Jan. 30, 1962 J. H. CASTEL 3,018,730

PERFORATING GUNS

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Fig. 1

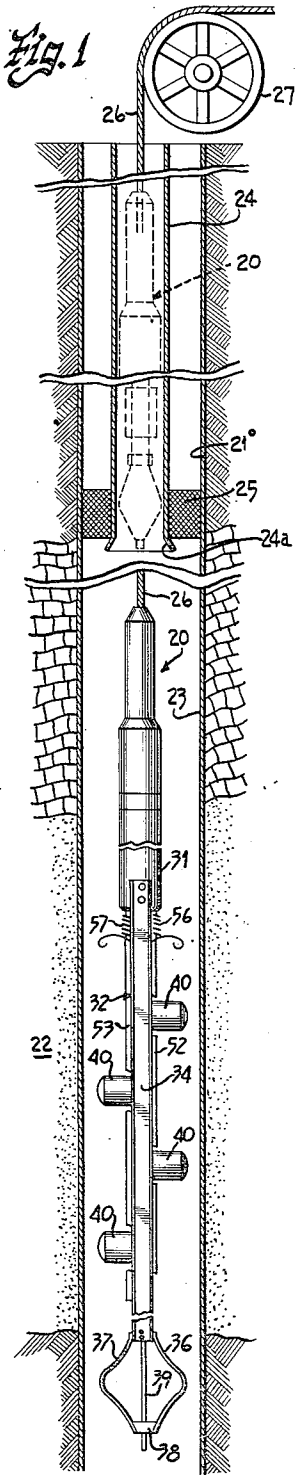
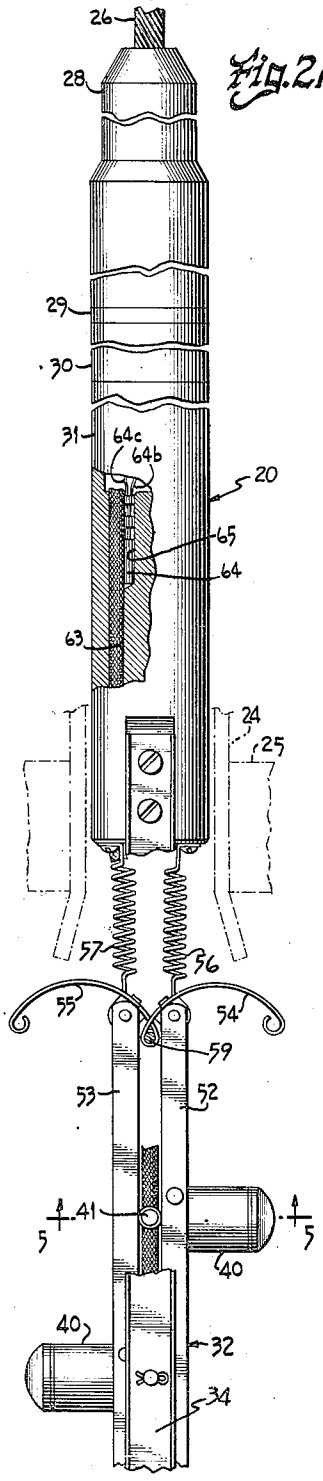



Fig. 2A



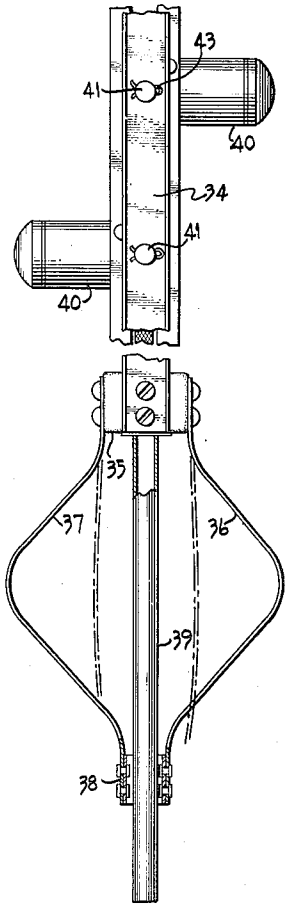




Fig. 2B

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Fig. 3

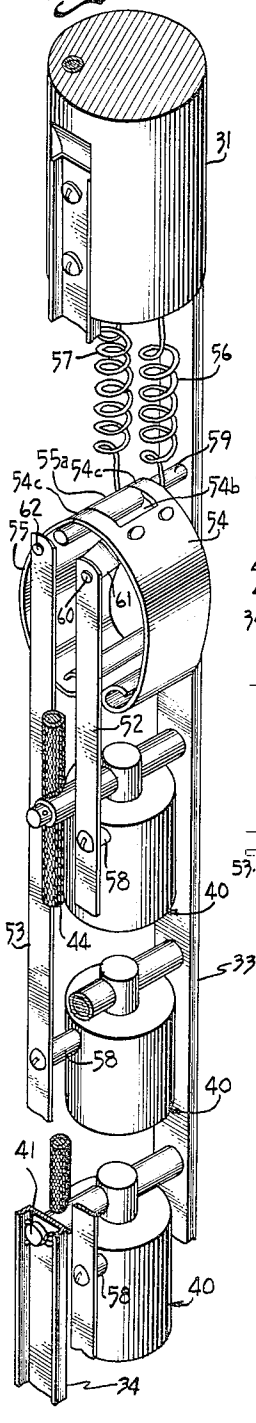



Fig. 4

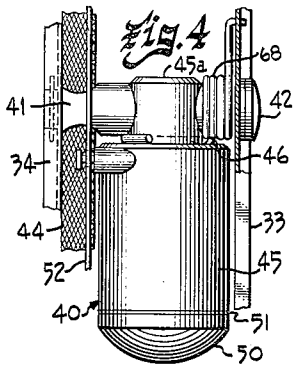



Fig. 5

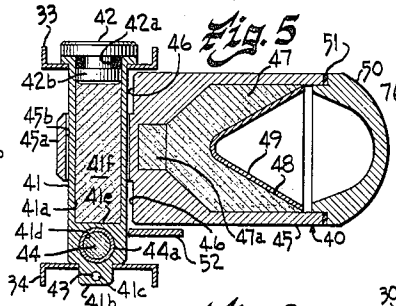



Fig. 6

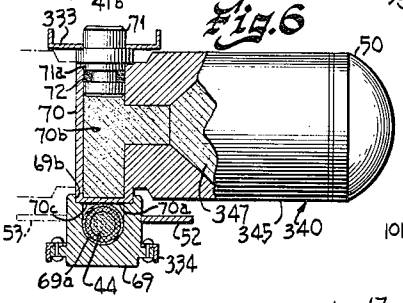
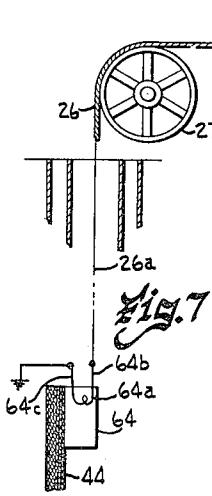



Fig. 7



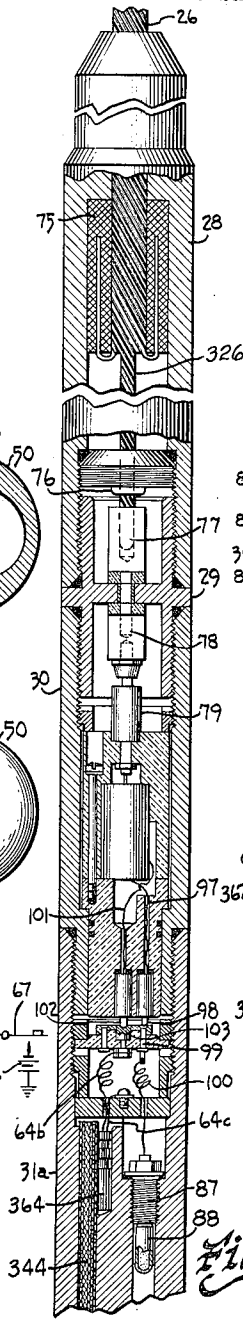
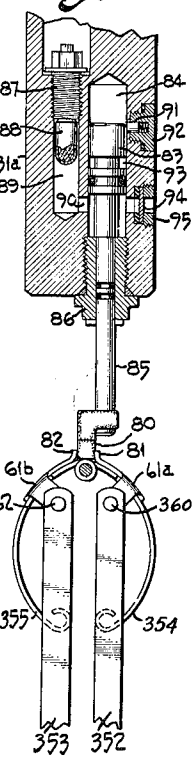




Fig. 8

Fig. 9




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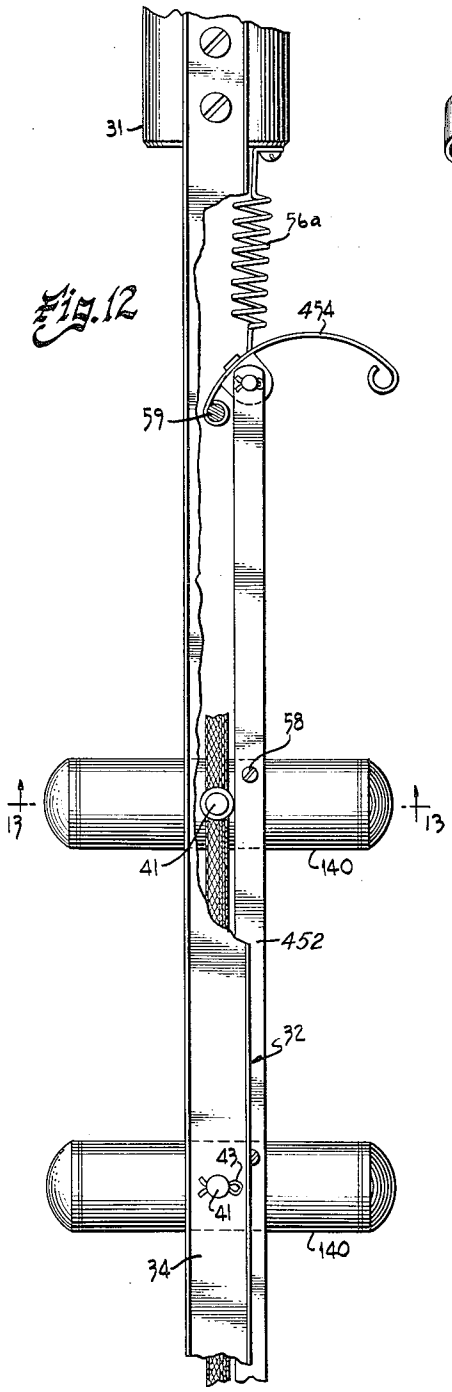



Fig. 12

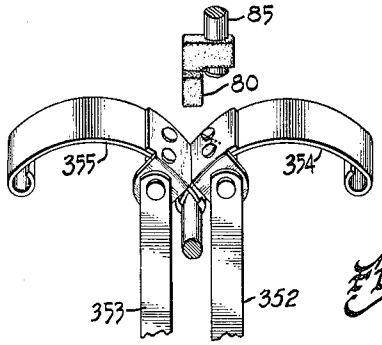



Fig. 10

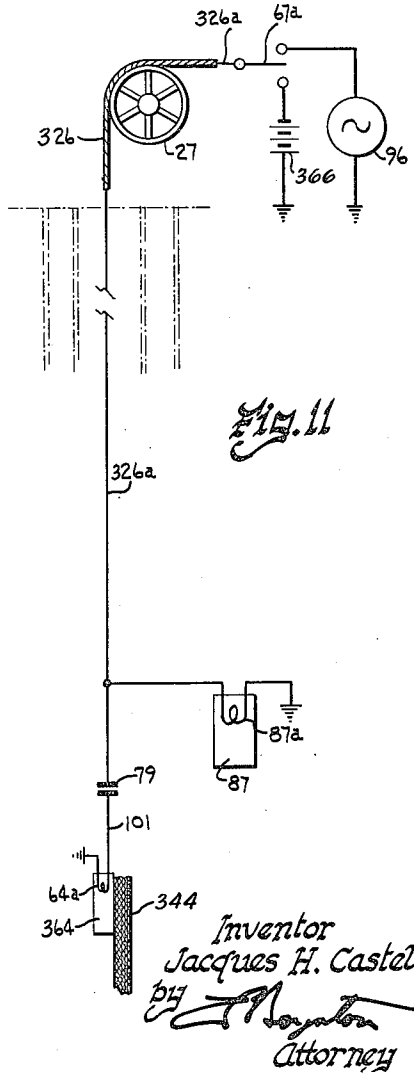



Fig. 11

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PERFORATING GUNS

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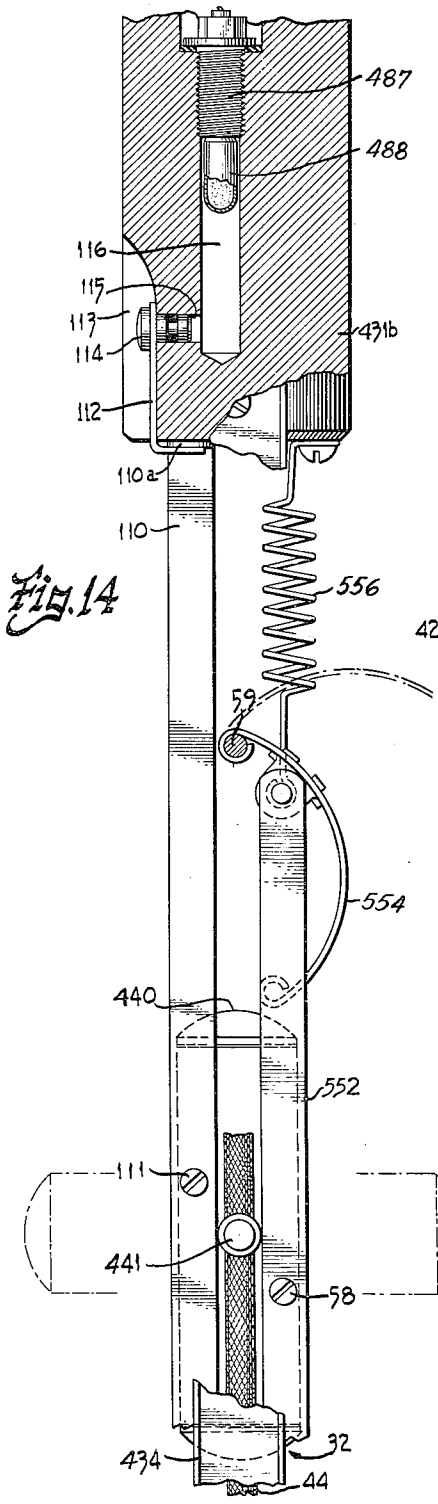



Fig. 14

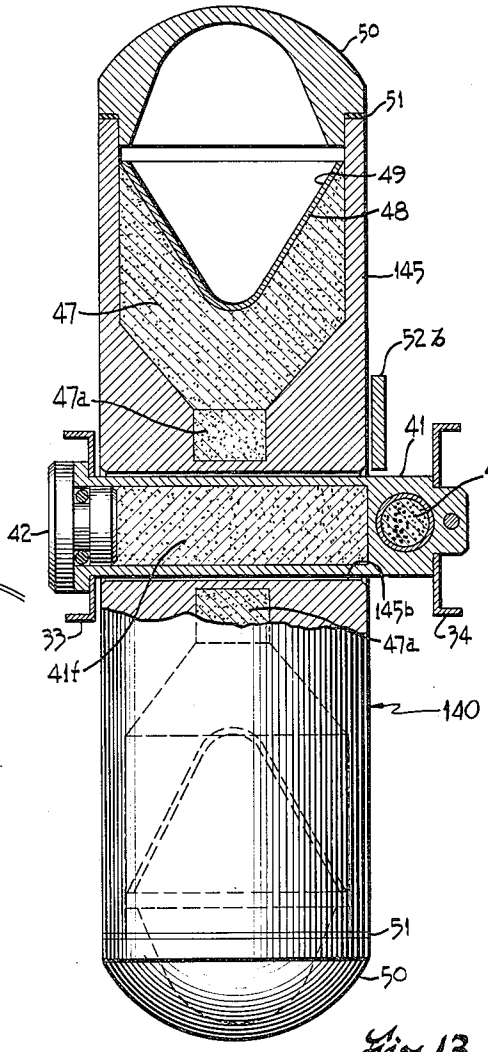



Fig. 13

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Fig. 15

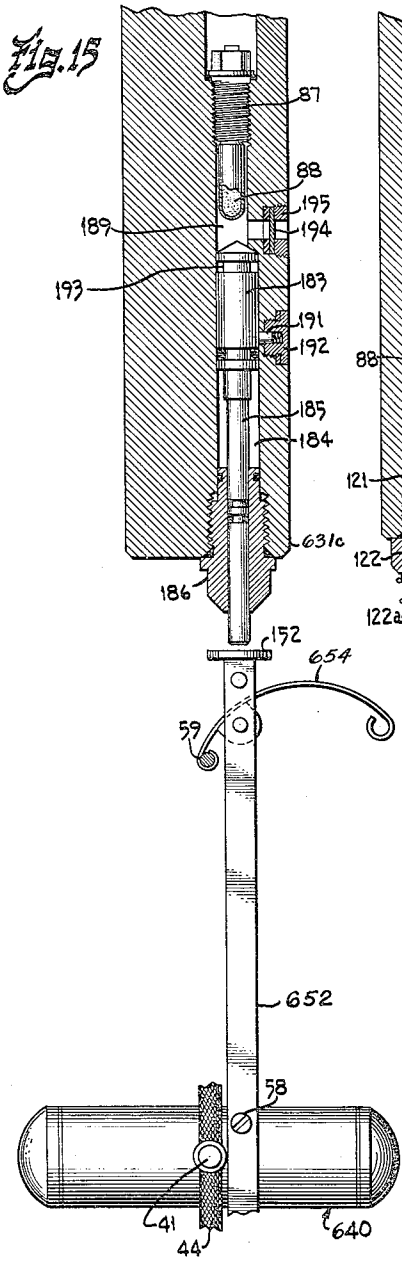



Fig. 16

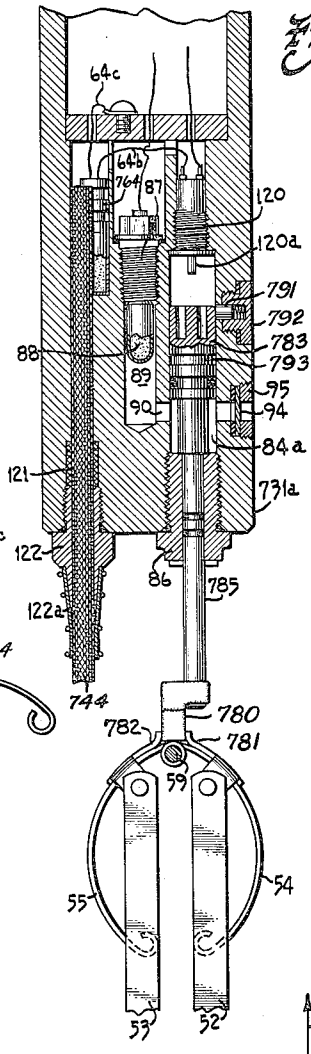



Fig. 17

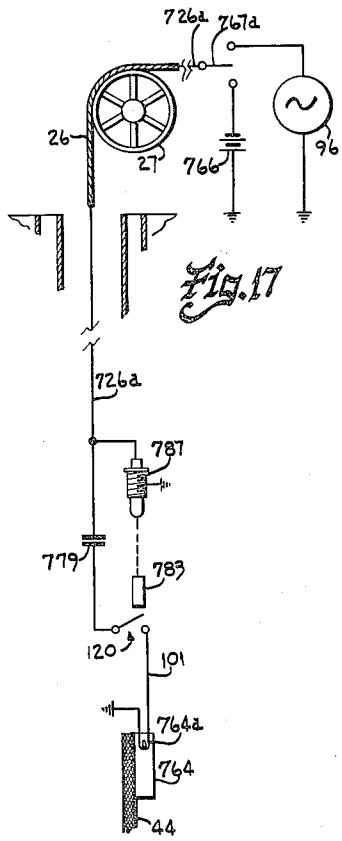
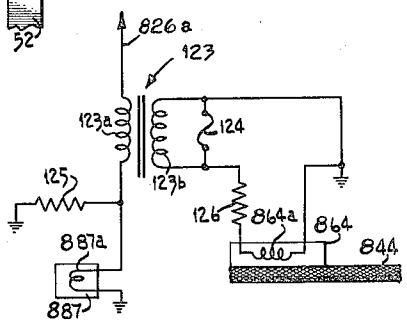



Fig. 18




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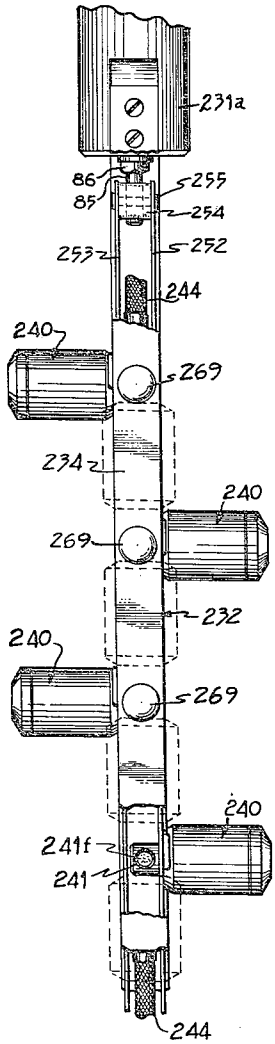



Fig. 20

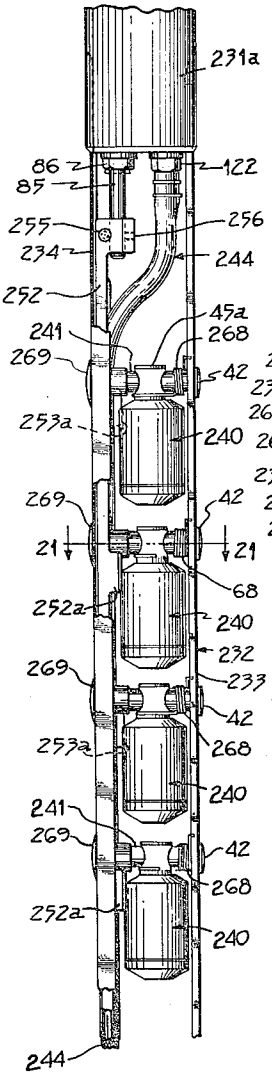



Fig. 19

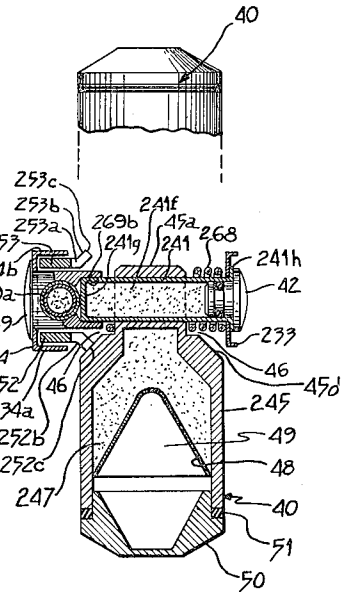



Fig. 21

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United States Patent Office 3,018,730 Patented Jan. 30, 1962



# 3,018,730
# PERFORATING GUNS

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Filed July 29, 1953, Ser. No. 370,990
14 Claims. (Cl. 102—20)

The present invention relates to perforating guns adapted to be used in the perforation of casing, cement, or well bore formations in boreholes, and more particularly to an improved jet type perforating gun of very small outside diameter which is so constructed that it may be run through small diameter openings or small diameter tubing without sacrificing the efficiency and effectiveness of a larger diameter gun of conventional design.

One of the methods now employed in completing a well drilled in the earth for the purpose of producing oil, gas or other fluid or liquid minerals, is that of first lining the borehole with casing or pipe in order to prevent the walls of the hole from caving and to preclude the entrance into the hole of undesired fluids from higher levels. In some cases, the hole is also cemented off at a level just below the desired producing zone. After these operations are completed, the casing is perforated by means of a perforating gun lowered into the casing to a position opposite the desired producing zone. After the perforating operation is completed, the gun is withdrawn from the hole and a string of small diameter pipe or tubing is run into the hole to a point usually just above the producing zone. Water or thin mud is then pumped down the tubing and back out of the casing in order to wash out the heavy mud and thereby reduce the hydrostatic head at the bottom of the hole, so that oil, gas or the other fluid or liquid mineral, may flow into the casing through the perforations at the bottom of the hole. A more modern method of well completion is that of setting the casing in the hole, running the small diameter tubing into the casing, washing out the heavy drilling mud, sealing off the bottom end of the tubing at a desired point above the producing zone by using a packer or the like, and then perforating the casing opposite the producing zone. When this latter method is used, it is evident that the perforating gun employed to perform the perforating operation must be of small diameter in order that it may be lowered through the small diameter tubing to the desired shooting position.

In general, perforating guns of the so-called bullet and jet types have both been used with great effectiveness to perform casing perforating operations of the type just described. However, the efficiency, and therefor the effectiveness of penetration, of a shaped charge of the type used in jet type perforating guns varies with the dimensions of the charge and the ratio of the length to the diameter of the charge, among other factors. Under certain conditions, a shaped or jet forming charge having the desired power of penetration has a length greater than the inside diameter of the tubing through which it must be run if the modern method of well completion described above is to be employed.

In order to solve this problem of lowering a jet type perforating gun embodying shaped charges of greater length than the internal diameter of the tubing through which the gun may pass, a gun arrangement has been proposed which utilizes a series of jet charges or cartridges arranged in pivotal position in a carrier or frame and whose axes are tilted after passing through the small diameter tubing through the influence of gravitational pull on the unbalanced ends of the charges. One of the disadvantages of this arrangement is that in many cases the weight and viscosity of the mud in the borehole is such as



to impede freedom of movement of the charges from their retracted positions to their extended perforating positions. A second and more serious difficulty is that in the event of a misfire, or if after moving the gun into shooting position it is desired to withdraw the gun without shooting, it is impossible to move the extended jet charges or cartridges back into their retracted positions so that the gun may be withdrawn into the tubing. A third important disadvantage of the described prior art arrangement resides in the fact that each charge is detonated by its own blasting cap, which means that as many wires or conductors as there are charges in the gun must be used in the cable which is employed to run the gun into the well, a large firing current is required, and a large number of misfires result.

It is an object of the present invention, therefore, to provide an improved small diameter perforating gun in which the perforating charges or cartridges may be moved from retracted positions to extended perforating positions after passing through small diameter openings, and which is not subject to the above-described disadvantages.

It is another object of the invention to provide an improved perforating gun of the character described, which is so arranged that the charges or cartridges may be rotated or pivoted, the longitudinal axes of the charges lying in retracted vertical positions parallel to the long axis of the gun while the gun is being lowered through small diameter tubing or pipe into a well, and the charges thereafter being forcibly pivoted to extended horizontal perforating positions in readiness for detonation or firing.

It is a further object of the invention to provide in a perforating gun of the character described, an improved and exceedingly simple mechanism for maintaining the charges or cartridges in their retracted positions while the gun is passing through small diameter tubing into a well and for moving the charges or cartridges to extended perforating positions after the gun has been lowered to the desired perforating position in the well.

It is a still further object of the invention to provide an improved perforating gun of the character described, which includes exceedingly simple facilities for retracting the charges or cartridges from their extended perforating positions to their retracted positions, thereby to permit withdrawal of the gun back into the small diameter tubing through which it is run without firing the charges.

It is another object of the invention to provide an improved perforating gun of the character described, wherein the charges or cartridges may be locked in their retracted positions and then moved to their extended perforating positions after the gun is lowered to a desired perforating position in the well at the will of an operator.

It is still another object of the invention to provide an improved perforating gun of the character described which includes exceedingly simple facilities, controllable at will from the earth's surface, for moving the charges or cartridges from their extended perforating positions back into their retracted positions to permit withdrawal of the gun into small diameter tubing through which the gun is lowered into the well.

In accordance with another object of the present invention, an arrangement is provided for positively precluding detonation of the charges or cartridges until the perforating gun has been lowered to the desired perforating position and the charges or cartridges have been moved from their retracted positions to their extended perforating positions.

A further object of the invention is to provide an improved jet cartridge supporting arrangement in which either a single or double ended jet charge or cartridge is supported for free rotation with respect to its detonating medium, without being directly connected thereto.

It is still another object of the invention to provide an

improved charge or cartridge supporting arrangement of the character described, wherein a plurality of charges or cartridges are pivoted around spaced pivots and wherein all of the charges are detonated by one substantially straight length of detonating cord which extends in a substantially straight line along the charge carrier and remains in a fixed position while the charges are rotated around their pivots.

According to still another more specific object of the invention, detonation of the freely rotatable charges or cartridges is accomplished by providing hollow pivot pins for supporting the charges and by providing booster charges of explosive material in the hollow pivot pins which are utilized to detonate the charges.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which:

FIG. 1 illustrates a small diameter perforating gun characterized by the features of the present invention at two positions in a cased borehole which extends into the earth and in which a string of small diameter tubing has been run and set;

FIGS. 2A and 2B, when considered end to end one above the other in the order named, illustrate one embodiment of the present improved perforating gun;

FIG. 3 is an oblique perspective view more clearly illustrating certain mechanical features of the lower portion of the perforating gun shown in FIGS. 2A and 2B;

FIG. 4 is an elevational view illustrating one of the cartridge biasing arrangements which may be employed in the gun;

FIG. 5 is a sectionalized view, taken along the lines 5—5 in FIG. 2A, illustrating the present improved arrangement for supporting and detonating the jet charges or cartridges;

FIG. 6 is a side view, partially in section, illustrating a modified arrangement for supporting and detonating the cartridges;

FIG. 7 is a circuit diagram illustrating the electrical system employed for firing the cartridges embodied in the gun shown in FIGS. 2A and 2B;

FIG. 8 is a side sectional view illustrating a slightly different embodiment of the present improved perforating gun and certain details of the gun shown in FIGS. 2A and 2B;

FIG. 9 is a side view, partially in section, illustrating the lower end of the modified gun arrangement shown in FIG. 8;

FIG. 10 is a perspective view illustrating certain parts of the gun assembly shown in FIGS. 8 and 9 in changed positions;

FIG. 11 is a circuit diagram illustrating the electrical control system for the modified gun arrangement shown in FIGS. 8 and 9;

FIG. 12 is a side-elevational view illustrating another embodiment of the invention which utilizes double ended jet forming cartridges;

FIG. 13 is a side sectional view taken along the lines 13—13 of FIG. 12, illustrating the details of one of the charges shown in FIG. 12 and the present improved detonating facilities therefor;

FIG. 14 is a side view, partially in section, illustrating a further embodiment of the present invention;

FIG. 15 is a side view, partially in section, illustrating another embodiment of the present improved perforating gun;

FIG. 16 is a side view, largely in section, illustrating a further modification of the present improved perforating gun;

FIG. 17 is a circuit diagram illustrating the electrical control system provided to control the gun embodiment illustrated in FIG. 16;

FIG. 18 is a circuit diagram illustrating an alternative circuit arrangement which may be employed in the control system shown in FIG. 11 or the control system shown in FIG. 17;

FIGS. 19 and 20 are side views illustrating another embodiment of the invention; and

FIG. 21 is a sectional view taken along the lines 21—21 in FIG. 19.

Referring now to the drawings and more particularly to FIG. 1 thereof, the present improved perforating gun, generally indicated by the reference numeral **20**, is there illustrated in two positions within a bore hole **21** which has been drilled into the earth to a point slightly below an oil bearing structure **22**. As shown, the bore hole **21** has been cased by casing or pipe **23** which has been run into the well and set, as by cementing or the like, to prevent the bore hole from caving and to prevent water or other fluids from seeping into the bottom of the hole from the upper regions of the earth through which the hole **21** extends. Small diameter tubing **24** has also been run into the hole to extend from the earth's surface to a position just above the upper level of the production zone **22**. As shown, the lower end **24***a* of the tube **24** has a bell-shaped configuration and has been sealed off by a packer **25** which effectively blocks fluid flow from the space between the casing **23** and the tubing **24** into the portion of the casing disposed below the lower end **24***a* of the tubing **24**. It will be understood, however, that before the packer **25** is set the heavy drilling mud which may have accumulated in the bottom of the hole is flushed out by pumping water or a light mud down the tubing **24** and back up the annular passageway between this tubing and the casing **23**.

After the bore hole has been cased and the tubing set in the manner explained in the preceding paragraph, the perforating gun **20** must, of course, be lowered to a perforating position opposite the producing zone **22** through the tubing **24**. This is conventionally accomplished by utilizing a steel sheathed cable **26** containing a single electrically insulated conductor to lower the gun **20** into the bore hole. To this end, the cable **26** is fixedly connected to the upper end of the gun **20** in a manner more fully explained below, is passed over a sheave or measuring wheel **27** at the earth's surface and is unwound from a cable drum, all in accordance with conventional practice. Conventionally, the tubing **24** through which the gun **20** is lowered to its perforating position at the bottom of the bore hole has an internal diameter of approximately two inches. Jet forming charges or cartridges of the type which the present improved gun utilizes, conventionally have lengths in excess of two inches when designed to have the requisite penetration power. This dimensional relationship between the internal diameter of the tubing **24** and the length of the cartridges utilized in the gun **20** gives rise to the above noted problem of lowering the gun into the bore hole through the tubing and perhaps withdrawing the gun into the tubing or out of the well without firing the cartridges with which the gun is loaded.

Referring now more particularly to FIGS. 2A, 2B and 3 of the drawings, one embodiment of the present improved perforating gun, constructed and arranged to overcome the above-noted difficulties, is there illustrated as generally comprising a fishing head **28** to which the lower end of the cable **26** is connected, a connecting sub-assembly **29**, a circuit component housing sub-assembly **30**, a detonating sub-assembly **31**, and a charge or cartridge carrier, generally indicated by the reference numeral **32**, connected together from top to bottom in the order named. In general, the components **28**, **29**, **30** and **31** may be identical with the corresponding components illustrated in FIG. 8 of the drawings and described below. As best shown in FIGS. 2A and 3 of the drawings, the carrier **32** comprises a pair of spaced apart parallel extending rails **33** and **34** of channel shaped cross section, the upper ends of which are disposed in receiving channels milled in the lower end of the detonating sub-assembly block

31 and are machine screw connected to this sub-assembly block. At their lower ends, the rails 33 and 34 are machine screw connected to a spacer block 35, which also functions to support a pair of positioning springs 36 and 37. These springs normally have a semi-loop-shaped configuration of the form illustrated in solid lines in FIG. 2B of the drawings and are adapted to be depressed to the substantially straight line configuration shown in dashed lines in this same figure in order that they may be passed through the small diameter tubing 24. At their extended ends, the springs 36 and 37 are connected to a small diameter slide ring 38, which is adapted to traverse a guide tube 39 projecting downwardly from the spacer block 35 along the central axis of the gun 20 and fixedly anchored to this block by suitable securing means at its upper end. With this arrangement, the springs 36 and 37 occupy their retracted straight line positions as the gun 20 is lowered through the tubing 24 and self-expand to their full line positions upon emergence from the lower end 24*a* of the tubing 24 to act as positioning elements for positioning the cartridge carrier 32 substantially centrally of the casing 23 when the gun 20 is lowered to its perforating position at the bottom of the bore hole. The shape of the springs 36 and 37 is obviously such that these springs may be retracted to their straight line positions to permit withdrawal thereof into the tubing 24 as the gun 20 is drawn out of the bore hole 21.

As best shown in FIGS. 2A and 3 of the drawings, a plurality of jet producing shaped explosive charges or cartridges are pivotally supported at spaced points along the carrier 32 between the carrier rails 33 and 34. The cartridges used in this embodiment of the present improved perforating gun are of the single ended type, i.e., produce explosive jets in one direction only upon detonation thereof. Pivot pins 41 extending transversely across and through the carrier rails 33 and 34 are utilized pivotally to support the spaced cartridges 40. More specifically, and as best shown in FIG. 5 of the drawings, each pivot pin 41 is hollow, being provided with a cylindrical internal chamber 41*a* throughout the major portion of the length thereof. This internal chamber is closed by means of a cap 42 driven or threaded into the open end of the pin 41 and provided with an enlarged head bearing against the carrier rail 33 to serve as a pivot pin retaining element. A sealing ring 42*a*, formed of rubber or the like and disposed in an annular recess circling the plug portion 42*b* of the cap 42 is provided to seal the opening into the chamber 41*a*. At the end thereof opposite the cap 42, the illustrated pin 41 is provided with an end portion 41*b* of reduced cross section which projects through a drill hole in the other carrier rail 34 and is transversely drilled as indicated at 41*c* to receive a cotter pin 43 which serves to retain the pin 41 in position between the rails 33 and 34. The pin 41 is also provided with a transversely extending drill hole 41*d* adjacent the pin end portion 41*b* and located adjacent the inner side of the carrier rail 34. This drill hole is provided to receive a detonating cord 44, which may be Primacord, or the like, and is separated from the closed end of the internal chamber 41*a* by a thin, rupturable partitioning wall 41*e*. In accordance with a very important feature of the invention, the internal chamber 41*a* within the pivot pin 41 is filled with a booster charge 41*f* of explosive material having the function, upon detonation thereof, of detonating the explosive material in the associated jet forming cartridge 40. The manner in which this is accomplished is explained more fully below.

As indicated above, the jet forming cartridges 40 are supported for free pivotal movement about their respective supporting pivot pins 41. This is in contrast with conventional practice which requires that the detonating cord for a series of spaced jet forming cartridges be threaded through the bases of the cartridges or affixed to the booster ends of the cartridges proper in order to effect detonation of the cartridges. Each of the cartridges 40 comprises a casing 45, formed of Bakelite or the like, and having an integrally formed neck portion 45*a* which is provided with a transverse opening therethrough for receiving the pivot pin 41. The opening 45*b* is located slightly away from the base of the casing 45 proper to provide clearance spaces on either side of the casing neck portion 45*a* between the pin 41 and the base of the casing 45. These spaces may be utilized to receive biasing springs in the manner more fully explained below with particular reference to FIG. 4 of the drawings. In accordance with conventional practice, the internal chamber of the casing 45 is filled with an explosive material 47, a portion 47*a* of which is disposed in a small cylindrical opening in the base of the casing 45. This portion of the charge is located closely adjacent the thin frangible walls of the pin 41 defining the chamber 41*a* to act as a booster charge in effecting detonation of the explosive material 47. Also in accordance with conventional practice, the explosive charge 47 is provided with a conical cavity 48 lined with a cone shaped liner 49 formed of copper or another suitable liner material. The open end of the casing 45 is closed and sealed against fluid entry by means of a closure cap 50 and a sealing gasket 51. It will be noted that the closure cap 50 is suitably formed to provide an effective stand-off distance immediately adjacent the mouth of the jet forming cavity 48 in which the explosive jet may form.

For the purpose of moving the pivotally supported jet forming cartridges 40 between their normal retracted positions between the carrier rails 33 and 34, illustrated in FIG. 3 of the drawings, and their extended perforating positions, illustrated in FIG. 2A of the drawings, an actuating mechanism is provided which comprises a pair of elongated links 52 and 53 located within the carrier rail 34 and extending longitudinally thereof, a pair of pivoted link actuating and restraining levers 54 and 55 which are pivotally supported between the carrier rails 33 and 34 and are pivotally connected, respectively, to the links 52 and 53, and spring means comprising a pair of coil springs 56 and 57 which are connected in tension between the lower end of the detonating sub-assembly block 31 and the levers 54 and 55, respectively. More specifically, the link 52 is pivotally connected, by means of suitable pivot assemblies 58, to alternate ones of the jet forming cartridges 40 at points therealong spaced from the points of pivotal support of these cartridges. Similarly, the link 53 is pivotally connected by means of pivot assemblies 58 to the intervening jet forming cartridges at points along these cartridges which are spaced from the points of pivotal support thereof. As best shown in FIG. 3 of the drawings, the link 52 is disposed to one side of the pivot pins 41 and is adapted to engage these pins to limit the inward pivotal movement of the jet forming cartridges to which this link is connected and thus define the retracted positions of the connected cartridges between the carrier rails 33 and 34. The link 53 is disposed upon the other side of the pivot pins 41 and is similarly adapted to engage these pins to limit inward pivotal movement of the jet forming cartridges to which this link is connected and thus define the retracted positions to which the connected cartridges may be moved between the carrier rails 33 and 34. The slide actuating levers 54 and 55 are commonly supported by a pivot pin 59 which extends between and is anchored to the carrier rails 33 and 34. At points displaced from the pivoted ends thereof, these levers are pivotally connected to the upper ends of the slides 52 and 53, respectively. More specifically, a pivot pin 60 extending through the legs of a U-shaped bracket 61 which is pin connected to the lever 54, is utilized pivotally to connect the lever 54 with the upper end of the link 52. An identical arrangement including a pivot pin 62 is employed pivotally to connect the upper end of the link 53 with the lever 55 at a point along the lever spaced from the pivot pin 59. As best shown in FIG. 2A, the upper ends of the springs 56 and

57 are machine screw connected to the lower end of the detonating sub-assembly block 31 and the lower ends of the springs are respectively connected to the pivot pins 60 and 62. A neck and slot arrangement is employed in pivotally connecting the levers 54 and 55 to the pivot pin 59. More specifically, the lever 55 is provided with a neck portion 55*a* which is wrapped around the pivot pin 59 and is disposed within a slot 54*b* formed in the lever 54. This slot defines legs 54*c*, disposed on either side of the lever neck 55*a*, which are wrapped around the pivot pin 59 in order pivotally to connect the lever 54 with this pin. With this arrangement, engagement of the lever neck portion 55*a* with the base of the U-shaped slot 54*b* in the lever 54 is utilized to limit pivotal movement of the levers toward each other in the manner more fully explained below and thus define the extended perforating positions of the jet forming cartridges 40.

As indicated in the preceding description, means including the booster charges 41*f* disposed in the chambers 41*a* of the hollow pivot pins 41 and a detonating cord 44 are utilized to detonate the explosive material 47 in the cartridges 40. More specifically, the detonating cord 44 is threaded through the transverse openings 41*d* in the pivot pins 41 and extends into a drill hole 63 in the body of the detonating sub-assembly 31. If the perforating gun 20 is to be used to perform a perforating operation in a well where very high bottom hole hydrostatic pressures are anticipated, the cord may be enclosed in a thin walled tubing 44*a*, in the manner illustrated in FIG. 5 of the drawings, capable of withstanding the high hydrostatic pressures which may be encountered. At its upper end, the detonating cord 44 is in contact with an electrical detonator or detonating cap 64 which is introduced into a cap receiving chamber 65, formed in the body of the detonating sub-assembly 31, from the upper end of this assembly.

As best shown in FIG. 7 of the drawings, the detonating cap 64 is provided with an electrical ignition element 64*a* which is serially included in an energizing circuit comprising a source of direct current potential 66 located at the earth's surface. More specifically, the single conductor 26*a* of the cable 26 is connected to one terminal wire 64*b* of the detonating cap 64 and the other terminal wire 64*c* of the detonating cap is connected to the grounded sheath conductor of the cable. Suitable facilities, described below, in reference to FIGS. 8, 9, 10 and 11 of the drawings, are provided for connecting the detonating cap terminal wire 64*b* with the cable conductor 26*a* through the sub-assemblies 28, 29, 30 and 31 of the gun 20. At the earth's surface, the cable conductor 26*a* is adapted to be connected to one terminal of the current source 66 through a firing switch 67, the opposite terminal of the source 66 being connected to the grounded sheath conductor of the cable 26 to provide a closed circuit for energizing the ignition element 64*a* of the detonating cap 64 upon closure of the switch 67.

In general, the operation of the above described embodiment of the present improved perforating gun will be apparent from the preceding description. Briefly summarized, however, it will be understood that as the gun 20 is lowered through the tube 24 into the bore hole 21. the levers 54 and 55 are held in the retracted positions thereof illustrated in FIG. 3 of the drawings, against the bias exerted thereon by the springs 56 and 57, through engagement thereof with the inner wall of the tubing 24. With the levers 54 and 55 occupying their retracted positions, the links 52 and 53 are pushed downwardly and bear against the pivot pins 41 to hold the jet forming cartridges 40 in their retracted positions illustrated in FIG. 3 of the drawings. With the movable components of the gun in the described positions, the outside dimensions of the carrier 32 and all parts supported thereby are no greater than the diameter of the sub-assemblies 28, 29, 30 and 31 which is approximately one and three quarters inches. During movement of the gun 20 through the tubing 24, the positioning springs 36 and 37 are held retracted in their dashed line positions as illustrated in FIG. 2B of the drawings through engagement thereof with the inner wall of the tubing 24. In this regard, it is noted that the overall weight of the gun is entirely adequate to overcome frictional engagement of the components 36, 37, 54 and 55 with the inner wall of the tubing and thus insure free sliding movement of the gun through the tubing 24.

It will be noted that all of the jet forming cartridges 40 are held in their retracted positions until the upper cartridge 40 and the link actuating levers 54 and 55 have emerged from the lower end of the tubing 24. Upon emerging from the lower end of the tubing, the levers 54 and 55, which in their extended positions have a total length substantially less than the inside diameter of the casing 23, are rapidly pivoted in counter-clockwise and clockwise directions respectively to the open positions thereof illustrated in FIG. 2A of the drawings under the influence of the springs 56 and 57. The opening movements of the levers 54 and 55 are checked and stopped through engagement of the lever neck 55*a* with the base of the U-shaped slot 54*b* in the lever 54 and when the slides 52 and 53 come to rest on the pivot pins 41. As the lever 54 is pivoted counter-clockwise from the position shown in FIG. 3 to the position shown in FIG. 2A, the link 52 is moved upward and outward from the pivot pins 41 to pivot the connected alternate jet forming cartridges 40 to the positions shown in FIG. 2A, i.e., to positions substantially at right angles to the carrier 32 and directly facing the casing 23. Similarly as the lever 55 is pivoted in a clockwise direction about the pivot pin 59 under the influence of the spring 57 from the position shown in FIG. 3 to the position shown in FIG. 2A, the link 53 is moved upward and outward from the pivot pins 41 to pivot the intervening jet forming cartridges 40 to their extended jet perforating positions, i.e., to positions extending substantially at right angles to the carrier 32 and directly facing the casing 23. It will be noted that the cartridge actuating mechanism, in performing the described functions, moves the jet forming cartridges so that alternate ones thereof face in opposte directions.

When the cartridges 40 are thus moved to their extended perforating positions, they are ready to be fired. In this regard, it will be understood that as the positioning springs 36 and 37 emerge from the lower end of the tube 24, they expand to the full line positions illustrated in FIG. 2B and serve centrally to position the gun carrier 32 in the casing 23, so that movement of the jet forming cartridges 40 from their retracted positions to their extended perforating positions cannot be interfered with through engagement of any of these cartridges with the wall of the casing 23 during opening movement of the cartridges, and so that these cartridges will be approximatly concentrically disposed within the casing 23 at the time they are fired.

In order to fire or detonate the cartridges 40 after they have been lowered to the desired positions in the bore hole 21, it is only necessary to close the switch 67 and thus establish a circuit including the current source 66 and the cable conductor 26*a* for energizing the ignition element 64*a* of the detonating cap 64. Firing of this cap serves to detonate the detonating cord 44 throughout the length thereof. As this cord detonates, the thin wall partitions 41*e* in the pivot pins 41 are ruptured to detonate the booster charges 41*f* in the pins. Detonation of the booster charges 41*f* serves to rupture the thin walls of the pins 41 and the adjacent thin wall base sections of the cartridge casings 45, thereby to detonate the booster charges 47*a* of the cartridges 40. As a result, the main bodies 47 of explosive material in these cartridges are detonated to produce explosive jets which serve to perforate the casing 23 and the material surrounding the casing, all in a manner well understood in the art.

In the event it is desired to withdraw the gun 20 back into the tubing 24 without firing or detonating the jet

forming cartridges 40, all that need be done is to pull the cable 26 out of the bore hole 21. In response to this operation and as the gun is moved back into the tubing 24, the levers 54 and 55 reengage the lower end of the tubing 24 and thus actuate the links 52 and 53 back to the retracted positions thereof illustrated in FIG. 3 of the drawings. Movement of the levers 54 and 55 and the links 52 and 53 back to their retracted positions, is, of course, effected against the biasing action of the springs 56 and 57. As the links 52 and 53 are moved back to their retracted positions, the jet forming cartridges are similarly moved back to their retracted positions between the carriage rails 33 and 34 in a manner which will be readily apparent from the preceding explanation. It will thus be understood that the gun 20 may be raised and lowered into that portion of the casing disposed below the lower end of the tubing 24 at the will of the operator, and that as the gun is so moved, the jet forming cartridges are pivoted back and forth between their retracted and perforating positions. When the cartridges are fired, they are, of course, disintegrated along with the pivot pins 41 and the carrier 32, and fall to the bottom of the bore hole. The remaining parts of the gun, including the subassembly 31, are non-expendable and may be withdrawn from the bore hole for reloading.

As indicated above, coil springs individual to the jet forming cartridges 40 may, if desired, be used to supplement or replace the coil springs 56 and 57. To this end and as best shown in FIG. 4 of the drawings, coil springs 68 individual to the cartridges 40 are utilized to rotate the cartridges 40 and the particular link 52 or 53 to which the cartridges are connected in response to release of the levers 54 and 55 upon emergence of the carrier 32 from the bottom end of the tubing 24. As shown in FIG. 4, the coil spring 68 is telescoped over the pivot pin 41 to be disposed between the rails 33 and 34 within the clearance space 46 between the base of the cartridge 40 and the pin 41. One end of the coil spring 68 is wrapped around the neck portion 45*a* of the cartridge casing 45 and the other end of the spring is fixedly attached to the adjacent carrier rail 33. The spring 68 is under tension in the extended perforating position of the cartridge 40 and arrangement is such that as the cartridge 40 is moved from this position to its retracted position, the tension in the coil spring is increased. Accordingly, when the levers 54 and 55 are released in the manner described above, the springs 68 function to pivot, or assist in pivoting, the cartridges 40 to their extended perforating positions.

In the cartridge and pin structure arrangement illustrated in FIG. 5, rupturing of the thin wall of the pin 41 and the adjacent thin base wall section of the cartridge casing 45 is relied upon to detonate the explosive charge 47 of the cartridge. If desired, the explosive charge 47 may be more directly detonated by employing the modified structure illustrated in FIG. 6 of the drawings. As there shown, a carrier rail 334 is employed to support pivot plugs 69 which are pin or screw connected to the rail 334. Each pivot plug is provided with a transversely extending opening 69*a* for receiving the detonating cord 44 and with a recess 69*b* which acts as a pivot seat for a jet forming cartridge 340. The casing 345 of each jet forming cartridge is provided with a pivot protrusion 70 having an end 70*a* seating in the recess 69*b* of the pivot plug 69. This pivot protrusion defines a chamber 70*b* which communicates directly with the booster charge chamber in the casing 345 and is separated from the detonating cord 44 only by a thin frangible end wall 70*c*. At the end of the protrusion 70 opposite the end wall 70*c*, the cartridge 340 is pivotally supported upon the carrier rail 333 by means of a pivot plug 71 which extends into a pivot opening in the rail 333 and is provided with a plug portion 71*a* extending into the open end of the chamber 70*b* to close the chamber. A sealing ring 72, disposed in an annular recess in the plug portion 71*a* of the plug 71, is utilized to seal the chamber 70*b* after the cartridge 340 is loaded with explosive material.

It will be understood that when the arrangement shown in FIG. 6 is employed to support the cartridges 340 on a carrier corresponding to the carrier 32, the advantage of free rotation of the cartridge relative to the carrier rails 333 and 334 and more particularly the detonating cord 44 is retained. Moreover, in order to detonate the explosive body 347 in the cartridge 340, it is only necessary to rupture the thin end wall 70*c* of the cartridge casing and detonate the explosive material in the chamber 70*b* to obtain full and complete detonation of the charge 347. Such rupturing of the wall 70*c* and detonation of the explosive material in the chamber 70*b* is easily and readily accomplished through detonation of the detonating cord 44.

Referring now more particularly to FIG. 8 of the drawings, the internal constructions of the sub-assemblies 28, 29, and 30 are there shown. As illustrated, the lower end of the cable 26 and more particularly the outer steel sheath or covering thereof is anchored in a body 75 of poured babbitt disposed within the fishing head 28, and the insulated conductor 26*a* is terminated in an insulated sealed contact 76 located in the base of the fishing head 28. An insulated pass-through contact 77 located within the double pin connecting sub-assembly 29 extends the electrical connection from the conductor 26*a* into the housing sub-assembly 30. In the above described gun arrangement illustrated in FIGS. 2A, 2B and 3 of the drawings, the opposite contact pin 78 of the sub-assembly 29 may be connected directly through the sub-assembly 30 to the terminal wire 64*b* of the detonating cap 64. However, when the components 28, 29 and 30 are used in combination with a detonating sub-assembly 31*a* of the form illustrated in FIGS. 8 and 9 of the drawings, the contact 78 of the connecting sub-assembly 29 is connected to one terminal of a condenser 79 disposed in the sub-assembly 30. This latter sub-assembly is screw connected to the detonating sub-assembly 31*a*, and the electrical connections which extend from the terminals of the condenser 79 to the detonators located in the detonating sub-assembly 31*a* are described more fully below.

It will be understood from the foregoing explanation that when the gun arrangement illustrated in FIGS. 2A, 2B and 3 is employed, pivotal movement of the cartridges 40 between their retracted positions and their extended perforating positions is effected solely in response to movement of the carrier 32 from the end of the tubing 24 and back into the lower end of this tubing. In the modified arrangement illustrated in FIGS. 8, 9 and 10 of the drawings, facilities are provided for locking the cartridges in their fully retracted positions after the carrier 32 emerges from the lower end of the tubing 24, and release means are provided which may be controlled at will from the earth's surface for releasing the locking means to permit movement of the cartridges from their retracted positions to their extended perforating positions. These facilities comprise a piston actuated latching plate 80 which is normally disposed between laterally offset latching fingers 81 and 82 mounted upon the levers 354 and 355, respectively, and a gas pressure operated piston 83 which is mounted for recipocation in a cylinder 84 extending upwardly from the lower end of the detonating sub-assembly 31*a*. The piston 83 is formed integral with a piston rod 85 which extends downward from the lower end of the sub-assembly 31*a* through a stuffing box 86 and supports the locking plate 80 at the extended lower end thereof. More specifically, the latching fingers 81 are formed integral with the bracket 61*a* which is mounted upon the lever 354 and supports the pivot pin 360. Similarly, the latching fingers 82 are formed integral with the bracket which is mounted upon the lever 355 and sup-

ports the pivot pin 362. The spacing between the fingers 81 and 82 is such that when the locking plate 80 is inserted therebetween in the manner illustrated in FIG. 9 of the drawings, the levers 354 and 355 are held in their fully retracted positions. In this regard, it is noted that when the gun arrangement illustrated in FIGS. 8 and 9 is used, the coil springs 56 and 57 are preferably dispensed with and coil springs corresponding to coil springs 68, individually associated with the cartridges 40, are utilized to bias the cartridges for pivotal movement from their fully retracted positions to their extended perforating positions. Thus, with the locking plate disposed between the latching fingers 81 and 82, the bias exerted by the springs 68 individual to the cartridges 40 is restrained against rotating the cartridges to their extended perforating positions by means of the links 352 and 353, the levers 354 and 355 and the locking plate 80 disposed between and engaged by the fingers 81 and 82.

For the purpose of moving the piston 83 upward in the cylinder 84 to withdraw the piston rod 85 into the sub-assembly 31*a* and thus withdraw the locking plate 80 from between the latching fingers 81 and 82, an ignitor or detonating element 87 provided with a small body of slow burning explosive material 88 is utilized to supply high pressure gases to the under side of the piston 83. More specifically, the ignitor element is threaded into a cylindrical chamber 89 from the upper end of the sub-assembly 31*a* and this chamber is in gas communication with the cylinder 84 at the under side of the piston 83 through a transverse passage 90 formed between the chamber 89 and the cylinder 84.

In order to retain the piston 83, piston rod 85 and locking plate 80 in their respective raised positions following detonation of the ignitor element 87, a spring loaded locking pin 91 is provided which is carried by a plug 92 threaded into a recess in the wall of the sub-assembly body 31*a*. This locking pin is adapted to be moved into an annular locking recess 93 formed around the piston 83 when the piston is raised to bring the pin 91 and recess 93 into registry. Release of the high pressure gases development in the chamber 89 and the under side of the piston 83 in the cylinder 84 following detonation of the ignitor element 87 and after the piston 83 has been raised to effect seating of the locking pin 91 in the annular recess 93, is effected through an opening formed through the wall of the sub-assembly body 31*a* in axial alignment with the passage 90. This gas release passage is normally closed by a frangible disk 94 which is sealed against the bottom of a larger recess in the sub-assembly 31*a* by means of a centrally apertured sealing plug 95. Suitable gaskets and sealing rings are employed where required and in the manner illustrated to seal both ends of the cylinder 84 and the explosion chamber 89 against fluid entry into these spaces.

The electrical control system for the perforating gun structure illustrated in FIGS. 8, 9 and 10 of the drawings is illustrated in FIG. 11 of the drawings. As there shown, the switch 67*a* located in the control equipment provided at the earth's surface is of the single pole-double throw type, such that when the movable contact element thereof is shifted to its lower position from its normal intermediate position, a voltage from the direct current source 366 is impressed between the insulated conductor 326*a* and the grounded outer sheath of the cable 326, and when this movable contact element is shifted to its upper position, the voltage of an alternating current source 96 is impressed between the conductor 326*a* and the outer grounded sheath of the cable 326. In the gun 20, the conductor 326*a* is connected through the sub-assemblies 28, 29, and 30 to one terminal of the condenser 79. This conductor is also connected by means of a branch conductor 97 and a spring loaded contact element 98 in the sub-assembly 30 to a contact element 99 in the detonating sub-assembly 31*a*. The latter contact element is connected by means of a conductor 100 to one terminal of an ignition element 87*a* embodied in the ignitor 87, the opposite side of this ignition element being connected to the grounded sheath of the cable 326*a* through the metallic case of the ignition element 87 and the metallic sub-assemblies 31, 30, 29 and 28. The opposite terminal of the condenser 79 is connected by way of a conductor 101, a spring loaded contact element 102 mounted in the sub-assembly 30, and a contact element 103 engaged by the spring loaded contact 102 to the terminal wire 64*c* of the detonating cap 364 provided in the detonating sub-assembly 31*a* to detonate the detonating cord 344.

With the above described control system arrangement, direct current transmitted to the ignition element 87*a* from the source 66 is utilized to fire the ignitor 87 and alternating current transmitted to the ignition element 54*a* from the alternating current source 96 is utilized to fire the detonating element 364. More specifically, when the movable contact element 67*a* is moved to connect the conductor 326*a* of the cable 326 with the ungrounded terminal of the direct current source 366, a circuit including a conductor 326*a* and the grounded sheath of the cable 326 is completed for energizing the ignition element 87*a* of the ignitor 87. The blocking condenser 79 prevents direct current from the source 366 from energizing the ignition element of the detonator 364. When energized in this circuit, the ignitor is fired to build up explosive gas pressures in the chamber 89 which are communicated through the passage 90 to the under side of the piston 83, with the result that this piston is moved from the lower position illustrated in FIG. 9 of the drawings to the raised position shown in FIG. 10 of the drawings wherein the spring loaded locking pin 91 is brought into registry with the annular recess 93 and falls into this recess to lock the piston 83 in its elevated position. After the piston 83 is thus locked in its elevated position and upward movement of the piston is stopped, the increase in gas pressure within the chamber 89, the passage 90 and the lower side of the cylinder 84 causes the frangible disk 94 to rupture, with the result that the explosion gas pressures are released to the medium surrounding the gun 20.

As the piston 83 is thus raised to its upper or elevated position in the manner just described, the piston rod 85 is withdrawn into the sub-assembly 31*a* to withdraw the locking plate 80 from between the latching fingers 81 and 82. As a consequence, the levers 354 and 355 are released so that these levers, together with the slides 352 and 353 and the jet forming cartridges corresponding to the cartridges 40, are all moved to their open positions, i.e., the position shown in FIGS. 2A and 10 of the drawings, under the influence of the coil springs corresponding to the springs 68 individually associated with the cartridges 40.

After these cartridges are thus pivoted to their extended perforating positions, the movable contact element of the switch 67*a* may be shifted to its upper position wherein the ungrounded terminal of the alternating current source 96 is connected to the conductor 326*a* of the cable 326. As a consequence, a circuit including the conductor 326*a*, the condenser 79 and the conductor 101 is completed for energizing the ignition element of the detonating cap 364 from the alternating current source 96. When the ignition element 364*a* of the detonating cap 364 is thus energized, this cap, the detonating cord 344 and the booster charges in the pivot pins corresponding to the pins 41 are all detonated to effect detonation of the cartridges 40, all in the manner previously explained with reference to FIGS. 2A, 2B, and 3 of the drawings.

From the above explanation, it will be understood that once the locking plate 80 is withdrawn from between the latching fingers 81 and 82, no further control over the positions occupied by the jet forming cartridges 40 may be exercised by the operator located at the earth's surface. However, should it be desired to withdraw the gun 20 through the tubing 24 from the perforating position to which it had previously been lowered in the casing 23, the

levers 354 and 355, upon engaging the lower end of the tubing 24 and acting through the links 352 and 353, function to retract the cartridges 40 from their extended perforating positions to their retracted positions before the uppermost cartridge reaches the lower end of the tubing 24, all in a manner which will be clearly apparent from the foregoing explanation with reference to the gun arrangement illustrated in FIGS. 2A, 2B and 3 of the drawings. To summarize, it will be apparent that in the modified arrangement illustrated in FIGS. 8, 9, 10 and 11 of the drawings, the initial release of the jet forming cartridges for movement from their retracted positions to their extended perforating positions may be controlled at will from the earth's surface through operator manipulation of the switch 67*a*. However, once these cartridges are moved to their extended perforating positions, they can only be pivoted back to their retracted positions in response to withdrawal of the gun 20 into the tubing 24.

In the modified embodiment of the invention illustrated in FIGS. 12 and 13 of the drawings, double ended jet forming cartridges 140 are used in lieu of the single ended cartridges 40 thus far described. Specifically and as best shown in FIG. 13 of the drawings, the double ended cartridges 140 are substantially end-to-end duplicates of the cartridges 40, except that two oppositely extending cartridges are housed in a single casing 145. This casing is provided with a transversely extending centrally located opening 145*b* for receiving the hollow pivot pin 41. Aside from the difference in construction of the casing 145 to provide for the housing of two jet forming charges in this casing rather than one, the structural arrangement of the cartridge 140 is identical with that of the cartridge 40, as will be apparent from a comparison of the reference characters used to identify corresponding parts of the two cartridge structures. Since double ended cartridges 140 are employed in the FIG. 12 embodiment of the invention, only a single link 452, a single lever 454 and a single biasing spring 56*a* are required in order to move the cartridges 140 from their retracted positions to their extended perforating positions in response to emergence of the carrier 32 from the lower end of the tubing 24 and to return the cartridges 140 to their retracted positions in response to withdrawal of the gun 20 into the tubing 24 to bring the lever 454 into engagement with the inner wall of the tubing. Corresponding reference characters have been employed to identify corresponding components of the arrangements respectively illustrated in FIGS. 2A and 12 of the drawings, and accordingly, it is believed that operation of the FIG. 12 embodiment of the invention will be entirely clear from the preceding explanation given with reference to the arrangement shown in FIGS. 2A and 3 of the drawings.

The modified construction illustrated in FIG. 14 of the drawings is similar to that just described with reference to FIGS. 12 and 13 of the drawings, except that the FIG. 14 construction embodies facilities for positively locking the cartridges 440 in their retracted positions, and additional facilities, controllable from the earth's surface, for releasing the locking means to permit rotation of the cartridges from their retracted positions to their extended perforating positions. These facilities comprise a locking link 110 which is pivotally connected to each of the cartridges 440 by means of pivot assemblies 111 and extends along the lower sides of the pivot pin 441 within the carrier rails 433 and 434. At its upper end, the link 110 is provided with a locking finger 110*a* which is held in engagement with the lower end of the detonating sub-assembly 431*b* by means of an L-shaped latch 112. The long leg of this latch is normally retained in the bottom of a channel 113 milled in the detonating sub-assembly 431*b* by means of a blow-out plug 114 which is driven into a transverse opening 115 extending inwardly from the base of the channel 113 to communicate with a small explosion chamber 116. An ignitor 487, embodying a charge of slow burning explosive material 488, is threaded into the explosion chamber 116 from the upper end of the sub-assembly 431*b*.

With the link 110 locked in the position illustrated in full lines in FIG. 14 of the drawings by means of the latch 112 and the blow-out plug 114, the cartridges 440, the link 552 and the lever 554 are all restrained in the full line retracted positions thereof against the action of the spring 556. However, when an electrical control system of the exact form illustrated in FIG. 11 of the drawings is utilized to detonate the explosive material 488 in the ignitor 487, the blow-out plug 114 is expelled from the opening 115 and carries the latch 112 with it to release the link 110. As a consequence, the spring 556 acting through the link 552 operates to pivot the lever 554 and the cartridges 440 to extended positions thereof illustrated in dashed lines in FIG. 14 of the drawings. After the cartridges 440 are thus moved to their perforating positions, they may be detonated in the exact manner explained above with reference to the embodiment of the invention illustrated in FIGS. 9, 10 and 11 of the drawings. Alternatively, if it is desired to withdraw the gun from the bore hole 21 without detonating the cartridges 440, the lever 554 upon engaging the lower end of the tubing 24, is moved to its retracted position to move the links 552 and 110 and the cartridges 540 to their retracted positions against the influence of the spring 556, so that the carrier 32 may be drawn into the tubing 24.

In the modified embodiment of the invention illustrated in FIG. 15 of the drawings, facilities are provided for permitting the double ended cartridges 640 to be retracted from their extended perforating positions to their retracted positions under the control of an operator at the earth's surface without drawing the gun 20 back into the tubing 24. These facilities comprise an explosion gas pressure operated piston 183 having an integrally formed piston rod 185 for driving the link 652, the lever 654 and the cartridges 640 to their fully retracted positions. More specifically, the lower end of the piston rod 185, which projects from the lower end of the detonating sub-assembly 631*c* through a stuffing box 186, is engageable with a headed extension 152 of the link 652, so that when the piston 183 is driven from its illustrated raised position to its lower position, the link 652 is moved downwardly to pivot the lever 654 and the cartridges 640 from their extended positions to their retracted positions. In general, the piston actuating and locking assembly embodied in the FIG. 15 arrangement is similar to that embodied in the FIG. 9 arrangement and described above. Thus, the piston 183 is supported for up and down reciprocating movement in a cylinder 184 and is provided at its upper end with an annular locking recess 193 which is adapted to receive a spring loaded locking pin 191 when the piston 183 is moved downward to bring the channel 193 and pin 191 into registry. The spring loaded locking pin 191 is carried by a plug 192 threaded into the wall of the sub-assembly 631*c*. Gas pressure release facilities are provided which comprise a transverse opening extending through the wall of the sub-assembly 631*c* and communicating with an explosion chamber 189 located above the piston 183. This passage is normally closed by a frangible disk 194 which is held in position over the gas release passage by means of a centrally apertured plug 195 threaded into a larger recess formed in the wall of the sub-assembly 631*c*.

The electrical control system for the gun arrangement illustrated in FIG. 15 may be as shown in FIG. 11 of the drawings, except that the ignition elements 64*a* and 87*a* are interchanged, so that the element 64*a* is energized by direct current applied to the conductor 326*a* and the element 87*a* is energized by alternating current applied to the conductor 326*a*. In operation, the cartridges 640, the link 652 and the lever 654 of the FIG. 15 gun arrangement are moved to their extended positions in response to emergence of the carrier 32 from the lower end of

the tubing **24**. Moreover, the lever **654**, operating in conjunction with the lower end of the tubing **24**, may be utilized to pivot the cartridges **640** back into their retracted positions in response to withdrawal of the carrier **32** back into the tubing **24**. Further, the cartridges **640** may be fired while in their extended perforating positions through application of direct current to the cable conductor **326***a*. The manner in which these operations are effected will be clearly apparent from the foregoing explanation. Should the operator at the earth's surface desire to lock the cartridges **640** in their fully retracted positions without withdrawing the gun **20** back into the tubing **24**, the control switch **67***a* is thrown to a position for connecting the ungrounded terminal of the alternating current source **96** to the cable conductor **326***a*, with the result that the ignition element **87***a* of the ignitor **487** is energized in a circuit including the condenser **79** and the conductor **326***a*. The resulting detonation of the explosive body **488** causes the piston **183** to be driven downward until the locking pin **191** drops into place in in the locking recess **193**, following which the frangible disk **194** is ruptured to release the explosion gases. Incident to downward movement of the piston **183**, the lower end of the piston rod **185** is engaged with the link head **152** and drives the link **452** downwardly to move this link, the cartridges **640** and the lever **654** back to their fully retracted positions. Since the piston **183** is now locked against further reciprocation in the cylinder **184**, further movement of the cartridges **640** to their extended perforating positions cannot be effected without withdrawing the gun **20** from the bore hole **21**.

The modified embodiment of the invention illustrated in FIG. 16 of the drawings is identical with that described above with reference to FIGS. 8, 9 and 10 of the drawings, except that means comprising a piston operated switch **120** are provided in the FIG. 16 arrangement for the purpose of positively preventing detonation of the cartridges until they have been pivoted to their fully extended perforating positions. Because of the similarity between the structure shown in FIG. 16 and that shown in FIG. 9, the disclosure of FIG. 16 has been abbreviated and similar reference characters have been employed to identify the same parts of the two arrangements. As shown in FIG. 16, the switch **120** is threaded into an extension of the piston cylinder **84***a* from the top end of the sub-assembly **731***a*. This switch is of the spring biased type such that the movable contact element **120***a* thereof is normally open and is only operated to its closed circuit setting when depressed. The operating protrusion of the movable contact **120***a* is disposed in axial alignment with the upper end of the piston **783** so that when this piston is moved to its elevated position to withdraw the locking plate **780** from between the fingers **781** and **782** and effect engagement of the locking pin **791** with the locking recess **793**, the switch **120** occupies its closed circuited position.

In FIG. 16 of the drawings, there is also shown an arrangement for sealing the entrance passage through which the detonating cord is threaded into the sub-assembly **731***a* for engagement by the detonating cap **764**, thereby to prevent the entry of bore hole fluids into the sub-assembly **731***a* through the detonating cord passage. Briefly, this arrangement comprises a compressible sealing material or gasket **121** which surrounds the detonating cord in an enlarged portion of the passage through which this cord extends into the sub-assembly **731***a*, and a centrally aperture sealing plug **122** which is threaded into an enlarged extension of the passage receiving the detonating cord **744**. The plug **122** is provided with a thin-walled conical extension **122***a* which is adapted to project between the detonating cord **744** and the protective sheath surrounding the same, thereby further to minimize the possibility of bore hole fluid seepage into the sub-assembly **731***a* through the detonating cord itself. The protective sheath surrounding the detonating cord **744**, may be a thin-walled metal tubing or may be formed of plastic or other suitable protective material such as neoprene. In assembling the cord **744** and the components **121** and **122** with the sub-assembly **731***a*, it will be understood that the elements **121** and **122** are first telescoped onto the end of the cord **744**, following which the cord is inserted into its entrance passage into the sub-assembly **731***a* and the sealing element **121** is pushed into the bottom of the enlarged portion of this passage. The sealing plug **122** is then threaded into the sub-assembly **731***a* to compress the sealing element **121** about the cord **744** and thus seal off the entrance passage through which the cord extends.

Aside from the added structural features just described, the detonating sub-assembly **731***a* illustrated in FIG. 16 of the drawings is identical with the similarly numbered sub-assembly illustrated in FIG. 9 of the drawings. The electrical control system for the FIG. 16 gun structure is illustrated in FIG. 17 of the drawings. From a comparison of this system with that shown in FIG. 11 of the drawings, it will be noted that the difference resides solely in the inclusion of the switch **120** in the circuit for energizing the ignition element **764***a* of the detonating cap **764**. With this circuit arrangement, energization of the element **764***a* to detonate the cap **764** cannot be effected until the switch **120** is closed, regardless of the setting of the switch **767***a* located at the earth's surface. As a consequence, it is impossible to detonate the cartridges corresponding to the cartridges **40** until these cartridges have been pivoted to their extended perforating positions. More specifically, when the switch **767***a* is operated to energize the ignition element of the ignitor **787** from the direct current source **766**, this ignitor is detonated to effect operation of the piston **783** to its raised position and thus effect release of the cartridges for movement from their retracted positions to their extended perforating positions, all in a manner which will be fully apparent from the above explanation. Incident to movement of the piston **783** to its raised position, the switch **120** is closed to prepare the operating circuit for the ignition element **764***a* of the detonator **764**. After the switch **120** has been closed, the switch **767***a* may be operated to connect the ungrounded terminal of the alternating current source **796** with the cable conductor **726***a* and thus energize the ignition element **764***a* of the detonator **764** in a circuit which includes the condenser **779** and the closed contacts of the switch **120**. Detonation of the detonator **764** resulting from energization of the ignition element **764***a* effects detonation of the cartridges corresponding to the cartridges **40** in the manner previously explained. It will thus be apparent that provision of the switch **120**, which operates solely in response to operation of the cartridge release piston rod **785**, results in an arrangement in which premature detonation of the cartridges **40** before they are operated to their fully extended perforating positions is positively prevented.

If desired, the perforating gun circuit arrangement illustrated in FIG. 18 of the drawings may be used in lieu of that shown in FIG. 11 of the drawings in the control of the gun embodiments illustrated in FIGS. 8 through 14 of the drawings. In the FIG. 18 circuit arrangement, a transformer **123** is used in lieu of the condenser **79** to separate the direct current circuit over which the ignition element **87***a* of the ignitor **87** is energized, from the alternating current circuit in which the ignition element **64***a* of the detonating cap **364** is excited. In addition, improved facilities of the character disclosed in applicant's copending application Serial No. 310,683, filed September 20, 1952, now U. S. Patent Number 2,703,053, granted March 3, 1955, are provided for positively preventing inadvertent detonation of the cap **864** which controls firing of the jet forming cartridges. These facilities comprise a resistor **126** connected in series with the ignition element **864***a* of the detonating element **864** across the secondary winding **123***b* of the transformer **123**, and a low resistance fuse link **124**

shunting the series connected resistor 126 and ignition element 864a. The circuit also includes a resistor 125 connected in shunt with the ignition element 887a of the ignitor 887 to provide a return path for alternating current after the ignition element 887a has been ruptured upon detonation of the ignitor 887.

When the FIG. 18 circuit arrangement is employed in the referred to embodiments of the gun 20, closure of the switch corresponding to switch 67a to connect the direct current source corresponding to source 66 to the cable conductor 826a results in energization of the ignition element 887a embodied in the ignitor 887 over a circuit which includes the conductor 826a and the primary winding 123a of the transformer 123. In this regard, it is noted that the resistance of the resistor 125 is many times greater than the resistance of the ignition element 887a, so that paralleling of the latter element by the resistor 125 does not interfere with energization of the ignition eelment. The transformer coupling between the primary winding 123a and the secondary winding 123b of the transformer 123 obviously prevents the ignition element 864a of the detonating cap 864 from being energized when direct current is applied to the cable conductor 826a. Following detonation of the cap 887, the ignition element 887a is destroyed, so that any further current transmitted over the cable conductor 826a must, of course, return to the grounded sheath of the cable through the resistor 125. To effect energization of the detonating cap ignition element 864a, the switch corresponding to switch 67a is thrown to a position for connecting the alternating current source corresponding to source 96 to the cable conductor 826a, and alternating current is thus caused to traverse this conductor, the primary winding 123a of the transformer 123 and the resistor 125. The resulting voltage developed across the transformer secondary winding 123b first effects energization of the fuse link 124. As a consequence, the fuse link 124 is ruptured after a short interval to permit alternating current traversal of the resistor 126 and the ignition element 864a in the detonating cap 864. Energization of the ignition element 864a effects detonation of the cap 864 to in turn effect detonation of the detonating cord 844.

As indicated above, the resistance of the fuse 124 is very low as compared with the series resistance of the resistor 126 and the ignition element 864a of the detonating cap 864. Accordingly, the ignition element of the cap 864 is effectively by-passed for current flow therethrough until the fuse 124 is blown. It will thus be apparent that the fuse corresponding to fuse 63 effectively constitutes a low impedance path shunting a second and high impedance path which serially includes the ignition element 864a and the resistor 126. Hence, stray currents which may be introduced into the electrical control and firing system either directly or by induction cannot effect sufficient energization of the ignition element 864a to produce detonation of the cap 864 with a resulting premature detonation of the perforating cartridges corresponding to cartridges 40. Moreover, the fuse 124 is the type of current responsive circuit interrupting device which has a definite time-current characteristic, such that energization thereof with current of a predetermined magnitude for a predetermined interval of time is required in order to rupture the fusible element of the fuse. As a consequence, high voltage transients of short duration which appear in the electrical system will not blow the fuse and hence cannot result in detonation of the cap 864.

In the preferred embodiment of the invention illustrated in FIGS. 19, 20, and 21 of the drawings, the individual cartridge biasing spring arrangement shown in FIG. 4 is utilized to bias the jet producing cartridges 240 for movement from their retracted positions to their extended perforating positions, and a locking bar or link arrangement comprising a pair of locking bars 252 and 253 is employed normally to lock the cartridges 240 in their retracted positions between the side rails 233 and 234 of the carrier 232. More specifically, the cartridge biasing springs 268 are so wound that alternate ones of the cartridges 240 are pivoted in one direction away from their retracted positions to their extended perforating positions, and the intermediate cartridges 240 are pivoted in the opposite direction away from their retracted positions to their extended perforating positions, when the locking bars 252 and 253 are moved to their non-locking positions in the manner more fully explained below. The locking bars 252 and 253 are slidably supported within inturned flanges 234a and 234b of the carrier rail 234, and are provided at spaced points therealong with integrally formed lugs or projections which perform the dual function of normally retaining alternate ones of the cartridges 240 in their retracted positions and of limiting pivotal movement of these cartridges to their extended perforating positions. Thus, the locking bar 253 is provided with lugs 253a at points therealong opposite the odd numbered cartridges 240, which normally overlie and engage the sides of these cartridges to prevent the same from moving from their retracted positions to their extended perforating positions under the influence of their biasing springs 268. Similarly, the locking bar 252 is provided with lugs 252a at points therealong opposite the even numbered cartridges 240 which normally overlie and engage the sides of these cartridges to restrain the same against movement from their retracted positions to their extended perforating positions.

The operating mechanism for the locking bars 252 and 253 may be identical with that illustrated in FIG. 16 of the drawings and described above. Specifically, this mechanism may be utilized for the purpose of retracting the bars 252 and 253 from the locking positions thereof, illustrated in FIG. 19 of the drawings, to the non-locking positions thereof, illustrated in FIG. 20 of the drawings. To this end, the upper ends of the bars 252 and 253 may be connected to the piston rod 785 of the operating mechanism shown in FIG. 16 of the drawings. A spacer block 254 pin connected by means of a pin 255 to the upper ends of the bars 252 and 253, and machine screw connected, by means of a machine screw 256 to the lower end of the piston rod 785, may be utilized for this purpose.

As best shown in FIG. 21 of the drawings, the cartridge supporting arrangement employed in the preferred embodiment of the invention under consideration, combines certain preferred features of the two cartridge supporting arrangements shown in FIGS. 5 and 6 of the drawings. Specifically, the hollow pivot pin 241 is provided with a closed end 241g which seats within a bore 269b formed in a short pin 269 which extends through an opening in the base wall of the carrier rail 234. This short pin is provided with a transverse opening 269a for receiving the detonating cord 244 which intersects and opens into the bottom of the bore 269b. Thus, only the thin frangible end wall 241g of the pivot pin 241 separates the detonating cord from the explosive material 241f with which the hollow pivot pin 241 is filled. The head of the pin 269, in cooperation with a flange 241h extending outwardly from the open end of the pin 241, serves to retain the latter pin in assembled relationship with the carrier rails 233 and 234. Aside from the features just described, the jet producing cartridge and cartridge supporting arrangement shown in FIG. 21 of the drawings embody substantially the same features as those illustrated in FIG. 5 of the drawings, as will be evident from a comparison of the parts which have been identified by the same reference characters in the two identified figures.

Referring to FIG. 21 of the drawings, each of the lugs or projections 252a provided along the inner edge of the locking bar 252 has an angularly outturned portion 252b which terminates in an edge 252c adapted to abut a coni-

cally tapered or beveled surface **45***d* formed around the lower edge of the cartridge casing **245** and thereby stop pivotal movement of the cartridge **240** after the cartridge has been pivoted to its fully extended perforating position. The lugs or projections **253***a* formed integral with the other locking bar **253** are similarly provided with outturned portions **253***b* which terminate in edges **253***c* having the function of arresting outward pivotal movement of the cartridges **40** with which these lugs are respectively associated.

As indicated above, the operating mechanism shown in FIG. 16 of the drawings as controlled by the control system illustrated in FIG. 17 of the drawings, may be employed for selectively operating the locking bars **252** and **253** from their respective locking positions to their respective non-locking positions. With this combination, operation of the switch **767***a* to connect the direct current source **766** in circuit with the ignition element of the ignitor **787** results in detonation of the explosive material **788** with the result that the piston **783** is moved upward from the position illustrated in FIG. 16 of the drawings until the locking pin **791** drops into the locking recess **793**. Incident to upward movement of the piston **783**, the piston rod **785** and the two locking bars **252** and **253** are moved upward from their locking positions as illustrated in FIG. 19 of the drawings to their non-locking positions as illustrated in FIG. 20 of the drawings, thereby to release the cartridges **240** for pivotal movement from their illustrated retracted positions to their extended perforating positions. As the bar **252**, for example, is moved from its locking position to its non-locking position, the lugs **252***a* are, of course, correspondingly moved to withdraw these lugs from engagement with the side walls of the cartridges **240** with which they are respectively associated. During such movement of the locking lugs **252***a*, the cartridges **240** associated therewith, pivot around the lower edges of the lugs into positions where they extend substantially at right angles to the carrier **232**, at which time, the beveled lower edge surfaces **45***d* thereof come into engagement with the edges **252***c* of the lugs **252** to prevent further movement of the cartridges. Thus, outward pivotal movement of the cartridges is arrested after they have been moved to their extended perforating positions. Following movement of the cartridges **240** to their perforating positions, the switch **767***a* may be operated to the position for connecting the alternating current source **796** in circuit with the ignition element **764***a* of the detonator **764** through the condenser **79** and the switch **120**, which, as explained above, is operated to its closed position in response to the described movement of the piston **83** to its upper position. In response to this operation, the detonating element **764** is detonated to detonate the cord **244**, the booster charges **241***f* and the charges **247** of the cartridges **240**, all in the manner previously explained.

As will be evident from the above explanation, no facilities are provided in the embodiment of the invention shown in FIGS. 19, 20, and 21 of the drawings for retracting the cartridges **240** from their extended perforating positions to their retracted position in unison and in response to withdrawal of the gun **20** into the tubing **24**. It will be understood, however, that should it be desired to withdraw the gun **20** from the borehole **21** without firing the cartridges **240**, this may readily be done by pulling the gun back into the tubing **24**. During such upward movement of the gun **20**, each cartridge **240** is returned to its retracted position against the bias of its associated spring **268** through engagement of the side of the cartridge with the lower end of the tubing **24**.

From the foregoing description with reference to FIGS. 19, 20, and 21, it will be understood that in the embodiment of the invention there shown, the cartridges **240** are positively locked in their retracted positions until such time as the gun is lowered to the desired perforating position in the borehole **21**, at which time the locking bars **252** and **253** are withdrawn to permit the cartridges to be moved to their extended perforating positions under the influence of their individual biasing springs **268**. This arrangement has the distinct advantage of permitting the use of much heavier biasing springs **268** and hence insures positive opening movement of the cartridges when the locking bars are withdrawn to their non-locking positions. Another important feature of the present invention is the structural arrangement whereby the explosive facilities connecting the detonating element corresponding to element **64** in the subassembly **231***a* with the explosive charges **247** in the cartridges **240** are completely enclosed and sealed. Thus, the sheath terminating at the assembly **122** and enclosing the detonating cord **244** is preferably sealed at its lower end so that the cord is not exposed to the fluids in the bore hole. Further, the booster charges **241***f* in the hollow pivot pins **241** are completely enclosed and sealed so that the fluid in the bore hole cannot penetrate the explosive material. In this regard, it will be understood that, if desired, short segments of detonating cord may be inserted into the internal chambers of the pivot pins **241** to serve as the booster charges. The described arrangement becomes very important when the gun is to be used in deep and hot wells, and more particularly in wells which are filled with oil. Thus, oil has the property of penetrating the plastic or cotton braid with which detonating cords are conventionally covered, and thus desensitizing the explosive material of the cord. Further, certain detonating cords, especially those employing PETN as the exposive material, are sensitive to heat and pressure. With the described arrangement, however, wherein the detonating cord **244** is completely enclosed in a sealed tube, it is protected against pressure as well as impregnation by the well fluids and hence will operate much more satisfactorily.

While there have been described what are at present considered to be the preferred embodiments of the invention, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of immobile pivot pins supported on said carrier at spaced points therealong, cartridges pivotally supported on said carrier by said pivot pins in retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges as said carrier is lowered through the tube into a well and adapted to be pivoted from their retracted positions to extended perforating positions after they emerge from the tube, each of said pivot pins having an elongated chamber and having at least one frangible wall in contacting engagement with said cartridge, and means including booster charges of explosive material disposed within said hollow pivot pins for detonating said cartridges.

2. A perforating gun adapted to be lowered from the earth's surface through a tube into a well where a perforating operation is to be performed, comprising a carrier, a plurality of cartridges supported by said carrier in retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges, said cartridges being supported so as to be movable between their retracted positions and higher extended perforating positions, a cable for lowering said carrier through said tube to the position in the well where the perforating operation is to be performed, said cable comprising an insulated conductor, actuating means including means biasing said cartridges to their extended perforating positions and an element energized by a first current transmitted over said conductor from the earth's surface for moving said cartridges from their retracted positions upwardly to extended perforating positions, a

detonating element energized by a second current having a frequency differing substantially from said first current transmitted over said conductor from the earth's surface, and means including said detonating element for detonating said cartridges.

3. In a perforating gun, a cartridge carrier, a hollow pivot pin supported on said carrier, a cartridge pivotally supported on said pivot pin and movable relative thereto, said pin having a transverse opening therethrough separated from the internal hollow of said pin by a thin rupturable wall, a detonating cord threaded through said transverse opening of said pin to rupture said thin wall and detonate a charge of explosive material disposed in said pin upon detonation of said cord, and means for detonating said cord.

4. A perforating gun adapted to be lowered from the earth's surface through a tube into a well where a perforating operation is to be performed, comprising a carrier, a plurality of cartridges supported by said carrier in retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges, means including an explosively actuated piston selectively controllable from the earth's surface for moving said cartridges from their retracted positions into extended perforating positions upon emergence from the lower end of said tube, detonating means for detonating said cartridges, and means including a switch controlled by said explosively actuated piston for preventing operation of said detonating means until the movement of said cartridges into their extended perforating positions has been initiated.

5. A jet producing cartridge comprising a casing, a jet producing charge of explosive material in said casing, supporting means extending transversely through said cartridge for supporting said cartridge, said supporting means being provided with an internal chamber, means for moving said cartridge relative to said supporting means, and means including an explosive charge disposed within said chamber for detonating said jet producing charge of explosive material.

6. A jet producing cartridge comprising a casing having an aperture extending transversely thereof, a jet producing charge of explosive material in said casing, hollow pivot means received in said aperture for pivotally supporting said cartridge, means for moving said cartridge about said pivot means and means including an explosive charge disposed within said hollow pivot means for detonating said jet producing charge of explosive material.

7. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of cartridges pivotally supported on said carrier at spaced points therealong in downwardly facing retracted positions such that they will pass through a tube having a lesser diameter than the length of said cartridge as said carrier is lowered through the tube into a well, spring means for pivoting said cartridges upwardly from their retracted positions to extended perforating positions, a locking bar extending longitudinally of said carrier and provided with spaced lugs therealong engaging the sides of said cartridges to restrain said cartridges in their retracted positions, and means controllable from the earth's surface for moving said bar longitudinally of said carrier to retract said lugs and thus release said cartridges for pivotal movement from their retracted positions to their extended perforating positions, the spring means being adapted to enable the respective cartridges to pivot from extended perforating positions downwardly toward their retracted positions on encountering an obstruction permitting gun withdrawal through a tube without cartridge damage after the cartridges have been moved to extended perforating positions.

8. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of cartridges pivotally supported on said carrier at spaced points therealong in downwardly facing retracted positions such that they will pass through a tube having a lesser diameter than the length of said cartridge as said carrier is lowered through the tube into a well, spring means for pivoting said cartridges upwardly from their retracted positions to extended perforating positions, a locking bar extending longitudinally of said carrier and provided with spaced lugs therealong engaging the sides of said cartridges to restrain said cartridges in their retracted and extended positions, said cartridges being provided with beveled surfaces adjacent the pivoted ends thereof and said lugs being provided with outwardly extending parts engageable by the beveled surfaces of the associated cartridges to arrest pivotal movement of the cartridges from their retracted positions to their extended perforating positions, and means controllable from the earth's surface for moving said bar longitudinally of said carrier to retract said lugs and thus release said cartridges for pivotal movement from their retracted positions to their extended perforating positions, the spring means yielding when the respective cartridges encounter an obstruction permitting the cartridges to pivot downward toward their retracted positions facilitating gun withdrawal through a tube after cartridge release but prior to shooting a well.

9. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of pivot pins supported on said carrier at spaced points therealong, cartridges pivotally supported on said carrier by said pivot pins in downwardly facing retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges as said carrier is lowered through the tube into a well and adapted to be pivoted upwardly from their retracted positions to extended perforating positions after they emerge from the tube, coil springs encircling said pivot pins and biasing said cartridges for pivotal movement from their retracted positions to their extended perforating positions, a locking bar extending longitudinally of said carrier and provided with means normally restraining said cartridges in their retracted and extended positions, and means for moving said bar longitudinally of said carrier to release said cartridges for movement from their retracted positions to their extended perforating positions, the coil springs resiliently urging the cartridges to their extending perforating positions but yielding when the respective cartridges are moved against an obstruction permitting gun withdrawal through a tube without cartridge damage subsequent to release of the cartridges.

10. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of pivot pins supported on said carrier at spaced points therealong, cartridges pivotally supported on said carrier by said pivot pins in downwardly facing retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges as said carrier is lowered through the tube into a well and adapted to be pivoted upwardly from their retracted positions to extended perforating positions after they emerge from the tube, coil springs encircling said pivot pins and biasing said cartridges for pivotal movement from their retracted positions to their extended perforating positions, said springs yielding when said cartridges encounter an obstruction on gun withdrawal permitting the cartridges to return undamaged to their retracted positions, a locking bar extending longitudinally of said carrier and provided with spaced lugs therealong engaging the sides of said cartridges to restrain said cartridges in their retracted and extended positions, and means controllable from the earth's surface for moving said bar longitudinally of said carrier to retract said lugs and thus release said cartridges for pivotal movement from their retracted positions to their extended perforating positions.

11. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of pivot pins supported on said carrier at spaced points therealong, cartridges pivotally supported on said carrier by said pivot

pins in downwardly facing retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges as said carrier is lowered through the tube into a well and adapted to be pivoted upwardly from their retracted positions to extended perforating positions after they emerge from the tube, coil springs encircling said pivot pins and biasing said cartridges for pivotal movement from their retracted positions to their extended perforating positions, a locking bar extending longitudinally of said carrier and provided with spaced lugs therealong engaging the sides of said cartridges to restrain said cartridges in their retracted positions, said cartridges being provided with beveled surfaces adjacent the pivoted ends thereof and said lugs being provided with outwardly extending parts engageable by the beveled surfaces of the associated cartridges to arrest pivotal movement of the cartridges from their retracted positions to their extended perforating positions, and means controllable from the earth's surface for moving said bar longitudinally of said carrier to retract said lugs and thus release said cartridges for pivotal movement from their retracted positions to their extended perforating positions.

12. A perforating gun for shooting wells comprising an elongated cartridge carrier, a plurality of cylindrical hollow pivot pins fixedly supported on said carrier at spaced points therealong, each of said pins having means defining an aperture for accommodating a detonating cord, cartridges having openings adapted to respectively receive said pins pivotally supported on said carrier by said pins in retracted positions such that they will pass through a tube having a lesser diameter than the length of the cartridges as said carrier is lowered through the tube into a well, said cartridges being adapted for pivotal movement from their retracted positions to extended perforating positions after they emerge from the tube, booster charges of explosive material respectively disposed within the hollow pivot pins, a detonating cord extending through said apertures connecting said pivot pins establishing an efficient detonating relationship between the cord and the respective booster charges carried within the pivot pins which is unaltered by pivotal movement of the cartridges due to the fixed support arrangement of said pivot pins, and means including said detonating cord for detonating said cartridges.

13. In a gun for carrying out a perforating operation in a borehole having an outer casing and a longitudinal section of borehole tubing enclosed by the casing in an upper portion thereof, the combination comprising: an elongated cartridge carrier having an outside diameter adapted to readily pass through a section of borehole tubing, said carrier including a retrievable upper portion of relatively durable construction and an expendable lower portion; a cable attached to said upper portion for lowering and suspending said carrier within a borehole and for withdrawing it therefrom, said cable having at least one insulated conductor therein; a plurality of jet cartridges each containing a jet forming shaped explosive charge respectively supported on said lower portion at spaced points therealong; pivotal mounting means for said cartridges enabling them to be disposed in vertically extending retracted positions, whereby said carrier is adapted for lowering through a section of borehole tubing having a lesser diameter than the length of the cartridges, said pivotal mounting means being adapted to enable said cartridges to pivot upward into extended perforating positions, and also to pivot downward upon wiping contact with borehole tubing on movement of a carrier therethrough after the cartridges have moved to their extended perforating positions but prior to their detonation; means biasing said cartridges to pivot upwardly from said retracted positions to said extended perforating positions; means comprising a substantially rigid locking bar operable from the earth's surface for positively and releasably restraining each of the said cartridges in its respective retracted position against said bias; means controlled over said cable from the earth's surface for releasing said restraining means at a selected depth location within a borehole, whereupon the respective cartridges will pivot to their extended perforating positions; and means also controlled over said cable from the earth's surface for detonating said charges, whereby when the carrier has been lowered through a section of borehole tubing and the cartridges have moved to their extended perforating positions, an operator may selectively detonate said cartridges or withdraw the gun through borehole tubing with the cartridges in undamaged condition.

14. In combination with a perforating cartridge having a transverse opening at one end and provided with an explosive charge, a carrier for said cartridge, an immobile hollow pin mounted on said carrier and extending through said transverse opening to support said cartridge, said pin having a frangible wall disposed in proximity to the explosive charge of said cartridge, biasing means to urge said cartridge to pivotably move about said pin to an extended perforating position, means including a booster charge of explosive material disposed within said hollow pin and extending into close proximity to at least one end thereof for detonating the explosive charge of said cartridge, and means comprising a detonating column to ignite said booster charge connected to an end of said pin which is in close proximity to said booster charge to establish a positive operative relationship between said ignition means and said booster charge within said pin which is uninterrupted by cartridge movement.

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