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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR MANAGING DOWNHOLE COMBUSTION

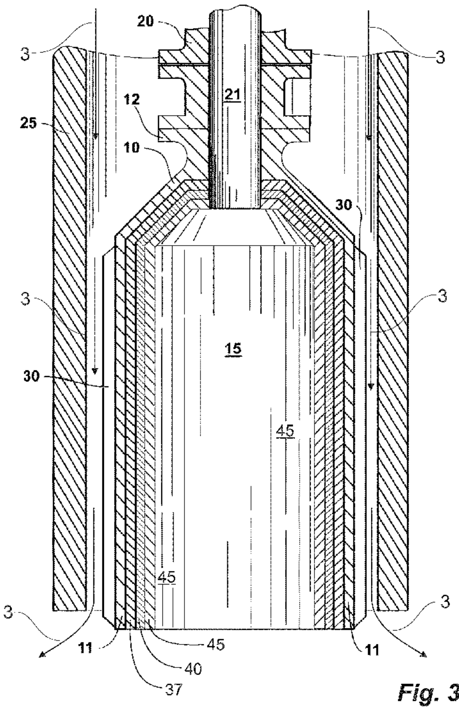

Fig. 3A

(57) Abstract: A downhole burner is provided above a combustion cavity in a target zone of a subterranean hydrocarbon reservoir. The burner is shielded by a shroud for protecting the burner with water flowing past the burner. The water is used for in-situ steam generation. The shroud is arranged in the annulus about the burner for controlling the flow of the water into the combustion cavity while preventing reverse flow of the hot products of combustion.

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

— *of inventorship (Rule 4.17(iv))*

Published:

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

APPARATUS AND METHOD FOR MANAGING DOWNHOLE COMBUSTION

FIELD

A downhole burner for in-situ steam generation and a method for managing downhole combustion is provided. More particularly, a downhole burner is provided with an annular area restrictor, such as a shroud for controlling the flow of injected water about the burner and into a combustion cavity.

BACKGROUND

Enhanced oil recovery (EOR) is a conventional practice wherein heat and mobilizing fluids are introduced to hydrocarbon formations where primary recovery processes are no longer feasible. Mobilizing fluids, including steam, light hydrocarbons and other solvents are injected into a hydrocarbon formation, upon which the hydrocarbon deposits entrained in the reservoir are mobilized towards production wells drilled adjacent to the injector(s).

A variety of enhanced oil recovery (EOR) processes, for recovery of hydrocarbons from a hydrocarbon reservoir in a subterranean formation, utilize steam including as a thermal source and to drive hydrocarbons towards a production well for recovery. Typically steam is either generated at surface and injected downhole or a burner or combustor is lowered downhole and operated in-situ to generate steam at the formation. Downhole combustors are operated on natural gas (predominately methane) and air or oxygen.

For downhole steam generators that create in-situ steam for enhanced oil recovery from a hydrocarbon bearing reservoir in a subterranean formation, a downhole burner is positioned adjacent a target zone in the formation using a conveyance string. Fuel and oxidant can be delivered to the burner through the conveyance string and the downhole burner is operated to create hot products of combustion or hot flue gases. Unlike conventional in-situ generators, Applicant injects water downhole through an annulus between the conveyance string and the wellbore, such as open hole or a casing wall. The water contacts the hot flue gases in a cavity downhole of the burner or in the target zone, and vaporizes to form steam. Such a downhole combustor can operate in a constrained downhole environment including a water-flooded environment.

The design of a flooded, oxy-fuel combustor for downhole in-situ combustion and steam generation has a number of design challenges. Because of the very high combustion temperature of oxy-fuel mixtures, there is significant dissociation of the combustion products leading to free oxygen and unburned fuel in the hot flue gases. If the gases are cooled too quickly (quenched), the combustion process is stopped and the un-reacted oxygen and fuel can flow into the reservoir leading to reduced combustion efficiency, potential corrosion problems in the production wells and associated production facilities and equipment, and degradation of the recovered hydrocarbons.

It is known to provide a protective shroud around the combustor so as to extract heat from the gases before quenching, improving combustion efficiency and reducing free oxygen. However, very high combustion temperatures can damage the shroud.

Further, hot flue gases from the combustion, being naturally buoyant, have a tendency to rise through the annulus between the casing and the conveyance string. Further, pressure variations can result in backflow up the annulus, both of which can cause heat damage to any downhole instrumentation uphole of the burner and can also negatively impact the equilibrium between wellbore pressure and the water pressure created by the head of injected water in the conveyance string.

There is a need for better controls of the combustion process, the annular flows and protection of the equipment.

SUMMARY

Due to the very high combustion temperature of the oxy-fuel mixtures of the combustor, which are not effectively diminished by co-flow of water for steam generation, a shroud is provided for cooling. Flowing the injected water for steam generation over the outside of the shroud provides cooling. In some cases, the injected water can contain very high dissolved solids, as is typical of produced water available for injection. If so, the dissolved solids can precipitate out on the surface of the shroud, forming scale and reducing the heat transfer away from the combustion, leading to shroud burn out, reduced combustion efficiency and free oxygen flowing into the hydrocarbon reservoir.

Embodiments herein relate to the injection of steam that is generated within a combustion cavity in a hydrocarbon reservoir. More specifically, an improvement on the apparatus and process described in US 8,333,239 to Applicant is disclosed, the subject matter of which is incorporated herein by reference.

Further, embodiments comprise a shroud adapted to be operatively connected to a downhole end of a downhole burner apparatus for shielding the burner with injected water flowing around and past the burner and controlling the flow of the injected water into the combustion cavity.

A particular geometry and size of the shroud can be set to provide a specific cross-sectional, or annular area between an exterior surface of the shroud and the inner surface of the wellbore, through which the injected water may flow through and into the combustion cavity in the target zone of the hydrocarbon reservoir. The hydraulics of the shroud and combustion cavity interface is sufficient to counteract buoyancy of flue gases created during combustion and to manage pressure in the wellbore. The flowing water also provides the additional benefit of cooling of the shroud, thereby cooling the burner. One measure of the interface hydraulics is to establish an exit velocity of water flowing past a downhole end of the shroud.

In a broad aspect a flow passage is provided for the controlled delivery of water to a downhole burner in a wellbore, comprising a cylindrical shroud located in an annulus between the burner and the wellbore for forming a generally annular and flow-restricting passage therebetween, the flow-restricting passage controlling the flow of water to burner for mixing with hot flue gases from the burner to form steam and for restricting the reverse flow of the hot flue gases up the annulus.

In an embodiment, the flow-restricting passage is a multiplicity of flow passages spaced circumferentially about the shroud, the shroud having circumferentially spaced and alternating axially-extending fins and flow channels thereabout. In an embodiment, the fins protrude radially towards the wellbore. In an embodiment, the flow-restricting passage has an annular area and a velocity of the water as it flows through the annular area is greater than an upward velocity of gas bubbles from the hot flue gases. In an embodiment, the upward velocity of gas bubbles is determined according to $Vb = K \sqrt{gd}$ where: K = a constant, g = the acceleration due to gravity, and d = the diameter of the bubbles. In an embodiment, K is about 0.7.

In another broad aspect, a downhole steam generator is provided and situate in a generally vertical wellbore for in-situ steam generation in a target zone of a subterranean formation comprising a burner located in the wellbore adjacent the target zone and forming an annulus therebetween; and a shroud positioned in the annulus between the burner and the wellbore to form a flow-restricting passage between the shroud and the wellbore. The burner produces hot flue gases in the target zone; and the flow-restricting passage controls the flow of water to the target zone for mixing with the hot flue gases to form steam and for restricting the reverse flow of the hot flue gases up the annulus.

In another broad aspect, a method is provided for generating in-situ steam in a target zone of a subterranean formation accessed by a generally vertical wellbore comprising: operating a burner to produce hot flue gases in the target zone; and injecting water in an annulus between the burner and the wellbore; restricting the flow of water in the annulus and past the burner to the target zone wherein a velocity of the water as it flows therethrough is greater than an upward velocity of gas bubbles from the hot flue gases. In an embodiment, the water is directed through a multiplicity of flow passages about the burner. In an embodiment, the upward velocity of gas bubbles is determined according to $Vb = K\sqrt{gd}$ where: K = a constant, g = the acceleration due to gravity, and d = the diameter of the bubbles.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross-sectional drawing of a combustion cavity within a hydrocarbon reservoir accessed by a wellbore, and a downhole burner having a burner shroud positioned therein;

Figure 2 is a side perspective view of an embodiment of the burner shroud;

Figure 3A is a side cross-sectional view of the burner shroud of Fig. 2, illustrating a thermal coating and a sacrificial moisture-resistant coating on an interior surface of the shroud;

Figure 3B is a top view of the shroud of Fig. 2; and

Figure 4 is a side cross-sectional view of a burner having a housing and a shroud added thereabout.

DESCRIPTION

As shown in Fig. 1, a downhole combustor or burner 5 is illustrated depending from a conveyance string 6 having fuel and oxidant lines running downhole in a vertically-extending wellbore W. In an embodiment, the fuel and oxidant lines need not be housed in a single conveyance string but can be discrete side-by-side, co-axial, or concentric units. In the context shown, the burner 5 is positioned for discharge of hot flue gases about a top of a combustion cavity 8 formed within a hydrocarbon-bearing reservoir 9 of a subterranean formation. The combustion cavity can be a pre-existing cavity, a naturally occurring cavity, or a cavity created through artificial means, such as reaming or melting.

At a downhole end of the burner 5, having a nozzle 21 (see Fig. 3A), is adapted to create and sustain combustion of the fuel and oxidant for creating products of combustion, including hot flue gases G. Water 3 required for the generation of in-situ steam S is injected from the surface through an annular space 7 created between the wellbore W and the conveyance string 6 and be directed towards the combustion cavity 8, for interacting with the hot combustion products and creating steam for enhanced oil recovery. The wellbore W is typically lined with casing 25.

As shown in Fig. 3A, a cylindrical shroud 10 is integrated with the structure of the burner 5. A combustion chamber 15 is formed within the burner 5. The burner defines this interior combustion chamber 15 for sheltering the combustion zone therein and provides a physical separation between the combustion zone and the injected water 3 passing into the combustion cavity.

With reference to Fig. 2, the shroud 10, has an uphole end 12, such as at a flanged connector to secured to the burner 5. The shroud 10 further comprises a tubular section 11 extending downwardly from the uphole end 12. The length of the tubular section 11 of the shroud 10 is complementary to length of the combustion chamber 15. Injected water 3 flows past the shroud to enter into the combustion cavity to interact with the hot combustion products G and create steam which is directed into the combustion cavity 8.

With reference to Fig. 3A, in an embodiment, the shroud 10 is installed onto the downhole end of a burner 5. The burner 5 is disposed within the wellbore W, shown here as lined with casing 25, directly uphole of the combustion cavity 8.

As fuel and oxidant exit the nozzle 21 and mix within the combustion chamber 15 and combust to create a flame and hot products of combustion, including hot flue gases G. The combustion chamber 15 is heated by the combustion process and cooled by conduction from the water-cooled shroud 10. The flame and hot products of combustion G are shielded from the concurrent flow of injected water flowing past the burner. This allows the combustion of fuel and oxidant to continue without being quenched by the injected water 3. As the combustion products exit the shroud 10 at its downhole end, they contact the injected water 3 within the combustion cavity 8 and produce heat, steam S and a gas drive within the hydrocarbon formation 9 to mobilize oil and heavy hydrocarbons to the adjacent production wells.

The wellbore W is typically at least partially lined with casing 25. In one embodiment, the wellbore W is lined with casing 25 until just below the shroud

10. The wellbore W downhole of the shroud 10 comprises the uncased, open-hole target zone in the reservoir.

In another embodiment, the wellbore W is lined with casing 25 past the shroud 10. The wellbore W downhole of the shroud 10 is in fluid communication with the target zone of the reservoir either through an uncased section or perforations within the casing 25.

The injected water 3 enters into the combustion cavity 8, or exits the annulus 7 at an exit velocity, the exit velocity depending on various hydraulic variables including the available cross-sectional area of the annular space between the casing 25 and the exterior of the shroud and the hydraulic head of the water in the annulus. Accordingly, a geometry and size of the shroud 10 can be manipulated to provide a specific cross-sectional area of the annulus 7 between the exterior of the shroud 10 and the interior wall of the wellbore W, thereby permitting control of the exit velocity of the injected water 3 entering into the combustion cavity 8. Thus, the cross-sectional area of the annulus 7 can be manipulated such as to result in the injected water 3 having an exit velocity sufficient to prevent a reverse flow of hot flue gases G uphole through the annulus 7. The exit velocity can also be manipulated to permit sufficient cooling of the shroud 10 as the water 3 passes thereby. The velocity and process mass flow requirements are managed for the particular downhole conditions. Velocity can be determined so as to balance against reverse flow, parameters for such a determination including hydraulic head, cross section of the annulus 7, configuration of the interface between the wellbore

W and the shroud 10 and length of the flow-restricting portion of the shroud 10 along which the water 3 must pass.

In an embodiment, the shroud 10 is sized to ensure that the velocity of the water Vw, as it flows through the annular space between the shroud 10 and the wellbore W, is greater than the upward velocity Vb of gas bubbles from the combustion reaction, Vw > Vb, where:

Vw = Downward velocity of the water as it flows past the shroud; and

Vb = Terminal upward velocity of the gas bubbles.

Vw may be calculated as follows:

Qw / A = Vw

Where:

Qw = Flow rate of water;

A = Annular area between the inside of the wellbore and the outside of the shroud; and

Vw = Velocity of the water as it flows past the shroud.

Vb may be an assumed value, for example 0.2 m/s, or calculated using any method of mathematical approximation, including the method described by Davies and Taylor (1950), namely R. M. Davies and G. I. Taylor, “The mechanics of large bubbles rising through liquids in tubes”, Proc. of Roy. Soc., London, 200, Ser. A, pp. 375-390, 1950, in Talaia, Mario, Terminal Velocity of a Bubble Rise in a Liquid Column, International Journal Of Mathematical, Computational, Physical, Electrical And Computer Engineering, Vol: 1, No: 4, 2007, the entirety of each of which are incorporated herein by reference, the relationship being generally defined as:

$Vb = K \sqrt{gd}$ (Eqn (1) Sousa) where:

K = a constant . Where bubbles are very large, surface tension and viscosity effects are negligible, K has been stated as being about 0.7 or 0.707 (Eqn (2) Talaia)

g = the acceleration due to gravity; and

d = the diameter of the bubbles;

The maximum bubble diameter can be an observed, calculated or assumed value, for example in the order of about 10mm.

As shown in Figs. 2, 3A and 3B, and in an embodiment, the shroud is axially splined, having a plurality of radially projecting fins 30 arranged around a circumference of the shroud 10. The fins 30 axially extend the length of the tubular section 11 of the shroud 10.

Best shown in Fig. 3B, a pair of adjacent fins 30,30 together create a channel 31 therebetween, each being one of a multiplicity of flow passages through which water 3 flows. Thus, having a plurality of adjacent fins 30 provides a plurality of channels 31.

The fins 30 and channels 31 increase an overall surface area of the shroud 10 that is in contact with the relatively cool flowing water 3 for increased cooling of the shroud and burner components in thermal contact therewith.

Further, the plurality of channels 31 and fins 30 enable maximizing of the outer diameter of the shroud 10, reducing the cross-sectional area between the wellbore W and the exterior surface of the shroud 10 for establishing the desired flow velocity, while minimizing a contact surface area at the tips of the fins 30 and the casing 25. Applicant notes that more substantive contact between the exterior of the shroud 10 and the casing 25 can result in uneven cooling of the shroud. The cross-sectional area of the aggregate of all the channels 31 available for the passage of water permits higher exit velocities.

The fins 30 also serve as a centralizer, for more uniform flow of water 3 around and past the shroud 10.

The fins 30 are radially sized and spaced to maximize the surface area of the shroud 10 in contact with the flowing water 3 while maintaining the material integrity of the shroud 10 and maintaining manufacturing costs within reasonable limits.

Applicant notes that the flow rate of water is mostly fixed based on requirements for steam quality and steam flow rates. Thus the burner capacity, including fuel and oxidant rates, is fixed for the most part as well. These rates are pre-determined with the objective of maximizing enhanced oil recovery. One could adjust water rates or fuel and oxidant rates in order to either adjust steam quality or steam flow rates, however the shroud is typically sized to overcome upward bubble velocity.

In an embodiment, and best shown in Fig. 2, one or more holes 35 may be provided in one or more of the fins in order to provide a sensor well or mounting location for instrumentation. Devices include those providing temperature, pressure or other measurements during downhole operations. For example, thermocouples can be inserted into the holes 35 and are thereby protected from the extreme conditions that would result from direct contact with combustion gasses G, while also being in thermal contact with the material of the shroud 10 to provide useful information about burner performance and water cooling. The shroud 10 provides water flow control and can also provide cooling of the burner components.

The shroud 10 can be incorporated into a burner 5 (Fig. 3A), or provided as a separate component between the burner 5 and the wellbore W (Fig. 4). For example, the shroud 10 could be installed with piping for the burner 5, such as an annular oxygen tube and a fuel tube, and then the combined burner assembly would be lowered into the wellbore W. In another embodiment, the shroud 10 could be installed first on the end of a conveyance string, and then an inner tubing string, that includes burner nozzle 21, could then be lowered into and through the outer conveyance string in order to form the combined burner assembly. In yet another embodiment, the shroud 10 could be installed at the end of an assembly that includes burner piping, a burner nozzle and a valve assembly. That entire assembly would be lowered into the wellbore W. One or more smaller-diameter inner tubing strings could then be lowered down through the outer conveyance string, and those inner tubing strings would latch into the burner assembly in order to connect to the burner piping. Those smaller inner tubing strings would then form annular and central passageways for the oxidant and fuel, and could include an annular space for nitrogen in between the oxidant and fuel, to provide additional separation and safety.

With reference to Fig. 3A, in an integrated embodiment with the shroud 10 forming a housing for the combustion chamber 15, the interior surface of the shroud 10 can be protected from direct exposure to the radiant flame and produced hot combustion products. As shown, a thermal barrier 40, such as a refractory liner having a high porosity, can be applied to the interior surface of the shroud 10.

With reference to Fig. 4, in an embodiment in which a shroud is added to the exterior of a burner housing 37, thermal coupling between the burner housing 37 and the cooler material of the shroud 10 is encouraged, and insulation, such as refractory 40 is typically installed on the inside of the burner housing 37 of the combustion chamber 15.

The water employed is often produced water, being brackish water instead of fresh water. Further, downhole burners for in-situ steam generation are typically used in a water-flooded environment. Thus, and particularly during start-up and burner light-off, the thermal barrier 40 can be vulnerable to water and any contaminants entrained therein, such as water-borne salts and chlorine As a result, and upon heating, the thermal barrier 40 can be damaged, such as by chlorine cracking. The risk to the refractory is reduced or non-existent during operation.
Accordingly, in an optional embodiment, a sacrificial protective liner 45 can be applied to the thermal barrier 40 to protect the thermal barrier 40 from exposure, including absorption, of water, oil, entrained contaminants and mud. The sacrificial liner 45 can be selected from moisture resistant coatings which tend to be burned off during one or more light-off events for the downhole burner 5.

THE EMBODIMENTS OF THE INVENTION FOR WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A flow passage for the controlled delivery of water to a downhole burner in a wellbore, comprising a cylindrical shroud located in an annulus between the burner and the wellbore for forming a generally annular and flow-restricting passage therebetween, the flow-restricting passage controlling the flow of water to burner for mixing with hot flue gases from the burner to form steam and for restricting the reverse flow of the hot flue gases up the annulus.

2. The flow passage of claim 1, wherein the flow-restricting passage is a multiplicity of flow passages spaced circumferentially about the shroud, the shroud having circumferentially spaced and alternating axially-extending fins and flow channels thereabout.

3. The flow passage of claim 1 or 2, wherein the fins protrude radially towards the wellbore.

4. The flow passage of claim 1, 2 or 3 wherein the flow-restricting passage has an annular area and a velocity of the water as it flows through the annular area is greater than an upward velocity of gas bubbles from the hot flue gases.

5. The flow passage of claim 4 wherein the upward velocity of gas bubbles is determined according to $Vb = K\sqrt{gd}$ where:

K = a constant,

g = the acceleration due to gravity, and

d = the diameter of the bubbles.

6. The flow passage of claim 5 wherein K is about 0.7.

7. A downhole steam generator in a generally vertical wellbore for in-situ steam generation in a target zone of a subterranean formation comprising:

a burner located in the wellbore adjacent the target zone and forming an annulus therebetween; and

a shroud positioned in the annulus between the burner and the wellbore to form a flow-restricting passage between the shroud and the wellbore, wherein

the burner produces hot flue gases in the target zone; and

the flow-restricting passage controls the flow of water to the target zone for mixing with the hot flue gases to form steam and for restricting the reverse flow of the hot flue gases up the annulus.

8. The downhole steam generator of claim 7, wherein the flow-restricting passage is a multiplicity of flow passages spaced circumferentially about the shroud, the shroud having circumferentially spaced and alternating axially-extending fins and flow channels thereabout.

9. The flow passage of claim 8, wherein the fins protrude radially towards the wellbore.

10. The flow passage of claim 7, 8 or 9, wherein the flow-restricting passage has an annular area and a velocity of the water as it flows through the annular area is greater than an upward velocity of gas bubbles from the hot flue gases.

11. The flow passage of claim 10 wherein the upward velocity of gas bubbles is determined according to $Vb = K\sqrt{gd}$ where:

K = a constant,

g = the acceleration due to gravity, and

d = the diameter of the bubbles.

12. The flow passage of claim 11 wherein K is about 0.7.

13. A method for generating in-situ steam in a target zone of a subterranean formation accessed by a generally vertical wellbore comprising:

operating a burner to produce hot flue gases in the target zone; and

injecting water in an annulus between the burner and the wellbore;

restricting the flow of water in the annulus and past the burner to the target zone wherein a velocity of the water as it flows therethrough is greater than an upward velocity of gas bubbles from the hot flue gases.

14. The method of claim 13 wherein the water is directed through a multiplicity of flow passages about the burner.

15. The method of claim 13 or 14 wherein the upward velocity of gas bubbles is determined according to $Vb = K \sqrt{gd}$ where:

K = a constant,

g = the acceleration due to gravity, and

d = the diameter of the bubbles.

16. The flow passage of claim 15 wherein K is about 0.7.

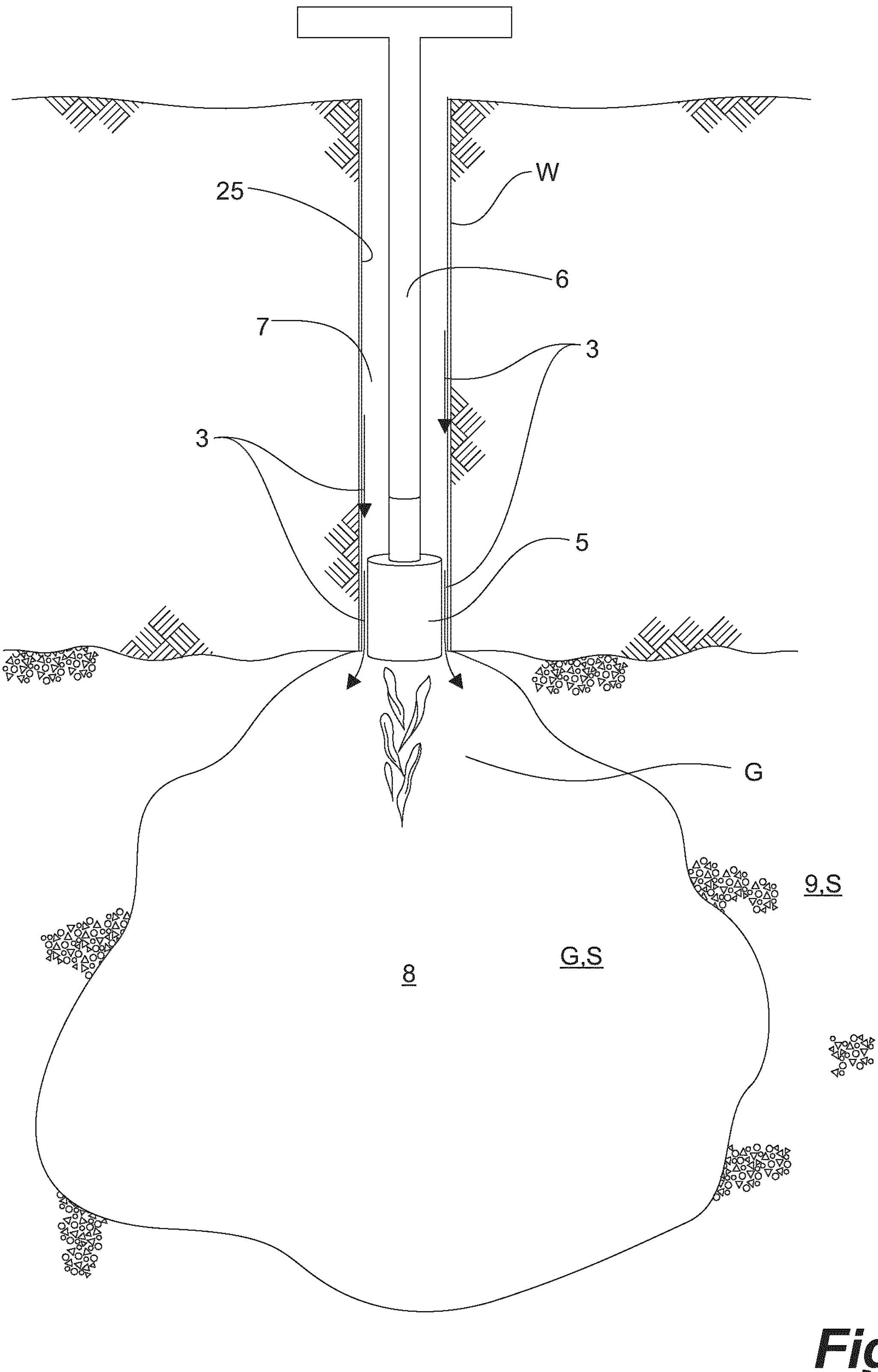

Fig. 1

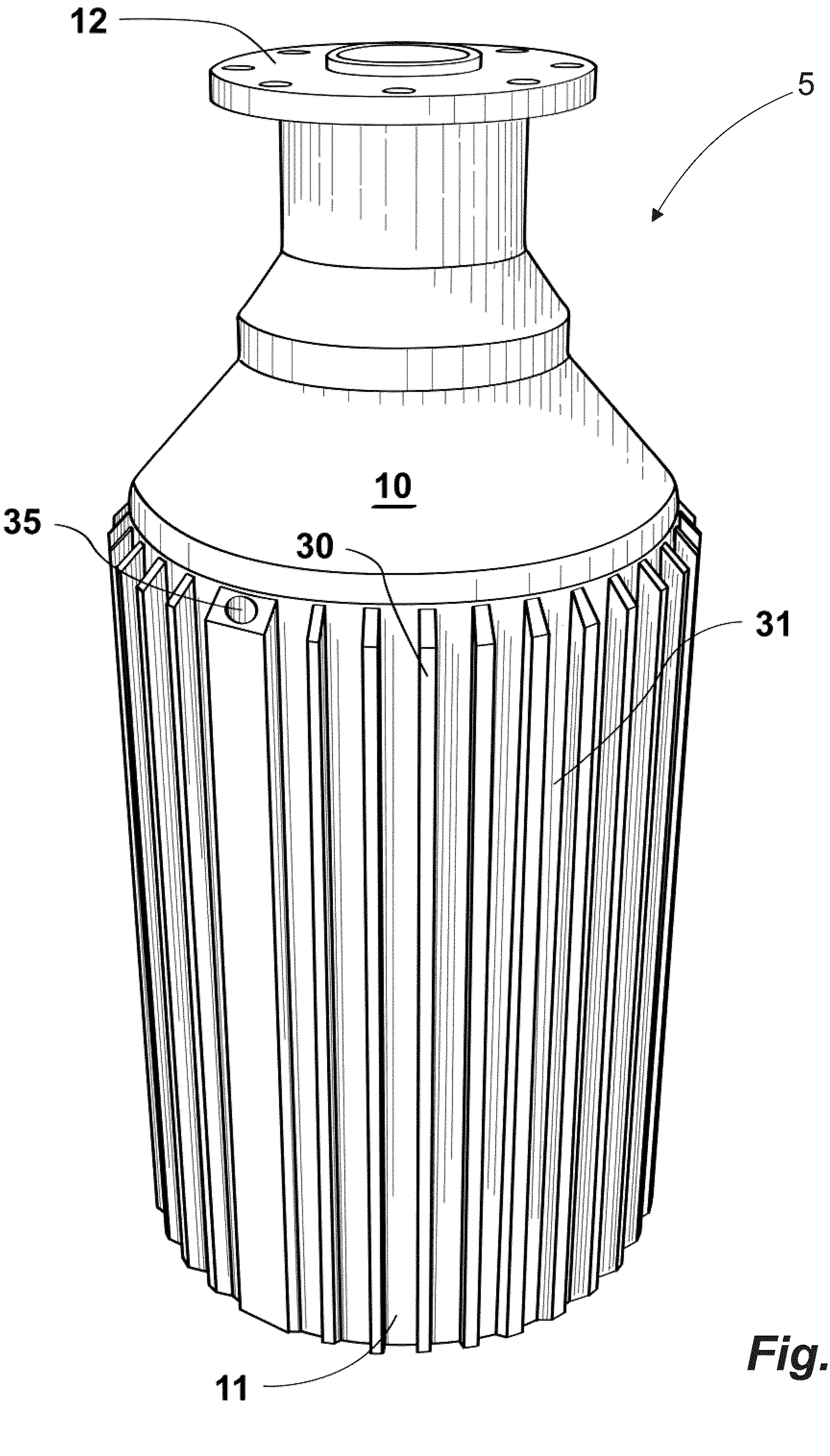

Fig. 2

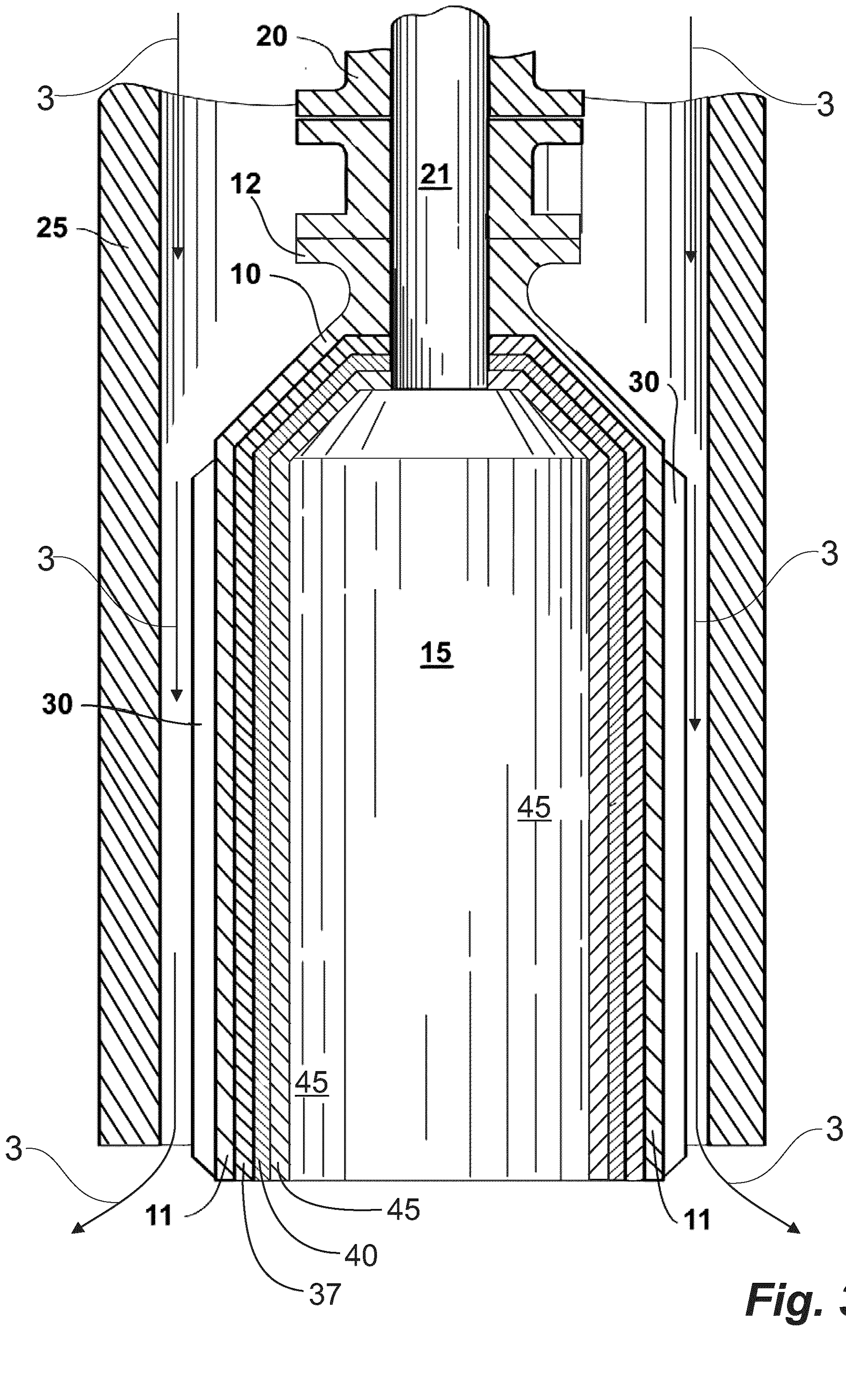

Fig. 3A

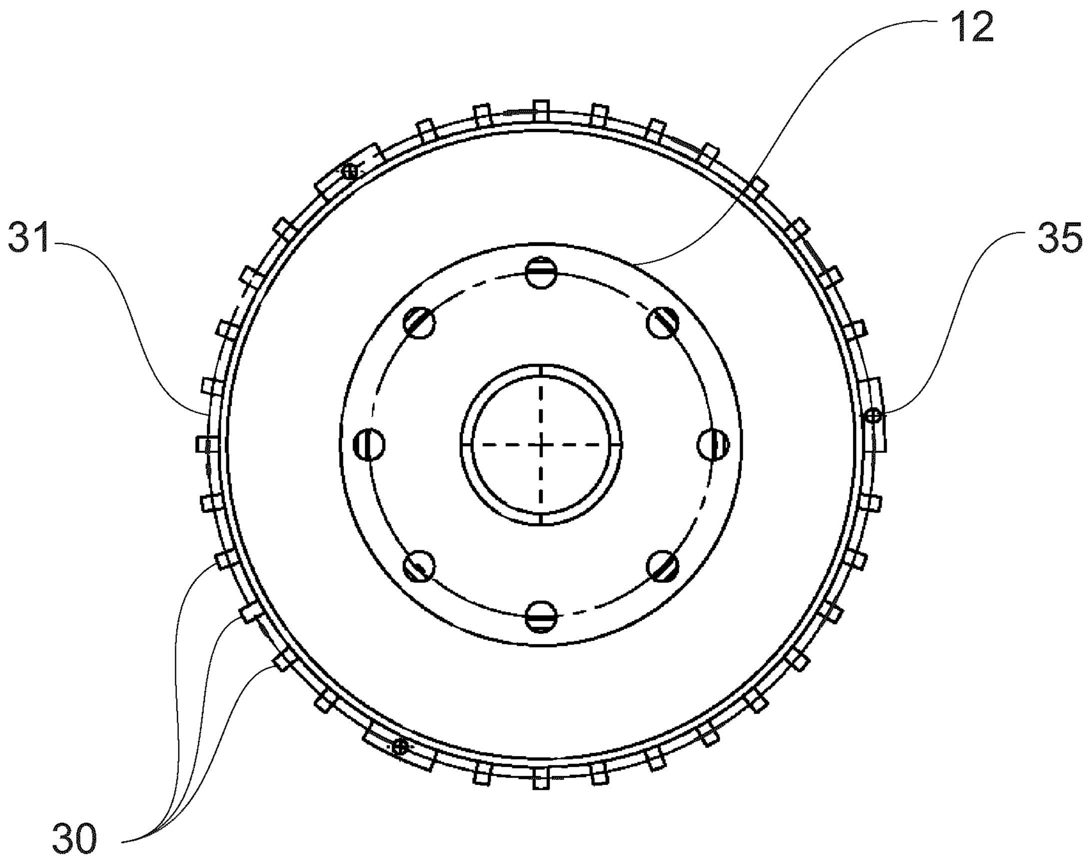

Fig. 3B

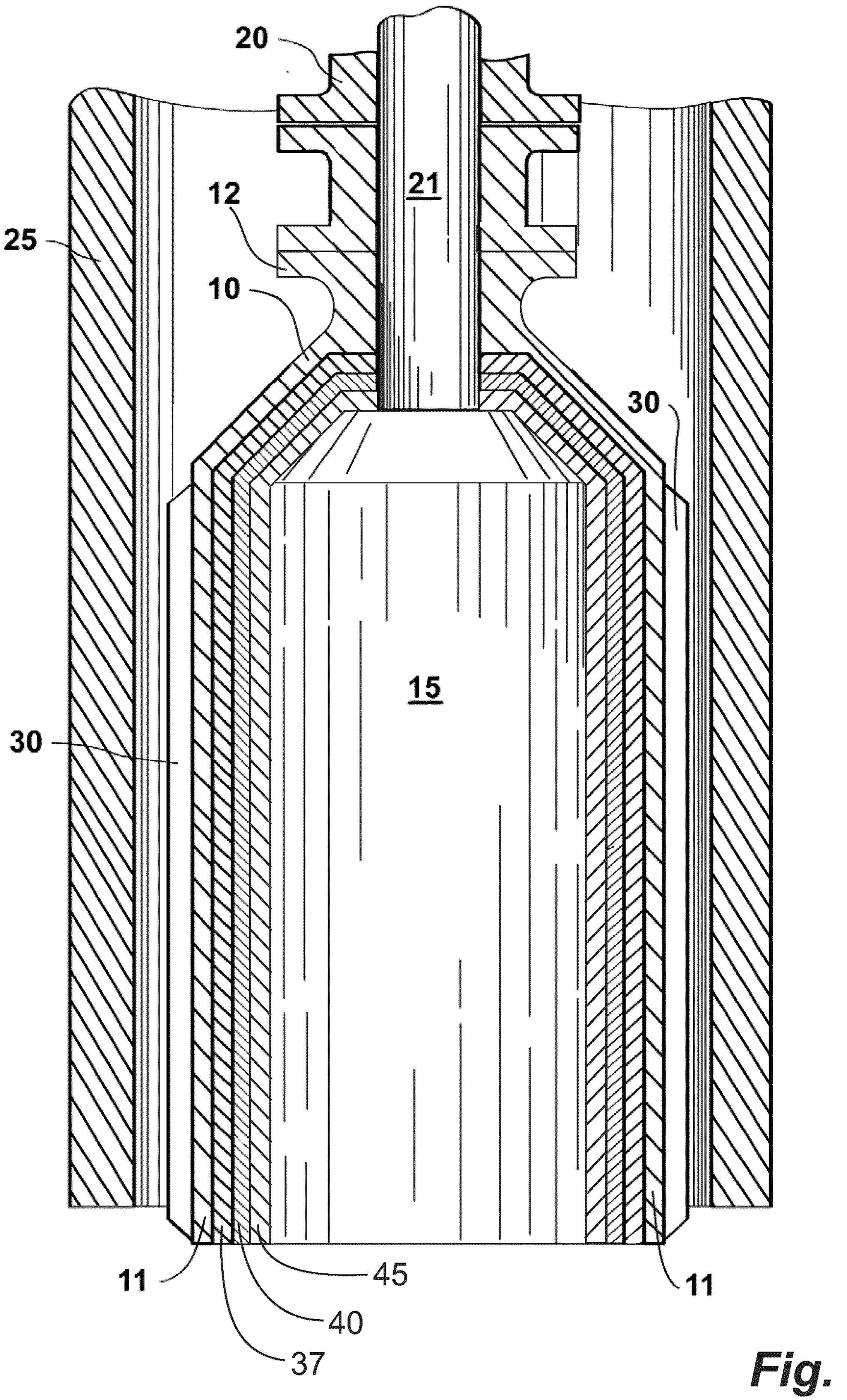

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2015/051367

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***E21B 43/24*** (2006.01) , ***E21B 43/12*** (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)
IPC: E21B 43/24 (2006.01), E21B 43/12 (2006.01), E21B 43/243 (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Questel Orbit Fampat: downhole, burner, steam, water, annul+, shroud, fin+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/0020076 A1 (SCHNEIDER, F. et al.) 24 January 2014 (21-01-2014) *Claims 1, 16-18*	
A	US 8387692 B2 (TILMONT, D. et al.) 5 March 2013 (05-03-2013) *col. 7, l. 45-50; figures; abstract*	

☐ Further documents are listed in the continuation of Box C.

☑ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"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 4 March 2016 (04-03-2016)	Date of mailing of the international search report 14 March 2016 (14-03-2016)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Christian Opris (819) 639-7855

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2013020076A1	24 January 2013 (24-01-2013)	US2013020076A1	24 January 2013 (24-01-2013)
		US9115579B2	25 August 2015 (25-08-2015)
		AU2010205878A1	08 September 2011 (08-09-2011)
		AU2010205878B2	16 July 2015 (16-07-2015)
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