219-121 SEARCH ROOM

Nov. 27, 1956 T. I. LESTON ET AL 2,772,346

HEAT BLASTING TOOL WITH FLUID JET

Filed Nov. 9, 1953 4 Sheets-Sheet 1

Fig. 1

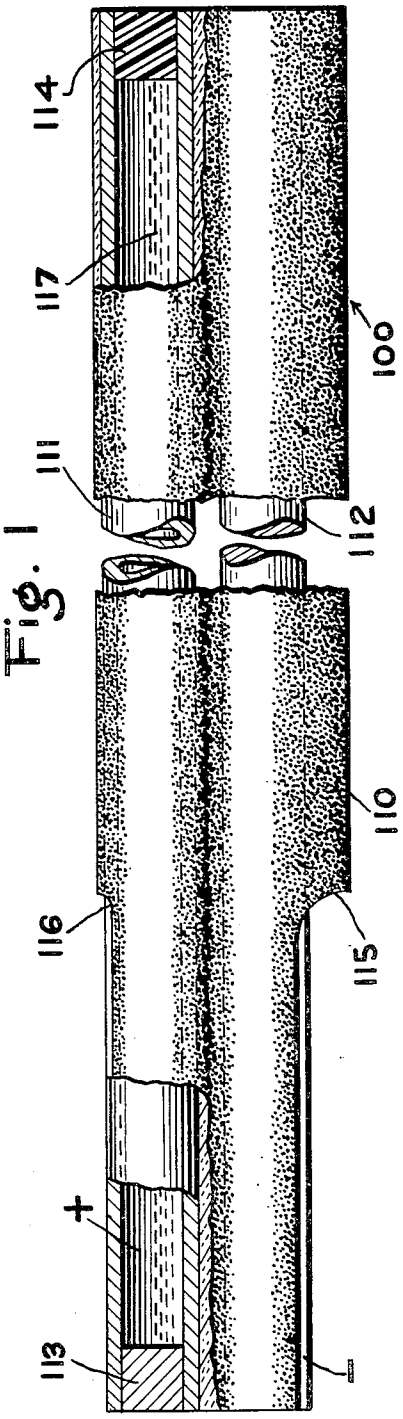


Fig. 3

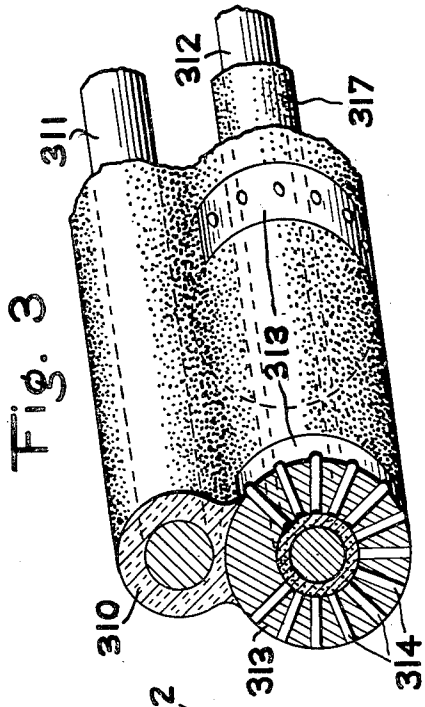
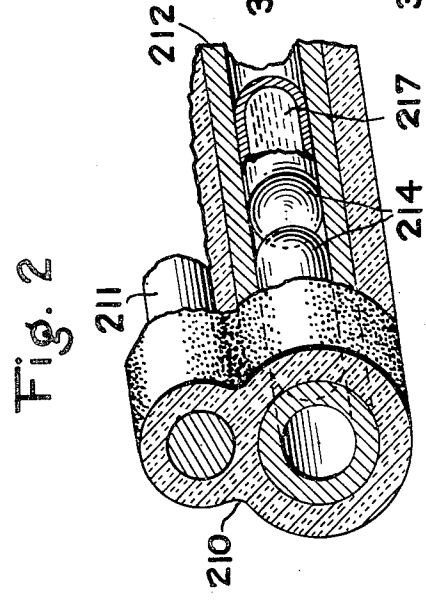


Fig. 2



INVENTORS
THEODORE I. LESTON and
WILLIAM B. KRIEWALL
BY
Connolly & Hutz
THEIR ATTORNEYS

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Filed Nov. 9, 1953 4 Sheets-Sheet 2

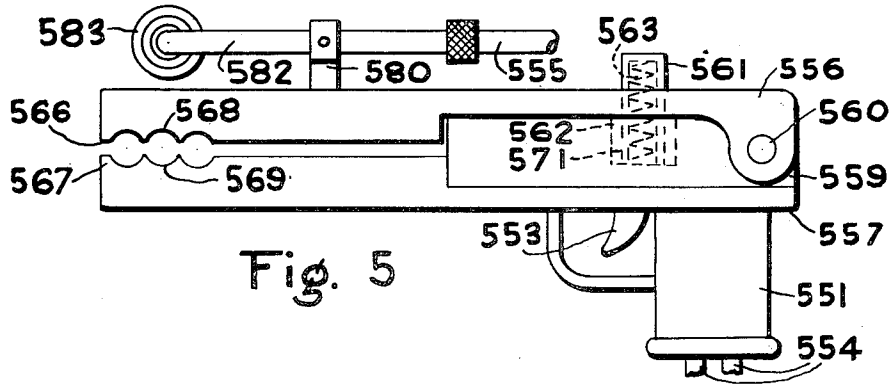


Fig. 5

Fig. 4c

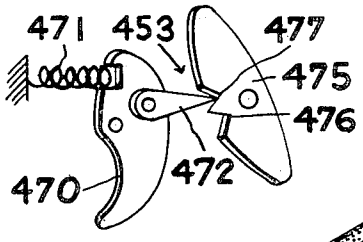


Fig. 4a

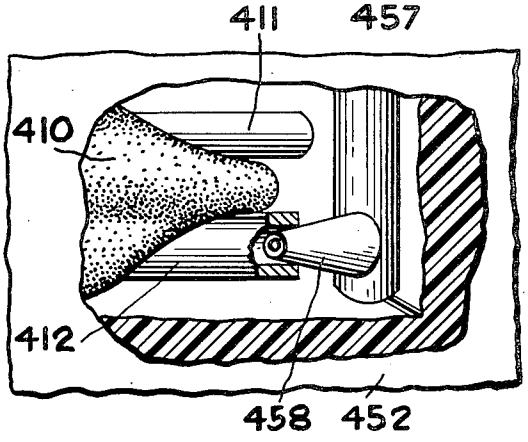


Fig. 4b

INVENTORS
THEODORE I. LESTON and
WILLIAM B. KRIEWALL
BY
Connolly & Hutz
THEIR ATTORNEYS

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HEAT BLASTING TOOL WITH FLUID JET

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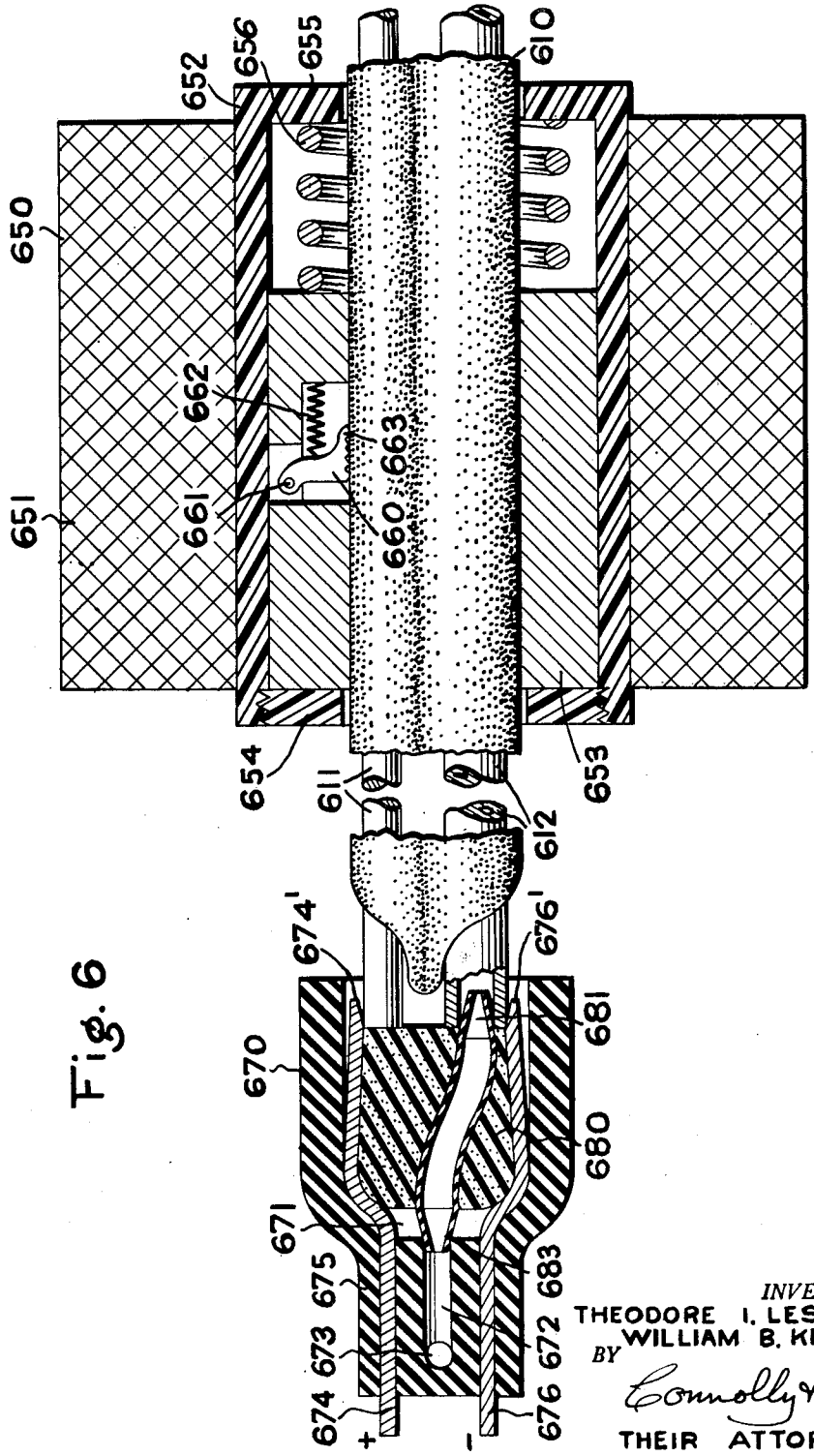


Fig. 6

INVENTORS
THEODORE I. LESTON and
WILLIAM B. KRIEWALL
BY
Connolly & Hutz
THEIR ATTORNEYS

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HEAT BLASTING TOOL WITH FLUID JET

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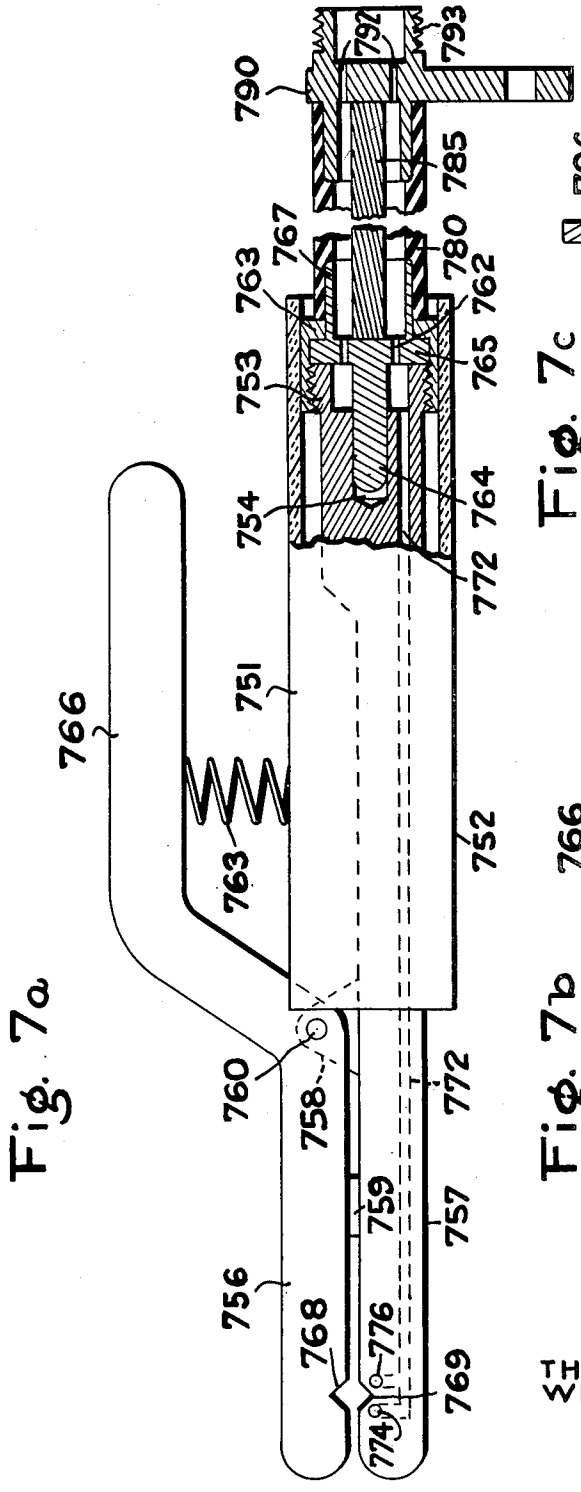


Fig. 7a

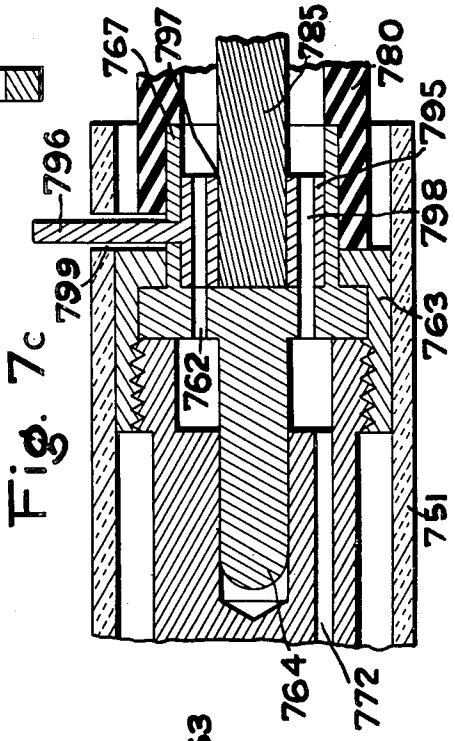


Fig. 7c

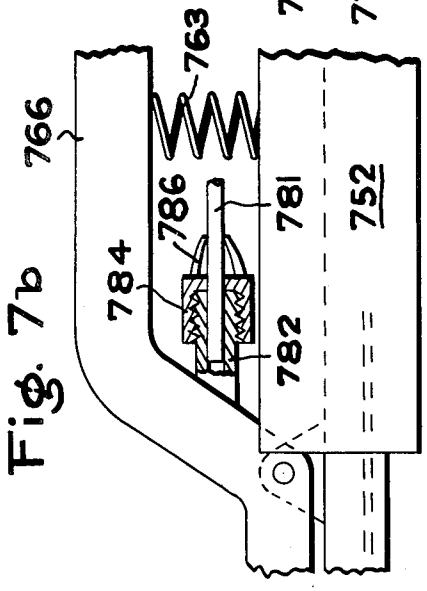


Fig. 7b

INVENTORS
THEODORE I. LESTON and
WILLIAM B. KRIEWALL
BY
Connolly & Hutz
THEIR ATTORNEYS

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2,772,346

HEAT BLASTING TOOL WITH FLUID JET

Theodore I. Leston, New York, and William B. Kriewall, Flushing, N. Y., assignors to All-Sil Welding Metals, Inc., New York, N. Y., a corporation of New York

Application November 9, 1953, Serial No. 391,042

13 Claims. (Cl. 219—121)

This invention relates to a new and revolutionary type of heating tool. More particularly the invention relates to a tool especially adapted for use in high temperature material removing processes of various types and which is independent of the electrically conductive or non-conductive nature of the work material. Specifically, the invention relates to a blasting tool employing a plurality of spaced-conductive members combined into an integral unit by means of a special gas and metal oxide-producing covering composition.

The revolutionary type tool of the present invention contemplates the use of a dipolar electrode which may be connected to a source of electrical energy, preferably D. C., to initiate an arc between spaced-conductive members with a resulting rapid disintegration of the surrounding covering composition accompanied by an extremely rapid exothermic action. The heat generated by such action approaches 10,000° F. and is so concentrated as to be readily directed upon various refractive and normally heat-resistant material to dissolve and/or disintegrate the same. In particular the tool is of special utility in cutting stone, rock, reinforced concrete, and any other nonmetallic highly refractory materials including silicon carbide and firebrick. The tool also is especially efficacious in treating electrically conductive solids such as metals.

The present invention contemplates effecting a substantial increase in the efficiency of the blasting action of such type tool through the simple expedient of applying an auxiliary fluid jet to the blasting zone during the operating of the tool to generate enormous quantities of gas which expand and assist in the cutting operation. According to a preferred form of the invention, liquid is directed into the region of the arc within the blasting zone to therein become disassociated into steam and gaseous vapors of rapidly expanding volume. In another form of the invention, water or a similar volatile liquid is enclosed within one of said dipolar conductor members whereby the desired gas-generating action is provided as the tool is consumed, independently of any external supply means. A further form of the invention contemplates applying solid coating to one or the other of said dipolar conductors, including integral gas-forming substances which may become disassociated as the tool is consumed to evolve a directional jet of gas in the region of the blast zone.

In accordance with the present invention, the gas-forming liquid may be supplied by reason of a cavity in said conductive members which may be filled with either a free liquid or individual capsules containing such liquid. Such type cavity may include spaced-isolating diaphragms or membranes, as for example in the form of expansible discs, in order to prevent the contained liquid from becoming prematurely discharged or activated. It is further contemplated that the jet generating fluid may be supplied from an external source via single or multiple channels in the dipolar conductor members or in

the covering composition, as desired. Alternatively, externally supplied fluid may be directed into the region of the blasting zone by means of independent nozzles of the fog or spray type supported by or in conjunction with the tool holder. In instances where the jet-forming substance comprises a solid coating, the covering composition on the spaced-conductor members may include means for directing gas generated from said coating laterally of the tool.

As set forth more fully in said co-pending applications, one of the important characteristics of the blast heating tool is its ability to maintain an electric arc between spaced-conductor members independently of the material desired to be processed. Such action is attributable to the inclusion of gas-generating and iron oxide-forming ingredients in the relatively thick covering composition employed. In operation, initiation of an arc between the ends of the conductor members causes the ingredients of the covering composition to disassociate with the rapid evolution of gas in the formation of a narrowly confined, conical gas stream axially directed from the end of the tool to a distance of several feet, which stream totally encompasses the arc between the conductor members. The heat evolved from the combination of the arc and blast stream exceeds temperatures of 8,000° F. and when directed upon siliceous materials rapidly melts, dissolves and substantially disintegrates the same in a matter of seconds. Applicant has found that this disintegrating action can be enormously enhanced by the provision of independent gas-supplying means and particularly by reason of directing a volatile fluid into the blasting stream adjacent to the arc. When such a condition occurs, the efficiency of disintegration of the material processed is accelerated by more than 50 per cent, causing an increase in the size of the hole formed by the blasting stream, accompanied by scavenging of molten slag which has accumulated from the intense heat of the operation.

This unusual phenomena is apparently attributable to the fact that as a gas expands it does work at the expense of its kinetic energy. If the gas is insulated, the loss of energy will produce a temperature drop or cooling effect. However, if the gas is in thermal contact with its surroundings (as in the instant case, the walls of a bored hole) heat will transfer from the surroundings to the gas and offset the loss of kinetic energy. The temperature of the gas thus remains substantially constant when confined. Thus, in the instant case, evolution of enormous quantities of gas deep within the blast zone results in exceedingly rapid expansion of the gas laterally towards the bounding walls of the cut and ultimately towards the open mouth thereof. This gas serves to push molten slag and disintegrated material externally of the bored hole whereby a substantially clean opening is obtained upon completion of the cutting operation. It will be appreciated that as the gas escapes from the open mouth, the rapid expansion thus permitted produces a large temperature drop with a consequent cooling effect on the molten slag at such point. This has proven exceedingly beneficial in scavenging the bored opening by coagulating the slag and ejecting it continuously, as though from an explosion.

The agents which may be used to provide the necessary rapid evolution of enormous quantities of gas may be in either fluid or solid form. When a liquid is used, the perferred agent is water. Other liquids of similar equivalent effects may be used, however, including ethyl alcohol, benzene, ethylene or trimethylene glycol, hydrogen peroxide, acetone, and the like. When it is desired to employ a gas-generating agent which is normally solid, the same is preferably formed from hydrated borax or sodium

bicarbonate, which may be applied to at least one of said dipolar conductor members as a coating, either with or without conventional binding agents. Alternatively, it may be desirable to use urea, ammonium chromate, calcium chloride or tetra oxide, crystalline nitrogen pentoxide, and hydrated ammonium nitrate. In cases where relatively little water vapor can be anticipated, it is also possible to employ calcium carbide. The use of this latter agent, however, is subject to the ability to control the discharge or combustion of any acetylene generated by combination with ambient water vapor.

Having broadly disclosed the generic concept of the invention, reference will now be made to the accompanying drawings in defining particular illustrative examples and in which:

Fig. 1 illustrates a dipolar blasting tool according to one form of the invention,

Fig. 2 illustrates a dipolar blasting tool according to another form of the invention,

Fig. 3 illustrates a dipolar blasting tool according to a further modified form of the invention,

Figs. *4a*, *4b*, *4c*, 5, 6, *7a*, *7b*, and *7c* illustrate other modifications of the invention.

It is essential to the successful operation of the heat blasting tool that the covering composition be relatively thick as compared with contemporary flux and gas-producing coverings, and that the same include substantial amounts of gas and iron oxide evolving constituents. In particular it is necessary that the covering composition include ingredients which will disintegrate and/or disassociate to evolve iron oxide and carbon dioxide. One preferred form of such covering composition includes 10 parts hydrogen, 23 parts cellulose, 2 parts cryolite, 15 parts iron powder, 7 parts graphite, 10 parts kaolin, 8.5 parts manganese, 1 part silica, 4 parts talc, and 9.5 parts zircon; all parts being by weight. In such type composition the iron powder and cellulose content may be effectively replaced by a different type gas-forming constituent, as for example, ferrous carbonate. In such case the ferrous carbonate may constitute 38 parts by weight while the iron powder is reduced substantially to zero and the cellulose reduced to 10 parts. Alternatively, the covering composition may consist of 30 parts carborundum, 30 parts calcium carbonate, 10 parts cellulose, 15 parts iron oxide, and 5 parts conventional binder agents. In this latter example, it also is possible to replace the iron oxide and calcium carbonate, either in whole or in part, by ferrous carbonate or mixtures of ferrous carbonate and iron powders.

The dipolar tool is preferably operated from a D. C. electrical energy source with current values exceeding 250 amps., and usually in the region of 500 amps. or higher. It will be appreciated that A. C. sources may also be used. The conductor members forming the dipolar electrode may comprise any of the well-known conductor materials, including substantially pure metals and alloys as well as carbon.

The operation is such that the iron compounds, or pure iron powders, contained within the special covering composition of the tool become blown under the effect of the arc as a substantially fanlike stream from the tool and are rapidly oxidized in exothermic reaction under a protective blastant of hydrogen and carbon dioxide gases evolved from the disintegration of the other cover components and resulting in the release of tremendous heat which fuses and melts the material processed. When such material comprises siliceous matter, it is believed that the iron compounds further combine chemically with such material to hasten the fusion and disintegration. As a result, the blast stream cuts an opening in the material present forcing molten slag and lavalike residues to the surface of the cut.

In accordance with the present invention, an auxiliary source of a highly volatile fluid is directed into the blasting stream, evolved from the arcing end of the dipolar tool, during operation of the tool. The fluid preferred is water in view of its ready availability and extreme inexpensiveness. This direction of a water stream into the blast zone in the region of the sustained arc between the dipolar electrode results in the evolution of steam, and at least a partial dissociation into the component gases of hydrogen and oxygen, due to the extremely high ambient temperatures.

It will be appreciated that this introduction of volatile fluids within the cut in the region of the arc stream will supplement the action of the tool by providing tremendous gas pressures which serve to expand and force the fused and molten slag from out of the cut as soon as formed. Although it has been impossible to acurately study the nature of the reaction taking place in the blast stream, it is assumed that evolution of hydrogen from the auxiliary water stream further aids the process in contributing additional heat generated by the splitting of molecular hydrogen into atomic hydrogen.

A simple arrangement for obtaining the advantages of the present invention is illustrated in Fig. 1 of the drawings. In this form of the invention a dipolar cutting tool **100** comprising a pair of spaced electrical conduits **111** and **112** bound together in parallel alignment by means of a special insulatory covering composition **110**, compounded in accordance with said co-pending applications, is provided with means forming a self contained fluid jet. Conductors **111** and **112** may be made from any of the well known metals and alloys but in the interest of efficiency are perferably formed from mild steel. The covering composition may be applied to the conductor members by any suitable means, as for example, by dipping or extrusion and a subsequent drying and/or partial fusing, but in any instance should provide a relatively thick cover about each conductor member with the thickness of the cover about the conductor intended to form the negative pole (for D. C. operation) exceeding the thickness of that on the companion conductor forming the positive pole. Generally, a portion of the covering is cut away as at **115** and **116** to facilitate connecting the dipolar members **111** and **112** to the energy source.

In the present example, conductor **111** is formed as a tube having one end sealed by means of a welded plug **113** and the other end sealed by fusible plug **114**. The plug **114** may be formed from any fusible materials but preferably comprises an epoxy resin. The interior of tube **111** is either partially or fully filled with a volatile fluid, as for example, water **117**. This arrangement provides a self-contained reservoir which is capable of generating tremendous quantities of steam and gas upon the initiation of an arc at the operating end of the tool, i. e. the right-hand end as viewed in the figure.

The above construction is extremely advantageous in that it permits the application of mass production techniques to forming tools according to the invention without requiring additional or costly equipment for the application of the tool in practical operation, other than a simple electrode holder having positive and negative contact terminals. A still further advantage of the present arrangement is the completely sealed character of the reservoir within the tool. This makes it possible to form either of the positive or negative conductors as a tubular reservoir, or alternatively, to form both conductors as tubular reservoir elements.

One unusual phenomenon which is observable with respect to the instant invention is the controlled discharge of fluid **117** during the blasting operation. Apparently the back pressure from the blast stream issuing from the working end of the tool prevents a gravity discharge of fluid **117** except as a control jet of steam and gases directed deep into the blast zone. A further unusual phenomenon is the obtaining of a much smoother and less terrifying operation in spite of the fact that the coagulated matter is continuously ejected from the hole formed in the material being treated. This apparently results

from a spaulding action in the melted slag residue, which is caused to explode or disintegrate as it flows out of the cut, as it is contacted by the auxiliary fluid. A still further feature of the invention is the substantial elimination of dust, fumes and smoke providing greater visibility and a reduction in personal hazard.

A modified form of the invention is illustrated in Fig. 2 of the drawings. In this form of the invention, the volatile fluid is supplied in the form of capsules **214** inserted in the bore of a tubular dipolar conductor member **212**. Capsules **214** may be formed of the usual gelatin or glutinous substance, or any other suitable fusible material. It will be appreciated that this form of the invention readily facilitates the controlled discharge of the desired fluid jet while wholly precluding undesirable dumping or surge during the initial stages of the blasting operation. A further advantage inherent in this form of the invention is the independent support of the fluid material **217** whereby different capsules may be formed to support different type fluids, as for example, a combination of capsules independently supporting trimethylene glycol and hydrogen peroxide. Alternatively, alternate capsules may contain water and a dry mixture such as calcium carbide which may be predeterminably combined during fusion of the selective capsules to generate a controlled amount of acetylene. The content of water and calcium carbide necessary to obtain a smooth even flowing jet of acetylene is easily controllable by varying the content and size of the individual capsules. If desired, sequential groups of water and calcium carbide containing capsules may be isolated, one from the other, as by means of a fusible diaphragm. It will further be appreciated that the instant innovation facilitates the obtaining of a multitude of chemical reactions in a controlled manner, progressively with the consumption of the tool.

It is further possible to use a single elongated capsule member **214** which may be inserted into a tubular conductor core to duplicate the action of the modification shown in Fig. 1, but without requiring an additional end seal **114**. An end seal may be provided, if desired, but need not be as strong or as massive as the end seal **114**, since it need function only for the purpose of preventing accidental or premature imperforation of the capsule and to keep out dirt and grime. Obviously, a fluid containing capsule or a plurality thereof may also be included in a fluid containing bore, such as **117** of the Fig. 1 modification, the fluid **117** remaining unconfined, except for the tubular boundaries. In the latter case, the capsule may contain a different type fluid which may or may not chemically combine with the free fluid **117** during operation of the tool. In any event, it will be understood that the present innovation facilitates lengthy storing of mass produced articles.

Another form of the invention is illustrated in Fig. 3 of the drawings wherein a section of the blasting tool is shown in perspective view. In this form of the invention the conductor members or electrode cores **311** and **312** are formed as solid rods in the manner set forth in said prior copending applications, the conductor **312** which is intended to function as the negative terminal for D. C. energization being smaller in diameter than the core member **311**. According to this form of the invention, the solid conductor **312** is covered with a surface coating, film or covering **317** containing substantial amounts of a fluid generating substance, as for example, hydrated borax. The coated core member is then combined with the parallel core member **311** and encased with the usual insulatory, gas and iron oxide evolving covering **310**. It will thus be appreciated that initiation of an arc between the conductor cores serves to heat and disassociate the covering **317** on core **312** with the evolution of substantial amounts of water vapor and/or steam which issues from the end of the arcing tool within the confines of the conical blasting stream.

It has been found most desirable and in some cases necessary, particularly in tools for deep drilling operations, to have the unconsumed part of the tool inserted into the bored opening. In such case, it has been found that the provision of means for accommodating lateral escape of the disassociated covering **317**, unexpectedly increases the efficiency of the operation. This mode of operation is facilitated in the present example by providing spaced, washerlike members **313** at intervals along the surface of the coated core member **312**. The washer members may be formed from any fusible material, as for example, a pressed cellulosic or paper annulus, and include a plurality of radially directed perforations **314** communicating between the central bore contacting the coating **317** and the periphery at the exterior boundary of coating **310**. Thus, as the heat from the electric arc and blast stream progressively consumes the coating **317**, the heat reaction products may escape laterally through openings **314** to contact the heated walls of the drilled hole. This arrangement permits the tool to develop a dual fluid jet having an axially directed component issuing from the end of the tool in alignment with the blast stream and a transverse component in the plane of the annular discs **313**. The result is the formation of tremendous gas pressures in the region of the blasting zone which serves to push molten lavalike slag towards the mouth of the bore, which slag is contacted during transit with fresh fluid issuing from perforations **314** to cause a spaulding action and a consequent coagulation in the slag. It will be appreciated that such operation insures the complete scavenging of deep bores by ejecting the spaulded slag residue in the nature of a controlled explosion.

The above described exemplary embodiments of the invention illustrate various modes of providing self-contained tools having an inherent fluid jet-producing unit integrated therewith. However, it will be recognized that the fluid may be supplied externally of the tool, and in most instances may comprise a simple connection to a source of water. Various modes of implementing this facet of the invention are illustrated in Figs. 4 through 7 inclusive of the drawings. In each case the water, or other fluid in the form of a liquid or gas, is supplied independently of the dipolar tool in conjunction with the means for maintaining the arc between the dipolar conductor member. In its simplest form this embodiment of the invention may employ an independent hose positioned to direct a stream of fluid into the blast stream issuing from a tool supported in a conventional plural polarity holder. Alternatively, the externally supplied fluid may be controlled through directing means associated with the holder and/or the tool, per se.

A simplified arrangement for obtaining the latter mode of operation is illustrated in Fig. 4*a* through 4*c* of the drawings. As shown in Fig. 4, a dipolar blast tool **410** having a solid conductor core **411** and a tubular conductor core **412** is supported for operation by a jet-type holder **450**. According to the present invention, the holder **450** includes a grip **451**, a main body **452** and a trigger mechanism **453**. A pair of electrical leads **454** comprising the positive and negative terminals of a conventional D. C. generator system or the output leads from a conventional A. C. transformer, are detachably connected at the rear of body **452** by any suitable means, as for example, male and female plug connections. A fluid hose **455** leading from a source of fluid, as for example, a water line, is connected to body **452** as by means of a threaded sleeve **456**.

The interior of body **452** includes an energization chamber supporting switch means (not illustrated) for connecting the dipolar conductor members **411** and **412** in circuit energizing relationship with leads **454**. Such switch means preferably includes a simplified switch connection in one of the lead lines, preferably the hot wire when D. C. is used. As shown more clearly in Fig. 4*b*, the water hose **455** connects with a distributor pipe **457**

extending between the upper exterior surface of body **452** and a point intermediate therein and includes an integral transversely extending nipple member **458**. The nipple includes a truncated extension **459** oriented in alignment with the axis of the tool receiving bore **460** in the front face of body **452**. The arrangement is such that insertion of the dipolar tool **410** into bore **460** serves to slide dipolar conductor **412** over the forward truncated end of nipple **458** to thereby directly connect the bore of tube **412** with the water hose **455**. By this arrangement water may be continuously fed through the bore of conductor **412** directly into the blast stream, in the region of the arc, to assist the blasting action in the manner set forth previously.

Supervision by the operator of the blasting tool at the blasting station is facilitated by providing selective control means as shown in Fig. 4*c*. This means includes a selectively operable trigger mechanism **453** having a pivoted finger actuated lever **470** which is adapted to cooperate with an oscillatable rocker arm **475** upon successive trigger squeezing actions to actuate a conventional type switch mechanism (not illustrated) to an operative or non-operative condition. According to the present form of the invention, trigger lever **470** is normally urged to a clockwise position by means of a compression spring **471** inserted between a fixed portion of body **452** and the upper free end of lever **470**. A switch actuating powl **472** is pivotally carried adjacent the upper free end of lever **470** and is normally maintained in a horizontally directed position, as illustrated, by means of a leaf or helical spring (not illustrated). Pawl **472** is adapted to contact one or the other of adjacent notches **476**, **477** on the front edge of the pivoted lever **475** to sequentially rock lever **475** between on and off positions in which one or the other of notches **476**, **477** is presented to the leading edge of pawl **472**. It will thus be appreciated that sequential operations of trigger mechanism **453** serves to energize and de-energize the tool at the will of the operator.

If desired, the switch controlling lever **475** may also be connected through any suitable means (as for example lever linkages) to a control valve in pipe **457** to control the supply of fluid in synchronism with the energization and de-energization of the tool. Obviously, other types of trigger actuated linkage systems, as for example, those commonly employed in firearms, may be used to control the electric and fluid connections. It will further be recognized that the switch mechanism which is connected for actuation by lever **475** may comprise any of the many well known types including arcuately or transversely moving contact members. If desired, lever **475** can comprise part of a snap actuated control linkage in which movement to the on and off positions, respectively, is accommodated in an extremely short period of time by initial movement of the lever to one or the other side of the medial position between the terminal positions denoting on or off conditions.

Another form of the invention is illustrated in Fig. 5 of the drawings in which the auxiliary fluid jet is supplied from an external source of fluid through a directing unit supported on a conventional type electrode holder. As shown in the figure, the holder **552** comprises a handle member **551**, a trigger actuating mechanism **553**, and a pair of opposed contact terminals **556**, **557** separated by an insulation block **558**. A pair of electric leads **554** are connected to the respective contact terminals through the handle member **551**.

The upper contact terminal **556** is pivoted on insulating block **558** as by means of a pivot pin **560** and preferably includes an upwardly extending tubular housing **561** which projects vertically through the terminal into a cavity **562** in the interior of insulation block **558**. A coiled compression spring **563** is inserted in tube **561** and normally bears against the bottom surface of cavity **562** to cause terminal **556** to pivot upwardly in a clockwise direction about its axis **560**. With this arrangement the extended ends **566** and **567** of contact terminals **556** and **557** are normally urged apart to permit insertion of the terminal ends of a dipolar tool, such as the tool described in said prior copending applications. The extended ends of the respective contact terminals include suitable relieved or notched areas **568** and **569** for receiving the respective dipolar cores. The seating notches are formed in conductor straps connected in circuit energizing relationship with the respective ones of leads **554** in a manner identical to conventional electrode holders.

A counterclockwise movement of the upper contact terminal **556** will thus serve to frictionally grip a dipolar electrode tool for supporting the same in circuit energizing relationship with leads **554**. In order to maintain contact terminals **556** and **557** in their tool gripping position, the tubular sleeve **561** includes a recessed area **571** adjacent its lower end which is adapted to be contacted by a latching tip **573** on the end of trigger **553**. The trigger lever **553** comprises the usual pivoted member and is normally urged into engagement with tube **561** by means of a spring **574**. This arrangement implements the instantaneous de-energization and release of the supported tool at any time during the operation should conditions warrant such action, as for example, when the tool is substantially completely consumed.

In order to provide the fluid jet in the region of the blast stream, the upper contact terminal **556** supports a post member **580** having a pivoted clamping bar **581** in which is inserted a tubular extension **582**. The arrangement is such that extension **582** may be interchangeably mounted on post **580** in fixed relationship to contact terminal **556**. The rear end of extension **582** includes a thread connection for cooperation with a coupling unit carried on the end of a fluid supply hose **555** whereby fluid may be directed through extension **582** to the discharge end terminating in a nozzle **583**. It will be appreciated that nozzle **583** may comprise any of the many well known types, as for example, of the fog type. It will further be appreciated that various types of nozzles and tubular extensions may be interchangeably mounted on post **580**. Alternatively, extension **582** may comprise an integral part of post **580** having means at its respective ends for connecting the hose and a suitable type nozzle.

One of the particular advantages of the above arrangement is the obtaining of a spray or curtain of coolant about the tool during its operation. This has proved very effective in reducing current variations since at least a portion of the moisture discharged from nozzle **583** collects upon the exterior of the tool and assists in dissipating heat transferred from the working end towards the holder. It will be understood that substantial increases in ambient temperatures of the core conductors serves to increase the electrical resistance of the same. In the instant case, this phenomenon is partially offset by the continuous consumption of the conductor members, thereby providing decreasing current paths which function to stabilize the current as the unit resistance is increased due to an increase in the surrounding temperature. The coolant ejected from nozzle **583** further assists such current compensation.

Another form of the invention in which the fluid jet may be supplied from an external source by directing the fluid through a dipolar conductor member to the operating end of the tool is illustrated in Fig. 6 of the drawings. This embodiment is particularly applicable for deep drilling operations in which an extremely long dipolar tool is required. It will be appreciated that tool lengths exceeding twenty inches are not readily accommodated by conventional holders. Accordingly, it is proposed to employ an automatic feeding mechanism of the step by step type which may serve to locate and feed an extended length of the tool while simultaneously permitting the supply of a continuous fluid stream through the tubular conduit in the tool. As shown in the draw-

ings, the feed structure preferably comprises a solenoid servo motor **650** including a wound coil section **651** supported on a centrally perforated coil form **652**. A tubular soft iron core member **653** is positioned to reciprocate in the coil form and is locked therein as by means of a snap ring **654** at one end of coil form **652**. The other end of the coil form includes a radially inwardly directed flange **655** which serves as an abutment member for a compression spring **656** positioned between the forward edge of core **653** and flange **655**. The arrangement is such that spring **656** normally urges core **653** to a retracted position in which it abuts snap ring **654**. However, upon energization of the solenoid coil **651**, core **653** is caused to reciprocate against the tension of spring **656** to center itself midway of the coil's length.

In order to utilize this movement for selectively advancing a tool **610**, positioned centrally of core **653**, the core carries a radially inwardly directed ratchet pawl **660** which is pivoted on a pin **661** carried by the core member and normally urged to extend transversely of the core by means of the spring **662**. The forward end of the ratchet pawl is serrated, as at **663**, to provide a firm, frictional group upon the surface of rod **610**. With this arrangement it will be understood that energization of coil **651** to pull core **653** to the right, as viewed in the figure, will also drag rod **610** forward a distance equal to the distance of movement of core **653**. Thereafter de-energization of coil **651** will serve to permit spring **656** to return the core member to its end abutting position against snap ring **654**. This return movement is accompanied by a pivoting of pawl **660** against the action of spring **662** by reason of the surface contour of the pawl. Thus, rod **610** may be fed selectively forward into a drilled opening in a step by step manner by sequential energization of coil **651**.

In order to continually supply liquid to the blasting zone, the tool **610** includes a tubular conductor **612** which is adapted to make contact with a special energizing connection **670**. Connection **670** provides a dual function in supporting means for electrically energizing the tool and for directing fluid through the tubular conductor. This connection comprises a pluglike member **675**, formed of any well known electrically insulating material, as for example, rubber, and supports a pair of spaced terminal posts **674** and **676**. The terminal posts are positioned in contact with the walls of a recessed opening **671** in the forward face of the plug member and which serves as a reception area for the terminal ends of the dipolar tool. The terminal posts are preferably formed of a resilient or flexible, electrically conductive material, such as copper, and each is kinked or bent, in the manner illustrated, to present the forward portions in flush alignment with the inner surface of cavity **671**. Due to the inherent resiliency or flexiblity of the posts, the forward ends **674'** and **676'** normally contract towards the center of cavity **671**, but are adapted to be flexed radially outwardly by insertion of the terminal end of the tool therebetween. For this purpose the forward portion of plug **670** may be slightly resilient in a radial direction.

An independent isolating member is positioned intermediate the forward ends **674'** and **676'** of the terminal element and comprises a thick disc of a soft, resilient dielectric material, as for example, sponge rubber. Disc **680** is adapted to expand and fill the interstitial spaces between the terminal elements in the absence of connection with the dipolar tool to prevent ingress of dirt, etc., and to obviate shorting. Upon insertion of the tool, however, the forward ends of the conductor cores serve to axially compress disc **680** to permit entrance of the tool between the terminal elements and into tight frictional engagement therewith.

To facilitate delivery of a fluid from an external source to the tubular core member of tool **610**, the disc **680** includes a resilient perforated nipple element **681** on its forward face. This nipple communicates with a flexible tubular conduit supported in the body of the disc and which terminates in a second, rearwardly extending nipple **683**. Nipple **683** is adapted to extend into and frictionally contact the wall surfaces of a tubular passageway **672** formed in the body of member **670** intermediate the terminal elements **674**, **676**. Passageway **672** in turn communicates with a transversely extending passageway **673** which includes means (not illustrated) for connection with an external fluid supply hose.

From the above description it will be obvious that insertion of a blasting tool into plug member **670** serves to bring terminal elements **674'** and **676'** into electrically conductive connection with the conductor members **611** and **612** of the tool while simultaneously serving to interconnect the tubular bore of conductor **612** with an external fluid supply through an internal communication system. It will further be appreciated that disc member **680** functions as an isolating member preventing accidental or unintended short circuiting between the terminal elements in the absence of connection with a blasting tool.

One of the features of the above described arrangement is the ability to feed abnormally long lengths of a dipolar blasting tool, as for example, lengths exceeding 6 feet, to drill and blast holes in reinforced concrete, or the like, formations to depths exceeding 4 feet. A further feature of this arrangement is the independent connection of the fluid supply and circuit energizing structure to the tool without interfering with the simplified feeding mechanism of servo unit **650**.

It will be obvious that the present feeding mechanism can be used for advancing an expendable liquid conduit into deep blast holes in parallel with a blasting dipolar tool supported and moved independently of the liquid conduit.

If desired, coil **651** may be connected to the same supply source, as that used to supply current for the tool with appropriate current control means for automatically advancing the tool in the bored hole. This may be conveniently provided by a time-rate circuit including a main discharge capacitor in an A. C. energizing circuit or a current interrupting device in a D. C. energizing circuit.

The amount of water supplied to the blast zone by any of the above described arrangements may be substantial but should not be excessive to the point of inundating the blasted hole. Generally the water may be fed to the blast zone at any desired rate, for a most efficient operation will vary with the size of tool, energizing current and voltage, etc.

A further modified point of the invention is illustrated in Figs. 7*a* through 7*c* of the drawings. This form of the invention is of particular efficacy in that the holder employs basic features including a fluid passageway which readily adapts it for use with the dipolar blasting tools, as set forth previously, as well as with conventional single or twin core electrodes. In the latter case, the fluid passageway formed in the holder may serve to supply compressed air or commercial gases of the inert or combustible type to the arc zone, as for example, nitrogen, hydrogen, or oxygen. Alternatively such passageways may be availed of to supply liquid such as water or the like during operation of the supported electrode.

The basic construction of the instant holder is illustrated at **752** in Fig. 7*a* and comprises a tubular main supporting body **751**, formed of any well known high voltage insulating material; a lower contact terminal **757** extending through said body and including a recessed notch **769** adjacent its terminal end for receiving the conductive core member of a conventional electrode, or one conductor core of a dipolar blasting tool; and an upper contact terminal member **756**, mounted in parallel alignment with terminal **757**, and including an angularly off-set trailing end **766** and a second recessed notch

768. A post member 758 is intergrally formed on terminal 757 and includes a pivot pin 760 extending through contact terminal 756 for supporting the latter for pivotal movement to move the opposed recessed notches 769 and 768 toward and away from each other selectively. A spring member 763 is carried by body 751 and normally contacts the end 766 of the upper contact terminal to bias the terminal in a counterclockwise direction with a consequent movement of notched area 768 into close alignment with notched area 769, such movement being limited by an isolating block 759 carried by terminal 757.

The respective contact terminals are illustrated in elevation for the sake of clarity, but it will be understood that each comprises the usual electrically conductive surface area surrounded by a suitable high voltage insulation layer, the insulation being absent in the region of notched areas 769 and 768 for an obvious purpose. In accordance with the present invention, contact terminal 757 extends through the main body 751 where it terminates in a threaded junction 753. This junction is adapted to receive a threaded clamping cap 763 for the purpose of fixedly clamping a connector member 765 into firm frictional engagement with the terminal junction 753. Connector member 765 includes an axially extending tongue 764 which engages a recessed bore 754 in the junction end. The connector member further includes a plurality of radially oriented, axially directed passageways 762, providing communication between opposite faces of the member.

An axially extending sleeve 767 is formed on the connector member and is adapted to support a hose element 780 in concentric relationship with a transmission cable 785. Cable 785 is joined to connector member 765 by any conventional means, such as bolts, soldering, welding, etc. The other end of the cable is similarly joined to a terminal tab 790. This terminal tab includes a pair of opposed sleeve members 791 and 793, sleeve 791 being adapted to receive the other end of hose 780, and sleeve 793 being externally threaded for engagement with a supply conduit connected to a source of compressed air, combustible gas or liquid. A second plurality of radially oriented, axially directed conduits 792 provide communication through member 790 between the opposite faces thereof. A laterally directed ear 794 is positioned to depend from terminal tab 790 and receives and makes electrical contact with one-output lead of a source of electrical energy, such as a D. C. generator or an A. C. transformer, the other lead being normally connected to the work, as for welding, etc.

The interconnected communication channels provided by sleeve 793, passageways 792, hose 780, passageways 762 and the bore 754 in contact terminal 757 provide a conduit for directing a fluid from a remote point to the work processed for use in combination with the supported electrode or blasting tool. For this purpose, an additional passageway is formed by a channel 772 in the contact terminal and which terminates in a pair of laterally directed outlet ports 774, 776 at either side of the electrode receiving notch 769. The arrangement is such that fluid medium supplied through the passageways 792 in terminal tab 790 will ultimately be discharged through ports 774 and 776 in parallel alignment with the supported electrode.

One of the particular advantages of the above arrangement is the utilization of a non-conductive fluid conduit such as the hose 780, comprising an electrically insulating medium such as rubberized fabric, to serve an additional function in insulating the electrical lead cable 785. As a result, the terminal tab 790 may be mounted directly on the device functioning as the electrical energy source, to prevent danger to personnel and operators of the holder through bare hot connections. A holder of the instant type has been found to be especially effective for use in gouging, edge preparation, and cutting operations in which the work functions as the negative terminal in an electric circuit, and terminal tab 794 functions as the positive terminal in the circuit, the supported electrode operating to establish an arc to the work in the conventional manner. During such operation, a fluid, preferably compressed air is continuously fed along the surface of the supported electrode, from parts 774 and 776 to blow the molten metal from the surface of the work as the electrode is moved thereby. The electrode used may be of any desired type, either consumable or non-consumable and formed of any conductive material such as tungsten, carbon, steel, etc., and with or without a coating.

An additional and most important feature of the present holder construction is the facility with which the basic structural arrangement may be altered for operation with a dipolar electrode type blasting tool, as previously described. According to this feature of the invention the upper contact terminal 756 may include detachable connection means adjacent the pivotal axis 760, as shown in Fig. 7*b*, to which may be applied an additional supply cable serving as one lead in the electrical energizing circuit, the other lead being provided via terminal tab 794, cable 785, and contact terminal 757. In the instant embodiment such arrangement is provided by an externally threaded hollow sleeve 782 which projects from the contact terminal 756 above the pivotal axis 760 and is electrically connected with the conductor portion of the contact terminal as by soldering, welding, etc. An internally threaded cup 784 is adapted to cooperate with sleeve 782 and includes friction-grip fingers 786 for slipping over and wedging an auxiliary electric lead cable 781 into sleeve 782, the auxiliary cable being supported upon the main body 751 of the holder as by means of a well known spring clamp or several turns of friction tape (neither of which is presently illustrated).

By reason of the above described innovation, a simple adjustment comprising the single step of connecting an insulated electrical cable into electrical contact with sleeve 782 by threading cup 784 thereover serves to transpose the holder for operation with a dipolar electrical energy source in such manner that contact terminal 756 may function at a positive polarity while contact terminal 757 functions at a negative polarity, the separate terminals serving to engage, grip and support the respective dipolar cores of a blast tool in a circuit energizing manner, similar to that set forth previously. The holder can be readily reconverted for use in conventional welding and heat treating operations, in which contact terminal 757 functions as either the positive or negative polarity while the work functions as the opposite polarity, through the simple expedient of disconnecting the cable from sleeve 782. It will be understood that the specific auxiliary cable connection means 782, 784 is merely illustrative and other and distinct connectors may be used, as for example a lug to which the auxiliary cable may be soldered or bolted, a bayonet type joint for cooperation with a plug on the extended end of the auxiliary lead cable, or the like.

A further feature of the present arrangement is the positioning of the connector means for such auxiliary cable without requiring additional insulation. By locating the connector 782 and 784 within the confines of the off-set portions 766 of contact terminal 756, the connector means is fully protected from contact by the work piece or the operator. It will be understood that the conventional insulation on such auxiliary lead cable prevents shorting or arcing with spring element 763. It will be further understood that when the holder is so connected the supply conduit provided by hose 780 and passageway 767 operates to supply the auxiliary fluid which is discharged from ports 774, 776 in parallel alignment with the supported blasting tool and into the blast stream.

Another feature of the present arrangement is the substantial cooling afforded the supported tool by reason

of movement of the fluid along the tool surface as the fluid stream expands after discharge from ports 774 and 776.

If desired, selective control of the fluid stream in hose 780 may be obtained by providing a single valve element for cooperation with the passageways 762 in connector member 765. A particular arrangement according to this form of the invention is illustrated in Fig. 7c in which like numerical subscripts denote like structural components. As shown in the figure, sleeve 767 and the insulator body 751 are formed with arcuate slots 799 of limited extent through which projects a radially directed finger 796. Finger 796 extends from the perimeter of an annular valve disc 795 which is centrally apertured as is 797 to seat over the electrical cable 785. This serves to center the valve disc within sleeve 767 of connector member 765. An additional set of axially directed passageways 798 are formed in valve disc 795 in alignment with passageways 762 in the connector member. The arrangement is such that oscillation of the disc about cable 785 as a center will displace passageways 798 from alignment with passageways 762, or alternatively, align the same, to selectively block or unblock communication between the fluid source and passageway 772 in contact terminal 757. Valve member 795 is preferably formed from one of the non-conductive synthetic resin materials.

From the above disclosure it will be obvious that the present invention contemplates manifold arrangements by which means in the form of a solid, liquid, or gas substance may be used conjointly with a blasting heat tool of the type more fully described in our copending applications, Serial No. 332,884, and 346,168, to evolve a fluid jet stream which assists the tool in blasting, boring, drilling and disintegrating operations on all types of siliceous material, as well as on metals, other inert matter, and substantially any heat resistant substance including fire brick, carborundum, and the like.

It will, of course, be apparent that the present invention may be widely adapted in forms other than those particularly described herein. For example, the evolution of the auxiliary fluid jet may be evolved from or supplemented by the provision of a carbon dioxide cartridge of conventional type, such as those used in paint and lacquer spray guns, which can be loaded in a tubular conductor of the tool to the rear of the fluid charge forming the source of the fluid jet material. The cartridge may be so constructed as to fire upon reaching a predetermined temperature initiated by the initial arcing of the tool. Alternatively, the cartridge can be adapted to be percussion fired in the usual manner, as by means of a suitable trip hammer or plunger provided in the sealed terminal end of the tool. It will further be apparent that auxiliary gun means adapted to be mounted on an electrode holder, or to be used in combination therewith, and so constructed as to interchangeably receive carbon dioxide cartridges and charges of the auxiliary fluid jet material, as for example, in the form of capsules or pellets, may also be provided. In the latter case, the gun will serve to eject the pellets into the drilled hole and may be controlled to fire at the beginning, the middle, or near the completion of the blasting operation.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that this invention is not limited except as defined in the appended claims.

What is claimed is:

1. An electrically operated consumable blasting tool for boring holes in refractory materials comprising an elongated cylindrical member having a substantially parallel pair of spaced elongated electrically conductive members embedded in a covering composition of a substantially electrically non-conductive insulatory nature, said conductive members being formed from an arc consumable material, said covering material including a substantial portion of iron oxide producing ingredients and gas-forming ingredients in homogeneous mixed granular form, and means associated with said member for supplying and directing a stream of expansible liquid in parallel alignment with said conductive members, said means providing an egress for said liquid, adjacent one terminal end of said parallel pair of members, whereby said members can be energized in a series electric circuit to form a self-sustained electric arc therebetween to heat and expand the liquid directed through said means.

2. An electrically operated consumable blasting tool for boring holes in refractory materials comprising an elongated cylindrical member having a substantially parallel pair of spaced elongated electrically conductive members embedded in a covering composition of a substantially electrically non-conductive insulatory nature, said conductive members being formed from an arc consumable material, said covering material including a substantial portion of iron oxide producing ingredients and gas-forming ingredients in homogeneous mixed granular form, one of said conductor members comprising a tubular member with a volatile liquid sealed therein, whereby said members can be energized in a series electric circuit to form a self-sustained electric arc therebetween to heat and expand the liquid directed through said tubular member.

3. An electrically operated consumable blasting tool for boring holes in refractory materials comprising an elongated cylindrical member having a substantially parallel pair of spaced elongated electrically conductive members embedded in a covering composition of a substantially electrically non-conductive insulatory nature, said conductive members being formed from an arc consumable material, said covering material including a substantial portion of iron oxide producing ingredients and gas-forming ingredients in homogeneous mixed granular form, one of said conductor members comprising a tubular member having at least one heat disintegrating capsule containing a heat expansible liquid seated therein, whereby said members can be energized in a series electric circuit to form a self-sustained electric arc therebetween to heat and expand the liquid directed through said tubular member.

4. An electrically operated consumable blasting tool for boring holes in refractory materials comprising an elongated cylindrical member having a substantially parallel pair of spaced elongated electrically conductive members embedded in a covering composition of a substantially electrically non-conductive insulatory nature, said conductive members being formed from an arc consumable material, said covering material including a substantial portion of iron oxide producing ingredients and gas-forming ingredients in homogeneous mixed granular form, an independent covering on one of said members including a granular mixture of heat disassociating volatile liquid forming materials selected from the group consisting of hydrated borax, sodium bicarbonate, ammonium chromate, calcium carbide, crystalline nitrogen pentoxide, and hydrated ammonium nitrate, whereby said members can be energized in a series electric circuit to form a self-sustained electric arc therebetween to heat said coverings and evolve a blastant stream comprising said gas, iron oxide and volatile liquid directed axially of said tool.

5. The process of boring holes in refractory materials, which comprises establishing a series metallic arc between a pair of arc consumable electrodes in proximity to said material, evolving a blastant stream containing rapidly expanding gases and iron oxide particles in the region of said arc and directing said stream as a confined blast toward said material, said blastant stream resulting from fusion in the arc of the arc consumable electrodes and a granular mixture of predominantly inorganic ingredients, and projecting a volatile liquid into said blastant stream

in the region of said arc whereby said blastant stream will be so constituted as to thermally, chemically and mechanically disintegrate the refractory material.

6. The process as set forth in claim 5 in which said volatile liquid is selected from the group consisting of water, ethyl alcohol, benzene, ethylene glycol, trimethylene glycol, hydrogen peroxide, and acetone.

7. The process as set forth in claim 5 in which said volatile liquid is evolved in the region of said arc from a dry composition of heat disassociating materials selected from the group consisting of hydrated borax, sodium bicarbonate, ammonium chromate, calcium carbide, crystalline nitrogen pentoxide, and hydrated ammonium nitrate.

8. An electric-arc refractory material cutting tool comprising a bipolar electrode element having a pair of elongated substantially parallel conductive core members fixedly spaced apart in a composite mineral covering of a substantially electrically non-conductive character, said covering comprising a mixture of granular particles containing substantial proportions of iron oxide and carbon dioxide producing constituents of an arc fusible character, and means associated with said electrode for evolving a heat-expandable fluid stream under the thermic action of the arc.

9. An electric-arc refractory material cutting tool as set forth in claim 8 in which said covering material includes a mixture of ferrous carbonate and iron powder.

10. An electric-arc refractory material cutting tool as set forth in claim 8 in which said means comprises a dry composition of heat-disassociating materials capable of forming volatile liquid under the thermic action of the arc and selected from the group consisting of hydrated borax, sodium bicarbonate, ammonium chromate, calcium carbide, crystalline nitrogen pentoxide, and hydrated ammonium nitrate.

11. An electric-arc refractory material cutting tool as set forth in claim 8 in which said means comprises a heat destructable capsule containing a volatile liquid selected from the group consisting of water, ethyl alcohol, benzene, ethylene glycol, trimethylene glycol, hydrogen peroxide, and acetone.

12. An electrically operated blasting tool as set forth in claim 2 in which said tubular member includes fluid blocking means permanently sealing one end and heat disintegratable means temporarily sealing the other end.

13. An electrically operated blasting tool as set forth in claim 1 in which said means comprises a separate coating covering at least one of said conductor members, said coating containing a mixture of granular particles of heat disassociating materials containing nitrogen.

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