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3,387,657

DOWNHOLE IGNITOR

Filed July 28, 1965

3 Sheets-Sheet 1

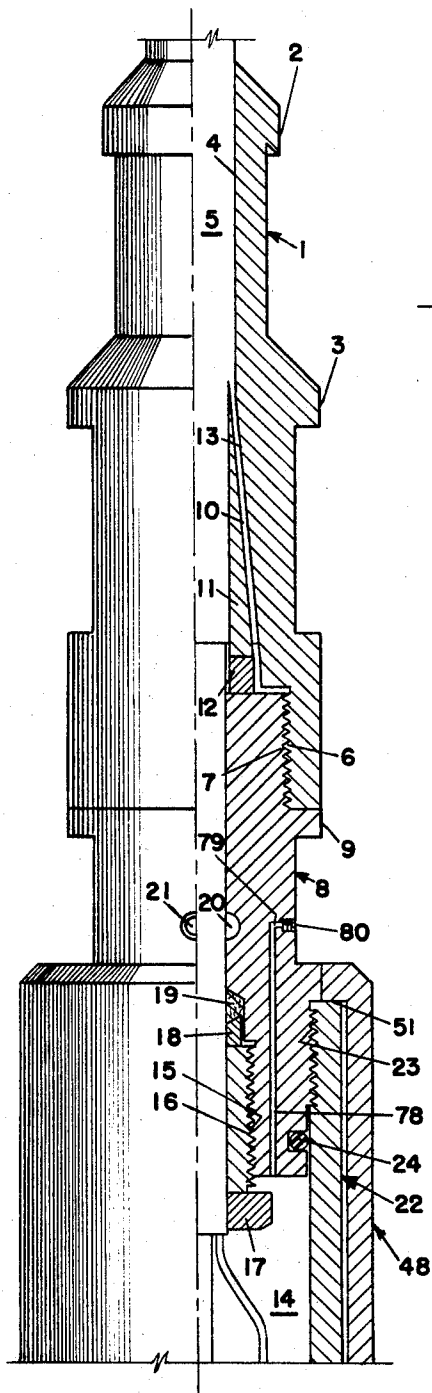


FIG. 1A

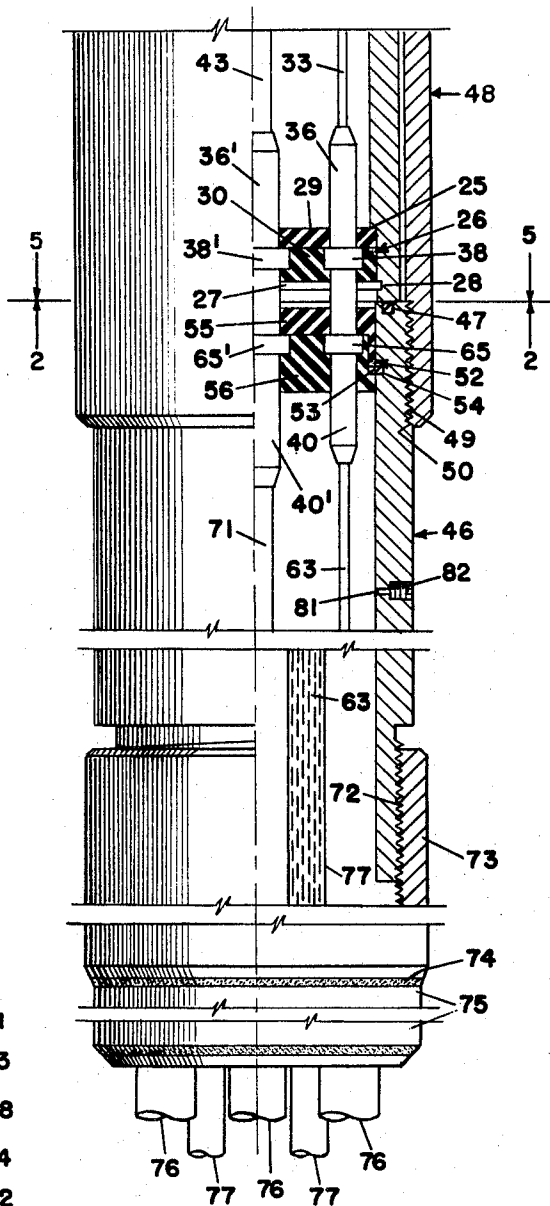


FIG. 1B

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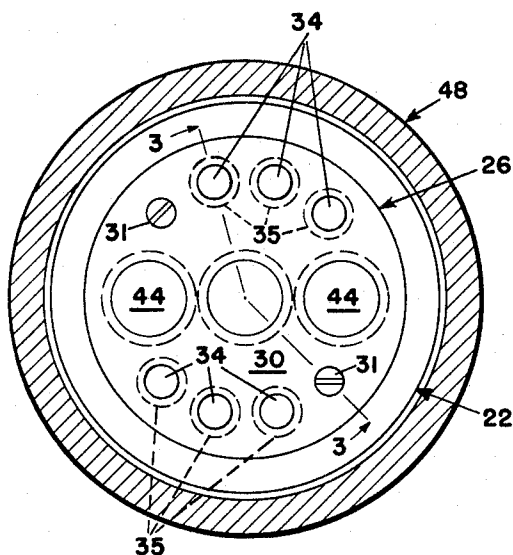


FIG. 2

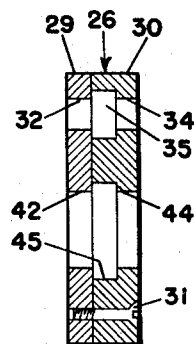


FIG. 3

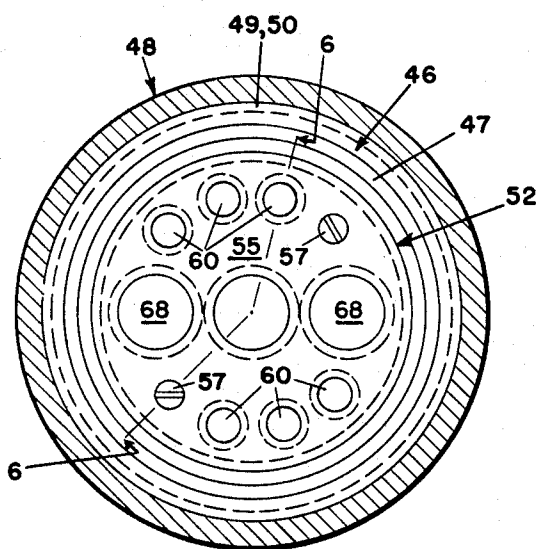


FIG. 5

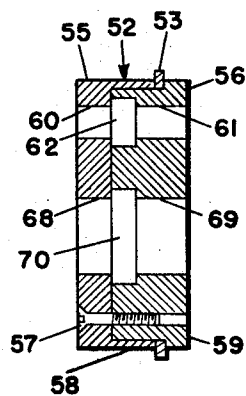


FIG. 6

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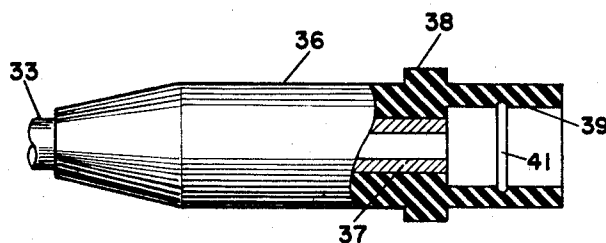


FIG. 4

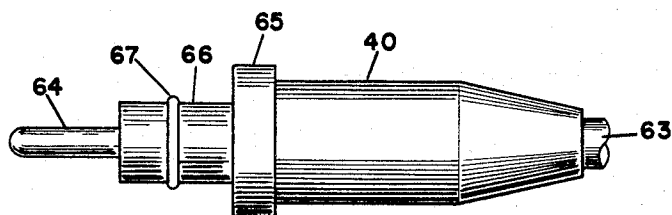


FIG. 7

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DOWNHOLE IGNITOR

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8 Claims. (Cl. 166—60)

ABSTRACT OF THE DISCLOSURE

For igniting subsurface formations, an elongated downhole tool, having an electrical heater secured to its lower end, is used. The heater is energized from the surface by means of an electrical cable, which is connected to the heater through a separable electrical connector located within the tool. A gas-tight housing is provided in the tool, around this electrical connector, and before the tool is lowered down the hole on a wire line (which is separate from the electrical cable), a suitable inert gas is fed into the housing, to provide an inert gas atmosphere therein.

This invention relates generally to the recovery of hydrocarbons from oil-bearing formations by a thermal recovery process involving in situ combustion, and particularly to an apparatus for igniting or starting combustion in such formations.

Recovery of hydrocarbons by the use of in situ combustion procedures is known, there being two classes of such procedures involving, respectively, forward and backward burning. Such combustion procedures are sometimes termed "fire flooding."

In carrying out such procedures, the petroleum-bearing formation from which recovery is sought is penetrated by one or more injection wells and one or more production wells, suitably drilled in what appears, from prior knowledge of the formation, to be optimum locations. Such procedures involve injection of air into the injection well or wells, the initiation and maintenance of burning starting at the injection point, and the collection of the resulting product from the production well or wells.

The combustion process is usually used as a secondary recovery process, but may be used when other procedures have failed either to initiate or continue production. For example, due to their geologic history, some beds, e.g., tar sands, may, when first located, contain only or largely, highly viscous and non-volatile hydrocarbon residues which cannot be made to flow by ordinary methods. In other cases, more conventional methods may have been used to remove more mobile and volatile constituents, leaving residually in the formation pores residues which are so viscous as not to flow, or which are in such quantities as to be held by wetting of the rock constituents without existing in a continuous liquid phase. To attack these or similar conditions, the burning process is used, which, consuming some of the hydrocarbon residues, provides heat which cracks other portions of the residues, producing gaseous and/or liquid products which will flow to the production point.

As previously stated, the in situ combustion procedure requires the initiation of burning starting at the injection point, which is made accessible by means of a borehole in the earth (which latter is the so-called injection well). In practice, it has been found convenient to start the combustion (i.e., to initiate the burning) by means of an ignitor tool, which is lowered into the injection borehole on a wire line and which is electrically energized from the surface, as by means of a cable. Such a tool, which may be termed a "downhole ignitor," is an elongated tool at the lower end of which there is an electrical heater (of some-

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what elongated form) which provides the active portion of the ignitor.

For convenience in installation of the ignitor (whose overall length is quite substantial) as well as in maintenance and repair thereof, it is desirable to provide a construction whereby the electrical heater may be readily separated from the remainder of the tool. This calls for a separable electrical connector, which involves exposed contacts. It is essential that no water or water vapor reach such exposed contacts, since if this occurs a short-circuit could develop; this means that special precautions must be taken when the tool is lowered into a borehole containing a fluid under superatmospheric pressure.

It has been found that one way of preventing water or water vapor from reaching the exposed contacts is to provide a gas-tight compartment around such contacts, and to pressurize this compartment with an inert gas.

An object of this invention is to provide a novel downhole ignitor.

Another object is to provide an ignitor tool with an electrical heater at one end thereof and so arranged that the heater can be readily disconnected from the remainder of the tool for repair or replacement purposes.

A further object is to provide, in a tool adapted to be lowered into a borehole, a pressurized compartment.

A still further object is to provide, in a downhole ignitor, a pressurized compartment for an electrical plug connector.

The objects of this invention are accomplished, briefly, in the following manner: An elongated tool (the ignitor device) which is adapted to be lowered into a bore hole (e.g., the injection well in a "fire flood") carries at its lower end an electrical heater assembly, which is energized from a source of electrical energy at the surface by means of a cable which extends into the other end of the tool. A gas-tight housing is provided in the tool, and within this housing there is a separable connector for electrically connecting the lower end of the cable to the heater assembly. Means are provided for pressurizing the housing with an inert gas prior to running the tool into the borehole, this inert gas atmosphere being retained in the housing while the tool is in the borehole.

A detailed description of the invention follows, taken in conjunction with the accompanying drawings, wherein: FIG. 1 (split into two parts, FIG. 1A and FIG. 1B) is a front view, partly in section, of a tool according to this invention;

FIG. 2 is a section taken on line 2—2 of FIG. 1 and looking in the direction of the arrows, but omitting certain elements;

FIG. 3 is a sectional view of a subassembly, taken on line 3—3 of FIG. 2;

FIG. 4 is an elevational view, partly broken away, of a socket-type contact member;

FIG. 5 is a section similar to FIG. 2 but taken on line 5—5 of FIG. 1;

FIG. 6 is a sectional view of a subassembly, taken on line 6—6 of FIG. 5; and

FIG. 7 is an elevational view of a pin-type contact member.

The tool of this invention is intended to be lowered into a borehole by means of a wire line. The downhole ignitor comprises a number of parts which are threadably secured together to form the assembled tool. Referring now to FIGS. 1A and 1B, at the upper end of the tool there is a retriever neck element 1 having an undercut fishing neck 2 below which is an external shoulder 3. Immediately below shoulder 3, flat areas are machined on opposite sides of neck element 1 to accommodate a wrench. Item 2 is a conventional wireline coupling, for

enabling mechanical coupling of an ordinary wire line to the tool, for running the same into and out of a borehole. The neck element 1 has a central longitudinal bore 4 therein, and a multiconductor electrical cable 5, whose conductors at their upper ends are connected to certain electrical instrumentalities at the earth's surface, passes through the bore 4.

The cable 5 is a jacketed cable which is armored on the outside and which contains (by way of example) three pairs of relatively small signal-carrying wires (for carrying signals to the surface from downhole thermocouples), and three heavier (No. 7 stranded wire, for example) power leads (for conveying electrical power from a source at the surface to the three-phase downhole heater assembly). The wires and leads mentioned run inside a copolymer tube or jacket, and the voids between the conductors within the cable are completely filled with a dielectric material such as silicone rubber.

At its lower end, neck element 1 has a set of internal threads 6 which threadedly engage (but with a loose fit) a set of external threads 7 provided at the upper end of a wireline adapter element 8. Immediately below threads 7, element 8 has an outwardly-extending flange 9 which engages the lower face of element 1 to provide a flush joint between elements 1 and 8.

The lower end of cable 5 is stripped of its armor, to a point somewhat above the upper end of element 8, and above this latter point the armor 10 is peeled away from the body of cable 5 to allow entry of a hollow frustoconical or wedge element 11 between the inner surface of the armor and the body of the cable. Element 8 has a central bore therein, through which the body of cable 5 passes, in the downward direction. One end face of a back-up ring 12 engages the larger-diameter end of wedge element 11, and the other end face of ring 12 engages the upper end of element 8. The inner bore of wedge element 11 engages the body of cable 5, and the outer (wedging) surface of element 11 wedges armor 10 outwardly against the wall of a tapered bore 13 provided in element 1. The angle of taper of bore 13 matches that of wedge element 11. Thus, it may be seen that the items 11-13 provide a means for mechanically anchoring the lower end of cable 5 in the tool, as threads 6, 7 are tightened.

The lower end face of adapter element 8 forms a part of a gas-tight housing 14. At its lower end, element 8 has a set of internal threads 15 which threadedly engage the external threads 16 on a packing gland 17 which surrounds the lower end of cable 5; packing gland 17 has a central bore through which the cable passes. The upper end of gland 17 bears against the adjacent annular face of a packing ring 18 whose upper (opposite) face is inclined and engages packing 19 which is positioned between this ring and an inclined shoulder provided in element 8, at the upper end of the enlarged bore in which items 17, 18, and 19 are located. It will be apparent that the packing structure 17-19 provides a seal around the outside of cable 5, at the upper end of housing 14. By tightening gland 17 in threads 15, this seal may be made gas-tight, as desired.

A semicircular internal groove 20 is provided in the wall of the bore in element 8, above packing 19, to enable silicone grease to be packed around the outside of cable 5. A radially-extending hole 21 is drilled from the outside of element 8 into communication with groove 20, to enable the silicone grease to be fed into groove 20. After this feeding operation, hole 21 (whose outer end is tapped) is closed by a suitable threaded plug.

A portion of the side wall of housing 14 is formed by a tubular upper contact sub 22 which is threadedly fastened at its upper end to the lower end portion of element 8, by means of internal threads on sub 22 which mate with a set of external threads 23 provided on element 8, near the lower end of the latter. Below the lower end of threads 23, a suitable groove is cut into the outer sur-

face of element 8, and in this groove is positioned an O-ring 24 which seals against the inner cylindrical wall of sub 22.

Near its lower end, the sub 22 has an internal downwardly-facing shoulder 25 against which seats the upper circular end face of an upper electrical contact wafer subassembly 26 which forms part of a separable electrical connector for connecting the conductors or wires of cable 5 to an electrical heater assembly carried by the tool of the invention, at the lower end of the tool. The subassembly 26 has an outer cylindrical or disc-like configuration, and this subassembly is held in position within the central bore of sub 22 (with the upper face of the subassembly in contact with shoulder 25, as previously described) by means of a somewhat resilient steel ring 27 which fits within an internal groove 28 in sub 22, near the lower end of this sub; a portion of the upper side of ring 27 engages the lower circular end face of subassembly 26.

Refer now to FIGS. 2 and 3, which illustrate the subassembly 26 in assembled condition, but without the electrically-conducting elements which normally form a part thereof. Subassembly 26 includes upper and lower disc-like insulating wafers 29 and 30, respectively, which are held together in assembled face-to-face relation by means of a pair of diametrically-opposite machine screws 31 passing through holes in lower wafer 30 and threading into respected tapped holes in upper wafer 29. Wafer 29 has therein, near its outer periphery, six spaced holes 32 (centered on a common base circle) for the accommodation, respectively, of the six signal-carrying leads 33 (see FIG. 1B) which convey the signals from the downhole thermocouples (which are referred to further hereinafter) to the surface. Wafer 30 has therein, near its outer periphery, six spaced holes 34 (centered on a common base circle, of the same diameter as holes 32, and aligned respectively therewith when the wafers 29 and 30 are assembled together) which also accommodate the six signal-carrying leads previously mentioned. Each of the holes 34 is counterbored, from the upper face of wafer 30, to a larger diameter, as illustrated at 35, these counterbores then being in the interior of the subassembly 26 when wafers 29 and 30 are assembled together.

Now refer to FIG. 4. As previously described, cable 5 contains six signal-carrying wires 33. At the lower end of cable 5, adjacent packing gland 17 and within housing 14, wires 33 fan out to locations appropriate for the respective holes 32 in wafer 29. The lower ends of these wires extend into the interior of respective molded, flanged rubber boots 36 at one end of such boots, and inside its respective boot the end of the wire is connected to a metallic sleeve or socket contact 37, one such contact being provided in each respective boot. Each boot 36 has thereon an integral outwardly-extending flange 38, which is located in a region adjacent the inner end of contact 37. Between the inner end of contact 37 and that end of boot 36 opposite to the end wherein wire 33 enters, boot 36 has a cylindrical bore 39 for reception of one end of a molded rubber boot 40 (see FIG. 7), to be later described. Approximately midway of the length of bore 39, boot 36 has an internal groove 41.

A rubber boot 36, as described, is provided for each of the six signal-carrying wires 33 of cable 5, and each such boot passes through a respective pair of aligned holes 32, 34 in the wafers 29, 30, the flange 38 of each boot 36 fitting into a respective one of the counterbores 35. The flanges 38 thus retain the rubber boots 36 in their respective aligned holes in subassembly 26 when the wafers 29 and 30 are fastened together. See FIG. 1B. This means that the six socket contacts 37 are retained in respective ones of the paired holes 32, 34.

Wafer 29 has therein spaced along a diameter of this wafer, three spaced holes 42 (which are considerably larger than holes 32) for the accommodation, respectively, of the three power leads (constituting, collectively,

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a three-phase source of A.C. power) 43 which convey electric power from the surface to the downhole heaters (to be referred to further hereinafter). Wafer 30 has therein, spaced along a diameter of this wafer, three spaced holes 44 (of the same diameter as holes 42, and aligned respectively therewith when the wafers 29 and 30 are assembled together) which also accommodate the three power leads previously mentioned. Each of the holes 44 is counter-bored as at 45, from the upper face of wafer 30, to a larger diameter, counterbores 45 then being in the interior of the subassembly 26 when wafers 29 and 30 are assembled together.

As previously described, cable 5 contains three power-carrying wires 43. At the lower end of cable 5, adjacent packing gland 17 and within housing 14, wires 43 fan out to locations appropriate for the respective holes 42 in wafer 29. The lower ends of these wires extend into the interior of respective molded, flanged rubber boots 36' at one end of such boots. Boots 36' may be similar in construction to boots 36, previously described, except that boots 36' are larger in diameter than boots 36, to accommodate the larger-diameter power wires 43. A rubber boot 36' is provided for each of the three power-carrying wires of cable 5 and boots 36' are mounted in wafers 29, 30 similarly to boots 36, with the flanges 38' of boots 36' fitting into the respective counterbores 45 in wafer 30. This means that the sleeve or socket contacts provided in the three boots 36' are retained in respective ones of the paired holes 42, 44.

At the lower end of upper contact sub 22, a hollow cylindrical cooling joint member 46 forms a continuation of the side wall of housing 14. In the upper end face of member 46, there is an annular groove in which is positioned an O-ring 47. O-ring 47 seals against the lower end face of sub 22, to provide a gas-tight joint between items 22 and 46. Sub 22 and member 46 are held in end-to-end sealing relationship by means of a compression ring member 48 which surrounds sub 22. At its lower end, member 48 carries internal threads 49 which threadedly engage external threads 50 provided at the upper end of member 46; at its upper end, member 48 has an abutment whose lower face 51 engages the upper end face of sub 22. It may be seen that, by screwing up the threads 49, 50, sub 22 and member 46 may be brought into sealing end-to-end relationship.

A lower electrical contact wafer subassembly 52 is mounted at the upper end of the cooling joint member 46, by means of a split ring 53 which fits into an internal groove 54 provided in member 46, near the upper end thereof. The radially-inner portion of ring 53 engages (on its opposite sides) the two respective wafers 55 and 56 which are included in subassembly 52. The subassembly 52 has an outer cylindrical or disc-like configuration, and this subassembly fits in the central bore of member 46. The subassembly 52 cooperates with the subassembly 26 to form the separable electrical connector which connects the conductors or wires of cable 5 to the electrical heater assembly located at the bottom end of the tool of the invention.

Refer now to FIGS. 5 and 6, which illustrate the subassembly 52 in assembled condition with ring 53, but without the electrically-conducting elements which normally form a part thereof. Subassembly 52 includes upper and lower insulating wafers 55 and 56, respectively, which are held together in assembled relation by means of a pair of diametrically-opposite machine screws 57 passing through holes in upper wafer 55 and threading into respective tapped holes in lower wafer 56. Wafer 55 has an integral collar 58 which extends outwardly away from the main disc-like portion of this wafer, and the O.D. of wafer 56 is such as to fit within the I.D. of collar 58, with the inner (upper) end face of wafer 56 in contact with the inner (lower) face of the disc-like portion of wafer 55. At its lower end, wafer 56 has an integral outwardly-extending flange 59 whose O.D. is the

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same as the O.D. of wafer 55. When the upper end face of wafer 56 is seated against the lower face of the central, disc-like portion of wafer 55, there is a space between the upper face of flange 59 and the lower end face of collar 58, and in this space is fitted the ring 53.

Wafer 55 has therein, near its outer periphery, six spaced holes 60 (centered on a common base circle) for the accommodation, respectively, of the six boots 40 (see FIG. 7) in which are mounted the signal-carrying thermocouple leads. When subassemblies 52 and 26 are brought into operative position with respect to each other, the holes 60 are aligned with the respective holes 34 in wafer 30 of subassembly 26. Wafer 56 has therein, near its outer periphery, six spaced holes 61 (centered on a common base circle, of the same diameter as holes 60, and aligned respectively therewith when the wafers 55 and 56 are assembled together) which also accommodate the boots 40. Each of the holes 61 is counterbored, from the upper face of wafer 56, to a larger diameter, as illustrated at 62, these counterbores then being in the interior of the subassembly 52 when wafers 55 and 56 are assembled together.

Now refer to FIG. 7. The six signal-carrying wires 63 fan out, from a location below subassembly 52 and adjacent the heater at the lower end of the tool, to locations appropriate for the respective holes 61 in wafer 56. The upper ends of these wires extend into the interior of respective molded, flanged rubber boots 40 at one end of such boots, and inside its respective boot the end of the wire is connected to a metallic pin contact 64, one such contact being provided in each respective boot. The pin 64, it will be noted, extends from the end of boot 40 opposite to the end whereat wire 63 enters the boot. Each boot 40 has thereon an integral outwardly-extending flange 65.

Between the flange 65 and the pin 64 end of the boot 40, this boot has an integral reduced-diameter portion 66 whose O.D. is substantially equal to the I.D. of bore 39 in boot 36 (see FIG. 4), so that when boots 36 and 40 are brought together, portion 66 of boot 40 can be pushed into bore 39 of boot 36, pin 64 then entering into socket 37 and making electrical contact therewith. This then electrically connects each of leads 33 to its corresponding lead 63. The diameter of boot portion 66 is somewhat less than the diameter of hole 60.

Approximately midway of the length of portion 66, boot 40 has thereon an integral outwardly-projecting ridge 67, which enters into groove 41 (of boot 36) when the mating boots are brought together, thus tending to keep them together.

A rubber boot 40, as described, is provided for each of the six signal-carrying wires 63, and each such boot passes through a respective pair of aligned holes 61, 60 in the wafers 56, 55, the flange 65 of each boot 40 fitting into a respective one of the counterbores 62. The flanges 65 thus retain the rubber boots 40 in their respective aligned holes in subassembly 52 when the wafers 55 and 56 are fastened together. See FIG. 1B. This means that the six pin contacts 64 are retained in respective ones of the paired holes 60, 61.

Wafer 55 has therein, spaced along a diameter of this wafer, three spaced holes 68 (which are considerably larger than holes 60) for the accommodation, respectively, of the three boots 40' in which are mounted the three power leads. When subassemblies 52 and 26 are brought into operative position with respect to each other, the holes 68 are aligned with the respective holes 44 in wafer 30 of subassembly 26. Wafer 56 has therein, spaced along a diameter of this wafer, three spaced holes 69 (of the same diameter as holes 68, and aligned respectively therewith when the wafers 55 and 56 are assembled together) which also accommodate the three boots 40' previously mentioned. Each of the holes 69 is counterbored as at 70, from the upper face of wafer 56, to a larger diameter, counterbores 70 then being in the in-

terior of the subassembly 52 when wafers 55 and 56 are assembled together.

The power-carrying wires 71 (which are in effect continuations of wires 43 below the lower contact subassembly 52; see FIG. 1B) fan out laterally, from a location below subassembly 52 and adjacent the heater at the lower end of the tool, to locations appropriate for the respective holes 69 in wafer 56. The upper ends of these wires extend into the interior of respective moulded, flanged rubber boots 40' at one end of such boots. Boots 40' may be similar in construction to boots 40, previously described, except that boots 40' are larger in diameter than boots 40, to accommodate the larger-diameter power wires 71. A rubber boot 40' is provided for each of the three power-carrying wires 71, and boots 40' are mounted in wafers 55, 56 similarly to boots 40, with the flanges 65' of boots 40' fitting into the respective counterbores 70 in wafer 56. This means that the pin contacts provided in the three boots 40' are retained in respective ones of the paired holes 68, 69.

It may be appreciated, from what has been said hereinabove, that when the tool of this invention is being assembled, the subassembly 26, with its boots 36 and 36' (nine boots in all) and the respective socket contacts such as 37, is mounted at the lower end of the contact sub 22; the subassembly 52, with its boots 40 and 40' (nine boots in all) and the respective pin contacts such as 64, is mounted at the upper end of the cooling joint member 46. Then, when the members 22 and 46 are brought into juxtaposition end-to-end (with the lower end of member 22 adjacent the upper end of member 46) the upper ends of the boots 40 enter into the respective lower ends of boots 36, and pins 64 engage the respective sockets 37; similarly, the upper ends of the boots 40' enter into the respective lower ends of the boots 36', and the pins carried by boots 40' engage the sockets carried by boots 36'. It will be realized that the complete subassemblies 26, 52 together form a separable electrical connector (which connector is located in the gas-tight housing 14) for connecting the six signal-carrying leads 63 to respective ones of the six wires 33, and for connecting the three power leads 71 to respective ones of the three wires 43. When members 22 and 46 are brought into juxtaposition as described, the bore 39 end of each boot 36 enters into the respective hole 60 in wafer 55, a limit being reached when this end of boot 36 comes into contact with the flange 65 of the matching boot 40. A similar statement applies to the matching boots 36' and 40'.

The tightening of member 48 causes the two parts of the electrical connector described to be brought into (and maintained in) firm electrical contact, as well as to cause a gas-tight joint to be made between members 22 and 46.

At its lower end, the cooling joint member 46 carries external threads (for example, 2½ inch standard pipe threads) 72 which mate with internal threads provided at the upper end of a collar (or pipe coupling) 73 which forms a continuation of the side wall of housing 14. The lower end of coupling 73 is welded at 74 to the upper end of the terminal housing 75 of the ignitor proper, that is to the terminal block of the heater assembly which is mounted at the lower end of the tool. The interior of housing 75 is completely (except, of course, for the wires and tubes therein or passing therethrough, as will be later described) filled with an electrical insulating material such as magnesium oxide; in this way, the housing 75 provides the lower end wall or lower end closure for the gas-tight housing 14.

Six heating elements (only three of which are illustrated at the bottom of FIG. 1B), each comprising for example a coil of high-electrical-resistance wire suitably mounted within a stainless steel tube 76, extend downwardly from terminal housing 75 to a base header (not shown), which is at the extreme lower end of the entire ignitor device. Two of these heating elements are connected in series across each phase of the three-phase al-

ternating current power supply; the three-phase power is fed from a three-phase source at the surface down to the tool via the three power leads 43 in cable 5, the contacts in the three paired boots 36' and 40', and the three lower power leads 71. The electrical connections between the leads 71 and the upper ends of the heating elements are made within the housing 75.

Three thermocouples are utilized to measure the temperature at various points in the lower or heater section of the ignitor device, each thermocouple employing, for example, one chromel wire and one alumel wire. Three stainless steel tubes 77 (which may be thought of as thermocouple wells, and only two of which are illustrated at the bottom of FIG. 1B) are utilized to convey the thermocouple leads from the points at which the temperatures are being measured to the vicinity of the separable connector or plug 26, 52. A pair of wires 63 (one alumel and one chromel) extends through each of the three tubes 77, as indicated by dotted lines 63 in the vicinity of the upper end of collar 73. The three tubes 77 extend upwardly from the vicinity of the aforementioned base header, through the terminal housing 75, to locations a little distance below the lower contact subassembly 52. In this connection, it is noted that the actual length of the cooling joint member 46 (shown interrupted) is about six feet. When the three pairs of wires come out of the upper ends of the tubes (below subassembly 52), they split or fan out, as previously stated, so that they go through separate, individual pins and sockets in the plug 26, 52. Thus, six thermocouple contacts are required in the plug. The thermocouple signals are conveyed to the surface via the lower signal leads 63, the contacts in the six paired boots 36 and 40, and the six (upper) signal leads 33.

In practice, five thermocouples are made up in each ignitor device, while using only the six wires previously mentioned. The two additional thermocouples are made by connecting together unlike wires from different ones of the three pairs of wires. The fourth and fifth thermocouples are located at the lower end of the cooling joint member 46 and at the plug 26, 52, respectively.

Upon assembly of the ignitor device, housing 14 becomes gas-tight. It will be remembered that plug 26, 52 is located within housing 14. According to this invention, the housing 14 is pressurized with an inert gas such as helium prior to lowering the downhole ignitor into the borehole. If the housing 14 is pressurized, the pressure in the plug chamber or housing 14 offsets the superatmospheric pressure in the well bore and positively prevents any water, liquid or vapor, from entering the plug chamber. If such material did enter, and came into contact with the plug, a short-circuit could easily be produced. Helium is preferred as the inert gas, since it has a low heat capacity (thus helping to keep the plug relatively cool), and since it is an electrical arc suppressor.

In order to properly scavenge or remove the air from housing 14 and to enable the same to be pressurized with an inert gas, two passages into housing 14 are provided, one for each end thereof. For the upper end of the housing, a longitudinally-extending (though not axial) small-diameter hole 78 extends from the lower end face of the wireline adapter element 8 to a location above the upper end of ring member 48, and a radially-extending small-diameter hole 79 is drilled from the outside of member 8 into communication with the upper end of hole 78. The outer end of radial hole 79 is enlarged and tapped, so that a sealing plug 80 can be threadedly mounted therein (with a sealing washer, not shown, below the plug) to seal off holes 78 and 79 from the atmosphere, after housing 14 has been pressurized.

For the lower end of housing 14, a radially-extending small-diameter hole 81 is drilled entirely through the wall of member 46, near the lower end of this member. The outer end of radial hole 81 is enlarged and tapped, so that a sealing plug 82 can be threadedly mounted

therein (with a sealing washer, not shown, below the plug) to seal off hole 81 from the atmosphere, after housing 14 has been pressurized.

After the tool of this invention has been assembled, and prior to lowering the same into a borehole, the housing 14 (in which the separable electrical connector or plug 26, 52 is mounted) is essentially purged of air and is pressurized (to a suitable superatmospheric pressure) with an inert gas such as helium. This purging and pressurizing may be done by way of holes 78, 79 and 81, using a jig-like structure (not shown) termed a "gas injector." After the pressurizing has been done, the sealing plugs 80 and 82 are inserted into their respective holes, so that the pressurized inert gas atmosphere will be maintained in the housing 14 during downhole use of the ignitor device. Generally, knowing the depth to which the ignitor is to be lowered, and at which it is to be operated, the pressure used in the housing 14 (in p.s.i.) is about equal to the depth in feet.

After the pressurizing as described has been effected, the ignitor device of the invention is lowered into the borehole (injection well) to the proper depth, by means of a wireline which is attached to the retriever neck 1 of the tool. The cable 5 extends from the ignitor device or tool to the surface. The thermocouple wires 33 of the cable are connected at the surface to the input of a controller whose output controls a three-phase electrical generator at the surface, and the output of this generator, in turn, is connected to the power wires or leads 43 of cable 5. In this way, controlled three-phase electrical power is supplied to the electrical heating elements at the lower end of the downhole ignitor. The heating elements being thus energized, a flow of air is supplied from an air compressor at the surface through the casing of the injection well to the formation whereat the ignitor of the invention is positioned, to establish the in situ combustion which is desired. By monitoring at the surface the signal outputs of the various downhole thermocouples, the establishing of downhole combustion may be detected.

The invention claimed is:

1. In combination, an elongated tool adapted to be lowered into a borehole in the earth, an electrically-energized device secured to one end of said tool, an electrical cable extending into the other end of said tool, a separable connector for electrically connecting the end of said cable to said device, means forming a gas-tight sealed housing around said connector, and an inert gas atmosphere in said sealed housing.

2. Combination as defined in claim 1, wherein said sealed housing forms a part of said tool.

3. Combination as set forth in claim 1, wherein said other end of said tool is provided with external neck and shoulder elements, for enabling mechanical coupling of a wire line separate from said cable thereto.

4. Combination as recited in claim 1, wherein said device comprises an electrical heater, and wherein said electrical cable comprises a power conductor for feeding electrical energy to said heater, and also a signal conductor for feeding an electrical signal from said heater to a remote point.

5. In a tool positioned in a borehole in the earth and carrying at its lower end an electrically-energized device: an electrical cable extending from the surface of the earth downwardly to said tool for feeding electrical energy from a source at the surface to said device, a separable electrical connector in said tool for connecting the tool end of said cable to said device, means providing a gas-tight sealed housing around said connector, and an inert gas atmosphere at superatmospheric pressure within said sealed housing.

6. Combination as defined in claim 5, wherein said sealed housing forms a part of said tool.

7. Combination as set forth in claim 7, wherein said tool is provided with external neck and shoulder elements, for enabling mechanical coupling of a wire line separate from said cable thereto.

8. Combination as recited in claim 5, wherein said device comprises an electrical heater, and wherein said electrical cable comprises a power conductor for feeding electrical energy to said heater, and also a signal conductor for feeding an electrical signal from said heater to the surface.

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