(54) Title: APPARATUS FOR HYDROCARBON OPERATIONS AND METHOD OF USE

![Fig. 3]

(57) Abstract: The present invention provides an apparatus (300) for performing an operation in a fluid conduit of a hydrocarbon exploration or production installation and methods of use. The apparatus comprises a body (302) configured to be received in a fluid conduit, which is coupled to a tool fluid conduit (304) defining a flow bore. An imaging device (314) is carried by the body and a flow direction arrangement provides a fluid circulation path between an annulus located between an interior wall of the fluid conduit and the body and the flow bore in use. The flow direction arrangement is configured to provide deployment thrust on the body when fluid is circulated between the annulus and the flow bore through the fluid circulation path. Applications to the inspection of flexible risers and applications to the placement of a fluid or material a treatment operation are described.
Apparatus for hydrocarbon operations and method of use

The present invention relates to apparatus for use in fluid conduits in the hydrocarbon exploration and production industry and methods of use, and in particular to methods of inspecting the interior of fluid conduits; placing treatment fluids in fluid conduits; and/or treating hydrate deposits in fluid conduits. Aspects of the invention relation to fluid conduit operations in hydrocarbon exploration and production installations in which the deployment of an apparatus is assisted by a fluid circulation method, and preferred embodiments relate to a method and apparatus for simultaneous inspection of a fluid conduit and placement of a fluid to an inspection location. The invention has particular application to the internal inspection of flexible riser systems using fluid circulation for tool deployment and/or fluid placement.

Background to the Invention

Inspection of fluid conduit systems in hydrocarbon exploration and production installations is necessary in order to monitor their condition and performance, and consequently a
variety of internal and external inspection techniques are in common use and form part of
c conduit inspection and monitoring regimes. Exterior inspection techniques can provide
relatively easy access and application of inspection equipment, but have limitations in their
assessment of structural or internal conditions. Internal inspection enables a number of
internal and/or structural characteristics to be assessed, including the thickness of an
internal wall, the presence of debris or scale within the conduit; the presence of interior
corrosion; and/or any damage or defects to the fluid conduit structure. However, internal
inspection techniques present challenges to oil and gas operators and service companies,
including those associated with successful tool deployment and robustness of the
inspection tools in hostile conditions.

An exemplary application is the internal inspection of subsea pipeline and flexible riser
production systems. Figure 1 shows schematically a subsea production system, generally
depicted at 100, at which a Floating Production Storage and Offloading vessel (FPSO) 102
is coupled to a subsea pipeline 104 via a pair of flexible risers 106a, 106b. The flexible
risers 106 are joined to the subsea pipeline 104 via Subsea Isolation Valves (SSIVs) 108a,
108b. The subsea pipeline 104 comprises a pigging loop, which may be several
kilometres in length. The pipeline is tied in to several subsea wells via manifolds 110. The
flexible risers 106, shown here in lazy S wave configuration, are subject to stress and
fatigue, and it is desirable to inspect the flexible risers regularly to ensure their integrity.
However, external inspection of flexible riser is challenging due to the multi-layer structure
of the riser carcass and the requirement for ROVs to provide deepwater access. It is also
desirable to inspect the interior of the SSIV to establish that it is in good condition and is
functioning correctly.

A conventional internal inspection of the flexible riser system shown in Figure 1 involves
complete de-watering and de-oiling of the subsea pipeline 104 and the flexible risers 106
to enable internal inspection tools to be deployed. This necessitates the complete
shutdown of production. Clearly this has significant and undesirable economical
implications for the operator of the production system.

It is known to use coiled tubing intervention to provide access to pressurised wellbores, for
example in wellbore cleanout and fluid placement methods. Coiled tubing is a long
continuous length of metal piping wound on a spool, which is straightened by plastic
deformation and inserted into the wellbore. In a cleaning application, fluid is circulated
through the inside of the coiled tubing and back out through the annulus between the
coiled tubing and the wellbore. Particulate matter in the wellbore is brought to surface by
the circulating fluid. When performing this type of wellbore operation, it is necessary to
employ procedures and equipment for controlling and retaining pressure in the wellbore
system to ensure it is isolated from surface. A typical pressure control system includes an
injector head, which contains a drive mechanism to push and pull the coiled tubing in and
out of the hole through a pressure control device.

The coiled tubing injector system described above is therefore a substantial and heavy
piece of equipment, with large footprint and high capital expense. The coiled tubing
injector system also requires a distance of several metres to be available above the
isolation valve to accommodate the injector and the gooseneck. This limits the number of
installations where coiled tubing operations can be performed and can make operations
more costly. These problems are particularly significant in the case of offshore operations,
for example in a turret of a floating production storage production and offloading vessel
(FPSO) where space is at a premium and cranes are unable to lift the components into
place. Even light coiled tubing units which are used onshore are still substantial pieces of
equipment which are large in size and weight in the context of offshore operations.

To alleviate the problems associated with coiled tubing injection such as helical lock-up,
coiled tubing thruster systems have been developed. Examples are described in
US 2005/247448 and US 2011/277255. The systems use thruster pigs on the end of the
cooled tubing to create an additional force on the coiled tubing which enables it to be
deployed to greater depth. Fluid is pumped down the annulus between the wellbore wall
and the coiled tubing, and applies pressure against the thruster pig, before the fluid passes
out of in front of the bottomhole assembly. The fluid then returns to surface through the
bore of the coiled tubing.

WO2006/001707 and US2005/0284504 also describe thruster pig systems for hydrate
removal which include return flow lines.

Other considerations limit the applications of coiled tubing. Firstly, blockages and
restrictions can occur in narrow bore fluid conduits, which are simply too small to receive
cooled tubing. In addition, the coiled tubing injector systems described above rely on the
rigidity of the coiled tubing to allow it to be pushed into a hole, rather than relying on
gravity only (as is the case in wireline operations). However, this rigidity also has
drawbacks that make coiled tubing interventions unsuitable for some applications. For
example, it may not be possible to inject coiled tubing into a fluid conduit which has a
deviated or convoluted path. In extreme cases, the rigid coiled tubing may not be able to
pass through some curved or bent pipeline systems. Even where passage is possible, the
frictional resistance between the coiled tubing and the inside wall of the wellbore will limit
the depth to which the coiled tubing can be deployed.

Furthermore, the systems described in US 2005/247448, US 2011/277255,
WO2006/001707 and US2005/0284504 are not concerned with inspection methodologies.

It is amongst the objects of the invention to provide an apparatus for performing operations
in fluid conduits of hydrocarbon exploration or production installations which mitigates or
obviates the drawbacks of currently available apparatus. It is an object of at least one
aspect of the invention to provide a method of inspecting the interior of a fluid conduit
which is improved with respect to previously proposed inspection methods. It is an aim of
an aspect of the invention to provide an improved method and apparatus for placing a fluid
at an interior of a fluid conduit.

A further aim of an aspect of the invention is to provide a method and apparatus for
deploying an inspection tool in a fluid conduit, which does not necessitate de-watering or
de-oiling the fluid conduit.

Further aims and objects of the invention will become apparent from the following
description.

Summary of the Invention

According to a first aspect of the invention, there is provided an apparatus for performing
an operation in a fluid conduit of a hydrocarbon exploration or production installation, the
apparatus comprising:
a body configured to be received in the fluid conduit and coupled to a tool fluid conduit
defining a flow bore;
an imaging device carried by the body; and
a flow direction arrangement configured to provide a fluid circulation path between an
annulus located between an interior wall of the fluid conduit and the body and the flow
bore in use;
wherein the flow direction arrangement is configured to provide a deployment thrust on the
body when fluid is circulated between the annulus and the flow bore through the fluid
circulation path.

The apparatus may be configured as an inspection apparatus. Alternatively or in addition
the apparatus may be configured as a fluid placement apparatus or a cleaning apparatus.

According to a second aspect of the invention, there is provided a method of inspecting the
interior of a fluid conduit in a hydrocarbon exploration or production installation, the
method comprising:
providing an inspection apparatus in the fluid conduit to be inspected, the apparatus
comprising: a body coupled to a tool fluid conduit defining a flow bore; an imaging device
carried by the body; and a flow direction arrangement disposed between an exterior of the
body and the flow bore;
circulating fluid between an annulus between an interior wall of the fluid conduit and the
tool fluid conduit and the flow bore, through a fluid circulation path defined by the flow
direction arrangement;
deploying the apparatus along the fluid conduit by a thrust on the apparatus resulting from
the circulation of fluid between the annulus and the flow bore through the fluid circulation
path;
imaging the fluid conduit using the imaging device; and
capturing, analysing and/or displaying imaging data.

The fluid conduit may comprise a flexible riser, and therefore the method may comprise a
method of inspecting the interior of a flexible riser.

Embodiments of the second aspect of the invention may comprise features of the first
aspect of the invention and its embodiments or vice versa.

According to a third aspect of the invention, there is provided a method of placing a
treatment material at an interior of a fluid conduit in a hydrocarbon exploration or
production installation, the method comprising:
providing a material placement apparatus in the fluid conduit, the apparatus comprising: a
body coupled to a tool fluid conduit defining a flow bore; an imaging device carried by the
body; and a flow direction arrangement disposed between an exterior of the body and the
flow bore;
circulating fluid between an annulus between an interior wall of the fluid conduit and the
tool fluid conduit and the flow bore, through a fluid circulation path defined by the flow
direction arrangement;
deploying the apparatus along the fluid conduit to a location displaced from the entry point
to the fluid conduit, by a thrust on the apparatus resulting from the circulation of fluid
between the annulus and the flow bore through the fluid circulation path;
placing a treatment material at the displaced location;
imaging the interior of the fluid conduit using the imaging device; and
capturing, analysing and/ or displaying imaging data.

The method may further comprise at least one of storing, analysing or displaying the
imaging data.

The treatment fluid comprises a blockage removal treatment fluid. In one embodiment, the
displaced location is the location of a hydrate deposit in the fluid conduit, and the method
may comprise removing at least a part of the hydrate deposit.

The method may further comprise monitoring the effect of the treatment fluid on the
hydrate deposit using the imaging device to acquire imaging data, and/or may comprise
advancing the apparatus towards the hydrate deposit for further fluid treatment.

Embodiments of the third aspect of the invention may comprise features of the first or
second aspects of the invention and their embodiments or vice versa.

According to a fourth aspect of the invention, there is provided a method of treating a
hydrate deposit at an interior of a fluid conduit in a hydrocarbon exploration or production
installation, the method comprising:
providing a fluid placement apparatus in the fluid conduit, the apparatus comprising: a
body coupled to a tool fluid conduit defining a flow bore; an imaging device carried by the
body; and a flow direction arrangement disposed between an exterior of the body and the
flow bore;
circulating fluid between an annulus between an interior wall of the fluid conduit and the
tool fluid conduit and the flow bore, through a fluid circulation path defined by the flow
direction arrangement;
deploying the apparatus along the fluid conduit to a location on one side of a hydrate
deposit in the fluid conduit, by a thrust on the apparatus resulting from the circulation of
fluid between the annulus and the flow bore through the fluid circulation path;
placing a treatment fluid at the location of the hydrate deposit; and
monitoring the effect of the treatment fluid on the hydrate deposit using the imaging device
to acquire imaging data.

The method may further comprise at least one of storing, analysing or displaying the
imaging data.

The method may further comprising removing a part of the hydrate deposit, and may
comprise advancing the apparatus towards the hydrate deposit for further fluid treatment.

Embodiments of the fourth aspect of the invention may comprise features of the first to
third aspects of the invention and their embodiments or vice versa.

According to a fifth aspect of the invention, there is provided a method of deploying an
inspection apparatus in a fluid conduit in a hydrocarbon exploration or production
installation, the method comprising:
providing an inspection apparatus in the fluid conduit to be inspected, the apparatus
comprising: a body coupled to a tool fluid conduit defining a flow bore; an imaging device
carried by the body; and a flow direction arrangement disposed between an exterior of the
body and the flow bore;
circulating fluid between an annulus between an interior wall of the fluid conduit and the
tool fluid conduit and the flow bore, through a fluid circulation path defined by the flow
direction arrangement; and
deploying the apparatus along the fluid conduit by a thrust on the apparatus resulting from
the circulation of fluid between the annulus and the flow bore through the fluid circulation
path.

Embodiments of the fifth aspect of the invention may comprise features of the first to fourth
aspects of the invention and their embodiments or vice versa.
Brief description of the drawings

There will now be described, by way of example only, various embodiments of the invention with reference to the drawings, of which:

Figure 1 is a schematic representation of a conventional subsea production system comprising a pigging loop and a pair of flexible risers;

Figure 2 is a schematic representation of a system according to an embodiment of the invention;

Figure 3 is a schematic representation of an a bottomhole assembly of the embodiment of Figure 2, shown in longitudinal section in a fluid conduit;

Figures 4A, 4B and 4C are respectively sectional views of umbilicals which may be used with the present invention;

Figure 5 is a schematic representation of an example application of the present invention in a method of inspecting a flexible riser;

Figures 6A to 6D are schematic representations of sequential steps in an example application of the present invention to a method of treating a hydrate in a fluid conduit;

Figures 7A to 7C are schematic representations of sequential steps in an example application of the present invention in a method of delivering a treatment fluid to a leak location in a fluid conduit.

Detailed description of preferred embodiments

As noted above, Figure 1 is a schematic representation of a typical subsea production system comprising a pigging loop and a pair of flexible risers according to the prior art. It is an aim of present invention to enable internal inspection of the flexible risers 106 and/or at least the riser side of the SSIVs 108 which is improved with respect to the de-watering and de-oiling methods performed conventionally.
Referring now to Figure 2, there is shown a system according to an embodiment of the invention, generally depicted at 200. The system 200 comprises an apparatus 300 (shown in more detail in Figure 3) formed from a bottomhole assembly 302 and a tool fluid conduit 304, which in this case is a flexible umbilical. The apparatus 300 is shown here in situ in a fluid conduit 202, which in this case is a flexible riser. The apparatus 300 is deployed from a storage reel 204 via an injector unit 206 and a stripper and blow out preventer (BOP) unit 208.

The injector unit 206 comprises a drive mechanism for pushing and/or pulling the umbilical into and out of the fluid conduit through the pressure control apparatus. The drive mechanism comprises an arrangement of blocks shaped and sized to engage with the outer surface of the umbilical by forming an indentation in the outer surface to a depth of 1 mm or less. This sufficient engagement with the umbilical to inject or retract it, but does not penetrate the outer wall of the umbilical.

The stripper comprises internal pack off elements formed from an elastomeric material, arranged to provide a fluid seal with the outer surface of an umbilical passing through the unit. The stripper 36 allows the umbilical to pass through the apparatus while retaining pressure in the conduit system beneath the stripper.

The blowout preventer comprises a shear and seal blowout preventer, which has the capability to cut or otherwise sever an umbilical introduced to the fluid conduit. This embodiment also comprises a chamber which functions as a lubricator, providing an access point for the coupling of the bottomhole assembly to the umbilical. A divertor (not shown) is also provided to create a fluid inlet for fluid pumped into the annulus between the introduced umbilical and the inner surface of the fluid conduit 202.

A control module 210 communicates with the other elements if the system to control its operation and receive data collected from the apparatus 200.

Figure 3 shows the apparatus 300 in more detail. The bottomhole assembly 302 comprises a body 306 coupled to the flexible umbilical 304, and the body defines a throughbore 308 from a leading end 310 of the bottomhole assembly to a trailing end 312 joined to the umbilical 304. The throughbore 308 is continuous with the flow bore 316 of
the fluid umbilical 304 and therefore there is a flow path through the bottomhole assembly
to the umbilical and to surface.

The body 306 supports an imaging device selected for internal conduit use. The imaging
device 314 must be capable of withstanding the hostile conditions (including impact forces,
pressure, temperatures, and exposure to corrosive fluids) of the interior of the fluid conduit,
and must be sufficiently small and lightweight for remote deployment. The imaging device
must also be capable of collecting and storing or transmitting imaging data of sufficient
quality and suitability for the applications envisaged.

In a preferred embodiment of the invention, the imaging device is an optical camera 314,
provided with a data transmission cable 318 which passes through the bottomhole
assembly to the umbilical, for the transmission of real-time images to the control module
210. In this embodiment, the camera comprises a fishbowl-type lens with a large field of
view around the circumference of the conduit, with digital control to enable the selection of
a section of the image received for additional attention and/or image collection. The
imaging device is therefore capable of imaging the entire length of the conduit in a single
pass. A suitable choice of imaging device is the Vision ReadyCAM™ camera system
available from VisionIO AS of Sandnes, Norway although alternative embodiments may
use other imaging devices.

The bottomhole assembly 302 also comprises a flow direction arrangement 320,
supported by the body 306, which provides a fluid circulation path between the annulus
324 located between an interior wall of the fluid conduit and the body and the throughbore.
In this embodiment, the flow direction arrangement defines a convoluted fluid path for fluid
passing down through the annulus to the bottomhole assembly 302, and out through an
outlet 322 at the leading end 310. As the fluid passes through the flow direction
arrangement 320, a thrust force is generated on the bottomhole assembly to deploy it into
the fluid conduit 202. The magnitude of the thrust force is controlled by the pressure of
fluid pumped down in the annulus from surface. The design of the flow direction
arrangement 320 is in this embodiment in accordance with the principles described in
US 2005/247448 and US 2011/277255 (the contents of which are incorporated into this
specification by reference), with suitable modifications to accommodate the mounting of
the imaging device 314 and the routing of the cable 318 through or past the bottomhole
assembly to the umbilical 304. In addition, in embodiments of the present invention the
bottomhole assembly need not create a seal with the interior of the conduit in order to
generate sufficient thrust to deploy the apparatus (which is lighter than the coiled tubing
systems described in US 2005/247448 and US 201 1/277255.

Figures 4A, 4B and 4C are respectively cross-sectional views through flexible umbilicals
according to exemplary embodiments of the invention. Referring firstly to Figure 4A, the
umbilical, generally shown at 400, defines a flow path for return fluids from the bottomhole
assembly and comprises the cables and conductors between the surface and the
bottomhole assembly (in particular the imaging device 314). The umbilical 400 defines an
internal flow bore 402 for the return fluids and has a multiple layer wall 404. The wall 404
includes an outer polymer coating layer 406, formed from polyamide and/or polyurethane
material, and a fibre-reinforced (e.g. KEVLAB™) braiding layer 408 to provide tensile
strength and sidewall compression protection. A resin filler layer 410 surrounds the cables
414, which are wires, conductors, fibre optic cables, or combinations thereof. In this case
the cables 414 are arranged rotationally symmetrically around the internal flow bore.
Together they function to enable transmission of data from the bottomhole assembly
(including data captured by the imaging device) and transmission of control signals from
surface to the apparatus and imaging device.

The overall outer diameter is selected to be around 1 1/2 inches (37mm) or less to facilitate
a range of fluid conduit applications and storage of significant lengths (e.g. greater than
500m) of the umbilical on a relatively lightweight and compact storage reel. The minimum
bend radius of the umbilical is selected to be less than 40 times the inner diameter of the
tubing, and in a preferred embodiment the hose has a minimum elastic bend radius of
approximately 12 times the inner diameter of the tubing (i.e. about 450mm for a 37mm
hose). The flexibility of the hose is a clear distinction from coiled tubing applications.
Typically steel coiled tubing has a minimum elastic bending radius of around 200 times the
inner diameter of the tubing.

Referring now to Figure 4B, an alternative umbilical is shown, generally depicted at 401.
The umbilical 401 is similar to the umbilical 400 and will be understood from Figure 4A and
the accompanying description, with like features given like reference numerals. However,
in the umbilical 401, the cables 414 (which are wires, conductors, fibre optic cables, or
combinations thereof) are grouped together in the resin filler layer, such that the internal
flow bore is not concentric in the umbilical. This allows a larger internal flow bore to be
accommodated in an umbilical with the same outer diameter.
Referring now to Figure 4C, an alternative umbilical is shown, generally depicted at 420. The umbilical 420 is similar to the umbilical 400 and will be understood from Figure 4A and the accompanying description, with like features given like reference numerals. However, in the umbilical 420, the cables 424 are not grouped together in a resin filler layer. Instead they run along the interior flow bore 402 defined by the multiple layer wall 404. In this embodiment, the cables 424 are decoupled from the wall and therefore are not subject to stresses due to the pressure control equipment.

There will now be described some exemplary applications of the apparatus and systems described above to illustrate the unexpected advantages of the invention. Referring firstly to Figure 5, there is shown schematically a subsea production system, generally depicted at 500, at which a Floating Production Storage and Offloading vessel (FPSO) 502 is coupled to a subsea pipeline 504 via a pair of flexible risers 506a, 506b. The flexible risers 106 are joined to the subsea pipeline 504 via Subsea Isolation Valves (SSIVs) 508a, 508b. The subsea pipeline 504 comprises a pigging loop (not shown), which may be several kilometres in length.

The system 200 is deployed on the FPSO and includes the apparatus 300 comprising the bottomhole assembly 302 and the umbilical 304. The SSIV 508a of the flexible riser 506a is closed to isolate the riser 506a from the pipeline 504. Production flow is diverted through the SSIV 508b and the riser 506b to the FPSO. With the riser 506a containing production fluids, the system 200 is coupled to the riser, and the apparatus 300 is conveyed along the riser by pumping fluid down the annulus 510 and through the flow direction arrangement 320 of the bottomhole assembly 302 to generate a deployment thrust. Return fluids pass through the bottomhole assembly and into the flow bore of the umbilical. As the bottomhole assembly is deployed in the riser, the imaging device 314 captures imaging data from the interior of the riser and transmits them to surface via the umbilical 304 for display in real-time, storage and/or analysis. The apparatus is able to inspect the riser all the way to the SSIV, and is also able to assess the condition of the SSIV on the riser side.

Significantly, in the above-described method the flexible riser is inspected while production fluids are present in the riser, obviating the need for a time-consuming and expensive de-watering and de-oiling process. In addition, the inspection of the riser 506a can take place
while production fluids are flowing through the riser 506b, avoiding the need to shut down production. The process may be repeated for the other riser, with production fluid flowing in riser 506b.

Referring now to Figures 6A to 6D, there is shown schematically the steps of a method for treating a hydrate build up in a fluid conduit. The Figures show the apparatus 300, including bottomhole assembly 302 and umbilical 304 in a fluid conduit 600. The presence of a blockage 602 has been identified, and the apparatus 300 is conveyed to the blockage location from surface by circulation of a deployment fluid (not shown) in the manner described above with respect to the previous embodiments (Figure 6A). At the blockage location the apparatus collects imaging data using the camera 314 and transmits it to surface for display in real-time to an operator. The operator may be able to determine the nature of the blockage from the imaging data, for example by distinguishing between the presence of a hydrate and a malfunctioning valve or collapse of a hose or jumper conduit. In some cases the nature of the blockage may already have been determined or inferred, in which case the details of the blockage may be verified. In either case, data relating to the position and/or nature of the blockage can be collected and recorded. In this case, the blockage is determined (or inferred) to be a hydrate blockage.

With the bottomhole assembly in the desired location and at the desired distance from the hydrate build-up, a treatment fluid is pumped from surface down the annulus 610 to the bottomhole assembly, where it passes through the bottomhole assembly to the surface of the hydrate (Figure 6B). The fluid may for example be ethylene glycol (MEG), methanol, or water, and may be heated. The effect of the treatment fluid on the hydrate build-up can be monitored by the imaging device to collect data relating to its removal, and to control the treatment process. For example, the parameters of the delivery of the treatment fluid can be modified in response to the imaging data to enable the process to be carefully controlled. As the hydrate build-up is released, fluid is returned through the apparatus to surface, and the apparatus is controllably advanced towards to the leading surface of the hydrate to maintain the desired distance (Figure 6C).

When the hydrate build up has been removed, as verified by the imaging data from the apparatus, the apparatus is used to inspect the interior of the fluid conduit to identify potential causes of the hydrate build-up (Figure 6D) before retrieval of the apparatus.
Referring now to Figures 7A to 7C, there is shown schematically the steps of a method for
treating a fluid conduit leak. The Figures show the apparatus 300, including bottomhole
assembly 302 and umbilical 304 in a fluid conduit 700. The presence of a leak 702 has
been identified, and the apparatus 300 is conveyed to the blockage location from surface
by circulation of a deployment fluid (not shown) in the manner described above with
respect to the previous embodiments (Figure 7A). At the leak location the apparatus
collects imaging data using the camera 314 and transmits it to surface for display in real-
time to an operator. The operator may be able to determine the nature of the leak from the
imaging data, for example by providing information about size or shape of the leak. In
some cases the nature of the leak may already have been determined or inferred by other
means, in which case the details of the leak may be verified. In either case, data relating
to the position and/or nature of the leak can be collected and recorded.

With the bottomhole assembly in the desired location and at the desired distance from the
leak, a sealant material is pumped from surface down the annulus 710 to the bottomhole
assembly, where it passes through the bottomhole assembly to the surface of the hydrate
(Figure 7B). The sealant material may for example be a leak sealing fluid or gel, or may
comprise particulate matter or a suspension thereof. Suitable sealant materials are known
in the art, and include without limitation pressure activated sealant systems that use
differential pressure across a leak site to cause liquid sealant to cause liquid sealant to
polymerize into a flexible solid. Examples are available from Seal-Tite International of
Louisiana, US and are described in SPE 91400 "Internal Repair of Pipeline Leaks Using

The effect of the sealant on the leak can be monitored by the imaging device to collect
data relating to its removal, and to control the treatment process. For example, the
parameters of the delivery of the sealant can be modified in response to the imaging data
to enable the process to be carefully controlled. As the leak is sealed, fluid and/or sealant
is returned through the apparatus to surface, and the position of the apparatus relative to
the leak may be controlled. When the leak has been sealed, as verified by the imaging
data from the apparatus, the apparatus is used to inspect the interior of the fluid conduit to
identify potential causes of leaks or damage to the interior of the conduit (Figure 7C)
before retrieval of the apparatus.
The applications described with reference to Figures 6 and 7 above share the principle of deploying an apparatus to a location in a fluid conduit using a fluid circulation mechanism to produce a thrust on the apparatus; using the fluid circulation mechanism in a second mode to place a material at the location; and using an imaging device carried by the apparatus to assist in the performance and/or verification of the operation. Other applications (not illustrated) are also within the scope of the invention. For example, the apparatus may be used to identify and/or locate the presence of debris in a fluid conduit, for example a build up of residue at the low point of a mid-water arch in a flexible riser. The debris can then be circulated out of the flexible riser using the apparatus, while the process is monitored. Its removal may then be verified by the imaging device, and the conduit may be inspected for lasting damage.

The present invention provides an apparatus for performing an operation in a fluid conduit of a hydrocarbon exploration or production installation and methods of use. The apparatus comprises a body configured to be received in a fluid conduit, which is coupled to a tool fluid conduit defining a flow bore. An imaging device is carried by the body and a flow direction arrangement provides a fluid circulation path between an annulus located between an interior wall of the fluid conduit and the body and the flow bore in use. The flow direction arrangement is configured to provide a deployment thrust on the body when fluid is circulated between the annulus and the flow bore through the fluid circulation path. Applications to the inspection of flexible risers and applications to the placement of a fluid or material a treatment operation are described.

Modifications to the embodiments described above are within the scope of the invention and the invention extends to combinations of features other than those expressly claimed herein.
Claims

1. An apparatus for performing an operation in a fluid conduit of a hydrocarbon exploration or production installation, the apparatus comprising:
   a body configured to be received in the fluid conduit and coupled to a tool fluid conduit defining a flow bore;
   an imaging device carried by the body; and
   a flow direction arrangement configured to provide a fluid circulation path between an annulus located between an interior wall of the fluid conduit and the body and the flow bore in use;
   wherein the flow direction arrangement is configured to provide a deployment thrust on the body when fluid is circulated between the annulus and the flow bore through the fluid circulation path.

2. The apparatus according to claim 1 wherein the body is configured to be coupled to a flexible umbilical.

3. The apparatus according to claim 1 or claim 2 wherein the imaging device comprises an optical camera.

4. The apparatus according to any preceding claim wherein the flow direction arrangement comprises a convoluted fluid path for fluid passing between the annulus and the flow bore of the tool fluid conduit.

5. A system for performing an operation in a fluid conduit of a hydrocarbon exploration or production installation, the system comprising:
   the apparatus according to any of claims 1 to 4; and
   a tool fluid conduit defining a flow bore.

6. The system according to claim 5 wherein the tool fluid conduit comprises a flexible umbilical.

7. The system according to claim 6 wherein the flexible umbilical has an inner diameter and the minimum bend radius of the umbilical is less than forty times the inner diameter.
8. The system according to any of claims 5 to 7 comprising a cable for the transmission of data from the imaging device of the apparatus.

9. The system according to any of claims 5 to 8 further comprising pressure control equipment which seals against an exterior surface of the tool fluid conduit.

10. The system according to any of claims 5 to 9 further comprising a drive mechanism for pushing and/or pulling the tool fluid conduit into and out of the fluid conduit through the pressure control equipment.

11. The system according to any of claims 5 to 10 further comprising a blowout preventer.

12. The system according to claim 11 wherein the blowout preventer comprises a shear and seal blowout preventer.

13. The system according to any of claims 5 to 12 wherein in use, the system defines a fluid circulation path between an annulus defined between the tool fluid conduit and the fluid conduit of the hydrocarbon exploration or production installation; the flow direction arrangement, and the flow bore defined by the tool fluid conduit.

14. A method of inspecting the interior of a fluid conduit in a hydrocarbon exploration or production installation, the method comprising:

   providing an inspection apparatus in the fluid conduit to be inspected, the apparatus comprising: a body coupled to a tool fluid conduit defining a flow bore; an imaging device carried by the body; and a flow direction arrangement disposed between an exterior of the body and the flow bore;

   circulating fluid between an annulus between an interior wall of the fluid conduit and the tool fluid conduit and the flow bore, through a fluid circulation path defined by the flow direction arrangement;

   deploying the apparatus along the fluid conduit by a thrust on the apparatus resulting from the circulation of fluid between the annulus and the flow bore through the fluid circulation path; and

   imaging the fluid conduit using the imaging device to acquire imaging data.
15. The method according to claim 14 further comprising at least one of storing, analysing or displaying the imaging data.

16. The method according to claim 14 or claim 15 wherein at least one of deploying the apparatus or imaging the fluid conduit are performed in the presence of production fluids in the fluid conduit.

17. The method according to any of claims 14 to 16 wherein at least one of deploying the apparatus and/or imaging the fluid conduit are performed while the hydrocarbon exploration or production installation is producing fluids.

18. The method according to any of claims 14 to 17 wherein the fluid conduit comprises a flexible riser.

19. The method according to claim 18 comprising inspecting the interior of a flexible riser to a location at which it is coupled to a subsea isolation valve.

20. The method according any of claims 14 to 19 comprising inspecting the riser side of a subsea isolation valve.

21. A method of placing a treatment material at an interior of a fluid conduit in a hydrocarbon exploration or production installation, the method comprising:
providing a material placement apparatus in the fluid conduit, the apparatus comprising: a body coupled to a tool fluid conduit defining a flow bore; an imaging device carried by the body; and a flow direction arrangement disposed between an exterior of the body and the flow bore;
circulating fluid between an annulus between an interior wall of the fluid conduit and the tool fluid conduit and the flow bore, through a fluid circulation path defined by the flow direction arrangement;
deploying the apparatus along the fluid conduit to a location displaced from the entry point to the fluid conduit, by a thrust on the apparatus resulting from the circulation of fluid between the annulus and the flow bore through the fluid circulation path;
placing a treatment material at the displaced location; and
imaging the interior of the fluid conduit using the imaging device to acquire imaging data.

22. The method according to claim 21 further comprising at least one of storing, analysing or displaying the imaging data.

23. The method according to claim 21 or claim 22 wherein the displaced location is the location of a blockage, and the treatment fluid comprises a blockage removal treatment fluid.

24. The method according to claim 23 further comprising monitoring the effect of the treatment fluid on the blockage using the imaging device to acquire imaging data.

25. The method according to claim 23 or claim 24 further comprising advancing the apparatus towards the blockage for further fluid treatment.

26. The method according any of claims 21 to 25 wherein the displaced location is the location of a hydrate deposit in the fluid conduit, and the method comprises removing at least a part of the hydrate deposit.

27. The method according to claim 26, further comprising advancing the apparatus towards the hydrate deposit for further fluid treatment.

28. The method according to claims 21 or 22 wherein the displaced location is the location of a leak in the fluid conduit, and the method comprises placing a sealant at the displaced location.

29. The method according to claim 28 further comprising monitoring the effect of the sealant on the leak using the imaging device to acquire imaging data.
### A. CLASSIFICATION OF SUBJECT MATTER

INV. F16L55/38 E21B37/04 G01M3/00

### ADD.

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)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search: 15 May 2014

Date of mailing of the international search report: 23/05/2014

Name and mailing address of the ISA:
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040
Fax: (+31-70) 340-3016

Authorized officer:
Kepka, Maciek
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