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(54) Title: INSTRUMENTATION SYSTEM FOR DETERMINING RISK FACTORS

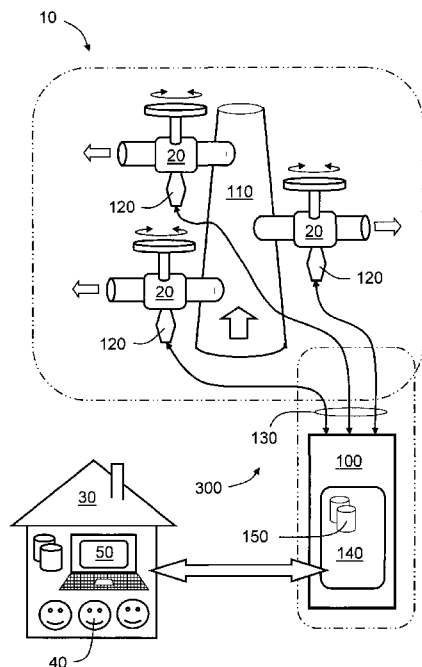


FIG. 1

(57) Abstract: An instrumentation system (300) for monitoring one or more valves (20) of an assembly (110) includes one or more sensors (120) coupled to the one or more valves (20), and a data processing arrangement (140) for processing sensor signals generated by the one or more sensors (120) to provide an indication of operation of said one or more valves (20). The one or more sensors (120) and the data processing arrangement (140) are operable to compute one or more risk factors (R) from the sensor signals indicative of operating reliability and/or safety of the one or more valves (20). The instrumentation system (300) is, for example, suitable for use with valves of the X-mas tree (Christmas tree) assembly for oil and gas production, for example in a sub-sea environment.



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## INSTRUMENTATION SYSTEM FOR DETERMINING RISK FACTORS

### Technical field of invention

The present invention relates to instrumentation systems for determining risk factors, for example to instrumentation systems for determining risk factors associated with apparatus including one or more valves, for example "X-mas tree" (Christmas tree) apparatus including master valves employed to cap oil and gas bore holes. Moreover, the present invention relates to methods of employing instrumentation systems for determining risk factor, for methods of employing instrumentation systems for determining risk factors associated with apparatus including one or more valves, for example "X-mas tree" (Christmas tree) apparatus including master valves employed to cap oil and gas bore holes. Furthermore, the invention also relates to software products executable on computing hardware for implementing aforementioned methods. The apparatus is optionally concerned with oil and/or gas production, although the apparatus is susceptible to being employed in other applications not related to oil and/or gas discovery and/or production.

### Background to the invention

In many contemporary installations, for example oil and/or gas production facilities, in nuclear reactors, in chemicals processing plants, there are critical components whose failure potentially results in devastating consequences. A major oil disaster in the Gulf of Mexico in the year 2010 ("Deep Water Horizon") is an example of potential damage which occurs when critical components fail. Moreover, later problems at atomic reactors at Fukushima, Japan in the year 2011 illustrate an importance that critical safety systems are able to function when required in an emergency, namely to provide interim cooling to atomic reactors which have been shut down but have not yet cooled down. In all of these installations, there are fluid flows which are controlled via control valves, for example via so-called "butterfly valves", pin-and-seat valves and so forth.

When operating installations whose failure could unleash colossal damage, operators are obliged to seek insurance to address damage costs in an event of a major accident occurring. Companies such as Veritas AS specialize in providing insurance for major technical projects, for example for off-shore oil and/or gas installations, for

civil engineering products such as bridge construction, as well as shipping and off-shore wind turbines. Often, a grant of insurance requires operators of installations to have taken adequate measures to reduce a risk of a potential accident from arising. Such adequate measures includes, for example, selection of suitable components and materials, inclusion of safety backup systems for coping in an event of an emergency arising, and monitoring systems for monitoring physical conditions within an installation.

A problem arising in practice with complex installations is that it is often difficult to determine an instantaneous risk factor which is potentially temporally dynamically varying depending on operating status of the installations. Determination of the risk factor, namely an indication of probability of failure of the installations, is often devolved to experienced personnel, for example engineers, who have personal experience with technologies employed within the installations.

In a United States granted patent no. US 3 865 142 ("Electrical remote control system for underwater wells", Begun *et al.*, FMC Corp., California, USA), there is described a fail-safe electrical system for controlling, from a remote location, operation of hydraulic, pneumatic and/or electrically powered mechanisms, for measuring pressures, temperatures and any other parameter transduceable to an electrical parameter and indicative of corresponding values thereof on a display panel at the remote location. As employed with valves and pressures at an underwater oil, gas, or other fuel well, the system comprises a control station at a suitable surface location, an underwater or sub-sea station adjacent to the well, a single electrical cable interconnecting the two stations, and additional single electrical cables from the sub-sea station to each of the valves to be operated and to each of the pressure locations to be monitored. Where valves, chokes, or other elements of the well are hydraulically or pneumatically powered, the system employs solenoid valves beneficially positioned in the sub-sea station to control the hydraulic or pneumatic pressures delivered to the elements. Where the valves are electrically powered, they are controlled by suitable relays in their electric circuit. A specific system for controlling operation of nine valves and for monitoring five pressures at a well's "X-mas tree" assembly (Christmas tree) is described, as also is a system for implementing procedures on a plurality of wells from a single control station.

A system and method for improved coordination between control and safety systems is disclosed in WO2010/039804A1, and comprises a plurality of field devices provided in a safety subsystem and a control subsystem, for monitoring one or more valves in an array. WO2005/059294A2 discloses a method for reducing  
5 consequences and risks of failure in a hydrocarbon pipeline system, and is a pipeline management system.

### Summary of the invention

The present invention seeks to provide an instrumentation system for determining  
10 one or more risk factors pertaining to an assembly including one or more valves provided with one or more sensors for sensing operation of the one or more valves.

Moreover, the present invention seeks to provide a method of determining one or more risk factors pertaining to the aforesaid assembly.

15 According to a first aspect of the invention, there is provided an instrumentation system as claimed in appended claim 1: there is provided an instrumentation system for monitoring one or more valves of an assembly, wherein the system includes one or more sensors coupled to the one or more valves, and a data processing  
20 arrangement for processing sensor signals generated by the one or more sensors to provide an indication of operation of the one or more valves,

characterized in that

25 said instrumentation system is adapted for monitoring said one or more valves incorporated into an Xmas-tree oil and/or gas production assembly;

said one or more sensors and said data processing arrangement are operable to compute one or more risk factors from said sensor signals indicative of operating  
30 reliability and/or safety of said one or more valves; and

each valve includes a corresponding adjustable flow controlling element, an actuator arrangement for actuating said flow controlling element, and said one or more sensors are operable to sense:

- (a) a dynamic pressure difference across said element;
- (b) a cavity pressure indicative of leakage of one or more seals of said element;
- (c) a torque generated by said actuator arrangement when actuating said element; and
- 5 (d) a pressure of actuating fluid supplied to said actuator arrangement.

The invention is of advantage in that computation of the one or more risk factors ( $R$ ) enables more reliable and/or safer operation of the one or more valves to be achieved in operation.

10

Optionally, the oil and/or gas production assembly and the system are adapted for sub-sea operation.

Optionally, the instrumentation system is implemented such that the one or more  
15 sensors and a communication arrangement coupling the one or more sensors to the data processing arrangement are arranged to be constructed to an intrinsically safe standard.

Optionally, the instrumentation system is implemented such that the data processing  
20 arrangement is operable to compute the one or more risk factors ( $R$ ) taking into account at least flow characteristics of a flow of fluid through the one or more valves as sensed by the one or more sensors.

According to a second aspect of the invention, there is provided a method of  
25 employing an instrumentation system for monitoring one or more valves of an assembly, characterized in that the method includes:

- (a) including one or more sensors coupled to the one or more valves, and a data processing arrangement for processing sensor signals generated by the one or more sensors; and
- 30 (b) using the data processing arrangement for processing sensor signals generated in operation by the one or more sensors to compute one or more risk factors ( $R$ ) from the sensor signals indicative of operating reliability and/or safety of the one or more valves and.

- (c) sensing using said one or more sensors in respect of each valve for a corresponding adjustable flow controlling element, and an actuator arrangement for actuating said flow controlling element, following parameters:
- (i) a dynamic pressure difference across said element;
  - 5 (ii) a cavity pressure indicative of leakage of one or more seals of said element;
  - (iii) a torque generated by said actuator arrangement when actuating said element; and
  - (iv) a pressure of actuating fluid supplied to said actuator arrangement,
- 10 wherein said instrumentation system is adapted for monitoring said one or more valves incorporated into an Xmas-tree oil and/or gas production assembly.

According to a third aspect of the invention, there is provided a software product recorded on machine-readable data storage media, characterized in that the software  
15 product is executable on computing hardware for implementing a method pursuant to the second aspect of the invention.

According to a fourth aspect of the invention, there is provided an assembly including one or more valves for controlling fluid flow within the assembly, characterized in that  
20 the assembly includes an instrumentation system pursuant to the first aspect of the invention.

Features of the invention are susceptible to being combined in various combinations without departing from the scope of the invention as defined by the claims.

25

### **Description of the diagrams**

Embodiments of the invention will now be described, by way of example only, with reference to the following diagrams wherein:

FIG. 1 is an illustration of a complex installation including one or more valves whose  
30 reliable operation is critical to the installation;

FIG. 2 is an illustration of an instrumentation system pursuant to the present invention;

FIG. 3 is an illustration of a contemporary ValveWatch system adapted pursuant to the present invention; and

FIG. 4 is an alternative illustration of an instrumentation system pursuant to the present invention.

### Description of embodiments of the invention

5 Assemblies including one or more valves are contemporarily employed in various installations which are safety critical, namely where valve failure may potentially have serious consequences. The one or more valves are provided with one or more corresponding actuators, and are operable to provide a controllable degree of resistance to fluid flow therethrough, for example in closed, open or partially-open  
10 states. Pursuant to the present invention, information indicative of a condition of the one or more valves and their one or more actuators is beneficially derived both from a finally actuated state thereof and also from their characteristics whilst they are being actuated. In an example complex installation indicated generally by **10** in FIG. 1, there are a plurality of valves **20**, wherein failure of merely one of the valves **20** is potentially susceptible to cause serious operating problems. In a central control  
15 room **30** of the complex installation **10**, to assist to avoid a potential information overload of operators **40**, a computer system **50** of the control room **30** is operable to aggregate data received at the control room **30** in order to present to the operators **40** an overall indication of a real-time state of the installation **10**. The operators **40**  
20 often do not have time to monitor operation of each individual valve **20** of the installation **10** in detail, for example to observe each every nuance of valve **20** operation. If the aggregation is not executed in a flexible and transparent manner, a risk potentially arises as occurred at the Harrisburg "Three Mile Island" nuclear disaster, wherein the operators **40** are blocked by the layers of software from  
25 appreciating what is really happening in respect of individual valves **20** which may have a critical function within the installation **10**.

The installation **10** is, for example, an oil and/or gas production installation, a nuclear power station, a chemical manufacturing facility, a water works, a hydroelectric power  
30 facility, a wind turbine array, although the present invention is also applicable to other types of complex installation. Although the one or more valves **20** are mentioned in the foregoing, the invention is optionally also pertinent to other types of actuated assemblies, for example nuclear fuel rod handling equipment. Optionally, for example, the one or more valves **20** are associated with a "X-mas tree" (Christmas



tree) assembly often employed in sub-sea locations to cap casing pipes leading to subterranean oil and/gas reservoirs, for example defined within geological anticlines. An example of a "X-mas tree" (Christmas tree) assembly is described in the aforementioned patent no. US 3 865 142 which is hereby incorporated by reference.

5

The present invention is concerned with an instrumentation system **100** for determining risk factors associated with configurations of the one or more valves **20**, for example as illustrated in FIG. 1. The one or more valves **20** are associated with an assembly **110**, for example a sub-sea "X-mas tree" assembly. The instrumentation system **100** includes one or more sensors **120** for measuring at the assembly **110** one or more physical parameters, for example a static pressure (i.e. "DC pressure"), a temporal variation in pressure (i.e. "AC difference"), a temperature, a flow rate, a relative position of a component or element and so forth. The instrumentation system **100** further includes a communication arrangement **130** for communicating signals generated by the one or more sensors **120** to a data processing arrangement **140**. The data processing arrangement **140** is optionally remote from the assembly **110**. Alternatively, the data processing arrangement **140** is optionally spatially local to the assembly **110**. Yet alternatively, the data processing arrangement **140** is implemented at several spatial locations, for example partially local to the assembly **110**, and partially spatially remote therefrom.

The data processing arrangement **140** is arranged to execute one or more software products **150** which are operable to receive sensed information regarding movement of one or more valve **20** of the assembly **110** and/or one or more actuators thereof, for example movement of valve **20** components, changes in pressure, changes in pressure variations, fluid flow rates and so forth. The sensed information is generated by the one or more sensors **120** associated with the one or more valve **20** and/or their corresponding one or more actuators. The one or more software products **150** are operable to process the sensed information according to a set of rules, which in conglomerate define a method, from which one or more risk factors are calculated. The one or more risk factors are beneficially, for example, brought to the attention of one or more operators **40** in a situation where the one or more computed risk factors exceed one or more corresponding threshold values or levels. Optionally, the one or more threshold values or levels are dynamically changed in

response to a type of mode of operation of the valves **20**, for example when required to control of flow of different types of fluid on different occasions with mutually different degrees of hazard associated therewith. Optionally, the one or more threshold values are defined by insurance organizations, for example Veritas AS.

5 Optionally, the one or more threshold values or levels are dynamically changed to account for corrosion and/or ageing characteristics of the one or more valves **20** being monitored by the one or more software products; for example an old worn out and/or corroded valve **20** is more likely to fail than a newly installed pristine quality-certified valve **20**. Optionally, the aforesaid set of rules are part of a parametric

10 model of the one or more valves **20** wherein sensed signals from the one or more valves **20** and/or their one or more actuators are input parameters to the parametric model, the outputs from the parametric model are employed to compute one or more risk factors which are compared against one or more threshold levels or values for providing various degrees of risk operating warnings from the one or more software

15 products **150** to the operators **40**. Optionally, the parametric model is arranged to change dynamically in response to input signals provided thereto, for example for modeling valve abrasion, corrosion and ageing.

Applicant (Solberg & Andersen AS) is a manufacturer of monitoring systems for

20 valves, for example a proprietary ValveWatch™ system. The ValveWatch™ system is operable to perform leak and condition monitoring of critical ON/OFF valves, for example ESD/ESV-type valves. The ValveWatch™ system is beneficially employed for implementing embodiments of the present invention.

25 An example of use of the ValveWatch system **300** is illustrated in FIG. 2 and FIG. 3, namely suitable for use with the aforementioned valve **20**. In an example, the valve **20** includes a rotatable element **310** mounted within a tube component **320**. Rotation of the element **310** about an axis **330**, which is orthogonal to an elongate axis **335** of the tube component **320**, is operable to control a flow of a fluid along the tube

30 component **320**. Upstream and downstream of the element **310**, there are included two dynamic pressure sensors **330**, **340** mounted into holes provided on the tube component **320** as illustrated; the dynamic pressure sensors **330**, **340** are operable to provide signals representative of temporal pressure variations, namely "AC coupled" pressure measurement signal. Moreover, the tube component **320** includes

a cavity **350** around upper and lower regions whereat the element **310** is rotatable mounted about pivot points **360, 370**. The cavity **350** is provided with a pressure sensor **380** as illustrated. Optionally, the tube component **320** is also provided with a strain gauge sensor mounted onto an outer circumferential surface of a yoke **390**;

5 the yoke **390** is operable to convey torsional force required for rotating the element **310** for opening or closing the valve **20**. For substantially sealing the cavity **350** in respect of an inner region **400** of the tube component **320**, the element **310** is provided with an annular seal **410**. In operation, the element **310** is rotated by a rotary actuator **420** coupled via the yoke **390** to the element **310** as illustrated. The

10 yoke **390** is conveniently implemented as a shaft having a substantially circular cross-section. Optionally, the actuator **420** is provided with two static pressure sensors **380** for measuring a pressure of actuating fluid supplied to the actuator **420**; in other words, the two static pressure sensors **380** are operable to measure static constant pressures, namely "DC coupled" pressure signals. The dynamic pressure

15 sensors **330, 340** are employed to monitor any increase in leakage through the valve **20**; moreover, the static pressure sensors **380** of the actuator **420**, and the strain gauge mounted to the yoke **390** are employed to monitor an overall operating condition of the valve **20**; for example, damage or corrosion to the element **310** or any component parts to which it abuts is potentially sensed by an increase in

20 actuator fluid pressure and/or torque at the yoke **390** necessary to change a state of the valve **20**, for example when being actuated between open and closed states. The strain gauge mounted to the yoke **390** is beneficially implemented in a full Wheatstone bridge configuration, such that the strain gauge not only measures torque, but also strain in at least two Cartesian directions, for example in mutually

25 orthogonal X and Y directions; in other words, the strain sensor is beneficially operable to measure torque, thrust, sheering and torsional forces in respect of the yoke **390**.

For purposes of detecting leakage through the valve **20**, two principal types of sensor

30 technology are susceptible to being employed: dynamic pressure sensors, acoustic sensors. Beneficially, both types of technology are employed for implementing the present invention. The types of technology include piezo-electric pressure sensors for example.

Thus, in overview, the system **300**, for example implemented in a context of a proprietary "ValveWatch™ system", incorporates sensors attached onto the valve **20** and to the actuator **420** to monitor and record their performance in a routine manner. Optionally, the system **300** is operable to operate the valve **20** periodically to characterize its operating performance. The strain sensor and the actuator pressure sensors monitor a performance of the valve **20** and its actuator **420** during operation; dynamic pressure sensors and acoustic sensors monitor the valve **20** for internal seal seat leaks, for potential leaks and for potential snagging or binding. In synergistic combination, these aforementioned sensors provide, via the data processing arrangement **140**, the operators **40** with an automated checkup on a real-time condition of the valve **20** and its associated actuator **420**, for example by providing one or more computed risk factors pertaining to the valve **20**, wherein the risk factors are indicative of likely probability of operating failure or complications which are likely to arise in respect of the valve **20**. The one or more computed risk factors have an advantage in that they can be rapidly appreciated by the operators **40** and their significance rapidly assessed. Optionally, the one or more risk factors can be used to trigger automatically emergency safety procedures and/or maintenance procedures.

The strain gauge sensor and the actuator pressure sensors provide valuable diagnostic data each time the valve **20** strokes, namely changes between its open and closed states wherein the element **310** is rotated by action of the actuator **420**. The strain gauge sensor is permanently bonded to the yoke **390** and is used for monitoring at least a torque applied to the element **310** during a stroke of the valve **20**. Technical problems with operation of the valve **20**, including damage to certain components thereof, are readily detectable from signals generated by the strain gauge sensor.

The pressure sensors **380** mounted to supply lines to the actuator **420** assist to enable recording in changes in actuator **420** pressure through a stroke of the valve **20**. Damage to the actuator **420** or a problem with air or hydraulic supply to the actuator **420** is susceptible to being detected using these pressure sensors **380**. The pressures sensors **380** mounted to the actuator **420** are also used to monitor when the element **310** of the valve **20** changes position, for example by way of detecting a

momentary reduction in hydraulic fluid pressure as the actuator **420** executes its stroke; beneficially, the system **300** is optionally operable to implement a valve stroke test in an event of a problem being identified, for further valve **20** characterization tests.

5

The data processing arrangement **140** optionally includes a local data acquisition unit (LDAU) assembly which includes a proprietary IP66 weather-proof box housing, and a plurality of modules installed spatially as closely as practically feasible to the valve **20**. The modules optionally include two strain/AC modules and a communications  
10 module. The communication module is operable to support communication via strain channels for use in monitoring signals from the strain gauge associated with the yoke **390** and from the static pressure sensors **380** associated with the actuator **420**. Moreover, the communication module is operable to provide AC channels for handling signals generated by the dynamic pressure sensors **330**, **340**. The data  
15 processing arrangement **140** is operable to condition and to convert signals received from the sensors **120**, **330**, **340**, **380** to a digital format for subsequent communication via the communication module for wireless or data-over-power transmission to a HUB assembly. The LDAU assembly and the sensors **120**, **330**,  
20 **340**, **380** are beneficially implemented in an intrinsically safe manner so that their operation is not capable of initiating any form of fire or explosion at the valve **20**, even in an event of a leakage of flammable fluids externally from the valve **20**; beneficially, the LDAU assembly and the sensors are certified according to North American and European standards for installation in Zone 0 areas.

25 Beneficially, additional communications apparatus and an Ethernet module are included in the HUB assembly together with all power supplies, terminal strips and intrinsic safety barriers. Beneficially, the HUB assembly is rack-mounted in a safe area with Zone 2 designation or equivalent room. Optionally, each HUB assembly is susceptible to being configured to monitor up to eight valves **20**. Conveniently, an  
30 Ethernet cable connects the HUB assembly to a sever whereat sensor data is stored, transmitted and then analyzed for leakage, for example in connection with computing one or more risk factors. Optionally, all test results from the one or more valves **20** are stored in a secure Oracle database application support by the data processing arrangement **140**.

Beneficially, for remote monitoring of risk factors and operation of valves **20**, the system **300** includes a simple Internet web interface for allowing easy access to the system **300** for monitoring its status from any location wherein Internet access is available. Beneficially, security, for example via encryption, is provided so that only authorized personnel are able to access the system **300**, for example for viewing its system map, alarm window and system tree to view valve **20** status as well a one or more computed risk factors. The one or more software products **150** executed by the data processing arrangement **140** are operable when executed upon computing hardware to generate reports and trend plots so that the operators **40** are able to evaluate valve **20** performance and one or more risk factors associated with the one or more valves **20**.

In the foregoing, it is elucidated that the data processing arrangement **140** is operable to compute one or more risk factors in relation to the valve **20** of the system **300**. Computed safety factors provided in respect of the system **300** are capable of providing increased operating safety and thereby more reliable production, for example where the valve **20** associated with the system **300** is a part of a "X-mas tree" assembly for oil and/or gas industries, for example sub-sea "X-mas tree" assemblies. Computation of the one or more risk factors is capable of reducing "down" time and therefore providing enhanced profitability. The invention is thus concerned with an instrumentation system **300** which is operable to monitor continuously one or more risk factors associated with a valve **20**, for example implemented as a wing-valve, for example for oil and/or gas platform operators.

The one or more risk factors are susceptible to being computed in different ways, but beneficially follow a general form as defined in Equation 1 (Eq. 1):

$$R = F(S, p_1 \dots p_n) \quad \text{Eq. 1}$$

wherein

$R$  = one or more risk factors;

$F$  = a mathematical function;

$S$  = a strain gauge measurement; and

$p$  = one or more pressure measurements from pressure sensor 1 to  $n$  associated with the valve **20**.

5 An example of the function  $F$  will now be elucidated for illustrating a specific manner of implementing the present invention, although alternative manners of computing the one or more risk factors are within the scope of the present invention. As elucidated in the foregoing, the function  $F$  is optionally based upon a parametric simulation model of the valve **20**.

10 In a first step of the computation of the risk factor  $R$ , a closing force  $C_f$  is computed pursuant to Equation 2 (Eq. 2):

$$C_f = S_f + B_f \quad \text{Eq. 2}$$

15 wherein

$B_f$  = a "blow out" force for the element **310** of the valve **20**;

$S_f$  = a spring force associated with the element **310** of the valve **20**.

20 In a second step of the computation of the risk factor  $R$ , an opposing force  $O_f$  from the actuator **420** is computed pursuant to Equation 3 (Eq. 3):

$$O_f = H_p \times A_p \quad \text{Eq. 3}$$

wherein

25  $H_p$  = a hydraulic pressure applied to a piston of the actuator **420**; and

$A_p$  = an area of the piston subjected to the hydraulic pressure  $H_p$ .

In a third step of the computation of the risk factor  $R$ , a friction  $M$  of the element **310** of the valve **20** is computed pursuant to Equation 4 (Eq. 4):

30

$$M = C_f - O_f \quad \text{Eq. 4}$$

In a fourth step of the computation of the risk factor  $R$ , a computation pursuant to Equation 5 (Eq. 5) is executed:

$$R = k \times \frac{C_f}{M} \quad \text{Eq. 5}$$

5

wherein

$k$  = scaling coefficient.

Although the present invention is described in the foregoing in respect of wing and master valves **20**, namely including the element **310** arranged to perform a translation movement rather than a rotational movement to control a flow of fluid through the valve **20**, the invention can be extended to pertain to ESD/ESV valves. Beneficially, the computation of the risk factor  $R$  pursuant to Equation 1 (Eq.1) takes into account a temperature  $T$  of the valve **20**, and also flow properties  $Q$  of the valve **20**, namely pursuant to Equation 6 (Eq. 6):

10  
15

$$R = F(S, p_1, n, T, Q) \quad \text{Eq. 6}$$

The valve **20** is beneficially furnished with a temperature sensor for providing in operation a measure of temperature of the valve **20**, the measure being used for use when risk factors are being calculated for the valve **20**.

20

By the operators **40** monitoring the one or more risk factors  $R$ , appropriate safety, repair and/or maintenance routine are beneficially implemented, therefore avoiding potential accident or unreliability. When the valve **20** is a critical component in an installation, the present invention is capable of potentially avoiding major incidents and disasters which can be highly expensing to rectify retrospectively. Thus, the present invention is capable of providing considerable operating benefits at installations.

25

30

Optionally, the aforementioned valves **20** are either of a rotary actuated type or a linear displacement actuated type as aforementioned. Although embodiments of the invention are described in respect of valves coupled to fluid-actuated actuators, the



invention is susceptible to being applied to electrically-powered actuators wherein current and voltage energization to the electrically-powered actuators are monitored for purposes of computing the one or more risk factors (*R*). Optionally, actuating fluid of the actuators **420** are provided via electrically-energized fluid-control solenoid valves, wherein the solenoid valves are also provided with sensors, for example current sensors and armature movement sensors, for detecting that the solenoid valves are also working reliably and for computing one or more risk factors associated therewith. Failure of the solenoid valve feeding the actuator **420** can, from a system point of view, be a disastrous as failure of the actuator **420** itself. For example, when assessing a risk factor *R* associated with the solenoid, an actuating speed and actuating electrical current required to operate the solenoid is monitored.

Referring to FIG. 4, there is shown a representation of instrumentation system pursuant to the present invention. The assembly **110** is shown including one or more valves **20** which are operated by one or more solenoids **570**. From the assembly **110**, sensors **120**, **330**, **340**, **380** provide valve **20** sensor data **580** which is provided to a proprietary "Safety factor" system **550** which is operable to perform data processing on the sensor data **580**. Processed data from the system **550** is conveyed to a SAS control system **560** via a data tunneler **590**. Outputs from the SAS control system **560** are employed to control the aforesaid one or more solenoids **570**. As aforementioned, operation of the solenoid **570** is beneficially is also beneficially monitored to contribute relevant data to the sensor data **580**.

The present invention is especially suitable for a Topside Christmas tree system, either sub-sea based or land-based. However, as elucidated in the foregoing, the present invention is susceptible to being employed in other types of systems.

Modifications to embodiments of the invention described in the foregoing are possible without departing from the scope of the invention as defined by the accompanying claims. Expressions such as "including", "comprising", "incorporating", "consisting of", "have", "is" used to describe and claim the present invention are intended to be construed in a non-exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural. Numerals included within parentheses in the

accompanying claims are intended to assist understanding of the claims and should not be construed in any way to limit subject matter claimed by these claims.

**CLAIMS**

1. An instrumentation system (300) for monitoring one or more valves (20) of an  
5 assembly (110), wherein said system (300) includes one or more sensors (120)  
coupled to said one or more valves (20), and a data processing arrangement (140)  
for processing sensor signals generated by said one or more sensors (120) to  
provide an indication of operation of said one or more valves (20),
- 10 characterized in that
- said instrumentation system (300) is adapted for monitoring said one or more valves  
(20) incorporated into an Xmas-tree oil and/or gas production assembly (110);
- 15 said one or more sensors (120) and said data processing arrangement (140) are  
operable to compute one or more risk factors (*R*) from said sensor signals indicative  
of operating reliability and/or safety of said one or more valves (20); and
- each valve (20) includes a corresponding adjustable flow controlling element (310),  
20 an actuator arrangement (420) for actuating said flow controlling element (310), and  
said one or more sensors (120) are operable to sense:
- (a) a dynamic pressure difference across said element (310);
  - (b) a cavity (350) pressure indicative of leakage of one or more seals of said  
element (310);
  - 25 (c) a torque generated by said actuator arrangement (420) when actuating said  
element (310); and
  - (d) a pressure of actuating fluid supplied to said actuator arrangement (420).
2. An instrumentation system (300) as claimed in claim 1, characterized in that  
30 said oil and/or gas production assembly (110) and the system (300) are adapted for  
sub-sea operation.

3. An instrumentation system (300) as claimed in claim 1, characterized in that said one or more sensors (120) and a communication arrangement (130) coupling said one or more sensors (120) to said data processing arrangement (140) are arranged to be constructed to an intrinsically safe standard.

5

4. An instrumentation system (300) as claimed in claim 1, characterized in that the data processing arrangement (140) is operable to compute said one or more risk factors (*R*) taking into account at least flow characteristics of a flow of fluid through said one or more valves (20) as sensed by said one or more sensors (120).

10

5. A method of employing an instrumentation system (300) for monitoring one or more valves (20) of an assembly (110), characterized in that said method includes:

(a) including one or more sensors (120) coupled to said one or more valves (20), and a data processing arrangement (140) for processing sensor signals generated by said one or more sensors (120); and

15

(b) using said data processing arrangement (140) for processing sensor signals generated in operation by said one or more sensors (120) to compute one or more risk factors (*R*) from said sensor signals indicative of operating reliability and/or safety of said one or more valves (20); and.

20 (c) sensing using said one or more sensors (120) in respect of each valve (20) for a corresponding adjustable flow controlling element (310), and an actuator arrangement (420) for actuating said flow controlling element (310), following parameters:

(i) a dynamic pressure difference across said element (310);

25 (ii) a cavity (350) pressure indicative of leakage of one or more seals of said element (310);

(iii) a torque generated by said actuator arrangement (420) when actuating said element (310); and

(iv) a pressure of actuating fluid supplied to said actuator arrangement (420),

30

wherein said instrumentation system (300) is adapted for monitoring said one or more valves (20) incorporated into an Xmas-tree oil and/or gas production assembly (110).

6. A software product (150) recorded on machine-readable data storage media, characterized in that said software product (150) is executable on computing hardware (140) for implementing a method as claimed in claim 5.
- 5 7. An assembly (110) including one or more valves (20) for controlling fluid flow within said assembly (110), characterized in that said assembly includes an instrumentation system (300) as claimed in claim 1.

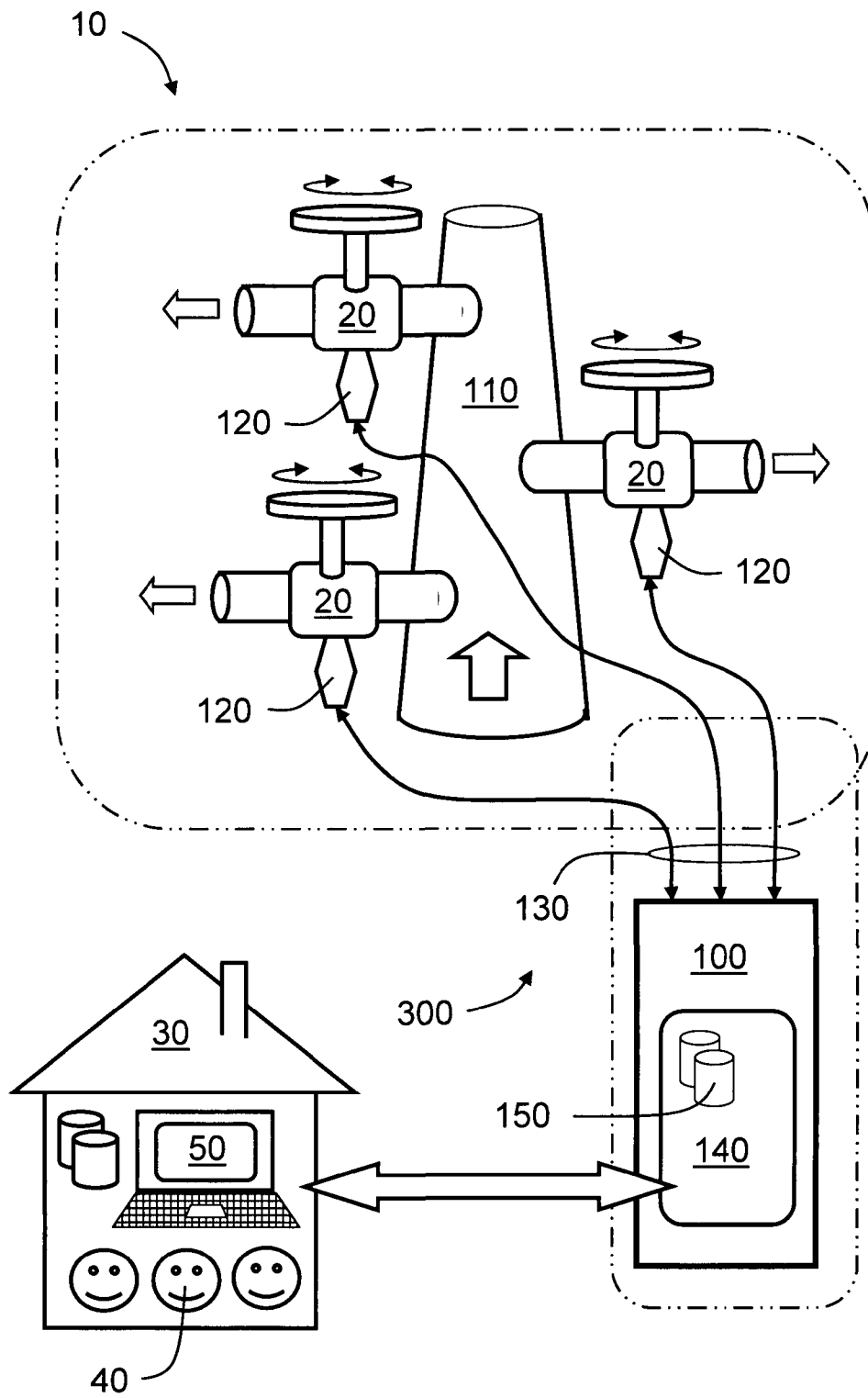


FIG. 1

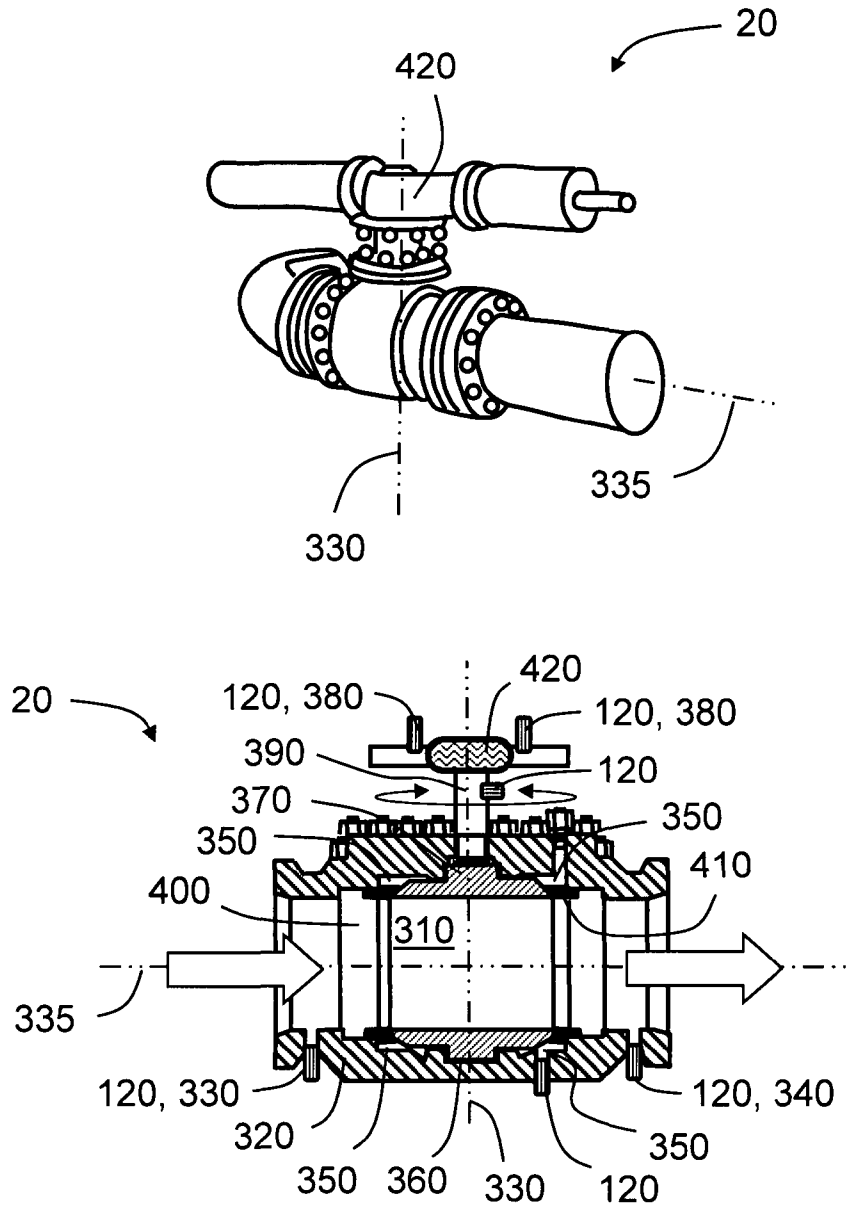


FIG. 2

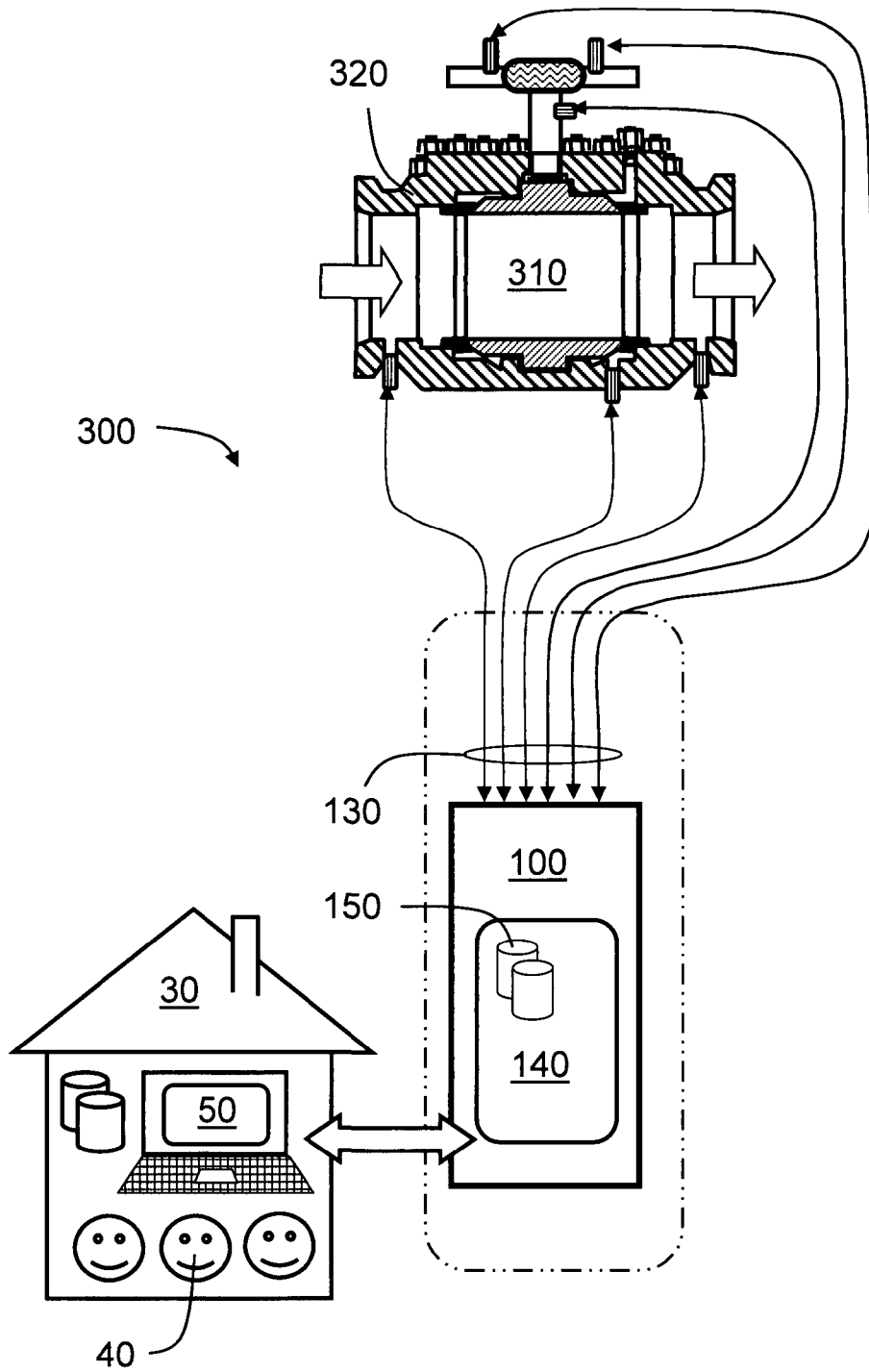


FIG. 3



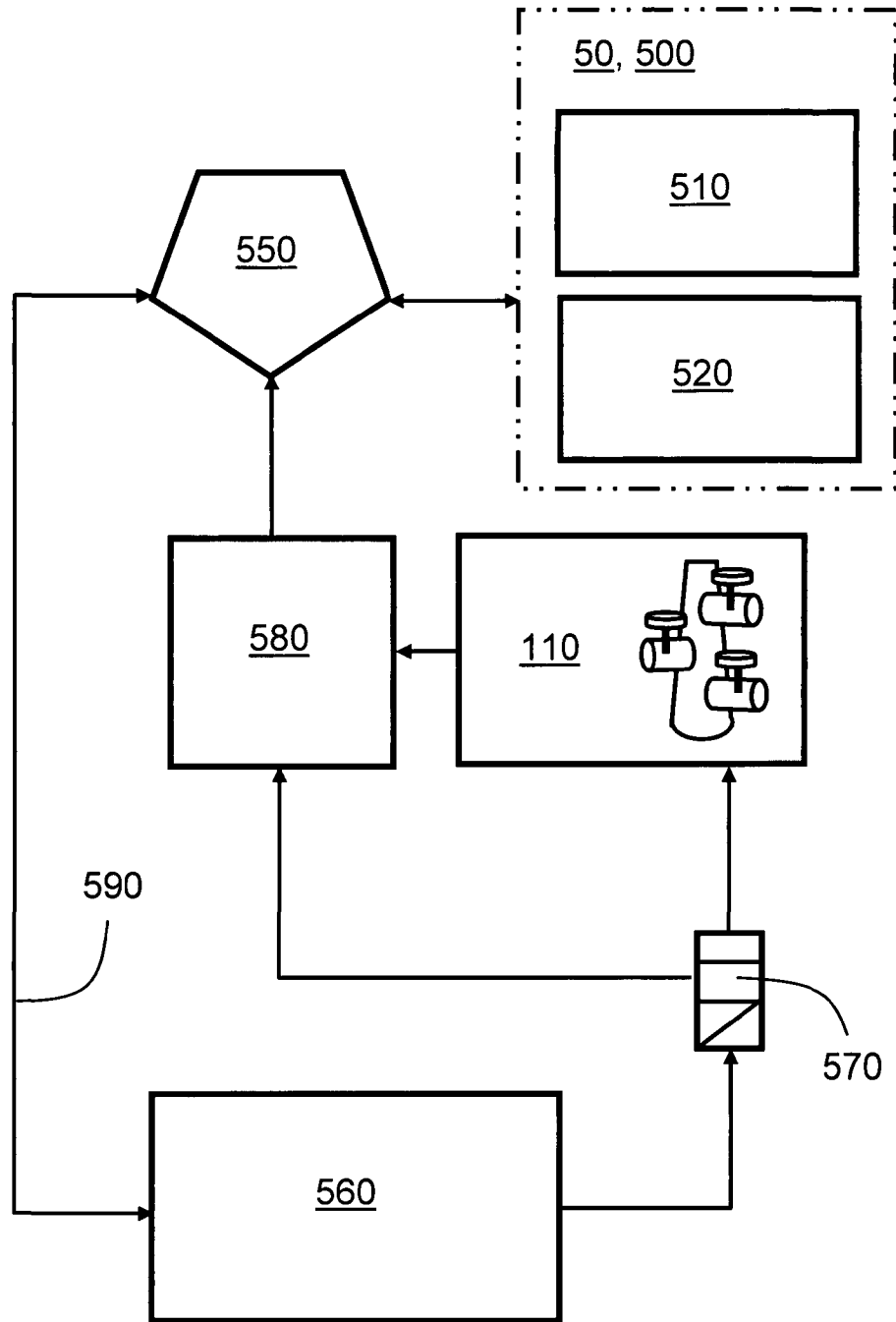


FIG. 4

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NO2012/000032

A. CLASSIFICATION OF SUBJECT MATTER IPC: see extra sheet 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) IPC: G06Q Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched SE, DK, FI, NO classes as above Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, PAJ, WPI data, INSPEC		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Selvik J T; Aven T, A framework for reliability and risk centered maintenance. Reliability Engineering and System Safety, vol 96, 2011. pp324-331. 2010-08-11.; page 325, column 1; page 329, column 2, line 19 - line 21; figures 1, 2 and table 2 --	1-7
X	US 20100153146 A1 (ANGELL ROBERT LEE ET AL), 17 June 2010 (2010-06-17); paragraphs [0005], [0023], [0037], [0048] --	1-7
A	US 20090204232 A1 (GURU ARUN K ET AL), 13 August 2009 (2009-08-13); paragraphs [0005]-[0006] --	1-7
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010039804 A1 (SAUDI ARABIAN OIL CO ET AL), 8 April 2010 (2010-04-08); abstract -- -----	1-7

**Continuation of:** second sheet

**International Patent Classification (IPC)**

**G06Q 10/06** (2012.01)

**G06Q 40/08** (2012.01)

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Information on patent family members

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US	20100153146	A1	17/06/2010	NONE		
US	20090204232	A1	13/08/2009	NONE		
WO	2010039804	A1	08/04/2010	CN	102209982	A 05/10/2011
				EP	2345015	A1 20/07/2011
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