(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 August 2012 (23.08.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/109711 A1

(51) International Patent Classification:
E21B 43/243 (2006.01) *E21B 43/295* (2006.01)

(21) International Application Number:
PCT/AU2012/000157

(22) International Filing Date:
20 February 2012 (20.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2011900555 18 February 2011 (18.02.2011) AU

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: IGNITING AN UNDERGROUND COAL SEAM IN AN UNDERGROUND COAL GASIFICATION PROCESS, UCG

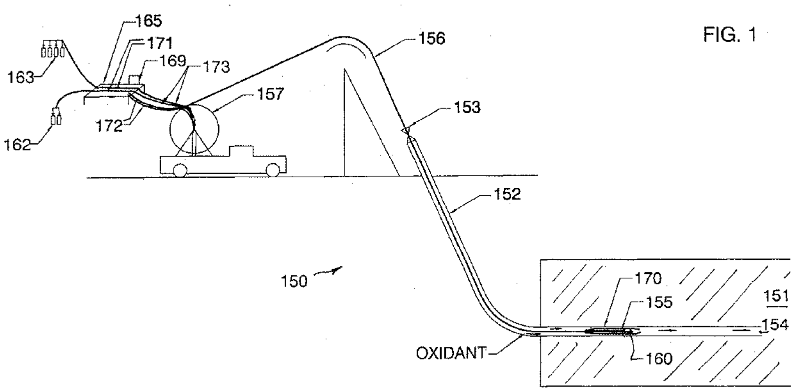

FIG. 1

(57) Abstract: An ignition apparatus (150) configured to ignite an underground coal seam (151). The ignition apparatus (150) comprising an ignition system, a positioning system, a sensor (170) and a controller (165). The ignition system comprises ignition means and an ignition tool (155) for igniting the underground coal seam (151) from within the well channel (154) or well liner encasing the well channel (154). The positioning system comprises coiled tubing (156) connected to the ignition tool (155) and extendible through a well head (153) within the well channel (154) to position the ignition tool (155) at a desired location within the well channel (154). The positioning system further comprises a spool (157) for transporting and dispensing the coiled tubing (156).

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IGNITING AN UNDERGROUND COAL SEAM IN AN UNDERGROUND COAL GASIFICATION PROCESS, UCG

Field of the Invention

This invention relates to a method and apparatus for igniting an underground coal seam, for *in-situ* conversion of coal to product gas.

Background of the Invention

Underground coal gasification (UCG) is a process by which product gas is produced from a coal seam by heating the coal *in situ* in the presence of an oxidant. The product gas is typically referred to as synthesis gas or syngas and can be used as a feedstock for electricity or chemical production, for example.

Conversion of coal into product gas takes place in a well which typically includes a well channel of sorts extending through the coal seam. Such a channel can be formed by one or more bore holes drilled into the coal seam that are in fluid communication with one another. The channel is also in fluid communication with an injection well, a production well as well as perhaps one or more ignition or service wells that extend from ground level to the well channel. Typically, oxidant is injected into the well channel via an injection well to promote combustion. Typically, an ignition source for initiating combustion of the coal seam is introduced into the well channel via an ignition well. Combustion can also be initiated using an ignition device, whereby an ignition device that is capable of igniting coal is inserted into the well channel via an ignition or injection well.

A coal seam panel is typically referred to as a coal gasifier. Gasification occurs adjacent a combustion zone of the well/gasifier and the coal is partially oxidized to produce product gas of low or medium heating value. Hot product gas flows from the gasification zone and exits the ground from a well head of the production well. As coal is consumed or gasified, a gasifier cavity within the coal seam develops and the channel grows in size.

One of the major challenges for UCG is to ignite the coal underground, particularly in a safe and cost effective manner. Several methods have been proposed and used. One such method involves dropping hot coal or lowering an electrical heat resistance device into a vertically extending ignition well directly into an intended combustion zone and then injecting oxygen into the combustion zone via the injection well so that combustion is autogenous. Another method involves dropping volatile chemicals such as TEB or silane which spontaneously ignite on contact with air to start ignition followed by the supply of ignition fuel and oxidant to the intended combustion zone so that combustion is autogenous.

One problem associated with UCG is that a combustion front produced at a combustion zone does not always progress along a coal seam as proposed in theory, and practically a coal seam may need to be reignited at different sites along the coal seam so as to maximise the production and life of the coal gasifier.

One of the problems associated with UCG when employing a well channel that extends substantially horizontally through the coal seam is that more than one vertically extending ignition well (bore hole) may be required in order to ignite/re-ignite the coal seam/gasifier at multiple locations, as installing ignition wells is an expensive and time consuming process. In addition, the use of TEB or silane can be dangerous for handlers due to the highly volatile nature of the material when exposed to air and any mistake in handling such materials can expose them to air and initiate fire or explosion events.

Summary of the Invention

It is an object of the present invention to provide a method or apparatus for igniting (or re-igniting) coal of an underground coal seam in a safe and/or cost effective manner, or to provide the public with a useful or commercial choice.

According to a first aspect of the present invention, there is provided an ignition apparatus for igniting an underground coal seam from within a well channel that extends through the seam, said apparatus comprising:

an ignition system comprising ignition means and an ignition tool for igniting the underground coal seam from within the well channel; and

a positioning system comprising coiled tubing connected to the ignition tool and extendible within the well channel to position the ignition tool at a desired location within the well channel.

According to a second aspect of the present invention, there is provided an ignition system comprising ignition means and an ignition tool for igniting an underground coal seam.

According to a third aspect of the present invention, there is provided ignition means for igniting an underground coal seam.

According to a fourth aspect of the present invention, there is provided an ignition tool for igniting an underground coal seam.

According to a fifth aspect of the present invention, there is provided a positioning system comprising coiled tubing extendible within a well channel to position an ignition tool at a desired location within the well channel.

According to a sixth aspect of the present invention, there is provided a method of igniting an underground coal seam from within a well channel that extends through the seam, said method comprising the steps of:

(1) moving an ignition tool of an ignition apparatus into the well channel; and

(2) igniting the underground coal seam at one or more locations within the well channel using the ignition tool,

wherein the ignition apparatus comprises:

an ignition system comprising ignition means and the ignition tool; and

a positioning system comprising coiled tubing connected to the ignition tool and extendible within the well channel to position the ignition tool at a said location within the well channel.

Integers of the first to sixth aspects of the invention are described below, including in the detailed descriptions of the embodiments of the invention section.

The invention is particularly suited to well channels that extend horizontally or substantially horizontally though a coal seam/gasifier or otherwise follow a non-vertical or non-linear course. That is, the invention is particularly suited for igniting coal seam zones that are not immediately below or immediately adjacent a bottom of an injection, ignition or other type of service well.

The ignition means can ignite the coal seam in any suitable way. The ignition means can directly ignite the coal seam itself, or ignite combustible fluid (eg. liquid or gas) either resident in the well channel or supplied to the well channel (eg. supplied as either a liquid, gas or solid).

In one embodiment, the ignition means comprises an electrical spark generator (eg. spark plug) and a power supply for generating the spark. The power supply can be located above ground or the spark generator can be powered by an *in seam* turbine and transformer electrically connected to the spark generator. The ignition means can further comprise an ignition fuel source and/or oxidant source for further initiating and/or fueling combustion.

In another embodiment, the ignition means comprises an electrical heat resistor (eg. glow plug) and a power supply for electrifying the resistor. The resistor can, for example, generate about 180 kW of heat. The power supply can be located above ground or the electrical heat resistor can be powered by an *in seam* turbine and transformer electrically connected to the resistor. The ignition means can optionally further comprise an ignition fuel source and/or oxidant source for further initiating and/or fueling combustion.

In another embodiment the ignition means comprises at least one type of ignition chemical (ignition chemical source). The ignition chemical can be a pyrophoric substance - eg. liquid such as triethylboron (TEB), gas such as silane, solids such as phosphorus or alkali metal, or a pyrophoric chemical and hydrocarbon mixture such as TEB vaporized in methane, or a pyrophoric chemical and an inert gas such as TEB and nitrogen. The hydrocarbon or inert gas flow can help transport/vaporize the pyrophoric chemical or slugs/plug flows of the pyrophoric chemical to the ignition tool. The ignition means can further comprise an ignition fuel source and/or oxidant source for further initiating and/or fueling combustion.

In yet another embodiment the ignition means comprises pure oxygen or substantially pure oxygen that ignites the coal seam directly. The ignition means can further comprise an oxidant source for fueling combustion.

The ignition tool can be of any suitable size, shape and construction and can be made of any suitable type of material or materials. In its simplest form, the ignition tool can be in the form of an end nozzle or probe for the coiled tubing. In a more complex form, the ignition tool can contain the ignition means and/or other components of the ignition apparatus.

The ignition tool can comprise a tool body. The body can be of unitary construction or can comprise two or more connectable body pieces. The body can be made of any suitable material or materials, including stainless steel and carbon steel. If the ignition tool/body is to have a sacrificial piece (eg. a blow-out plug or cap), then that piece can be made of metal or non-metallic materials such as plastic or rubber that can deform or melt.

The ignition tool or the tool body can have any suitable outer diameter and length. For example, the ignition tool or the tool body can have an outer diameter of about 2 inches, 3 inches or 4 inches, for example. Preferably the ignition tool or the tool body has a diameter of about 2 inches.

The body pieces can be screwed together. The body can house the ignition means or not. The tool body can have an inlet end and outlet end and these can be located at opposed ends of the body. The outlet end of the body can be tapered or otherwise shaped so as to reduce resistance when moving the ignition tool to its intended location within the coal seam. The inlet end of the body can be adapted to be connected to the coiled tubing.

The ignition tool can be connected to the coiled tubing in any suitable way. The tool body can be connected to the coiled tubing in a fluid-tight manner or not. The ignition tool body can be releasably connected or permanently connected to the coiled tubing. Preferably the body is connected to an end of the coiled tubing by way of a screw thread or weld.

The coiled tubing can be of any suitable size, shape and construction and can be made of any suitable material or materials. More particularly, the coiled tubing can be of any suitable length and diameter. Preferably, the coiled tubing is made of metal, such as stainless steel, carbon steel or copper. The coiled tubing can be of unitary construction or can comprise two or more connectable tube pieces. A preferred outer diameter for the coiled tubing is two inches.

The coiled tubing can comprise a single tube (line) connected to the tool body. The coiled tubing can alternatively comprise at least one inner tube (inner line) extending within an outer tube (outer line), wherein one or both of the inner and outer tubes are connected to the tool body. That is, the coiled tubing can comprise at least one inner tube and an outer tube that extend concentrically relative to one another. More than one inner tube may extend within the same outer tube. A preferred diameter for the outer tube is two inches whereas a preferred diameter for the inner tube is ¾ inches.

The positioning system can further comprise a spool from which the coiled tubing is unspooled. The spool can be of any suitable size, shape and construction and can be made of any suitable material or materials. Preferably, the spool can unspool coiled tubing having a length of at least about, 300m, 400m, 500m, 600m, 700m, 800m, 900m, 1000m, 1100m or 1200m.

The ignition fuel source can feed ignition fuel to or in close proximity of the ignition tool either within a tube of the coiled tubing or externally of the coiled tubing but within the well channel. The ignition fuel can be in the form of a solid or fluid, such as a gas or liquid. The ignition fuel can be a combustible hydrocarbon-based fluid such as methane, propane, butane or mixtures thereof. The ignition fuel can be a pyrophoric gas or liquid. The ignition fuel source can be a tank/cylinder of compressed combustible gas or liquefied gas. The ignition fuel source can be connected directly or indirectly to the coiled tubing in a fluid-tight manner.

The ignition apparatus can comprise an oxidant source that can feed oxidant to or in close proximity of the ignition tool either within the coiled tubing or externally of the coiled tubing but within the well channel. The oxidant can be in the form of a solid or fluid, but is preferably a fluid such as air (approximately 20% oxygen), air or a different gas/gas mixture enriched with oxygen (greater than about 20% oxygen, or about 30% to 80% oxygen), or substantially pure oxygen. The oxidant source can comprise an air compressor, a tank/cylinder of compressed air or oxygen, an air separation unit, or a tank/cylinder of liquid oxygen, for example. The source of oxidant can be connected directly or indirectly to the coiled tubing in a fluid-tight manner. The source of oxidant can be connected directly or indirectly to a well head of an injection well such that oxidant is injected into the well rather than the coiled tubing.

The ignition chemical source can feed ignition chemical to or in close proximity of the ignition tool either within the coiled tubing or externally of the coiled tubing but within the well channel. As already mentioned, the ignition chemical can be in the form of a solid or fluid, such as a gas or liquid. The source of ignition chemical can be a pressurised or non-pressurised tank/cylinder containing such a chemical. The ignition chemical can be a pyrophoric gas or liquid. The ignition chemical source can be connected directly or indirectly to the coiled tubing in a fluid-tight manner.

As mentioned, the coiled tubing can comprise a single tube. The tube can be used to convey one or more electrical cables/lines (for power or data) from above ground to the ignition tool body. The tube can be used to feed ignition fuel and/or ignition chemical to the ignition tool body.

As mentioned, the coiled tubing can comprise two or more tubes (lines) or more than two tubes, in which case the tubes could extend concentrically (one within the other). An inner tube can feed ignition fuel and/or ignition chemical to the ignition tool body. An outer tube can feed oxidant to the ignition tool body. The outer tube can also convey electrical (power or data) cables of the ignition apparatus.

For ignition apparatus comprising a single tube ('single coil tubing'), oxidant injected into the well may flow externally of the tube. Also for ignition apparatus comprising a single tube, ignition fuel and/or ignition chemical injected into the well may flow within the tube. For ignition apparatus comprising concentric tubes ('concentric coiled tubing'), oxidant injected into the well may flow within the outer tube (preferably as well as in the well itself externally of the outer tube) and ignition fuel may flow within the inner tube.

If using a single tube or concentric tubes, the (outer) tube can be made of stainless steel or carbon steel. If air is used as the oxidant, the outer tube can be made of carbon steel and the inner tube can be made of copper. If air or oxygen is used as the oxidant, the outer tube can be made of stainless steel and the inner tube can be made of copper or stainless steel.

The coiled tubing can further house other components of the ignition apparatus including components of the ignition tool, sensors and, as mentioned, power or data cables.

The coiled tubing can comprise heat-exchange formations, such as fins or vanes extending from a tube of the coiled tubing, for cooling an interior of the tube.

The coiled tubing can comprise positioners, such as fins or vanes, that extend from a tube of the coiled tubing and help position the ignition tool within the well channel (or well liner, if present). That is, they help centralise the ignition tool within the well channel (or well liner, if present).

The ignition tool can comprise at least one inlet in the body that is in fluid communication with at least one tube of the coiled tubing. However, it need not be a fluid-tight connection. The inlet can be of any suitable size and shape. The inlet can be provided by a mere opening in the body or a pipe (spigot) that extends within and/or externally of the body. An electrical cable, sensor or other component of the ignition assembly can extend through the inlet. Ignition fuel and/or ignition chemical can be fed through the inlet.

The ignition tool can comprise a first inlet connected to an inner tube that feeds ignition fuel and/or ignition chemical to the body. The ignition tool can comprise a second inlet connected to an outer tube that feeds oxidant or conveys a cable (power or sensor) or sensor to the tool body.

The ignition tool can comprise at least one outlet from the tool body that is in fluid communication with the at least one inlet. That is, the ignition tool can comprise a passage extending between the inlet and outlet. However, it need not be a fluid-tight communication. The outlet can be of any suitable size and shape. The outlet can be provided by a mere opening in the body or a pipe (spigot) that extends within and/or externally of the body. An outlet of reduced diameter can help direct flames away from the tool body, for example.

The tool body can comprise a detachable cap or plug (blow-out plug) covering an outlet from the body, that can be detached from a remainder of the body prior to ignition. The cap or plug can be bull nose, long nose or conical in shape. Detachment can be achieved in any suitable way. For example, an increase in gas pressure due to oxidant, ignition fuel or ignition chemical flow through the body can be used to detach the cap or plug. The cap/plug piece can friction fit to a remainder of the tool body. If in the form of a plug, a stem of the plug can friction fit to the outlet from the body using an o-ring that extends around the stem.

In addition to the inlet/s and outlet/s, the ignition tool can have one or more intakes extending through the body for drawing oxidant/gas from the well channel into the body passage by way of a Venturi effect when ignition fuel and/or oxidant flows through the passage to the outlet from the body.

The ignition tool can comprise a mixing chamber located within the tool body within which the ignition fuel, oxidant and/or ignition chemical mix. Mixing can be achieved in any suitable way. Typically this will involve providing turbulence and/or resistance to flow of the gases through the mixing chamber. To that end, the mixing chamber can comprise at least one mixing structure or device, such as a Venturi device, one or more baffles (eg. spirals) or other turbulence-creators located within the mixing chamber (that create a pressure differential for the two gas streams to mix) or that define walls of the mixing chamber. The mixing structure or device can be, for example, integrally formed with the tool body or can be a separate component insertable into the tool body. In one embodiment, the mixing structure or device is in the form of a Venturi device positioned within the mixing chamber.

The ignition tool can comprise a diffuser designed to control the characteristics of the mixture of gases leaving the outlet from the tool body. Any suitable type of diffuser, such as a perforated plate, can be used.

The ignition tool can comprise flow deflectors extending from an outside surface of the tool body, for deflecting the flow of gas (such as the oxidant) away from a downstream region of the tool body, such that the downstream region is not cooled by the flowing gas.

The ignition tool can comprise heat-exchange formations, such as fins or vanes extending from the tool body, for cooling the outlet from and/or interior of the body.

The mixing chamber can be defined by the tool body and a diffuser plate extending transversely across the tool body adjacent the outlet from the body.

The ignition tool can comprise a support for supporting the ignition means or other component within the tool body or externally of the body. Any suitable type of support can be used. The support can be, for example, integrally formed with the tool body or can be a separate component insertable into the tool body. In one embodiment, the support is in the form of a spacer sleeve or stay that snugly fits within the tool body and supports the ignition means within an interior region of the sleeve.

The ignition tool can comprise a non-return/check valve (ball and spring, spring loaded flapper valve or the like) to prevent ignition fuel and product gas (syngas) reverse flow up a tube of the coiled tubing.

The coiled tubing can comprise a non-return/check valve (ball and spring, spring loaded flapper valve or the like) fitted within a tube to prevent product gas (syngas) reverse flow up the tube.

The ignition apparatus can comprise one or more sensors for sensing and reporting conditions in the ignition tool, adjacent the ignition tool, well channel and/or adjacent coal seam. Any suitable type of sensor can be used. For example, the sensor can be a: thermocouple for sensing the temperature in the well channel, coal seam or ignition tool etc; a gas sensor for sensing the nature of the gas within the well/well channel; a pressure sensor for sensing pressure within the well/well channel; an optical sensor for viewing the well, well channel or coal seam; or a position sensor for reporting the location of the ignition tool within the well/well channel. The sensor can be connected to the ignition tool outer body or housed within the tool body or coiled tubing or both. An electrical cable of the sensor can extend within the coiled tubing and internally or externally of the tool body.

The ignition apparatus can comprise a controller operable to trigger ignition, including the provision of electrical energy or ignition fuel, oxidant or the release of a combustible ignition chemical. The controller can comprise a control cabinet. The controller can comprise a pipe manifold in fluid communication with the coiled tubing and ignition chemical, ignition fuel and oxidant sources.

The controller can be operable remotely from the ignition tool to (1) control the ignition fuel/ignition chemical and oxidant ratio of the mixture, (2) monitor combustion of the mixture, and (3) control the supply of electrical energy to the ignition. The controller can comprise a voltage and current measuring and controlling device connected to an electrical ignition device by means of an electrical cable extending through the coiled tubing.

The controller can consist of trim, non-return and isolation valves, flow measuring devices and pressure relief devices. Such operating devices can allow for injection rate measurement and control for oxidant and ignition fuel respectively. It can also allow purging of the ignition fuel with inert gases such as nitrogen. Oxidant / ignition fuel mixture can be adjusted using flow controlling devices, such devices being either pneumatically actuated, manually choked, quarter-turn types or electrically actuated.

The controller can comprise pressure safety devices, filtration, flow metering devices in addition to isolation valves. Control logic can allow the oxidant / ignition fuel to flow as per the required settings. In case of power failure or loss of oxidant the control logic can stop flow of the ignition fuel.

The source of oxidant (eg. compressor for air or liquid or gaseous oxygen storage tank or generator etc), ignition fuel (eg. compressed gas or liquid cylinders etc.) and ignition chemical (eg. compressed gas or liquid cylinders etc.) can be connected to a pipe manifold of the controller and further to the coiled tubing and well head of the injection well. A power supply (generator) can be electrically connected to the controller and further to the electrical cable and sensor cable extending through the coiled tubing. The controller can be skid-mounted for ease of transport.

The controller can supply electrical energy to the ignition tool to: ignite the ignition fuel/ignition chemical/oxidant mixture; monitor the condition of the ignited mixture and ramping the oxidant flow as well as ignition fuel gas up or down when re-igniting the mixture if the ignition is extinguished before combustion is established in the coal seam; and, once ignition is sustained, ramp up the flows of ignition fuel followed by oxidant or vice versa depending on the ratio attained for sustainable ignition, until combustion has been established in the coal seam.

The controller controls the fuel/oxidant ratios to between the lower flammability limit (LFL) of the fuel and the upper flammability limit (UFL) of the fuel. This ensures that not only can the gas mixture at the ignition tool ignite but the flame is sustainable.

Once combustion has been established, the method according to the invention further includes a step of maintaining the oxidant at a level to support the combustion.

In order to continue the underground coal gasification process through the coal seam, it may be necessary to reposition the ignition tool to a new ignition site where the coal in the vicinity of the new ignition site can be ignited and a new combustion zone created to progress the combustion along the coal seam and have optimum consumption of the coal resource. At the new combustion site the energy produced during the gasification process is also sufficient to maintain the temperature within the new combustion zone at a level which supports the chemical reactions taking place.

Thus to support particularly the movement of the combustion zone the coiled tubing and ignition tool can be drawn along the coal seam and re-ignited periodically to not only maintain the combustion in the combustion zone but also to initiate subsequent combustion zones in the coal seam. Hence, the method according to the invention further includes a step of moving the ignition tool along the coal seam. While this is most applicable to substantially horizontal bore holes/well channels, the invention may also be used with vertical or inclined boreholes or boreholes which have a combination of configurations.

Preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying figures.

Brief Description of the Figures

Figure 1 depicts general features of an ignition apparatus configured to ignite an underground coal seam, according to an embodiment of the present invention;

Figure 2 depicts parts of ignition apparatuses (utilising single coiled tubing) for igniting an underground coal seam, according to embodiments of the present invention;

Figure 3 depicts parts of ignition apparatuses (utilising concentric coiled tubing) for igniting an underground coal seam, according to embodiments of the present invention;

Figure 4 depicts parts of ignition apparatuses (utilising single coiled tubing) for igniting an underground coal seam, according to embodiments of the present invention;

Figure 5 depicts part of an ignition apparatus (utilising single coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention;

Figure 6 depicts part of an ignition apparatus (utilising single coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention;

Figure 7 depicts part of an ignition apparatus (utilising single coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention;

Figure 8 depicts part of an ignition apparatus (utilising single coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention;

Figure 9 depicts part of an ignition apparatus (utilising single coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention;

Figure 10 depicts part of an ignition apparatus (utilising concentric coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention; and

Figure 11 depicts part of an ignition apparatus (utilising concentric coiled tubing) for igniting an underground coal seam, according to an embodiment of the present invention.

Detailed Description of the Embodiments

In the figures, like reference numerals refer to like features.

Referring first to figure 1, there is generally depicted an ignition apparatus 150 configured to ignite an underground coal seam 151. There is shown an injection well 152 having a well head 153 and a well channel 154 extending from a heel of the well 152 through the coal seam 151.

The ignition apparatus 150 comprising an ignition system, a positioning system, a sensor 170 and a controller 165.

The ignition system comprises ignition means and an ignition tool 155 for igniting the underground coal seam 151 from within the well channel 154 (or well liner encasing the well channel 154).

The positioning system comprises coiled tubing 156 connected to the ignition tool 155 and extendible through the well head 153 within the well channel 154 to position the ignition tool 155 at a desired location within the well channel 154. The positioning system further comprises a spool 157 for transporting and dispensing the coiled tubing 156.

The coiled tubing 156 of the positioning system can comprise a single tube ('single coiled tubing') or concentrically arranged inner and outer tubes ('concentric coiled tubing'), and an end of each tube is connected to an end of the ignition tool 155 either directly or by way of an adaptor that is welded to the end of each tube and is usually either welded or screwed to an end of the ignition tool 155. A preferred diameter for the outer tube is two inches whereas a preferred diameter for the inner tube is ¾ inches.

The coiled tubing 156 is also in fluid communication with pipes of a manifold 171 of the controller 165 by way of hoses 172 and further in fluid communication with sources of fluids 162, 163 (ignition chemical, ignition fuel and oxidant – as the case may be).

The single or outer tube of the coiled tubing 156 is used to convey electrical and/or sensor cables (eg. from a sensor/thermocouple 170) from the ignition tool 155 to the controller 165 via also electrical lines 173 that extend from the spool 157.

The ignition means can directly ignite the coal seam 151 itself, or ignite combustible fluid (gas, liquid) either resident in the well channel/well liner or supplied to the well channel/well liner as a gas, liquid or solid.

In one concentric coiled tubing embodiment, the ignition means comprises an electrical spark generator 160 (eg. spark plug) electrically connected by an electric cable to a power supply (generator - not shown) for generating the spark. In another concentric coiled tubing embodiment, the ignition means comprises an electrical heat resistor (eg. glow plug) 160 electrically connected by an electric cable to a power supply (not shown) for electrifying the resistor. The resistor can, for example, generate about 180 kW of heat. For both embodiments, the ignition means further comprises an ignition fuel source (compressed gas or liquid cylinders

162, eg. containing hydrocarbons such as methane) and oxidant source (eg. air compressor 163) for fueling combustion. Ignition fuel is fed to the ignition tool 155 via the inner tube of the coiled tubing 156 and oxidant is fed to the ignition tool 155 via the outer tube of the coiled tubing 156. The electrical spark generator/electrical heat resistor 160 is housed within the ignition tool 155 (or possibly outside the ignition tool 155) and in the path of the mixture of combustible gases (ignition fuel and oxidant) that flow through the ignition tool 155. In a single coiled tubing embodiment, ignition fuel alone can flow through the tube to the ignition tool 155.

In yet another concentric coiled tubing embodiment the ignition means comprises at least one type of ignition chemical and ignition chemical source (eg. compressed gas or liquid cylinders 162). The ignition chemical can be a pyrophoric substance - eg. a liquid such as triethylboron (TEB), a gas such as silane, solids such as phosphorus or alkali metal, a pyrophoric chemical and hydrocarbon mixture such as TEB vaporized in methane, or a pyrophoric chemical and an inert gas such as TEB and nitrogen. The hydrocarbon or inert gas flow can help transport/vaporize the pyrophoric material or slugs/plug flows of the pyrophoric chemical to the ignition tool 155. The ignition means can further comprise an oxidant source (eg. air compressor 163) for fueling ignition and combustion. The ignition chemical specifically reacts with oxidant (air or oxygen) within the well channel or the coal seam itself to ignite the coal seam. The ignition chemical can be specifically released when the ignition tool 155 is at the desired well/well channel location. The ignition chemical can be fed to the ignition tool 155 from cylinders 162 via the inner tube whereas the oxidant can be fed to the ignition tool 155 from the air compressor 163 via the outer tube. In a single coiled tubing embodiment, ignition chemical alone can flow through the tube to the ignition tool 155.

In a single coiled tubing embodiment the ignition means can comprise pure oxygen or substantially pure oxygen (cylinders 162) fed through the tube of the coiled tubing and ignition tool 155. The oxygen ignites the coal seam directly. The ignition means can further comprise an oxidant source (air compressor 163) for fueling combustion.

To generalize, for ignition apparatus comprising single coiled tubing, oxidant injected into the well channel may flow externally of the tube of the coiled tubing. Also for ignition apparatus comprising single coiled tubing, ignition fuel and/or ignition chemical injected into the well channel may flow within the tube. For ignition apparatus comprising concentric tubes, oxidant injected into the well channel may flow within the outer tube (preferably as well as in the well channel itself externally of the outer tube) and ignition fuel/ignition chemical may flow within the inner tube.

If using a single coiled tubing (having a single tube) or concentric coiled tubing (having inner and outer tubes), the (outer) tube can be made of stainless steel or carbon steel. If air is used as the oxidant, the outer tube can be made of carbon steel and the inner tube can be made of copper. If air or oxygen is used as the oxidant, the outer tube can be made of stainless steel and the inner tube can be made of copper or stainless steel.

The ignition tool 155 can be made chiefly of stainless steel or carbon steel. Sacrificial pieces of the ignition tool, such as a blow-out plug (as described later), can be made of heat intolerant materials such as aluminum, plastics material or rubber. The ignition tool or the tool body can have any suitable outer diameter and length. For example, the ignition tool or the tool body can have an outer diameter of about 2 inches, 3 inches or 4 inches, for example. Preferably the ignition tool or the tool body has a diameter of about 2 inches.

The controller 165 (skid) is operable to trigger ignition, including the provision of electrical energy or ignition fuel, oxidant or the release of a combustible ignition chemical. The controller 165 comprises a control cabinet 169. The controller 165 comprises a pipe manifold 171 in fluid communication with the coiled tubing 156 and ignition chemical, ignition fuel and oxidant sources 162, 163.

The controller 165 further comprises trim, non-return and isolation valves, flow measuring devices and pressure relief devices. Such operating devices allow for injection rate measurement and control for oxidant and ignition fuel gases respectively. It also allows purging of the ignition fuel gases with inert gases such as nitrogen. Oxidant / ignition fuel mixture can be adjusted using flow controlling devices, such devices being either pneumatically actuated, manually choked, quarter-turn types or electrically actuated. The controller 165 comprises pressure safety devices, filtration, flow metering devices in addition to isolation valves. Control logic allows the oxidant / ignition fuel gas to flow as per the required settings. In case of power failure or loss of oxidant the control logic slams shut the ignition fuel gas. The controller 165 enables the use of volatile chemicals such as TEB, silane or mixture of any kind.

The controller can maintain the ratio of the oxidant gas and ignition fuel between predetermined limits which are preferably the upper flammability limit and the lower flammability limit for the ignition fuel and works on the basis of the stoichiometric ratio of oxidant to ignition fuel.

The controller is configured to supply power to the electrical ignition device when the fuel ratio is between the lower flammability limit and upper flammability limit. The thermocouple on the ignition tool indicates that no flame is present, and a flame is required to either maintain or initiate combustion at the ignition site.

The supply of power and temperature sensing for the monitoring system are managed through multi-core electrical cable extending within the tube to the ignition tool. The temperature monitoring system indicates via the thermocouple fixed at the ignition tool whether the ignition is successful and further confirms the presence of the flame within the combustion zone of coal seam.

The ignition is sustained by the supply of ignition fuel and oxidant with the fuel gas ratio being controlled from above ground. Appropriate adjustment to the oxidant to fuel ratio is made depending on confirmation of the coal ignition at the coal seam. Preferably the ratio is maintained close to the lower flammability limit of the fuel gas to ensure sufficient oxidant is provided to initiate combustion within the combustion zone. Once ignition has taken place, the combustion gases as well as any volatile gases emanating from the coal seam are pushed out from an end of the well (ie. production well) and routed to a flare. The product gas (syngas) quality is monitored and once the coal in the combustion zone is confirmed as having been ignited and combustion maintained, the ignition fuel to the ignition tool is cut back gradually until only oxidant is provided to the combustion zone. The coiled tubing can then be retracted from the bore hole/well and the supply of oxidant can be increased up to the supply required for full coal gasification production conditions.

Ignition of the coal seam can take place at any predefined ignition points. This enables further re-ignition of the coal seam by simply retracting the ignition tool along the coal seam and reinitiating the ignition process. This can be done either when the combustion process in an earlier combustion zone has been completed or while the underground coal gasification is taking place in other positions along the coal seam. The ability to retract and reignite the coal seam is advantageous in that it has the ability to reduce underground gasification costs by enabling much longer stretches of horizontal bore hole/well channel within the seam to be ignited. This enables the combustion in the coal seam to be supported for a longer time thereby increasing the well production life and amortizing the cost over a longer period of production.

In order to install the ignition apparatus, the ignition tool together with the coiled tubing are inserted into the bore hole/well which is lined with a casing. The casing extends at least to the section of the bore hole/well channel which is substantially horizontal, inclined or vertical within the coal seam. The ignition tool is first fitted to the tip of the coiled tubing together with cables running within the tube/tubes. The ignition tool together with the coiled tubing are inserted into the bore hole/well and positioned at a predefined location or ignition site within the coal seam. The ignition fuel and oxidant are supplied through the coiled tubing and the space/void between the tubing and the bore hole casing at a predefined rate. This rate is determined by the required oxidant to ignition fuel ratio and the heat required to ignite the coal seam. Once the ignition fuel and oxidant have reached the ignition tool, the electrical ignition device is energized to ignite the ignition fuel and oxidant at the ignition tool.

The apparatus allows ignition of the coal seam to take place at any predefined ignition points. This enables further re-ignition of the coal seam by simply retracting the ignition tool along the coal seam and reinitiating the ignition process. This can be done either when the combustion process in an earlier combustion zone has been completed or while the underground coal gasification is taking place in other positions along the coal seam.

Further depictions of various single coiled tubing embodiments are shown in figure 2.

Figure 2 generally depicts parts of ignition apparatuses 110 (110a, b, c) for igniting an underground coal seam 111 from within a well channel 112 (shown encased in a well liner) that extends through the seam 111. Each ignition apparatus 110 comprises an ignition system comprising ignition means and an ignition tool 113 (113a, b, c) for igniting the underground coal seam 111 from within the well channel 112. Each ignition apparatus 110 further comprises a positioning system comprising coiled tubing 114 (114a, b, c) connected to the ignition tool 113 and extendible within the well channel 112 to position the ignition tool 113 at a desired location within the well channel 112. Other components of each apparatus 110 not shown in figure 2 can be gleaned from figure 1.

The positioning system includes coiled tubing 114 comprising a single tube 114 and an end of the tube 114 is connected to an end of the ignition tool 113 either directly or by way of an adaptor. For coiled tubing 114 comprising a single tube 114, oxidant will normally be injected into a well and flow on the outside of the coiled tubing/tube 114 but within the well channel 112.

As explained previously, the ignition apparatuses 110 can have various ignition means.

In figure 2 (a) the ignition means includes an electrical heater (glow plug) 116 and an electrical cable 117 extends from the heater 116 through the tube 114a to the surface to a power controller. Ignition fuel (eg. hydrocarbon, such as methane) is fed from an above ground source through the tube 114a and through the ignition tool 113a to the electrical heater 116 for ignition and for further combustion with the oxidant within the well channel 112 so as to ignite the coal seam 111.

In figure 2 (b) the ignition means includes an ignition chemical 117 (eg. pyrophoric gas) that is fed from an above ground source through the tube 114b and completely through the ignition tool 113b where upon mixing with the oxidant it ignites the coal seam 111.

In figure 2 (c) the ignition means includes an electrical heater 118 and an electrical cable 119 extends from the heater 118 through the tube 114c to the surface to a power controller. When energised, the heater 118 ignites the oxidant and coal seam 111. In this embodiment, no gas flow occurs through the tube 114c. Rather, the tube 114c merely conveys the electrical cable 119.

Figure 3 generally depicts parts of ignition apparatuses 120 (120a, b, c) for igniting an underground coal seam 121 from within a well channel 122 (shown encased in a well liner) that extends through the seam 121. Each ignition apparatus 120 comprises an ignition system comprising ignition means and an ignition tool 123 (123a, b, c) for igniting the underground coal seam 121 from within the well channel 122. Each ignition apparatus 120 further comprises a positioning system comprising coiled tubing 124 (124a, b, c) connected to the ignition tool 123 and extendible within the well channel 122 to position the ignition tool 123 at a desired location within the well channel 122. Other components of each apparatus 120 can be gleaned from figure 1.

The positioning system includes coiled tubing 124 comprising dual concentrically arranged tubes and an end of each tube is connected to an end of the ignition tool 123 either directly or by way of an adaptor. An inner tube 125 (125a, b, c) extends within an outer tube 126 (126a, b, c).

For concentric coiled tubing 124, ignition fuel (such as the hydrocarbon gas methane) and/or ignition chemical (such as pyrophoric gas) is normally fed from an above ground source through the inner tube 125 and through the ignition tool 123. Oxidant (such as air or oxygen) is normally fed from an above ground source through the outer tube 126 and through the ignition tool 123. Oxidant can also be fed from an above ground source externally of the outer tube 126 but within the well channel 122.

As explained previously, the ignition apparatuses 120 can have various ignition means.

In figure 3 (a) the ignition means includes an ignition device 130a in the nature of an electrical heater (glow plug) or spark generator (spark plug) and an electrical cable 131 extends from the device 130 through the outer tube 126a to a power controller. Ignition fuel is fed from an above ground source through the inner tube 125a and to an inlet pipe 133 of the ignition device 130. Oxidant is fed from an above ground source through the outer tube 126a to the ignition device 130 whereupon it mixes with the ignition fuel. After mixing, igniting and passing through a diffuser plate 132 of the ignition tool 123a, the flame ignites the coal seam 121.

In figure 3 (b) the ignition means includes an ignition chemical 135 (eg. pyrophoric gas) that is fed from an above ground source through the inner tube 125b and to an inlet pipe 135 of the ignition tool 123b. Oxidant is fed from an above ground source through the outer tube 126b (as well as within the well externally of the outer tube 126b) to the ignition tool 123b. Upon leaving the tool 123b, the oxidant mixes with the ignition chemical and ignites the coal seam 121.

In figure 3 (c) the ignition means includes an ignition device 140 in the nature of an electrical heater (glow plug) or spark generator (spark plug) and an electrical cable 141 extends from the device 140 through the outer tube 126c to a power controller. Ignition fuel is fed from an above ground source through the inner tube 125c and out a spray nozzle 141 to the ignition device 140. Oxidant is fed from an above ground source through the outer tube 126c to the ignition device 140. Prior to being ignited by the ignition device 140, the gases pass through a mixing chamber 142 containing a Venturi device 143 and are thoroughly mixed. After mixing, igniting and passing through a diffuser plate 147 of the ignition tool 123c, the flame is exposed to a further source of oxidant and ignites the coal seam 121.

Yet further examples of ignition apparatuses 200 (200a, b, c, d) comprising concentrically arranged tubes/coiled tubing 201 (201a, b, c, d) connected to ignition tools 202 (202a, b, c, d) are shown in figure 4. In each case the ignition means includes an electrical ignition device 203 (203a, b, c, d) in the nature of an electrical heater (glow plug) or spark generator (spark plug) and an electrical cable 204 (204a, b, c, d) extends from the device 203 through an outer tube 205 (205a, b, c, d) to the surface to a power controller. Ignition fuel or ignition chemical (gas) is fed from an above ground source through an inner tube 206 (206a, b, c, d) and to the ignition device 203 via an inlet pipe 218 (218a, b, c, d) of the ignition tool 202. Oxidant (gas) is fed from an above ground source through the outer tube 205 to the ignition device 203.

Each ignition apparatus 200 also has a sensor/thermocouple 210 (210a, b, c, d), a cable of which extends through the outer tube 205. Although not completely labeled, each ignition tool 202 comprises various tool body pieces that are screwed to one another and further welded to the coiled tubing 201. Body piece 219 (219a, b, c, d) is a coiled tubing adapter.

Prior to being ignited by the ignition device 203, the gases pass through various types of mixing chambers 211 (211a, b, c, d). The ignition tool 202a of figure 4 (a) has a mixing chamber 211a containing a spiral baffle or baffles 213. The ignition tool 202b of figure 4 (b) has a mixing chamber 211b containing a diffuser plate 214. The ignition tool 202c of figure 4 (c) has a mixing chamber 211c containing a Venturi device 216. The ignition tool 202d of figure 4 (d) has a mixing chamber 211d containing a diffuser plate 217 and mixing is further assisted in that an inlet pipe 218 of the ignition tool 202d ends with a spray nozzle.

After mixing, igniting and exiting the ignition tool 202, the flame is exposed to a further source of oxidant and ignites the coal seam.

Yet further examples of ignition apparatuses comprising single tubes/single coiled tubing connected to ignition tools are shown in figure 5-7.

Referring now to figure 5, there is shown an ignition apparatus 301 for igniting an underground coal seam 302. The ignition apparatus 301 comprises an ignition system comprising ignition means and an ignition tool 304 for igniting the underground coal seam 302 from within the well channel 303. The ignition apparatus 301 further comprises a positioning system comprising coiled tubing 305 connected to the ignition tool 304 and extendible within the well channel 303 to position the ignition tool 304 at a desired location within the well channel 303. The ignition apparatus 301 can have other components as generally shown in figure 1.

The coiled tubing 305 comprises a single tube 306 (stainless steel or carbon steel) and an end of the tube 306 is threaded 307. The coiled tubing 305 further comprises heat-exchange fins 310 extending from the tube 306. These fins 310 keep the tube 306 interior cool (to protect the electrical cable 311 of the ignition means that extends through the tube 306). These fins 310 also help centralise the ignition tool 304 within the well channel 303.

The ignition tool 304 includes a tool body 308 having an inlet end 309 that is threaded and connected to the threaded end 307 of the tube 306. This connection need not be a threaded one. Alternatively, the tube 306 and body 308 could be welded together. The body 308 is made of high melting point and oxidation resistant metal such as stainless steel, inconel, monel or hastelloy.

The ignition means comprises an electrical ignition device 312 electrically connected to an above-ground power supply (not shown) with the cable 311. The device 312 includes an electrical heating element 313 wound around a non-conductive (ceramic) core 314. The device 312 includes two non-conductive (ceramic) spacers 315, 316 that position the heating element 313 within the body 308. Wires (not labeled) of the heating element 313 extend through spacer 315 and contact the cable 311.

The ignition tool 304 includes a flow diverter protrusion 317 that diverts the flow of oxidant away from a heating element 313 end of the body 308, as shown by the arrows. The spacer 313 shields the electrical cable 311 and prevents it from melting and being destroyed.

The ignition apparatus 301 further comprises a thermocouple 319 that extends from within the tube 306 and part way into the tool body 308. The thermocouple 319 is used to determine whether heating element 313 reaches its intended temperature as well as to keep a watch on the temperature of the cable 311 so that it does not get destroyed.

A trip condition (of the power supply to the heating element 313) can be configured at the surface once the thermocouple 319 at the electrical cable 311 indicates the electrical cable 311 is operating above its design temperature. The electrical cable 311 is protected by having air flow around the tube 306. This is further enhanced by the heat-exchange fins 310 that provide a bigger surface area for cooling with the addition of a conductive paste to improve contact between the tube 306 and electrical cable 311.

In use, the heating element 313 heats up the body 308 and radiates this heat 320 onto the coal seam surface 302 until the coal reaches its auto-ignition temperature in the presence of oxidant and results in the combustion of the coal. The flow diverter 317 diverts the flow of oxidant away from the heating element 313 containing end of the body 308, as shown by the arrows and therefore prevents excessive cooling of the heating element 313 containing end of the body 308.

Referring now to figure 6, there is shown another type of ignition apparatus 331. The ignition apparatus 331 comprises an ignition system comprising ignition means and an ignition tool 334 for igniting the underground coal seam 332. The ignition apparatus 331 further comprises a positioning system comprising coiled tubing 335 connected to the ignition tool 334 and extendible within the well channel 333 to position the ignition tool 334 at a desired location within the well channel 33. The ignition apparatus 331 can have other components as generally shown in figure 1.

The coiled tubing 335 comprising a single tube 336 (stainless steel or carbon steel) and an end of the tube 336 is threaded 337. The coiled tubing 335 further comprises positioning fins 340 to help centralise the ignition tool 334 within the well channel 333.

The coiled tubing 336 further comprises a non-return/check valve 345 (ball and spring, spring loaded flapper valve or the like) fitted within the tube 336, to prevent product gas/syngas reverse flow up the tube 336 when removing the coiled tubing 335 from the well channel 333.

The ignition tool 334 includes a body 338 having an inlet end 339 (having inlet 339) that is threaded and connected to the threaded end 337 of the tube 336 in a fluid-tight manner. This inlet end 339 connection need not be a threaded one. Alternatively, the tube 336 and body 338 could be welded together in a fluid-tight manner.

The tool body 338 further has an outlet end 341 (having outlet 341). The outlet 341 is of reduced diameter relative to the inlet 339. The outlet end 341 of the body 338 is in the form of a blow-out plug 342 that is connected to a remainder of the body 338. The blow-out plug 342 has a stem around which extends an o-ring 343 and the o-ring 343 friction fits within the outlet 341.

The blow-out plug 342 can be made of aluminium or can alternatively be fabricated from durable rubber or plastic. This blow-out plug 342 material will be consumed within the gasifier due to the high temperatures present. The tool body 338 is chiefly made of high melting point and oxidation resistant metal such as stainless steel, inconel, monel or hastelloy.

The tube 336 can convey ignition chemical to the inlet 339 of the ignition tool 334 and the tool body 338 provides a passage 344 for conveying ignition chemical from the tube 336 to the outlet 341.

The ignition apparatus 331 can further include a thermocouple attached to the tube 336 and/or tool body 338 (not shown). Although not shown, the ignition apparatus 331 can further comprise a source of oxidant as mentioned in respect of figure 1.

Although not shown, the ignition apparatus 331 can further comprise a source of ignition chemical connected to the tube 336 in a fluid-tight manner. The ignition chemical can be a pyrophoric chemical (eg. a liquid such as TEB, a gas such as silane, solids such as phosphorus or alkali metal), or a pyrophoric chemical and hydrocarbon mixture (e.g. TEB vaporized in methane), or a pyrophoric chemical and an inert gas (e.g. TEB and nitrogen). The hydrocarbon or inert gas flow 347 can help transport/vaporize the pyrophoric chemical or slugs/plug flows 346 of the pyrophoric chemical to the ignition tool 334.

Although not shown, the ignition apparatus 331 comprises a controller operable to trigger ignition. The controller controls the flow of ignition chemical etc. into the tube 335 and well as the flow of oxidant into the well – as generally described for figure 1.

In use, the pyrophoric chemical provides the heat for ignition or alternatively the initial flame for the hydrocarbon material mixed with it or following it in a plug flow 346 to sustain the flame until the coal is ignited. The inert gas 347 can be used to either transport the pyrophoric chemical 346 through the tube 336 or can be used to inert the tube 336 before starting the ignition process and after ignition before the coiled tubing 335 is removed from the well channel 333.

Injected oxidant around the ignition tool 334 provides the oxidant to sustain the ignition when the oxidant and pyrophoric chemical mixture come into contact with each other at the outlet end 341 of the tool body 338. The heat generated by the oxidant and pyrophoric chemical / mixture exothermic chemical reaction provides heat to the coal surface 332 to heat the coal up until the coal combusts at temperatures exceeding the auto-ignition temperature of the coal.

The reduced diameter outlet 341 enables a higher exit velocity of the pyrophoric chemical / mixture to project the flame away from the coiled tubing 335 and prevent excessive heat at the body outlet end 341.

The ignition tool 334 can be engineered with a finned profile on an outer circumference of the body 338 so as to provide a larger heat-exchange surface for enhanced cooling of the body 338 from the injection oxidant flow down the injection well annulus, around the ignition tool 334.

The blow-out plug 342 prevents coal dust, drilling mud or water from entering the ignition tool 334 when inserted down hole and past the well casing 348. The blow-out plug 342 is pushed out of engagement with the outlet 341 by the pressurized flow of the pyrophoric chemical/mixture or inert gas.

Referring now to figure 7, there is shown an ignition apparatus 351 for igniting an underground coal seam 352 from within a well channel 353 that extends through the seam 352. The ignition apparatus 351 comprises an ignition system comprising ignition means and an ignition tool 354 for igniting the underground coal seam 352. The ignition apparatus 351 further comprises a positioning system comprising coiled tubing 355 connected to the ignition tool 354 and extendible within the well channel 353 to position the ignition tool 354 at a desired location within the well channel 353. The ignition apparatus 351 can have other components as generally shown in figure 1.

The positioning system includes coiled tubing 355 comprising a single tube 356 (stainless steel or carbon steel) and an end of the tube 356 is threaded 357.

The ignition tool 354 includes a body 358 having an inlet end 359 (having inlet 359) that is also threaded and connected to the threaded end 357 of the tube 356 in a fluid-tight manner. This inlet end connection need not be a threaded one.

The tool body 358 further has an outlet end 361 (having outlet 361) that extends to the inlet 359 by way of a passage 364. The outlet end 361 of the body 358 is in the form of a blow-out plug 362 that is connected to a remainder of the body 358. The blow-out plug 362 has a stem around which extends an o-ring 363 and o-ring 363 friction fits with the outlet 361, as described for figure 6.

The tube 356 can convey ignition fuel 372 such as methane to the inlet 359 of the ignition tool 354 and the passage 364 conveying the ignition fuel 372 from the inlet 359 to the outlet 361.

The ignition tool 354 comprises a gas mixing (turbulence-creating) chamber 370 located within the body 358 within which the oxidant and ignition fuel mix. The body 358 provides a wall of the chamber 370 and a diffuser plate 371 extending across the body 358 defines a downstream end of the chamber 370. The mixing chamber 370 includes an upstream Venturi device 372. The ignition tool 354 comprises oxidant intakes 373 in the body 358 through which oxidant may be drawn by way of the pressure differential caused by the Venturi device 372.

The ignition tool 354 further comprises a non-return/check valve 365 (ball and spring, spring loaded flapper valve or the like) fitted within the passage 364 to prevent ignition fuel and product gas (syngas) reverse flow up the tube 356.

The body 358 comprises four body pieces that are connectable end to end, such that the ignition tool 354 can be readily assembled from its components. Three of the body pieces are threaded and the fourth is the friction-fitted blow-out plug 362.

The ignition means comprises an electrical ignition device 366 electrically connected to an above-ground power supply (not shown) with cable 367 that, when electrified, heats up or sparks. The ignition device 366 can comprise dual glow plugs, each having a heating element located at a respective tip of a ceramic body. Alternatively, the ignition device 366 could be a spark generator (spark plug) that generates sparks when electrified. However, an advantage of a glow plug-type device is that lower voltage is needed and there is a considerable drop in voltage over the distance from above ground to the coal seam.

The electrical ignition device 366 is connected to an external surface of the tool body 358. The electrical cable 367 extends from the electrical ignition device 366 along the body 358, through a fluid-tight port 374 into the passage 364 and further through the tube 356 to the power supply.

The ignition apparatus 351 has a thermocouple 369 attached the external surface of the body 358 for measuring the temperature at the outlet 361. A signal cable (not labelled) of the thermocouple 369 extends through the port 374 and further through the tube 356. The thermocouple 369 is used to determine whether the ignition tool 354 reaches the correct temperature. Compression fittings (not shown) around the cable 367 and the thermocouple cable tighten the electrical cables 367 and provide port 374 with a pressure-tight seal.

The ignition tool 354 further comprises positioning fins 360 extending from the body 358. These fins 360 protect the electrical/signal cables 367 and the ignition device 366 from damage when running the tool 354 down hole. These fins 360 help centralise the tool body 358 within the well channel 353.

Although not shown, the ignition apparatus can further comprise a source of oxidant as described for figure 1. Although not shown, the ignition apparatus 351 comprises a controller operable to trigger ignition, as generally described for figure 1.

In use, ignition fuel (hydrocarbon gas, preferably methane) is fed through the tube 356 to the tool inlet 359, following which the gas flows through the non-return check valve 365 and further through the Venturi device 372. The Venturi device 372 is sized to create a pressure differential required such that oxidant surrounding the ignition tool 354 is drawn into the body's passage 364 to mix with the ignition fuel in the mixing chamber 370 downstream of the Venturi device 372. The higher the ignition fuel flow, the greater the pressure drop across the Venturi device 372, the more oxidant is sucked in to achieve the stoichiometric ratio of oxidant to ignition fuel (in the range of 5:1 to 20:1). From here the ignition fuel and oxidant mixture flows through the diffuser plate 371 where it is ignited by the ignition device 366 to produce a flame so as to combust the coal seam 352.

Referring now to figure 8, there is shown an ignition apparatus 381 for igniting an underground coal seam 382 from within a well channel 383 that extends through the seam 382. The ignition apparatus 381 comprises an ignition system comprising ignition means and an ignition tool 384 for igniting the underground coal seam 382 from within the well channel 383. The ignition apparatus 381 further comprises a positioning system comprising coiled tubing 385 connected to the ignition tool 384 and extendible within the well channel 383 to position the ignition tool 384 at a desired location within the well channel 383. The ignition apparatus 381 can have other components as generally shown in figure 1.

The positioning system includes coiled tubing 385 comprising a single tube 386 (stainless steel or carbon steel) and an end of the tube 386 is threaded 387. The ignition tool 384 includes a body 388 having an inlet end 389 (having inlet 389) that is also threaded and connected to the threaded end 387 of the tube 386 in a fluid-tight manner. This inlet end connection need not be a threaded one.

The tool body 388 further has an outlet end 391 (outlet 391). The outlet end 391 of the body 388 is in the form of a blow-out plug 392 that is connected to a remainder of the body 388, as described for the earlier figures.

The tube 386 can convey a pneumatic gas such as air 393 to the inlet 389 of the ignition tool 384 and the tool body 388 has a passage 394 for conveying the pneumatic gas 393 from the tube 386 to the outlet 391.

The ignition means comprises a turbine coupled with a transformer 397 located within the body 388 through which the pneumatic gas flows. The ignition means further comprises a pneumatic air supply, such as an air compressor, connected to the tube 386. The ignition means also comprises an electrical ignition device 400 electrically coupled to the transformer 397. When electrified by the transformer 397, the device 400 heats up.

The electrical heating device 400 includes an electrical heating element 401 wound around a non-conductive piece of the tool body 388. The ignition tool 384 comprises protective positioning fins 402, 403 that extend from the body 338.

The ignition tool 384 further comprises a non-return/check valve 395 (Baal and spring type, cone and spring type, flapper with spring type or the like) fitted within the passage 394 upstream of the turbine and transformer 384 to prevent pneumatic gas and product gas (syngas) reverse flow up the tube 386.

The body 388 comprises body pieces that are connectable end to end, such that the ignition tool 384 can be readily assembled from its components. The body pieces are threaded, apart from the friction-fitted blow-out plug 392.

Although not shown, the ignition apparatus 381 can comprise a thermocouple for monitoring the temperature adjacent the outlet 391. Although not shown, the ignition apparatus can further comprise a source of oxidant.

In use, pneumatic gas 393 such as air is fed through the tube 386 and check valve 395 and into the turbine and transformer 384 to generate electrical power to energise the heating element 400 so as to ignite the coal seam 382. The air drives the turbine 384 to generate electrical current, which can then be altered to higher voltage by the transformer 387.

The remainder of the air flows out of the body outlet 391 and into the well channel 383 and cools the outlet 391.

The heating element 401 is fitted on the outside of the tool body 388 and can be a separate threaded piece if it is deemed disposable, since the heating element 401 is installed on the outside of the tool body 388.

Protective fins 402, 403 shield the heating element 401 from damage. The heating element 401 can be coated in a wax layer to protect it from moisture when being run down hole. Alternatively, a burn-away sheath can be installed to protect against moisture.

The heating element 401 will heat up the coal seam 382 to above its auto-ignition temperature and as a result ignite the coal in the presence of the oxidant flow around the tool 384.

Referring now to figure 9, there is shown an ignition tool 22 of an ignition apparatus, like that of figure 5.

The ignition tool 22 includes a tool body 23 having an inlet end 24 (for a power cable 29) welded to an end of a tube of single coiled tubing 21.

Ignition means of the ignition apparatus comprises an electrical ignition device 25 electrically connected to an above-ground power supply (not shown) with a power cable 29. The device 25 includes a series of electrical heating elements 26 spaced around a non-conductive core 27. Spacers 30, 31 are positioned each end of the core 27.

In use, the heating elements 26 heat up the body 23 and the body radiates this heat onto the coal seam surface until the coal reaches its auto-ignition temperature in the presence of oxidant and results in the combustion of the coal.

Referring now to figure 10 there is shown part of an ignition apparatus 1 for igniting an underground coal seam. The ignition apparatus 1 has an ignition tool 2 and concentric coiled tubing 3 that is very similar to that shown in figure 3(c). Other non-illustrated components of the ignition apparatus 1 are as generally described for figure 1.

The ignition tool 2 comprises a body 4, an ignition device 5, an ignition device support 6, and a mixing chamber 7.

The ignition tool 2 has separate inlets for oxidant 8 and ignition fuel 9 at one end of the body 4 that is connected to concentric tubes 10, 11 of the coiled tubing 3, and an outlet 12 for ignited fuel at an opposing end of the body 4.

The body 4 comprises various body pieces (not labeled) that are connectable end to end, such that the ignition tool 2 can be readily assembled from its components.

The outlet end 12 of the body is tapered and in the form of a blow-out plug 25 (essentially as described earlier). The inlet end 8, 9 of the body 4 is welded to the coiled tubing 3.

The ignition device 5 is an electrical heat resistor electrically coupled by way of a cable 26 to a power source that, when electrified, heats due to its electrical resistance. The ignition device 5 comprises dual glow plugs 13, each having a heating element located at a respective tip of a ceramic body. The glow plugs can, for example, generate about 180 kW of heat. Alternatively, the ignition device 5 could equally be a spark generator that generates sparks when electrified. The electric cable 26 extends from the power source to the ignition device 5 through the outer tube 10.

The ignition device support 6 comprises a spacer sleeve. This support 6 fits snugly within the body 4. The ceramic body of the ignition device 5 is supported by and extends from within the sleeve 6 and further through openings in a diffuser plate 15 that extends across the body 4, such the glow plug tip heating elements are located immediately adjacent the outlet 12 of the body 4.

The ignition tool 2 comprises a gas mixing (turbulence-creating) chamber 7 located within the body 4 within which the oxidant and the ignition fuel mix. The body 4 provides a wall of the chamber 7 and the diffuser plate 15 defines a downstream end of the chamber 7. The mixing chamber 7 includes a Venturi device 17 for creating back pressure. The Venturi device 17 is in the form of a cylindrical insert that snugly fits within the body 4.

The ignition apparatus 1 further comprises a temperature sensor/thermocouple 18 located within the body 4 adjacent the ignition device 5. An electrical cable of the thermocouple 18 extends within the outer tube 10.

The inner tube 11 feeds ignition fuel such as methane, propane, butane or mixtures thereof (or another type of volatile hydrocarbon gas) to the mixing chamber 7. The outer tube 10 feeds oxidant such as air or oxygen-enriched air or substantially pure oxygen (20 to approximately 100% oxygen) also to the mixing chamber 7.

The oxygen and ignition fuel first contact one another within the mixing chamber 7. The Venturi device 17 ensures that these gases mix prior to traveling through the spacer sleeve 6 and diffuser plate 15 to the heating elements of the glow plugs. When electrified, the heating elements cause the gas mixture to ignite and the ignited gas mixture then exits the body 4 via the outlet 12.

Referring now to figure 11, there is shown part of an ignition apparatus for igniting an underground coal seam. The ignition apparatus has an ignition tool 30 and concentric coiled tubing (not shown) that is very similar to that shown in figure 3(b). Other non-illustrated components of the ignition apparatus are as generally described for figures 1 and 3(b).

The ignition apparatus comprises an ignition system comprising ignition means and the ignition tool 30 for igniting the underground coal seam from within the well channel. The ignition apparatus comprises a thermocouple 42 for monitoring temperature. Although not shown, the ignition apparatus can further comprise a source of oxidant and ignition chemical.

The coiled tubing comprises dual concentrically arranged tubes and an end of each tube is connected to the inlet end of the ignition tool 30 either directly or by way of an adaptor (but usually by welding). An inner tube extends within the outer tube.

A cable of the thermocouple 42 together with an electrical cable 41 (but non-operational in this embodiment) extend through the outer tube.

The ignition tool 31 has a body 32 having an inlet end 33 and an outlet end 34. The inlet end 33 has an inlet pipe 35 for receiving ignition chemical and a second inlet 36 adjacent the inlet pipe 35 for receiving oxidant. The outlet end 34 of the body 32 is in the form of a blow-off cap 37 that, when removed, exposes pipe 35 to a well channel.

The ignition means includes an ignition chemical, eg. pyrophoric gas, (and possibly ignition fuel, eg. methane) that is fed from an above ground source through the inner tube which is further fed to pipe 35. Oxidant is fed from an above ground source through the outer tube (as well as within the well externally of the outer tube 33) and further to the inlet 36 of the ignition tool 30.

The ignition tool comprises an o-ring/sleeve 43 that extends between the body 32 and pipe 35, and keeps the pipe 35 centralised.

Oxidant flowing within the body 32 from the inlet 36 exits via an outlet 50 created when the blow-off cap 34 is removed. Ignition chemical flowing within the pipe 35 exits via an outlet

51 created when the blow-off cap 34 is removed. It is at this point that the oxidant mixes with the ignition chemical and ignites the coal seam.

After the cap 34 has been removed from a remainder of the body 32, the ignition tool 30 resembles the tool shown in figure 3(b).

It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or figures. All of these different combinations constitute various alternative aspects of the invention.

As used herein, except where the context requires otherwise, the term "comprise" and variations of the term, such as "comprising", "comprises" and "comprised", are not intended to exclude further additives, components, integers or steps.

Reference to any prior art in the specification is not, and should not be taken as, an acknowledgment or any form of suggestion that this prior art forms part of the common general knowledge in Australia or any other jurisdiction.

Claims

1. An ignition apparatus for igniting an underground coal seam from within a well channel that extends through the seam, said apparatus comprising:

an ignition system comprising ignition means and an ignition tool for igniting the underground coal seam from within the well channel; and

a positioning system comprising coiled tubing connected to the ignition tool and extendible within the well channel to position the ignition tool at a desired location within the well channel.

2. The ignition apparatus of claim 1, wherein the ignition means comprises an electrical spark generator and a power supply for generating the spark.

3. The ignition apparatus of claim 1, wherein the ignition means comprises an electrical heat resistor and a power supply for electrifying the resistor.

4. The ignition apparatus of claim 1, wherein the ignition means comprises at least one type of ignition chemical, such as a pyrophoric substance.

5. The ignition apparatus of claim 1, wherein the ignition means comprises pure oxygen or substantially pure oxygen that ignites the coal seam directly.

6. The ignition apparatus of any one of the preceding claims, wherein the ignition tool is connected to the coiled tubing in a fluid-tight manner.

7. The ignition apparatus of claim 6, wherein the ignition tool is connected to the coiled tubing by way of a screw thread or weld.

8. The ignition apparatus of any one of the preceding claims, wherein the ignition tool comprises a tool body having an inlet end connected to the coiled tubing.

9. The ignition apparatus of any one of the preceding claims, wherein the coiled tubing comprises a single tube connected to the tool body.

10. The ignition apparatus of any one of claims 1 to 9, wherein the coiled tubing comprises an inner tube extending within an outer tube, and one or both of the inner and outer tubes are connected to the tool body.

11. The ignition apparatus of any one of the preceding claims, wherein the positioning system further comprises a spool from which the coiled tubing is unspooled.

12. The ignition apparatus of claim 9, wherein the ignition means comprises an oxidant source and oxidant is fed to the ignition tool externally of the single tube.

13. The ignition apparatus of claim 11 or claim 12, wherein the ignition means comprises an ignition fuel source and/or ignition chemical source, and ignition fuel and/or ignition chemical is fed to the ignition tool via the single tube.

14. The ignition apparatus of claim 10, wherein the ignition means comprises an oxidant source and oxidant is fed to the ignition tool via the outer tube.

15. The ignition apparatus of claim 10 or claim 11, wherein the ignition means comprises an ignition fuel source and/or ignition chemical source, and ignition fuel and/or ignition chemical is fed to the ignition tool via the inner tube.

16. The ignition apparatus of any one of the preceding claims, wherein the coiled tubing comprises heat-exchange formations.

17. The ignition apparatus of any one of the preceding claims, wherein the coiled tubing comprises positioners that help position the ignition tool within the well channel.

18. The ignition apparatus of any one of the preceding claims, wherein the ignition tool comprises at least one inlet that is in fluid communication with at least one tube of the coiled tubing.

19. The ignition apparatus of claim 18, wherein the ignition tool comprises at least one outlet that is in fluid communication with the at least one inlet.

20. The ignition apparatus of claim 19, wherein the ignition tool comprises a detachable cap or plug covering the outlet.

21. The ignition apparatus of any one of the preceding claims, wherein the ignition tool comprises a mixing chamber within which ignition fuel, oxidant and/or ignition chemical can mix.

22. The ignition apparatus of claim 21, wherein the mixing chamber contains a Venturi device and/or at least one baffle.

23. The ignition apparatus of claim 19 or claim 20, wherein the ignition tool comprises a gas diffuser adjacent the at least one outlet.

24. The ignition apparatus of any one of the preceding claims, wherein the ignition tool comprises flow deflectors.

25. The ignition apparatus of any one of the preceding claims, wherein the ignition tool comprises heat-exchange formations.

26. The ignition apparatus of any one of the preceding claims, wherein the coiled tubing comprises heat-exchange formations.

27. The ignition apparatus of any one of the preceding claims further comprising one or more sensors for sensing and reporting conditions in the ignition tool, adjacent the ignition tool, well channel and/or adjacent coal seam.

28. The ignition apparatus of any one of the preceding claims further comprising a thermocouple for sensing the temperature in the well channel, coal seam or ignition tool.

29. The ignition apparatus of any one of the preceding claims further comprising a controller operable to trigger ignition, including the provision of electrical energy or ignition fuel, oxidant or the release of a combustible ignition chemical.

30. The ignition apparatus of claim 29, wherein the controller comprises a pipe manifold in fluid communication with the coiled tubing and ignition chemical, ignition fuel and/or oxidant sources.

31. The ignition apparatus of claim 29 or 30, wherein the controller is operable remotely from the ignition tool to (1) control the ignition fuel/ignition chemical and oxidant ratio of the mixture, (2) monitor combustion of the mixture, and (3) control the supply of electrical energy to the ignition.

32. A method of igniting an underground coal seam from within a well channel that extends through the seam, said method comprising the steps of:

(1) moving an ignition tool of an ignition apparatus into the well channel; and

(2) igniting the underground coal seam at one or more locations within the well channel using the ignition tool,

wherein the ignition apparatus comprises:

an ignition system comprising ignition means and the ignition tool; and

a positioning system comprising coiled tubing connected to the ignition tool and extendible within the well channel to position the ignition tool at a said location within the well channel.

33. The method of claim 32, wherein the ignition apparatus is as defined in any one of claims 1 to 31.

34. The method of claim 32 or claim 33 further comprising a step of maintaining oxidant in the well channel at a level to support the combustion.

35. The method of any one of claims 32 to 34 further comprising a step of repositioning the ignition tool to a new ignition site in the well channel.

36. An ignition system comprising ignition means and an ignition tool for igniting an underground coal seam.

37. The ignition system of claim 36, having features as described in any one of claims 1 to 31.

38. Ignition means for igniting an underground coal seam.

39. The ignition means of claim 38, having features as described in any one of claims 1 to 31.

40. An ignition tool for igniting an underground coal seam.

41. The ignition tool of claim 40, having features as described in any one of claims 1 to 31.

42. A positioning system comprising coiled tubing extendible within a well channel to position an ignition tool at a desired location within the well channel.

43. The positioning system of claim 42, having features as described in any one of claims 1 to 31.

44. An ignition system as defined in claim 36, ignition means as defined in claim 38, an ignition tool for igniting an underground coal seam as defined in claim 40, or a positioning system as defined in claim 42, and substantially as hereinbefore described in the written description including as shown in the figures.

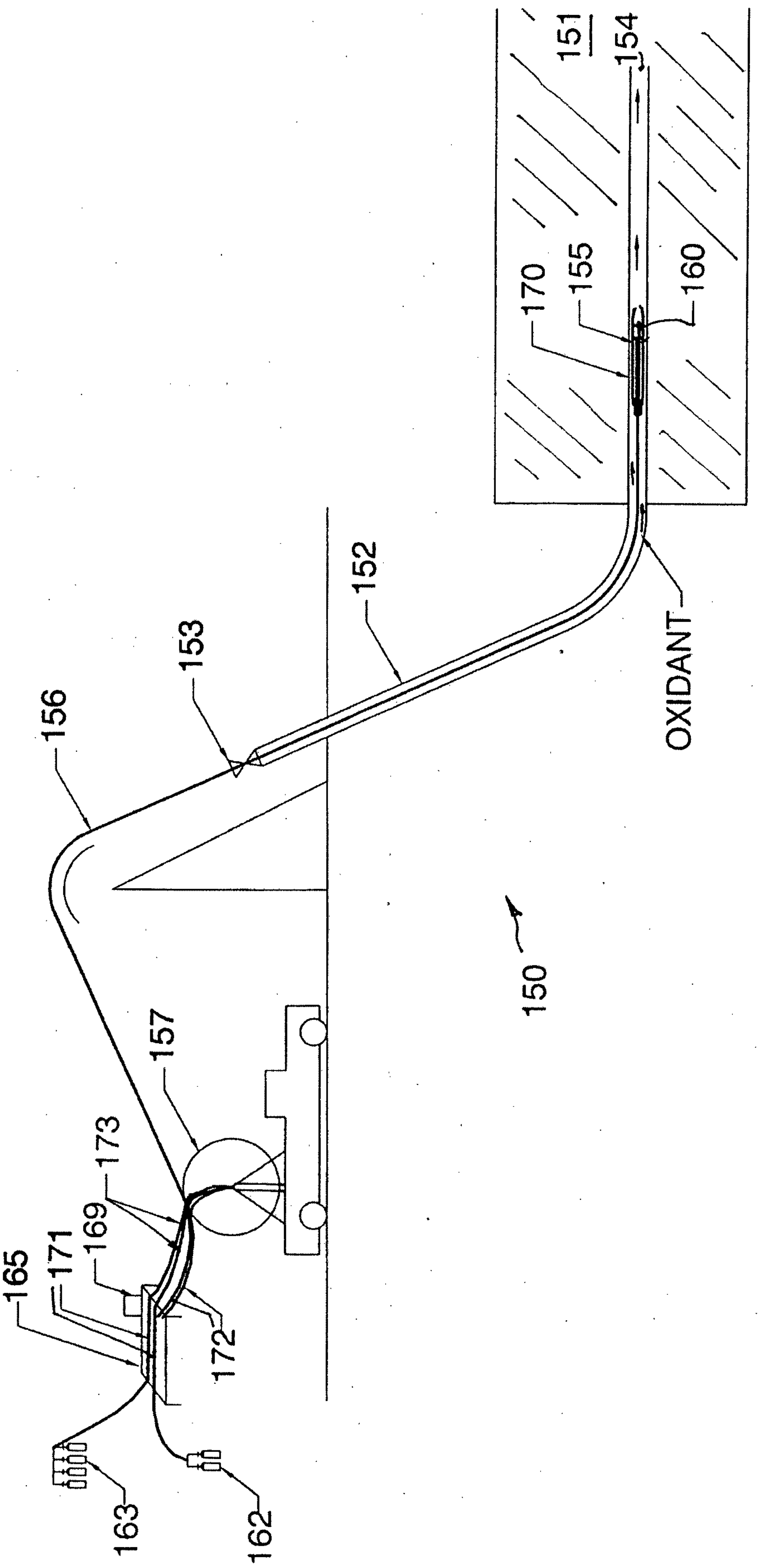
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FIG. 1

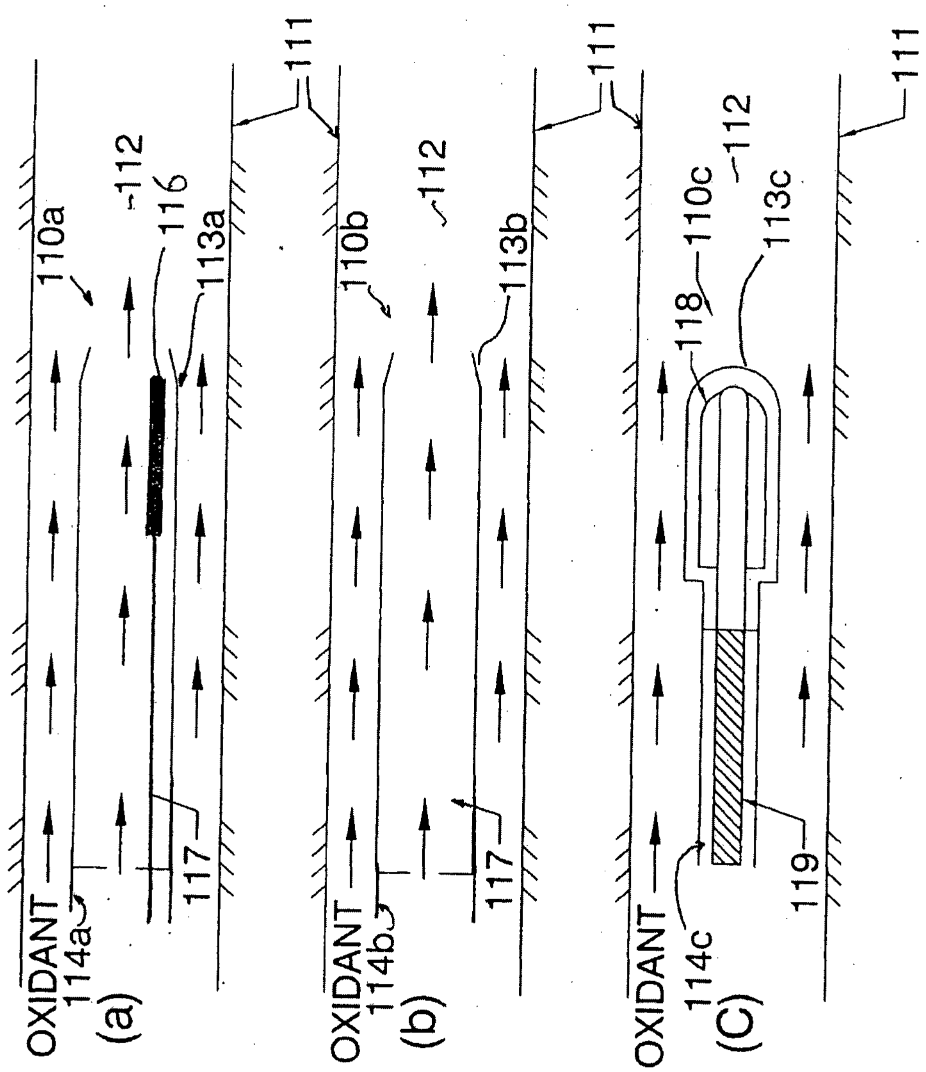
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FIG. 2

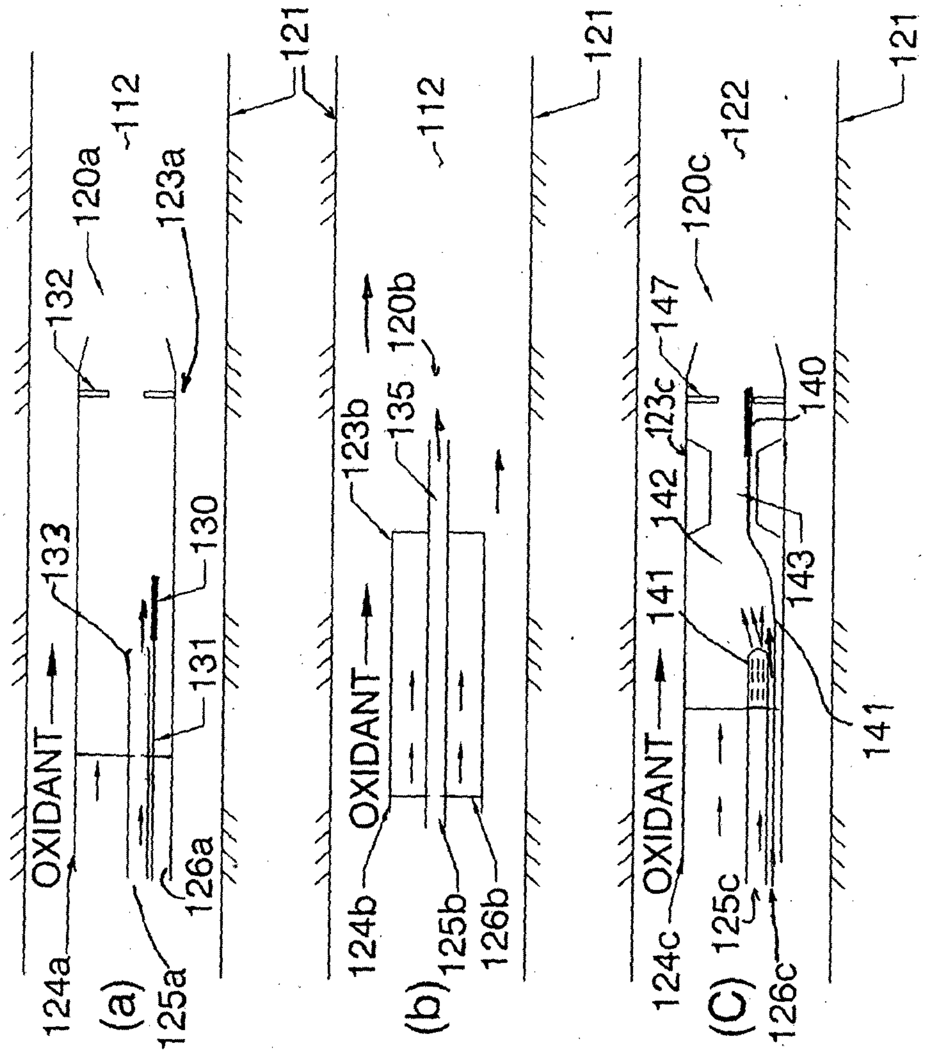
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FIG. 3

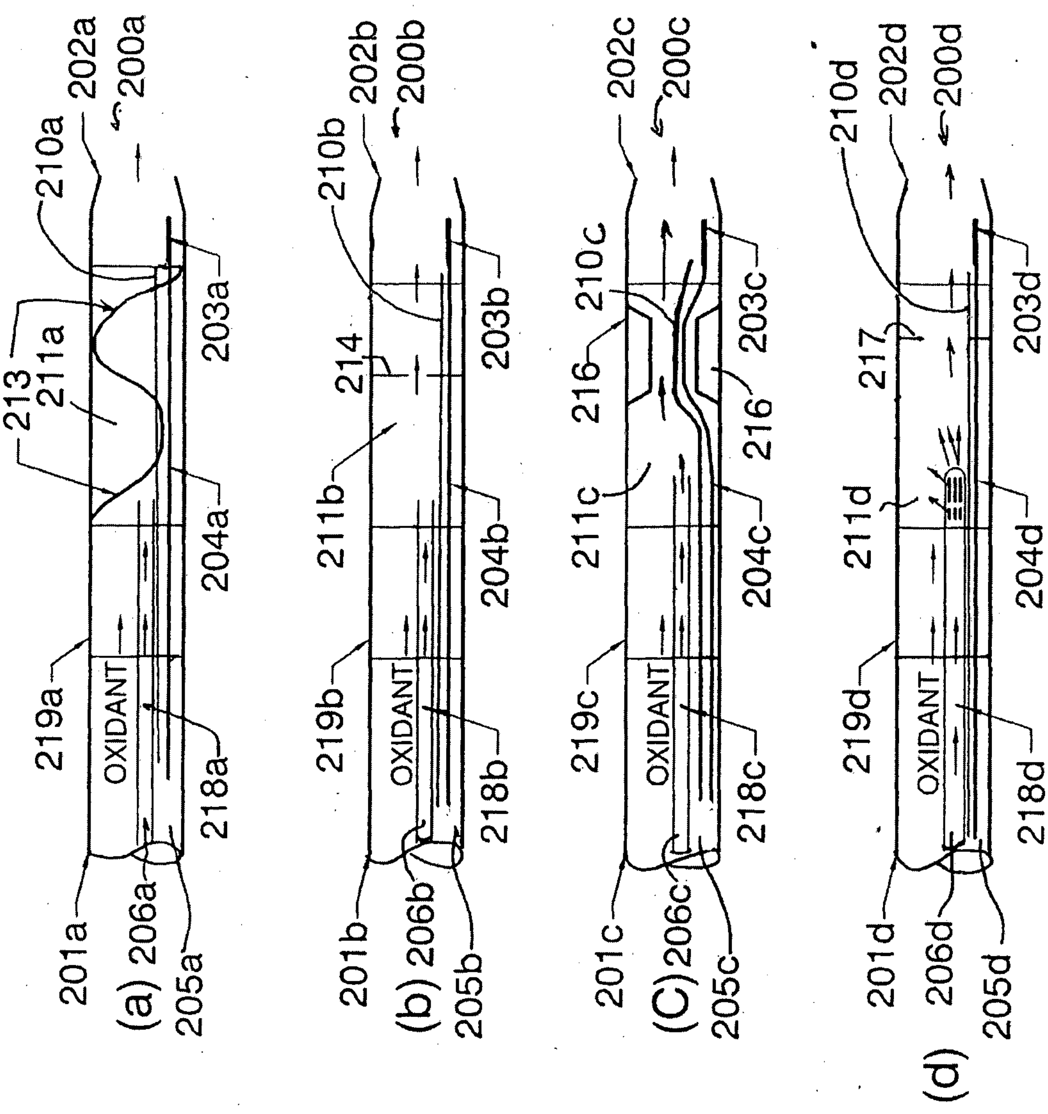
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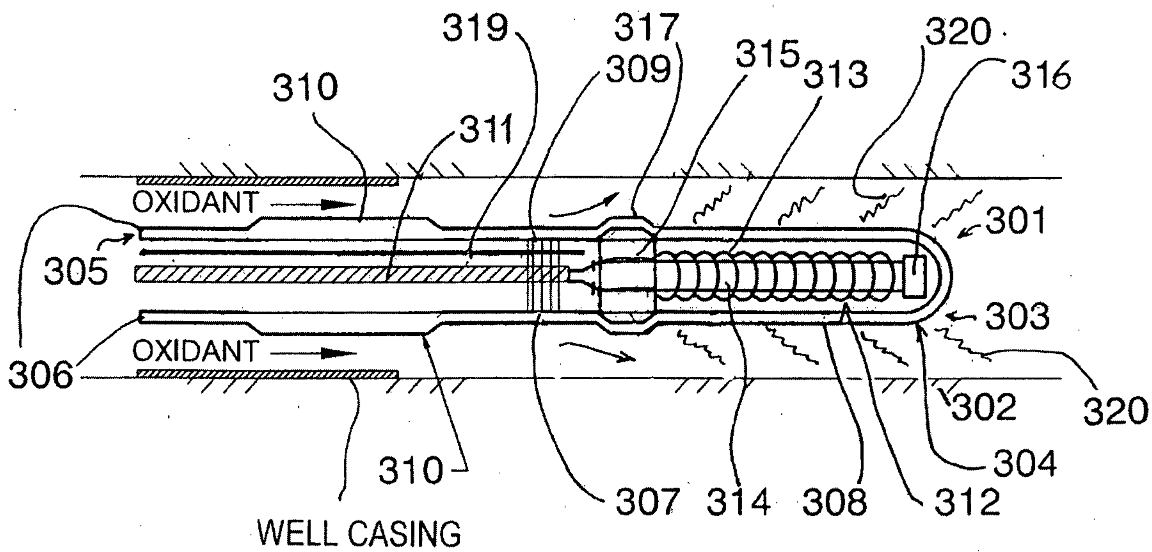
FIG. 4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WELL CASING

FIG. 5

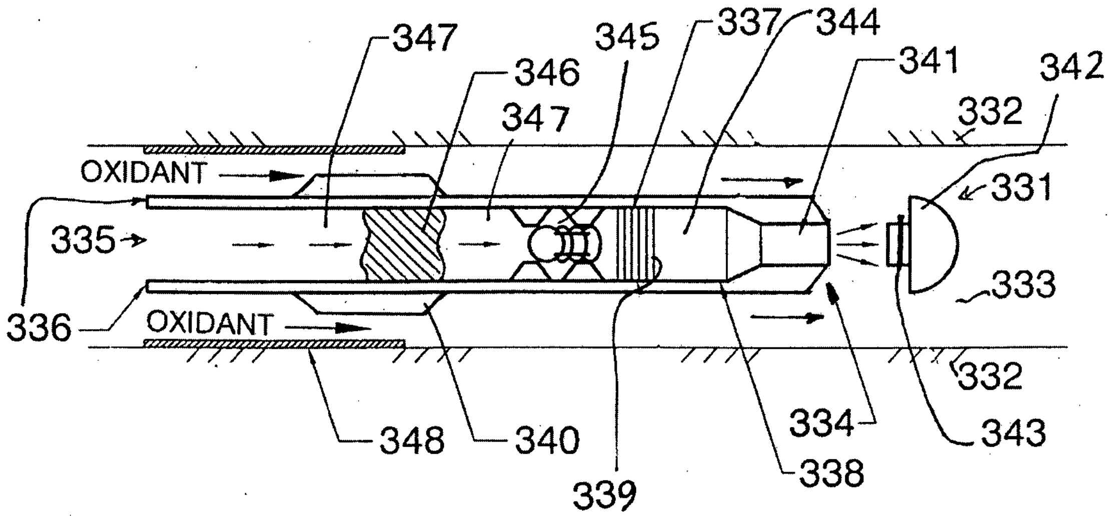
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FIG. 6

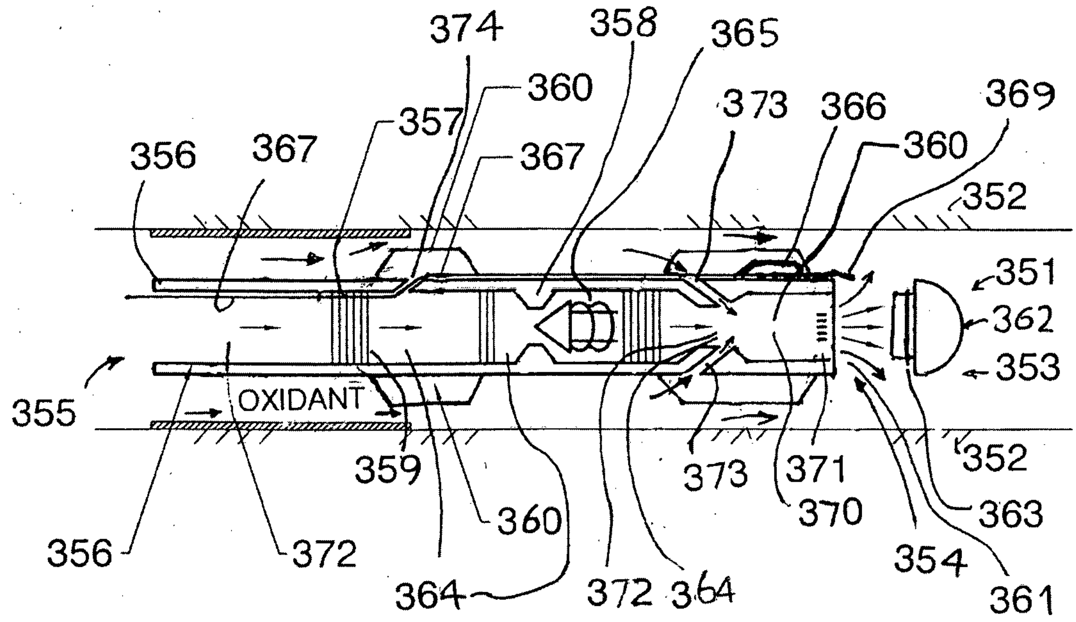
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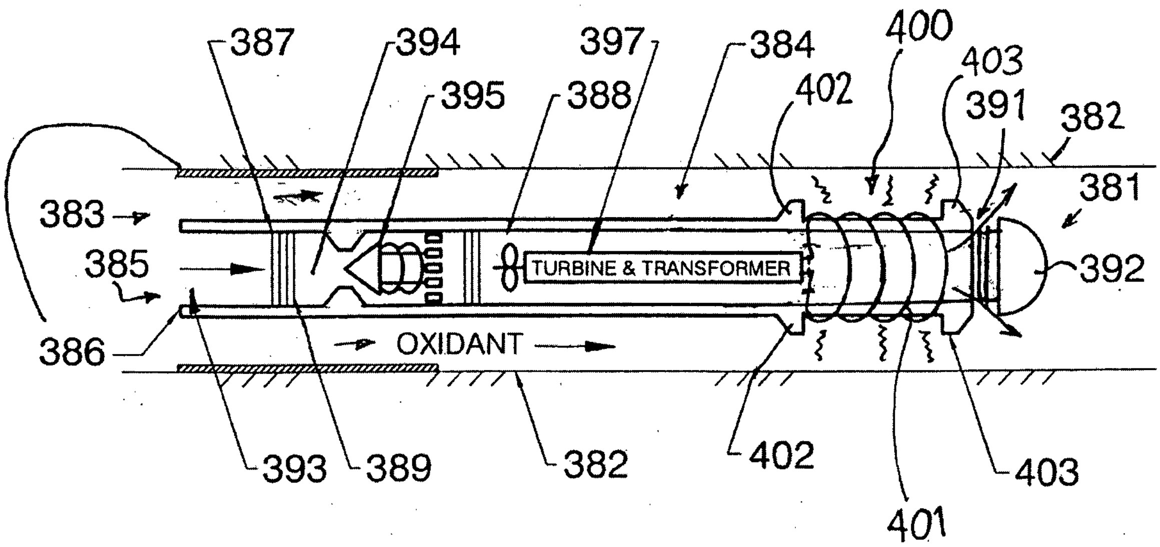
FIG. 7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TURBINE & TRANSFORMER
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OXIDANT
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FIG. 8

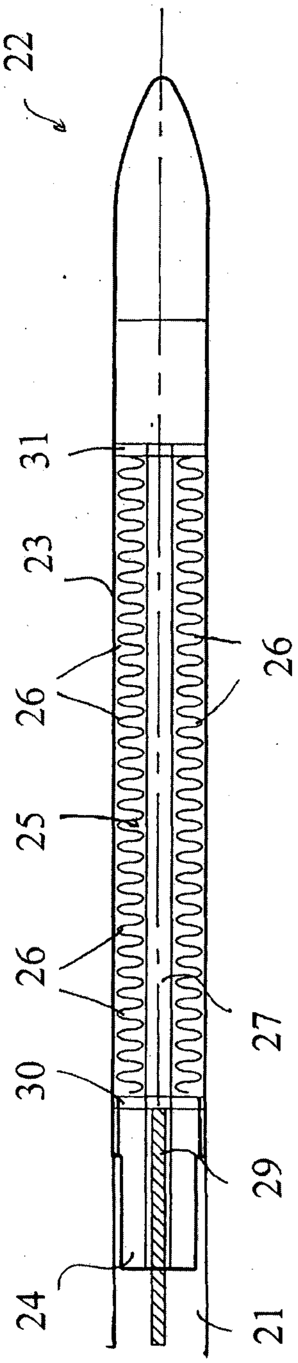
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FIG. 9

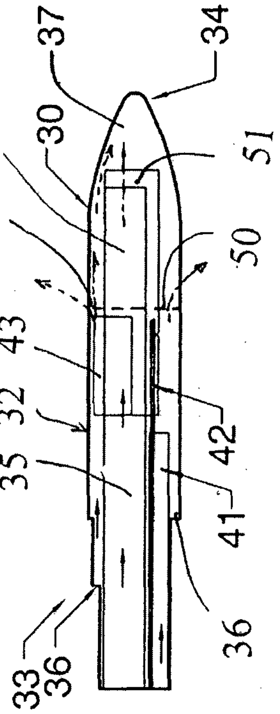
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FIG. 11

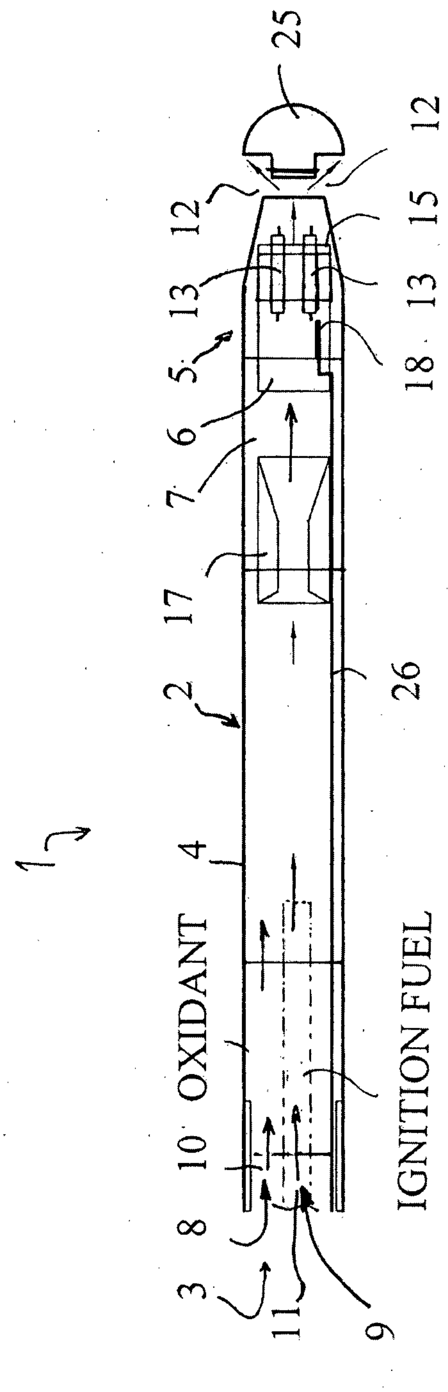
OXIDANT
IGNITION FUEL
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FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2012/000157

A.	CLASSIFICATION OF SUBJECT MATTER
Int. Cl.	*E21B 43/243* (2006.01) *E21B 43/295* (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC	
B.	FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)	
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Derwent WPI, EPODOC – IPC as above and keywords - ignite, ignition, combustion, spark, trigger, tube, tubing, coil, coal, UCG and like terms	

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Conference Paper, "Using Stainless Steel Coiled Tubing in a Novel Application" by Adrichem et al. Publisher - Society of Petroleum Engineers, Document ID – 46054-MS. SPE/ICoTA Coiled Tubing Roundtable, 15-16 April 1998, Houston, Texas, ISBN - 978-1-55563-392-9. Publication/Copyright date 1998. See abstract http://www.onepetro.org/mslib/servlet/onepetropreview?id=00046054	1-43
X	CN 201196071 Y (LIAOHE PETROLEUM EXPLORATION) 18 February 2009. See English language abstract, Derwent Accession number AN – 2009-F86943 [22]. Note use of term "hose", which by nature is coilable.	1-3, 5, 32-43
X Y	GB 1597952 A (SABOL) 16 September 1981. See figures and note use of flexible "composite bendable" hose 4. (Claim 1) (which by nature is coilable)	1-3,5-15,18-24, 29-43 16, 17, 25-31

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A"	document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 8 May 2012	Date of mailing of the international search report 17 May 2012
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **DAVID LEE** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2107

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 7735554 B2 (TILLMAN) 15 June 2010. See figures and note column 11 lines 30-40, and the use of flexible pipe.	1-3,5-15, 18-24, 29-43 16, 17, 25, 26
Y	EP 155598 A2 (BASF AG) 25 September 1985. See Derwent English language abstract, Acc No. 1985-237561 [39].	1-43
Y	US 4368781 A (ANDERSON) 18 January 1983. See Fig. 1.	1-43
Y	US 4422505 A (COLLINS) 27 December 1983. See abstract.	1-43
Y	US 5117912 A (YOUNG) 2 June 1992. See Figs 3-5 & Column 4 lines 31-60.	1-43

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim No
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims No.: **44**
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
The claims do not comply with Rule 6.2(a) because they rely on references to the description and/or drawings.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please see extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box #1

Continuation of Box No. III Observations where unity of invention is lacking

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-35 defines a UCG system with a coiled tubing and an ignition means for an underground coal seam. The feature of coiled tubing and ignition means for UCG in an underground coal seam is specific to this group of claims.

- Claims 36-41 define a mere ignition means. The feature of a mere ignition means is specific to this group of claims.

- Claims 42 defines a positioning system with coiled tubing to position an ignition means in <u>any</u> well channel. The feature of a positioning system with coiled tubing to position an ignition means in <u>any</u> well channel is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions is an ignition means. However it is considered that this feature is generic in this particular art. See <u>all</u> the citations listed under Box "C. DOCUMENTS CONSIDERED TO BE RELEVANT" of this International Search Report. They all disclose ignition means, furthermore, all disclose ignition means for UCG.

Therefore this common feature cannot be a special technical feature. Hence there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori*.

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
CN	201196071	NONE					
GB	1597952	AU	48823/79	CA	1061772	DE	2756045
		FR	2461871	GB	1597951	US	4168752
US	7735554	US	2008236817	US	2010276139	WO	2008121782
EP	0155598	AU	40094/85	DE	3409245	ZA	8501869
US	4368781	CA	1170980	DE	3141638	FR	2492452
US	4422505	NONE					
US	5117912	CA	2060160				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX