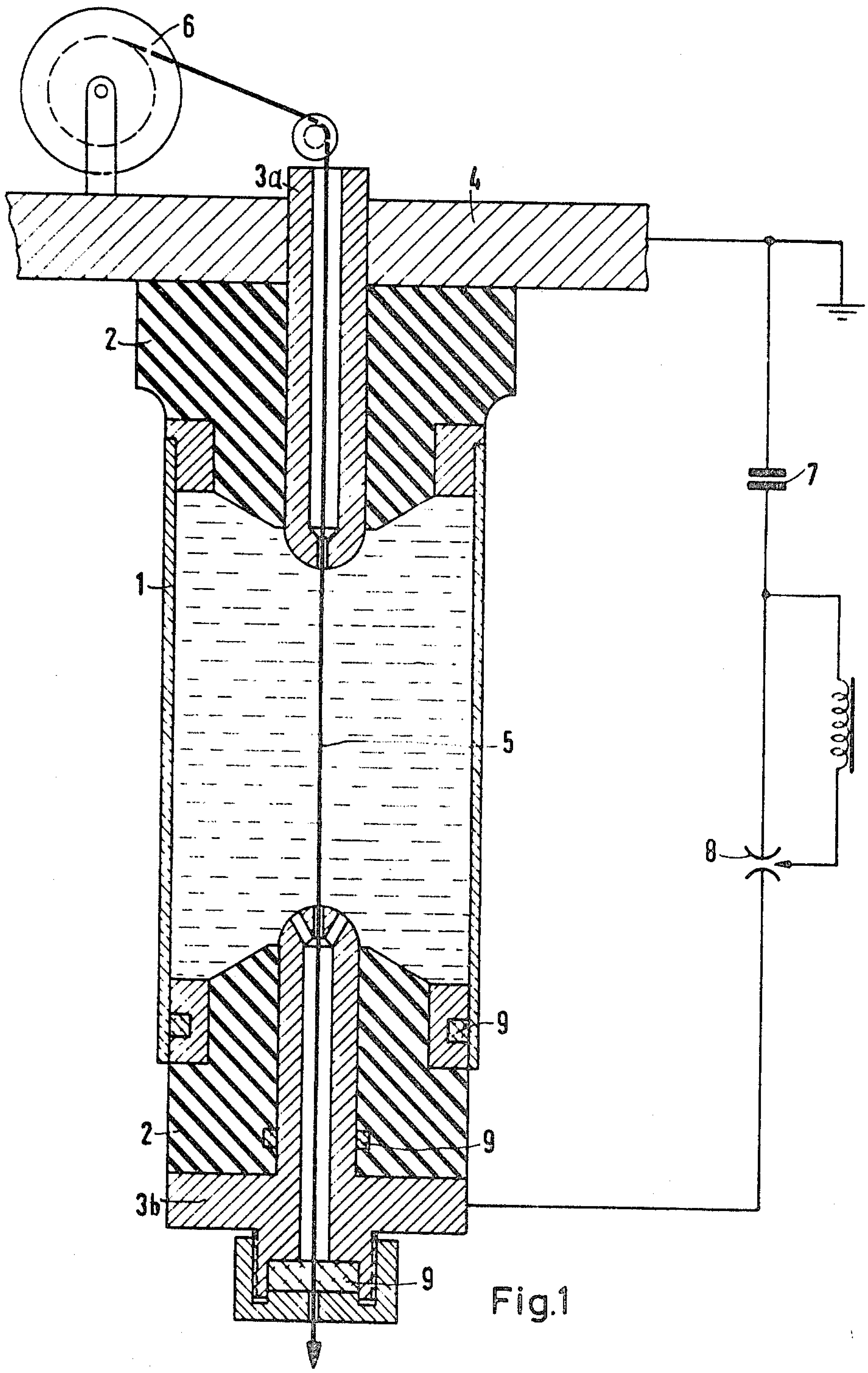


Fig.1

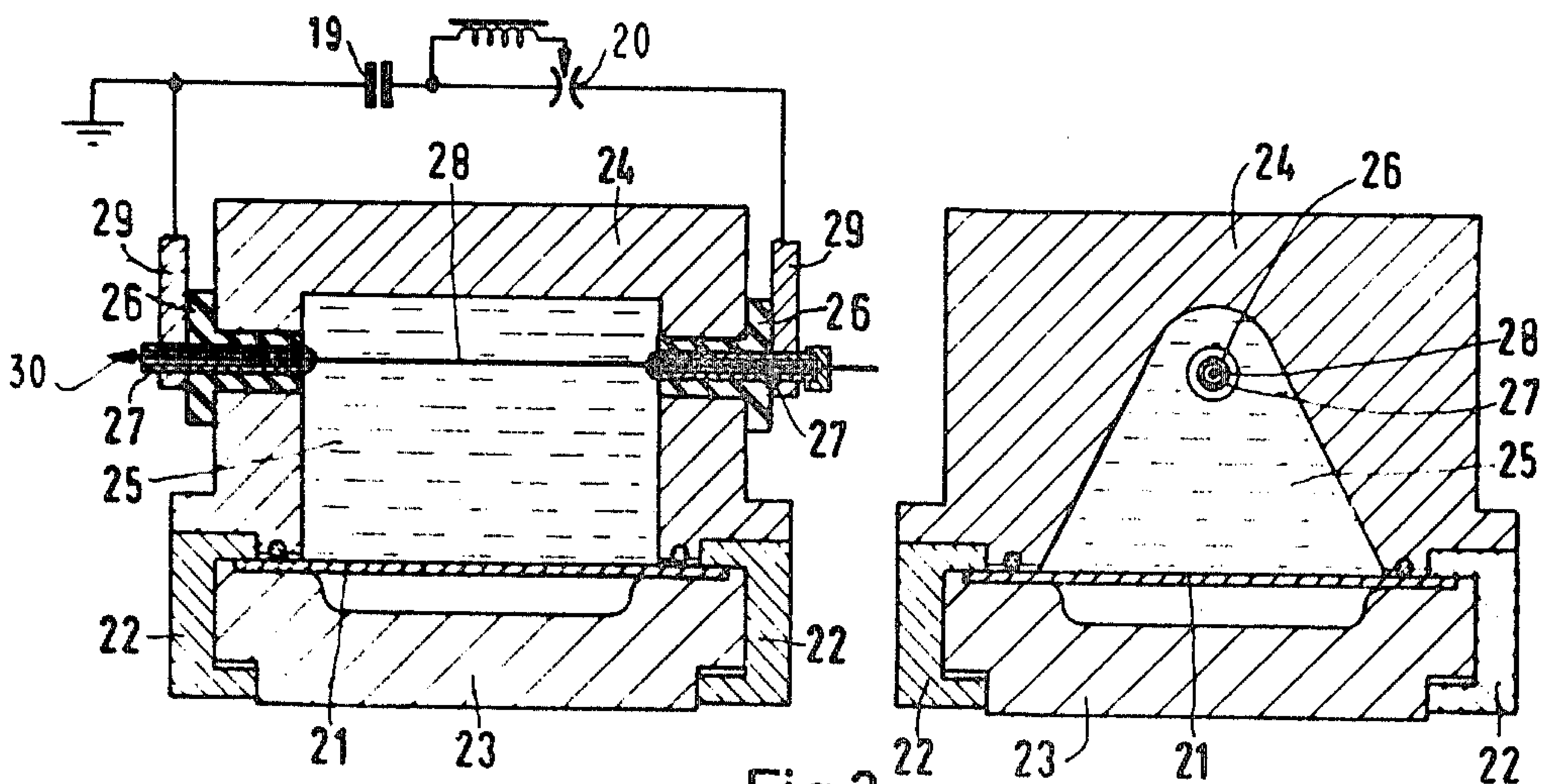

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Fig.2

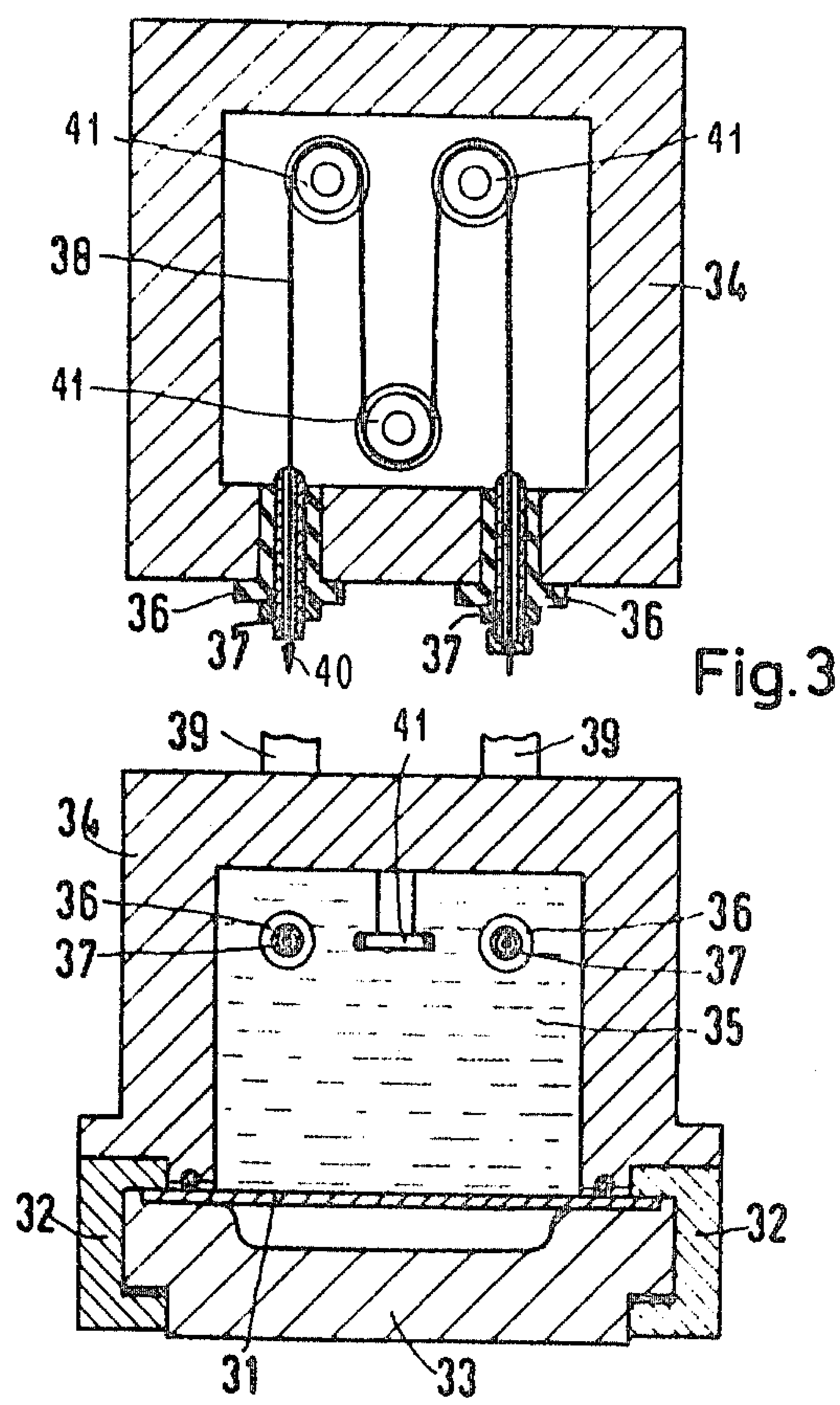
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Fig.3

DEVICE FOR FORMING WORKPIECES HYDROELECTRICALLY

Our invention relates to a device for forming workpieces wherein pressures waves are produced by underwater spark discharges of a bank of capacitors over a spark gap, an ignitor being arranged between the electrodes in the spark gap.

During high-speed forming, according to the hydrospark method, the pressure wave required for forming the workpiece is produced by an underwater spark discharge. The sparkover occurs between electrodes disposed in the water after a bank of capacitors charged to a high voltage is switched in. In this connection it is necessary that the electrical field strength which results from the electrode spacing and the capacitor voltage suffices for impact ionizing the water or other suitable transfer medium. Because the charge voltage in known installations does not exceed 25 kv. to 30 kv., the electrode spacing for a free sparkover is limited to several centimeters. As discussed in published German Pat. application No. 1,252,449, this limitation remains when the liquid which functions as a transfer medium contains particles, preferably metallic, in the form of a fine distribution or suspension. Consequently, the electrode spacing for a free sparkover cannot be arbitrarily increased. Also, since the particles are evenly distributed in the liquid in order to prevent sparkovers to the workpiece, the electrode spacing should be shorter than the shortest distance between the workpiece and the electrodes.

However, if the forming task necessitates an electrode spacing which cannot be bridged by a free sparkover or if a slight distance cannot be avoided between the electrodes and the workpiece, the ignition must be provided by means other than a free sparkover. The most well-known solution in such instances is to use thin wires which are clamped between the electrodes and which are vaporized in the manner of an explosion at the start of the capacitor discharge. The use of ignition wires has the disadvantage that its automatic introduction into the spark gap is associated with various difficulties such as the welding of the contact regions at the electrodes.

Until now it was believed that the use of ignition wires fundamentally impairs efficiency, depending upon the installation, and that a determination of an optimal wire diameter must be undertaken, see published German Pat. application No. 1,213,514.

Consequently, a number of suggestions have been made for initiating the ignition in some other way. For example, without providing any indication of efficiency, the Zeitschrift für Instrumente 74, 1966, pages 260 to 263 discloses the use of a metal ray in a gaseous medium, the ray being injected through an electrode. Also suggested was the ignition of air blown from an electrode into the water, see published German Pat. application No. 1,223,333. Similarly for ignition purposes, helium and argon were blown into a shielded spark duct, see U.S. Pat. No. 3,200,626. Finally, an arrangement for ionizating the spark gap between the electrodes was suggested wherein various forms of high energy radiation are employed, see published German Pat. application No. 1,213,514.

Although each of the known arrangements eliminates the wire, they require additional devices such as melting furnaces or sources of high-energy radiation.

It is, accordingly, an object of our invention to provide a workpiece-forming device which overcomes the aforementioned difficulties associated with the known devices.

It is another object of the invention to provide a workpiece-forming device wherein the installation of the ignitor is greatly facilitated.

It is still another object of our invention to provide a workpiece-forming device wherein the discharge via the ignitor produces only a slight burn-off of the electrodes.

According to a feature of the invention, the workpiece-forming device is provided with an ignitor comprising a thread of a nonconductive carrier enclosed in a conductive sheath. The formation of an underwater spark discharge of a bank of capacitors is thereby facilitated.

A most significant advantage afforded by the invention is the considerable ease with which the ignitor is placed in the spark gap as compared with the wires used in some of the known devices. In addition, a workpiece-forming device according to the invention operates at maximum efficiency and only a slight burn-off of the electrodes from the discharge of the ignitor occurs. Following the discharge, the nonconductive carrier remains almost intact and is only divested of its conductive sheath. This is especially surprising since the materials used as carriers can be ignited even by the flame of a match whereas the temperatures in the spark gap occurring during explosions of the wires are estimated to be at several thousand degrees Kelvin and the carriers are subjected to pressures which act to form the workpiece. Since the carrier and the electrodes are intact, another advantage is afforded namely, of facilitating the automatic introduction of the ignitor into the spark gap, for example, by fastening the ignitor to a plunger which is accelerated by the pressure produced by the discharge for forming the workpiece so that a conductive sheath is introduced into the spark gap to renew the bridge between the electrodes preparatory to the next discharge.

The thread which functions as the ignitor can, for example, be comprised of a carrier of textile fibers and a sheath of conductive powder. Carrier threads made from any of the following materials are suitable: cotton, hemp, silk and synthetic material such as, for example, Perlon. The most suitable sheath is conductive silver, graphite, nickel-, copper- and tungsten-powder prepared in a mixture of a nitrovarnish and solvent.

The choice of the solvent portion and of the thickness of the sheath can influence the resistance of the ignitor. Thus, for example, an electrode spacing of 180 mm. and a resistance range of 1Ω to 10Ω establish the same optimal forming of the workpiece. Thus, the sheath or coating is not a critical magnitude and can, therefore, be applied with an inexpensive dipping process. The sheath can also be applied, for example, by vapor deposition, galvanically or by other appropriate methods.

The invention will be further elucidated with reference to the accompanying drawings which show by way of example embodiments of workpiece-forming devices according to the invention.

FIG. 1 is a schematic illustration of an embodiment of the invention for forming cylindrical workpieces; and

FIGS. 2 and 3 are schematic illustrations of embodiments of the invention for forming planar workpieces.

FIG. 1 illustrates an embodiment of the invention used for forming workpieces having a cylindrical configuration. This embodiment makes it possible for the first time to form an elongated cylindrical workpiece according to the hydrospark method with multiple discharges and a one-time installation of the workpiece in the workpiece-forming device.

The table below illustrates various combinations of nonconductive carrier and conductive sheath materials which can make up the ignitor of the forming device for forming an annealed steel pipe 60 mm. in diameter and having a wall thickness of 1 mm. The electrode spacing is 180 mm. and the charge on the capacitor battery is 20 kv., the latter having a capacitance of 16.8 μf.

Referring now to FIG. 1, reference numeral **1** denotes the workpiece to be formed, namely, a water-filled tube which is sealed on top and bottom by insulating parts **2**. By means of a central bore through the insulating parts **2**, two electrodes **3**a, **3**b extend into the water chamber and are screwed into the terminal brackets **4** of the hydrospark installation. The ignitor **5** starts from a reel **6** and is guided through the bore of earth-grounded electrode **3**a. Provided the insulation is adequate, electrode **3**b is connected to a bank of capacitors **7** via three-electrode spark gap **8**. When the capacitor bank is energized, a high voltage is applied to electrode **3**b. The energizing circuit for the capacitor bank and an ignition electrode for energizing the three-electrode spark gap **8** are disclosed in copending application Ser. No. 803,179, filed on Feb. 28, 1969 and having the title: Hydroelectric Forming of Cylindrical Workpiece by Capacitor Discharge.

TABLE

Carrier jacket	Cotton thread 2.0–3.0φ		Perlon thread 0.5–1.0φ		Hemp thread 1.0–2.0φ		Silk thread 0.3–0.5φ	
	R/Ω [b]	2s/mm. [c]	R/Ω	2s/mm.	R/Ω	2s/mm.	r/Ω	2s/mm.
Conductive silver	210	2.5	2.2	3.6	0.8	2.7	130	3.9 3.1 3.0
Graphite	90	3.4	3.2	3.7			200 115 2.10^3 $2.8.10^3$	3.5 3.0 2.3 2.6
Copper powder [a] (grain 0.04 mm.)	26	2.6			50 230	3.1 3.3		
Nickel powder [a] (grain 0.04 mm.)			100	3.0	$>50.10^3$	2.35		
Tungsten powder [a] (grain 0.06 mm.)	135 $>50.10^3$	2.4 1.8	10^3	3.0	50.10^3	2.3 2.6 2.75		

[a] Prepared in nitro-varnish and solvent.
[b] R is the resistance of the ignitor at 180 mm. length.
[c] 2s is the double deforming path.

After a discharge is completed, the nonconductive carrier of the ignitor **5** is transported along the electrode **3b** such that the segment of the ignitor **5** between the electrodes will again have a sheath and so conductively bridge the electrodes. The second discharge can follow provided the assembly remains tight after the first discharge. The assembly will remain tight because the second and subsequent discharges are of significant consequence only if the preceding discharge results in a slight forming of the workpiece. The means required to ensure a good seal are only symbolically represented by the sealing rings **9**.

Since the pressure wave which travels outwardly from an elongated ignitor is cylindrical, the same as when a discharge is effected through elongated wires, the entire pressure wave is utilized in the cylindrical forming of a workpiece. However, a planar pressure wave is not so easily established. Planar pressure waves are desirable, for example, for forming workpieces such as sheet metal by stamping, deep drawing and punching, the workpieces being planar prior to forming.

To produce approximately planar pressure waves, only a portion of a pressure wave produced at a sufficient distance from the workpiece is used. The operational efficiency of such an arrangement is only slight unless the remaining portions of the pressure wave are used to form other workpieces.

Also, the portion of the pressure wave which does not impinge directly upon the planar workpiece can be directed to the workpiece with the aid of reflectors and with a shift in the transit time. Finally, by superimposing a plurality of simultaneously produced cylindrical waves, an almost planar pressure front can be formed. In this connection, the discharge channels that produce the cylindrical waves can be connected either in parallel or in series.

Since workpiece forming is dependent upon cylindrical pressure waves, even for forming planar workpieces, the ignitor according to the invention, which works at optimum efficiency for cylindrical forming as indicated by the table, can also be applied successfully for forming the planar workpiece.

FIGS. **2** and **3** illustrate embodiments of the invention which function to produce approximately planar pressure waves. The arrows **30** and **40** in FIGS. **2** and **3** respectively emphasize that here too the ignitor permits a renewed bridging of the spark gap through an additional transport of the carrier.

The embodiment of FIG. **2** is exemplary of a device for forming planar workpieces with a cylindrical pressure wave and a reflector cap. The workpiece **21** to be formed is clamped to a form **23** with a holding implement. The reflector cap **24** is disposed above the workpiece and the space between workpiece **21** and cap **24** is filled with water **25**. The perpendicular walls of the cap hold two insulating parts **26** through which pass the electrodes **27**. The ignitor **28** runs through a bore in the electrodes, and its continuous transport is achieved as depicted in FIG. **1**. The electrodes **27** are connected via terminal brackets **29** to a bank of capacitors **19** which is dischargeable through a three-electrode spark gap **20**.

FIG. **3** shows another embodiment of a device for forming a planar workpiece **31** by means of several superimposed, cylindrical pressure waves. The workpiece **31** is secured to a form **33** with a holddown device **32**. The water chamber **35** is sealed above by cap **34** which contains several wall-mounted insulating parts **36**. Electrodes **37** are guided through two of these insulating parts and are connected to a capacitor bank (not shown) via terminal brackets **39**. The other insulating parts contain eyelets or guide rollers **41** for directing the ignitor **38**. Following a discharge of the capacitor bank the ignitor is transported further by the unimpaired carrier and thereby establishing a renewed bridging of the spark gap.

To those skilled in the art it will be obvious upon a study of this disclosure that our invention permits of various modifications and may be given embodiments other than particularly illustrated herein, without departing from the essential features of the invention and within the scope of the claims annexed hereto.

1. A device for forming workpieces by pressure waves generated in a liquid by an undersurface spark discharge, said device comprising two electrodes immersed in said liquid and mutually separated so as to define a spark gap, a capacitor battery connected across said electrodes, and an ignitor suspended between said electrodes in said spark gap, said ignitor comprising a carrier thread of textile fibers and a coating of conductive powder covering said thread.

2. In a device according to claim **1**, said textile fibers being selected from the group consisting of cotton, synthetic material, hemp and silk.

3. In a device according to claim **1**, said conductive powder being selected from the group consisting of conductive silver, graphite, copper, nickel and tungsten.

4. In a device according to claim **1**, said carrier thread consisting of cotton fibers and having a thickness of 2 to 3 mm.

5. In a device according to claim **1**, said carrier thread consisting of hemp fibers and having a thickness of 1 to 2 mm.

6. In a device according to claim **1**, said carrier thread consisting of Perlon fibers and having a thickness of 0.5 to 1.0 mm.

7. In a device according to claim **1**, said carrier thread consisting of silk fibers and having a thickness of 0.3 to 0.5 mm.