(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 February 2017 (02.02.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/019921 A1

(51) International Patent Classification:
F23N 1/00 (2006.01)

(21) International Application Number:
PCT/US2016/044599

(22) International Filing Date:
29 July 2016 (29.07.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/198,162 29 July 2015 (29.07.2015) US

(71) Applicant *(for US only)*: **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).

(71) Applicant *(for CA only)*: **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).

(71) Applicant *(for FR only)*: **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).

(71) Applicant *(for all designated States except CA, FR, US)*: **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).

(72) Inventors: **CARELLI, Daniel**; c/o Schlumberger Servicos de Petroleo Ltda, Av. Presidente Wilson 231 - 20 andar, 20030-021 Rio de Janeiro (BR). **MARINHO E SILVA, Daniel**; Street: Jose Henrique da Silva, 494, Ap. 304., 27920-0 10. Macae-RJ (BR). **LOPES, Thiago Sigiliano**; Av . Sidney, Vasconcellos de A gu iar 275, Ap. 204B ., 27937-0 10. Macae-RJ (BR).

(74) Agents: **SNEDDON, Cameron** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: METHODS AND APPARATUS TO AUTOMATICALLY CONTROL OIL BURNING OPERATIONS

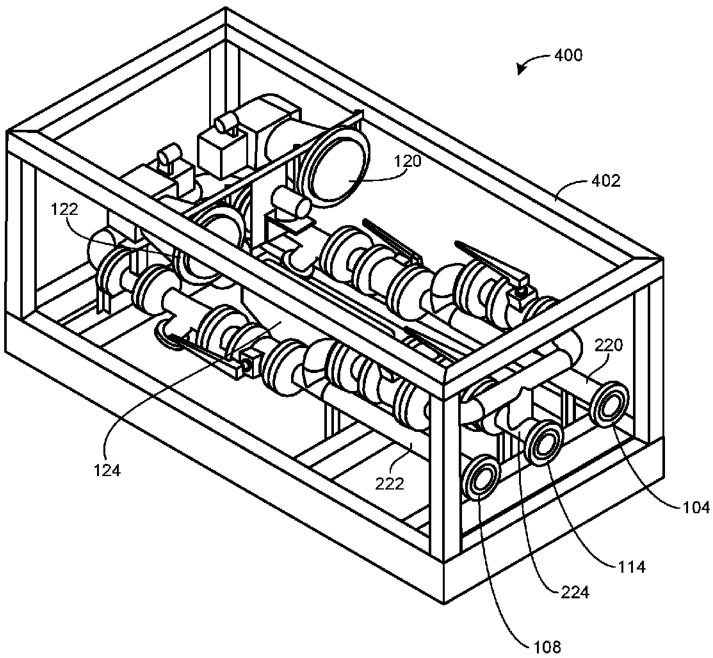

FIG. 4

(57) Abstract: Methods and apparatus to automatically control oil burning operations are disclosed. An example apparatus includes a first control valve to control a flow of a first fluid into a fluid mixture to be burned; and a second control valve to control a flow of a second fluid into the fluid mixture. The example apparatus further includes a meter to monitor a property of the fluid mixture in substantially real-time, the property indicative of a flammability of the fluid mixture, at least one of the first control valve or the second control valve to be automatically adjusted based on a measured value of the property of the fluid mixture

WO 2017/019921 A1

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

METHODS AND APPARATUS TO AUTOMATICALLY CONTROL OIL BURNING OPERATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent claims priority to U.S. Provisional Application Serial No. 62/198,162, which was filed on July 29, 2015, and is incorporated herein by reference in its entirety.

BACKGROUND

Field

[0002] This disclosure relates generally to hydrocarbon production and exploration and, more particularly, to methods and apparatus to automatically control oil burning operations.

Description of the Related Art

[0003] Hydrocarbons are widely used as a primary source of energy, and have a great impact on the world economy. Consequently, the discovery and efficient production of hydrocarbon resources is increasingly noteworthy. As relatively accessible hydrocarbon deposits are depleted, hydrocarbon prospecting and production has expanded to new regions that may be more difficult to reach and/or may pose new technological challenges. During typical operations, a borehole is drilled into the earth, whether on land or below the sea, to reach a reservoir containing hydrocarbons. Such hydrocarbons are typically in the form of oil, gas, or mixtures thereof which may then be brought to the surface through the borehole.

[0004] Well testing is often performed to help evaluate the possible production value of a reservoir. During well testing, a test well is drilled to produce a test flow of fluid from the reservoir. During the test flow, parameters such as fluid pressure and fluid flow rate are monitored over a period of time. The response of those parameters may be determined during various types of well tests, such as pressure drawdown, interference, reservoir limit tests, and other tests generally known by those skilled in the art. The data collected during well testing may be used to assess the economic viability of the reservoir. The costs associated with performing the testing operations may be substantial.

Therefore, testing operations should be performed as efficiently and economically as possible.

SUMMARY

[0005] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0006] An example apparatus includes a first control valve to control a flow of a first fluid into a fluid mixture to be burned; and a second control valve to control a flow of a second fluid into the fluid mixture. The example apparatus further includes a meter to monitor a property of the fluid mixture in substantially real-time, the property indicative of a flammability of the fluid mixture. At least one of the first control valve or the second control valve to be automatically adjusted based on a measured value of the property of the fluid mixture.

[0007] An example method includes monitoring a property of a fluid mixture being pumped to a burner; and automatically adjusting at least one of a first control valve or a second control valve based on the monitored property of the fluid mixture, the property indicative of a flammability of the fluid mixture. The first control valve controls flow of a first fluid into the fluid mixture, and the second control valve controls a flow of a second fluid into the fluid mixture.

[0008] Example instructions stored on a tangible computer readable storage medium, when executed, cause a machine to at least: monitor a property of a fluid mixture being pumped to a burner, the property indicative of a flammability of the fluid mixture; and automatically adjust at least one of a first control valve or a second control valve based on the monitored property of the fluid mixture. The first control valve controls flow of a first fluid into the fluid mixture, and the second control valve controls a flow of a second fluid into the fluid mixture.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features can be understood in detail, a more particular description may be had by reference to embodiments, some of which are illustrated in the appended drawings, wherein like reference numerals denote like elements. It is to be noted, however, that the appended drawings illustrate various embodiments and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

[0010] FIG. 1 illustrates an example environment in which the teachings disclosed herein may be implemented.

[0011] FIG. 2 illustrates a schematic of an example implementation of the oil burning controller apparatus of FIG. 1.

[0012] FIG. 3 is an isometric view of another example implementation of the oil burning controller apparatus of FIG. 1.

[0013] FIG. 4 is an isometric view of another example implementation of the oil burning controller apparatus of FIG. 1.

[0014] FIG. 5 is a graph representing the density of fluid sent to a burner over time during an actual burning operation implemented using an example oil burning controller apparatus similar to the apparatus of FIGS. 1-4.

[0015] FIG. 6 is a flowchart illustrating an example process that may be carried out to implement the example oil burning controller apparatus of FIGS. 1-4.

[0016] FIG. 7 is a flowchart illustrating another example process that may be carried out to implement the example oil burning controller apparatus of FIGS. 1-4.

[0017] FIG. 8 is a schematic illustration of an example computer that may be used and/or programmed to carry out the example process of FIG. 6 and/or, more generally, to implement the example oil burning controller apparatus of FIGS. 1-4.

DETAILED DESCRIPTION

[0018] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0019] In the specification and appended claims: the terms “connect”, “connection”, “connected”, “in connection with”, and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements”; and the term “set” is used to mean “one element” or “more than one element”. Further, the terms “couple”, “coupling”, “coupled”, “coupled together”, and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements”. As used herein, the terms “up” and “down”, “upper” and “lower”, “upwardly” and downwardly”, “upstream” and “downstream”; “above” and “below”; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly describe some embodiments of the disclosure.

[0020] Fluids produced from a test well are generally considered to be waste effluent because the well site has not been configured with a production line to collect and transport the formation fluids to market and/or the fluids cannot be used for other purposes. Therefore, fluids produced during well testing (referred to herein as production fluids) are typically disposed of by burning. Often, oil produced from a reservoir through a borehole may be contaminated by other fluids, or have certain properties that may negatively affect the burning process. For example, in addition to oil, the production fluid may include water-based fluids (*e.g.*, water from the reservoir, water-based drilling fluids, fracturing fluids, etc.). Furthermore, the collected production fluid may include high density and/or high viscosity oil-based drilling fluids that contaminate the oil.

[0021] The burning of production fluid that includes hydrocarbons raises environmental and safety concerns. Conventionally, the fluids may be separated into gas and liquids inside a separator vessel, then burned using one of three types of burners: 1) a liquid phase oil burner capable of mixing crude oil and air to achieve a good combustion, 2) a gas flare that will directly burn the dry gas, and/or 3) a multiphase burner that can burn both phases simultaneously within certain limits.

[0022] Burners are designed to combust waste effluent at a maximum flow rate corresponding to a burning capacity of the burner. Typically, the waste effluent is provided at a much lower flow rate to test the well under any conditions. The operational range of flow rates of a burner can be expressed in terms of a turndown ratio for the burner. The turndown ratio for a burner is defined as the ratio of the maximum flow rate capacity of the burner to the minimum flow rate capacity of the burner. If the flow rate of waste effluent decreases below the turndown ratio limit, the combustion may become unsafe, environmentally harmful, and/or otherwise unacceptable. For example, when the waste effluent flow rate drops below the minimum flow rate for the burner, a condition known as “fallout” may occur during which the waste effluent containing hydrocarbons does not undergo complete combustion but, at least partially, falls out of the burner head and is, thus, discharged into the surrounding environment (*e.g.*, on the surface of the sea in offshore drilling). Oil burning operations have been statistically shown to be one of the main causes of oil spills during well testing. Thus, better control of the fluid burning operation and avoiding mixture of non-flammable fluids within the burner that frequently causes “fallout” will enable reduction of oil spills.

[0023] To improve the efficiency of burning operations, when other control measures fail, a commonly applied technique is to mix diesel with the production fluid prior to pumping the fluid to a burner head. This technique helps to ensure that a burning operation is maintained within the limits of the operating conditions of the burner, thereby preventing fallout events. This technique is normally applied manually by well test operators, based solely on the observation of the flame created by the burner during the combustion process at the end of the process chain. Thus, the traditional approach is a reactive approach that responds to observed results at the burner head of the fluid mixture being burned. As such, the entire length of piping from the burner head back to the storage tanks (representing several barrels) may become filled with a low flammability fluid mixture that will result in incomplete combustion (*e.g.*, producing fallout) before an operator becomes aware of the fact such that it is too late to revert the process.

[0024] Some examples disclosed herein include a device to monitor (*e.g.*, measure), in substantially real-time, a property of a fluid mixture (*e.g.*, fluids including production fluids to be burned as waste effluent) that is being pumped to a burner from two or more fluid streams, which property corresponds to the flammability of the fluid mixture. A PLC (Programmable Logic Control) may use the fluid property data to control inlet valves disposed within a manifold for the two or more fluid streams in order to maintain the property of the combined fluid stream exiting the device within a range that maintains flammability of the mixed fluid. Some examples include a method including flowing a first fluid comprising well test production fluid and a second fluid comprising a flammable fluid to a device for mixing the first and second fluids into a third fluid that exits the device, measuring the density of the third fluid exiting the device and, if the density of the third fluid is outside an acceptable range corresponding to its flammability, adjusting the flow rate of at least one of the first and second fluid to bring the third fluid density back within the flammable range. While the examples disclosed herein are suitable for implementation during well testing operations, the teachings disclosed herein may suitably be used at well sites that are fully operational to gather and process crude oil.

[0025] FIG. 1 illustrates an example environment 100 in which the teachings disclosed herein may be applied to implement a burning operation of production fluids at a well site. The example environment 100 of FIG 1 includes an oil burning controller apparatus 102 constructed in accordance with the teachings disclosed herein. In the illustrated example, the apparatus 102 includes a first inlet 104 to receive production fluid from a production fluid storage tank 106. Additionally, the example apparatus 102 includes a second inlet 108 to receive a flammable fuel from a flammable fuel storage tank 110. In some examples, the production fluid storage tank 106 and the flammable fuel storage tank 110 are atmospheric storage tanks. As shown in the illustrated example, the apparatus includes piping 112 to enable the mixture of the production fluid (from the production fluid storage tank 106) and the flammable fuel (from the flammable fuel storage tank 110). The resulting fluid mixture exits from an outlet 114 of the apparatus 102 and is directed by a pump 116 to a burner 118 to be burned.

[0026] In the illustrated example, the production fluid in the production fluid storage tank 106 is retrieved from an oil well as part of a well testing operation. During well testing, the crude oil in the production fluid obtained from a well is sometimes separated from the water and gas before storage in the production fluid storage tank 106. In some examples, non-flammable fluids (*e.g.*, water based liquids) are separated from the flammable fluids (*e.g.*, crude oil) within a production fluid based on gravity. That is, once placed into the production fluid storage tank 106, the water based fluids will settle at the bottom of the tank separate from the flammable fluids that rise to the top. However, complete separation of non-flammable fluids (*e.g.*, water) from the flammable fluids in the production fluid may be difficult or impracticable. The incomplete separation of non-flammable fluids from flammable fluids within the production fluid creates challenges for efficient and environmentally safe burning procedures. For instance, while certain levels of water based fluids may be vaporized during a burning operation, a high proportion of such non-flammable fluids may extinguish the combustion process and/or prevent complete combustion, thereby resulting in smoke and/or non-consumed hydrocarbons (*e.g.*, crude oil) falling out of the burner head (referred to as fallout), and into the environment.

[0027] To increase the flammability of the fluid flowing to the burner and reduce the likelihood of pollution in the form of smoke and/or fallout, especially when a high percentage of water based liquid may be contained within the production fluid, the production fluid is mixed with the flammable fuel reducing the overall portion of water in the fluid mixture (referred to as the water cut of the fluid mixture). In some examples, the flammable fuel is a flammable fluid with known properties (unlike the production fluid, which can vary in its properties depending on its composition). More particularly, in some examples, the flammable fuel is diesel.

[0028] In many known burning operations associated with well testing, the mixture of a production fluid (*e.g.*, crude oil) and a flammable fluid (*e.g.*, diesel) for burning at a burner head has been done manually. That is, in the past, well test specialists or other individuals often manually operate outlet valves on the storage tanks 106, 110 (or other valves downstream of the tanks) to control the proportion of each fluid being pumped to the burner in an attempt to improve combustion efficiency and avoid the release of pollutants into the environment. In such situations, the ability to achieve efficient combustion is dependent on the experience and skills of the well test specialists that are operating the burning operation. More specifically, the operators adjust the flow rates of the fluid from the production fluid storage tank and the flammable fuel storage tank to the burner generally based on visual observations of the burner combustion itself. That is, operators may adjust the flow rates of the fluids if smoke appears and/or if fallout is visible. Additionally or alternatively, to avoid the possibility of such pollution, the operators may set the flow rates with relatively high margins of safety that are significantly less than optimal for efficient combustion of the production fluid.

[0029] In contrast to these known techniques, the example apparatus 102 of FIG. 1 enables the automatic control of flow rates of the production fluid and the flammable fuel from the corresponding storage tanks 106, 110. As shown in the illustrated example, the apparatus 102 includes a first control valve 120 to control the flow rate of the production fluid (*e.g.*, waste effluent produced during well testing) and a second control valve 122 to control the flow rate of the flammable fuel (*e.g.*, diesel). The valves 120, 122 may be controlled to be fully open, fully closed, or any position in between fully open and fully closed. In some examples, the first control valve 120 has a failsafe position that is fully closed while the second control valve 122 has a failsafe position that is fully open.

[0030] In some examples, the control valves 120, 122 are structured such that they are actuated in opposite directions. That is, in some examples, a particular control sent to both control valves 120, 122 will cause the first control valve 120 to open further towards the fully open position while the same control signal will cause the second control valve 122 to move closer to the fully closed position. More particularly, in some examples, the control valves 120, 122 are structured and/or configured to have complementary positions when adjusted between their fully open and fully closed positions. As used herein, “complementary positions” of two valves means that the positions of the two valves, when expressed as a percentage, total 100%. That is, when the first control valve 120 is fully closed (position is 0%) the second control valve 122 is fully open (position is 100%). Further, if the first control valve 120 is controlled to an intermediate position, such as 30%, the second control valve 122 will be controlled to the complementary intermediate position, which in this example is 70% (30% + 70% = 100%). Thus, as used herein, two valves being moved, opened, or closed a “complementary amount” means that the proportion of movement of each valve is substantially equivalent to the proportion of movement of the second valve but in the opposite direction. That is, if the first control valve 120 is opened an additional 30% from an initial position of 30% (resulting in a final position of 60%), the second control valve 122 will be closed a substantially equivalent proportion (30%) from an initial position of 70% (resulting in a final position of 40%). This proportional, complementary movement of the control valves 120, 122 enables a single control signal to be provided to both control valves 120, 122 to implement some of the teachings disclosed herein, according to various embodiments.

[0031] In some examples, operation of the control valves 120, 122 is based on feedback from a meter 124 on the apparatus 102 monitoring a property of the fluids after they have been mixed together. In some examples, the property of the fluid mixture corresponds to a flammability of the fluid mixture. In some examples, the property of the fluid mixture falling outside a certain range may indicate the flammability of the fluid is decreasing corresponding to a reduction in a burning efficiency of the burner 118. Furthermore, certain values of the measured property of the fluid mixture may indicate that the fluid mixture has become non-flammable or at least cannot be burned by the burner 118.

[0032] If the fluid property falls outside specified limits corresponding to an acceptable range for the fluid property, the control valves 120, 122 may be automatically actuated to adjust the flow rates of the fluid streams flowing from the corresponding production fluid storage tank 106 and the flammable fuel storage tank 110 to bring the property of the fluid mixture back within the acceptable range. Additionally or alternatively, the property of the fluid mixture may be controlled to a particular set point within the acceptable range regardless of the particular limits of the range (which may be set to trigger alerts and/or alarms). That is, in some examples, the apparatus 102 enables the substantially constant and substantially real-time control of the fluid property as soon as it rises above or falls below a configured set point. In some examples, the value of the set point is determined empirically. In some examples, an operator may adjust the set point during a well test based on observation of the burning operation. This approach enables the improvement (*e.g.*, optimization) of the production fluid disposal flow rate while reducing costs (based on reduction in the volume of the flammable fuel included in the fluid mixture to be burned). Furthermore, this approach significantly reduces the risk of environmental harm arising from the combustion process because the flammability of the fluid mixture (associated with the measured fluid property) is controlled upfront in a proactive manner rather than in a reactive manner based on visual observation of the combustion at the burner head.

[0033] In some examples, the meter 124 is a density meter and the property of the fluid mixture used to determine flammability is density. More particularly, in some examples, the meter 124 is a Coriolis meter to measure or determine the density of the fluid mixture in substantially real time. Other density measurements may be performed with density sensors or similar technology. As described above, the particular fluid properties or characteristics (including density) of the production fluid may be unknown and/or variable overtime. However, the properties (including the density) of the flammable fuel (such as diesel) are known and consistent over time. Thus, changes to the density of fluid mixture detected by the meter 124 are indicative of changes in the density of the production fluid. Thus, based on this single monitored value, appropriate adjustments to one or both of the control valves 120, 122 can be implemented automatically to increase or decrease the flow rates of each of the production fluid and the flammable fuel through the apparatus 102 to achieve and maintain a fluid mixture with a desired density associated with efficient combustion. In this manner, the likelihood of the burning operation resulting in pollution is significantly reduced because it removes the risk of human error as well as the delay of a human response to changes in fluid properties based on visual observation of the burner flare.

[0034] In some examples, monitoring feedback from the meter 124 and controlling the control valves 120, 122 based on such feedback is accomplished using a controller 126. As described above, in some examples, a single control signal from the controller 126 may actuate both the control valves 120, 122 in opposite directions a complementary amount. The controller 126 may be any suitable type of controller (*e.g.*, a programmable logic controller (PLC)) that communicates with the control valves 120, 122 and the meter 124 using any desired communication media (*e.g.*, wireless, hardwired, etc.) and protocols (*e.g.*, Foundation Fieldbus, Profibus, etc.). In some examples, the controller 126 implements a proportional-integral-derivative (PID) control loop. In such examples, the controller 126 may calculate an error (and its integral and derivative) between a desired input value for the property of the fluid mixture (*e.g.*, density) and a measured output value for the property (*e.g.*, as measured by the meter 124). The initial desired input value may be based on fluid samples taken on site during the well testing operation.

[0035] As shown in the illustrated example, the controller 126 is separate from the apparatus 102. However, in other examples, the controller 126 may be built into and/or manufactured as a unit with the apparatus 102. Additionally or alternatively, in some examples, the controller 126 and/or the apparatus 102 include the ability to communicate the measured density (and/or other measured properties) of the fluid mixture, the density set point and/or alarm limits, and/or the valve positions of the control valves 120, 122, to another location on site (such as a cabin where the operators observe and run the equipment) and/or a remote location. Such communications may be performed through wired or wireless communication devices and methods.

[0036] In some examples, the apparatus 102 is rated for H2S, CO2 and acid service (fluid class “m”), and can handle a maximum flow rate of 8,000 barrels per day, under a maximum line pressure of 1339 psi [92.3 bar] at 121°C [250°F]. In some examples, the operational temperature range of the apparatus 102 may vary from -20°C to 121°C [-4°F to 250°F].

[0037] FIG. 2 illustrates a schematic of an example oil burning controller apparatus 200 that may be used to implement the example apparatus 102 of FIG. 1. As shown in the illustrated example, the apparatus 200 includes the first inlet 104 that is in fluid communication with the first control valve 120 on a first input fluid line 220 to control the flow of production fluid from the production fluid storage tank 106 (shown in FIG. 1). Similarly, the example apparatus 200 includes the second inlet 108 in fluid communication with the second control valve 122 on a second input fluid line 222 to control the flow of the flammable fuel from the flammable fuel storage tank 110. Additionally, as shown in the illustrated example, the apparatus 200 includes the meter 124 (which is a Coriolis meter in FIG. 2) positioned downstream from the two input fluid lines 220, 222 after they have merged into the single output fluid line 224 leading to the outlet 114. In the illustrated example, the apparatus 200 includes a mixer 202 to facilitate the mixing of the production fluid and the flammable fuel before the Coriolis meter 124 measures the density of the resulting fluid mixture. In the illustrated example, the mixer 202 is a static mixer without moving parts.

[0038] In some examples, one or both of the input lines 220, 222 of the example apparatus 200 includes a filter 204, 205 to prevent any solids from reaching and potentially blocking the burner 118. Additionally, in some examples, the flammable fuel input line (the second input fluid line 222) includes a check valve 206 to prevent flow back to the flammable fuel storage tank 110 once the production fluid storage tank 106 may be pressurized with a higher hydrostatic pressure. Further, in some examples, the apparatus 200 provides one or more line access valves 208, 209, 210, 211, 212 to provide tapping points to enable collection of samples, drainage of fluids, pressure tests, and/or installation of pressure indicators as needed. In some examples, the line access valves 208, 209, 210, 211, 212 are ball valves.

[0039] The example apparatus 200 of FIG. 2 includes operation mode selection valves 214, 215, 216, 217, 218 to configure the apparatus 200 to operate in either a normal operation mode or a by-pass mode. In the illustrated example, the normal operation mode corresponds to when the fluids pass through the control valves 120, 122, are mixed together (via the mixer 202), and then pass through the Coriolis meter 124 to enable the density measurement before reaching the outlet 114. That is, in the illustrated example, the normal operation mode corresponds to the automatic control of the fluid mixture provided to the burner 118. While the control valves 120, 122 are configured to be automatically controlled, in some examples, the automatic control may be overridden to enable manual control of the control valves 120, 122. In the normal operation mode, the first two operation mode selection valves 214, 215 (branching between the inlet and outlet lines 220, 222, 224) are closed while the other three operation mode selection valves 216, 217, 218 (on the inlet and outlet lines 220, 222, 224) are open. By contrast, in the by-pass mode, the first two operation mode selection valves 214, 215 are open while the other three operation mode selection valves 216, 217, 218 are closed. The by-pass mode enables the production fluid and the flammable fuel to be sent directly to the outlet 114 without passing (*i.e.*, by-passing) the filters 204, 205, the control valves 120, 122, the mixer 202, and the meter 124. In some examples, the operation mode selection valves 214, 215, 216, 217, 218 are ball valves.

[0040] FIG. 3 is an isometric view of another example oil burning controller apparatus 300 that may be used to implement the example apparatus 102 of FIG. 1. As shown in the illustrated example, the apparatus 300 includes the first inlet 104 that is in fluid communication with the first control valve 120 to control the flow of production fluid from the production fluid storage tank 106 shown in FIG. 1. Similarly, the example apparatus

300 includes the second inlet 108 in fluid communication with the second control valve 122 to control the flow of the flammable fuel from the flammable fuel storage tank 110. Additionally, as shown in the illustrated example, the apparatus 300 includes the meter 124 (which is a Coriolis meter in FIG. 3) positioned downstream from the two input lines 220, 222 after they have merged into the single output line 224 leading to the outlet 114.

[0041] Additionally, as shown in FIG. 3, the example apparatus 300 includes operation mode selection valves 302, 303, 304, 305 to configure the apparatus 300 to operate in either a normal operation mode or a by-pass mode. In the illustrated example of FIG. 3, the first operation mode selection valve 302 is closed while the remaining three operation mode selection valves 303, 304, 305 are open to configure the apparatus for normal operation (*e.g.*, automatic control of the fluid mixture at the outlet 114 based on density values measured by the meter 124). In the by-pass mode, the first operation mode selection valve 302 is open while the remaining three operation mode selection valves 303, 304, 305 are closed. Thus, the by-pass mode of the illustrated example of FIG. 3 corresponds to the production fluid being directed to the outlet 114 without being mixed with the flammable fuel. In other implementations, the flammable fluid may be connected to the first inlet 104 shown in FIG. 3 to enable the flammable fuel to be directed to the outlet 114 in the by-pass mode without being mixed with the production fluid.

[0042] FIG. 4 is an isometric view of another example oil burning controller apparatus 400 that may be used to implement the example apparatus 102 of FIG. 1. As shown in the illustrated example, the apparatus 400 includes the first inlet 104 that is in fluid communication with the first control valve 120 to control the flow of production fluid from the production fluid storage tank 106 (shown in FIG. 1). Similarly, the example apparatus 400 includes the second inlet 108 in fluid communication with the second control valve 122 to control the flow of the flammable fuel from the flammable fuel storage tank 110. Additionally, as shown in the illustrated example, the apparatus 400 includes the meter 124 (which is a Coriolis meter in FIG. 4) positioned downstream from the two input lines 220, 222 after they have merged into the single output line 224 leading to the outlet 114.

Additionally, as shown in FIG. 4, the example apparatus 400 includes additional valves that may be closed or opened to configure the apparatus 400 to operate in either a normal operation mode or a by-pass mode in a similar manner described above in connection with FIGS. 2 and 3.

[0043] As shown in the illustrated example of FIG. 4, the apparatus 400 is manufactured as a unitary process skid with all of the components mounted on a skid framework 402. In some examples, the skid framework 402 is constructed to be lifted from underneath (*e.g.*, using a forklift) or from above (*e.g.*, using a crane).

[0044] FIG. 5 is a graph 500 representing the density of fluid sent to the burner 118 over time during an actual burning operation implemented using an example oil burning controller apparatus similar to the apparatus 102, 200, 300, 400 of FIGS. 1-4. In the illustrated example, the density represented in the graph 500 is based on measured values obtained by the Coriolis meter 124. A first time period 502 represented in the graph 500 corresponds to a time before the piping lines (*e.g.*, the input and output lines 220, 222, 224) of the apparatus 200 are filled. During a second time period 504, the piping lines, including the Coriolis meter 124 are being filled. The transition point 506 between the first and second time periods 502, 504 corresponds to when the pump 116 is initially turned on. In the illustrated example, the apparatus is initially filled exclusively with the flammable fuel while the production fluid is introduced after the combustion process has begun. A third time period 508 in the graph 500 represents when the Coriolis meter 124 is filled with the flammable fuel. As mentioned above, the flammable fuel corresponds to a fluid with known properties that are consistent over time as indicated by the relatively flat line during the third time period 508. In this example, the flammable fuel is diesel with a density of approximately 850 kg/m^3 as shown in the example graph 500.

[0045] In some examples, the burner 118 is ignited during the third time period. That is, in the illustrated example, the combustion begins exclusively with the flammable fuel being provided to the burner 118. At some point in time after initiation of the combustion process (*e.g.*, at the point 510 in the graph 500), the production fluid is introduced into the combustion process. That is, at the point 510, the first control valve 120 is opened to begin mixing the production fluid with the flammable fuel. Typically, well effluent (*e.g.*, the production fluid) has a higher density than diesel (*e.g.*, the flammable fuel). Thus, as shown in the illustrated example, during a fourth time period 512 beginning after the point 510 when the production fluid is introduced into the operation, the measured density increases based on the mixture of the production fluid with the flammable fuel.

[0046] As shown in the illustrated example, the density of the fluid mixture changes during the fourth time period 512 based on changes in the density of the production fluid and the resulting response of the apparatus 200 adjusting the flow rates of each fluid included in the output fluid mixture. More particularly, during the burning process, the flow rates are adjusted so that the measured density of the combined fluid mixture stays within an acceptable range and/or is adjusted to reduce an error between the measured density value and a specified set point to ensure fluid flammability and burner efficiency. In some examples, the apparatus 200 may maintain fluid flammability until all the production fluid from the production fluid storage tank 106 is burned, including any water based liquids. For example, a downward spike 514 at the end of the fourth time period 512 is indicative of the pump 116 cavitating due to the production fluid storage tank 106 being emptied of production fluid. At that point, the first control valve 120 is closed and the burning operation returns exclusively to burning the flammable fuel during a fifth time period 516 at which point the pump 116 may be stopped and the combustion process ended.

[0047] Flowcharts representative of example methods for implementing the oil burning controller apparatus 102, 200, 300, 400 of FIGS. 1-4 are shown in FIGS. 6 and 7. In these examples, the methods may be implemented using machine readable instructions that comprise a program for execution by a processor such as the processor 812 shown in the example processor platform 800 discussed below in connection with FIG. 8. The program may be embodied in software stored on a tangible computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a digital versatile disk (DVD), a Blu-ray disk, or a memory associated with the processor 812, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor 812 and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowcharts illustrated in FIGS. 6 and 7, many other methods of implementing the example apparatus 102, 200, 300, 400 may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined.

[0048] As mentioned above, the example method of FIGS. 6 and 7 may be implemented using coded instructions (*e.g.*, computer and/or machine readable instructions) stored on a tangible computer readable storage medium such as a hard disk drive, a flash memory, a read-only memory (ROM), a compact disk (CD), a digital versatile disk (DVD), a cache, a random-access memory (RAM) and/or any other storage device or storage disk in which information is stored for any duration (*e.g.*, for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term tangible computer readable storage medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media. As used herein, "tangible computer readable storage medium" and "tangible machine readable storage medium" are used interchangeably. Additionally or alternatively, the example method of FIG. 6 may be implemented using coded instructions (*e.g.*, computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory and/or any other storage device or storage disk in which information is stored for any duration (*e.g.*, for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media. As used herein, when the phrase "at least" is used as the transition term in a preamble of a claim, it is open-ended in the same manner as the term "comprising" is open ended.

[0049] The method of FIG. 6 begins at block 602 where a controller (*e.g.*, the controller 126 of FIG. 1) opens a first valve 120 to provide flow of production fluid (*e.g.*, obtained during well testing). At block 604, the example controller 126 opens a second valve 122 to provide flow of a flammable fluid of known properties. In some examples, the flammable fluid is diesel fuel. At block 606, a mixer (*e.g.*, the mixer 202 of FIG. 2) mixes the production fluid and the flammable fluid. At block 608, the example meter 124 monitors a property of the fluid mixture indicative of a flammability of the fluid mixture. At block 610, the example controller 126 determines whether the property of the fluid mixture deviates from a set point. In some examples, the deviation is determined based on the measured density being outside an acceptable range of density values corresponding to the flammability of the fluid mixture. That is, in some examples, the density deviates from the set point when the deviation exceeds a threshold. If the density has not deviated (exceeded a threshold) from the set point, control returns to block 608. If the example controller 126 determines that the property of the fluid mixture has deviated from the set point, control advances to block 612. At block 612, the example controller 126 adjusts at least one of the first control valve 120 or the second control valve 122 based on the property of the fluid mixture. At block 614, the example controller 126 determines whether to continue the process. If so, control returns to block 608. Otherwise, the example method of FIG. 6 ends.

[0050] The method of FIG. 7 begins at block 702 where a controller (*e.g.*, the controller 126 of FIG. 1) opens first and second control valves 120, 122 to complementary positions, where the first control valve 120 is to provide flow of production fluid (*e.g.*, obtained during well testing) and the second control valve 122 is to provide flow of a flammable fluid with known properties. In some examples, the flammable fluid is diesel fuel. In some examples, the complementary positions of the first and second control valves 120, 122 are accomplished via a single control signal sent to both valves. At block 704, a mixer (*e.g.*, the mixer 202 of FIG. 2) mixes the production fluid and the flammable fluid. At block 706, the example meter 124 monitors a density of the fluid mixture. At block 708, the example controller 126 determines whether the density of the fluid mixture equals a set point. If so, control returns to block 706 to continue monitoring the density of the fluid mixture. That is, no action is taken to modify the fluid mixture when the density corresponds to the set point because such a density will result is safe and efficient combustion of the production fluid in that there should be no fallout and there is a reduced (*e.g.*, minimum) volume of the flammable fluid being used.

[0051] If the example controller 126 determines that the density of the fluid mixture does not equal the set point (block 708), control advances to block 710. At block 710, the example controller 126 determines whether the density of the fluid mixture is above or below the set point. A fluid mixture density that is above the set point is indicative of a fluid mixture having lower flammability than is desirable, which may result in incomplete combustion. To increase the flammability of the fluid mixture, the proportion of the flammable fluid may need to be increased. Thus, if the example controller 126 determines that the density of the fluid mixture is above the set point, control advances to block 712 where the example controller 126 decreases the opening of the first control valve and increases the opening of the second control valve a complementary amount. Decreasing the opening of the first control valve will decrease the flow of the production fluid, while increasing the opening of the second control valve will increase the flow of the flammable fluid. The openings or positions of the first and second control valves 120, 122 are increased or decreased a complementary amount, in the illustrated example, to maintain the overall flow of the fluid mixture while adjusting the ratio of the flammable fluid to the production fluid. In this manner, the density of the fluid mixture can be adjusted to approach the set point. In some examples, the complementary nature of the valve movement enables the control of both the first and second control valves 120, 122 to be accomplished through the use of a single control signal to both valves. After adjusting the openings of the control valves 120, 122 at block 712, control advances to block 716, where the example controller 126 determines whether to continue the process. If so, control returns to block 706. Otherwise, the example method of FIG. 7 ends.

[0052] Returning to block 710, a fluid mixture density that is below the set point is indicative of a fluid mixture that includes an excess (waste) amount of the flammable fluid, which reduces the efficiency (increases costs) of the burning operation. Thus, if the example controller 126 determines that the density of the fluid mixture is below the set point (block 710), control advances to block 714 where the example controller 126 increases the opening of the first control valve and decreases the opening of the second control valve a complementary amount. Increasing the opening of the first control valve will increase the flow of the production fluid, while decreasing the opening of the second control valve will decrease the flow of the flammable fluid. In this manner, the ratio of the flammable fluid to the production fluid in the fluid mixture will change resulting in a change to the density of the mixture until it again settles on, or at least approaches, the set point. In some examples, the complementary nature of the valve movement enables the control of both the first and second control valves 120, 122 to be accomplished through the use of a single control signal to both valves. After adjusting the openings of the control valves 120, 122 at block 714, control advances to block 716 to either continue or end the example method of FIG. 7.

[0053] FIG. 8 is a block diagram of an example processor platform 800 capable of executing the methods of FIGS. 6 and 7 to implement the apparatus 102, 200, 300, 400 of FIGS. 1-4. The processor platform 800 can be, for example, a server, a personal computer, a mobile device (*e.g.*, a cell phone, a smart phone, a tablet such as an iPad™), a personal digital assistant (PDA), an Internet appliance, or any other type of computing device.

[0054] The processor platform 800 of the illustrated example includes a processor 812. The processor 812 of the illustrated example is hardware. For example, the processor 812 can be implemented by one or more integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer.

[0055] The processor 812 of the illustrated example includes a local memory 813 (*e.g.*, a cache). The processor 812 of the illustrated example is in communication with a main memory including a volatile memory 814 and a non-volatile memory 816 via a bus 818. The volatile memory 814 may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS Dynamic Random Access Memory (RDRAM) and/or any other type of random access memory device. The non-volatile memory 816 may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory 814, 816 is controlled by a memory controller.

[0056] The processor platform 800 of the illustrated example also includes an interface circuit 820. The interface circuit 820 may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), and/or a PCI express interface.

[0057] In the illustrated example, one or more input devices 822 are connected to the interface circuit 820. The input device(s) 822 permit(s) a user to enter data and commands into the processor 812. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

[0058] One or more output devices 824 are also connected to the interface circuit 820 of the illustrated example. The output devices 824 can be implemented, for example, by display devices (*e.g.*, a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display, a cathode ray tube display (CRT), a touchscreen, a tactile output device, a light emitting diode (LED), a printer and/or speakers). The interface circuit 820 of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip or a graphics driver processor.

[0059] The interface circuit 820 of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem and/or network interface card to facilitate exchange of data with external machines (*e.g.*, computing devices of any kind) via a network 826 (*e.g.*, an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

[0060] The processor platform 800 of the illustrated example also includes one or more mass storage devices 828 for storing software and/or data. Examples of such mass storage devices 828 include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

[0061] Coded instructions 832 to implement the methods FIGS. 6 and 7 may be stored in the mass storage device 828, in the volatile memory 814, in the non-volatile memory 816, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

[0062] Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

Claims:

1. A method, comprising:

monitoring a property of a fluid mixture being pumped to a burner, the property indicative of a flammability of the fluid mixture; and

automatically adjusting at least one of a first control valve or a second control valve based on the monitored property of the fluid mixture, the first control valve controlling flow of a first fluid into the fluid mixture, the second control valve controlling a flow of a second fluid into the fluid mixture.

2. The method of claim 1, wherein the first fluid corresponds to production fluid from an oil well.

3. The method of claim 1, wherein the second fluid is a flammable fluid with known properties.

4. The method of claim 3, wherein the second fluid is diesel fuel.

5. The method of claim 1, wherein the property of the fluid mixture is density monitored using a Coriolis meter.

6. The method of claim 5, wherein the first control valve, the second control valve, and the Coriolis meter are mounted on a skid framework.

7. The method of claim 1, where the first control valve is adjusted to a valve position complementary to the second control valve.

8. The method of claim 1, further including providing a single control signal to both the first control valve and the second control valve, the first and second control valves to move complementary amounts in response to the control signal.

9. An apparatus, comprising:

a first control valve to control a flow of a first fluid into a fluid mixture to be burned;

a second control valve to control a flow of a second fluid into the fluid mixture; and

a meter to monitor a property of the fluid mixture in substantially real-time, the property indicative of a flammability of the fluid mixture, the at least one of the first control valve or the second control valve to be automatically adjusted based on a measured value of the property of the fluid mixture.

10. The apparatus of claim 9, wherein the property of the fluid mixture is density.

11. The apparatus of claim 9, wherein the first fluid corresponds to production fluid from an oil well.

12. The apparatus of claim 9, wherein the second fluid is a flammable fluid with known properties.

13. The apparatus of claim 9, further including a skid framework, the first control valve, the second control valve, and the meter mounted on the skid framework.

14. The apparatus of claim 9, wherein the first control valve is actuated in an opposite direction to the second control valve.

15. The apparatus of claim 14, wherein both the first control valve and the second control valve are adjusted in response to a single control signal.

16. The apparatus of claim 15, wherein the first and second control valves are adjusted complementary amounts.

17. A tangible computer readable storage medium comprising instructions that, when executed, cause a machine to at least:

monitor a property of a fluid mixture being pumped to a burner, the property indicative of a flammability of the fluid mixture; and

automatically adjust at least one of a first control valve or a second control valve based on the monitored property of the fluid mixture, the first control valve controlling flow of a first fluid into the fluid mixture, the second control valve controlling a flow of a second fluid into the fluid mixture.

18. The storage medium of claim 17, wherein the property of the fluid mixture is density monitored using a Coriolis meter.

19. The storage medium of claim 17, wherein the instructions further cause the machine to automatically adjust both the first control valve and the second control valve in response to a single control signal provided to both the first and second control valves.

20. The storage medium of claim 19, wherein an opening of the first control valve is increased a first proportion when an opening of the second control valve is decreased a second proportion, the first proportion substantially equivalent to the second proportion.

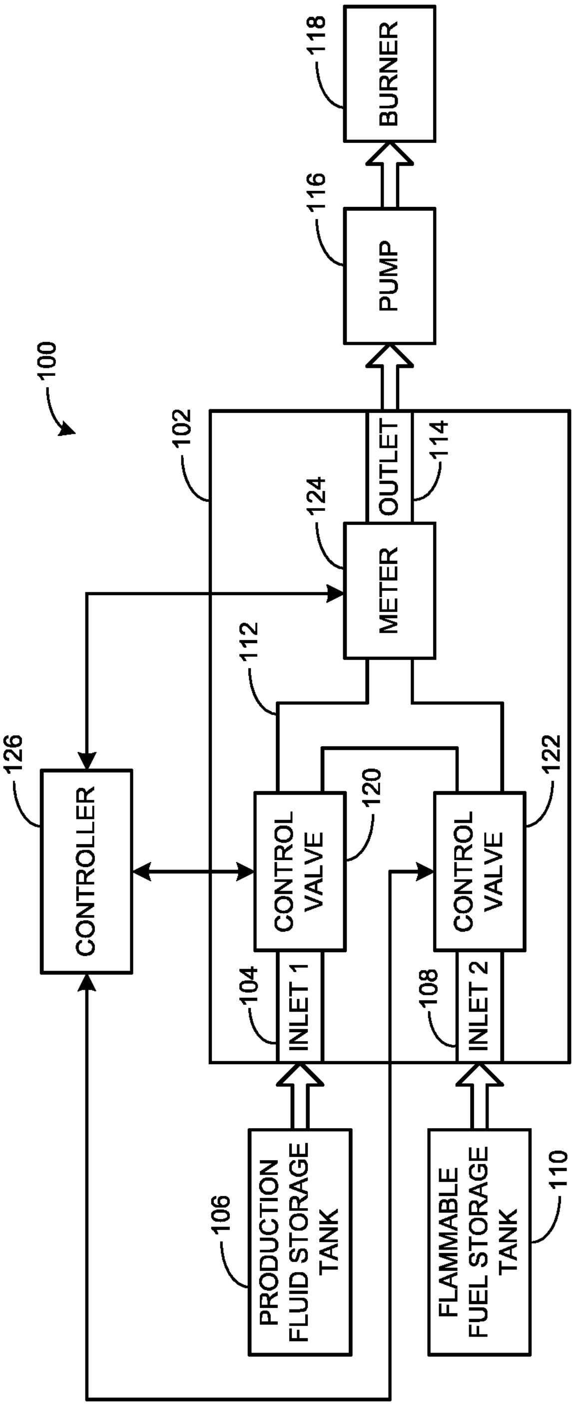
100
102
BURNER
118
PUMP
116
OUTLET
114
METER
124
112
CONTROLLER
126
CONTROL VALVE
120
CONTROL VALVE
122
INLET 1
104
INLET 2
108
PRODUCTION FLUID STORAGE TANK
106
FLAMMABLE FUEL STORAGE TANK
110

FIG. 1

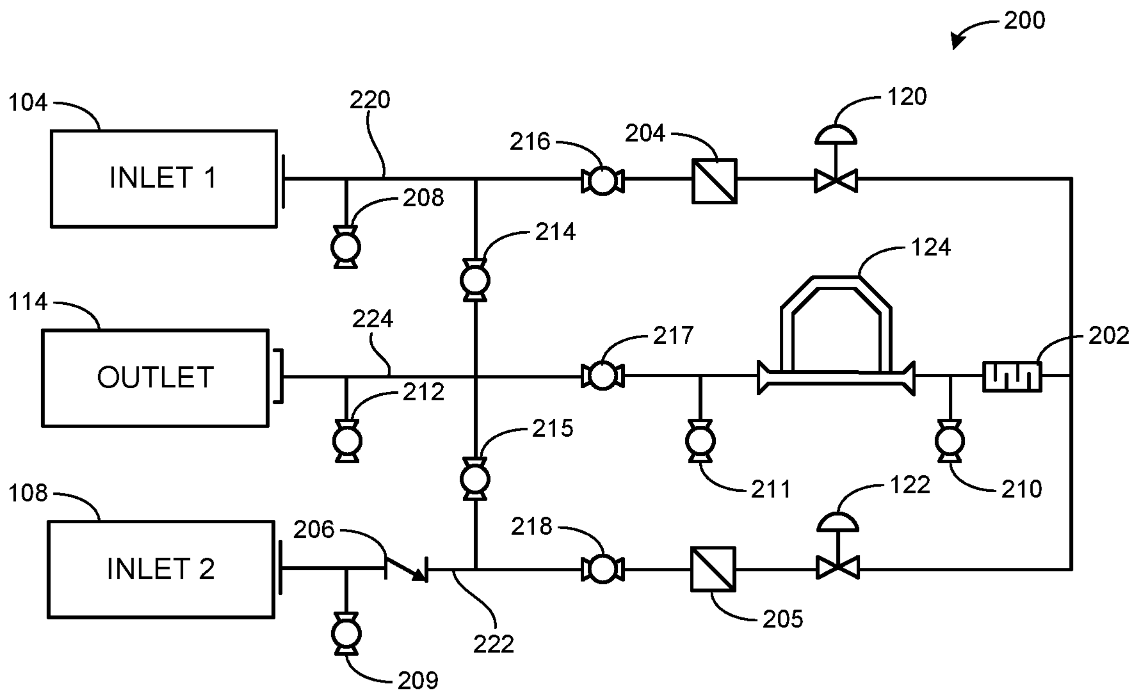
200
104
220
120
216
204
INLET 1
208
214
124
114
224
217
202
OUTLET
212
215
211
210
108
122
206
218
INLET 2
205
222
209

FIG. 2

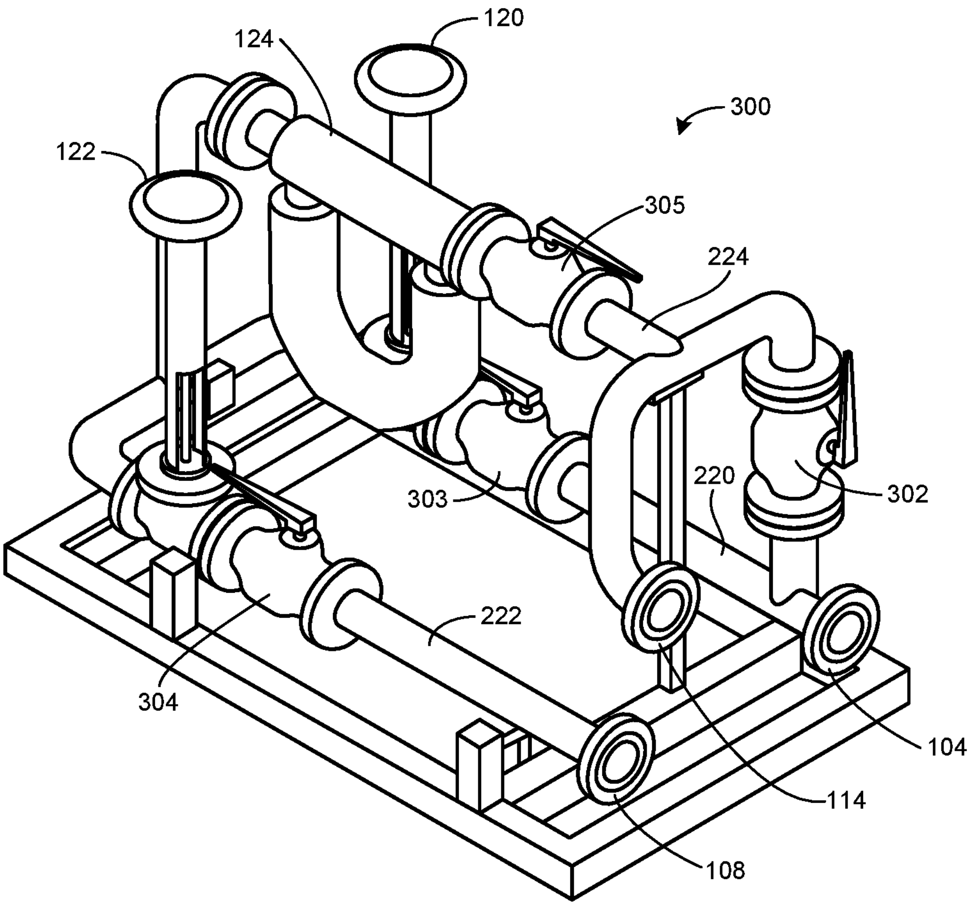

FIG. 3

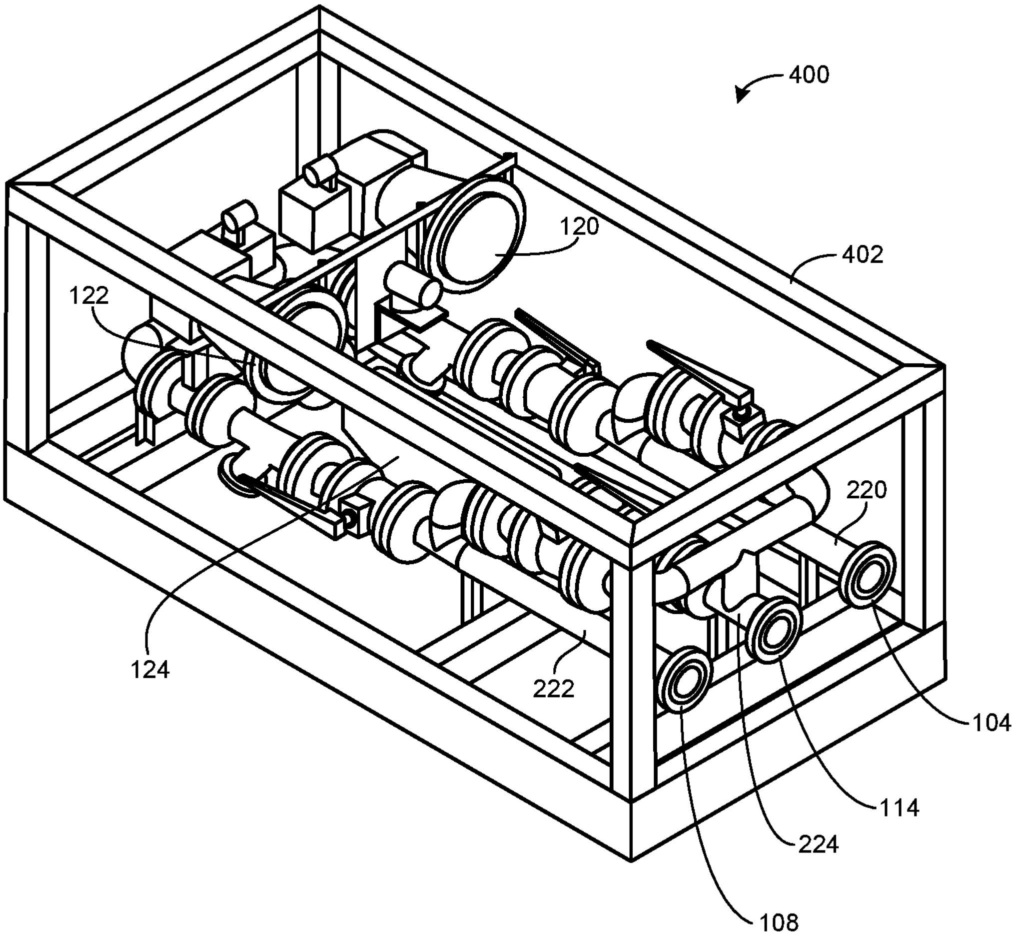

FIG. 4

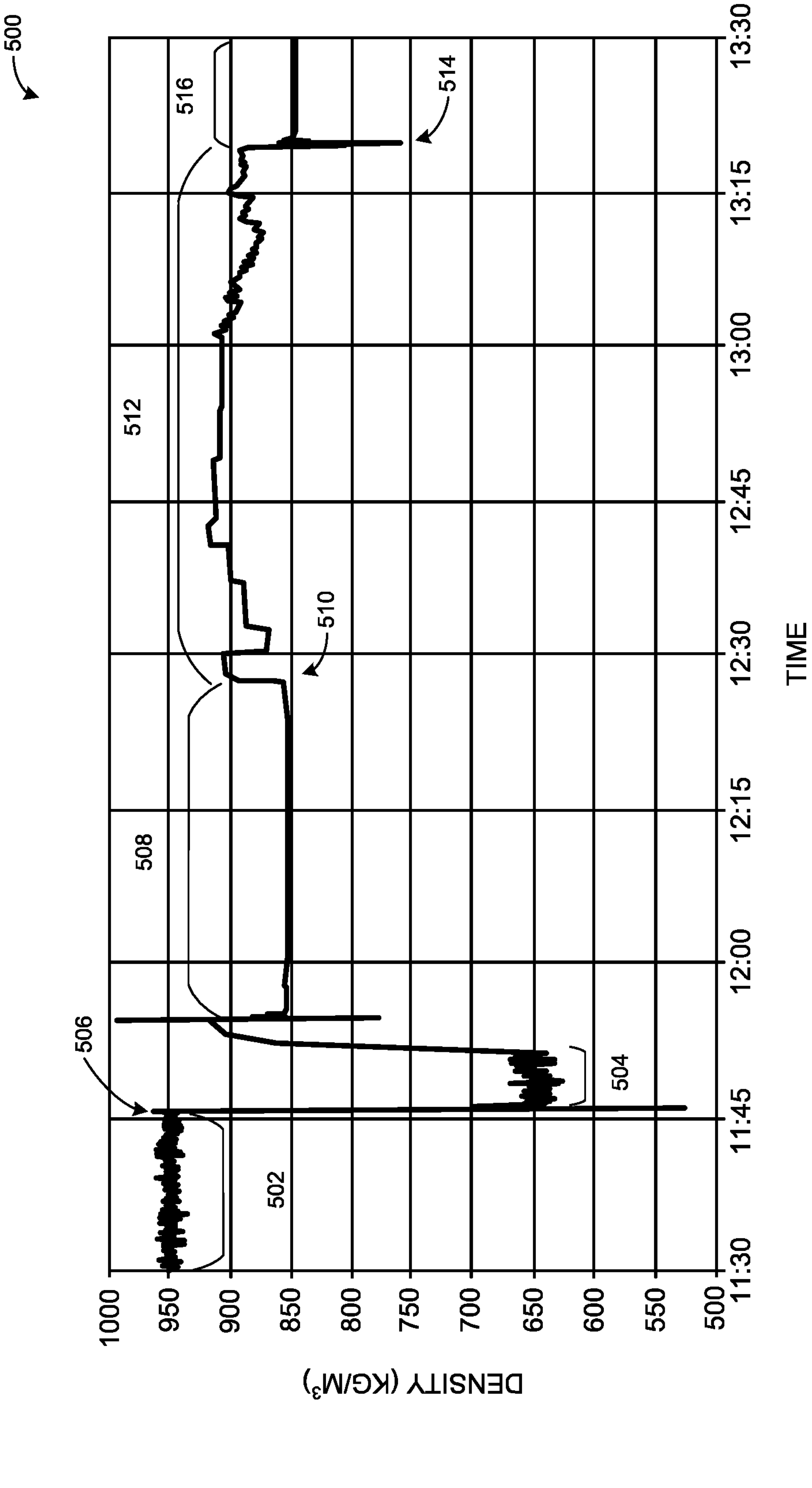
500
DENSITY (KG/M3)
1000
950
900
850
800
750
700
650
600
550
500
TIME
11:30
11:45
12:00
12:15
12:30
12:45
13:00
13:15
13:30
502
504
506
508
510
512
514
516

FIG. 5

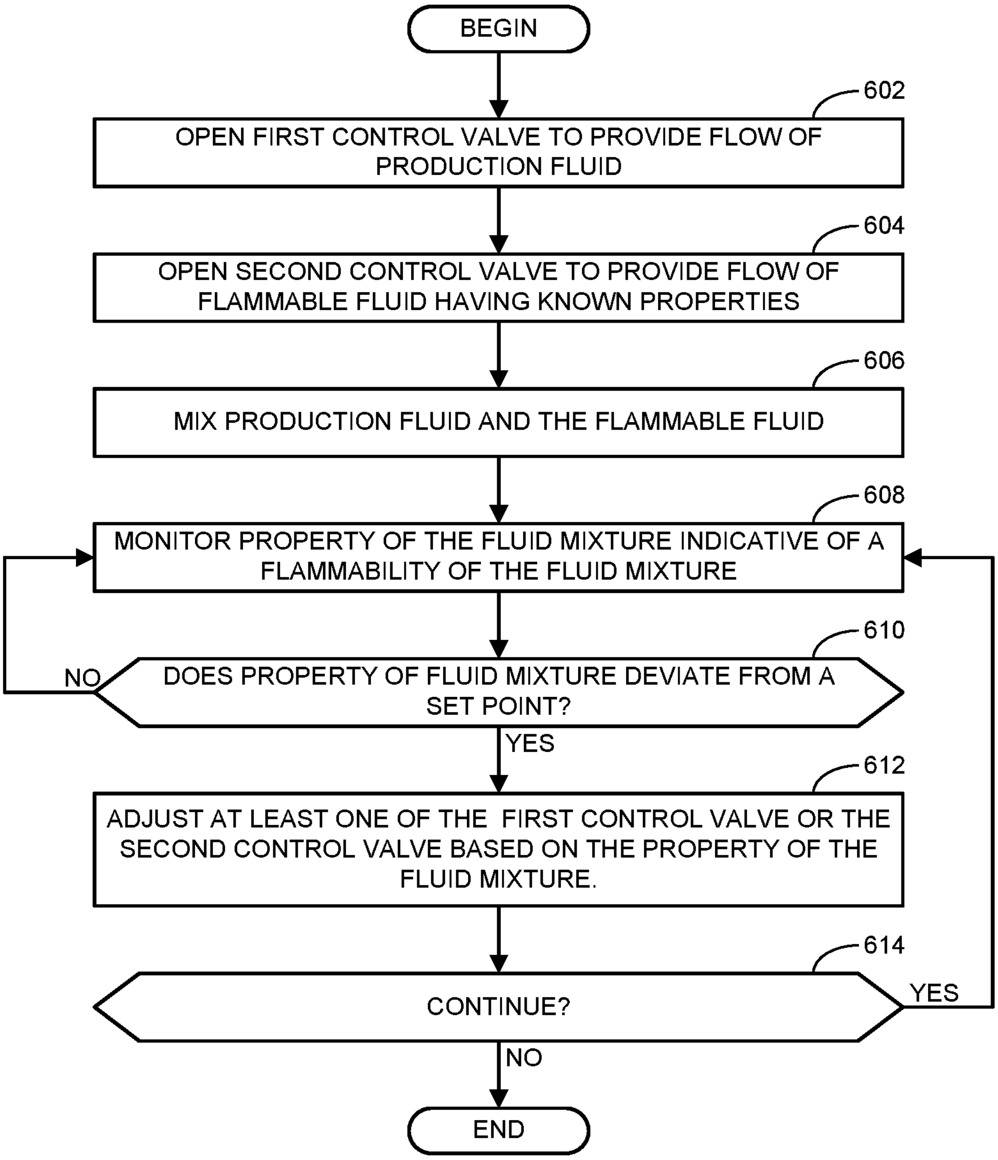
BEGIN
602
OPEN FIRST CONTROL VALVE TO PROVIDE FLOW OF PRODUCTION FLUID
604
OPEN SECOND CONTROL VALVE TO PROVIDE FLOW OF FLAMMABLE FLUID HAVING KNOWN PROPERTIES
606
MIX PRODUCTION FLUID AND THE FLAMMABLE FLUID
608
MONITOR PROPERTY OF THE FLUID MIXTURE INDICATIVE OF A FLAMMABILITY OF THE FLUID MIXTURE
610
NO
DOES PROPERTY OF FLUID MIXTURE DEVIATE FROM A SET POINT?
YES
612
ADJUST AT LEAST ONE OF THE FIRST CONTROL VALVE OR THE SECOND CONTROL VALVE BASED ON THE PROPERTY OF THE FLUID MIXTURE.
614
CONTINUE?
YES
NO
END

FIG. 6

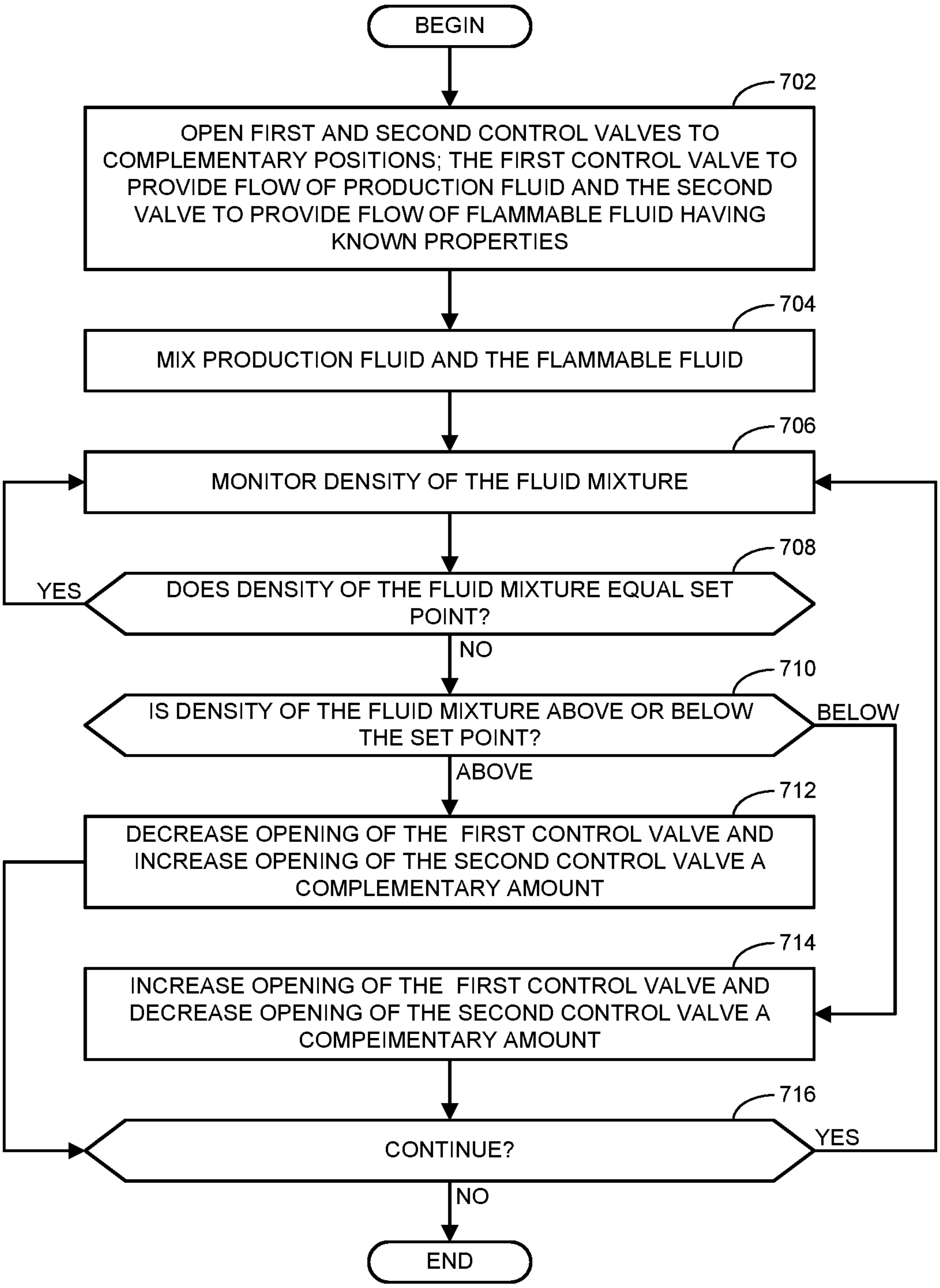
BEGIN
702
OPEN FIRST AND SECOND CONTROL VALVES TO COMPLEMENTARY POSITIONS; THE FIRST CONTROL VALVE TO PROVIDE FLOW OF PRODUCTION FLUID AND THE SECOND VALVE TO PROVIDE FLOW OF FLAMMABLE FLUID HAVING KNOWN PROPERTIES
704
MIX PRODUCTION FLUID AND THE FLAMMABLE FLUID
706
MONITOR DENSITY OF THE FLUID MIXTURE
708
DOES DENSITY OF THE FLUID MIXTURE EQUAL SET POINT?
YES
NO
710
IS DENSITY OF THE FLUID MIXTURE ABOVE OR BELOW THE SET POINT?
BELOW
ABOVE
712
DECREASE OPENING OF THE FIRST CONTROL VALVE AND INCREASE OPENING OF THE SECOND CONTROL VALVE A COMPLEMENTARY AMOUNT
714
INCREASE OPENING OF THE FIRST CONTROL VALVE AND DECREASE OPENING OF THE SECOND CONTROL VALVE A COMPEIMENTARY AMOUNT
716
CONTINUE?
YES
NO
END

FIG. 7

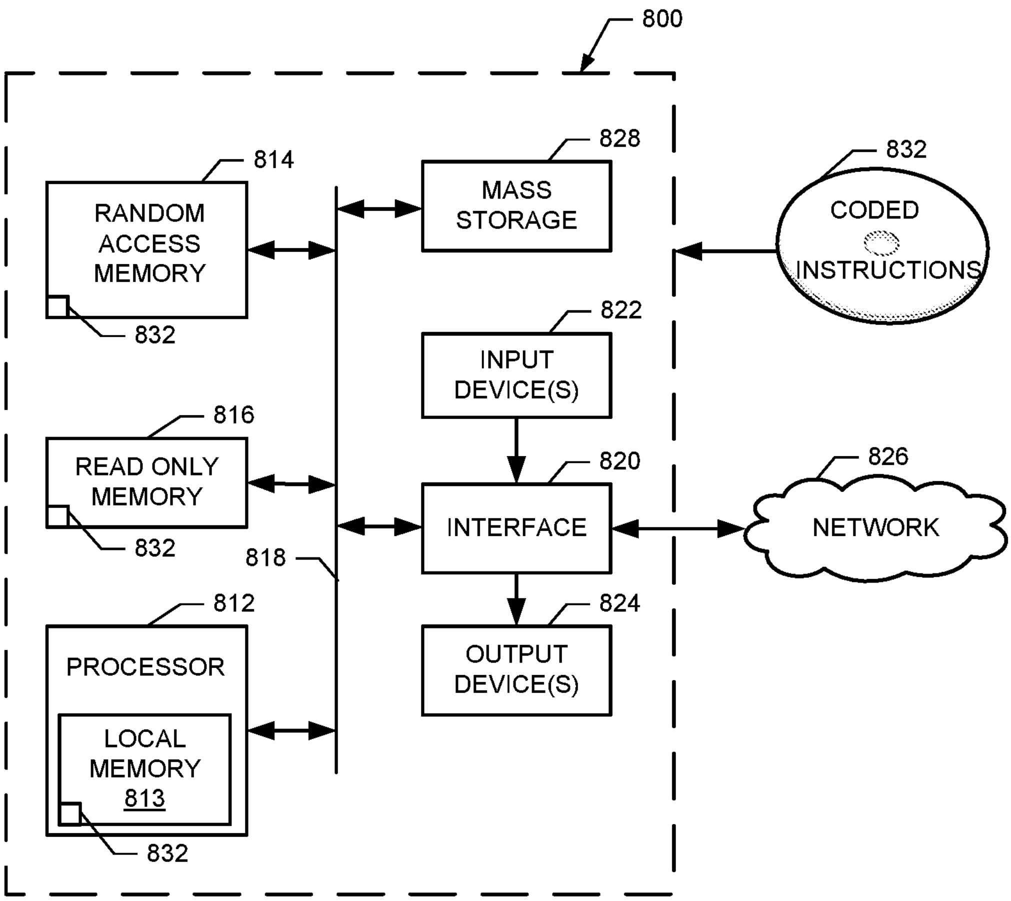
800
814
RANDOM ACCESS MEMORY
832
828
MASS STORAGE
832
CODED INSTRUCTIONS
822
INPUT DEVICE(S)
816
READ ONLY MEMORY
832
820
INTERFACE
826
NETWORK
818
812
PROCESSOR
LOCAL MEMORY 813
832
824
OUTPUT DEVICE(S)

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/044599

A. CLASSIFICATION OF SUBJECT MATTER

F23N 1/00(2006.01)i

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)
F23N 1/00; G01H 3/00; F02C 3/22; G06F 19/00; F02C 9/26; G05D 7/06; G01F 1/36; G01M 19/00; F23N 5/24; G06F 15/32

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: engine, burner, valve, adjust, monitor, control, indicative, measure, and test

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4761948 A (SOOD et al.) 09 August 1988 See column 4, lines 9-12, column 5, lines 2-5 and figure 1.	1-20
Y	US 4250553 A (SEBENS et al.) 10 February 1981 See abstract; column 4, lines 36-42; and figures 2-3.	1-20
Y	US 2002-0194902 A1 (GEHNER et al.) 26 December 2002 See abstract; paragraph [0023]; and claim 1.	5-6,10,18
A	US 2005-0165535 A1 (MILLER, NATHAN TODD) 28 July 2005 See abstract and paragraphs [0008]-[0011].	1-20
A	US 2015-0045971 A1 (HONEYWELL INTERNATIONAL INC.) 12 February 2015 See abstract; paragraphs [0005]-[0008]; and claim 1.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 October 2016 (27.10.2016)	**28 October 2016 (28.10.2016)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
LEE, Dal Kyong
Telephone No. +82-42-481-8440

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/044599

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4761948 A	09/08/1988	EP 0309485 A1	05/04/1989
		EP 0309485 B1	19/08/1992
		JP 03-501146 A	14/03/1991
		JP 06-081907 B2	19/10/1994
		US 4833878 A	30/05/1989
		WO 88-08075 A1	20/10/1988
US 4250553 A	10/02/1981	JP 55-132934 A	16/10/1980
US 2002-0194902 A1	26/12/2002	US 6675641 B2	13/01/2004
US 2005-0165535 A1	28/07/2005	US 2005-0021213 A1	27/01/2005
		US 6882924 B2	19/04/2005
		US 7069137 B2	27/06/2006
US 2015-0045971 A1	12/02/2015	None	