Abstract:

A method of calibration of an in-line monitoring instrument in a subsea installation (6), comprises using an umbilical (4) for transportation of a sample fluid from the subsea installation (6) to a topside installation (2) and/or for transportation of a reference fluid from the topside installation (2) to the subsea installation (6); comparing measurements of the sample fluid or the reference fluid by the in-line monitoring instrument with measurements of the same fluid obtained previously or subsequently by topside instruments; and adjusting the calibration of the in-line monitoring instrument in the subsea installation (6), if required, based on the results of the comparison of measurements.

Fig. 1
The invention relates to a method and an apparatus for calibration of an in-line monitoring instrument in a subsea installation. In some examples, the in-line monitoring instruments are for measurement of data relating to production in an oil and gas installation, such as fiscal metering for an oil and gas production installation.

In the oil and gas industry, amongst other industries, there is a need for obtaining information regarding subsea installations and the fluids that are passed through such installations. It will be appreciated that there are various challenges connected with this, due to the location of the subsea installation and since the fluids concerned are naturally produced fluids with unpredictable characteristics. One particular example is the need to monitor production fluids for an oil and gas production installation, and to obtain in-line measurements such as water fraction (also denoted water cut), gas to oil ratio and the like in order to allow production to be measured and potentially optimised, and in order for fiscal metering/hydrocarbon accounting to be carried out. An installation might include multiple production lines far below the surface of the sea, with the lines combining before they reach a top side installation. For effective monitoring it is necessary to carry out measurements in line with the subsea pipelines, and this hence requires instruments to be mounted in remote locations below the surface of the sea.

In this context, a problem arises since, as with any monitoring equipment, periodic calibration is required for the monitoring instruments that are mounted in the subsea pipelines. In a prior publication by the inventor, "A method for remote in-line calibration of water fraction meters" by Dag Flølo, presented at 25th International North Sea Flow Measurement Workshop 2007 and available at http://www.linknovate.com/publication/a-method-for-remote-in-line-calibration-of-water-fraction-meters-763441/, the issues relating to remote in-line calibration in the context of water fraction meters are discussed and a method for remote in-line calibration is proposed that involves settling of water in a vertical line under no flow conditions.

The proposal involves the use of new metering stations with various limitations compared to existing metering stations, for example the ability to remotely access the metering station and water fraction meter, the ability to ensure that shutdowns with no flow conditions and without depressurisation can occur (or the redesign of valve arrangements so that no flow conditions can be created without shutdown), amongst other things. Metering station with the ability for remote in-line calibration as described in the prior publication would provide great benefits, but as yet this does not exist in a practical form.
Viewed from a first aspect, the present invention provides a method of calibration of an in-line monitoring instrument in a subsea installation, the method comprising: using an umbilical for transportation of a sample fluid from the subsea installation to a topside installation and/or for transportation of a reference fluid from the topside installation to the subsea installation; comparing measurements of the sample fluid or the reference fluid by the in-line monitoring instrument with measurements of the same fluid obtained previously or subsequently by topside instruments; and adjusting the calibration of the in-line monitoring instrument in the subsea installation, if required, based on the results of the comparison of measurements.

The inventor has made the realisation that problems with subsea calibration can be resolved by the use of an umbilical for physical transportation of fluids between the subsea installation and a topside installation. In many cases an umbilical will already be present, and therefore all that is required is that the umbilical is provided with a suitable fluid transfer mechanism and appropriate attachments to enable liquid to be extracted or introduced into the in-line monitoring instrument at the subsea installation.

In the case where a sample fluid is used then the sample fluid can be obtained from the subsea installation, transported up the umbilical to the topside installation, and passed to a suitable topside instrument for measurements to be taken. A measurement of the sample fluid or of equivalent fluid may be taken by the in-line monitoring instrument at around the same time that the sample is obtained, for example within a specific time period and from the same fluid source.

The method may include measuring a sample of the fluid using the in-line monitoring instrument at the subsea installation, and then transporting the exact same fluid to the topside installation for the comparative measurement to be taken. This latter approach means that there is no risk of change in the parameters of the fluid flowing through the subsea installation between the time that the sample is taken and the comparative measurement is taken at the subsea installation. After the topside measurements have been taken and compared with the subsea measurements then calibration of the in-line monitoring device can be adjusted based on a difference between the two measurements.

Alternatively, fluid measured by the in-line monitoring instrument in the subsea installation may be sampled at a later point, after it has passed through the in-line monitoring instrument. The sampling location and the timing of the sample may be set so as to ensure that the fluid which is sampled is the same as or very similar to the fluid measured by the in-line monitoring instrument. In this case there will be a greater delay between the initial measurement by the in-line monitoring instrument and the comparative measurement at the topside installation, and the calibration of the in-line monitoring instrument can be adjusted retrospectively based on comparison of the measurements.
In another alternative the sample fluid may be extracted upstream of the in-line monitoring instrument, i.e. before the working fluid has reached the in-line monitoring instrument. The sample fluid is measured at the topside installation after it has been passed upward through the umbilical, and the in-line monitoring instrument measures the working fluid at a later point. The timing and location of extraction of the sample is known and can be used to determine when the appropriate part of the working fluid will reach the in-line monitoring instrument. Calibration of the in-line monitoring instrument could be adjusted during the measurement in order to ensure that the two readings match, or again the calibration could be adjusted retrospectively.

In the case where a reference fluid is used then the reference fluid can be first measured using a suitable topside instrument, then transported down the umbilical to the subsea installation, and introduced into the in-line monitoring instrument at the subsea installation to thereby enable a measurement of the reference fluid to be obtained for comparison purposes. In this case the two measurements will always relate to the same fluid. The reference fluid could be a specifically designed calibration fluid, or it may simply be a sample with known qualities where an accurate measurement can be taken by the topside instrument for comparison with the subsequent measurement by the subsea installation instrumentation. In this case calibration of the in-line monitoring instrument could occur retrospectively, after the measurements, or as for the upstream sampling option mentioned above the calibration could occur simultaneous with measurement of the reference fluid in order to ensure that the measurement is consistent with the measurement from the topside instrumentation.

The method may be utilised with a single sample fluid or reference fluid, and the calibration step carried out for a single set of measurements then optionally repeated for further single fluids. Alternatively the method may make use of multiple samples taken over a period of time in order to obtain an average of the fluid parameter for a given volume of the working fluid, with calibration then being based on the average values. Combinations of these two possibilities may also be used in order to further optimise calibration of the in-line monitoring instruments.

The measurements taken by the in-line monitoring instrument can be any type of measurement dependent on the nature of the subsea installation. They may for example be measurement of fluid parameters concerning water fraction, density, viscosity, permittivity, conductivity, gas-oil ratio, gas quality measurements, gas composition, and/or water quality measurements. In some examples the measurements are of the type taken for fiscal metering/hydrocarbon accounting.

The method may involve calibration of multiple in-line monitoring instruments, with the umbilical being used for transportation of multiple sample fluids or reference fluids, each
being relevant to a different monitoring instrument. The calibration step may use any suitable technique for the monitoring instrument in question. In some cases the calibration will be done by a human operator adjusting appropriate settings based on the measured data or based on a comparison of the data produced by a measuring device and/or by a data processing device such as a computer. In other cases there may be automated calibration through remote adjustment of the in-line monitoring instrument using a data processing device such as a computer. The data processing device may be arranged to communicate with the in-line monitoring device via the umbilical.

Transportation of the fluid through the umbilical may be propelled by the pressure already present at the subsea installation when fluid is being transported upward to the topside installation, and/or may be assisted by pumping. Transportation of the fluid downward through the umbilical would typically require pumping in order to overcome the pressure difference between topside installation and the subsea installation. The umbilical is preferably provided with sample lines for the purpose of transporting the sample or reference fluid. The sample lines may take the form of heated tube bundles. When multiple in-line monitoring instruments are being calibrated then separate sample lines may be used for fluids for separate instruments. Typically the inner diameter of the sample lines will be in the range 6 to 20 mm. The flow velocity may be in the range 0.5 to 60 m/s.

Viewed from a second aspect the invention provides a system for calibration of an in-line monitoring instrument in a subsea installation, the system comprising: an umbilical equipped with a sample line for transporting fluid between a subsea installation and a topside installation; a subsea coupling for connecting the sample line to the subsea installation and enabling extraction or introduction of fluid from or to the subsea installation; a topside coupling for introduction of fluid to the sample line or extraction of fluid from the sample line; and one or more measurement device(s) for receiving one or more measurement(s) of the fluid from a topside instrument, receiving one or more measurement(s) of the same or a similar fluid from the in-line monitoring instrument and providing data enabling calibration of the in-line monitoring instrument based on a comparison of the measurements.

The system of this aspect may be used with a sample fluid or reference fluid as described above in connection with the first aspect. Thus, a sample fluid can be obtained from the subsea installation and transported up the umbilical to the topside installation, or a reference fluid could be transported down the umbilical from the topside installation to the subsea installation. Where a reference fluid is used then the in-line monitoring instrument will be able to measure the reference fluid and hence take measurements of the same fluid that is measured topside, and where a sample fluid is used then the in-line monitoring instrument
may take a measurement of the same fluid, or of a similar fluid upstream or downstream of the sampling point.

The measurement device(s) may be arranged to determine an appropriate timing for a measurement by the in-line monitoring instrument and/or an appropriate timing for a sample to be extracted upstream or downstream in the fluid flow through the in-line monitoring instrument. The timing may, for example, be determined based on the relative locations of the in-line monitoring instrument and the location of the subsea coupling, along with information regarding flow speeds between the two points, which could be based on known operating parameters, or on measured flow rates.

The measurement device(s) may be arranged to provide appropriate data to enable a human operator to compare measurements and determine an appropriate adjustment to calibrate the in-line monitoring instrument. Alternatively, the measurement device(s) may have the ability to compare data and optionally to propose an adjustment for calibration of the in-line monitoring instrument. For example the measurement device(s) may be embodied by a data processing device such as a computer. There may be an automatic calibration device for communications with the in-line monitoring instrument and automatic remote calibration thereof, based on data from the measurement device(s). Advantageously the calibration device may communicate with the in-line monitoring instrument via the umbilical. In some examples there are multiple measurement devices with a first device communicating with, or provided as a part of, the in-line monitoring instrument to receive measurements therefrom and to provide data indicative of the fluid properties as measured at the in-line monitoring instrument, and a second device communicating with, or provided as a part of, the topside instrument to receive measurements therefrom and to provide data indicative of the fluid properties as measured at the topside instrument.

The in-line monitoring instrument can be any type of measurement/metering instrument. It may for example be an instrument for measurement of fluid parameters concerning water fraction, density, viscosity, permittivity, conductivity, gas-oil ratio, gas quality measurements, gas composition, and/or water quality measurements. In some examples the measurements are of the type taken for fiscal metering/hydrocarbon accounting.

There may be multiple in-line monitoring instruments, with the umbilical being arranged for transportation of multiple fluids each being relevant to a different monitoring instrument.

A pump or pumps may be included in the system for transportation of the fluid through the umbilical. The system may include one or more valves or the like for control of flow, and the measurement calibration device, or alternatively a separate control system,
may be arranged for controlling the valves and optionally the pumps if they are included in
order to achieve the desired flow of the fluid through the umbilical.

The umbilical is provided with sample lines for the purpose of transporting the sample
or reference fluid. The sample lines may take the form of heated tube bundles. When
multiple in-line monitoring instruments are being calibrated then separate sample lines may
be used for fluids for separate instruments. Typically the inner diameter of the sample lines
will be in the range 6 to 20 mm. The flow velocity may be in the range 0.5 to 60 m/s.

The umbilical may further include control lines for control of any of the various parts
of the system (for example, the couplings, the in-line monitoring instrument and calibration
thereof, valves, pumps and so on). The control lines may be of any suitable type such as
control lines use conventionally in umbilical is for similar purposes, and might conveniently
be control lines for electrical signals.

A preferred embodiment of the invention will now be described by way of example
only and with reference to the accompanying figure in which:

Figure 1 illustrates connections between a subsea installation and a topside
installation.

As shown in the figure a host topside installation 2 can be provided in the form of an
oil and gas production installation equipped with the ability for various analysis and
monitoring tasks to be carried out. The topside installation 2 is connected via an umbilical 4
to a subsea installation 6. The subsea installation includes one or more in-line monitoring
instruments connected to pipelines for working fluids such as hydrocarbon fluids. The in-line
monitoring instruments are arranged for ongoing measurement of fluid parameters of the
working fluids, for example measurements as used for fiscal metering.

The host topside installation 2 can, in particular, include suitable measurement
instruments for providing a qualified accurate measurement of a sample fluid or reference
fluid to act as comparison measurements for measurements taken by the in-line monitoring
instruments.

The umbilical 4 can include typical known features for an umbilical used to couple
between the subsea installation 6 and the topside installation 2, and it is further provided
with sampling lines in the form of heated tube bundles within the umbilical for transportation
of sample or reference fluids between the subsea installation 6 and the topside installation 2.

At the topside end of the umbilical there is a topside coupling arranged to permit fluid
to be introduced into the sample line at the topside and, or removed from the sample line at
the topside end. The fluid removed at the topside end may be passed to an instrument in the
same location, via tubing or by human transfer of a sample vessel. Alternatively the fluid
may be transported to a topside instrument at a different location, remote from the topside
end of the umbilical, for example an on-shore laboratory.
At the subsea end of the umbilical there is a subsea coupling arranged to permit fluid to be introduced or removed at the subsea end. The subsea coupling can be attached directly to the in-line monitoring instrument, enabling fluid to be passed between the two and therefore ensuring that identical fluid is measured at the in-line measuring instrument and is conveyed along the umbilical. Alternatively, the subsea coupling can be attached to a pipeline upstream or downstream of the in-line monitoring instrument, for upstream or downstream sampling as discussed above.

Measurements from the topside instrument and the in-line monitoring instrument can be taken using one or more measurement device. The measurement device(s) may output data representative of the fluid parameters as measured by the respective instrument, and this data can be used by a human operator to compare the performance of the in-line monitoring instrument with the topside instrument and to determine an appropriate adjustment for calibration of the in-line monitoring instrument. Alternatively, an automatic measurement and calibration system may be included, and could typically be located at the topside installation 2, although it could be remotely located. The measurement and calibration system might include measurement devices connected to or formed as a part of a data processing system, with the data processing system also having the capability to compare measurements and determine a suitable adjustment for calibration of the in-line monitoring instrument. A measurement and calibration system can thus be arranged to receive measurements taken by the in-line monitoring instrument at the subsea installation 6 and measurements taken by the topside measuring instruments. The measurement and calibration system can then compare the measurements from subsea and topside in order to check the calibration of the in-line monitoring instrument. If the comparison reveals any discrepancies then the calibration of the in-line monitoring instrument is adjusted, for example via adjustment of operating parameters of the in-line monitoring instrument by the measurement and calibration system using an automated adjustment system, which can advantageously communicate with the in-line monitoring system via the umbilical.
CLAIMS

1. A method of calibration of an in-line monitoring instrument in a subsea installation, the method comprising:

   using an umbilical for transportation of a sample fluid from the subsea installation to a topside installation and/or for transportation of a reference fluid from the topside installation to the subsea installation;

   comparing measurements of the sample fluid or the reference fluid by the in-line monitoring instrument with measurements of the same fluid obtained previously or subsequently by topside instruments; and

   adjusting the calibration of the in-line monitoring instrument in the subsea installation, if required, based on the results of the comparison of measurements.

2. A method as claimed in claim 1, wherein a sample fluid is used and the sample fluid is obtained from the subsea installation, transported up the umbilical to the topside installation, and passed to the topside instrument for measurements to be taken.

3. A method as claimed in claim 2, wherein a measurement of the sample fluid or of equivalent fluid is taken by the in-line monitoring instrument at around the same time that the sample is obtained.

4. A method as claimed in claim 2, comprising: measuring a sample of the fluid using the in-line monitoring instrument at the subsea installation, and then transporting the exact same fluid to the topside installation for the comparative measurement to be taken.

5. A method as claimed in claim 2, wherein sample fluid is first measured by the in-line monitoring instrument in the subsea installation and then sampled at a later point, after the fluid has passed through the in-line monitoring instrument.

6. A method as claimed in claim 1, wherein the sample fluid is extracted upstream of the in-line monitoring instrument, the sample fluid is measured at the topside installation after it has been passed upward through the umbilical, and the in-line monitoring instrument measures the same working fluid at a later point.

7. A method as claimed in any preceding claim, wherein multiple samples of the fluid are taken over a period of time with measurements taken by the in-line instrument and
also by the topside instrument in order to obtain an average of the fluid parameter for a given volume of the working fluid, with calibration then being based on the average values.

8. A method as claimed in claim 1, wherein a reference fluid is used and the reference fluid is first measured using a suitable topside instrument, then transported down the umbilical to the subsea installation, and introduced into the in-line monitoring instrument at the subsea installation to thereby enable a measurement of the reference fluid to be obtained for comparison purposes.

9. A method as claimed in any preceding claim, being used for calibration of multiple in-line monitoring instruments, with the umbilical being used for transportation of multiple sample fluids or reference fluids, each being relevant to a different monitoring instrument.

10. A method as claimed in any preceding claim, wherein the calibrating step is carried out by a human operator adjusting appropriate settings based on the measured data or based on a comparison of the data produced by the measuring device(s) and/or by a data processing device such as a computer.

11. A method as claimed in any preceding claim, wherein the calibrating step comprises automated calibration through remote adjustment of the in-line monitoring instrument using a data processing device.

12. A method as claimed in claim 11, wherein the data processing device is arranged to communicate with the in-line monitoring device via the umbilical.

13. A method as claimed in any preceding claim, wherein the umbilical is provided with one or more sample line(s) for the purpose of transporting the sample or reference fluid.

14. A method as claimed in claim 13, wherein the sample lines take the form of heated tube bundles.

15. A method as claimed in claim 14, wherein the inner diameter of the sample line(s) is in the range 6 to 20 mm and/or the flow velocity is in the range 0.5 to 60 m/s.
16. A system for calibration of an in-line monitoring instrument in a subsea installation, the system comprising:

an umbilical equipped with a sample line for transporting fluid between a subsea installation and a topside installation;

a subsea coupling for connecting the sample line to the subsea installation and enabling extraction or introduction of fluid from or to the subsea installation;

a topside coupling for introduction of fluid to the sample line or extraction of fluid from the sample line; and

one or more a measurement device(s) for receiving one or more measurement(s) of the fluid from a topside instrument, receiving one or more measurement(s) of the same or a similar fluid from the in-line monitoring instrument and providing data enabling calibration of the in-line monitoring instrument based on a comparison of the measurements.

17. A system as claimed in claim 16, wherein the measurement device(s) are arranged to provide appropriate data to enable a human operator to compare measurements and determine an appropriate adjustment to calibrate the in-line monitoring instrument.

18. A system as claimed in claim 16, wherein the measurement device(s) are arranged to compare data and optionally to propose an adjustment for calibration of the in-line monitoring instrument. For example the measurement device(s) may be embodied by a data processing device such as a computer.

19. A system as claimed in claim 16, comprising an automatic calibration device for communications with the in-line monitoring instrument and automatic remote calibration thereof, based on data from the measurement device(s).

20. A system as claimed in claim 19, wherein the calibration device communicates with the in-line monitoring instrument via the umbilical.

21. A system as claimed in any of claims 16 to 20, wherein the system is for calibration of multiple in-line monitoring instruments, with the umbilical hence being arranged for transportation of multiple fluids each being relevant to a different monitoring instrument.

22. A system as claimed in any of claims 16 to 21, comprising a pump or pumps for transportation of fluid through the umbilical.
23. A system as claimed in any of claims 16 to 22, wherein the umbilical is provided with one or more sample lines for the purpose of transporting the sample fluid or reference fluid.

24. A system as claimed in claim 23, wherein the sample line(s) are heated tube bundles.

25. A system as claimed in claim 23 or 24, wherein the inner diameter of the sample lines is in the range 6 to 20 mm and/or the flow velocity is in the range 0.5 to 60 m/s.

26. A method substantially as hereinbefore described with reference to the accompanying drawing.

27. A system substantially as hereinbefore described with reference to the accompanying drawing.
INTERNATIONAL SEARCH REPORT

PCT/EP2015/058156

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B33/035 E21B41/00 E21B47/10

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)
E21B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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See patent family annex.

Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search
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European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk
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Manolache, Iustin
# INTERNATIONAL SEARCH REPORT

Information on patent family members

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