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GB 2279092 A **GB 2275282 A**

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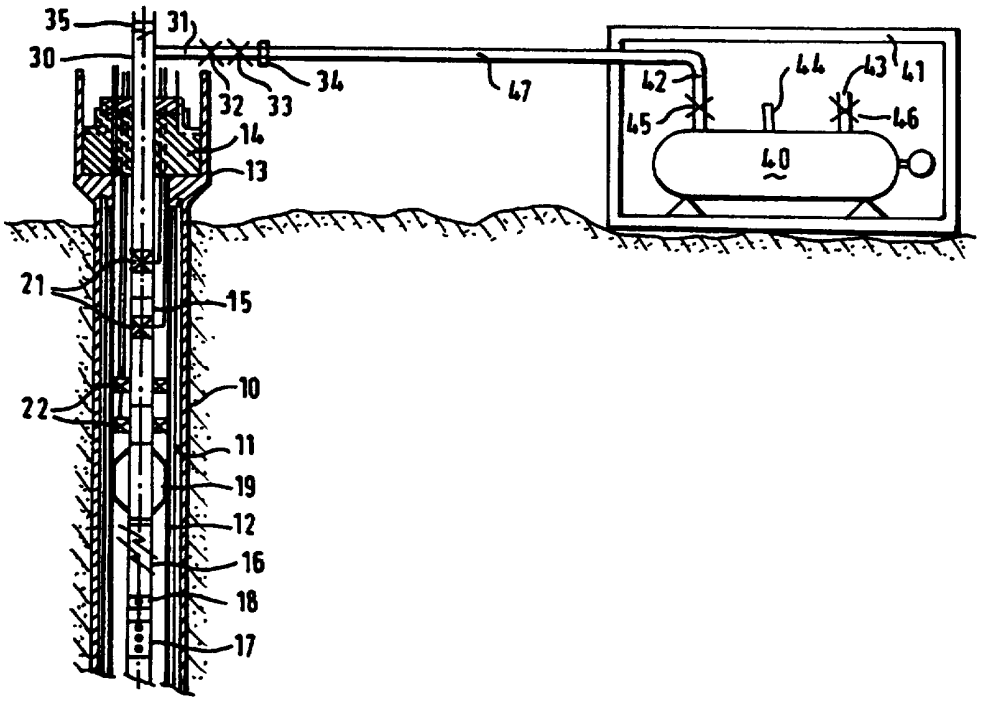
(54) Method and apparatus for abandoning sub-sea wells

(57) Apparatus for the abandonment of a sub-sea well has a tubing hanger 14 with a length of pipe 15 fitted thereto, so as to depend downwardly from the hanger. The pipe 15 is sized to fit within the inner casing of the well to be abandoned. An umbilical connects the pipe 15 back to a surface vessel, and a branch pipe 31 is fitted either into the umbilical or into the pipe 15 at a location above the hanger 14. The branch pipe is adapted for connection to a pressure vessel 40, with at least one isolating valve 32, 33 in the branch pipe 31. During the abandonment process, the pressure in the pipe is monitored, and the or each isolating valve 32, 33, is opened to place the pressure vessel 40 in communication with the pipe 15 in the event that pressure in the pipe exceeds a pre-determined value.



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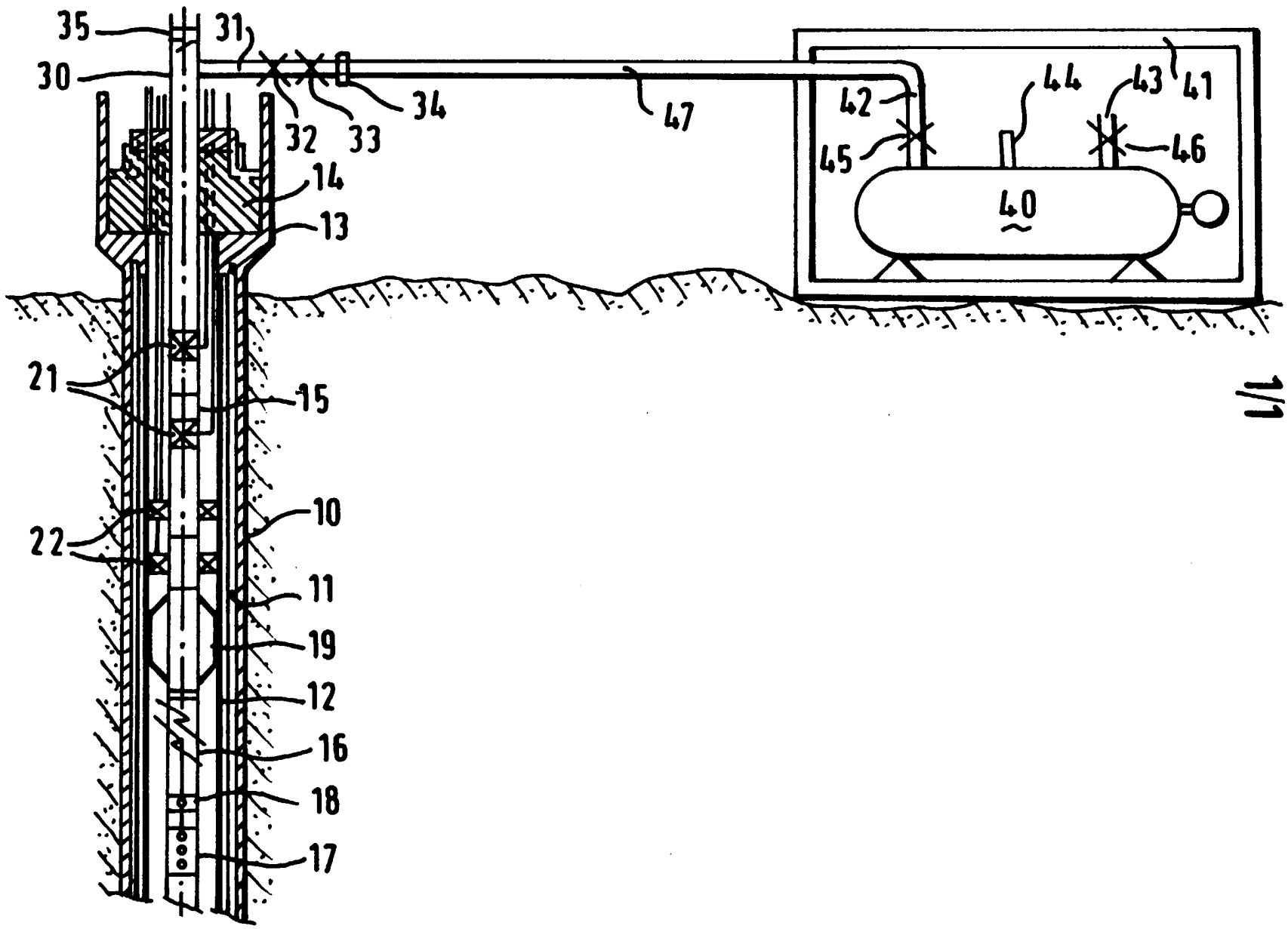
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.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METHODS AND APPARATUS FOR ABANDONING SUB-SEA WELLS

This invention relates to a method of abandoning a suspended sub-sea well fitted with a sub-sea well head housing, and also to apparatus for performing such a method.

In the oil exploration and production industry wells are frequently suspended, either because a well no longer can economically produce oil or gas, or because the well was drilled for exploratory purposes and is not required for commercial production. Unless production is at some stage to be resumed, a suspended well must eventually be finally and irretrievably abandoned.

When a decision is taken finally to abandon a suspended sub-sea well, it is necessary permanently to seal the well significantly below the mud line so as to prevent leakage from the well in the future. Also, government regulations require removal of the well head housing so leaving the sea bed wholly unobstructed. The removal of the well head housing prevents subsequent operations on the well and so it is important that the sealing of the well is completed in a totally permanent manner.

It is the usual practice when abandoning a suspended well to position a rig over the well, so that the rig may be re-engaged with the well head housing to

permit the performance of the required abandoning operations. Typically, this is achieved by removing a non-pressure retaining cap from the well head housing and installing a sub-sea lubricator on that housing, with divers assisting as necessary. The lubricator effects a seal at the well head so that appropriate equipment can be used to perforate the inner casing (which usually is the production casing) below the lubricator. Any pressure within the annular space surrounding the inner casing will be released into the inner casing, but that pressure is contained by the lubricator. The perforating guns are retrieved through the lubricator whereafter cement is pumped into the inner casing through the lubricator and outwardly through the perforations into the annular space. This seals that annular space and so isolates the downhole formations from the mud line.

Once a successful cementing operation has been achieved, pressure within the upper part of the well can be relieved and the lubricator retrieved by the rig. The rig may then be moved away from the well and the well head housing separated from the casings to which that housing is attached by means of explosive charges which cut through the casings, typically about 3m below the mud line. Finally, the severed well head housing is retrieved from the sea bed.

A lubricator has a series of shut off and safety

valves and pack-offs which can be sequentially opened and closed to allow a tool string to enter or leave a well bore under pressure. A lubricator may thus contain within the well any sudden release of pressure, such as may occur on penetrating the inner casing. Unfortunately, the installation of a lubricator on a well head housing usually requires the use of a drilling rig or a purpose-built well-servicing vessel, and the abandonment of a well is thus a relatively expensive operation.

During an abandonment operation, there is always a small risk that oil or gas at well-bore pressure will be encountered. The quantity of any such fluid released from a suspended well is likely to be relatively small, but despite that, it is necessary for the intervention vessel being used for abandonment (usually a rig, as discussed above) to have full hydrocarbon certification. Such certification is very expensive and adds considerably to the cost of well abandonment.

In our UK Patent Application No 96 01341.2, filed 18th January, 1996, we have described and claimed a method of and apparatus for abandoning a sub-sea well, which may be performed from a diving support vessel (DSV). Such a vessel is not normally certified for the handling of hydrocarbons extracted from a well, and so should oil or gas at well-bore pressure be encoun-

tered, the method of abandonment must be terminated and the well left for the performance of a conventional well abandonment process, using a rig or other certified intervention vessel.

By modifying the method and apparatus described in our previous Application No 93 01341.2, it becomes possible to handle small quantities of well bore fluid as may be encountered during an abandonment operation, without the need to use a vessel having full hydrocarbon certification.

According to one aspect of the present invention, there is provided a method of abandoning a suspended sub-sea well fitted with a sub-sea well head housing, which method includes the steps of:

- lowering into the well-head housing a tubing suspension means having a length of tubing depending therefrom, the tubing being receivable within the inner casing of the well and being connected by an umbilical back to a vessel on the surface, there being a branch pipe fitted into the umbilical or into the tubing above the tubing suspension means and there being at least one isolating valve in the branch pipe;

- monitoring the pressure in the tubing during the abandonment operation;

- connecting a sub-sea pressure vessel to the branch pipe in the event the pressure in the tubing exceeds a predetermined value; and

opening said at least one isolating valve to bleed off the excess pressure into the pressure vessel.

When performing the method of the present invention, should any small quantity of reservoir fluids, such as hydrocarbons, be encountered, they may be led away from the well head into a connected sub-sea pressure vessel, without the need to return those fluids under pressure to a surface vessel. Consequently, the vessel - which typically may be a diving support vessel - need not have full hydrocarbon certification. In turn, this greatly reduces the cost of an abandonment operation on a suspended sub-sea well.

It is possible that during the abandoning operation on a suspended well, there is more than just a small quantity of reservoir fluid at well bore pressure. For example, if the well had been plugged insufficiently during the suspending operation, the Annulus around the inner casing may be exposed to the reservoir, in which case there still will be full well bore pressure in the tubing, following the connection of the sub-sea pressure vessel to the branch pipe. Should this occur, the pressure vessel may be isolated and the tubing also closed off to permit the disconnection of the umbilical, whereafter the DSV may leave the well for full abandonment operations using a fully certified intervention vessel or rig.

A non return valve, such as a flap valve, may be fitted either in the umbilical or in the tubing above the branch pipe, to prevent the flow of well fluids up the umbilical to the surface vessel. Such a valve may have a relatively small orifice therein, to permit the monitoring of pressure on the well side of the valve, the orifice being sufficiently small to prevent any significant flow of hydrocarbons upwardly from the well.

In the event that it is determined there is a need for the pressure vessel to be connected to the branch pipe, it would be expected that following the opening of the isolating valve the pressure within the tubing will rapidly fall as the reservoir fluids are bled into the pressure vessel. Provided that the pressure does fall in this way, the abandoning operations may be continued, for example by the procedures described and claimed in our UK Patent Application No. 96 01341.2 as aforesaid. Any hydrocarbon liquids collecting in the pressure vessel may be pumped to the surface, for storage in a suitable tank located for example on a DSV. Any gas in the vessel may be vented sub-sea, by divers.

According to a second aspect of the invention, there is provided apparatus for the abandonment of a sub-sea well, comprising tubing suspension means having a length of tubing depending therefrom which tubing is

sized to fit within the inner casing of the well, an umbilical arranged to connect the tubing back to a surface vessel, a branch pipe fitted into the umbilical or into the tubing above the tubing hanger and adapted for the connection thereto of a pressure vessel, and at least one isolating valve in the branch pipe.

It will be appreciated that the apparatus of this aspect of the invention is intended for use in performing a method of this invention as described above.

The tubing suspension means may comprise a conventional tubing hanger adapted to fit within and effect a seal with a well head housing. In the alternative, the tubing suspension means may comprise a casing hanger intended to be secured in a sealing manner within the inner casing of the well to be abandoned, below the well head housing itself.

The pressure vessel may be essentially conventional and typically may comprise a cylindrical vessel supported within a frame adapted to permit the vessel to be located on the sea bed, adjacent a well being abandoned. Such a vessel may be provided with inlet and outlet pipes fitted with suitable valves, and also with an excess pressure safety valve. Means may also be provided to monitor the pressure prevailing within the pressure vessel.

By way of example only, one specific embodiment of

apparatus of this invention for use in the final abandonment of a suspended sub-sea well and the method by which that apparatus is used will now be described in detail, reference being made to the accompanying drawing, which is a vertical section through the upper 100m or so of a suspended well with the apparatus fitted thereto.

In the drawing there is shown the upper part of a suspended well, including an outer casing 10, and arranged concentrically therewithin an intermediate casing 11 and a production casing 12. The method is equally applicable to wells having only two such casings or having more than three casings, as will be appreciated by those skilled in the art. Just above the sub-sea mud line, a well head housing 13 is attached to the upper ends of those casings.

At the time of suspending the well, one or more cementitious plugs (not shown not shown in the drawing) are installed within the production casing 12, typically at the downhole formations and at other depths below the mud line, as required. In addition, the annular spaces between the casings may have been sealed but if they have not been sealed, there may be relatively high pressures within those spaces.

When a suspended well is finally to be abandoned by the method of this invention, a DSV is positioned over the well head and if a non-pressure retaining cap

has been fitted to the well head housing 13, that is removed by lifting from the DSV. A tubing hanger 14, having a length (typically about 15m) of steel pipe 15 fitted thereto and a length of flexible high pressure hose 16 connected to the lower end of that pipe 15, is lowered into the well from the DSV until the hanger connects with the head housing. The hanger is then secured in position, using a known form of lock-down for this purpose. At the free end of the hose 16 is a perforating gun 17, which employs explosive charges to penetrate at least the production casing 12 but possibly also the intermediate casing 11, generally radially of the gun position. The gun is triggered by the pressure within the hose 16, or within the production casing 12, reaching a pre-set value. For some circumstances, it may be advantageous to fit into the hose 16 a fluid circulating port 18, some way above the gun 17.

A centraliser 19 may be fitted to the hose 17 or to the pipe 15, in order to ensure that those components remain substantially co-axial with the casings.

The pipe 15 is provided with a series of two sub-surface safety valves 21, to allow any release of pressure to be contained within the well, in the event that it is determined the abandonment operation from a DSV must be terminated. A seal is effected between the

pipe 15 and the production casing 12 by means of two annular inflatable collars 22 (or packers) though for some abandoning operations, it may be sufficient to rely on the seal at the well head, between the housing 13 and the tubing hanger 14. The pipe 15 projects upwardly above the tubing hanger 14, as shown at 30. A branch pipe 31, in the form of a Tee, is connected to that part 30 and is provided with two isolation valves 32 and 33. The branch pipe 31 terminates in a hose connector 34. Above the branch pipe 31, that part 30 of the pipe 15 is provided with a flapper valve 35, which serves as a non-return valve to prevent fluids rising up an umbilical (not shown) which connects a DSV used for the abandonment operation to pipe 15.

Also shown in the drawing is a pressure vessel 40 comprising a tank mounted within a framework 41. The tank is provided with an inlet pipe 42, an outlet pipe 43 and a safety valve 44 the pipes 42 and 43 being provided with the respective shut-off valves 45 and 46. A pressure hose 47 is used to connect the branch pipe 31 to the inlet pipe 42.

To perform a final abandonment method of this invention, the tubing hanger 14 is connected to the well-head housing and all necessary seals are perfected. Then a pressure test is performed to check the integrity of the seals and also of the plug in the production casing. If this pressure test does not give

a satisfactory result, and the seals are determined as function correctly, the production casing may be re-plugged before proceeding, or the operations may be terminated until a rig may be brought to the well.

Once a satisfactory pressure test has been obtained, the pressure within the production casing below the housing 13 is increased to the pre-set value at which the perforating gun fires. This value is chosen so as to be of the same order as the expected maximum pressure which could be prevailing in the annulus spacing around the casing.

The pressure within the pipe 15, below the well-head, is then determined. If it is apparent from this that there are reservoir fluids (such as hydrocarbons) under pressure present in the pipe, the pressure vessel 40 may be connected by hose 47 to the branch pipe 31 and the valves 32, 33 and 45 opened to permit the bleeding of those hydrocarbons into the pressure vessel. If only a relatively small quantity of such fluids are present, the pressure within pipe 15 will fall rapidly. The vessel 40 may then be isolated from pipe 15 and the abandonment operation completed by pumping cementitious material down the umbilical and into the well finally to plug that well, whereafter the well-head may be cut free from the casings by explosives and then removed from the sea-bed.

If the pressure within pipe 15 does not fall

rapidly following the opening of the valves between pipe 15 and the pressure vessel 40, it may be presumed that the annulus surrounding the inner casing is exposed to a significant pressure source such as full reservoir pressure. In this case, all of the valves 21, 32, 33 and 45 may be closed, the hose 47 disconnected from branch pipe 31, the pressure vessel recovered from the sea-bed and the umbilical disconnected from pipe 15. The well may be left in this condition ready for a more complex abandonment operation, using a fully hydrocarbon certified rig or other intervention vessel.

CLAIMS

1. A method of abandoning a suspended sub-sea well fitted with a sub-sea well head housing, which method includes the steps of:

- lowering into the well-head housing a tubing suspension means having a length of tubing depending therefrom, the tubing fitting within the inner casing of the well and being connected by an umbilical back to a vessel on the surface, there being a branch pipe fitted into the umbilical or into the tubing above the tubing suspension means and there being at least one isolating valve in the branch pipe;

- monitoring the pressure in the tubing during the abandonment operation;

- connecting a sub-sea pressure vessel to the branch pipe in the event the pressure in the tubing exceeds a predetermined value; and

opening said at least one isolating valve to bleed off the excess pressure into the pressure vessel.

2. A method as claim in claim 1, in which a non-return valve is fitted in the umbilical or in the tubing above the branch pipe, to prevent the flow of well fluids up the umbilical to the surface vessel.

3. A method as claim in claim 2, in which the non-return valve comprises a flap valve.

4. A method as claim in claim 2 or claim 3, in which the pressure is monitored through an aperture in the

on-return valve.

5. A method as claim in any of the preceding claims, wherein the abandonment operation is performed from a non-hydrocarbon-certified support vessel.

6. A method as claim in claim 5, in which any liquid collecting in a pressure vessel connected to the branch pipe is pumped to the surface vessel to be stored under substantially atmospheric pressure in a holding tank.

7. A method as claimed in any of the preceding claims, wherein the tubing depends from a tubing hanger connectable to the well head housing.

8. A method of abandoning a suspended sub-sea well and substantially as hereinbefore described with reference to the accompanying drawings.

9. Apparatus for the abandonment of a sub-sea well, comprising tubing suspension means having a length of tubing depending therefrom which tubing is sized to fit within the inner casing of the well, an umbilical arranged to connect the tubing back to a surface vessel, a branch pipe fitted into the umbilical or into the tubing above the tubing hanger and adapted for the connection thereto of a pressure vessel, and at least one isolating valve in the branch pipe.

10. Apparatus as claimed in claim 9, wherein the tubing suspension means comprises one of a tubing hanger or a casing hanger.

11. Apparatus as claimed in claim 9 or claim 10,

wherein the branch pipe comprises a Tee fitted to the upper end of the tubing projecting from the tubing suspension means, and the umbilical is connected to the upper end of the Tee.

12. Apparatus as claimed in any of claims 9 to 11, wherein the branch pipe is provided with two isolating valves, arranged in series.

13. Apparatus as claimed in any of claims 9 to 12, wherein there is provided a non-return valve in the umbilical or in the tubing above the branch pipe, to prevent the flow of well fluids up the umbilical.

14. Apparatus as claimed in claim 13, wherein the non-return valve comprises a flap valve.

15. Apparatus as claimed in any of claims 9 to 14, wherein means are provided to monitor the pressure in the tubing below the tubing suspension means.

16. Apparatus as claimed in any of claims 9 to 16, wherein the pressure vessel includes means to permit the release therefrom of fluids under pressure.

17. Apparatus as claimed in any of claims 9 to 16, wherein the pressure vessel is supported within a frame to permit the vessel to be disposed on the sea-bed adjacent a well head.

18. Apparatus for the abandonment of a sub-sea well and substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

The Patent Office

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Application No:	GB 9602103.5	**Examiner:**	David Harrison
Claims searched:	1 to 18	**Date of search:**	20 March 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F (FLA)

Int Cl (Ed.6): E21B

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2279092 A	(Philip Head)	1
A	GB 2275282 A	(Halliburton Company)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.