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(54) **HYDRAULIC FRACTURING OF GROUND FORMATIONS**

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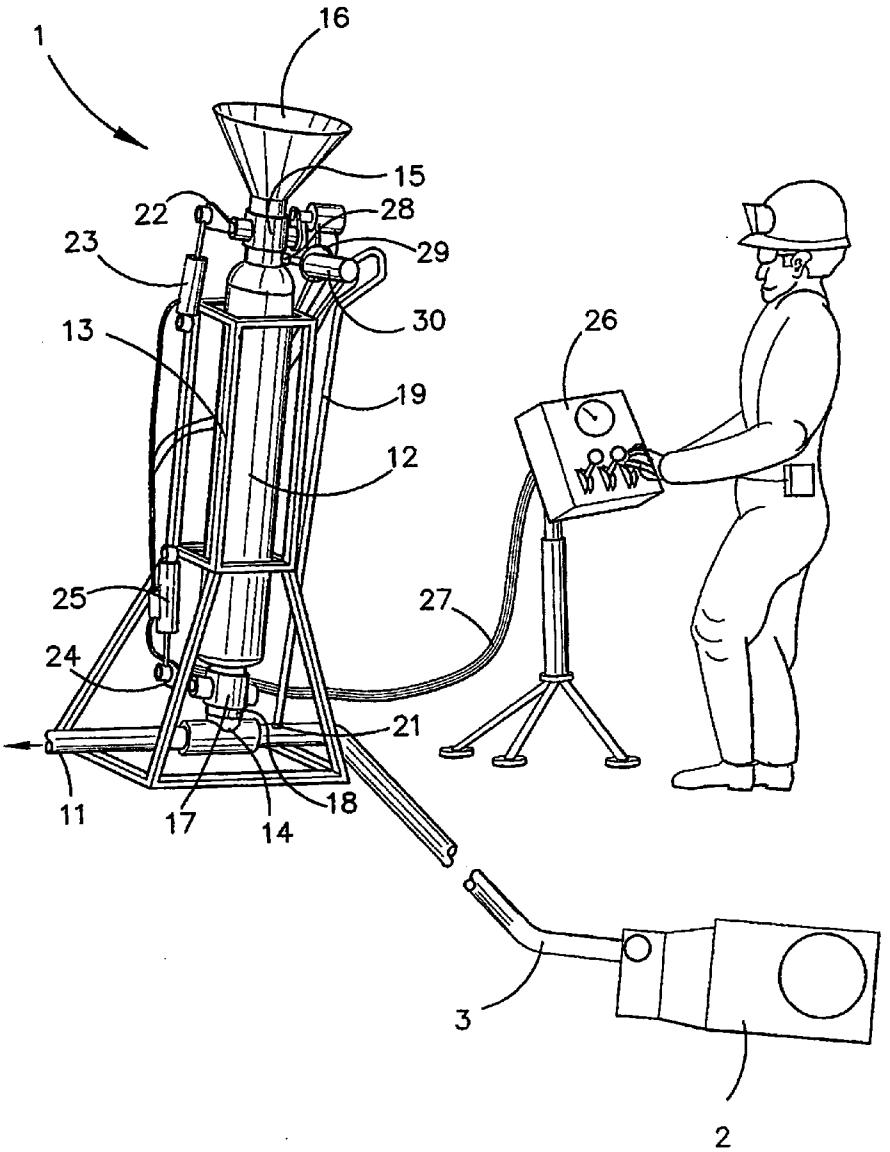
(57) **ABSTRACT**

A method of hydraulic fracturing of ground formations. Such formations may be natural rock, earth or mineral formations and may be located on land or under a sea bed.



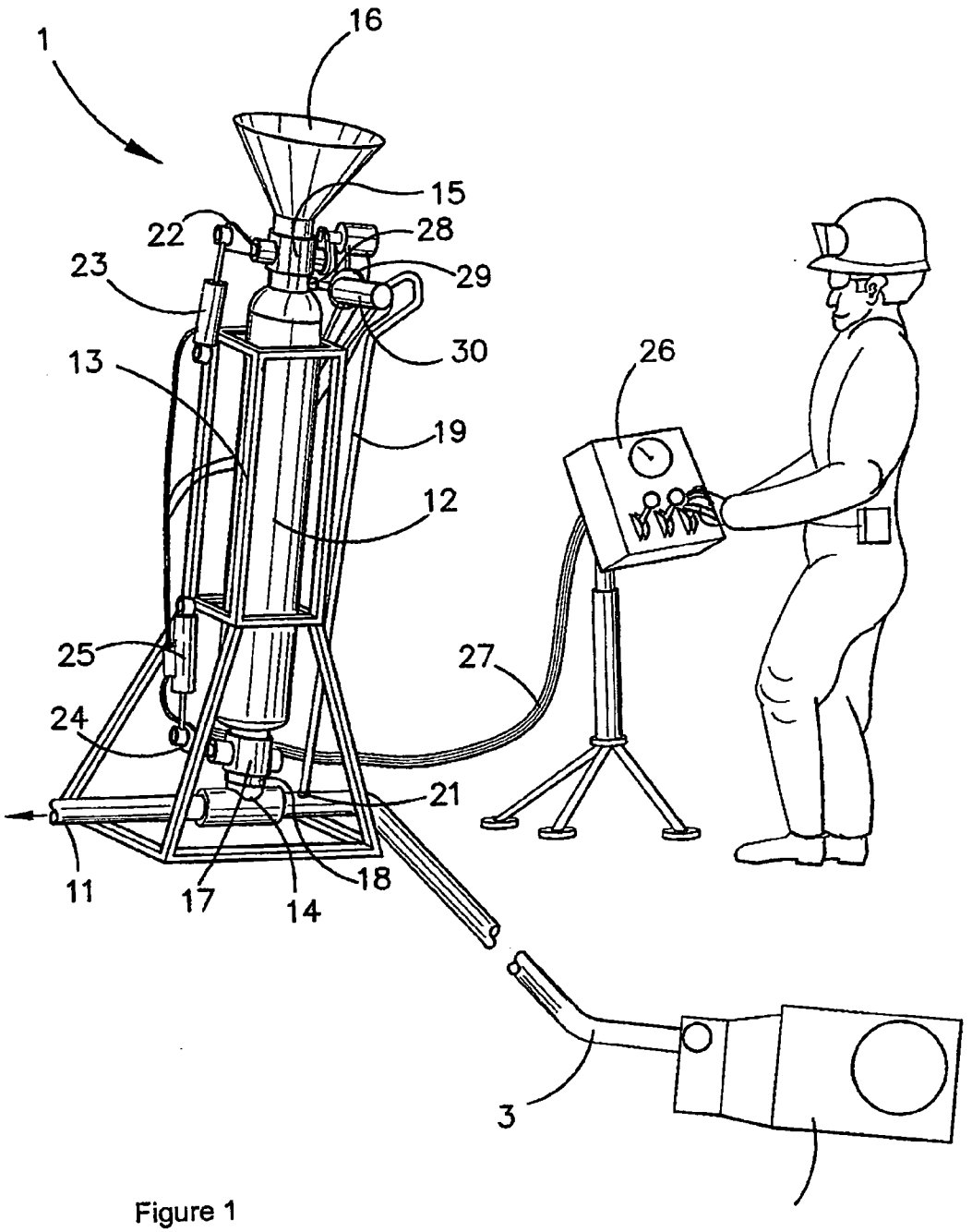


Figure 1

HYDRAULIC FRACTURING OF GROUND FORMATIONS

TECHNICAL FIELD

[0001] This invention relates to hydraulic fracturing of ground formations. Such formations may be natural rock, earth or mineral formations and may be located on land or under a sea bed.

[0002] Hydraulic fracturing is carried out in the oil and gas industry to stimulate the rate that hydrocarbons can be produced from a reservoir. The stimulation effect is achieved by placing proppant (often a round and sorted sand) into a fracture created by hydraulic fracturing. A fracture is created by pumping water containing the proppant into a bore hole extended into the ground formation. After pumping stops, the fracture is propped by the sand or other particulate material used as the proppant, causing it to remain as a permeable zone in the reservoir. The propped permeable fracture acts to connect the well bore to a large surface area of the reservoir and to act as a drain through which the reservoir fluids can flow back to the well and then to the surface.

[0003] In conventional hydraulic fracturing equipment, the proppant is added to the pumped water or other fracturing fluid on the low-pressure side of a triplex fracturing pump. This is accomplished by adding the sand or other proppant to the fracturing fluid at a blender that produces a continuously stirred slurry which is fed to the triplex pump. Large amounts of proppant can be added during a treatment using such a system, but the high pressure triplex pump must be a slurry pump. This is an expensive item of equipment and requires constant and expensive maintenance.

[0004] We have applied the hydraulic fracturing technique to stimulate gas drainage from commercial coal mine formations so as to improve operational safety in mining. In that implementation we have found that very significant stimulation effect can be achieved with the placement of relatively small amounts of proppant in each fracture and we have developed equipment which allows proppant to be added as a solids feed on the high pressure side of a fracturing pump, so enabling use of a standard fluid pump rather than a much more expensive slurry pump. Although this equipment has been developed in a program for stimulating gas drainage from coal mines, it may also find application in the oil and gas industry in stimulating extraction of hydrocarbons from a ground formation and in stimulating water wells for domestic, agricultural or industrial use or for other purposes when it is desirable to inject a particulate material with the fracturing fluid.

DISCLOSURE OF THE INVENTION

[0005] The invention generally provides a method of hydraulic fracturing a ground formation comprising:

[0006] passing a fracturing fluid through a fluid pump to generate a flow of pressurised fracturing fluid in a pumping line,

[0007] holding saturated particulate proppant in a proppant storage vessel disposed above the pumping line,

[0008] feeding saturated proppant from the storage vessel downwardly into the flow of pressure fluid downstream from the pump, and

[0009] passing the pressurised fracturing fluid with added proppant into the ground formation.

[0010] The fracturing fluid may comprise water or a water based gel. More specifically, it may comprise water containing viscosity enhancing organic polymer material, although it may be any of a wide range of fluids available for use in hydraulic fracturing. Before the addition of proppant, the fracturing fluid is generally referred to as clean fluid.

[0011] The pressurised fracturing fluid may be directed from the pump via a pumping line to a bore hole extended into the ground formation and the proppant may be fed into the flow within the pumping line from at least one pressure vessel connected to the pumping line.

[0012] The pressure vessel may contain proppant saturated with clean fluid and held under pressure generally equal to the pressure in the pumping line to allow the proppant to feed downwardly into the pumping line as a solids feed under gravity.

[0013] When the proppant in the pressure vessel is saturated with the fracturing fluid no capillary forces arise, allowing the proppant to flow freely under gravity into the injection line. All surfaces that the proppant flows over may be oriented at an angle greater than 35 degrees from the horizontal, which is greater than the internal friction angle of saturated sand, so that the saturated sand will flow freely.

[0014] Clean fluid may be tapped from the pumping line upstream from the pressure vessel to substantially equalise the pressure in the vessel with that of the pumping line.

[0015] The invention further provides apparatus for producing a supply of fracturing fluid containing a particulate proppant for use in hydraulic fracturing of ground formations, said apparatus comprising:

[0016] a clean fluid pump;

[0017] an output line from the pump for flow of pressurised clean fluid from the pump;

[0018] a proppant storage vessel to contain particulate proppant disposed above the output line from the pump and connectable to the output line to feed proppant from the vessel downwardly into the output line.

[0019] The apparatus may further comprise a pressure equalisation line connected or connectable between an upper part of the vessel and the pump output line at a location upstream from the pressure vessel to enable the proppant to be held in the vessel at a pressure generally equal to the pressure in the pumping line to allow the proppant to feed into the pumping line as a solids feed under gravity.

[0020] There may be a proppant meter to meter the admission of proppant from the pressure vessel into the output line.

[0021] The proppant meter may be located at the bottom of the vessel to meter the proppant at a controlled rate from the vessel into the output line.

[0022] The meter may comprise a metering gate.

[0023] The pressure vessel may be provided with a top valve operable to allow the vessel to be filled with proppant through the open valve and closed to allow the vessel to be pressurised.

[0024] A valve on the pressure equalization line may be operable to close off the line for filling of the vessel with proppant.

[0025] The top valve may be operable to close off the connection of the fluid equalisation line with the upper part of the vessel when it is opened for filling of the vessel with proppant. The vessel may also be provided with a bottom valve operable to isolate the interior of the vessel from the output line.

[0026] The top and bottom valves may be actuable by a common actuation device effective to cause the bottom valve to be closed so as to isolate the vessel from the output line when the top valve is opened for a filling operation. The equalisation line valve may be actuable by this device to cause the equalisation valve to be closed when the top valve is open and open when the top valve is closed.

[0027] The pressure vessel may be one of a series of such vessels to contain proppant and each connectable to the pump output line. In that case, the apparatus may be operated so that proppant is admitted to the pump output line from the pressure vessels simultaneously or sequentially. If proppant is admitted from the pressure vessels sequentially, one vessel may be filled while another is feeding proppant to enable continuous feeding of proppant into the pump output line.

BRIEF DESCRIPTION OF THE DRAWING

[0028] In order that the invention may be more fully explained, an embodiment will be described in some detail with reference to the accompanying drawing which illustrates one specific form of apparatus constructed in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0029] The illustrated apparatus comprises a proppant feed unit **1** connected to the output line of a conventional high pressure water or clean fluid pump **2** and is operable to feed proppant into a flow of pressurised fluid delivered from the pump. The pump may be a high pressure pump capable of delivering clean fluid at a pressure of up to 50 MPa at a fluid rate of up to 1500 litres per minute. The proppant will normally be sand and the ensuing description will assume that sand is to be used.

[0030] The proppant feed unit **1** apparatus comprises a high pressure line pipe **11** connected into the outlet line **3** from the pump **2** and an elongated cylindrical pressure vessel **12** which is supported in a vertical disposition by a free standing support frame **13** and is connected at its lower end to the high pressure line **11** through a T-connector **14**. The pressure vessel **12** may be inclined from vertical to lower the overall height of the system for better use in underground mine openings. In such a case, the vessel **12** and other parts over which the sand flows must be at an angle from horizontal that is greater than the internal angle of friction of the saturated sand in the vessel.

[0031] During operation of the apparatus, pressure vessel **12** contains fluid-saturated sand to be fed into the flow of fluid in the high pressure injection line **11** as a solids feed through the T-connector **14**. A top valve **15** allows the top of the vessel to be opened to allow it to be refilled with sand through a hopper **16** and a bottom valve **17** is operable to isolate the interior of the vessel **12** from the high pressure injection line **11** during filling. A sand metering device **18** is fitted to the bottom of the vessel below the isolation valve **17** to meter sand at a regular and controlled rate into the injection line **11**.

[0032] A clean fluid equalisation line **19** is connected between the top of the vessel **12** and the high pressure injection line **11** at a location **21** upstream from the connection with the pressure vessel **12**. This allows clean fluid to be tapped from the high pressure injection line into the upper part of the vessel **12** so as to admit clean fluid into the upper part of the vessel to replace discharged sand thereby to ensure substantially equalised pressure within the vessel. The sand is held in the vessel as close packed particulate material that is placed in the vessel saturated with the fracturing fluid, allowing it to flow freely under gravity as a solids feed from the pressure vessel through the metering device.

[0033] Top valve **15** is actuable through a crank **22** by operation of a hydraulic cylinder unit **23** and bottom valve **17** is actuable via a crank **24** by operation of a hydraulic cylinder unit **25**. Top valve **15** could alternatively be direct coupled to a hydraulic rotary actuator or other device that delivers the required torque. An equalisation line valve **28** is actuable via a crank **29** by operation of a hydraulic cylinder unit **30**. Cylinder units **23**, **25** and **30** and the sand meter **18** are controlled from a remote control panel **26** through an extended control lead **27**. The controls for hydraulic cylinder units **23**, **25** and **30** may be linked so that when top valve **15** is opened to enable pressure vessel **12** to be filled, the bottom valve **17** and the equalisation line valve **28** are closed to isolate the pressure vessel from the high pressure injection line **11**.

[0034] The illustrated apparatus will have particular application in implementing sand propped fractures to stimulate gas drainage from in-seam holes in coal mines. Trials undertaken at Dartbrook Coal Mine in New South Wales have shown that sand propped fractures in horizontal in-seam holes in longwall mining operations have increased gas drainage rates between factors ranging from 5 to more than 10 and that relatively small amounts of sand (20-200 kg per fracture) are needed to produce the desired stimulation effect in in-seam coal gas drainage holes. This can be achieved quite readily with apparatus of the kind illustrated. However, this apparatus has been advanced by way of example only and it could be modified considerably. For example, one or more further pressure vessels with appropriate valves and metering equipment could be connected to the high pressure line **11** so as to be operable simultaneously or sequentially to admit sand into the high pressure line. In relatively high capacity operations, it will generally be more economic to provide a series of small pressure vessels than a single large capacity pressure vessel which would need to be of relatively massive construction. The provision of multiple pressure vessels would also enable sequential operation so that one could be filled while another was feeding sand into the injection line, allowing continuous addition of sand. It is to be understood that such modifications fall within the scope of the appended claims.

1. A method of hydraulic fracturing a ground formation comprising:

passing a fracturing fluid through a fluid pump to generate a flow of pressurised fracturing fluid in a pumping line,

holding saturated particulate proppant in a proppant storage vessel disposed above the pumping line,

feeding saturated proppant from the storage vessel downwardly into the flow of pressure fluid downstream from the pump, and

passing the pressurised fracturing fluid with added proppant into the ground formation.

2. A method as claimed in claim 1, wherein the saturated proppant is held in the storage vessel under pressure generally equal to the pressure in the pumping line to allow the saturated proppant to feed downwardly into the pumping line as a solids feed under gravity.

3. A method as claimed in claim 2, wherein clean fluid is tapped from the pumping line upstream of the vessel to substantially equalise the pressure in the vessel with that of the pumping line.

4. A method as claimed in claim 1, wherein the proppant in the vessel is saturated with the clean fracturing fluid and held in the vessel as close packed solid particulate material.

5. A method as claimed in claim 1, wherein the fracturing fluid comprises water or a water based gel.

6. A method as claimed in claim 5, wherein the fracturing fluid comprises water containing viscosity enhancing polymer material.

7. A method as claimed in claim 1, wherein the proppant comprises sand.

8. Apparatus for producing a supply of fracturing fluid containing a particulate proppant for use in hydraulic fracturing of ground formations, said apparatus comprising:

a clean fluid pump;

an output line from the pump for flow of pressurised clean fluid from the pump;

a proppant storage vessel to contain particulate proppant disposed above the output line from the pump and connectable to the output line to feed proppant from the vessel downwardly into the output line.

9. Apparatus as claimed in claim 8, and further comprising a pressure equalisation line connected or connectable between an upper part of the vessel and the pump output line at a location upstream from the pressure vessel to enable the proppant to be held in the vessel at a pressure generally equal to the pressure in the pumping line to allow the proppant to feed into the pumping line as a solids feed under gravity.

10. Apparatus as claimed in claim 8, further comprising a proppant meter to meter the admission of proppant from the vessel into the output line.

11. Apparatus as claimed in claim 10, wherein the proppant meter is located at the bottom of the vessel to meter the proppant at a controlled rate from the vessel into the output line.

12. Apparatus as claimed in claim 11, wherein the meter comprises a metering gate.

13. Apparatus as claimed in claim 8 wherein the pressure vessel is provided with a top valve operable to allow the vessel to be filled with proppant through the valve when opened and to be closed to allow the vessel to pressurised.

14. Apparatus as claimed in claim 13, wherein there is a valve on the pressure equalisation line operable to close off that line for filling of the vessel with proppant.

15. Apparatus as claimed in claim 14, wherein the top valve and the valve on the pressure equalisation line are operatively linked such that opening of the top valve causes the valve on the pressure equalisation line to close thereby to close off the connection of the fluid equalisation line with the upper part of the vessel.

16. Apparatus as claimed in claim 13 wherein the vessel is provided with a bottom valve operable to isolate the interior of the vessel from the output line.

17. Apparatus as claimed in claim 16, wherein the top and bottom valves are operatively linked such that the bottom valve to be closed so as to isolate the vessel from the output line when the top valve is opened for a filling operation.

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