CHEMICAL CUTTING METHOD AND APPARATUS

William G. Sweetman, Houston, Tex.

Application May 9, 1955, Serial No. 507,316

20 Claims. (Cl. 166—35)

This application is a continuation-in-part of my earlier filed application Serial No. 288,479, filed May 17, 1952, now abandoned.

This invention relates to methods and apparatus for cutting objects generally and more particularly to methods and apparatus employing a chemical cutting fluid of highly reactive incendiary character such that when brought into contact with an oxidizable object, such as a wall of a well or other object within the well, it will ignite with and burn through the object.

The term "cutting" is used herein as a generic term to include cutting, severing, perforating or slotting of objects, as well as their complete disintegration. The objects referred to may be metal pipe or other well bore lining, the earth formations surrounding or forming the wall of the well bore, extraneous foreign objects, such as lost drilling tools, which may be present in the well bore, or other objects of metal, stone or the like which may be in or part of the well bore.

The cutting fluids employed in accordance with the present invention are fluids which are extremely active chemically and which, when brought into contact with most oxidizable substances, react violently therewith in the generation of extremely high temperatures sufficient to melt, cut, or burn the object. Examples of such fluids are fluorine and the halogen fluorides, including such compounds as chlorine trifluoride, chlorine monofluoride, bromine trifluoride, bromine pentafluoride, iodine pentfluoride and iodine heptafluoride.

Fluorine may be considered as a fixed gas under most practical operating conditions, since it has a very low critical temperature, about —200° F. Chlorine trifluoride, which is a particularly effective cutting fluid for most applications, is a volatile liquid boiling at 52.3° F. and may, therefore, be readily liquefied and maintained in the liquid phase by holding it under moderate pressures. The other halogen fluorides are all relatively low boiling liquids readily vaporizable in the performance of the method of the present invention wherein these fluids will ordinarily be applied in the gaseous phase to the object to be cut.

Generally stated, and in accordance with one useful application of this invention, an incendiary chemical fluid of the character described is introduced into a well bore in a confined body from which the fluid is caused to discharge in one or more high velocity streams or jets by applying to the body of the fluid a suitable pressurizing medium. Such pressurizing mediums may be hydraulic or pneumatic fluids. The pneumatic fluids may be gases generated by the ignition of one of the various types of relatively slow-burning gun powders, or other deflagrating types of explosives, examples of which are black powders such as are used in sporting ammunition, rocket propellant powders and the like. By appropriate selection of the explosive and by means of pre-preparation procedures well-known to those skilled in the art of such explosives, the ignition and burning rates of such explosives may be effectively controlled to generate gases at any desired rate and volume suitable for applying the desired pressurizing forces to the confined body of the cutting fluid. Gaseous pressurizing fluids such as carbon dioxide, nitrogen and the like may be employed for applying the desired pressurizing forces to the body of the cutting fluid.

It is found that the efficiency and speed of the cutting action of the incendiary fluids which is obtained by the method in accordance with this invention may be greatly increased and made more effective by causing "pre-ignition" of the cutting fluid while it is being ejected from the body thereof under high pressures applied thereto by the pressurizing medium and before discharge from the cutting jets.

This term "pre-ignition" is employed herein to describe a phenomenon, the mechanism of which is largely unknown, but which constitutes a most important improvement in the primary process of this invention.

It has been found that if the incendiary chemical cutting fluid, immediately prior to its discharge from the outlet passages or jets and while it is under the high pressures exerted thereon by the pressurizing medium, is brought into direct contact with certain substances, to be described in greater detail hereinafter, a form of reaction, which appears to be somewhat presently unknown type of pre-ignition of the incendiary fluid, occurs such that the cutting efficiency of the discharging fluid is very greatly intensified. Whether the phenomenon is catalytic or the result of a chemical reaction such as extremely rapid oxidation has not been determined but the result is, as noted, a great increase in the efficiency and speed of the cutting action of the incendiary fluid over that obtained without the use of such pre-ignition step or means.

The substances which will function effectively to produce such pre-ignition have been found to be many and widely varied in character. In general, it appears that numerous metallic and non-metallic solid materials are effective igniters, particularly if employed in finely divided form, as in fibrous, spongy, granular or powdered form. A preferred material is ordinary steel wool of conventional commercial grades. Glass wool is a very effective igniter. Hydrocarbon materials, such as oil or grease, especially if deposited on a suitable carrier adapted to provide extended surface area for exposure to contact with the incendiary chemical fluid, are also very effective.

Accordingly, it is a primary object of the present invention to provide a method of cutting objects by the employment of an incendiary chemical fluid.

An important object is to provide a method for cutting inside a well by the employment of an incendiary chemical fluid.

Another object is to provide a method for cutting inside a well by introducing into the well a confined body of an incendiary chemical fluid, and ejecting said fluid from said body in one or more narrow streams or jets directed against the object in the well by the action of a pressurizing fluid applied to the body of the cutting fluid.

An additional object is to provide a method for cutting objects by pre-igniting a highly pressurized stream of an incendiary cutting fluid and directing the pre-ignited stream against the object.

A further object is to provide a method by which the cutting inside of a well may be done introducible into the well a confined body of an incendiary chemical fluid, ejection the fluid from the body thereof in one or more narrow jets directed against the object to be cut, and pre-igniting the streams of fluid prior to contact thereof with the object.

Still another object is to provide a method of the character described wherein the pressurizing medium comprises gases generated by the ignition of an explosive material.

Yet another object is to provide a method of the character described wherein the pressurizing medium is a
hydraulic fluid conducted to the cutting tool from the surface. An additional object is to provide a method of the character described in which the pre-ignition material is a finely divided solid substance. A more specific object is to provide a method of the character described in which the incendiary chemical fluid is a member of the class consisting essentially of fluorine and the halogen fluorides.

A further object is the provision of apparatus suitable for performing the methods in accordance with this invention. Other and more specific objects and advantages of this invention will become more readily apparent from the following detailed description when read in conjunction with the accompanying drawing which illustrates several embodiments of apparatus in accordance with this invention which are particularly useful for conducting the methods in accordance with this invention.

In the drawings:

Fig. 1 is an elevational view showing cutting apparatus in accordance with one embodiment of this invention installed in a well;

Figs. 2A, 2B and 2C, together, comprise a longitudinal sectional view of the cutting apparatus illustrated in Fig. 1;

Fig. 3 is a view of the discharge portion of apparatus similar in general to the portion of the apparatus illustrated in Fig. 2C but showing a modified arrangement of pre-ignition material and showing the positions of some of the parts during discharge of the cutting fluid;

Fig. 4 is a cross-sectional view taken along line 4-4 of Fig. 3 illustrating the discharge jet arrangement employed in effecting a circular cut in a well; Fig. 5 is a fragmentary longitudinal sectional view showing another form of connection for conducting a pressurizing fluid to the portion of the tool containing the cutting fluid;

Figs. 6A, 6B and 6C, together, comprise a longitudinal partly sectional view of a modified form of cutting apparatus in accordance with this invention; and

Fig. 7 is a cross-sectional view taken generally along line 7-7 of Fig. 6B.

Referring to the drawing, in particular to Fig. 1 there is shown a cutting tool, designated generally by the numeral 1, which is inserted in a string of tubing or other pipe 2 extending into a well bore B which may be lined with the usual metal casing 3. The cutting tool comprises in downwardly arranged succession, a pressurizing portion, designated generally by the numeral 4, a chemical container portion, designated generally by the numeral 5, an igniter portion, designated generally by the numeral 6, and a discharge head portion, designated generally by the numeral 7. These several portions, which are constructed of suitable strong metal, such as steel, are generally cylindrical and connected together in end to end relation to form an elongated cylindrical tool of substantially uniform exterior diameter, which is adapted for insertion into the tubing string. A head section, designated generally by the numeral 8, is connected to the upper end of the tool and includes a rope socket 7 of generally conventional form which connects the upper end of the tool to a conventional flexible cable 10 which is employed for lowering and raising the tool in the well bore. Cable 10 may include electrical leads 11 for transmitting electric current from a suitable source (not shown) at the surface to the interior of the tool, for purposes to be subsequently described.

Head section 8 may carry any suitable and generally conventional form of anchor means, designated generally by the numeral 12, adapted to releasably anchor the tool to the wall of the string of pipe 2 in a manner to effectivly resist upward movement of the tool as a consequence of the thrust resulting from actuation of the tool as will be subsequently described. The conventional anchor means illustrated by way of example, comprises a slip cage 13 longitudinally slidably mounted on head section 8, fitted with radially projecting bow springs 14 frictionally engaging the pipe wall and carrying downwardly depending wall gripping slips 15 adapted when urged radially outwardly to firmly grip the pipe wall. Secured to head section 8 below the slip cage is an upwardly tapered frusto-conical mandrel 16 adapted upon upward movement of the tool relative to slips 15 to move inside the slips and urge the slips radially outwardly into gripping engagement with the pipe wall.

It will be understood that any other well-known anchor means may be employed to effectively anchor the tool in the pipe or well bore against upward movement therein. Such another anchor means is shown in the aforementioned application Serial No. 288,479, being adapted particularly for anchoring the tool by means of resilient flumes which are designed to enter pipe joint crevices or to engage internal shoulders in the well bore. Referring to Figs. 2A, 2B and 2C, head section 8 comprises a generally cylindrical body 17 connected at its upper end to rope socket 9 and provided at its lower end with an externally threaded frusto-conical pin member 18 for connection into a complementary internally threaded socket 19 in the upper end of pressurizing portion 4. Body 17 is axially bored to form a relatively large diameter chamber 20 which opens through the lower end of pin member 18 and is internally threaded at its lower end to receive a tubular barrel 21 having a bore 22 extending axially through the barrel and communicating with the interior of chamber 20. The latter communicates at its upper end with a reduced diameter bore 23 extending through body 17, thereby forming a downwardly facing internal shoulder 24 at the upper end of chamber 20.

An electrode 25, encased in a suitable electrical insulating sleeve 26, is mounted in bore 23 to have one end extending into chamber 20. This end of electrode 25 will be placed in electrical contact with the end of an electrically fired explosive initiator cap 73 of generally conventional and well known form positioned in bore 22 of barrel 21. It will be understood that the opposite end of electrode 25 (not shown) will be placed in electrical connection with leads 11 by conventional contact means (not shown) positioned within rope socket 9.

Pressurizing portion 4 comprises a tubular metallic body 27 having an axial bore 28 extending entirely therethrough. The upper portion of body 28 is provided with the somewhat enlarged diameter counterbore 29 to receive the lower end of barrel 21 when head section 8 is made up with pressurizing portion 4. The lower portion of counterbore 29 is internally threaded at 30 to threadedly receive a choke bushing 31 provided with an axial choke passage 32 registering with bore 22 of the barrel 21 and providing communication between the interior of pressurizing chamber 28 and the bore 36 of an internally threaded tubular socket 37 carried by the lower end of body 27.

Chemical container portion 5 comprises a tubular metallic body 38 having an enlarged axial bore therethrough forming a chamber 39 communicating at its opposite ends with upper and lower internally threaded frusto-conical sockets 40 and 41, respectively. The upper end of body 38 is connected to the lower end of body 27 by means of an upper connector sub 42 having at its lower end a frusto-conical externally threaded pin 43 threadedly receivable in upper socket 40 and having at its upper end a generally cylindrical externally threaded pin 44 threadedly receivable in socket 37 in the lower end of body 27. Upper connector sub 42 has an axial
bore 45 extending therethrough and communicating at its lower end with chamber 39 to form an extension thereof. The upper end of bore 45 is provided with the internally threaded counterbore 46 forming an upwardly facing annular shoulder 47 about the upper end of bore 45 on which is seated an upper shear disk 48 which serves as a rupturable closure for the upper end of chamber 39. Shear disk 48 is held tightly in place on shoulder 47 by means of an annular threaded tubular jam nut 49 which is screwed into counterbore 46 and bears against an annular washer 50 positioned between the outer face of shear disk 48 and the inner end of jam nut 49. The latter has an axial throughbore 51 communicating with bore 56 of body 27.

The lower connector sub 42b which is substantially identical in form to upper connector sub 42, being provided with a frusto-conical pin member 43a threadedly receivable in socket 41 and an externally threaded cylindrical pin 44a for connection to igniter portion 6. Lower connector sub 42b is provided with the axial bore 45a communicating at one end with chamber 39 and at the other end with an enlarged internally threaded counterbore 46a defining the downwardly facing shoulder 47a on which is seated the lower shear disk 48a adapted to form a rupturable closure for the lower end of chamber 39, and held in position against shoulder 47a by means of the externally threaded tubular jam nut 49a screwed into counterbore 46a and bearing against the annular washer 50a positioned between the outer face of shear disk 48a and the inner end of jam nut 49a. The latter has an axial throughbore 51a.

Shear disks 48—48a are constructed of metal proportioned and otherwise designed to rupture at desired predetermined pressures. These shear disks are desirably constructed of a metal which will not be attacked by the chemical in chamber 39 under ordinary storage conditions. Copper is found particularly useful for this application although other metals, including nickel and various alloys thereof, may be used successfully.

Suitable seal packings 52 and 52a, such as conventional O-rings, are positioned, respectively, between pin 44 and the wall of socket 37 and between pin 44a and socket 54 on the igniter portion 6, in order to form fluid-tight seals between these connections.

Igniter portion 6 comprises a generally tubular body 53 having an internally threaded socket 54 at its upper end adapted to threadedly receive pin 44c at the lower end of chemical container portion 5. The lower end of body 53 is provided with an externally threaded pin 55 for connection to discharge head portion 7. Body 53 is axially bored throughout its length, the bore being formed by a plurality of bore sections 56a, 56b and 56c of successively reduced diameters in descending order. Bore portion 56a may have seated therein a tubular bushing 57 having an axial bore 55 registering with, and providing connection between, bore 51a and bore portion 56b and 56c, bore 58 being intermediate in diameter between the diameters of bore 51a and bore portion 56b.

Discharge head portion 7 comprises a body 59 having an internally threaded socket 60 adapted to threadedly receive pin 55 of the igniter section. A suitable pack-
ing 61, such as a conventional O-ring, may be installed between pin 55 and the wall of socket 60 to form a fluid-tight seal therebetween. Body 59 is provided with an axial chamber 62 which communicates at its upper end with the interior of socket 60 and at its lower end with a reduced diameter bore 63 which opens to the lower end of body 59. Bore 63 is internally threaded from its lower end to receive a threaded plug 64 adapted to close the lower end of bore 63. A plurality of passages 65 of restricted diameter extend radially through body 59 to provide communication between chamber 62 and the exterior of discharge head portion 7. Chamber 62 forms a cylinder containing a piston 66 having longitudinally spaced circumferential packings 67—67, such as conventional O-rings, seated in the exterior surface of the piston. The longitudinal spacing between the packings 67—67 is such that when the piston is in its uppermost position, illustrated in Fig. 2C, the packings will seal with the wall of chamber 62 on opposite sides of passages 65, thereby sealing off these passages from communication with the interior of chamber 62, and also thereby sealing off chamber 62 and its connecting chambers from the atmosphere exteriorly of the tool. The length of piston 66 relative to that of chamber 62 is made such that the piston may be moved downwardly below passages 65, as illustrated in Fig. 3, to open communication between the passages 65 and the interior of chamber 62 above the piston, and to thereby place the passages in communication with the interior of the tool as a whole.

Chamber 28 in the pressurizing portion of the tool will have disposed therein a suitable pressurizing medium. In accordance with the embodiment illustrated in Figs. 2A, 2B and 2C, the pressurizing medium comprises a body of a relatively slow-burning or deflagrating explosive material 70 of the character previously described. The body of the explosive may be in molded cylindrical form slightly smaller in diameter than the bore of chamber 28 to allow free passage of gases about the explosive body. The latter may also be supported by a longitudinally extendible and retractable spacer member 71 disposed between the bottom of chamber 28 and explosive body 70 held body 70 away from the bottom of chamber 28. The lower end of spacer member 71 is provided with slots 72 to permit free passage of gases formed by burning of explosive 70 from chamber 28 into choke passage 35.

Bore portions 56b and 56c in igniter portion 6 will have disposed therein a suitable igniter substance 75 having the properties and general physical form described heretofore. As illustrated in Fig. 2C, the igniter substance may be ordinary steel wool of a medium commercial fineness grade which will be packed in relatively loose manner in bore portions 56b and 56c.

Chamber 39 of chemical container portion 5 will be charged with incendiary chemical 74 of the general character and properties previously described. Because of the extremely reactive character of these fluids, the section of the tool comprising chemical container portion 5, including the connector sub 42 and 42a and the rupturable closure disks 48 and 48a, will ordinarily be charged with the cutting fluid by the supplier thereof, who will then furnish the charged container portion 5 as an individual but complete unit for installation in the tool.

The above-described device is operated in the following manner: The parts of the device will be charged with explosive material 70 and igniter substance 75, as described, and assembled as illustrated in Figs. 2A, 2B and 2C, and connected to head 8 and lowering cable 10. The structure will then be lowered into the tubing to the point at which it is to be operated. The tool will be firmly anchored to the pipe wall by upward pull applied to cable 10 which will move mandrel 16 upwardly relative to slips 15 which will be held stationary by frictional engagement by bow spring 14 with the pipe wall. Electric current, from any suitable and conventional source (not shown) will then be applied to leads 11 to set off cap 73. Flames resulting from ignition of the cap will be discharged through choke passages 29 into chamber 28 where it will ignite the body of explosive 70. The choke passages 32 and 35 are employed to maintain pressure in chamber 28 in order to control the burning rate of the explosive. The latter will, as a result of the ignition, generate gases which will escape...
from chamber 28 through choke passage 35 into bore 51. The ignition of explosive 70 will, in a very brief time, generate sufficient gas to create a pressure against upper shear disk 48 which will be great enough to exceed the rupture strength of the disk. The rupture of the upper shear disk will admit the gas pressure against the body of the chemical fluid 74 which will transmit the pressure exerted against it by the explosive gas to the lower shear disk 48a, which will be ruptured thereby. Upon rupture of lower shear disk 48 the chemical cutting fluid will be forced through bores 51a and 58 into and through bores portions 56b and 56c. In the latter, the fluid will contact the igniter substance 75 and undergo a pre-ignition with resulting build-up in pressure which will be exerted against the end of piston 66, forcing the latter downwardly in cylinder 62 to uncover the inner ends of discharge passages 65. The preignited fluid will discharge from passages 65 at tremendous pressures and velocity, as well as at high temperatures, such that when the discharging fluid strikes the pipe wall opposite the ends of the passages, the fluid will react with the material composing the pipe wall at a rate such as to cause the fluid to burn through the wall. Where the device is employed to perforate the casing 3 or the wall of the borehole, the fluid will burn into the surrounding earth formations to a substantial depth, depending in general upon the volume and pressure of the incendiary fluid being discharged from the tool.

By the method described, pressures of any desired magnitude may be exerted upon the incendiary fluid by suitable selection of the pressurizing mediums. Pressures of many thousand pounds may be thus applied, which will be sufficient to project the streams of incendiary fluid through any intervening well fluids, irrespective of their pressures, against the well wall. Whatever the initial pressures exerted on the fluid may be, it is apparent that rapid build-up of pressure results not only from the increasing amounts of gas generated by the explosive pressurizing material, but also by the reaction of the fluid with the igniter substance before the fluid discharges from the tool.

Ordinarily, the external diameter of the discharge head will be made as near as possible to the internal diameter of the pipe or well without interfering with the free movement of the tool into the well, so that the incendiary fluid will be required to traverse a minimum amount of intervening space before striking the well wall. Reference to the "well wall" is intended to include not only the casings, but other well bore linings, as well as the earth formations themselves which form the wall of the borehole.

The cutting action of the discharging fluid does not appear to be hindered by well fluids intervening between the discharge head and the object against which the cutting fluid is directed. Indeed, it appears that the discharge of the incendiary fluid through well liquids under high hydrostatic heads results in more efficient cutting action than in the absence of intervening liquids or under relatively low hydrostatic heads.

The time factor in cutting in accordance with the method hereinabove described, is extremely short, being ordinarily of the order of a magnitude of a very small fraction of a second from the moment of ignition of the pressurizing explosive to completion of the cutting action. Nevertheless, it is found in many cases to be desirable to regulate even this extremely short time factor to some degree by the provision of choke passage 35 which tends to slightly extend the time required for the discharge of the quantity of incendiary fluid contained in the tool. Even though the time factor is thus slightly lengthened, nevertheless for all practical purposes, the action is substantially instantaneous.

Where the incendiary fluid is normally a gas, such as fluorine, chamber 39 will be charged with such gaseous fluid to any suitable and convenient pressure, for example, 300 or 400 pounds per square inch. The shear disks 48 and 48a forming the end closures for the chamber will be selected to have a strength considerably in excess of such pressure; for example, several thousand pounds per square inch, so that the pressure of the pressurizing medium must be built up to a pressure exceeding the rupture strength of the shear disks in order to apply the desired high pressure for discharging the incendiary fluid from the discharge head at the desired high pressure.

Where the incendiary fluid is volatile liquid, such as chlorine trifluoride, the pressure in chamber 39 will be relatively nominal, being determined by the vapor pressure of the fluid at the temperature of operation, and the incendiary liquid will be forced from the tool by pressure of the pressurizing medium exceeding the bursting strength of the closure disks. At the temperatures normally existing in well bores, and particularly by the pre-ignition occurring in bore portions 56b and 56c, the normally liquid chemicals will vaporize when ejected from the discharge head.

As best seen in Fig. 4, the discharge passages 65 may be arranged in a relatively close angular spacing about the discharge head so that the discharging streams of cutting fluid, which will ordinarily assume a diverging form as they emerge from the discharge passages, will strike the pipe at points immediately adjacent to each other or in slightly overlapping relation. This will effectively form a substantially continuous circular jet of cutting fluid which will produce a complete circular cut through the wall of the pipe.

By increasing the angular spacing between the discharge passages sufficiently to avoid close contact or overlap of the cutting jets, a series of perforations may be made simultaneously through the pipe or in the well wall. Similarly, by appropriate shaping and arrangement of the discharge passages, such as the examples disclosed in my aforementioned earlier-filed application, cuts of any desired shape and arrangement may be made in the objects against which the cutting fluid is directed as described.

Fig. 3, which illustrates the lower end portion of chemical container portion 5, igniter portions 6 and discharge head portion 7, illustrates a modified arrangement of igniter substance 75 which is found to be useful in some instances to provide additional efficiency in the cutting action of the cutting fluid.

In this modification, the igniter substance is arranged in bore portions 56b and 56c to provide a plurality of bodies of the igniter substance which are of increasing particulate size and of decreasing density per unit volume in the downward direction through the igniter portion. In the illustrative example, there is shown an arrangement of three bodies of steel wool 75a, 75b and 75c, which are of progressively increasing coarseness and decreasing density toward the discharge end of the igniter portion. Similarly, other igniter substances of graduated particulate sizes may be arranged in the igniter portion.

In Fig. 5, pressurizing portion 4 containing the pressurizing gas generating material has been eliminated and chemical container portion 5 has its upper end connected directly to the lower end of a string of pipe 76 which extends through the well to the surface and has a bore 77. Any suitable hydraulic pressurizing medium, such as drilling mud, water, oil or the like, may be pumped from the surface short time cutting fluid, the invention (not shown) to exert the desired pressurizing force against and through the rupture disks to the confined body of cutting fluid 74.

The modification illustrated in Figs. 6A, 6B, 6C and 7, includes generally the several tool portions comprising the previously described embodiment, but differs from the latter in a number of structural details and particularly in the form of the anchor means, its position and mode of operation, as will appear more fully hereinafter.
As noted, the modified tool comprises in downwardly arranged succession, the pressurizing portion, designated generally by the numeral 5a, the ignitor portion, designated generally by the numeral 6a and the discharge head portion, designated generally by the numeral 7a, these several portions functioning in substantially the same manner as the corresponding portions of the previously described embodiment. It will be understood that pressurizing portion 4a will be connected to a head section rope socket and cable (not shown) corresponding in form and function generally to those elements of the previously described embodiment. In the present embodiment, however, anchor means, designated generally by the numeral 12a, is carried by pressurizing portion 4a instead of by the head section as in the previous embodiment, and is adapted to be actuated by the fluid pressure employed to pressurize the cutting fluid.

Pressurizing portion 4a comprises an elongate tubular body 27a having an axial bore 28a extending entirely therethrough, the upper portion of bore 28a, being enlarged in diameter to provide the pressurizing chamber 25b and to form the upwardly facing internal shoulder 28c. The upper portion of chamber 28b, as in the previous embodiment, is internally threaded at 30 to receive the choke bushing 31 having the axial choke passage 33a. The lower end of bore 28c is diametrically enlarged at 33a and internally threaded at 33b to receive choke bushing 34a having the axial choke passage 35a providing a constriction in the lower end of bore 28a. The lower end portion of body 27a is reduced in external diameter and is externally threaded to form the pin member 37a.

Chemical container portion 5a comprises a tubular metallic body 38a having an enlarged axial bore therethrough forming a chamber 39a communicating at its opposite ends with upper and lower internally threaded sockets 40a and 41a respectively, which define at their inner ends about bore 39a the annular shoulders 47a and 47c respectively. A rupturable shear disk 48b is seated on shoulder 47b and is held tightly in place thereon by an externally threaded tubular jam nut 49b which is screwed into the threads in socket 40a. Jam nut 49b has the axial bore 51b communicating with choke passage 35a when pin member 37a is screwed into socket 40a. A copper washer 80 is interposed in socket 40a between the opposing end faces of pin member 37a and jam nut 49b. A rupturable shear disk 48c is seated on lower shoulder 47c and is held tightly against the latter by a tubular jam nut 49c which is screwed into the threads in socket 41a. Jam nut 49c has the axial through bore 51c.

Igniter portion 6a and discharge head portion 7a are substantially identical in form and construction to these portions in the previously described embodiment, except that igniter portion 6a has at its upper end the externally threaded pin member 53a which is threadedly receivable in lower socket 41a on portion 5a and a copper washer 80c is interposed in socket 41a between the opposing ends of pin member 53a and jam nut 49c. The other parts of portion 6a and 7a carry the same identifying numerals as in the previous embodiment.

Anchor means 12a may comprise one or more anchor units of identical form and construction. In the illustrative embodiment, three such units are illustrated, the units being longitudinally spaced along the portion of body 27a below the lower end of pressurizing chamber 28a and angularly oriented about body 27a as shown. Each of the anchor units comprises a lower cylinder 81 extending diametrically entirely through body 27a and intersecting bore 28a. Slidably mounted in opposite ends of cylinder 81 are generally cylindrical slips 82 having appropriately shaped teeth or wickers 83 on their outer end faces. The inner ends of the slips carry inwardly projecting centrally positioned bosses 84 adapted to abut when the slips are retracted inwardly of the outer ends of bore 80 to provide clearance about the abutting bosses (see Fig. 7) sufficient to permit free passage of pressurizing fluid through bore 28a. Suitable seal packings, such as conventional O-rings 85, are circumferentially disposed about the exterior of slips 82 to form slideable fluid-tight seals between the slips and the wall of cylinder 81. The outer end faces of slips 82 are provided with diametrically opposite recesses 86—86 which register with elongated slots 87—87 formed in the exterior of body 27a. Leaf springs 88—88 are mounted in each of the slots 87—87 to resiliently urge slips 82 inwardly of cylinder 81. Each of the leaf springs has one end secured to body 27a, as by means of a stud 89, the other free end extending into the registering recess 86 to press against the outer end face of the slip.

Chamber 28a will have disposed therein a suitable pressurizing medium of the same character as that employed in the previously described embodiment, such as the explosive material 70. In the present embodiment explosive material 70 is supported on the upper end of a tubular spacer 71a which is adapted to rest on shoulder 28c. The wall of spacer 71a is provided with a plurality of openings 71b to permit gases generated by the burning of explosive material 70 to pass freely from chamber 28b into bore 28a.

Chamber 28a is adapted to be charged with the appropriate quantity of incendiary chemical fluid 74 and bore portions 56b and 56c of igniter portion 6a will have disposed therein igniter substance 75 as previously described.

Except with respect to operation of anchor means 12a, the operation of modified structure last described is substantially like that of the previously described embodiment. In the present instance, when the tool has been lowered into the well to the desired depth, explosive material 70 will be ignited in the manner previously described. The gases generated by the burning of material 70 will in flowing through bore 28a exert pressure against the inner ends of slips 82 driving them radially outwardly (see broken line positions, Fig. 7) into anchoring engagement with pipe 2. Choke passage 35a will provide sufficient back pressure in bore 28a to assure application of sufficient pressure to the slips to securely anchor the tool to the pipe. The anchoring action will occur in advance of the discharge of the incendiary fluid from the tool so that the tool will be held firmly against upward thrust resulting from the discharge and resulting chemical action of the incendiary cutting fluid. So long as pressurizing gases continue to discharge from chamber 28b, the slips will remain anchored to the pipe. As soon as explosive material 70 has been consumed or the internal pressure fully dissipated, springs 88 will then act on the outer end faces of slips 82 to urge them back into cylinders 81 and release the tool from the pipe so that it may be withdrawn from the well.

As is known to those skilled in the art, fluorine and the halogen fluorides may be safely stored at ordinary temperatures in containers constructed of steel and iron. Accordingly, the containers for the incendiary chemical fluids and the other principal parts of the cutting tools described herein are preferably constructed of steel. Despite the high temperatures and pressures generated in the cutting operations herein described, the tools remain substantially undamaged and may be re-used. Apparently, the extremely high velocities obtained in the discharge passages and channels prevents any appreciable reaction with the tool parts including particularly the discharge head.

The pre-ignition material will be consumed in use and will have to be replaced when the tool is re-used.

It will be understood that numerous additional alterations and modifications may be made in the details of the illustrative embodiments within the scope of the appended claims without departing from the spirit of this invention.
2,918,128

What I claim and desire to secure by Letters Patent is:

1. An apparatus for cutting an object within the bore of a well and below the surface thereof, comprising, a means adapted to be lowered into the well to a point adjacent the said object to be cut, which member includes a container having therein a body of an incendiary chemical cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, the said member having a discharge passage extending through the container in the direction of the member to be cut, means associated with the member and communicable with the body of chemical cutting fluid contained within the member and operable from the surface of the ground to initiate high pressure upon the chemical cutting fluid to eject the chemical cutting fluid from the body through said discharge passage as a high velocity stream and an ignition initiating means in the path of said high velocity chemical cutting fluid before the discharge passage to initiate ignition of the chemical fluid prior to ejection thereof through said passage whereby to accelerate the chemical action of the cutting fluid with the object and to confine the chemical cutting action substantially to the said object to be cut.

2. In a device for cutting an object within a well below the surface thereof comprising a casing, a body of incendiary chemical cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, confined within said casing, a body of explosive material contained within the casing and communicable with the body of chemical cutting fluid, means within the casing including a discharge passage for confining the chemical cutting fluid to a narrowly restricted stream, means at the surface of the ground for initiating an explosion of said explosive material to eject said chemical cutting fluid from the confined body thereof through the discharge passage whereby the chemical cutting fluid is impinged at high velocity against the body within the well to be cut, and means within the discharge passage for initiating ignition of the chemical cutting fluid prior to impingement against the said object whereby the chemical action of the chemical cutting fluid and the object is accelerated and the cutting action of the chemical fluid is substantially confined to the object to be cut.

3. In a device for cutting an object within a well comprising a casing insertable into the well bore to a point adjacent to the object to be cut, means for anchoring the casing in the well at said point against displacement upon operation of chemical cutting operation, a body of incendiary chemical cutting fluid confined within said casing, said chemical cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, said casing having one or more restricted diameter discharge passages communicable with the body of chemical cutting fluid and directed toward the object within the well to be cut, means within the casing and operable from the surface of the ground for imposing high pressure upon the chemical cutting fluid to eject the chemical cutting fluid through each of the discharge passages as a narrowly confined high pressure stream and ignition initiating means within said passages adapted to ignite said chemical cutting fluid within said passage immediately prior to impingement on the object within the well to accelerate the rate of chemical reaction of said chemical cutting fluid with said object so that the chemical reaction may be substantially confined to said object.

4. An apparatus as defined in claim 3 wherein the ignition initiating means comprises a body of the class consisting of mineral wool, glass wool, hydrocarbon oil, and grease.

5. An apparatus as defined in claim 3 wherein the pressurizing means includes a body of a slow burning deflagrating type explosive, and means for igniting the said explosive from the surface of the ground.

6. Apparatus for cutting inside of a well, comprising, a tubular casing insertable in a well, said casing having an upper and a lower chamber therein, a passageway providing communication between said chambers, a discharge passage communicating with the exterior of said casing, sepa rate downwardly opening closure means controlling said passageway and said discharge passage, a body of an incendiary chemical cutting fluid confined in said lower chamber, means for igniting said incendiary chemical cutting fluid in said lower chamber, means for initiating ignition of said cutting fluid as it passes through said discharge passage.

7. Apparatus for cutting inside a well, comprising a casing insertable in a well bore, a chamber in said casing containing a body of an incendiary chemical cutting fluid consisting of a member of the class consisting of fluorine and halogen fluoride, one or more discharge passages providing communication between said chamber and the exterior of said casing, pressure actuated closure means controlling communication between said chamber and said passages, and means for applying pressure to said body of cutting fluid to open said closure means and to force said fluid outwardly through said passages, and means for initiating ignition of said fluid prior to its discharge from said passages.

8. The method of cutting an object, comprising, confining within a zone isolated from the atmosphere a body of an incendiary chemical cutting fluid and a substance isolated from said body and adapted to initiate ignition of said cutting fluid, said cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, said object having one or more restricted diameter discharge passages communicable with the body of chemical cutting fluid and directed toward the object within the well to be cut, means within the casing and operable from the surface of the ground for imposing high pressure upon the chemical cutting fluid to eject the chemical cutting fluid through each of the discharge passages as a narrowly confined high pressure stream and ignition initiating means within said passages adapted to ignite said chemical cutting fluid within said passage immediately prior to impingement on the object within the well to accelerate the rate of chemical reaction of said chemical cutting fluid with said object so that the chemical reaction may be substantially confined to said object.

9. The method of cutting an object, comprising, confining within a zone isolated from the atmosphere a body of an incendiary chemical cutting fluid and a substance isolated from said body and adapted to initiate ignition of said cutting fluid, said cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, said object having one or more restricted diameter discharge passages communicable with the body of chemical cutting fluid and directed toward the object within the well to be cut, means within the casing and operable from the surface of the ground for imposing high pressure upon the chemical cutting fluid to eject the chemical cutting fluid through each of the discharge passages as a narrowly confined high pressure stream and ignition initiating means within said passages adapted to ignite said chemical cutting fluid within said passage immediately prior to impingement on the object within the well to accelerate the rate of chemical reaction of said chemical cutting fluid with said object so that the chemical reaction may be substantially confined to said object.

10. The method of cutting an object according to claim 9 wherein said pressurizing step comprises generating high pressure gases by the ignition of a deflagrating type explosive, and means for applying the pressure of said gases against said body of cutting fluid.

11. The method of cutting an object according to claim 9 wherein said substance adapted to initiate ignition of said cutting fluid comprises a member of the class consisting of steel wool, glass wool, oil and grease.

12. The method of cutting an object, comprising, confining within a zone isolated from the atmosphere a body of an incendiary chemical cutting fluid and a substance isolated from said body and adapted to initiate ignition
of said cutting fluid, said cutting fluid consisting of chlorine trifluoride, positioning the confined body of cutting fluid and ignition-initiating substance adjacent an object to be cut, forcing the cutting fluid under elevated pressure into direct contact with the substance in said zone to thereby initiate ignition of said cutting fluid in said zone whereby to enhance the chemical cutting property of said fluid, and directing the so-ignited fluid in a confined stream under elevated pressure against said object, whereby to cause said cutting fluid to ignite with and penetrate said object.

13. The method of cutting an object according to claim 12, wherein said substance adapted to initiate ignition of the cutting fluid comprises a member of the class consisting of steel wool, glass wool, oil, and grease.

14. The method of cutting an object, comprising, positioning adjacent an object to be cut a confined body of an incendiary chemical cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, pressurizing said body of cutting fluid to an elevated pressure by imposing thereon a high pressure fluid pressurizing medium, ejecting said chemical cutting fluid under the pressure of said pressurizing medium, restricting the ejection of the fluid to a hydrocarbon said body until the pressure imposed thereon has reached a predetermined minimum, thereafter pressurizing the cutting fluid into direct contact with a substance adapted to initiate ignition of said cutting fluid whereby to intensify the chemical cutting action of said cutting fluid, and directing the so-ignited cutting fluid in a confined stream against said object whereby to cause said cutting fluid to ignite with and penetrate said object.

15. The method of cutting an object inside of a well, comprising, confining within a zone isolated from the atmosphere a body of an incendiary chemical cutting fluid and a substance isolated from said body and adapted to initiate ignition of said cutting fluid, said cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, introducing the confined body of cutting fluid and ignition-initiating substance into a well at a point adjacent an object to be cut, forcing the cutting fluid under elevated pressure into direct contact with said substance in said zone to thereby initiate ignition of said cutting fluid in said zone whereby to enhance the chemical cutting property of said fluid, and directing the so-ignited fluid in a confined stream under elevated pressure against said object, whereby to cause said cutting fluid to ignite with and penetrate said object.

16. The method of cutting an object inside of a well, comprising, introducing into a well at a point adjacent an object to be cut a confined body of an incendiary chemical cutting fluid comprising a member of the class consisting of fluorine and halogen fluoride, pressurizing said body of cutting fluid to an elevated pressure by imposing thereon a fluid pressurizing medium, ejecting said chemical cutting fluid under the pressure of said pressurizing medium, passing the pressurized cutting fluid leaving said body into direct contact with a substance adapted to initiate ignition of said cutting fluid whereby to intensify the chemical cutting action of said cutting fluid, and directing the so-ignited fluid in a confined stream against said object whereby to cause said cutting fluid to ignite with and penetrate said object, said pressurizing step comprising generating high pressure gases by the ignition of a deflagrating type explosive, and applying the pressure of said gases against said body of cutting fluid.

17. The method of cutting an object inside of a well according to claim 15, wherein said substance adapted to initiate ignition of said cutting fluid comprises a member of the class consisting of steel wool, glass wool, oil and grease.

18. The method of cutting an object inside of a well comprising, introducing into a well at a point adjacent an object to be cut a confined body of an incendiary chemical cutting fluid consisting of chlorine trifluoride, igniting a deflagrating explosive inside the well to generate high pressure gases, directing the pressure of said gases against said body of cutting fluid whereby to eject said chemical cutting fluid under elevated pressure, passing the pressurized cutting fluid leaving said body into direct contact with a substance adapted to initiate ignition of said cutting fluid whereby to intensify the chemical cutting action of said fluid, said substance comprising a member of the class steel wool, glass wool, oil and grease, and directing the so-ignited fluid in a confined stream against said object whereby to cause said cutting fluid to ignite with and penetrate said object.

19. The method of cutting pipe inside of a well, comprising, introducing into the bore of the pipe at a distance below the surface, a confined body of an incendiary chemical cutting fluid consisting of chlorine trifluoride, igniting a deflagrating explosive inside the bore of the pipe to generate high pressure gases, directing the pressure of said gases against said body of cutting fluid whereby to eject said chemical cutting fluid thereof under elevated pressure, passing the pressurized cutting fluid leaving the body thereof into direct contact with steel wool impregnated with an igniting mixture whereby to intensify the cutting action of said cutting fluid, and directing the so-ignited fluid in a radially directed confined stream against the wall of said pipe whereby to cause said cutting fluid to ignite with and penetrate the wall of said pipe.

20. Apparatus for cutting an object comprising, a casing disposed adjacent the object to be cut, a chamber in said casing containing a body of an incendiary chemical cutting fluid consisting of a member of the class consisting of fluorine and halogen fluoride, one or more discharge passages providing communication between said chamber and the exterior of said casing and directed to said object, pressure actuated closure means controlling communication between said chamber and said passages, and means for applying pressure to said body of cutting fluid to open said closure means and to force said fluid outwardly through said passages, and means in said passages for initiating ignition of said fluid prior to its discharge therefrom.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,543,263</td>
<td>Bitterlin</td>
<td>Feb. 28, 1882</td>
</tr>
<tr>
<td>968,330</td>
<td>Harrison</td>
<td>Aug. 23, 1910</td>
</tr>
<tr>
<td>1,376,100</td>
<td>Kendall</td>
<td>Apr. 26, 1921</td>
</tr>
<tr>
<td>2,144,208</td>
<td>Van Meter</td>
<td>Jan. 17, 1939</td>
</tr>
<tr>
<td>2,302,567</td>
<td>O'Neill</td>
<td>Nov. 17, 1942</td>
</tr>
<tr>
<td>2,324,087</td>
<td>Jelley</td>
<td>July 13, 1944</td>
</tr>
<tr>
<td>2,337,460</td>
<td>French</td>
<td>Dec. 21, 1944</td>
</tr>
<tr>
<td>2,451,422</td>
<td>Wagner</td>
<td>Oct. 12, 1948</td>
</tr>
<tr>
<td>2,463,839</td>
<td>Tallis</td>
<td>Mar. 8, 1949</td>
</tr>
<tr>
<td>2,569,933</td>
<td>Kendall et al.</td>
<td>Oct. 2, 1951</td>
</tr>
<tr>
<td>2,571,636</td>
<td>Watkins</td>
<td>Oct. 16, 1951</td>
</tr>
<tr>
<td>2,653,853</td>
<td>Crake</td>
<td>Apr. 21, 1953</td>
</tr>
<tr>
<td>2,642,656</td>
<td>Grosse</td>
<td>June 23, 1953</td>
</tr>
<tr>
<td>2,680,486</td>
<td>Carpenter</td>
<td>June 8, 1954</td>
</tr>
<tr>
<td>2,680,487</td>
<td>Carpenter</td>
<td>June 8, 1954</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>90,917</td>
<td>Switzerland</td>
<td>Oct. 1, 1921</td>
</tr>
</tbody>
</table>

OTHER REFERENCES


UNITED STATES PATENT OFFICE
Certificate
Patent No. 2,918,125 Patented December 22, 1959

William G. Sweetman

Application having been made jointly by William G. Sweetman, the inventor named in the patent above identified; Texas National Bank of Houston, a national banking association, assignee of O. J. McCullough; Ira J. McCullough of the county of Los Angeles, Los Angeles, California; and Otis J. McCullough of the county of Harris, Houston, Texas, for the issuance of a certificate under the provisions of Title 35, Section 256 of the United States Code, adding the names of the said Ira J. McCullough and Otis J. McCullough to the patent as joint inventors, and a showing and proof of facts satisfying the requirements of the said section having been submitted, it is this 9th day of July 1963, certified that the names of the said Ira J. McCullough and Otis J. McCullough are hereby added to the said patent as joint inventors with the said William G. Sweetman.

EDWIN L. REYNOLDS,
First Assistant Commissioner of Patents.

[SEAL]