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E21B 33/035 41/00

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E1F FJA

(56) Documents cited
GB 2251639 A GB 2244074 A

(58) Field of search
UK CL (Edition K) **E1F FJA**
INT CL[5] **E21B**
Online databases: WPI

(54) **Sub-sea well installation**

(57) Pressure gas from a source 3 at an offshore platform 1 passes via a conduit 8 to power a prime mover such as a turbine 13 at a sub-sea well-head 10. The turbine 13 drives an electricity generator 14 which may, for example, power valves 19 and 32 to 35 at the well-head. In another embodiment (not shown), for example, the pressure gas may power a prime mover generating hydraulic pressure supply for the actuation of such valves. In order to reduce the amount of energy which must be supplied from the platform, the gas passes via one or more heat exchangers 36, 38 which transfer heat energy from the well product in a transfer line 31 to the gas to assist in powering the prime mover. The exhaust gas from the prime mover, as the turbine 13, may also pass via a further heat exchanger 40 to receive heat from the well product in order to prevent freezing at the sub-sea exhaust port. In other proposals (not shown) exhaust from the prime mover 13 may be used to cool equipment at the well-head such as actuator 18, or to generate hydraulic pressure for operation of sub-sea hydraulic equipment.

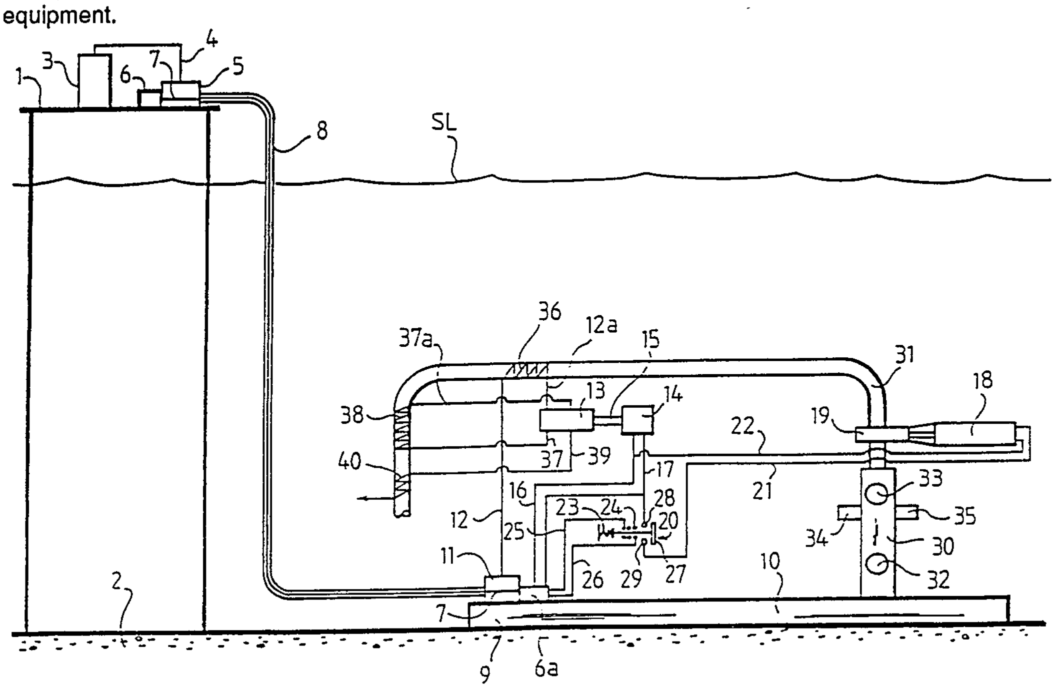

FIG 1

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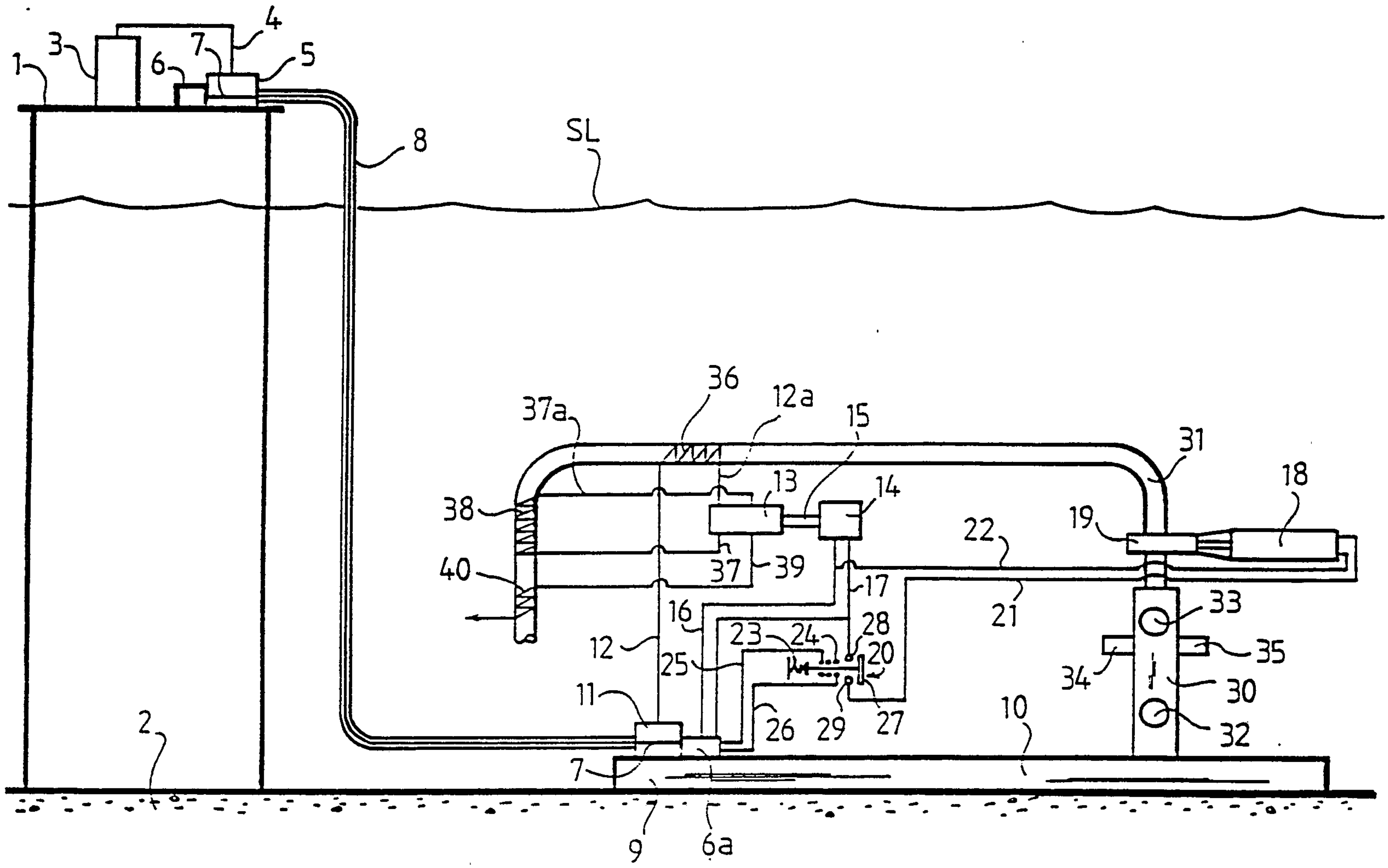
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FIG 1

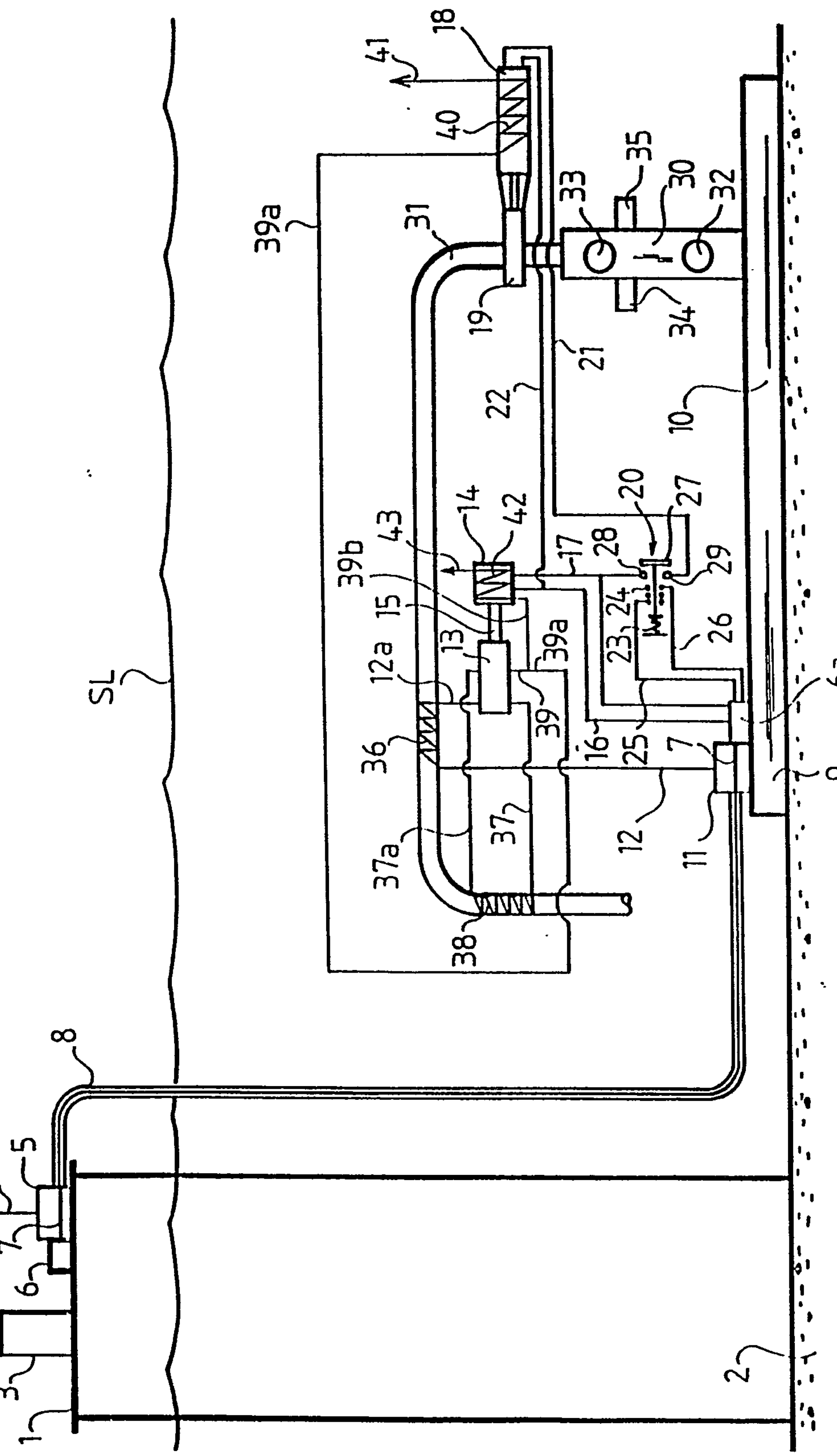

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FIG 2

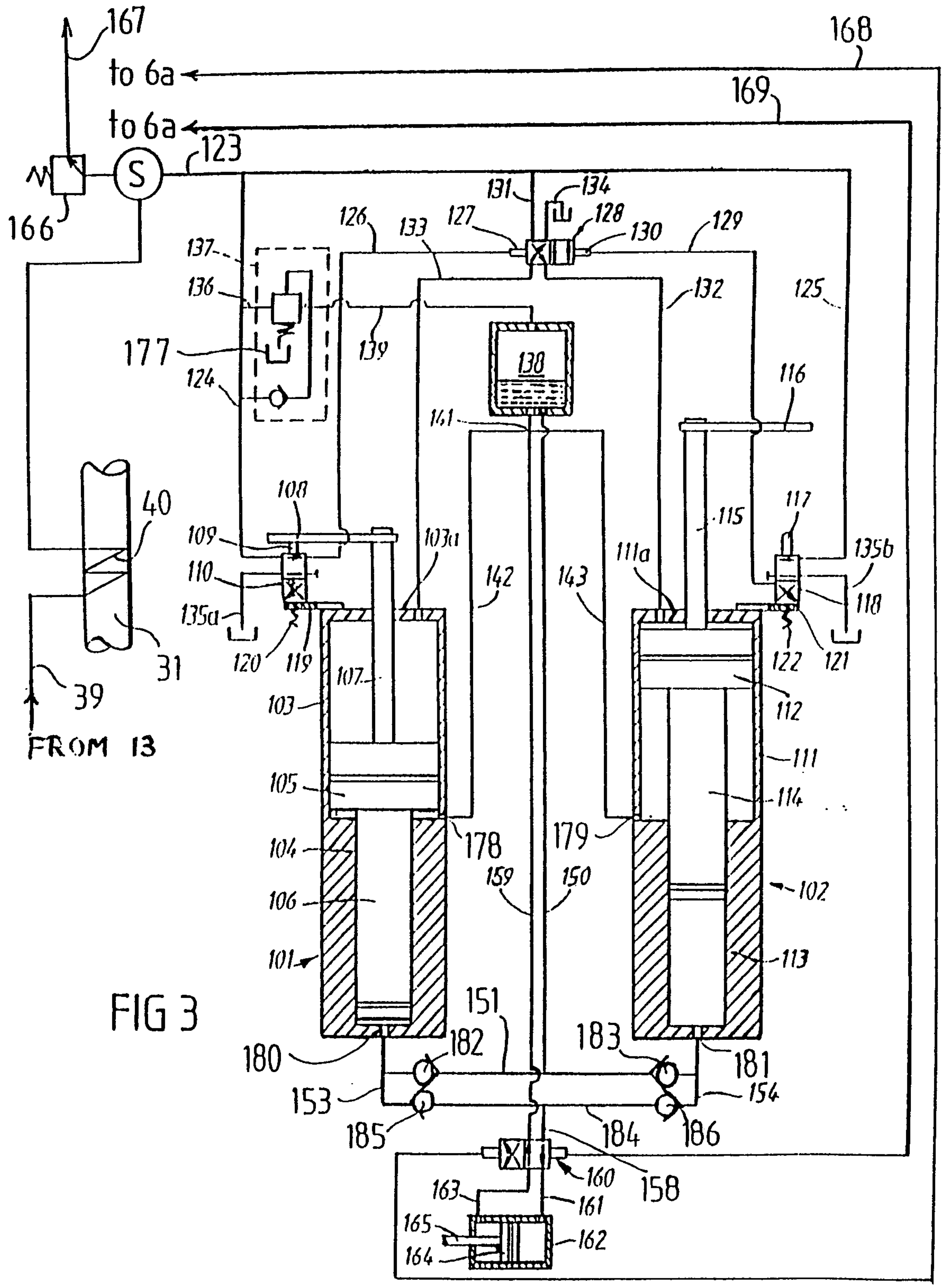
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FIG 3

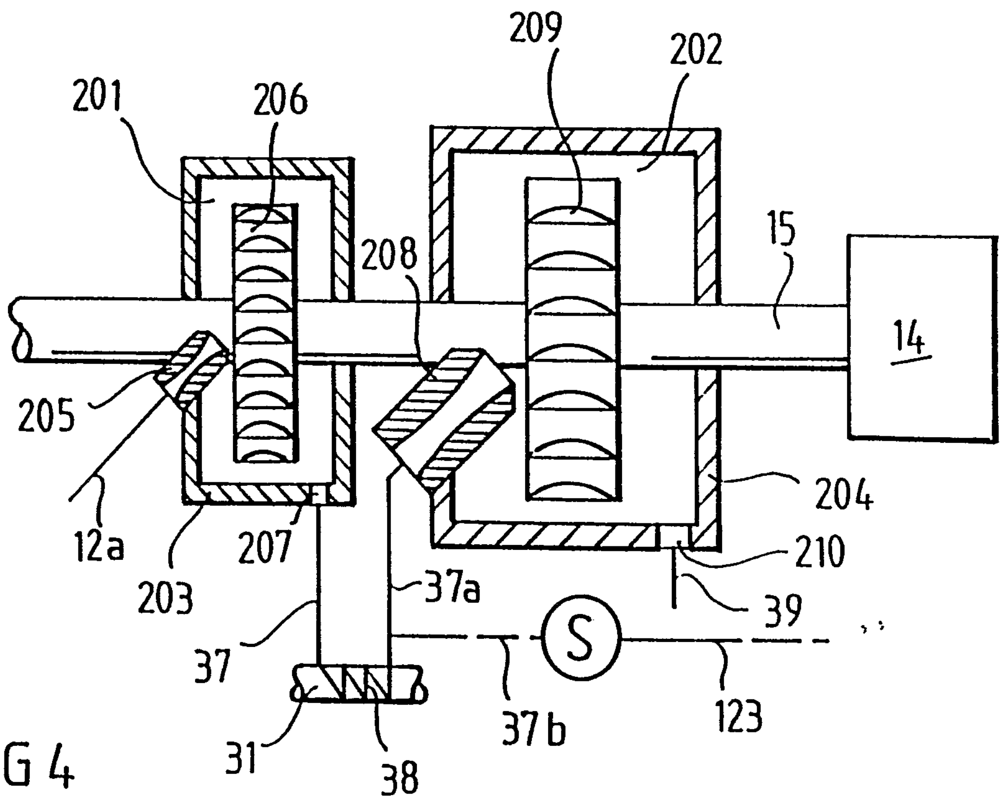

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FIG 4

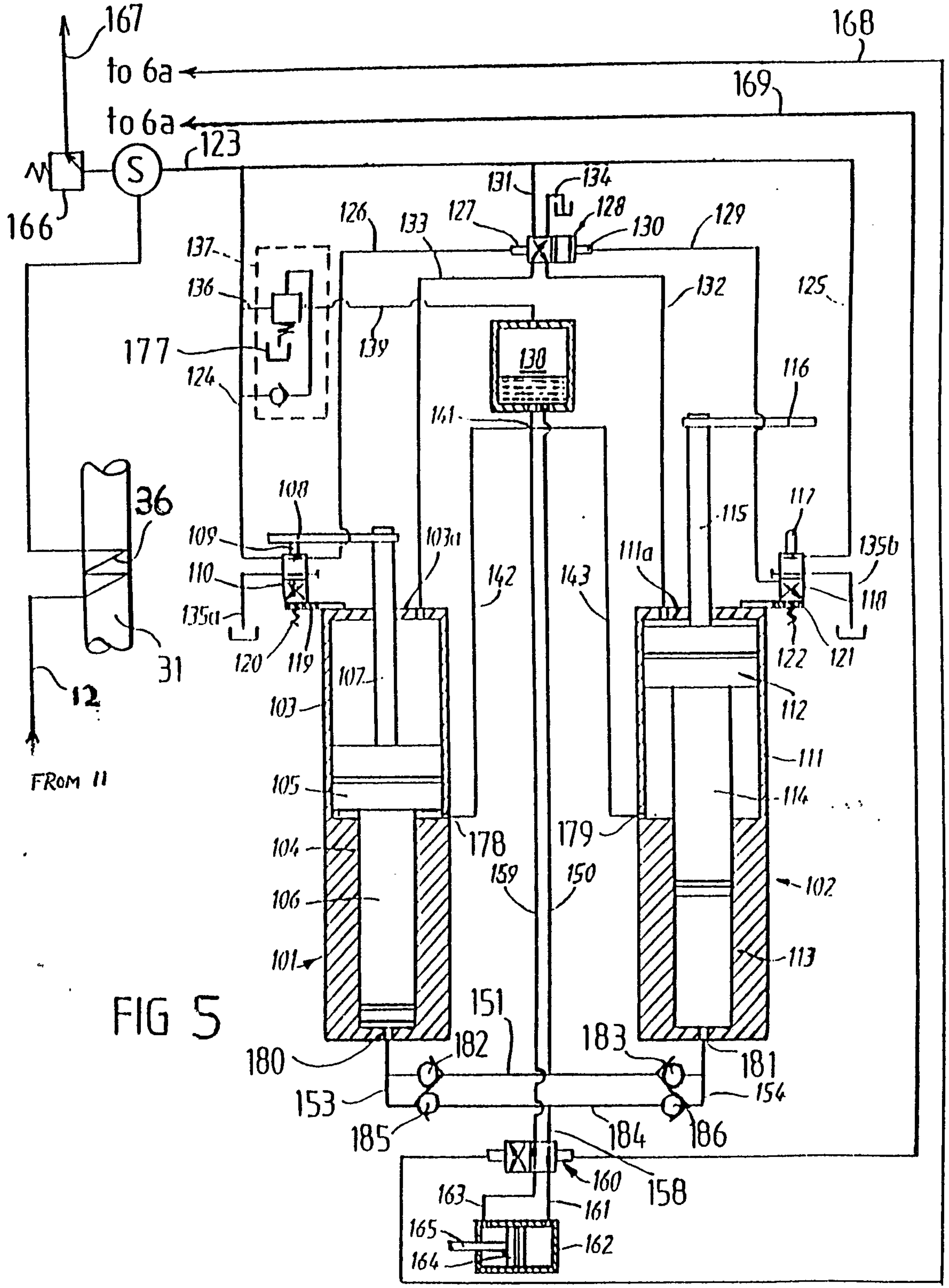
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FIG 5

REMOTE CONTROL APPARATUS

TECHNICAL FIELD OF THE INVENTION

This invention relates to remote control apparatus for controlling underwater arrangements, as sub-sea well-heads, from a remote control location (usually, but not always, a platform disposed above sea level).

BACKGROUND

The control of sub-sea well-heads from platforms requires an electrical supply at the well-head for the operation of electronic and electrical control equipment, and, in recent developments, for the operation of electric actuators of so-called christmas tree and flow line valves which control the flow of oil or gas from the well. The last-mentioned devices substantially increase the electrical power requirement.

Whilst electrical power may be supplied from the platform through conductors, these have to be of substantial size to avoid excessive voltage drops over long distances, and electrical connections are required to be made up sub-sea. Both the electrical power supply wiring and the associated connections are troublesome in a marine environment.

In other sub-sea arrangements a hydraulic pressure supply is required for the operation of hydraulic actuators. Again whilst hydraulic power may be supplied from the platform through conduit, and connected sub-sea, this arrangement is troublesome requiring high pressure fluids to be conveyed through long lengths of conduit.

To overcome the above problems it has been proposed to supply power from the platform to sub-sea well-head in the form of compressed gas, the energy of which may be converted sub-sea to electrical energy.

It has also been proposed to convert the energy of the compressed gas at the sub-sea installation to hydraulic fluid pressure for the operation of actuators.

A primary aim of the present invention may be viewed as being to reduce the amount of compressed gas energy which is required to be supplied from the platform.

Further important considerations are as follows:-

1. To avoid freezing of the sea in the region of any gas discharge ports.

2. To provide energy-efficient means of cooling the necessary sub-sea generator and/or other well-head equipment.

3. To provide energy-efficient means of powering hydraulic equipment at the sub-sea well-head.

SUMMARY OF THE INVENTION

The present invention proposes an installation which comprises a control position (eg. an offshore platform) including a source of pressure gas, conduit means connecting the source of pressure gas to a remote sub-sea well-head, the well-head including at least one prime mover driven by energy from the pressure gas, and heat exchange means for transferring heat energy from the product of the well (eg. gas or oil) to the pressure gas for use by the prime mover.

By thus adding heat energy to the pressure gas at the well-head the energy which is required to be supplied from the platform is reduced.

The installation preferably includes further heat exchange means for transferring heat energy to the exhaust gas from the prime mover. By thus heating the exhaust gas the risk of freezing at any gas discharge port is reduced. The further heat exchange means may extract heat from the well product or it may extract heat which is generated by one or more items of equipment at the well-head, or both. This latter arrangement has the additional advantage of providing energy-efficient means of cooling the said item of equipment.

A prime mover may, for example, comprise a turbine arranged to drive an electricity generator, an air motor arranged to drive an hydraulic pump, or a gas operated cylinder, or cylinders, arranged to generate hydraulic pressure supply.

With the object of still greater energy efficiency the exhaust gas from a first prime mover may be utilised for driving a second or other prime movers, for example the cylinders of hydraulic-pressure-generating apparatus. A prime mover may, for example, comprise two gas-driven stages connected in series, and a proportion of the exhaust gas from the first stage is utilised for driving hydraulic-pressure-generating apparatus. The exhaust gas from the first stage is preferably heated from the well product before driving the hydraulic-pressure-generating apparatus, thereby extracting additional energy from the well product for use by the hydraulic equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is exemplified in the accompanying drawings, in which:-

Figure 1 is a schematic diagram of a sub-sea installation of the invention.

Figure 2 is a schematic diagram of a modified installation based on that of Fig. 1.

Figure 3 is a schematic diagram of hydraulic pressure generating apparatus for use with the installation of Fig. 1.

Figure 4 is a diagrammatic sectional view of a turbine which is suitable for use in the installations of Figs. 1 and 2, and incorporating a modification to the arrangement of Fig. 3.

Figure 5 is a schematic diagram similar to Fig. 3, but in which there is no generator drive and the gas supplied acts directly on pistons of the prime mover cylinder arrangement to generate hydraulic pressure.

DETAILED DESCRIPTION OF THE DRAWINGS

In the drawings, the conventions of BS 2917, 1957 are used in regard to directional control valves, showing internal flow paths in envelope form. The flow path envelope is adjacent to the end to which pilot control pressure is applied.

Referring to Fig. 1, a platform 1 standing on the sea bed 2 above sea level SL has a source of pressurised gas 3 which is supplied by a conduit 4 to a manifold 5. A conduit 8 transfers compressed gas from the manifold 5 to a template 9 at a sub-sea well-head 10 by connecting into a manifold/distributor 11.

A fibre optic coder/decoder unit 6 at the platform 1 connects with an optical cable (fibre optic) 7, which passes through the manifold 5 into the conduit 8. At the well-head the fibre optic 7 travels through the manifold/distributor 11 and enters a coder/decoder unit 6a, thereby providing communication facilities between the platform 1 and the sub-sea well-head 10.

The manifold/distributor 11 provides compressed gas from conduit 8 through a conduit 12 to a prime mover in the form of a two-stage turbine 13 (an example of which is described in more detail below) which drives an electricity generator 14 via a shaft 15. The generator 14 provides power to the coder/decoder 6a through wires 16 and 17, and also supplies power to the electrical actuator 18 of a gate valve 19 through the wire 17, via a switch 20 and wire 21 to one terminal of the electrical actuator 18. The other terminal of the actuator 18 connects by a further wire 22 to the wire 16 from generator 14.

The switch 20 is normally open, being held open by a spring 23, but on receipt of a command signal sent from the platform 1 via the fibre optic 7, the coder/decoder 6a energises solenoid 24 through wires 25 and 26 to draw the switch element 27 into contact with switch contacts 28 and 29, so completing the circuit between wires 17 and 21.

The actuator 18 regulates the flow of well product (oil or gas) from a production tree (christmas tree) 30 into a flow line 31, through which the product is supplied to the platform for processing. Other christmas tree valves 32, 33, 34 and 35 may be controlled by electrical actuators which are powered from the generator 14 in a similar manner to valve 19 and actuator 18. A normal temperature for the hot product is in the order of 180°F, and to preserve the heat of the product in the flow line 31, to ensure ease of flow, the flow line may be lagged.

The pressurised gas supply conduit 12 from the manifold/distributor 7 to the turbine 13 has a heat exchange coil arrangement 36 wound around the flow line 31 (underneath any lagging of course) prior to entry into the first stage of the turbine 13. The gas supply to the turbine thus receives heat from the hot product in flow line 31, so increasing the energy and volume of the gas and therefore its power for driving the turbine 13. In the course of expansion through the first stage of the turbine the temperature of the gas is substantially reduced. The outlet gas from the first stage passing through conduit 37 is taken through a second coil arrangement 38 which is wound about the flow line 31, downstream of the first coil 36, so that the gas gains further heat energy prior to entry into the second stage of the turbine.

The exhaust from the second stage of the turbine passes through conduit 39 from whence the low pressure gas may be exhausted into the sea or returned to the platform. In either event, to avoid ice formation due to the reduced temperature of the expanded gas, a further coil arrangement 40 is wound around the flow line 31, downstream of the second coil 38, to heat the exhaust gas to a sufficient temperature to avoid ice formation.

The arrangement described above thus enables a substantial part of the energy which drives the prime mover for the electrical generator (ie. the turbine) to be provided by the natural heat of the product from the well, thereby substantially reducing the requirement for provision of gas power from the platform and for its transmission from platform to well-head.

In the modified arrangement shown in Fig. 2 items which correspond to those of Fig. 1 have the same reference numerals. In this case, the cool exhaust gas from the second stage of turbine 13 passes into two branches 39a and 39b. Branch conduit 39a travels to a heat exchange coil 40 which surrounds the electrical actuator 18. Thus, heat which is generated in the actuator 18 is transferred to the exhaust gas travelling through the coil 40 so that the exhaust gas which exits to the sea from outlet 41 is raised sufficiently to avoid ice formation.

Branch conduit 39b is coupled to a further heat exchange coil 42 which surrounds the generator 14 so that the exhaust gas passing through the coil 42 receives heat from the generator, thus raising the temperature of the exhaust gas at sea outlet 43 sufficiently to avoid freezing.

The exhaust gas which has been used for electrical power generation can also be used to pressurise hydraulic fluid in order to provide hydraulic power at the well-head, eg. for operating hydraulic actuators. Suitable means for achieving this will now be described with reference to Fig. 3. The hydraulic pressure-generating apparatus shown therein is intended to be used in conjunction with the arrangement of Fig. 1.

In Fig. 3 the pressure gas which has been used to drive the turbine 13, after passing through the heat exchanger 40, supplies a sub-sea gas reservoir S which is provided with a pressure maintaining valve 166 to maintain a constant pressure in the reservoir. The valve 166 exhausts through conduit 167 into the sea, or via a return to the platform 1. The hydraulic apparatus is fed with pressure gas from the reservoir S via a conduit 123.

The hydraulic apparatus includes two piston and cylinder devices 101 and 102. Device 101 includes a first cylinder 103 and a second cylinder 104 of smaller diameter but axially aligned with cylinder 103. A piston head 105 is slidably disposed in the cylinder 103 and is fixed with a secondary piston 106 extending into the cylinder 104. A piston rod 107 extends from the piston head 105 through the end wall 103a of cylinder 103 which is remote from cylinder 104. Piston rod 107 rigidly carries an arm 108 which, when piston head 105 is adjacent to cylinder 104, is arranged to move the actuating plunger 109 of a stroke limiting valve 110.

Device 102 is similar to device 101, and includes a first cylinder 111 and a second cylinder 113 of smaller diameter but axially aligned with cylinder 111. A piston head 112 is slidably disposed in the cylinder 111 and is fixed with a secondary piston 114 extending into the cylinder 113. A piston rod 115 extends from the piston head 112 through the end wall 111a of cylinder 111 which is remote from cylinder 113. This piston rod 115 rigidly carries an arm 116 which, when piston head 112 is adjacent to cylinder 113, is arranged to move the actuating plunger 117 of a stroke limiting valve 118.

The two stroke limiting valves 110 and 118 are conveniently supported by brackets 119, 121 attached to the respective cylinders 103 and 111, and the plungers 109, 117 are spring-loaded to a projecting position by respective compression springs 120, 122. Valves 110 and 118 receive pressure gas from a reservoir S via a conduit 123 and branches 124 and 125. When the plungers 109 and 117 of the two valves 110 and 118 are extended, the valves block the flow of pressure gas, as shown for valve 118, and connect conduits 126 and 129 respectively to exhausts 135a and 135b respectively. However, when the respective plunger 109, 117 is depressed the valve permits pilot pressure gas from reservoir S to flow via the respective conduit 126, 129 to a respective pilot pressure chamber 127, 130 of a change-over valve 128. Once this valve 128 has moved to one position it is detent held until it receives control pressure from the other stroke limiting valve 110 or 118.

A conduit 131 conducts pressure gas from branch 125 to valve 128 from which, in the valve position shown, pressure gas flows via conduit 132 to the upper chamber of cylinder 111 remote from cylinder 113. Valve 128 also connects conduit 133, which leads from the corresponding chamber of device 101, to exhaust 134. When valve

128 is changed over, conduit 132 is connected to exhaust and conduit 133 receives pressure gas.

Pressure gas from branch conduit 124 also passes via conduit 136, through a pressure reducing valve 137 and conduit 139 to maintain a predetermined reduced pressure in the upper region of a low pressure hydraulic fluid reservoir 138. The pressure reducing valve 137 maintains the desired pressure in the reservoir 138 by allowing flow into or out of the reservoir to maintain the desired pressure. Accordingly, the valve 137 has an exhaust connection to the exhaust arrangement 177.

Reservoir 138 supplies hydraulic fluid via conduit 141 and branch conduits 142 and 143 to the lower end (as shown) of respective cylinders 103 and 111 via ports 178 and 179 respectively.

Ports 180 and 181 at the lower end (as shown) of the cylinders 104 and 113 respectively connect with conduits 153 and 154. Conduit 153 connects with a conduit 151 through a non-return valve 182 which permits flow only in the direction from conduit 151 to conduit 153. The conduit 151 connects with the conduit 154 through the non-return valve 183 which permits flow only in the direction from conduit 151 to the conduit 154. The conduit 153 also connects with a conduit 184 through a further non-return valve 185 which permits flow only in the direction from the conduit 153 to the conduit 184. The conduit 154 also connects with the conduit 184 through the non-return valve 186 which allows flow only in the direction from the conduit 154 to the conduit 184. A conduit 150 conducts hydraulic fluid from the reservoir 138 to the conduit 151. Thus, the conduit 184 receives hydraulic output from the cylinders 104 and 113, and the conduit 151 supplies charging fluid to the cylinders 104 or 113 when the piston 106 or 114 commences its return stroke.

Conduit 184 connects to conduit 158 which supplies a port of solenoid operated control valve 160. Conduit 159 connects another port of the control valve 160 to the hydraulic fluid reservoir 138. The valve 160 is actuated by control signals on wires 168 and 169 from the platform 1 through the fibre optic communicating link 7 and coder/decoder unit 6a. In its illustrated position, valve 160 connects conduit 158 with a conduit 161 opening to one end of an hydrualic actuator cylinder 162, whilst conduit 159 is in communication, via valve 160, with a conduit 163 opening to the opposite end of cylinder 162. A piston 164 is slidably disposed in cylinder 162 and is rigidly connected to a piston rod 165 which extends from the cylinder 162 to operate a well-control valve (not shown). In the other operative position of valve 160 conduit 158 (the pressure conduit) is connected to conduit 163, and conduit 159 (the return conduit) is connected to conduit 161, thus reversing movement of the piston rod 165.

The operation of the hydraulic equipment will now be described, commencing at the position illustrated, in which piston rod 107 is in a fully retracted position so that arm 108 is depressing plunger 109. Piston rod 115 is extended, and change-over valve 128 is admitting pressure gas from reservoir S to the upper chamber (as shown) of cylinder 111, urging piston 112 downwardly to pressurise hydraulic fluid in cylinder 113. The upper chamber of cylinder 103 is connected via valve 128 to exhaust port 134.

Thus hydraulic pressure fluid from cylinder 113 passes via non-return valve 186 to control valve 160 which, in the position shown, passes hydraulic pressure fluid to the piston head end of cylinder 162. Return fluid from the piston rod end of the cylinder 162 passes through valve 160 to return fluid to the reservoir 138.

As the upper chamber of cylinder 103 is at this stage connected to exhaust, low pressure fluid from the reservoir 138 (through conduits 141 and 142 and port 178) acts on the underside of the piston 105. Piston 105 is thus urged upwards causing hydraulic fluid from the reservoir 138 to pass via non-return valve 182 into cylinder 104 below the piston 106. Cylinder 104 is thus recharged in preparation for the next delivery stroke.

Upward movement of the piston 105 lifts the piston rod 107, moving arm 108 out of contact with the plunger 109, so allowing the valve 110 to change position putting chamber 127 of the valve 128 to exhaust. Valve 128, being detent held, remains in its current position so that the delivery stroke of the unit 102 continues.

It is noted that the positive charging of cylinder 104 by pressure fluid from the reservoir 138 ensures that the unit 101 is fully charged before the delivery stroke of unit 102 is completed.

As the piston 112 travels down the cylinder 111 hydraulic fluid is returned to the low pressure reservoir 138 through port 179 and conduit 143. The hydraulic reservoir 138 is, of course, at a lower pressure than the pressure gas supply acting on piston 112 due to pressure reducing valve 137.

When arm 116 eventually engages plunger 117, valve 118 admits pressure gas to the operating chamber 130 of valve 128. Valve 128 thus changes over to remove the supply of pressure gas from the upper chamber of cylinder 111, which is admitted to exhaust, and to supply pressure gas to the upper chamber of cylinder 103. With the upper chamber of cylinder 111 connected to exhaust, pressure fluid from the reservoir 138 urges the piston 112 upwards (as shown) to recharge the cylinder 113 from the reservoir 138. Fluid pressure from cylinder 104 is now delivered through non-return valve 185 and control valve 160 to cylinder 162.

Return flow from the cylinder 162 passes through valve 160 to reservoir 138.

It will thus be seen that the devices 101 and 102 operate alternately to supply the control valve 160, and through it the actuator 162, and that each piston 106, 114 completes its stroke before changeover occurs, and that the cylinders 104 and 113 are fully recharged with fluid prior to the delivery stroke. Since the piston heads 105 and 112 have a larger area exposed to the pressure gas than the area of pistons 104 and 114 exposed to the hydraulic fluid, the pressure gas required to achieve a desired hydraulic pressure can be many times less than the said hydraulic fluid pressure. As the pressure in reservoir 138 is low and the annular areaa bove the piston 105 (112) is great in comparison with the area of the bore 104 (113), the hydraulic output pressures of the units 103 and 111 are several times that of the gas pressure. Precise maximum hydraulic fluid output pressures are determined by the pressure of the gas supply.

In one arrangement, when the gas pressures at the exhaust 134, 135a, 135b and 177, are greater than the pressure of the surrounding environment these exhausts release the exhaust gases into the surrounding environment. However, when it is desirable to reduce the exhaust pressures, as when operating in a deep water location, the exhaust can be connected to an exhaust conduit extending to sea level, conveniently at the platform 1.

With the above described hydraulic arrangement it will be noted that:-

(a) The hydraulic equipment is powered by the energy of the exhaust gas from the prime mover.

(b) The gas energy thus supplied to the hydraulic equipment is increased by heat received from the hot product.

(c) The hydraulic output pressure is greater than that of the pressure of the gas supplied.

(d) The changeover arrangement employed provides a substantially continuous delivery of hydraulic output.

(e) Other means of effecting changeover switching may be used - for example, pressure, electrical, or nucleonic.

(f) Arrangements may be made for change-over under control from the platform 1 in an emergency.

(g) A full charge of the hydraulic devices 101, 102 before the next delivery stroke is ensured by provision of pressurised charging fluid from the low pressure reservoir.

(h) Although the hydraulic output from the low pressure reservoir is shown as pressurised by low pressure gas, other means of providing the necessary liquid head may be used, for example, by the use of weights or by elevating the reservoir in relation to the rest of the hydraulic equipment.

(i) Hydraulic fluid from the hydraulic equipment is returned to the reservoir.

(j) Several actuators could be connected in parallel, each controlled from the control location by a respective control valve 160.

(k) Whilst in the foregoing examples the control apparatus has been illustrated as including a pair of hydraulic units in which hydraulic fluid is pressurised it will be appreciated that one or more additional pressurising hydraulic devices may be added to increase the volume of hydraulic pressure fluid available and/or to smooth the supply of hydraulic fluid.

(l) The hydraulic arrangement may comprise several sets of hydraulic devices operating in series or in parallel to provide output at a variety of pressures.

(m) The pressurised hydraulic output may be used for purposes other than driving actuators.

(n) The exhaust gas from the turbine 13 may be fed directly to the reservoir S without passing through the coil 40, or it may pass via a heat exchange coil associated with the actuator 18 or other well-head equipment.

Fig. 4 shows a typical two stage turbine 13 having a first stage rotor 201 and a second stage rotor 202 driving a common shaft 15 supported in respective turbine casings 203 and 204.

A gas nozzle 205 of the first stage rotor 201 receives compressed gas from the conduit 12a (Fig. 1) and directs it at a high velocity onto turbine blades 206 to turn the rotor. Exhaust from the first stage 201 passes out of the casing 203 via an exhaust port 207 to the conduit 37 and thence through the heat exchange coil 38. The heated gas then passes through the second stage compressed gas supply conduit 37a and through nozzle 208 of the second stage rotor 202.

Nozzle 208 drives the rotor 202 by directing gas at high velocity onto the turbine blades 209. Exhaust gas from the second stage casing 204 passes through exhaust port 210 to the conduit 39.

In a modification to the arrangement of Fig. 3, part of the gas supply to the second stage nozzle 208 is diverted through conduit 37b (Fig. 4) to supply gas reservoir S, which in turn supplies the hydraulic-pressure-generating apparatus via conduit 123.

Fig. 5 is similar to Fig. 3 except that the gas supply to the heat exchanger 36 is taken direct from the platform gas supply through the conduit 8 and the manifold/distributor 11 and the conduit 12 to the gas reservoir S such that the arrangement may operate in parallel with the turbine 13, or other prime movers, or may operate quite separately in an arrangement not including other prime movers. Otherwise, the description of equipment shown in Fig. 5 and its operation is identical with that of Fig. 3.

CLAIMS

1. An installation which comprises a control position (eg. an offshore platform) including a source of pressure gas, conduit means connecting the source of pressure gas to a remote sub-sea well-head, the well-head including at least one prime mover driven by energy from the pressure gas, and heat exchange means for transferring heat energy from the product of the well (eg. gas or oil) to the pressure gas for use by at least one prime mover.

2. An installation according to Claim 1, including further heat exchange means for transferring heat energy to the exhaust gas from the prime mover.

3. An installation according to Claim 2, in which the further heat exchange means extracts heat from the well product.

4. An installation according to Claim 2, in which the further heat exchange means extracts heat which is generated by one or more items of equipment at the well-head.

5. An installation according to any preceding claim, in which a prime mover is arranged to drive an electricity generator.

6. An installation according to any preceding claim, in which a prime mover is arranged to generate hydraulic fluid pressure supply.

7. An installation according to any preceding claim, in which the exhaust gas from a prime mover is utilised for driving hydraulic-pressure-generating apparatus.

8. An installation according to Claim 7, in which the prime mover comprises at least two gas-driven stages connected in series and a proportion of the exhaust gas from one stage is utilised for driving hydraulic-pressure-generating apparatus.

9. An installation according to Claim 8, in which the exhaust gas from one stage is heated from the well product before driving the hydraulic-pressure-generating apparatus.

10. An installation which is substantially as described with reference to Figures 1, 2, 1 and 3, or 1 and 3 as modified in Figure 4 and Figure 5 of the accompanying drawings.

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Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9216004.3

Relevant Technical fields

(i) UK Cl (Edition K) E1F (FJA)

(ii) Int Cl (Edition 5) E21B

Search Examiner

D J HARRISON

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Date of Search

25 SEPTEMBER 1992

Documents considered relevant following a search in respect of claims 1 TO 10

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A,P	GB 2251639 A (R C PEARSON) 15 July 1992	1
A	GB 2244074 A (R C PEARSON)	1

SJJ - doc99\fil000772

SF2(p)

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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