

April 27, 1965

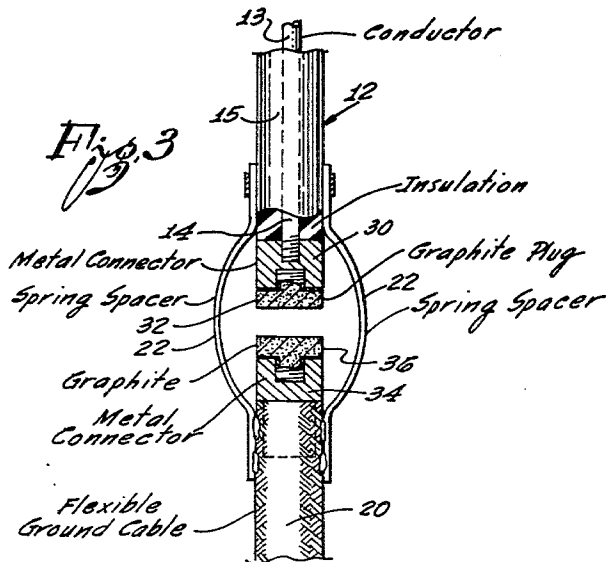
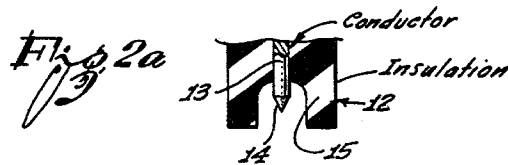
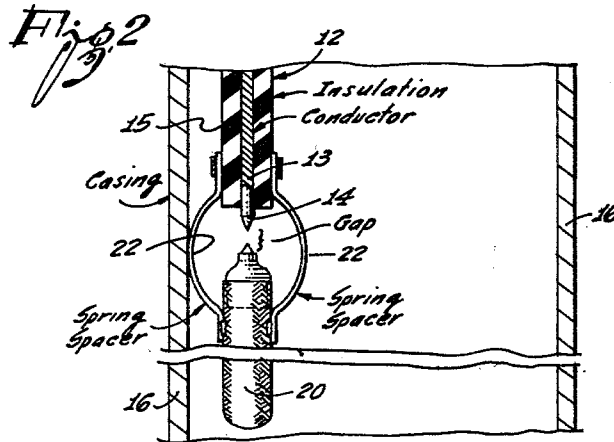
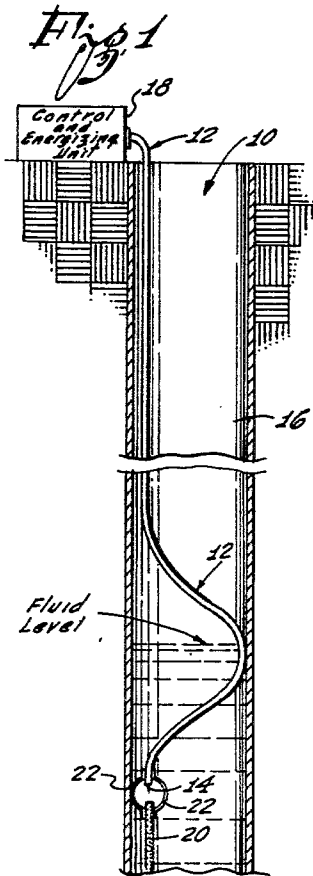
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3,180,418

CASING DESCALING METHOD AND APPARATUS

Filed Aug. 16, 1961

3 Sheets-Sheet 1



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CASING DESCALING METHOD AND APPARATUS

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Fig. 4

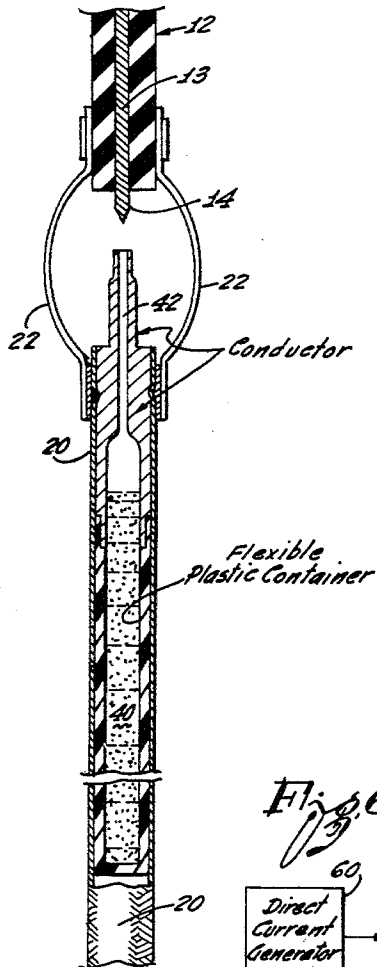


Fig. 5

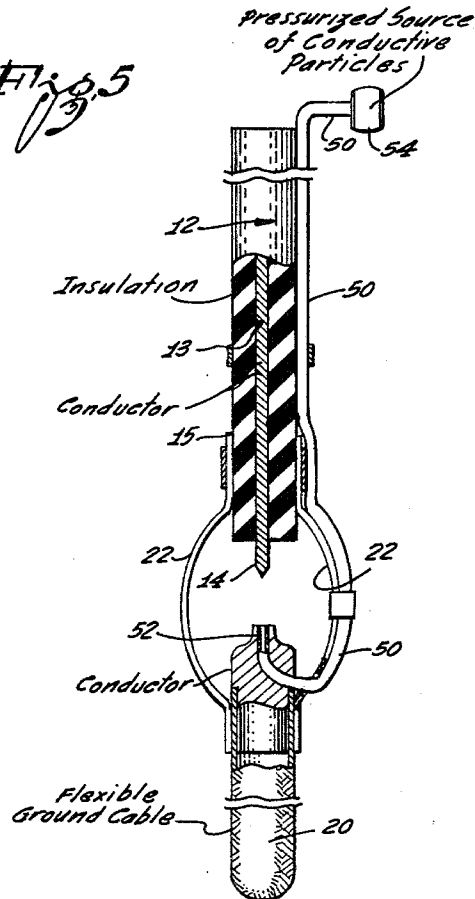
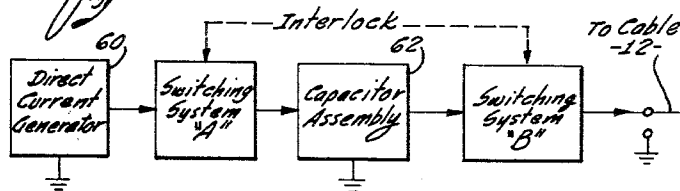


Fig. 6



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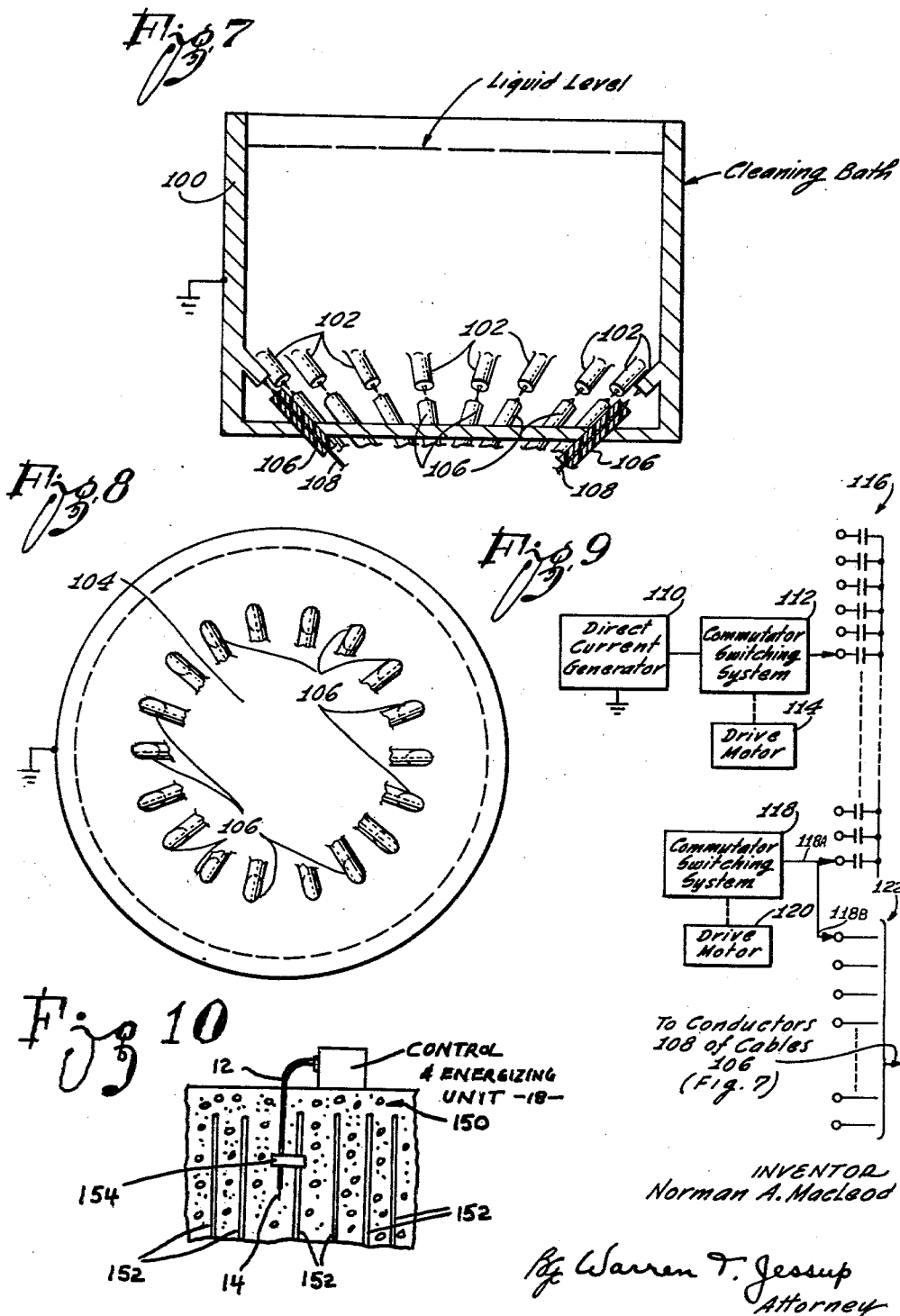
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CASING DESCALING METHOD AND APPARATUS

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3,180,418 CASING DESCALING METHOD AND APPARATUS

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13 Claims. (Cl. 166—43)

The present invention is concerned generally with an improved method, system and apparatus for cleaning articles, or for removing scale, or similar foreign material, from the casing of a water well or oil well, or from boiler tubes, tanks and the like.

The invention relates more particularly to an improved method, system and apparatus for performing the above-mentioned cleaning and descaling functions by means of electrically produced shock waves in a liquid.

A relatively small amount of energy is represented in electrical spark discharges under normal atmospheric conditions, such as those developed across the electrodes of an induction coil, or produced from a charged capacitor. This is because the resistance of the air in the path of the spark discharge drops to such a low value that the spark gap acts substantially as a short circuit.

The energy developed in any load, as is well known, is expressed as the square of the current multiplied by the resistance of the load. Therefore, in order that a high energy spark may be developed, it is not enough for the activating potential to be high, but an appreciable resistance must also be present in the discharge path.

High energy spark discharges have been produced by immersing the electrical spark-producing equipment in water. Then, an instant after the spark discharge is initiated, the path of the spark discharge is transformed into a volume of gas and water vapor expanding against the water. The inertia of the water causes a build-up of the pressure which can be as high as 10,000 atmospheres.

Most of the prior art underwater experiments have been made by discharging a capacitor into the electrical spark-producing equipment, the capacitor having previously been charged to a potential level of the order of 25 kilovolts.

Measurements in the prior art experiments show that the initial potential of the spark discharge absorbs power of the order of 400 megawatts from the capacitor, and that the current reaches a peak value of 85 kiloamps. The resulting shock wave propagated through the water is capable of exerting pressures up to 70 tons per square inch.

The present invention provides a system and apparatus which is predicated upon the underwater spark discharge principles set forth above, and which utilizes the tremendous shock waves produced by electrical discharges under water, or other fluid, for cleaning articles, descaling the casings of wells, tanks or the like. The descaling operations particularly related to wells have usually, heretofore, been carried out in the prior art by the use of explosives. The ultrasonic cleaning of articles in the prior art has usually been carried out by transducer-generated ultrasonic vibrations.

An important advantage of the present invention in its particular use in wells, therefore, is that, unlike many prior art systems, it does not require or use high explosives. The transportation and utilization of apparatus embodying the invention is not accompanied, therefore, by the usual hazards, regulations and inconveniences attendant to the use and transportation of high explosives to such wells.

Another important advantage of the present invention is that readily available electrical power sources can be used to produce the desired shock waves in the liquid; and

a convenient and flexible control is possible with respect to the duration, frequency and intensity of the shock waves so that the desired degree of cleaning or descaling action can be obtained.

Another advantage of the invention is that the danger of structural damage to a thin well casing can be reduced to a minimum by carefully controlling the size and frequency of the electrically produced shock wave.

The present invention is predicated on the above-described principles which demonstrate that when an electric cable, constructed to provide a relatively small electric spark discharge area within a liquid, is immersed in the liquid, and if a high voltage is applied to the cable, the resulting spark discharge which is initiated in the spark area in the liquid will set up an extremely powerful shock wave in the liquid. In the practice of the invention, these shock waves are used for descaling the surface of the casing containing the fluid, or for general cleaning purposes, as will be described. When the liquid is water, the shock is extremely intense because of the rapid vaporization of the water by the rapid release of energy in the electric spark discharge. As noted above, the spark discharge can be initiated by discharging a highly charged capacitor into the cable or other conductive system.

As also mentioned above, it has been found that the use of a capacitor of the order of 10 microfarads, charged to a level of 20 kilovolts, and then discharged into the submerged electrical system, produces an extremely powerful shock wave in the liquid. A series of shock waves can be produced by using a plurality of similar capacitors, and sequentially charging and discharging the capacitors into the cable. This control may be such that any desired frequency and intensity may be obtained, within limits dictated by factors such as the impedance of the electrical system.

It is, accordingly, an object of the invention to provide an improved method, system and apparatus for general cleaning purposes, or for descaling the casing of an oil well or water well, or for general descaling purposes in conjunction with the casings of boiler tubes, tanks and the like; and which method, system and apparatus does not require high explosives and their concomitant hazards, not only in handling above ground but in causing structural damage underground when used for this purpose.

A further object of the invention is to provide such an improved method, system and apparatus which is relatively simple to construct, and which utilizes relatively inexpensive and readily available components.

Yet another object is to provide such an improved method, system and apparatus which is subject to convenient and flexible control to be effective for general cleaning or descaling purposes in a wide variety of applications and conditions.

The concepts of the present invention also have general utility in the cleaning of articles. When the method, apparatus and system is utilized for descaling the casings of wells, and the like, electric cable of from 100 to 10,000 feet is involved with attendant electrical impedance. With such an application, the usual high impedance of the cable precludes the rapid successive discharges of high energy into the cable, with the attendant rapid series of electrical discharges at the spark gap area.

However, in its general application, the concepts of the invention can be applied, as will be described, to the cleaning of articles, and in this general application a large number of electrodes may be provided in a relatively shallow bath. These electrodes may be positioned peripherally, or otherwise arranged to have a minimum length of lead, with corresponding minimum impedance, and the electrodes may be fired in rapid sequence.

For example, ultrasonic vibrations may be derived by

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firing the above-mentioned electrodes of the preceding paragraph at the rate of 50,000 discharges per second. With 500 electrodes provided, for example, all the electrodes would fire in a total time of 10 milliseconds and each electrode would fire every 10 milliseconds, which would allow sufficient time for the vapor produced by the previous discharge to condense and condition the electrode area for the subsequent discharge.

In certain of the embodiments to be described, an insulated electric cable having an inner copper or aluminum conductor, for example, is used. In such embodiments, the lower end of the inner conductor is exposed to provide a spark discharge. A heavy flexible outer sheath may be provided on the lower ten feet of the cable, for example, to prevent kinking. This sheath may be composed, for example, of lead, or woven steel wire. The electric cable is lowered into the well whose casing is to be descaled, and it may be raised or lowered at will during the treatment.

When a high voltage is introduced between the upper end of the inner conductor in the cable and ground, a spark discharge is initiated at the exposed extremity of the conductor at the lower end of the cable down in the liquid in the well. This spark discharge sets up the desired shock waves in the liquid for descaling purposes.

To facilitate the initiation and rapid discharge of the spark into the liquid at the sparking area, and in accordance with the teaching of the present invention, a suitable concentration of colloidal graphite, fine metal powder, electrolytic solution, gas, or other suitable substance may be dispersed into the liquid at the sparking area, as will be described.

The other more general embodiment of the invention, in which the shock waves are initiated at high speed from a low impedance electrode system within the liquid for cleaning purposes, may also make use of suitable substances similar to those described in the preceding paragraph, the substances being dispersed into the sparking area in the liquid to facilitate the initiation and rapid flow of the spark discharge or otherwise change the nature of the spark discharge.

Other objects, features and advantages of the invention will become apparent from a consideration of the following description, when taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic representation of the apparatus and system of one embodiment of the invention being used in conjunction with the casing of a well and including an electric cable which is lowered down into the well;

FIGURE 2 is an enlarged fragmentary view, partly in section, of a portion of the embodiment shown in FIGURE 1;

FIGURE 2A is a fragmentary sectional view showing a modification of the lower extremity of the cable used in the apparatus of FIGURES 1 and 2;

FIGURE 3 is a representation of a further embodiment of the invention, and is a fragmentary sectional view of a portion of apparatus incorporating the further embodiment;

FIGURE 4 is a fragmentary sectional view of yet another embodiment of the invention;

FIGURE 5 is a fragmentary sectional view of a still further embodiment of the invention;

FIGURE 6 is a schematic block diagram of a suitable energizing system for the cable used in the above-mentioned embodiments of the invention;

FIGURE 7 is a side sectional view of a further embodiment of the invention, in which the concepts of the invention are used for general cleaning purposes;

FIGURE 8 is a bottom view of the embodiment of FIGURE 7;

FIGURE 9 is a schematic representation of an electrical system suitable for use in conjunction with the embodiments of FIGURES 7 and 8; and

FIGURE 10 is a schematic representation of the sys-

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tem of the invention being used to impact wet concrete.

The representation of FIGURE 1 shows a sectional view of a well 10 which may, for example, be an oil well, a water well, etc. In accordance with the invention, an insulated electric cable 12 is lowered down into the well. As noted above, the cable 12 includes an inner conductor 13 which may be composed, for example, of aluminum or copper. The inner conductor 13 is surrounded by an insulating sheath 15. However, the lower extremity 14 of the inner conductor is exposed, as best shown in FIGURE 2.

The lower end of the cable 12 may be enclosed by a sheath composed of lead, or wire mesh, for example, to prevent kinking, as mentioned above. As shown in FIGURE 1, the lower end of the cable 12 has a helical configuration, and it is composed of a flexible material. This configuration of the lower end of the cable assures propinquity to one side of the casing of the lower extremity of the cable. Then, the cable may be rotated as it is lifted or lowered in the well to assure that adequate descaling shock waves will reach all portions of the casing.

The well 10 includes a tubular metal casing 16 which, in accordance with usual practice, is perforated to permit the water, oil or other liquid to seep into the well. As is well known, after prolonged periods of time, scale and similar foreign material form on the inner surface of the casing 16. It is the purpose and intention of the present invention in one of its aspects to provide an improved system and apparatus for removing such scale and foreign material from the inner surface of the metal casing.

A control and energizing unit 18 is coupled to the upper end of the cable 12. The cable is fed out from the unit 18 and down into the well. When a descaling operation is to be carried out, the unit 18 applies a high voltage between the upper end of the conductor 13 and ground. The unit 18 may be a portable unit and it may include, for example, generators and power packs supported on a truck, or on any other appropriate vehicle. The unit 18 may also include a bank of capacitors which can be charged successively from the power pack and discharged into the cable 12.

It is preferable that high voltages be used, since the use of high voltages results in low line losses and permits a small diameter cable to be used.

The introduction of such a high voltage between the upper end of the inner conductor 13 and ground results in a spark discharge within the liquid in the well at the lower protruding extremity 14 of the conductor. This spark discharge produces water vapor which condenses and it may also produce small amounts of hydrogen and oxygen which recombine and condense, the results of this action being the generation of a hard, single shock wave in the liquid. This shock wave impinges on the inner surfaces of the casing 16 for descaling purposes.

The discharge rate is limited by the line impedance, as mentioned above. The design may be such that successive discharges may be made to occur at the lower extremity 14 of the conductor 13, so that the desired descaling action can be continuously carried out as the cable is lifted or lowered in the well, and as the cable is rotated so as to bring the lower extremity 14 of the inner conductor 13 adjacent different portions of the inner surface of the casing 16.

The resulting mechanical shocks can range, for example, up to 10,000 joules for water wells, and from 10,000 to 50,000 joules for oil wells. At 10,000 volts, and using a 10 microfarad capacitor, 500 joules can be produced. Likewise, when the 10 microfarad capacitor is used, 1,000 volts produces 75 joules; 20,000 volts produces 2,000 joules; and 50,000 volts produces 12,500 joules. If a 20 microfarad capacitor is used, 50,000 volts will produce 25,000 joules; and 100,000 volts will produce 10,000 joules.

For many applications it is desirable for a flexible, electrically conductive ground cable 20 to be suspended

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from the lower end of the cable 12. The ground cable may be so suspended by a plurality of bulged flexible spring spacers 22. These spring spacers serve to hold the upper end of the ground cable 20 in spaced relationship from the lower exposed extremity 14 of the conductor 13. The spring spacers 22 also serve to engage the adjacent surface of the casing 16 to prevent direct contact between the lower exposed extremity 14 of the conductor 13 and the casing.

With the illustrated arrangement of FIGURES 1 and 2, a reproduceable, highly localized spark discharge may be produced in the gap between the lower exposed extremity 14 of the conductor 13 and the upper end of the ground cable 20.

Graphite, or other electrically conductive particles may be dispersed in the spark area, as will be described, to facilitate the initiation of the spark discharge in the gap, and to modify its characteristics. The use of the ground cable 20 provides a fixed ground distance for the gap, and enables the discharge characteristics of the system to be conveniently controlled.

The ground cable 20 can be formed to have its lower end define a helical spiral starting, for example, about 12 inches below the top of the cable. The cable can be made resilient, and the diameter of the resulting helix can be normally slightly greater than the diameter of the casing. This configuration of the ground cable will assure that it makes a good connection with the casing 16. This is most desirable in oil wells, for example, where grounding conditions are not as satisfactory as in water wells.

When graphite particles are used for the above-described purpose, it should be noted that such particles have a negative coefficient of electrical conductivity. That is, as is well known, the resistivity of graphite decreases with temperature rise. This provides a rapid unloading of energy by providing an optimum path between electrodes formed by the shortest, most conductive, chain of particles between the electrodes.

When colloidal or fine metal powders are used for the above purposes, such particles will affect the discharge conditions by providing a chain of particles which form the shortest path of least resistance. As pointed out above, electrolytes or gases, or any combination of the above-mentioned substances, can be used for this purpose.

The fragmentary diagram of FIGURE 2 shows on an enlarged scale, the details of the various components of the system of FIGURE 1 adjacent the spark area. As clearly shown in FIGURE 2, the spacer springs 22 support the ground cable in a spaced relationship with the lower extremity of the conductor 14 to provide the desired spark gap. As noted above, the assembly can be designed and constructed so that a desired distance exists between the lower extremity of the conductor 14 and the upper end of the ground cable 20 to provide a spark gap of desired characteristics.

If so desired, the lower end of the insulating sheath 15 of the cable 12 may be formed, in the manner shown in FIGURE 2A, to have an inverted cup-shaped configuration surrounding the lower extremity 14 of the conductor 13. This cup-shape of the insulating sheath provides a gas pocket around the spark gap to facilitate the initiation of the spark discharge.

As shown in FIGURE 3, the lower protruding extremity 14 of the inner conductor 13 of the cable 12 may be threaded to receive a metallic connector 30, and a graphite electrode 32 may be threaded into the lower end of the connector 30. Likewise, the upper end of the flexible ground cable 20 may be equipped with a metallic connector 34, and a second graphite electrode 36 may be threaded into the connector 34. The graphite electrodes 32 and 36 are supported in spaced relationship, as shown in FIGURE 3, and the resulting current flow through the inner conductor 13 results in a spark discharge between the graphite electrodes. This creates a dispersion of graphite particles in the fluid in the vicinity of the spark

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gap which facilitates the initiation of successive electric spark discharges through the liquid.

In the embodiment of FIGURE 4, the flexible, electrically conductive ground cable has a chamber formed in its upper end, and this chamber communicates with the spark gap area through a passageway 42. A flexible plastic container, or other appropriate container, filled with graphite particles in suspension in oil or "Aquadag," for example, is positioned in the chamber 40. Then, the shock waves from each successive electric spark discharge across the spark gap, cause the container 40 to become compressed. This forces the container to discharge an amount of graphite particles into the liquid in the vicinity of the spark gap to facilitate the initiation of successive electric spark discharges. As mentioned above, other appropriate metal particles in liquid suspension, or an electrolyte solution, may be used for this purpose.

In the embodiment of FIGURE 5, a tube 50 extends down the side of the insulating sheath 15 of the cable 12 from the upper surface, and the lower end of the tube 50 extends into the upper end of the ground cable 20, as shown. A passageway 52 is formed in the ground cable, and the passageway extends up through the upper end of the ground cable. Under the control of apparatus at the surface, a measured amount of graphite, or other metallic particles, or other substances, can be sent down through the tube 50 from a pressurized source 54 to be dispersed through the passageway 52 into the area of the spark discharge. These particles, as in the previous embodiments, facilitate the initiation of each of the spark discharges at the spark discharge area.

As mentioned above, the high voltage can be applied to the upper end of the cable 12 by charging a capacitor to a high voltage, and then by discharging the capacitor down into the cable. This charging and discharging of capacitors is, per se, known to the art. As also suggested, a plurality of capacitors can be used, so that a first bank may be discharging into the cable, while a second bank is being charged.

Suitable apparatus for applying the high voltage to the cable 12 is shown in schematic block form in FIGURE 6. The apparatus of FIGURE 6 includes, for example, a direct current generator 60 which produces a charging current for a capacitor 62. This direct current generator may, for example, include a transformer for stepping the normal 110 volt A.C. voltage up to 25,000 volts A.C. and it may also include a suitable full-wave rectifier for converting the alternating current voltage into the desired direct current charging voltage. Vacuum tube rectifiers designed for high voltage applications are available, and may be used. For example, a diode manufactured by the Radio Corporation of America and designated 5825 has an inverse peak voltage rating of 60,000 volts, and is well suited for the present purposes.

A switching system A is controlled to connect the direct current generator 60 to the capacitor assembly 62 to enable the capacitor assembly to be charged to the desired high potential level. Then, a switching system B introduces the high potential charge from the capacitor assembly between the upper end of the inner conductor 13 of the cable 12 and ground. As indicated by the dotted lines, the switching systems A and B are interlocked, so that when the switching system A connects the direct current generator 60 to the capacitor assembly 62, the switching system B is open. Likewise, when the switching system B connects the capacitor assembly 62 to the cable 12, the switching system A is open.

As mentioned above, the concepts of the present invention can also be used in conjunction, for example, with a relatively shallow bath for creating ultrasonic vibrations in a liquid contained in the bath for cleaning articles immersed in the liquid. The resulting system is advantageous over the usual prior art ultrasonic systems using magnetostrictive or piezoelectric transducers, in that there is no energy bottleneck in the spark discharge type of

ultrasonic vibration system, as there often is in the prior art systems.

A typical bath is shown, for example, in FIGURE 7. The illustrated bath is formed of a cylindrical-shaped metallic container 100 which has a closed bottom and an open top. The container 100 is grounded, so as to provide a return for the spark discharges initiated in the water, or other liquid, contained in the container. In accordance with the invention, a plurality of ground electrodes 102 are formed in the inner surface of the wall of the container 100. The electrodes 102 may extend, for example, directly around the periphery of the container. As illustrated, the electrodes 102 are inclined from the inner surface of the container wall. For example, the electrodes 102 can number 32 for an appropriate practical embodiment.

Extending through the bottom 104 of the container 100 are a plurality of insulated cables 106. The insulated cables 106 extend through the bottom in insulated relationship therewith, and each has an inner conductor 108. The inner end of each of the inner conductors 108 is exposed, and is spaced from a similar conductor of respective ones of the ground electrodes 102.

The inner conductors 108 of the cables 106 may be connected to an appropriate energizing source, and relatively short leads may be used so that cable impedance is reduced to a minimum. This permits the rapid energizing of the cables in succession to set up the desired ultrasonic vibrations in the liquid in the container 10. These vibrations may then serve to clean any article placed in the liquid in the container. Because of the much higher individual energy capability from each capacitor discharge, this embodiment of the invention can also work effectively in the sonic frequency range.

The energizing system for the conductors 108 of the cables 106 would include, for example, a capacitor for each of the cables. In the suggested arrangement of 32 electrodes, it would be possible to fire the electrodes successively at one-tenth second intervals. This could be carried out by firing the electrodes in a staggered sequence to prevent adjacent after-effect interference. For example, the electrodes 1, 6, 11, 16, 21, 26, 31; 4, 9, 14, 19, 24, 29; 2, 7, 12, 17, 22, 27, 32; and so on could be sequentially fired.

It is of course obvious that in the sequence of firing, the number of electrodes in each successive firing must not be a factor of the total number of electrodes used. For instance, in using 32 electrodes, every 3rd, 5th, 7th, 11th, 13th, 17th, 19th, 23rd, 29th, etc., could be used.

It is evident that by increasing the number of electrodes and the rate of firing it would be possible to produce a frequency in the ultrasonic range.

As noted above, an advantage of the system of FIGURES 7 and 8 is that there is no need for energy limiting transducers, such as piezoelectric or magnetostrictive transducers. Also, the peripheral arrangement of the electrodes, together with rapid and frequent discharge, would set up interference of the shock wave so as to produce a very intense and complicated vibrational pattern in the article being cleaned.

A typical switching and energizing system for the apparatus of FIGURES 7 and 8 is shown in FIGURE 9. The switching and energizing system of FIGURE 9 may include a direct current generator 110. This generator, as was the case with the generator 60 of FIGURE 6, may include a suitable transformer and high voltage rectifier. The resulting direct current voltage from the generator 110 is applied to a commutator switching system 112 which is driven by an appropriate drive motor 114. The commutator switching system 112 serves to connect the high voltage from the generator 110 successively to different ones of a bank 116 of capacitors. The operation of the commutating system 112 causes the capacitors in the bank 116 to be successively charged to a desired high voltage in each of a succession of recurrent cycles.

The system of FIGURE 9 also includes a second commutating switching system 118 which is driven by a drive motor 120. The latter commutating switching system is also driven to be connected successively with the capacitors of the bank 116 in a phase displaced relationship from the commutating system 112. The commutating system 118 has a first arm 118A to contact the capacitors in bank 116, and also has a second arm 118B which successively and cyclically engages a plurality of contacts in a bank 122. These latter contacts are connected to different ones of the inner conductors 108 of the cables 106 of FIGURES 7 and 8. Thus, the charge from each of the capacitors is delivered to the proper inner conductors 108.

The commutating system 118 causes the charged capacitors of the bank 116 to be successively discharged into selected ones of the cables 106 in a plurality of successive cycles. The connections from the conductors 108 of the cables 106 may be made in a predetermined pattern to the terminals of the bank 122, so that the above described sequence of firing may be realized.

The improved system and apparatus of the invention can further be used also, for example, for compacting gravel around the casing of an oil or water well; and it can also be used, for example, to remove mill scale in metal rolling mills. In general, the system and apparatus of the invention finds utility in applications where ultrasonic vibrations are used for cleaning or descaling purposes.

A further application of the system and apparatus of the invention, as shown in FIGURE 10, is in compacting wet concrete. In this latter application the apparatus can be removed from the concrete before the concrete has completely hardened, or left abandoned in the concrete. In this application, for example, a series of discharge lines can be used in the concrete at different positions and at varying depths.

In the illustrated embodiment of FIGURE 10, the cable 12 is immersed down in a mass of wet concrete 150. A plurality of usual metallic reinforcing rods 152 extend up through the mass of concrete 150. These rods are at electrical ground potential. The cable 12 is clamped to one of these rods by means of a clamp 154. The clamp provides a fixed spark discharge gap between the exposed end 14 of the central conductor and the adjacent grounded reinforcing rod 152.

The resulting spark discharge between the end 14 and the adjacent rod 152 in the concrete sets up the desired internal shock waves, as described, which perform the impacting function. If the cable 12 is to be removed from the concrete, the clamp 154 may be constructed to be capable of being torn apart when the cable is pulled.

The invention provides, therefore, an improved method, system and apparatus for descaling casings and for general cleaning purposes. As described above, the apparatus serves to set up shock waves in a contained liquid, and these shock waves may be used to descale the walls of the container, or for cleaning articles placed in the container.

The apparatus and system of the invention is advantageous in that no high explosives are required, and in that the required shock waves are electrically produced in a simple, straightforward and easily controlled manner.

While particular embodiments of the invention have been shown and described, modifications may be made, and it is intended in the claims to cover all such modifications as fall within the scope of the invention.

What is claimed is:

1. The method of descaling a casing containing a liquid including: introducing an electrically conductive cable into the liquid in the vicinity of the casing, and applying an electric potential to the cable to produce an electric spark discharge in the vicinity of the casing and thereby set up descaling shock waves in the liquid.

2. The method of descaling a casing containing a liquid including: introducing down into the liquid in the vicinity of the casing an electrical conductor having an insulating sheath with the lower extremity of said conductor protruding through the sheath, and applying an electric potential to the conductor to produce an electric spark discharge at the lower extremity thereof in the vicinity of said casing, and thereby setting up descaling shock waves in said liquid.

3. The method of descaling a casing containing a liquid including: introducing an electrically conductive cable into the liquid in the vicinity of the casing, applying an electric potential to the cable to produce a localized electric spark discharge in the liquid in the vicinity of the casing and thereby set up descaling shock waves in the liquid, and introducing electrically conductive particles into the liquid in the area of the spark discharge to facilitate the initiation of the spark discharge.

4. Apparatus for descaling a casing containing a liquid including: an electrically conductive cable adapted to extend down into the liquid in the vicinity of the casing, said cable having an insulating sheath and having an inner electrical conductor with the lower extremity thereof protruding through the lower end of said sheath, means for applying a potential to said inner conductor to produce an electric spark discharge at the lower extremity thereof in the vicinity of the casing and thereby set up descaling shock waves in the liquid and which includes means for introducing electrically conductive particles into the liquid in the vicinity of the electric spark discharge to facilitate the initiation of the spark discharge.

5. Apparatus for descaling a casing containing a liquid including: an electrically conductive cable adapted to extend down into the liquid in the vicinity of the casing, said cable having an insulating sheath and having an inner electrical conductor with the lower extremity thereof protruding through the lower end of said sheath, an electrically conductive flexible ground cable adapted to be positioned in said liquid, bulged resilient spacing members secured to said first-named cable and to said ground cable for holding the lower end of said first-named cable and the upper end of said ground cable in spaced relationship and to prevent direct contact between the exposed lower extremity of said inner conductor and said casing, and means for applying a potential to said inner conductor to produce an electrical spark discharge between the exposed lower extremity of said inner conductor and the upper end of said ground cable in the vicinity of said casing and thereby set up descaling shock waves in the liquid.

6. The combination defined in claim 5 and in which said ground cable includes a chamber therein and a passageway extending from the chamber to the upper end of said ground cable, and flexible container means for supporting conductive particles in said chamber to be discharged through the passageway into the area between the exposed lower extremity of said inner conductor and the upper end of said ground cable so as to facilitate the initiation of the electrical spark discharge.

7. The combination defined in claim 5 and which includes tubular means extending down into the liquid and terminating at the area between the exposed lower extremity of said inner conductor and the upper end of said ground cable to introduce electrically conductive particles into said area so as to facilitate the initiation of the spark discharge.

8. The method of setting up vibrations in a casing containing a liquid including: introducing an electrically conductive cable having electrode means associated therewith down into the liquid, and applying an electric potential to the cable to produce an electric spark discharge at said electrode means in the liquid, and thereby set up shock waves in the liquid to be transmitted to the casing.

9. The method of setting up vibrations in a casing containing a liquid including: introducing down into the liquid an electric conductor having an insulating sheath with

the lower extremity of said conductor protruding through said sheath, and applying an electric potential to the conductor to produce an electric spark discharge at the lower extremity thereof, and thereby set up shock waves in the liquid to be transmitted to the casing.

10. Apparatus for removing material from the surface of an article, which surface is in contact with a liquid, including: an electrically conductive element adapted to extend into the liquid and having a first electrode formed at the extremity thereof; electrically conductive means adapted to be positioned in the liquid for forming a second electrode in spaced relationship with said first electrode so as to define a spark gap therebetween; means for introducing electrically conductive particles in the liquid in the area of the spark gap to facilitate the initiation of the spark discharge between said first and second electrodes; and means for applying a potential across said first and second electrodes to produce an electrical spark discharge between said electrodes within said liquid to set up shock waves in the liquid for removing material from the surface of the article.

11. The method of removing material from the surface of an article, which surface is in contact with a liquid, which includes:

setting up a spark discharge in the liquid to produce shock waves therein for removing the material from the surface of the article, including the step of introducing electrically conductive particles into the liquid in the area of the spark discharge to facilitate the initiation of the spark discharge.

12. The method of removing material from the surface of an article, which surface is in contact with a liquid, which includes:

setting up a spark discharge in the liquid to produce shock waves therein for removing the material from the surface of the article, including the step of introducing graphite particles into the liquid in the area of the spark discharge to facilitate the initiation of the spark discharge.

13. Apparatus for removing material from the surface of an article including:

a container adapted to hold a liquid into which the article may be immersed, a plurality of electrically conductive elements extending into the container, each having a first electrode formed at the extremity thereof, means forming a plurality of second electrodes within the container, one for each first electrode in spaced relationship with said first electrode to form a spark gap therebetween, energizing means for applying a potential to said electrically conductive element to produce an electric spark discharge between said first and second electrodes to set up shock waves in the liquid for removing material from the surface of the article; and

means for controlling the energizing means to recurrently apply the potential across said pairs of electrodes in a sequential manner to produce a recurrent series of spark discharges between said pairs of electrodes so as to set up shock waves in the liquid for removing material from the surface of the article.

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