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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16170695
Filing Date	2018-10-25
First Named Inventor	Jared Oehring
Art Unit	
Examiner Name	
Attorney Docket Number	047158.100032

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	109	20090093317		2009-04-09	Kajiwara et al.	
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	111	20160312108		2016-10-27	Lestz et al.	
	112	20130343858		2013-12-26	Flusche	
	113	20160186531		2016-06-30	Harkless et al.	
	114	20170145918		2017-05-25	Oehring	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.H.G/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16170695
	Filing Date	2018-10-25
	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	115	20180156210		2018-06-07	Oehring	
	116	20170226839		2017-08-10	Broussard	
	117	20180183219		2018-06-28	Oehring	
	118	20180258746		2018-09-13	Broussard	
	119	20180274446		2018-09-27	Oehring	

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2004264589	JP		2004-09-24	Toshiba KK [TOKE]		☒
	2	101977016	CN		2011-02-16	Univ Tianjin Technology		☒
	3	2966672	CA		2012-10-07	Evolution Well Services LLC		☒

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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First Named Inventor	Jared Oehring
Art Unit	
Examiner Name	
Attorney Docket Number	047158.100032

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	UK Power Networks - Transformers to Supply Heat to Tate Modern - from Press Releases May 16, 2013.	☒
	2	Non-Final Office Action issued in corresponding Application No. 15/293,681 dated February 16, 2017.	☒
	3	Non-Final Office Action issued in corresponding Application No. 15/294,349 dated March 14, 2017.	☒
	4	Final Office Action issued in corresponding Application No. 15/145,491 dated January 20, 2017.	☒
	5	Non-Final Office Action issued in corresponding Application No. 15/145,443 dated February 7, 2017.	☒
	6	Notice of Allowance issued in corresponding Application No. 15/217,040 dated March 28, 2017.	☒
	7	Notice of Allowance issued in corresponding Application No. 14/622,532 dated March 27, 2017.	☒
	8	Non-Final Office Action issued in corresponding Application No. 15/291,842 dated January 6, 2017.	☒
	9	Final Office Action issued in corresponding Application No. 14/622,532 dated December 7, 2016.	☒
	10	Non-Final Office Action issued in corresponding Application No. 14/622,532 dated May 17, 2016.	☒

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	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	11	Final Office Action issued in corresponding Application No. 14/622,532 dated December 21, 2015.	☒
	12	Non-Final Office Action issued in corresponding Application No. 14/622,532 dated August 5, 2015.	☒
	13	Non-Final Office Action issued in corresponding Application No. 15/145,491 on September 12, 2016.	☒
	14	Non-Final Office Action issued in corresponding Application No. 15/217,040 dated November 29, 2016.	☒
	15	Non-Final Office Action issued in corresponding Application No. 15/235,788 dated December 14, 2016.	☒
	16	Non-Final Office Action issued in corresponding Application No. 15/145,491 dated May 15, 2017.	☒
	17	Non-Final Office Action issued in corresponding Application No. 15/486,970 dated June 22, 2017	☒
	18	Non-Final Office Action issued in corresponding Application No. 15/487,656 dated June 23, 2017	☒
	19	Non-Final Office Action issued in corresponding Application No. 15/487,694 dated June 26, 2017	☒
	20	Final Office Action issued in corresponding Application No. 15/294,349 dated July 6, 2017	☒
	21	Non-Final Office Action issued in corresponding Application No. 14/884,363 dated September 5, 2017	☒

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	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	22	Final Office Action issued in corresponding Application No. 15/145,491 dated September 6, 2017	☒
	23	Non-Final Office Action issued in corresponding Application No. 14/881,535 dated October 6, 2017	☒
	24	Non-Final Office Action issued in corresponding Application No. 15/145,414 dated November 29, 2017	☒
	25	Non-Final Office Action issued in corresponding Application No. 15/644,487 dated November 13, 2017	☒
	26	Canadian Office Action dated March 2, 2018 in related Canadian Patent Application No. 2,833,711	☒
	27	Office Action dated April 10, 2018 in related U.S. Patent Application No. 15/294,349	☒
	28	Office Action dated April 2, 2018 in related U.S. Patent Application No. 15/183,387	☒
	29	Office Action dated May 29, 2018 in related U.S. Patent Application No. 15/235,716	☒
	30	Candian Office Action dated April 18, 2018 in related Canadian Patent Application No. 2,928,711	☒
	31	Canadian Office Action dated June 22, 2018 in related Canadian Patent Application No. 2,886,697	☒
	32	Office Action dated July 25, 2018 in related U.S. Patent Application No. 15/644,487	☒

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	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	33	Office Action dated October 4, 2018 in related U.S. Patent Application No. 15/217,081	☒
	34	International Search Report and Written Opinion dated September 19, 2018 in related PCT Patent Application No. PCT/US2018/040683	☒
	35	Canadian Office Action dated September 28, 2018 in related Canadian Patent Application No. 2,945,281	☒

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EXAMINER SIGNATURE

Examiner Signature	/JENNIFER H GAY/	Date Considered	02/06/2019

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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First Named Inventor	Jared Oehring
Art Unit	
Examiner Name	
Attorney Docket Number	047158.100032

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Taylor P. Evans/	Date (YYYY-MM-DD)	2018-11-05
Name/Print	Taylor P. Evans	Registration Number	60506

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16170695
Filing Date	2018-10-25
First Named Inventor	Jared Oehring
Art Unit	3676
Examiner Name	Jennifer Hawkins Gay
Attorney Docket Number	047158.100032

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	4432064		1984-02-14	Barker	
	2	5006044		1991-04-09	Walker, Sr.	

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20170292513		2017-10-12	Haddad	
	2	20140095114		2014-04-03	Thomeer	
	3	20150217672		2015-08-06	Shampine	
	4	20170328179		2017-11-16	Dykstra	

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	First Named Inventor	Jared Oehring
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	Examiner Name	Jennifer Hawkins Gay
	Attorney Docket Number	047158.100032

	5	20040040746		2004-03-04	Niedermayr	
	6	20140379300		2014-12-25	Devine et al.	
	7	20060052903		2006-03-09	Bassett	
	8	20170037717		2017-02-09	Oehring	
	9	20110247878		2011-10-13	Rasheed	
	10	20160230524		2016-08-11	Dumoit	
	11	20170114625		2017-04-27	Norris	
	12	20170022807		2017-01-26	Dursun	
	13	20160208595		2016-07-21	Tang	
	14	20150075778		2015-03-19	Walters	

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	1	2016/144939	WO		2016-09-15	Schlumberger Technologies Corporation		☒
	2	2016/160458	WO		2016-10-06	Schlumberger Technology Corporation		☒

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	1	Office Action mailed December 12, 2018 in related U.S. Patent Application No. 16/160,708	☒
	2	International Search Report and Written Opinion mailed January 2, 2019 in related PCT Patent Application No. PCT/US18/54542	☒
	3	International Search Report and Written Opinion mailed January 2, 2019 in related PCT Patent Application No. PCT/US18/54548	☒
	4	International Search Report and Written Opinion mailed December 31, 2018 in related PCT Patent Application No. PCT/US18/55913	☒
	5	International Search Report and Written Opinion mailed January 4, 2019 in related PCT Patent Application No. PCT/US18/57539	☒

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EXAMINER SIGNATURE

Examiner Signature	/JENNIFER H GAY/	Date Considered	02/07/2019

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☒ A certification statement is not submitted herewith.

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Signature	/Taylor P. Evans/	Date (YYYY-MM-DD)	2019-01-22
Name/Print	Taylor P. Evans	Registration Number	60506

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Examiner Name	Jennifer Hawkins Gay
Attorney Docket Number	047158.100032

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	4432064		1984-02-14	Barker	
	2	5006044		1991-04-09	Walker, Sr.	

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	1	20170292513		2017-10-12	Haddad	
	2	20140095114		2014-04-03	Thomeer	
	3	20150217672		2015-08-06	Shampine	
	4	20170328179		2017-11-16	Dykstra	

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	5	20040040746		2004-03-04	Niedermayr	
	6	20140379300		2014-12-25	Devine et al.	
	7	20060052903		2006-03-09	Bassett	
	8	20170037717		2017-02-09	Oehring	
	9	20110247878		2011-10-13	Rasheed	
	10	20160230524		2016-08-11	Dumoit	
	11	20170114625		2017-04-27	Norris	
	12	20170022807		2017-01-26	Dursun	
	13	20160208595		2016-07-21	Tang	
	14	20150075778		2015-03-19	Walters	

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Filing Date	2018-10-25
First Named Inventor	Jared Oehring
Art Unit	3676
Examiner Name	Jennifer Hawkins Gay
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	1	2016/144939	WO		2016-09-15	Schlumberger Technologies Corporation		☒
	2	2016/160458	WO		2016-10-06	Schlumberger Technology Corporation		☒

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	Application Number	16170695
	Filing Date	2018-10-25
	First Named Inventor	Jared Oehring
	Art Unit	3676
	Examiner Name	Jennifer Hawkins Gay
	Attorney Docket Number	047158.100032

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16170695
Filing Date	2018-10-25
First Named Inventor	Jared Oehring
Art Unit	3676
Examiner Name	Jennifer Hawkins Gay
Attorney Docket Number	047158.100032

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Signature	/Taylor P. Evans/	Date (YYYY-MM-DD)	2019-01-22
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[Continued on next page]

(54) Title: AUTOMATED OPERATION OF WELLSITE EQUIPMENT

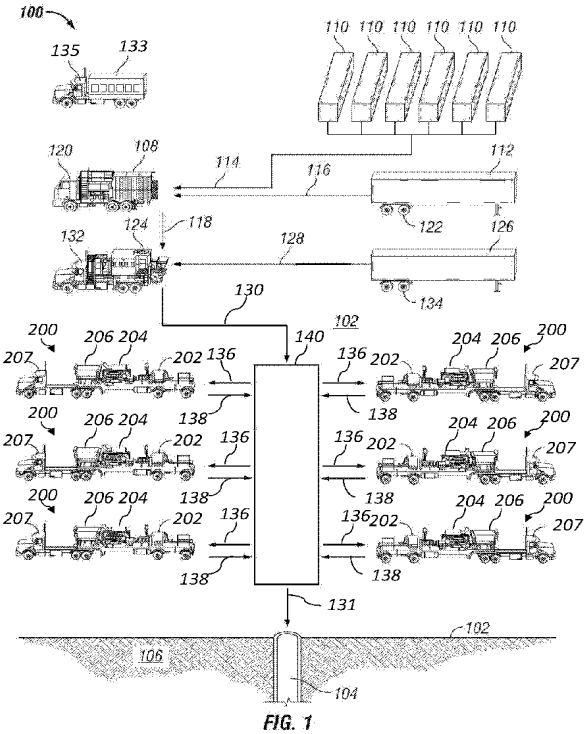


FIG. 1

(57) Abstract: Systems and method for controlling wellsite equipment, including pumps and a manifold having a low-pressure (LP) manifold, having LP ports with LP valves, and a high-pressure (HP) manifold, having HP ports with HP valves and bleed ports with bleed valves. The pumps are fluidly coupled with the LP manifold via LP conduits and with the HP manifold via HP conduits. Communication is established between a controller and the LP valves, the HP valves, the bleed valves, the pumps, and sensors for monitoring pressure within the HP conduits. The controller is operable to, with respect to each pump, cause the LP valve to transition to a closed position, cause the HP and/or bleed valve to transition to an open position, and determine that the HP conduit is not pressurized based on the information generated by the sensors.

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AUTOMATED OPERATION OF WELLSITE EQUIPMENT

Cross-Reference to Related Applications

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 62/130,045, titled "METHOD OF AUTOMATIC MANIFOLD VALVES SANITY TEST," filed March 9, 2015, the entire disclosure of which is hereby incorporated herein by reference.

[0002] This application claims priority to and the benefit of U.S. Provisional Application No. 62/130,174, titled "AUTOMATED RELEASE OF TRAPPED PRESSURE AND FLUID FROM HIGH PRESSURE PUMP LINES," filed March 9, 2015, the entire disclosure of which is hereby incorporated herein by reference.

[0003] This application also claims priority to and the benefit of U.S. Provisional Application No. 62/195,104, titled "REMOTE MANIFOLD VALVE AND PUMP PAIRING TECHNIQUE FOR A MULTI-PUMP SYSTEM," filed July 21, 2015, the entire disclosure of which is hereby incorporated herein by reference.

Background of the Disclosure

[0004] High-volume, high-pressure pumps are utilized at wellsites for a variety of pumping operations. Such operations may include drilling, cementing, acidizing, water jet cutting, hydraulic fracturing, and other wellsite operations. In some pumping operations, several pumps may be fluidly connected to a well via various fluid conduits and at least one manifold. During such operations, the manifold distributes low-pressure fluid from mixer, blender, and/or other units among the pumps and combines pressurized fluid from the pumps for injection into the well. The manifold may have a large physical size and weight to satisfy intended fluid flow rates and operating pressures generated by the pumps. For example, the manifold may convey fluid at a pressure exceeding about 15,000 pounds per square inch (PSI) and a fluid flow rate exceeding about 1,500 gallons per minute (GPM).

[0005] The success of the oilfield operations may be related to many factors, including operational efficiency, failure rates, and safety of the pumps and the manifold at the wellsite. High fluid pressures, flow rates, and vibrations generated by the pumps may cause mechanical fatigue, wear, and other damage to the pumps and various downstream components, including the manifold and various associated fluid sensors, valves, couplings, and conduits. Such mechanical fatigue and wear cause leaks and/or other failures in the pumps and the downstream

components. To ensure that the fluid sensors and valves are not stuck, worn out, or otherwise damaged, human operators at the wellsite approach the manifold during pumping operations to visually and/or manually inspect the fluid sensors and valves, thus exposing themselves to a potentially dangerous environment.

[0006] The operators also manually disconnect the pumps from the manifold, such as after completion of a job, when switching to a different well on a multi-well site, or when changing a pump due to mechanical problems. The task of fluidly disconnecting the pump from the manifold can be dangerous, because high-pressure fluid trapped within the pump and/or the connected conduits may escape, which can lead to serious injuries. The pump and/or the conduits may also contain leftover fluid, which may spill onto the ground when the fluid conduits are disconnected from the pump and/or the manifold, potentially having an adverse environmental impact.

Summary of the Disclosure

[0007] 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 indispensable features of the claimed subject matter, nor is it intended for use as an aid in limiting the scope of the claimed subject matter.

[0008] The present disclosure introduces an apparatus that includes a manifold unit and a controller. The manifold unit includes ports and valves. Each valve is operable to control flow through a corresponding one of the ports. The controller is operable to, with respect to each of the valves: remotely control the valve by transmitting a command signal to the valve to transition the valve from an existing setting to an intended setting; after transmitting the command signal, receive a feedback signal from the valve indicative of an actual setting of the valve; and assess an operational health of the valve based on the intended and actual settings.

[0009] The present disclosure also introduces a method that includes establishing communication between a controller and each of the valves of a manifold unit. Each valve is operable to control flow through a corresponding port of the manifold unit. The method also includes operating the controller to, with respect to each of the valves: remotely control the valve by transmitting a command signal to the valve to transition the valve from an existing setting to an intended setting; after transmitting the command signal, receive a feedback signal from the

valve indicative of an actual setting of the valve; and assess an operational health of the valve based on the intended and actual settings.

[0010] The present disclosure also introduces an apparatus that includes a manifold unit. The manifold unit includes a low-pressure (LP) manifold having LP ports, LP valves each operable to control flow through a corresponding one of the LP ports, a high-pressure (HP) manifold having HP ports, HP valves each operable to control flow through a corresponding one of the HP ports, bleed ports each fluidly coupled with a corresponding one of the HP ports, and bleed valves each fluidly coupled with and remotely operable to control flow through a corresponding one of the bleed ports from the corresponding HP port. The apparatus also includes pumps, LP conduits each fluidly coupling a corresponding one of the pumps and a corresponding one of the LP ports, HP conduits each fluidly coupling a corresponding one of the pumps and a corresponding one of the HP ports, and sensors each operable to generate information indicative of fluid pressure within a corresponding one of the HP conduits. The apparatus also includes a controller in communication with the LP valves, the HP valves, the bleed valves, the sensors, and the pumps. The controller is operable to, with respect to each of the pumps: cause the LP valve corresponding to the pump to transition to a closed flow position; cause one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump to transition to an open flow position; and determine whether the HP conduit corresponding to the pump is pressurized based on the information generated by the corresponding one of the sensors.

[0011] The present disclosure also introduces a method performed in conjunction with a number of pumps and a manifold unit. The manifold unit includes an LP manifold having LP ports, LP valves each operable to control flow through a corresponding one of the LP ports, an HP manifold having HP ports, HP valves each operable to control flow through a corresponding one of the HP ports, bleed ports each fluidly coupled with a corresponding one of the HP ports, and bleed valves each fluidly coupled with and remotely operable to control flow through a corresponding one of the bleed ports from the corresponding HP port. The method includes fluidly coupling each of the pumps with the LP manifold via LP conduits each fluidly coupling a corresponding one of the pumps with a corresponding one of the LP ports, fluidly coupling each of the pumps with the HP manifold via HP conduits each fluidly coupling a corresponding one of the pumps with a corresponding one of the HP ports, and establishing communication between a controller and each of the LP valves, the HP valves, the bleed valves, the pumps, and a number

of sensors. Each sensor is operable to generate information indicative of fluid pressure within a corresponding one of the HP conduits. The method also includes operating the controller to, with respect to each of the pumps, cause the pump to operate and then: cause the LP valve corresponding to the pump to transition to a closed flow position; and cause one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump to transition to an open flow position. The method also includes operating the controller to, with respect to each of the pumps, determine that the HP conduit corresponding to the pump is not pressurized based on the information generated by the corresponding one of the sensors.

[0012] These and additional aspects of the present disclosure are set forth in the description that follows, and/or may be learned by a person having ordinary skill in the art by reading the materials herein and/or practicing the principles described herein. At least some aspects of the present disclosure may be achieved via means recited in the attached claims.

Brief Description of the Drawings

[0013] The present disclosure is understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0014] FIG. 1 is a schematic view of an example implementation of apparatus according to one or more aspects of the present disclosure.

[0015] FIG. 2 is a schematic view of a portion of an example implementation of the apparatus shown in FIG. 1 according to one or more aspects of the present disclosure.

[0016] FIG. 3 is a perspective view of a portion of an example implementation of the apparatus shown in FIG. 1 according to one or more aspects of the present disclosure.

[0017] FIG. 4 is a sectional view of the apparatus shown in FIG. 3 according to one or more aspects of the present disclosure.

[0018] FIG. 5 is a schematic view of an example implementation of apparatus according to one or more aspects of the present disclosure.

[0019] FIG. 6 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

[0020] FIG. 7 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

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Detailed Description

[0021] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for simplicity and clarity, and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

[0022] FIG. 1 is a schematic view of at least a portion of an example wellsite system 100 according to one or more aspects of the present disclosure. The figure depicts a wellsite surface 102 adjacent to a wellbore 104 and a partial sectional view of the subterranean formation 106 penetrated by the wellbore 104 below the wellsite surface 102. The wellsite system 100 may comprise a first mixer 108 fluidly connected with one or more tanks 110 and a first container 112. The first container 112 may contain a first material and the tanks 110 may contain a liquid. The first material may be or comprise a hydratable material or gelling agent, such as guar, polymers, synthetic polymers, galactomannan, polysaccharides, cellulose, and/or clay, among other examples, and the liquid may be or comprise an aqueous fluid, which may comprise water or an aqueous solution comprising water, among other examples. The first mixer 108 may be operable to receive the first material and the liquid via two or more fluid conduits 114, 116, and mix or otherwise combine the first material and the liquid to form a base fluid, which may be or comprise that which is known in the art as a gel. The first mixer 108 may then discharge the base fluid via one or more fluid conduits 118.

[0023] The first mixer 108 and the first container 112 may each be disposed on corresponding trucks, trailers, and/or other mobile carriers 120, 122, respectively, such as may permit their transportation to the wellsite surface 102. However, the first mixer 108 and/or first container 112 may be skidded or otherwise stationary, and/or may be temporarily or permanently installed at the wellsite surface 102.

[0024] The wellsite system 100 may further comprise a second mixer 124 fluidly connected with the first mixer 108 and a second container 126. The second container 126 may contain a second material that may be substantially different than the first material. For example, the second material may be or comprise a proppant material, such as sand, sand-like particles, silica, quartz, and/or propping agents, among other examples. The second mixer 124 may be operable to receive the base fluid from the first mixer 108 via one or more fluid conduits 118, and the second material from the second container 126 via one or more fluid conduits 128, and mix or otherwise combine the base fluid and the second material to form a mixture, which may be or comprise that which is known in the art as a fracturing fluid. The second mixer 124 may then discharge the mixture via one or more fluid conduits 130. For clarity, the mixture discharged from the second mixer 124 via the one or more fluid conduits 130 will be referred to hereinafter simply as "a fluid."

[0025] The second mixer 124 and the second container 126 may each be disposed on corresponding trucks, trailers, and/or other mobile carriers 132, 134, respectively, such as may permit their transportation to the wellsite surface 102. However, the second mixer 124 and/or second container 126 may be skidded or otherwise stationary, and/or may be temporarily or permanently installed at the wellsite surface 102.

[0026] The fluid may be communicated from the second mixer 124 via the one or more fluid conduits 130 to a manifold unit 140, which may be or comprise what known in the art as a manifold trailer or missile. The manifold unit 140 may be operable to distribute the fluid among a plurality of pump units 200. The manifold unit 140 comprises a low-pressure (LP) portion having a plurality of LP inlet ports and LP outlet ports (shown in FIG. 2). The LP inlet ports are operable to receive the fluid via the one or more fluid conduits 130, and the LP outlet ports are operable to discharge the fluid to the pump units 200 via a corresponding one or more LP fluid conduits 136. The manifold unit 140 also comprises a high-pressure (HP) portion having HP inlet ports and HP outlet ports (shown in FIG. 2). The HP inlet ports are operable to receive the pressurized fluid from the pump units 200 via a corresponding one or more HP fluid conduits 138 and the HP outlet ports are operable to discharge the pressurized fluid. The fluid may then be injected into the wellbore 104, via one or more fluid conduits 131, perhaps through various additional conduits, valves, and/or other hydraulic circuitry fluidly connected between the manifold unit 140 and the wellbore 104.

[0027] The manifold unit 140 may be mounted on one or more trucks, trailers, and/or other mobile carriers (not shown), such as may permit its transportation to the wellsite surface 102. However, the manifold unit 140 may be skidded or otherwise stationary, and/or may be temporarily or permanently installed at the wellsite surface 102.

[0028] Each of the pump units 200 may comprise a pump 202, a prime mover 204, and a heat exchanger 206. The pumps 202 may be implemented as reciprocating pumps, each comprising fluid pressurizing chambers (shown in FIG. 4) and fluid displacing members (shown in FIG. 4). Depending on the size of each pump 202 and the operating speed of the corresponding prime mover 204, each pump 202 may be operable to transfer or otherwise move the fluid into the HP portion of the manifold unit 140 at a flow rate ranging between about 100 GPM and about 1,500 GPM.

[0029] The pump units 200 may each be mounted on corresponding trucks, trailers, and/or other mobile carriers 207, such as may permit their transportation to the wellsite surface 102. However, the pump units 200 may be skidded or otherwise stationary, and/or may be temporarily or permanently installed at the wellsite surface 102. Although the pump fleet of the wellsite system 100 is shown comprising six pump units 200, each disposed on the corresponding mobile carrier 207, a pump fleet comprising other quantities of pump units 200 is also within the scope of the present disclosure.

[0030] The wellsite system 100 may also comprise a control/power center 133, such as may be operable to provide control and/or centralized electric power distribution to one or more portions of the wellsite system 100. The control/power center 133 may be operable to monitor and control at least a portion of the wellsite system 100 during pumping operations. For example, the control/power center 133 may be operable to monitor and control one or more portions of the first mixer 108, the second mixer 124, the pump units 200, and other pumps and/or conveyers (not shown), such as may be operable to move the fluids, materials, and/or mixtures described above. The control/power center 133 may also be operable to monitor and control operations of the manifold unit 140 prior to and during the pumping operations. The control/power center 133 may comprise an engine-generator set, such as a gas turbine generator, an internal combustion engine generator, and/or other sources of electric power. Electric power and/or control signals may be communicated between the control/power center 133 and other wellsite equipment via electric conductors (not shown). However, other means of signal

communication, such as wireless communication, are also within the scope of the present disclosure.

[0031] The control/power center 133 may be disposed on a corresponding truck, trailer, and/or other mobile carrier 135, such as may permit its transportation to the wellsite surface 102. However, the control/power center 133 may be skidded or otherwise stationary, and/or may be temporarily or permanently installed at the wellsite surface 102.

[0032] FIG. 1 depicts the wellsite system 100 as being operable to form fluids and/or mixtures that may be pressurized and individually or collectively injected into the wellbore 104 during hydraulic fracturing of the subterranean formation 106. However, it is to be understood that the wellsite system 100 may be operable to mix and/or produce other mixtures and/or fluids that may be pressurized by the pump units 200 and individually or collectively injected into the wellbore 104 during other oilfield operations, such as drilling, cementing, acidizing, chemical injecting, and/or water jet cutting operations, among other examples.

[0033] FIG. 2 is a schematic view of at least a portion of an example implementation of the manifold unit 140 shown in FIG. 1 according to one or more aspects of the present disclosure. The manifold unit 140 may be utilized in various implementations of a wellsite system. However, for the sake of clarity and ease of understanding, the manifold unit 140 is described below in the context of the wellsite system 100 shown in FIG. 1. Thus, the following description refers to FIGS. 1 and 2, collectively.

[0034] The manifold unit 140 may be or comprise a manifold system operable to distribute LP fluid received from the mixers 108, 124 among the pump units 200 and combine the HP fluid received from the pump units 200 for injection into the wellbore 104. The manifold unit 140 comprises one or more LP manifolds 142, 144 that receive the LP fluid from the mixers 108, 124 via the fluid conduit 130 and distribute the fluid among the pumps 202. The manifold unit 140 also comprises one or more HP manifolds 146 that receive and combine the HP fluid from the pumps 202 and discharge the fluid for injection into the wellbore 104 via the fluid conduit 131.

[0035] The manifold unit 140 also comprises a plurality of fluid valves (described below via reference numbers 153, 157, 163, 167, 173, 177, and 183) operable to control fluid flow into and/or out of the LP and HP manifolds 142, 144, 146. The fluid valves may comprise ball valves, globe valves, butterfly valves, and/or other types of valves operable to shut off fluid flow or otherwise control fluid flow into and/or out of the LP and HP manifolds 142, 144, 146. Each fluid valve may be actuated remotely by an actuator, including an electric actuator, such as a

solenoid or motor, or a fluid actuator, such as a pneumatic or hydraulic cylinder or rotary actuator. The fluid valves may also be manually actuated by the human operators.

[0036] Each fluid valve may also include a corresponding feedback sensor operable to generate a signal or information indicative of an actual position or setting of that fluid valve, such as to monitor in-real time the actual setting of that fluid valve. The actual setting of each fluid valve may include an open-flow setting, a closed-flow setting, and an intermediate or transitional setting between the open-flow and closed-flow settings. Each feedback sensor may be disposed in association with the corresponding fluid valve in a manner permitting sensing of the actual setting of that fluid valve. For example, each feedback sensor may monitor position or orientation of a fluid-blocking portion of the fluid valve, such as a ball or flapper, or another moving portion of the fluid valve, such as a rotating shaft or stem. Each feedback sensor may be coupled with or disposed adjacent the corresponding fluid valve, or each feedback sensor may be incorporated as part of the corresponding fluid valve. The feedback sensors may include proximity sensors, such as capacitive sensors, inductive sensors, magnetic sensors, Hall effect sensors, and/or reed switches, among other examples. The feedback sensors may also or instead include linear position sensors, such as linear potentiometers. The feedback sensors may also or instead include rotary position sensors, such as encoders, rotary potentiometers, synchros, resolvers, and/or rotary variable differential transformers (RVDT), among other examples.

[0037] The manifold unit 140 may comprise a first LP portion or manifold 142 implemented as a fluid conduit arranged in a closed loop configuration. The first LP manifold 142 may comprise a plurality of LP inlet valve assemblies 150, each comprising an LP fluid inlet port 152 operable to fluidly connect with the one or more fluid conduits 130 to receive the fluid from the second mixer 124. The first LP manifold 142 may also comprise a plurality of LP outlet valve assemblies 151 disposed on opposing sides of the first LP manifold 142, each comprising an LP fluid outlet port 156 operable to fluidly connect the first LP manifold 142 with the pumps 202 via corresponding LP fluid conduits 136. Each LP inlet valve assembly 150 may further include an LP fluid valve 153 disposed at a corresponding LP fluid inlet port 152 for selectively opening and closing the corresponding LP fluid inlet port 152, such as may selectively permit or otherwise control fluid flow into the first LP manifold 142. Similarly, each LP outlet valve assembly 151 may include an LP fluid valve 157 disposed at a corresponding LP fluid outlet port 156 for selectively opening and closing the corresponding LP fluid outlet port 156, such as may selectively permit fluid flow out of the first LP manifold 142. Each LP fluid valve 153, 157 may

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be selectively shifted or transitioned between open flow and closed flow settings by a corresponding actuator 154, 158, respectively, disposed in association with each LP fluid valve 153, 157. The actual setting of each LP fluid valve 153, 157 may be monitored or otherwise determined in real-time by feedback sensors 155, 159, respectively, disposed in association with the LP fluid valves 153, 157. For clarity, just one of the LP ports 152, 156, the LP fluid valves 153, 157, the actuators 154, 158, and the feedback sensors 155, 159 of the LP inlet and outlet valve assemblies 150, 151, respectively, are identified with numerals in FIG. 2. Although the first LP manifold 142 is shown comprising three LP inlet valve assemblies 150 and eight LP outlet valve assemblies 151, it is to be understood that the first LP manifold 142 may include other quantities of LP inlet and outlet valve assemblies 150, 151.

[0038] The manifold unit 140 may further comprise a second LP portion or manifold 144 implemented as a fluid conduit arranged in a closed loop configuration. The second LP manifold 144 may comprise a plurality of LP inlet valve assemblies 160, each comprising an LP fluid inlet port 162 operable to fluidly connect with the one or more fluid conduits 130 to receive the fluid from the second mixer 124. The second LP manifold 144 may also comprise a plurality of LP outlet valve assemblies 161 disposed on opposing sides of the second LP manifold 144, each comprising an LP fluid outlet port 166 operable to fluidly connect the second LP manifold 144 with the pumps 202 via corresponding LP fluid conduits 136. Each LP inlet valve assembly 160 may further include an LP fluid valve 163 disposed at a corresponding LP fluid inlet port 162 for selectively opening and closing the corresponding LP fluid inlet port 162, such as may selectively permit or otherwise control fluid flow into the second LP manifold 144. Similarly, each LP outlet valve assembly 161 may include an LP fluid valve 167 disposed at a corresponding LP fluid outlet port 166 for selectively opening and closing the corresponding LP fluid outlet port 166, such as may selectively permit fluid flow out of the second LP manifold 144. Each LP fluid valve 163, 167 may be selectively transitioned between open flow and closed flow settings by a corresponding actuator 164, 168, respectively, disposed in association with each LP fluid valve 163, 167. The actual setting of each LP fluid valve 163, 167 may be determined in real-time by feedback sensors 165, 169, respectively, disposed in association with each LP fluid valve 163, 167. For clarity, just one of the LP ports 162, 166, the LP fluid valves 163, 167, the actuators 164, 168, and the feedback sensors 165, 169 of the LP inlet and outlet valve assemblies 160, 161, respectively, are identified with numerals in FIG. 2. Although the second LP manifold 144 is shown comprising four LP inlet valve assemblies 160 and eight LP

outlet valve assemblies 161, it is to be understood that the second LP manifold 144 may include other quantities of LP inlet and outlet valve assemblies 160, 161.

[0039] The manifold unit 140 may also comprise an HP portion or manifold 146 implemented as a fluid conduit arranged in a closed loop configuration. The HP manifold 146 may comprise a plurality of HP inlet valve assemblies 170 disposed on opposing sides of the HP manifold 146, each comprising an HP fluid inlet port 172 operable to fluidly connect the pumps 202 with the HP manifold 146 via corresponding HP fluid conduits 138. The HP manifold 146 may also comprise a plurality of HP outlet valve assemblies 171, each comprising an HP outlet port 176 operable to fluidly connect with the one or more fluid conduits 131 to inject the fluid into the wellbore 104. Each HP inlet valve assembly 170 may further include an HP fluid valve 173 disposed at a corresponding HP fluid inlet port 172 for selectively opening and closing the corresponding HP fluid inlet port 172, such as may selectively permit or otherwise control fluid flow into the HP manifold 146. Similarly, each HP outlet valve assembly 171 may include an HP fluid valve 177 disposed at a corresponding HP fluid outlet port 176 for selectively opening and closing the corresponding HP fluid outlet port 176, such as may selectively permit fluid flow out of the HP manifold 146. Each HP fluid valve 173, 177 may be selectively transitioned between open flow and closed flow settings by a corresponding actuator 174, 178, respectively, disposed in association with each HP fluid valve 173, 177. The actual setting of each HP fluid valve 173, 177 may be determined in real-time by feedback sensors 175, 179, respectively, associated with the HP fluid valves 173, 177. For clarity, just one of the HP ports 172, 176, the HP fluid valves 173, 177, the actuators 174, 178, and the feedback sensors 175, 179 of the HP inlet and outlet valve assemblies 170, 171, respectively, are identified with numerals in FIG. 2. Although the HP manifold 146 is shown comprising eight HP inlet valve assemblies 170 and four HP outlet valve assemblies 171, it is to be understood that the HP manifold 146 may include other quantities of HP inlet and outlet valve assemblies 170, 171.

[0040] Each HP fluid inlet port 172 of the HP manifold 146 may be fluidly connected with a corresponding bleed valve assembly 180 operable to release fluid and pressure from the HP fluid inlet port 172 and, perhaps, portions of the pump unit 200 in fluid communication with the corresponding HP fluid conduit 138. If a corresponding HP fluid valve 173 is open, the bleed valve assembly 180 may also bleed fluid and pressure from the HP manifold 146. Each bleed valve assembly 180 may comprise a bleed port 182 and a corresponding fluid bleed valve 183 disposed at the bleed port 182 for selectively opening and closing the bleed port 182, such as to

selectively permit or otherwise control fluid flow out of a corresponding HP fluid inlet port 172. Each fluid bleed valve 183 may be selectively transitioned between open flow and closed flow settings by a corresponding actuator 184 disposed in association with each fluid bleed valve 183. The actual setting of each fluid bleed valve 183 may be determined in real-time by a corresponding feedback sensor 185 associated with each fluid bleed valve 183. The fluid bled or released by the bleed valve assemblies 180 via corresponding bleed ports 182 may be communicated to a fluid container (not shown). The fluid container may be or comprise an external fluid container, such as a fluid pit or another container that may be constructed on or transported to the wellsite surface 102, in which case the bleed ports 182 may be fluidly connected with the fluid container. The fluid container may also be or comprise the first and/or second LP manifolds 142, 144, in which case the bleed ports 182 may be fluidly connected with the LP fluid inlet ports 152, 162. For clarity, just one of the bleed ports 182, the fluid bleed valves 183, the actuators 184, and the feedback sensors 185 of the bleed valve assemblies 180 are identified with numerals in FIG. 2.

[0041] Although shown in FIG. 2 as single continuous members, one or more of the manifolds 142, 144, 146 may comprise a plurality of fluid conduits or other fluid conveying members connected together to collectively form the manifold unit 140. The plurality of the fluid conduits may be fixedly connected together via threaded means, fasteners, bolts, flanges, welding, and/or other connection means. Furthermore, although shown as comprising a closed loop configuration, one or more of the manifolds 142, 144, 146 may comprise otherwise shaped open or closed loop or configurations, including a U-shaped configuration, a T-shaped configuration, an I-shaped configuration, or other configurations operable to communicate the fluid from the LP and HP fluid inlet ports 152, 162, 172 to the LP and HP fluid outlet ports 156, 166, 176. Although FIG. 2 depicts the manifolds 142, 144, 146 as being progressively larger, it is to be understood that FIG. 2 is a schematic representation and that the manifolds 142, 144, 146 may be the same size or may have other relative dimensions.

[0042] A fluid power unit 190 may provide pressurized fluid to operate the actuators 154, 158, 164, 168, 174, 178, 184. For example the fluid power unit 190 may comprise an air and/or compressor in implementations in which the actuators 154, 158, 164, 168, 174, 178, 184 are operable by pressurized air and/or other gas. However, the fluid power unit 190 may comprise a hydraulic power pack in implementations in which the actuators 154, 158, 164, 168, 174, 178, 184 are operable by pressurized hydraulic fluid. The fluid power unit 190 may comprise a fluid

storage container 191, such as an air tank or a hydraulic fluid tank, and a prime mover 192, such as an electric motor, a hydraulic motor, or an engine for pressurizing the fluid. Fluid interconnections between the fluid power unit 190 and the actuators 154, 158, 164, 168, 174, 178, 184 may be via various piping, hoses, and/or other fluid conduits. However, for the sake of clarity and ease of understanding, such interconnections are not depicted in FIG. 2, as a person having ordinary skill in the art will readily recognize how such interconnections may be implemented within the scope of the present disclosure without further illustration in FIG. 2.

[0043] The manifold unit 140 may also comprise pressure sensors 186, 187, 188 fluidly connected with the manifold unit 140. The pressure sensors 186, 187, 188 may be operable to generate signals or information indicative of the fluid pressure within the LP and HP manifolds 142, 144, 146, respectively.

[0044] FIG. 3 is a perspective view of a portion of an example implementation of one pump unit 200 shown in FIG. 1 according to one or more aspects of the present disclosure. FIG. 4 is a side sectional view of a portion of the pump unit 200 shown in FIG. 3. The following description refers to FIGS. 1-4, collectively.

[0045] As described above, the pump unit 200 comprises the pump 202 operatively coupled with and actuated by the prime mover 204. The pump 202 comprises a power section 208 and a fluid section 210. The fluid section 210 may comprise a pump housing 216 having a plurality of fluid chambers 218. One end of each fluid chamber 218 may be plugged by a cover plate 220, such as may be threadedly engaged with the pump housing 216 while the opposite end of each fluid chamber 218 may contain a reciprocating member 222 slidably disposed therein and operable to displace the fluid within the corresponding fluid chamber 218. Although the reciprocating member 222 is depicted as a plunger, the reciprocating member 222 may also be implemented as a piston, diaphragm, or another reciprocating fluid displacing member.

[0046] Each fluid chamber 218 is fluidly connected with a corresponding one of a plurality of fluid inlet cavities 224 each adapted for communicating fluid from an LP fluid inlet conduit 226 into a corresponding fluid chamber 218. The LP fluid inlet conduit 226 may be in fluid communication with a corresponding LP fluid outlet port 156, 166 of the manifold 140 via the one or more LP fluid conduits 136. Each fluid inlet cavity 224 contains an inlet valve 228 operable to control fluid flow from the LP fluid inlet conduit 226 into the fluid chamber 218. Each inlet valve 228 may be biased toward a closed flow setting by a first spring or another biasing member 230, which may be held in place by an inlet valve stop 232. Each inlet valve

228 may be actuated to an open flow setting by a selected or predetermined differential pressure between the corresponding fluid inlet cavity 224 and the LP fluid inlet conduit 226.

[0047] Each fluid chamber 218 is also fluidly connected with a fluid outlet cavity 234 extending through the pump housing 216 transverse to the reciprocating members 222. The fluid outlet cavity 234 is adapted for communicating pressurized fluid from each fluid chamber 218 into one or more HP fluid outlet conduits 235 fluidly connected at one or both ends of the fluid outlet cavity 234. The HP fluid outlet conduits 235 may be in fluid communication with a corresponding HP fluid inlet port 172 of the manifold 140 via the one or more HP fluid conduits 138. The fluid section 210 also contains a plurality of outlet valves 236 each operable to control fluid flow from a corresponding fluid chamber 218 into the fluid outlet cavity 234. Each outlet valve 236 may be biased toward a closed flow setting by a spring or another biasing member 238, which may be held in place by an outlet valve stop 240. Each outlet valve 236 may be actuated to an open flow setting by a selected or predetermined differential pressure between the corresponding fluid chamber 218 and the fluid outlet cavity 234. The fluid outlet cavity 234 may be plugged by cover plates 242, such as may be threadedly engaged with the pump housing 216.

[0048] During pumping operations, portions of the power section 208 of the pump unit 200 rotate in a manner that generates a reciprocating linear motion to move the reciprocating members 222 longitudinally within the corresponding fluid chambers 218, thereby alternatingly drawing and displacing the fluid within the fluid chambers 218. With regard to each reciprocating member 222, as the reciprocating member 222 moves out of the fluid chamber 218, as indicated by arrow 221, the pressure of the fluid inside the corresponding fluid chamber 218 decreases, thus creating a differential pressure across the corresponding fluid inlet valve 228. The pressure differential operates to compress the biasing member 230, thus actuating the fluid inlet valve 228 to an open flow setting to permit the fluid from the LP fluid inlet conduit 226 to enter the corresponding fluid inlet cavity 224. The fluid then enters the fluid chamber 218 as the reciprocating member 222 continues to move longitudinally out of the fluid chamber 218 until the pressure difference between the fluid inside the fluid chamber 218 and the fluid within the LP fluid inlet conduit 226 is low enough to permit the biasing member 230 to actuate the fluid inlet valve 228 to the closed flow setting. As the reciprocating member 222 begins to move longitudinally back into the fluid chamber 218, as indicated by arrow 223, the pressure of the fluid inside of fluid chamber 218 begins to increase. The fluid pressure inside the fluid chamber 218 continues to increase as the reciprocating member 222 continues to move into the fluid

chamber 218 until the pressure of the fluid inside the fluid chamber 218 is high enough to overcome the pressure of the fluid inside the fluid outlet cavity 234 and compress the biasing member 238, thus actuating the fluid outlet valve 236 to the open flow setting and permitting the pressurized fluid to move into the fluid outlet cavity 234 and the HP fluid outlet conduit 235. Thereafter, the fluid may be communicated to the manifold 140 via the one or more HP fluid conduits 138 and the wellbore 104 via the one or more fluid conduits 131.

[0049] The fluid flow rate generated by the pump unit 200 may depend on the physical size of the reciprocating members 222 and fluid chambers 218, as well as the pump operating speed, which may be defined by the speed or rate at which the reciprocating members 222 cycle or move within the fluid chambers 218. The speed or rate at which the reciprocating members 222 move may be related to the rotational speed of the power section 208 and/or the prime mover 204. Accordingly, the fluid flow rate may be controlled by controlling the rotational speed of the power section 208 and/or the prime mover.

[0050] The prime mover 204 may be operatively coupled with a drive shaft 252 of the power section 208. The drive shaft 252 may be enclosed and maintained in position by a power section housing 254, such that the prime mover 204 is operable to drive or otherwise rotate the drive shaft 252. The prime mover 204 may comprise a rotatable output shaft 256 operatively connected with the drive shaft 252 by a transmission or gear train, which may comprise at least one spur gear 258 coupled with the drive shaft 252 and at least one pinion gear 260 coupled with a support shaft 261. The output shaft 256 and the support shaft 261 may be coupled, such as may facilitate transfer of torque from the prime mover 204 to the support shaft 261, the pinion gear 260, the spur gear 258, and the drive shaft 252. For clarity, FIGS. 3 and 4 show the transmission comprising a single spur gear 258 engaging a single pinion gear 260, however, it is to be understood that the transmission may comprise two or more sets of gears, such as may permit the transmission to be shifted between different gear configurations to control the operating speed of the drive shaft 252 and, thus, the pumping rate of the fluid section 210. To prevent relative rotation between the power section housing 254 and the prime mover 204, the power section housing 254 and prime mover 204 may be fixedly coupled together or to a common base, such as a trailer of the mobile carrier 148. The prime mover 204 may comprise an engine, such as a gasoline engine or a diesel engine, an electric motor, such as a synchronous or asynchronous electric motor, including a synchronous permanent magnet motor, a hydraulic motor, or another prime mover operable to rotate the drive shaft 252.

[0051] The drive shaft 252 may be implemented as a crankshaft comprising a plurality of axial journals 264 and offset journals 266. The axial journals 264 may extend along a central axis of rotation of the drive shaft 252, while the offset journals 266 may be offset from the central axis of rotation by a selected or predetermined distance and spaced 120 degrees apart with respect to the axial journals 264. The drive shaft 252 may be supported in position within the power section 208 by the power section housing 254, wherein two of the axial journals 264 may extend through opposing openings in the power section housing 254.

[0052] The power section 208 and the fluid section 210 may be coupled or otherwise connected together. For example, the pump housing 216 may be fastened with the power section housing 254 by a plurality of threaded fasteners 282. The pump 202 may further comprise an access door 298, which may facilitate access to portions of the pump 202 located between the power section 208 and the fluid section 210, such as during assembly and/or maintenance of the pump 202.

[0053] To transform and transmit the rotational motion of the drive shaft 252 to a reciprocating linear motion of the reciprocating members 222, a plurality of crosshead mechanisms 285 may be utilized. For example, each crosshead mechanism 285 may comprise a connecting rod 286 pivotally coupled with a corresponding offset journal 266 at one end and with a pin 288 of a crosshead 290 at an opposing end. During pumping operations, walls and/or interior portions of the power section housing 254 may guide each crosshead 290, such as may reduce or eliminate lateral motion of each crosshead 290. Each crosshead mechanism 285 may further comprise a piston rod 292 coupling the crosshead 290 with the reciprocating member 222. The piston rod 292 may be coupled with the crosshead 290 via a threaded connection 294 and with the reciprocating member 222 via a flexible connection 296.

[0054] Although FIGS. 3 and 4 show the pump unit 200 comprising a triplex reciprocating pump 202, which has three fluid chambers 218 and three reciprocating members 222, implementations within the scope of the present disclosure may include the pump 202 as or comprising a quintuplex reciprocating pump having five fluid chambers 218 and five reciprocating members 222, or a pump having other quantities of fluid chambers 218 and reciprocating members 222. It is further noted that the pump 202 described above and shown in FIGS. 3 and 4 is merely an example, and that other pumps, such as diaphragm pumps, gear pumps, external circumferential pumps, internal circumferential pumps, lobe pumps, and other positive displacement pumps, are also within the scope of the present disclosure.

[0055] The wellsite system 100 may further comprise flow sensors disposed in association with the pumps 202, the manifold unit 140, and/or the LP and HP fluid conduits 136, 138 in a manner permitting the sensing of fluid flow generated by the pumps 202. Each flow sensor is operable to generate an electrical signal and/or information indicative of the rate of fluid flow from a corresponding pump 202 to the manifold unit 140. For example, flow sensors 304 may be fluidly coupled along the HP fluid outlet conduits 235 of the pumps 202, as shown in FIG. 3. The flow sensors 304 may also be fluidly coupled along the HP fluid conduits 138 extending between the HP fluid outlet conduits 235 and the HP fluid inlet ports 172 of the manifold unit 140. The flow sensors 304 may also be disposed in association with the manifold unit 140. For example, the flow sensors 304 may be fluidly coupled with the HP fluid inlet ports 172.

[0056] The wellsite system 100 may further comprise pressure sensors disposed in association with the pumps 202, the manifold unit 140, and/or the LP and HP fluid conduits 136, 138 in a manner permitting the sensing of fluid pressure within the pumps 202, the manifold unit 140, and/or the LP and HP fluid conduits 136, 138. Each pressure sensor is may be operable to generate an electrical signal and/or information indicative of the fluid pressure within the pumps 202, the manifold unit 140, and/or the LP and HP fluid conduits 136, 138. For example, one or more pressure sensors 306 may extend through one or more of the cover plates 242 or other portions of the corresponding pump housing 216 to monitor pressure within the fluid outlet cavity 234 and, thus, the HP fluid outlet conduits 235 and the HP fluid conduits 138. The pressure sensors 306 may also be fluidly coupled along the HP fluid outlet conduits 235 and/or along the HP fluid conduits 138. Other pressure sensors, such as the pressure sensors 186, 187, 188 shown in FIG. 2, may be disposed in association with the manifold unit 140 to monitor the pressure within the manifolds 142, 144, 146.

[0057] The wellsite system 100 may further comprise a controller 310 in communication with the valve actuators 154, 158, 164, 168, 174, 178, 184 to permit the controller 310 to open and close or otherwise control the fluid valves 153, 157, 163, 167, 173, 177, 183. The controller 310 is further in communication with the valve feedback sensors 155, 159, 165, 169, 175, 179, 185 to permit the controller 310 to receive the feedback signals generated by the feedback sensors 155, 159, 165, 169, 175, 179, 185 and, thus, verify that the fluid valves 153, 157, 163, 167, 173, 177, 183 transitioned to the intended position or setting. The controller 310 is also in communication with the prime movers 204 and/or other portions of the pump units 200, such as may permit the controller 310 to activate, deactivate, shift transmission gears or speeds, or

otherwise operate the pump units 200. The controller 310 is also in communication with the pressure sensors 186, 187, 188 associated with the manifold unit 140 and the pressure and flow sensors 306, 304 associated with each pump 202 or HP fluid conduit 138, such as may permit the controller 310 to receive the information indicative of fluid pressure and flow within the pumps 202, the HP fluid conduits 138, and/or the manifold 140. For clarity, the components in communication with the controller 310 will be collectively referred to hereinafter as "feedback and controlled components." Communication between the controller 310 and the feedback and controlled components may be via wired and/or wireless communication means. However, for clarity and ease of understanding, such communication means are not depicted in FIGS. 1-4, and a person having ordinary skill in the art will appreciate that myriad means for such communication means are within the scope of the present disclosure. The controller 310 may be implemented as part of the control/power center 133, or as a discrete component located externally from the control/power center 133.

[0058] FIG. 5 is a schematic view of at least a portion of an example implementation of the controller 310 according to one or more aspects of the present disclosure. The controller 310 may be operable to execute example machine-readable instructions to implement at least a portion of one or more of the example methods and/or processes described herein, and/or to implement at least a portion of one or more of the example systems described herein. The controller 310 may be or comprise, for example, one or more processors, special-purpose computing devices, servers, personal computers, personal digital assistant (PDA) devices, smartphones, internet appliances, and/or other types of computing devices.

[0059] The controller 310 may comprise a processor 312, such as a general-purpose programmable processor. The processor 312 may comprise a local memory 314, and may execute coded instructions 332 present in the local memory 314 and/or another memory device. The processor 312 may execute, among other things, machine-readable instructions or programs to implement the example methods and/or processes described herein. The programs stored in the local memory 314 may include program instructions or computer program code that, when executed by an associated processor, facilitate the pump units 200 and the manifold unit 140 to perform the example methods and/or processes described herein. The processor 312 may be, comprise, or be implemented by one or a plurality of processors of various types suitable to the local application environment, and may include one or more of general-purpose computers, special-purpose computers, microprocessors, digital signal processors (DSPs), field-

programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as non-limiting examples. Of course, other processors from other families are also appropriate.

[0060] The processor 312 may be in communication with a main memory, such as may include a volatile memory 318 and a non-volatile memory 320, perhaps via a bus 322 and/or other communication means. The volatile memory 318 may be, comprise, or be implemented by random access memory (RAM), static random access memory (SRAM), synchronous dynamic random access memory (SDRAM), dynamic random access memory (DRAM), RAMBUS dynamic random access memory (RDRAM), and/or other types of random access memory devices. The non-volatile memory 320 may be, comprise, or be implemented by read-only memory, flash memory, and/or other types of memory devices. One or more memory controllers (not shown) may control access to the volatile memory 318 and/or non-volatile memory 320. The controller 310 may be operable to store or record information entered by the human operators and/or information generated by the feedback and controlled components on the main memory.

[0061] The controller 310 may also comprise an interface circuit 324. The interface circuit 324 may be, comprise, or be implemented by various types of standard interfaces, such as an Ethernet interface, a universal serial bus (USB), a third generation input/output (3GIO) interface, a wireless interface, and/or a cellular interface, among others. The interface circuit 324 may also comprise a graphics driver card. The interface circuit 324 may also comprise a communication device, such as a modem or network interface card to facilitate exchange of data with external computing devices via a network (*e.g.*, Ethernet connection, digital subscriber line (DSL), telephone line, coaxial cable, cellular telephone system, satellite, *etc.*). One or more of the feedback and controlled components may be connected with the controller 310 via the interface circuit 324, such as may facilitate communication between the feedback and controlled components and the controller 310.

[0062] To further facilitate communication between the manifold unit components and the controller 310, one or more of the feedback and controlled components may also comprise an interface circuit (not shown), which may permit signals or information generated by the feedback and controlled components to be sent to the controller 310 for monitoring and/or controlling operation of the one or more of the feedback and controlled components, or perhaps for monitoring and/or controlling operation of the entirety of the manifold unit 140. The interface

circuits of the one or more of the feedback and controlled components may also permit signals to be received from the controller 310 to control operation of the one or more of the feedback and controlled components, or perhaps to control operation of the entirety of the manifold unit 140.

[0063] One or more input devices 326 may also be connected to the interface circuit 324. The input devices 326 may permit the human operators to enter the coded instructions 332, operational parameter thresholds, and/or other data into the processor 312. The input devices 326 may be, comprise, or be implemented by a keyboard, a mouse, a touchscreen, a track-pad, a trackball, an isopoint, and/or a voice recognition system, among other examples. One or more output devices 328 may also be connected to the interface circuit 324. The output devices 328 may be, comprise, or be implemented by display devices (*e.g.*, a liquid crystal display (LCD) or cathode ray tube display (CRT), among others), printers, and/or speakers, among other examples. The controller 310 may also connect with one or more mass storage devices 330 and/or a removable storage medium 334, such as may be or include floppy disk drives, hard drive disks, compact disk (CD) drives, digital versatile disk (DVD) drives, and/or USB and/or other flash drives, among other examples.

[0064] The coded instructions 332, the operational parameter thresholds, and/or other data may be stored in the mass storage device 330, the volatile memory 318, the non-volatile memory 320, the local memory 314, and/or the removable storage medium 334. Thus, components of the controller 310 may be implemented in accordance with hardware (perhaps implemented in one or more chips including an integrated circuit, such as an application specific integrated circuit), or may be implemented as software or firmware for execution by the processor 312. In the case of firmware or software, the implementation may be provided as a computer program product including a computer readable medium or storage structure embodying computer program code (*i.e.*, software or firmware) thereon for execution by the processor 312.

[0065] The coded instructions 332 may include program instructions or computer program code that, when executed by the processor 312, may cause the wellsite system 100 (or at least components thereof) to perform methods and processes as described herein. For example, the controller 310 may cause the pump units 200, the manifold unit 140, and the feedback and controlled components to conduct and/or undergo depressurizing and flushing operations, such as to permit the pump units 200 and the manifold unit 140 to be safely fluidly disconnected. The controller 310 may also assess operational health of the fluid valves 153, 157, 163, 167, 173,

177, 183 and/or the sensors 186, 187, 188, 304, 306 before and/or after the depressurizing and flushing operations or other pumping operations.

[0066] The operational parameter thresholds may be entered into the controller 310 by the human operators to be processed by the processor 312 prior to or during the depressurizing and flushing operations. The operational parameter thresholds may include a predetermined fluid pressure threshold (hereinafter referred to as the "pressure threshold"). When the fluid pressure within the HP fluid conduit 138 and perhaps portions of the pump unit 200 and the manifold unit 140 in fluid communication with the HP fluid conduit 138 is greater than the pressure threshold, the HP fluid conduit 138 and portions of the pump unit 200 and the manifold unit 140 in fluid communication with the HP fluid conduit 138 may be considered to be pressurized or under pressure. However, when the fluid pressure within the HP fluid conduit 138 and portions of the pump unit 200 and the manifold unit 140 in fluid communication with the HP fluid conduit 138 is less than the pressure threshold, the HP fluid conduit 138 and portions of the pump unit 200 and the manifold unit 140 in fluid communication with the HP fluid conduit 138 may be considered to be substantially depressurized or not under pressure. When the HP fluid conduit 138 and portions of the pump unit 200 and the manifold unit 140 in fluid communication with the HP fluid conduits 138 are not under pressure, the pump unit 200 may be caused to cease operation and the pump unit 200 may be fluidly uncoupled from the manifold 140. In an example implementation, the pressure threshold may include a fluid pressure ranging between about zero PSI and about fifteen PSI.

[0067] Another operational parameter threshold may include a predetermined fluid flow rate threshold (hereinafter referred to as the "flow threshold"). When a fluid flow rate between the pump units 200 and the manifold unit 140 through the corresponding HP fluid conduits 138 is greater than the flow threshold, the HP fluid conduit 138 and perhaps portions of the pump unit 200 in fluid communication with the HP fluid conduit 138 may be considered containing fluid or not flushed. However, when the fluid flow rate between the pump unit 200 and the manifold unit 140 through the corresponding HP fluid conduit 138 is less than the flow threshold, the HP fluid conduit 138 and portions of the pump unit 200 in fluid communication with the HP fluid conduit 138 may be considered substantially free of fluid or flushed. When the HP fluid conduit 138 and portions of the pump unit 200 in fluid communication with the HP fluid conduit 138 are substantially flushed, the pump unit 200 may be caused to cease operation and the pump unit 200 may be fluidly uncoupled from the manifold 140. In an example implementation, the flow

threshold may include a fluid flow rate ranging between about zero GPM and about one GPM. Accordingly, the coded instructions 332, when executed, may further cause the controller 310 to receive and process the pressure and flow thresholds entered by the human operators.

[0068] To depressurize an HP fluid conduit 138 and portions of a pump units 200 and the manifold unit 140 in fluid communication with the HP fluid conduit 138, the controller 310 may cause the pump unit 200 to operate and then cause the LP fluid valves 157, 167 corresponding to the pump unit 200 to transition to the closed flow position and cause the HP fluid valve 173 corresponding to the pump unit 200 and/or the fluid bleed valve 183 corresponding to the pump unit 200 to transition to the open flow position. Afterwards, the controller 310 may determine that the HP fluid conduit 138 corresponding to the pump unit 200 is not pressurized based on the information generated by the corresponding one of the pressure sensors 188, 306. The controller 310 may be operable to determine whether the HP fluid conduit 138 corresponding to the pump unit 200 is not pressurized by comparing the pressure threshold to the fluid pressure indicated by the information generated by a corresponding pressure sensor 188, 306.

[0069] The controller 310 may also determine whether the HP fluid conduit 138 corresponding to the pump unit 200 and portions of the pump unit 200 in fluid communication with the HP fluid conduit 138 is substantially flushed based on the information generated by a corresponding one of the flow sensors 304. The controller 310 may be operable to determine whether the HP fluid conduit 138 corresponding to the pump unit 200 is substantially flushed by comparing the flow threshold to the fluid flow rate indicated by the information generated by the corresponding one of the flow sensors 304, wherein the HP fluid conduit 138 is considered substantially flushed when the flow threshold is greater than the fluid flow rate indicated by the information generated by the corresponding one of the flow sensors 304.

[0070] Before the pump units 200 are activated, the human operators may perform several safety and operational health assessments. For example, the human operators may visually check that no other human operators are present near the pump units 200 and the manifold unit 140. The human operators may also visually inspect the LP and HP fluid conduits 136, 138 and other associated fluid conduits and/or couplings to check for leaks and physical damage. The human operators may also visually and/or manually asses if the various sensors and fluid valves associated with the pump units 200 and the manifold unit 140 are functioning properly. For example, the human operators may check if the pressure sensors 186, 187, 188, 306, the flow sensors 304, and the fluid valves 153, 157, 163, 167, 173, 177, 183 are operationally healthy. If

one or more of these safety and operational health assessments identify a safety or functionality problem, the human operators may abort the depressurizing and flushing operations before the pump units 200 are activated.

[0071] Instead of or in addition to the human operators performing the safety and operational health assessments, the coded instructions 332, when executed, may further cause the controller 310 to assess safety conditions and functionality or operational health of the sensors 186, 187, 188, 304, 306 and/or the fluid valves 153, 157, 163, 167, 173, 177, 183. For example, the controller 310 may be operable to transmit diagnostic signals to one or more of the pressure sensors 186, 187, 188, 306, the flow sensors 304, and the fluid valves 153, 157, 163, 167, 173, 177, 183 and receive corresponding feedback signals indicative of the operational health of these components.

[0072] To assess the operational health of the fluid valves 153, 157, 163, 167, 173, 177, 183, before and/or after the depressurizing and flushing operations, the controller 310 may be operable to, with respect to each of the fluid valves 153, 157, 163, 167, 173, 177, 183, remotely control the fluid valve 153, 157, 163, 167, 173, 177, 183 by transmitting a command signal to the fluid valve 153, 157, 163, 167, 173, 177, 183 to transition the fluid valve 153, 157, 163, 167, 173, 177, 183 from an existing setting to an intended setting. After transmitting the command signal, the controller 310 may receive a feedback signal from the fluid valves 153, 157, 163, 167, 173, 177, 183 indicative of an actual setting of the fluid valve 153, 157, 163, 167, 173, 177, 183 and assess an operational health of the fluid valve 153, 157, 163, 167, 173, 177, 183 based on the intended and actual settings. If the intended and actual settings are different, than the fluid valves 153, 157, 163, 167, 173, 177, 183 may be determined to be faulty or not healthy. To further verify if the fluid valves 153, 157, 163, 167, 173, 177, 183 are healthy, the fluid valves 153, 157, 163, 167, 173, 177, 183 may be transitioned and reassessed additional number of times.

[0073] The operational health of the fluid valves 153, 157, 163, 167, 173, 177, 183 may be assessed simultaneously, wherein the controller 310 simultaneously transmits the command signals to the fluid valves 153, 157, 163, 167, 173, 177, 183, and assesses the operational health of the fluid valves 153, 157, 163, 167, 173, 177, 183 based on the intended and actual settings. The operational health of the fluid valves 153, 157, 163, 167, 173, 177, 183 may also be checked sequentially, wherein the controller 310 transmits the command signals to each of the fluid valves 153, 157, 163, 167, 173, 177, 183 one at a time, and assesses the operational health of one

of the fluid valves 153, 157, 163, 167, 173, 177, 183 based on the intended and actual settings before transmitting a command signal to another one of the fluid valves 153, 157, 163, 167, 173, 177, 183.

[0074] If the controller 310 determines that one or more of the sensors 186, 187, 188, 306 and fluid valves 153, 157, 163, 167, 173, 177, 183 are not healthy, the controller 310 may abort the depressurizing and flushing operations before activating the pump units 200.

[0075] FIG. 6 is a flow-chart diagram of at least a portion of an example implementation of a method (400) according to one or more aspects of the present disclosure. The method (400) may be performed utilizing at least a portion of one or more implementations of the apparatus shown in one or more of FIGS. 1-5 and/or otherwise within the scope of the present disclosure.

[0076] The method (400) comprises establishing (410) communication between the controller 310 and each of the plurality of valves 153, 157, 163, 167, 173, 177, 183 of a manifold unit 140, wherein each of the valves 153, 157, 163, 167, 173, 177, 183 is operable to control flow through a corresponding one of a plurality of ports 152, 156, 162, 166, 172, 176, 182 of the manifold unit 140. The method (400) further comprises operating (420) the controller 310, with respect to each of the valves 153, 157, 163, 167, 173, 177, 183, to remotely control (430) the valve 153, 157, 163, 167, 173, 177, 183 by transmitting a command signal to the valve 153, 157, 163, 167, 173, 177, 183 to transition the valve 153, 157, 163, 167, 173, 177, 183 from an existing setting to an intended setting, after transmitting the command signal, receive (440) a feedback signal from the valve 153, 157, 163, 167, 173, 177, 183 indicative of an actual setting of the valve 153, 157, 163, 167, 173, 177, 183, and assess (450) an operational health of the valve based on the intended and actual settings.

[0077] The operating (430), receiving (440), and assessing (450) may be repeated additional times for each valve 153, 157, 163, 167, 173, 177, 183, such that the command signal is a first command signal, the feedback signal is a first feedback signal, the intended setting is a first intended setting, and the actual setting is a first actual setting. Accordingly, the method (400) may further comprise operating the controller 310 to, with respect to each of the valves 153, 157, 163, 167, 173, 177, 183, further remotely control the valve 153, 157, 163, 167, 173, 177, 183 by transmitting a second command signal to the valve 153, 157, 163, 167, 173, 177, 183 to transition the valve 153, 157, 163, 167, 173, 177, 183 to a second intended setting. After transmitting the second command signal, the controller 310 may receive a second feedback signal from the valve 153, 157, 163, 167, 173, 177, 183 indicative of a second actual setting of

the valve and reassess the operational health of the valve 153, 157, 163, 167, 173, 177, 183 based on the second intended setting and the second actual setting. The first intended setting may be a closed flow setting and the second intended setting may be an open flow setting.

[0078] The method (400) may also comprise operating the controller 310 to, with respect to each of the valves 153, 157, 163, 167, 173, 177, 183, remotely control the valve 153, 157, 163, 167, 173, 177, 183 by transmitting a third command signal to the valve 153, 157, 163, 167, 173, 177, 183 to transition the valve 153, 157, 163, 167, 173, 177, 183 to a third intended setting. After transmitting the third command signal, the controller 310 may receive a third feedback signal from the valve 153, 157, 163, 167, 173, 177, 183 indicative of a third actual setting of the valve 153, 157, 163, 167, 173, 177, 183, and reassess the operational health of the valve 153, 157, 163, 167, 173, 177, 183 based on the third intended setting and the third actual setting. The third intended setting may be a closed flow setting.

[0079] The method (400) may also include operating the controller 310 with respect to each of the valves 153, 157, 163, 167, 173, 177, 183 one at a time. The plurality of valves 153, 157, 163, 167, 173, 177, 183 may comprise a first valve, a second valve, and a third valve. Accordingly, operating the controller 310 may include remotely controlling the first valve by transmitting a first command signal to the first valve to transition the first valve to a first intended setting, then receiving a first feedback signal from the first valve indicative of a first actual setting of the first valve, and then assessing a first operational health of the first valve based on the first intended setting and the first actual setting. The method may further include, after assessing the first operational health, remotely controlling the second valve by transmitting a second command signal to the second valve to transition the second valve to a second intended setting, then receiving a second feedback signal from the second valve indicative of a second actual setting of the second valve, and then assessing a second operational health of the second valve based on the second intended setting and the second actual setting. The method (400) may also include, after assessing the second operational health, remotely controlling the third valve by transmitting a third command signal to the third valve to transition the third valve to a third intended setting, then receiving a third feedback signal from the third valve indicative of a third actual setting of the third valve, and then assessing a third operational health of the third valve based on the third intended setting and the third actual setting.

[0080] FIG. 7 is a flow-chart diagram of at least a portion of a method (500) according to one or more aspects of the present disclosure. The method (500) may be performed utilizing at least

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a portion of one or more implementations of the apparatus shown in one or more of FIGS. 1-5 and/or otherwise within the scope of the present disclosure.

[0081] The method (500) may include providing (510) a plurality of pumps (200) and a manifold unit (140), fluidly coupling (520) each of the pumps (200) with the LP manifold 142, 144 via a plurality of LP conduits 136 each fluidly coupling (520) a corresponding one of the pumps (200) with a corresponding one of the LP ports 156, 166, and fluidly coupling (520) each of the pumps (200) with the HP manifold 146 via a plurality of HP conduits 138 each fluidly coupling a corresponding one of the pumps 200 with a corresponding one of the HP ports 172. The method (500) further comprises establishing (530) communication between a controller 310 and each of the LP valves 157, 167, the HP valves 173, the bleed valves 183, the pumps 200, and a plurality of sensors 188, 306 each operable to generate information indicative of fluid pressure within a corresponding one of the HP conduits 138. The method (500) further includes operating (540) the controller 310 to, with respect to each of the pumps 200, cause (542) the pump 200 to operate and then cause (544) the LP valves 157, 167 corresponding to the pump 200 to transition to a closed flow position and cause (546) one of the HP valve 173 corresponding to the pump 200 and the bleed valve 183 corresponding to the pump 200 to transition to an open flow position. The controller 310 may also be utilized to determine (548) that the HP conduit 138 corresponding to the pump 200 is not pressurized based on the information generated by the corresponding one of the sensors 188, 306. With respect to each of the pumps 200, after the controller 310 determines that the HP conduit 138 corresponding to the pump 200 is not pressurized, the pump 200 may be fluidly uncoupled (550) from the manifold unit 140.

[0082] The method (500) may also comprise, prior to transitioning (544, 546) the LP valves 157, 167, the HP valve 173, and the bleed valve 183, operating the controller 310 to, with respect to each of the pumps 200, confirm that the LP valve 157, 167 corresponding to the pump 200 is in the closed flow position and confirm that the one of the HP valve 173 corresponding to the pump 200 and the bleed valve 183 corresponding to the pump 200 is in the open flow position.

[0083] The method (500) may further comprise, prior to causing (542) the pump 200 to operate and/or after causing the pump 200 to cease to operate, operating the controller 310 to, with respect to each of the pumps 200, remotely control the LP, HP, and bleed valves 157, 167, 173, 183 corresponding to the pump 200 by transmitting corresponding command signals to the LP, HP, and bleed valves 157, 167, 173, 183 to transition the LP, HP, and bleed valves 157, 167, 173, 183 from corresponding existing settings to corresponding intended settings. After

transmitting the command signals, the controller 310 may receive corresponding feedback signals from the LP, HP, and bleed valves 157, 167, 173, 183 corresponding to the pump 200, the feedback signals being indicative of corresponding actual settings of the LP, HP, and bleed valves 157, 167, 173, 183, such that the controller may be utilized to assess an operational health of each of the LP, HP, and bleed valves 157, 167, 173, 183 corresponding to the pump 200 based on the corresponding intended and actual settings.

[0084] After operating the controller 310 to cause the transition (544, 546) of the LP valves 157, 167 and the one of the HP and bleed valves 173, 183 corresponding to each of the pumps 200, the controller 310 may be operated to cause each of the pumps 200 to operate at an increased flow output, such as to increase fluid suction, fluid velocity, or otherwise increase the ability for the pump units 200 to expel the fluid from the HP fluid conduits 138 and, perhaps, portions of the pumps 202 in fluid communication with the HP fluid conduits 138.

[0085] The plurality of sensors 188, 306 may be pressure sensors 188, 306, and the method may further comprise establishing communication between the controller 310 and each of a plurality of flow sensors 304 operable to generate information indicative of rate of fluid flow within a corresponding one of the HP conduits 138. The controller 310 may thus also be utilized to, with respect to each of the pumps 200, determine whether the HP conduit 138 corresponding to the pump 200 is substantially flushed based on the information generated by the corresponding one of the flow sensors 304. The controller 310 may also be operated to, with respect to each of the pumps 200, cease operation of the pump 200 after the controller 310 determines that the HP conduit 138 corresponding to the pump 200 is substantially flushed.

[0086] In view of the entirety of the present disclosure, including the figures and the claims, a person having ordinary skill in the art will readily recognize that the present disclosure introduces an apparatus comprising: (a) a manifold unit comprising a plurality of ports and a plurality of valves, wherein each of the valves is operable to control flow through a corresponding one of the ports; and (b) a controller operable to, with respect to each of the valves: (1) remotely control the valve by transmitting a command signal to the valve to transition the valve from an existing setting to an intended setting; (2) after transmitting the command signal, receive a feedback signal from the valve indicative of an actual setting of the valve; and (3) assess an operational health of the valve based on the intended and actual settings.

[0087] The command signal may be a first command signal, the feedback signal may be a first feedback signal, the intended setting may be a first intended setting, the actual setting may

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be a first actual setting, and the controller may be further operable to, with respect to each of the valves: further remotely control the valve by transmitting a second command signal to the valve to transition the valve to a second intended setting; after transmitting the second command signal, receive a second feedback signal from the valve indicative of a second actual setting of the valve; and reassess the operational health of the valve based on the second intended setting and the second actual setting. The first intended setting may be a closed flow setting, and the second intended setting may be an open flow setting. The controller may be further operable to, with respect to each of the valves: further remotely control the valve by transmitting a third command signal to the valve to transition the valve to a third intended setting; after transmitting the third command signal, receive a third feedback signal from the valve indicative of a third actual setting of the valve; and reassess the operational health of the valve based on the third intended setting and the third actual setting. The third intended setting may be a closed flow setting.

[0088] The plurality of valves may comprise a first valve, a second valve, and a third valve, and the controller may be operable to: remotely control the first valve by transmitting a first command signal to the first valve to transition the first valve to a first intended setting, then receive a first feedback signal from the first valve indicative of a first actual setting of the first valve, and then assess a first operational health of the first valve based on the first intended setting and the first actual setting; after assessing the first operational health, remotely control the second valve by transmitting a second command signal to the second valve to transition the second valve to a second intended setting, then receive a second feedback signal from the second valve indicative of a second actual setting of the second valve, and then assess a second operational health of the second valve based on the second intended setting and the second actual setting; and after assessing the second operational health, remotely control the third valve by transmitting a third command signal to the third valve to transition the third valve to a third intended setting, then receive a third feedback signal from the third valve indicative of a third actual setting of the third valve, and then assess a third operational health of the third valve based on the third intended setting and the third actual setting.

[0089] The present disclosure also introduces a method comprising: (a) establishing communication between a controller and each of a plurality of valves of a manifold unit, wherein each of the valves is operable to control flow through a corresponding one of a plurality of ports of the manifold unit; and (b) operating the controller to, with respect to each of the valves: (1)

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remotely control the valve by transmitting a command signal to the valve to transition the valve from an existing setting to an intended setting; (2) after transmitting the command signal, receive a feedback signal from the valve indicative of an actual setting of the valve; and (3) assess an operational health of the valve based on the intended and actual settings.

[0090] The command signal may be a first command signal, the feedback signal may be a first feedback signal, the intended setting may be a first intended setting, the actual setting may be a first actual setting, and the method may further comprise operating the controller to, with respect to each of the valves: further remotely control the valve by transmitting a second command signal to the valve to transition the valve to a second intended setting; after transmitting the second command signal, receive a second feedback signal from the valve indicative of a second actual setting of the valve; and reassess the operational health of the valve based on the second intended setting and the second actual setting. The first intended setting may be a closed flow setting, and the second intended setting may be an open flow setting. The method may further comprise operating the controller to, with respect to each of the valves: further remotely control the valve by transmitting a third command signal to the valve to transition the valve to a third intended setting; after transmitting the third command signal, receive a third feedback signal from the valve indicative of a third actual setting of the valve; and reassess the operational health of the valve based on the third intended setting and the third actual setting. The third intended setting may be a closed flow setting.

[0091] The plurality of valves may comprise a first valve, a second valve, and a third valve, and operating the controller may include: remotely controlling the first valve by transmitting a first command signal to the first valve to transition the first valve to a first intended setting, then receiving a first feedback signal from the first valve indicative of a first actual setting of the first valve, and then assessing a first operational health of the first valve based on the first intended setting and the first actual setting; after assessing the first operational health, remotely controlling the second valve by transmitting a second command signal to the second valve to transition the second valve to a second intended setting, then receiving a second feedback signal from the second valve indicative of a second actual setting of the second valve, and then assessing a second operational health of the second valve based on the second intended setting and the second actual setting; and after assessing the second operational health, remotely controlling the third valve by transmitting a third command signal to the third valve to transition the third valve to a third intended setting, then receiving a third feedback signal from the third

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valve indicative of a third actual setting of the third valve, and then assessing a third operational health of the third valve based on the third intended setting and the third actual setting.

[0092] The present disclosure also introduces an apparatus comprising: (a) a manifold unit comprising: (1) a low-pressure (LP) manifold having a plurality of LP ports; (2) a plurality of LP valves each operable to control flow through a corresponding one of the LP ports; (3) a high-pressure (HP) manifold having a plurality of HP ports; (4) a plurality of HP valves each operable to control flow through a corresponding one of the HP ports; (5) a plurality of bleed ports each fluidly coupled with a corresponding one of the HP ports; and (6) a plurality of bleed valves each fluidly coupled with and remotely operable to control flow through a corresponding one of the bleed ports from the corresponding HP port; (b) a plurality of pumps; (c) a plurality of LP conduits each fluidly coupling a corresponding one of the pumps and a corresponding one of the LP ports; (d) a plurality of HP conduits each fluidly coupling a corresponding one of the pumps and a corresponding one of the HP ports; (e) a plurality of sensors each operable to generate information indicative of fluid pressure within a corresponding one of the HP conduits; and (f) a controller in communication with the LP valves, the HP valves, the bleed valves, the sensors, and the pumps, wherein the controller is operable to, with respect to each of the pumps: (1) cause the LP valve corresponding to the pump to transition to a closed flow position; (2) cause one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump to transition to an open flow position; and (3) determine whether the HP conduit corresponding to the pump is pressurized based on the information generated by the corresponding one of the sensors.

[0093] With respect to each of the pumps, the controller may be operable to determine whether the HP conduit corresponding to the pump is pressurized by comparing a predetermined threshold to the fluid pressure indicated by the information generated by the corresponding one of the sensors.

[0094] With respect to each of the pumps, the controller may be further operable to: determine whether the LP valve corresponding to the pump is in the closed flow position; and determine whether the one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump is in the open flow position.

[0095] Prior to causing the transition of the LP, HP, and/or bleed valves corresponding to each of the pumps, the controller may be further operable to cause each of the pumps to commence operation.

[0096] Prior to causing each of the pumps to commence operation, the controller may be further operable to, with respect to each of the pumps: remotely control the LP, HP, and bleed valves corresponding to the pump by transmitting corresponding command signals to the LP, HP, and bleed valves to transition the LP, HP, and bleed valves to corresponding intended settings; after transmitting the command signals, receive corresponding feedback signals from the LP, HP, and bleed valves corresponding to the pump, wherein the feedback signals are indicative of corresponding actual settings of the LP, HP, and bleed valves; and assess an operational health of each of the LP, HP, and bleed valves corresponding to the pump based on the corresponding intended and actual settings.

[0097] The controller may be further operable to, after causing the transitions of the LP valve and the one of the HP and bleed valves corresponding to each of the pumps, cause each of the pumps to operate at an increased flow output.

[0098] The plurality of sensors may be a plurality of pressure sensors, the apparatus may further comprise a plurality of flow sensors in communication with the controller and each operable to generate information indicative of rate of fluid flow through a corresponding one of HP conduits, and the controller may be further operable to, with respect to each of the pumps, determine whether the HP conduit corresponding to the pump is substantially flushed based on the information generated by the corresponding one of the flow sensors. With respect to each of the pumps, the controller may be further operable to determine whether the HP conduit corresponding to the pump is substantially flushed by comparing a predetermined threshold to the flow rate indicated by the information generated by the corresponding one of the flow sensors, and the HP conduit may be substantially flushed when the predetermined threshold is greater than the flow rate indicated by the information generated by the corresponding one of the flow sensors. The controller may be further operable to cause each of the pumps to cease operation after determining that the HP conduits corresponding to each of the pumps are each substantially flushed. After causing each of the pumps to cease operation, the controller may be further operable to, with respect to each of the pumps: remotely control the LP, HP, and bleed valves corresponding to the pump by transmitting corresponding command signals to the LP, HP, and bleed valves to transition the LP, HP, and bleed valves to corresponding intended settings; after transmitting the command signals, receive corresponding feedback signals from the LP, HP, and bleed valves corresponding to the pump, wherein the feedback signals are indicative of corresponding actual settings of the LP, HP, and bleed valves; and assess an

operational health of each of the LP, HP, and bleed valves corresponding to the pump based on the corresponding intended and actual settings.

[0099] The present disclosure also introduces a method comprising: (a) providing a plurality of pumps and a manifold unit, wherein the manifold unit comprises: (1) a low-pressure (LP) manifold having a plurality of LP ports; (2) a plurality of LP valves each operable to control flow through a corresponding one of the LP ports; (3) a high-pressure (HP) manifold having a plurality of HP ports; (4) a plurality of HP valves each operable to control flow through a corresponding one of the HP ports; (5) a plurality of bleed ports each fluidly coupled with a corresponding one of the HP ports; and (6) a plurality of bleed valves each fluidly coupled with and remotely operable to control flow through a corresponding one of the bleed ports from the corresponding HP port; (b) fluidly coupling each of the pumps with the LP manifold via a plurality of LP conduits each fluidly coupling a corresponding one of the pumps with a corresponding one of the LP ports; (c) fluidly coupling each of the pumps with the HP manifold via a plurality of HP conduits each fluidly coupling a corresponding one of the pumps with a corresponding one of the HP ports; (d) establishing communication between a controller and each of the LP valves, the HP valves, the bleed valves, the pumps, and a plurality of sensors each operable to generate information indicative of fluid pressure within a corresponding one of the HP conduits; and (e) operating the controller to, with respect to each of the pumps: (1) cause the pump to operate and then: (i) cause the LP valve corresponding to the pump to transition to a closed flow position; and (ii) cause one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump to transition to an open flow position; and (2) then determine that the HP conduit corresponding to the pump is not pressurized based on the information generated by the corresponding one of the sensors.

[00100] The method may further comprise, with respect to each of the pumps, fluidly uncoupling the pump from the manifold unit after the controller determines that the HP conduit corresponding to the pump is not pressurized.

[00101] The method may further comprise operating the controller to, with respect to each of the pumps: confirm that the LP valve corresponding to the pump is in the closed flow position; and confirm that the one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump is in the open flow position.

[00102] The method may further comprise operating the controller to, with respect to each of the pumps: remotely control the LP, HP, and bleed valves corresponding to the pump by

transmitting corresponding command signals to the LP, HP, and bleed valves to transition the LP, HP, and bleed valves from corresponding existing settings to corresponding intended settings; after transmitting the command signals, receive corresponding feedback signals from the LP, HP, and bleed valves corresponding to the pump indicative of corresponding actual settings of the LP, HP, and bleed valves; and assess an operational health of each of the LP, HP, and bleed valves corresponding to the pump based on the corresponding intended and actual settings.

[00103] The method may further comprise, after operating the controller to cause the transition of the LP valve and the one of the HP and bleed valves corresponding to each of the pumps, operating the controller to cause each of the pumps to operate at an increased flow output.

[00104] The plurality of sensors may be a plurality of pressure sensors, the method may further comprise establishing communication between the controller and each of a plurality of flow sensors operable to generate information indicative of rate of fluid flow within a corresponding one of the HP conduits, and the controller may be operable to, with respect to each of the pumps, determine whether the HP conduit corresponding to the pump is substantially flushed based on the information generated by the corresponding one of the flow sensors. The method may further comprise operating the controller to, with respect to each of the pumps, cease operation of the pump after the controller determines that the HP conduit corresponding to the pump is substantially flushed.

[00105] The foregoing outlines features of several embodiments so that a person having ordinary skill in the art may better understand the aspects of the present disclosure. A person having ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. A person having ordinary skill in the art should also realize that such equivalent constructions do not depart from the scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

[00106] The Abstract at the end of this disclosure is provided to comply with 37 C.F.R. §1.72(b) to allow the reader to quickly ascertain the nature of the technical disclosure. It is

submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

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WHAT IS CLAIMED IS:

1. An apparatus comprising:

a manifold unit comprising a plurality of ports and a plurality of valves, wherein each of the valves is operable to control flow through a corresponding one of the ports; and

a controller operable to, with respect to each of the valves:

remotely control the valve by transmitting a command signal to the valve to transition the valve from an existing setting to an intended setting;

after transmitting the command signal, receive a feedback signal from the valve indicative of an actual setting of the valve; and

assess an operational health of the valve based on the intended and actual settings.

2. The apparatus of claim 1 wherein the command signal is a first command signal, the feedback signal is a first feedback signal, the intended setting is a first intended setting, the actual setting is a first actual setting, and the controller is further operable to, with respect to each of the valves:

further remotely control the valve by transmitting a second command signal to the valve to transition the valve to a second intended setting;

after transmitting the second command signal, receive a second feedback signal from the valve indicative of a second actual setting of the valve; and

reassess the operational health of the valve based on the second intended setting and the second actual setting.

3. The apparatus of claim 2 wherein the first intended setting is a closed flow setting and the second intended setting is an open flow setting.

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4. The apparatus of claim 2 wherein the controller is further operable to, with respect to each of the valves:

further remotely control the valve by transmitting a third command signal to the valve to transition the valve to a third intended setting;

after transmitting the third command signal, receive a third feedback signal from the valve indicative of a third actual setting of the valve; and

reassess the operational health of the valve based on the third intended setting and the third actual setting.

5. The apparatus of claim 4 wherein the third intended setting is a closed flow setting.

6. The apparatus of claim 1 wherein the plurality of valves comprises a first valve, a second valve, and a third valve, and wherein the controller is operable to:

remotely control the first valve by transmitting a first command signal to the first valve to transition the first valve to a first intended setting, then receive a first feedback signal from the first valve indicative of a first actual setting of the first valve, and then assess a first operational health of the first valve based on the first intended setting and the first actual setting;

after assessing the first operational health, remotely control the second valve by transmitting a second command signal to the second valve to transition the second valve to a second intended setting, then receive a second feedback signal from the second valve indicative of a second actual setting of the second valve, and then assess a second operational health of the second valve based on the second intended setting and the second actual setting; and

after assessing the second operational health, remotely control the third valve by transmitting a third command signal to the third valve to transition the third valve to a third intended setting, then receive a third feedback signal from the third valve indicative of a third actual setting of the third valve, and then assess a third operational health of the third valve based on the third intended setting and the third actual setting.

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7. A method comprising:

establishing communication between a controller and each of a plurality of valves of a manifold unit, wherein each of the valves is operable to control flow through a corresponding one of a plurality of ports of the manifold unit; and

operating the controller to, with respect to each of the valves:

remotely control the valve by transmitting a command signal to the valve to transition the valve from an existing setting to an intended setting;

after transmitting the command signal, receive a feedback signal from the valve indicative of an actual setting of the valve; and

assess an operational health of the valve based on the intended and actual settings.

8. The method of claim 7 wherein the command signal is a first command signal, the feedback signal is a first feedback signal, the intended setting is a first intended setting, the actual setting is a first actual setting, and wherein the method further comprises operating the controller to, with respect to each of the valves:

further remotely control the valve by transmitting a second command signal to the valve to transition the valve to a second intended setting;

after transmitting the second command signal, receive a second feedback signal from the valve indicative of a second actual setting of the valve; and

reassess the operational health of the valve based on the second intended setting and the second actual setting.

9. The method of claim 8 wherein the first intended setting is a closed flow setting and the second intended setting is an open flow setting.

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10. The method of claim 8 further comprising operating the controller to, with respect to each of the valves:

further remotely control the valve by transmitting a third command signal to the valve to transition the valve to a third intended setting;

after transmitting the third command signal, receive a third feedback signal from the valve indicative of a third actual setting of the valve; and

reassess the operational health of the valve based on the third intended setting and the third actual setting.

11. The method of claim 10 wherein the third intended setting is a closed flow setting.

12. The method of claim 8 wherein the plurality of valves comprises a first valve, a second valve, and a third valve, and wherein operating the controller includes:

remotely controlling the first valve by transmitting a first command signal to the first valve to transition the first valve to a first intended setting, then receiving a first feedback signal from the first valve indicative of a first actual setting of the first valve, and then assessing a first operational health of the first valve based on the first intended setting and the first actual setting;

after assessing the first operational health, remotely controlling the second valve by transmitting a second command signal to the second valve to transition the second valve to a second intended setting, then receiving a second feedback signal from the second valve indicative of a second actual setting of the second valve, and then assessing a second operational health of the second valve based on the second intended setting and the second actual setting; and

after assessing the second operational health, remotely controlling the third valve by transmitting a third command signal to the third valve to transition the third valve to a third intended setting, then receiving a third feedback signal from the third valve indicative of a third actual setting of the third valve, and then assessing a third operational health of the third valve based on the third intended setting and the third actual setting.

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13. An apparatus comprising:

a manifold unit comprising:

a low-pressure (LP) manifold having a plurality of LP ports;

a plurality of LP valves each operable to control flow through a corresponding one of the LP ports;

a high-pressure (HP) manifold having a plurality of HP ports;

a plurality of HP valves each operable to control flow through a corresponding one of the HP ports;

a plurality of bleed ports each fluidly coupled with a corresponding one of the HP ports; and

a plurality of bleed valves each fluidly coupled with and remotely operable to control flow through a corresponding one of the bleed ports from the corresponding HP port;

a plurality of pumps;

a plurality of LP conduits each fluidly coupling a corresponding one of the pumps and a corresponding one of the LP ports;

a plurality of HP conduits each fluidly coupling a corresponding one of the pumps and a corresponding one of the HP ports;

a plurality of sensors each operable to generate information indicative of fluid pressure within a corresponding one of the HP conduits; and

a controller in communication with the LP valves, the HP valves, the bleed valves, the sensors, and the pumps, wherein the controller is operable to, with respect to each of the pumps:

cause the LP valve corresponding to the pump to transition to a closed flow position;

cause one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump to transition to an open flow position; and

determine whether the HP conduit corresponding to the pump is pressurized based on the information generated by the corresponding one of the sensors.

14. The apparatus of claim 13 wherein, with respect to each of the pumps, the controller is operable to determine whether the HP conduit corresponding to the pump is pressurized by comparing a predetermined threshold to the fluid pressure indicated by the information generated by the corresponding one of the sensors.

15. The apparatus of claim 13 wherein, with respect to each of the pumps, the controller is further operable to:

determine whether the LP valve corresponding to the pump is in the closed flow position; and

determine whether the one of the HP valve corresponding to the pump and the bleed valve corresponding to the pump is in the open flow position.

16. The apparatus of claim 13 wherein:

prior to causing the transition of the LP, HP, and/or bleed valves corresponding to each of the pumps, the controller is further operable to cause each of the pumps to commence operation; and

prior to causing each of the pumps to commence operation, the controller is further operable to, with respect to each of the pumps:

remotely control the LP, HP, and bleed valves corresponding to the pump by transmitting corresponding command signals to the LP, HP, and bleed valves to transition the LP, HP, and bleed valves to corresponding intended settings;

after transmitting the command signals, receive corresponding feedback signals from the LP, HP, and bleed valves corresponding to the pump, wherein the feedback signals are indicative of corresponding actual settings of the LP, HP, and bleed valves; and

assess an operational health of each of the LP, HP, and bleed valves corresponding to the pump based on the corresponding intended and actual settings.

17. The apparatus of claim 13 wherein the controller is further operable to, after causing the transitions of the LP valve and the one of the HP and bleed valves corresponding to each of the pumps, cause each of the pumps to operate at an increased flow output.

18. The apparatus of claim 13 wherein the plurality of sensors is a plurality of pressure sensors, wherein the apparatus further comprises a plurality of flow sensors in communication with the controller and each operable to generate information indicative of rate of fluid flow through a corresponding one of HP conduits, and wherein the controller is further operable to, with respect to each of the pumps, determine whether the HP conduit corresponding to the pump is substantially flushed based on the information generated by the corresponding one of the flow sensors.

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19. The apparatus of claim 18 wherein, with respect to each of the pumps, the controller is further operable to determine whether the HP conduit corresponding to the pump is substantially flushed by comparing a predetermined threshold to the flow rate indicated by the information generated by the corresponding one of the flow sensors, and wherein the HP conduit is substantially flushed when the predetermined threshold is greater than the flow rate indicated by the information generated by the corresponding one of the flow sensors.

20. The apparatus of claim 18 wherein:

the controller is further operable to cause each of the pumps to cease operation after determining that the HP conduits corresponding to each of the pumps are each substantially flushed; and

after causing each of the pumps to cease operation, the controller is further operable to, with respect to each of the pumps:

remotely control the LP, HP, and bleed valves corresponding to the pump by transmitting corresponding command signals to the LP, HP, and bleed valves to transition the LP, HP, and bleed valves to corresponding intended settings;

after transmitting the command signals, receive corresponding feedback signals from the LP, HP, and bleed valves corresponding to the pump, wherein the feedback signals are indicative of corresponding actual settings of the LP, HP, and bleed valves; and

assess an operational health of each of the LP, HP, and bleed valves corresponding to the pump based on the corresponding intended and actual settings.

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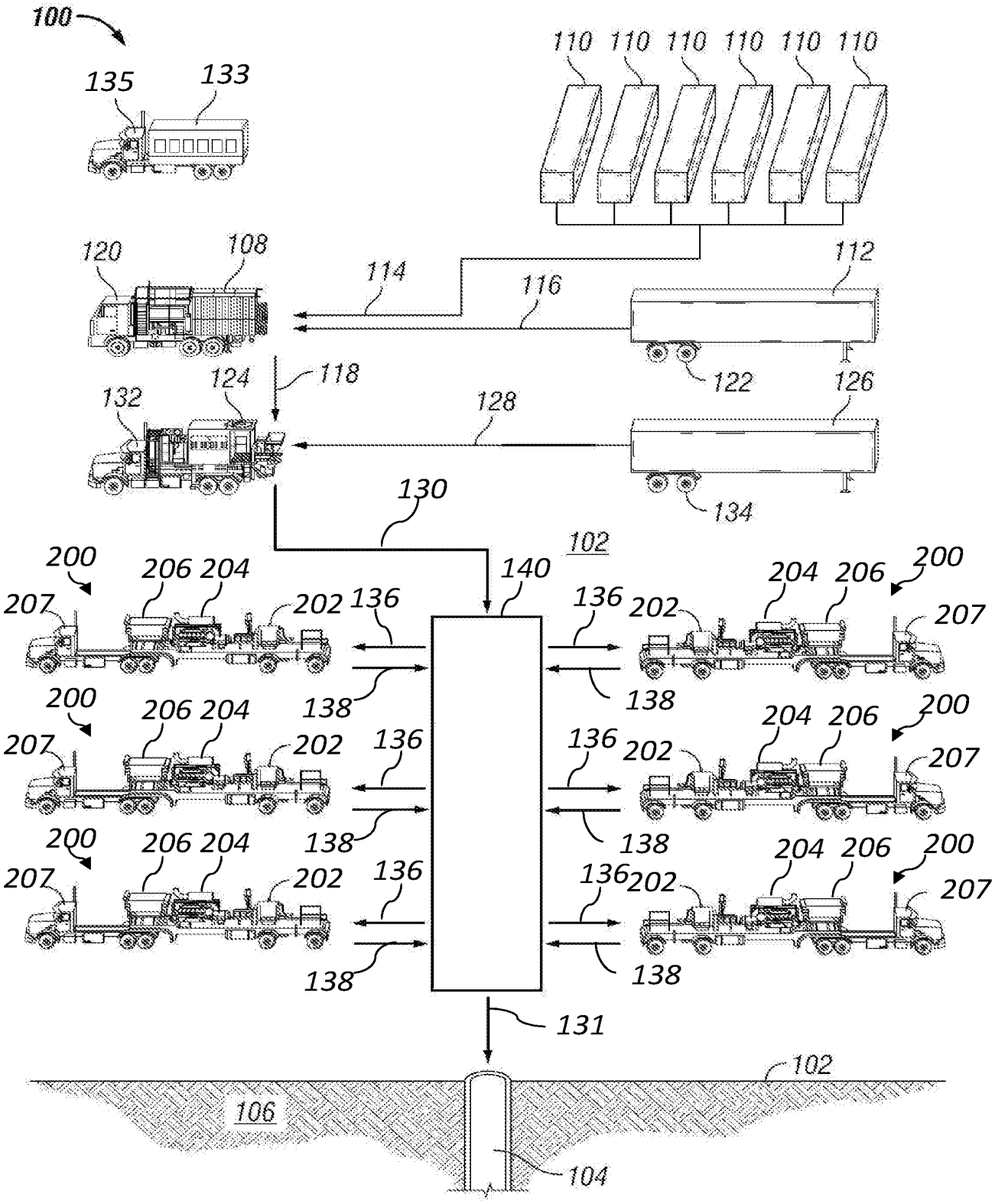

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FIG. 1

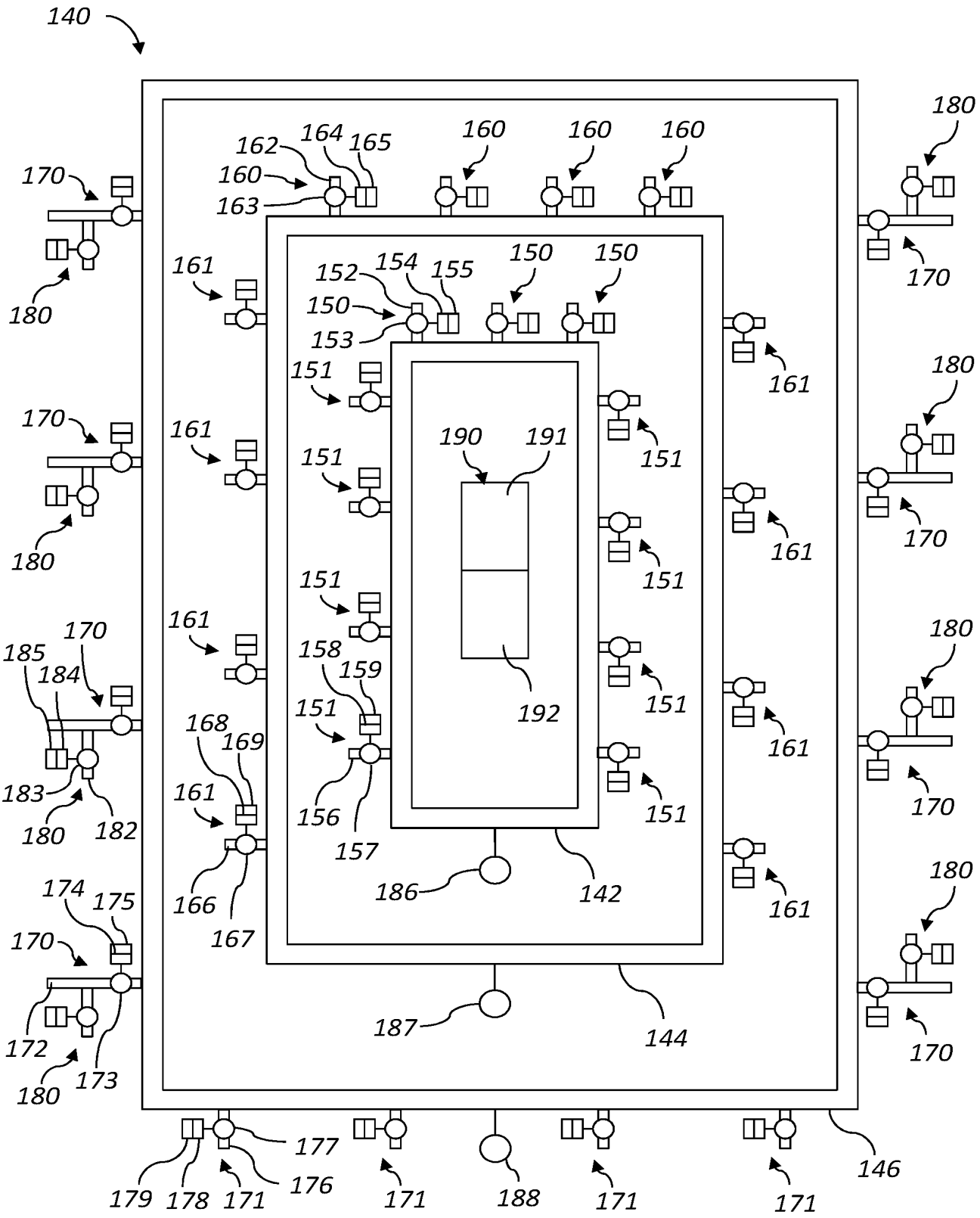

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FIG. 2

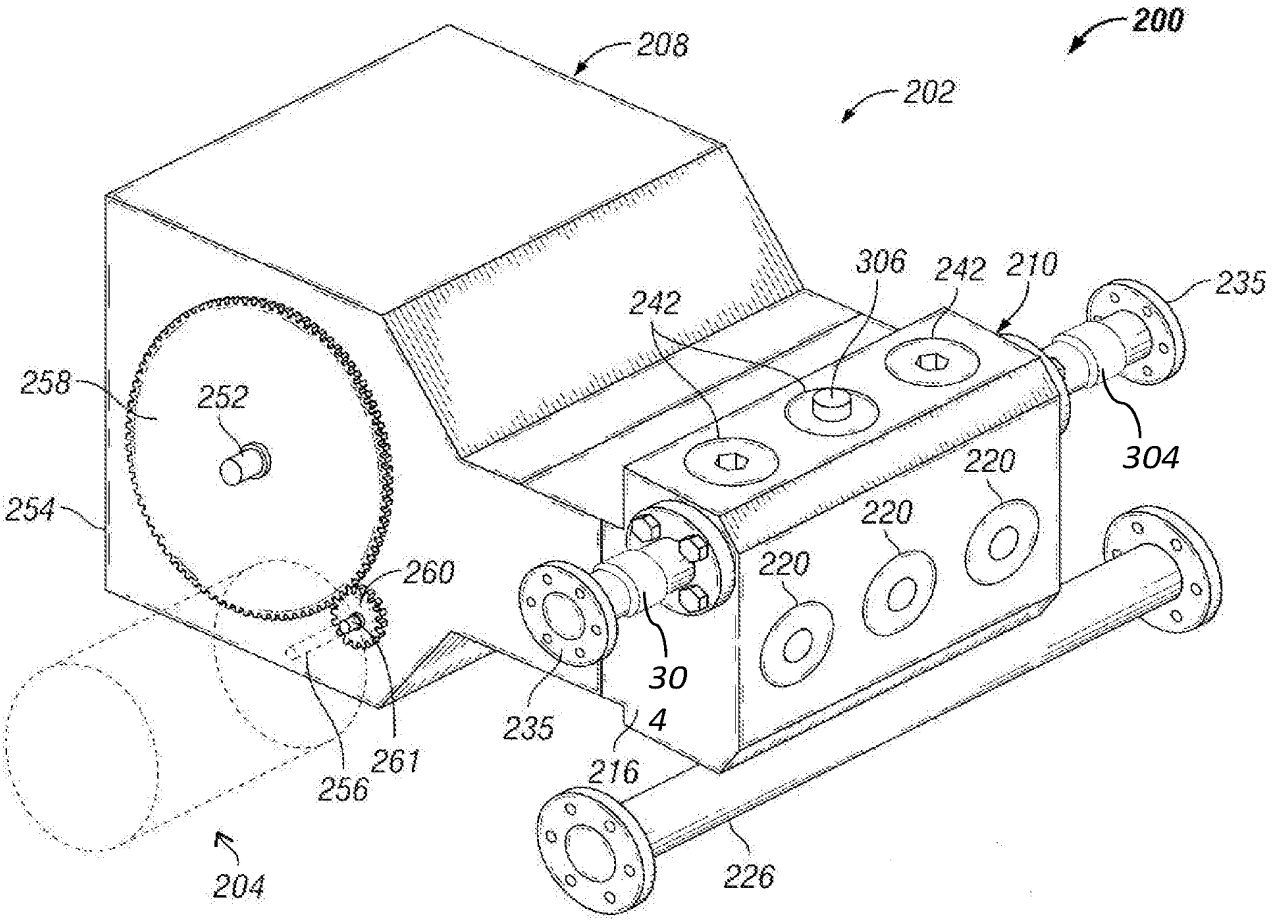

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FIG. 3

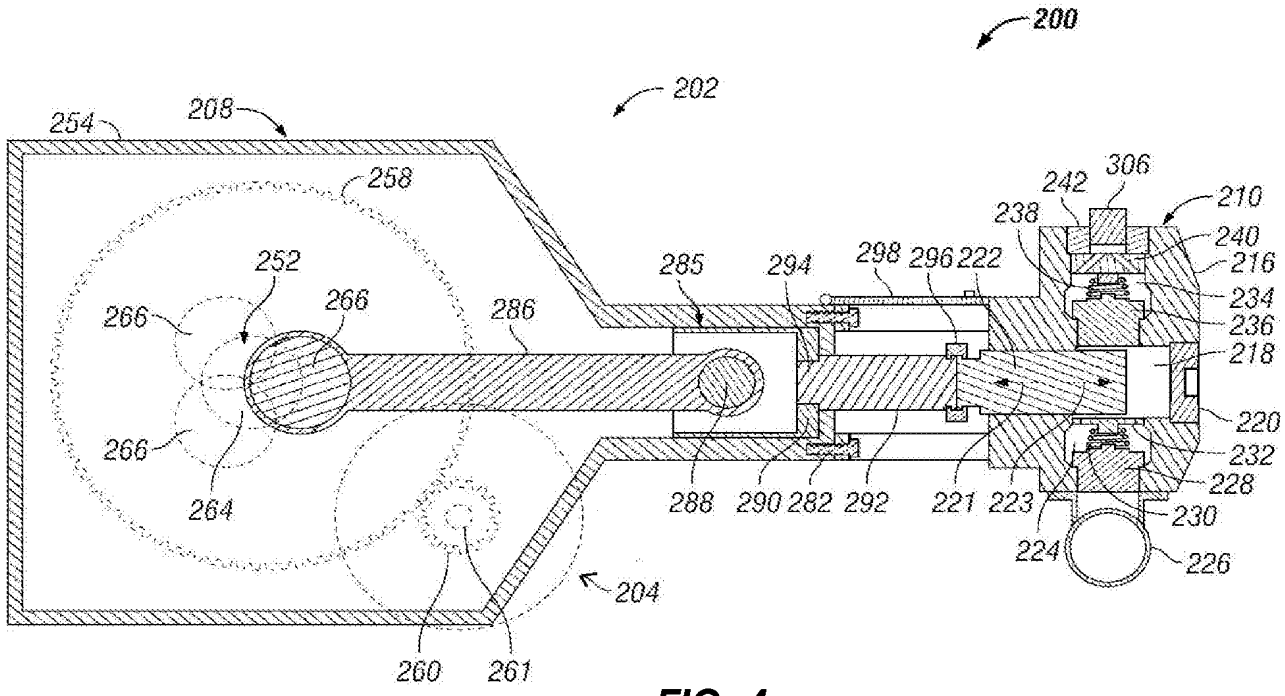

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FIG. 4

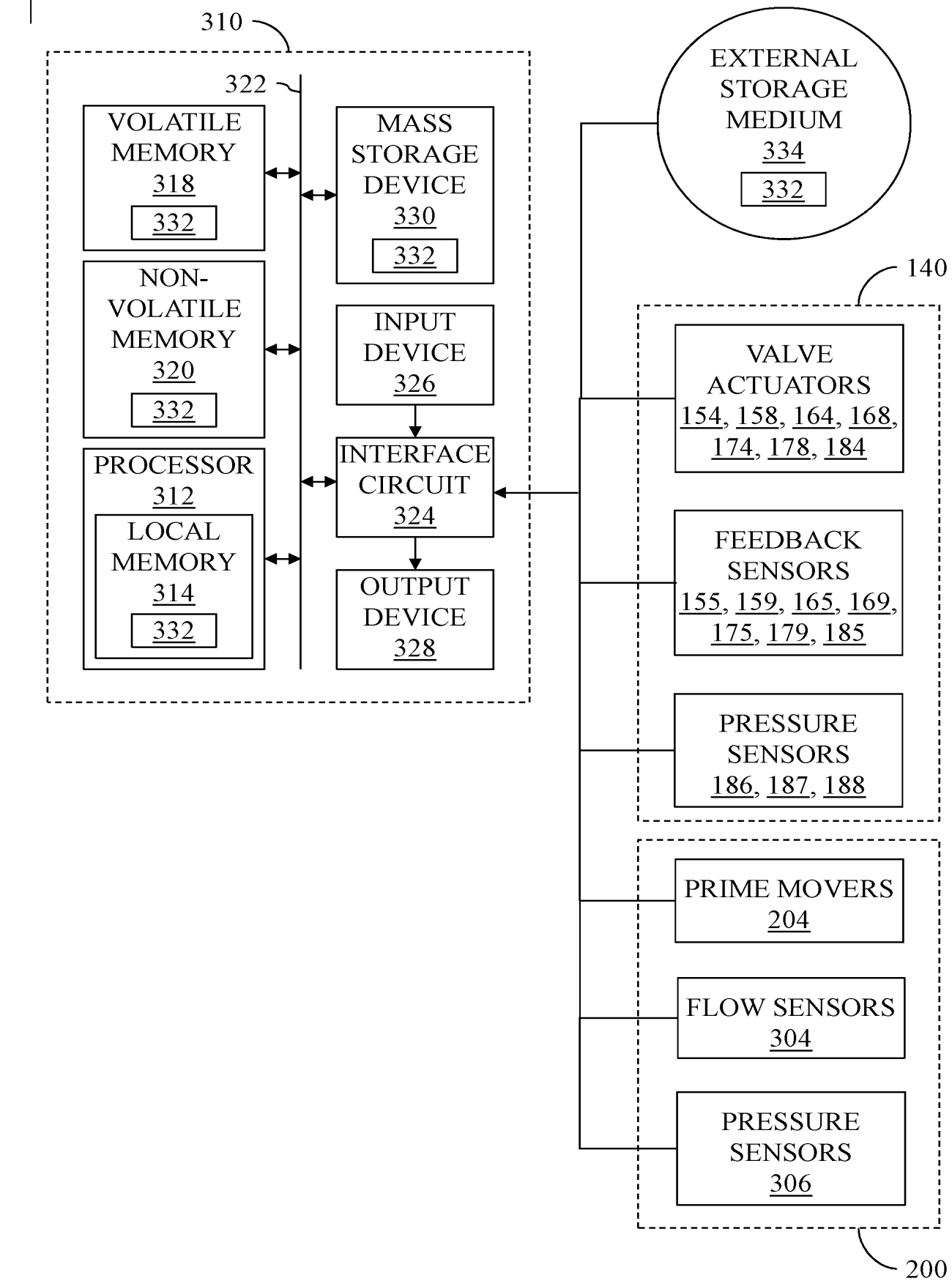

310
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VOLATILE MEMORY 318
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NON-VOLATILE MEMORY 320
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PROCESSOR 312
LOCAL MEMORY 314
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MASS STORAGE DEVICE 330
332
INPUT DEVICE 326
INTERFACE CIRCUIT 324
OUTPUT DEVICE 328
EXTERNAL STORAGE MEDIUM 334
332
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VALVE ACTUATORS 154, 158, 164, 168, 174, 178, 184
FEEDBACK SENSORS 155, 159, 165, 169, 175, 179, 185
PRESSURE SENSORS 186, 187, 188
PRIME MOVERS 204
FLOW SENSORS 304
PRESSURE SENSORS 306
200

FIG. 5

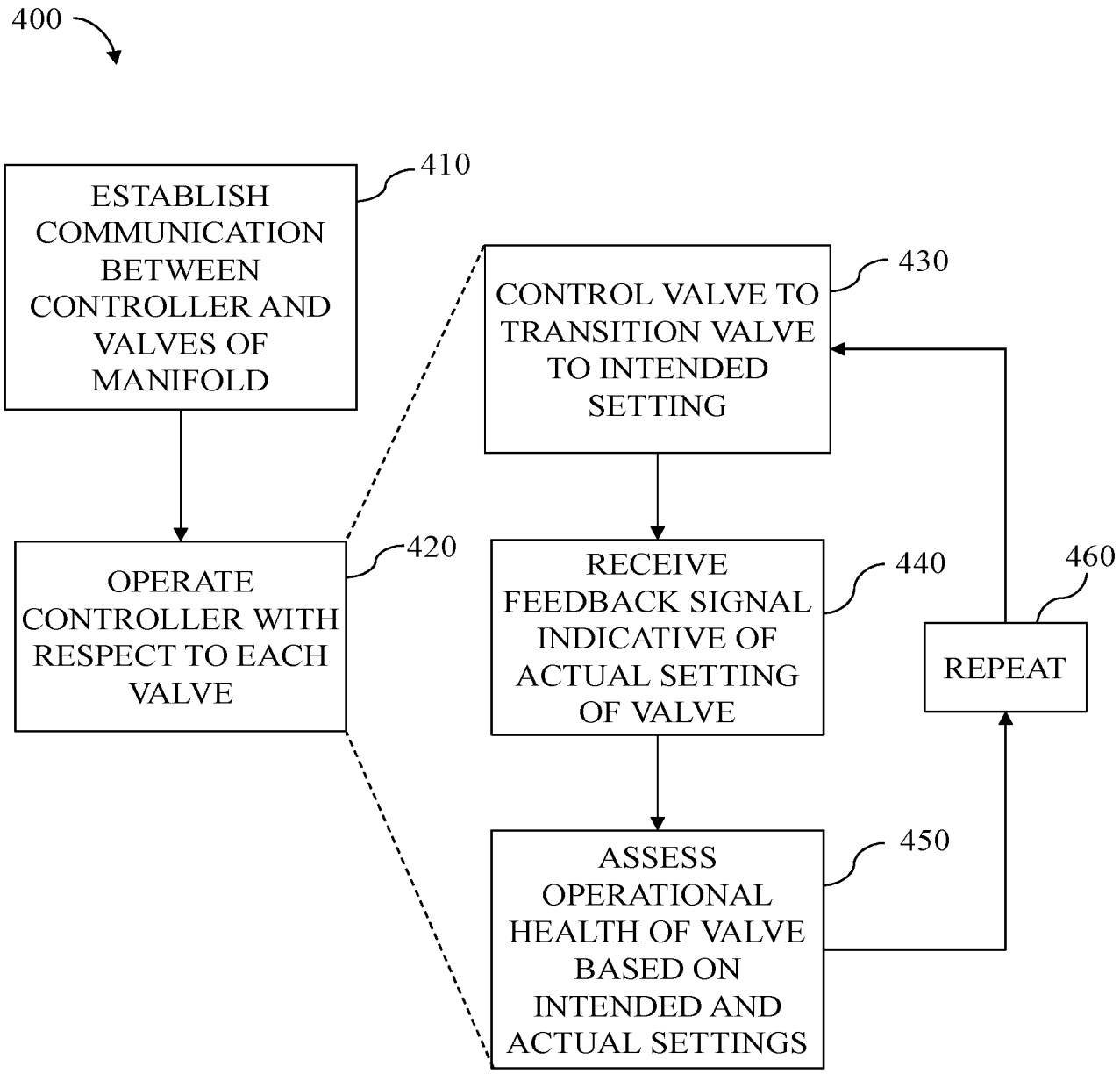

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ESTABLISH COMMUNICATION BETWEEN CONTROLLER AND VALVES OF MANIFOLD
410
OPERATE CONTROLLER WITH RESPECT TO EACH VALVE
420
CONTROL VALVE TO TRANSITION VALVE TO INTENDED SETTING
430
RECEIVE FEEDBACK SIGNAL INDICATIVE OF ACTUAL SETTING OF VALVE
440
ASSESS OPERATIONAL HEALTH OF VALVE BASED ON INTENDED AND ACTUAL SETTINGS
450
REPEAT
460

FIG. 6

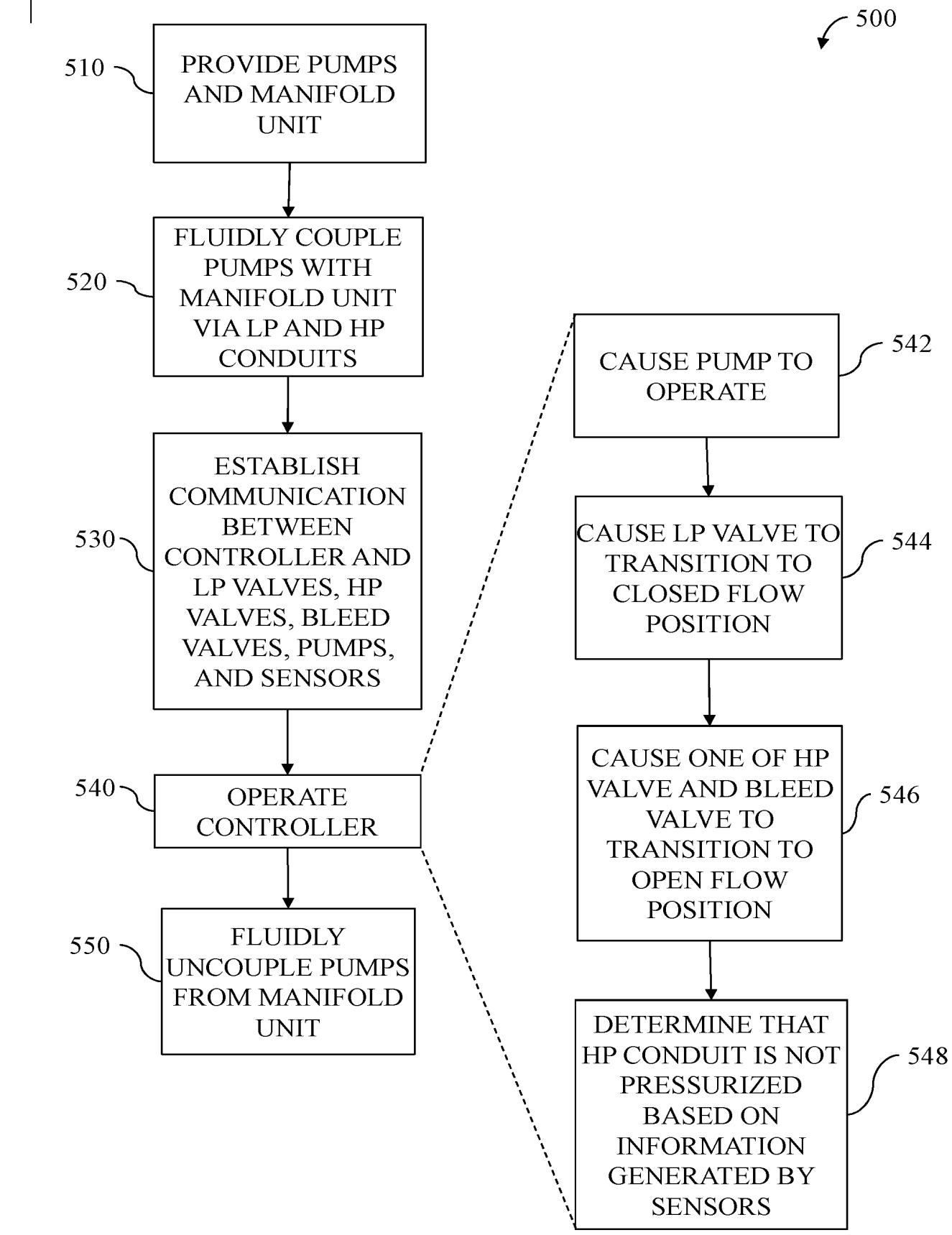

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PROVIDE PUMPS AND MANIFOLD UNIT
520
FLUIDLY COUPLE PUMPS WITH MANIFOLD UNIT VIA LP AND HP CONDUITS
530
ESTABLISH COMMUNICATION BETWEEN CONTROLLER AND LP VALVES, HP VALVES, BLEED VALVES, PUMPS, AND SENSORS
540
OPERATE CONTROLLER
550
FLUIDLY UNCOUPLE PUMPS FROM MANIFOLD UNIT
542
CAUSE PUMP TO OPERATE
544
CAUSE LP VALVE TO TRANSITION TO CLOSED FLOW POSITION
546
CAUSE ONE OF HP VALVE AND BLEED VALVE TO TRANSITION TO OPEN FLOW POSITION
548
DETERMINE THAT HP CONDUIT IS NOT PRESSURIZED BASED ON INFORMATION GENERATED BY SENSORS

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/021336

A. CLASSIFICATION OF SUBJECT MATTER

F17D 3/01(2006.01)i, F17D 1/00(2006.01)i, F17D 1/14(2006.01)i, F17D 1/02(2006.01)i, E21B 7/18(2006.01)i, E21B 33/14(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)
F17D 3/01; E21B 47/00; E21B 43/26; E21B 29/02; B60S 5/02; F17D 1/00; F17D 1/14; F17D 1/02; E21B 7/18; E21B 33/14

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: manifold unit, port, valve, controller, existing setting, intended setting, actual setting, operational health, pump, and sensor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014-158806 A1 (SCHLUMBERGER CANADA LIMITED et al.) 02 October 2014 See paragraphs [0035]-[0045], [0053], [0063]-[0077] and figures 1-6, 14.	1-20
Y	US 2014-0090475 A1 (GENERAL ELECTRIC COMPANY) 03 April 2014 See paragraphs [0033]-[0036] and figure 4.	1-12,16,20
Y	US 4821564 A (PEARSON et al.) 18 April 1989 See column 7, line 22 - column 8, line 24 and figure 1.	13-20
A	US 2013-0284455 A1 (GE OIL & GAS PRESSURE CONTROL LP) 31 October 2013 See paragraphs [0028]-[0033] and figures 1-2.	1-20
A	US 2004-0140092 A1 (ROBISON, CLARK E.) 22 July 2004 See paragraph [0037] and figure 9.	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
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"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
31 May 2016 (31.05.2016)	**02 June 2016 (02.06.2016)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/021336

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(74) Agents: **GREENE, Rachel** 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.

(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,

[Continued on next page]

(54) Title: AUTOMATED OPERATION OF WELLSITE EQUIPMENT

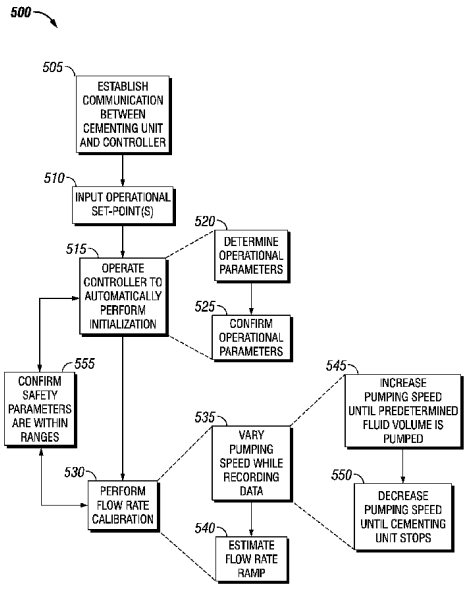


FIG. 6

(57) Abstract: Systems and methods for controlling wellsite equipment, including a cementing unit comprising a plurality of sensors operable to generate information related to operational status of the cementing unit and a controller comprising a processor and a memory including computer program code. Communication is established between the cementing unit and the controller. The controller is operable to operate the controller to automatically perform initialization of operation of the cementing unit, operate the controller to automatically perform a flow rate calibration of the cementing unit, and/or operate the controller to automatically perform a cement pumping operation of the cementing unit.

WO 2016/160458 A1

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))*

AUTOMATED OPERATION OF WELLSITE EQUIPMENT

Cross-Reference to Related Applications

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 62/139,963, titled "WELL CEMENTING METHODS," filed March 30, 2015, the entire disclosure of which is hereby incorporated herein by reference.

Background of the Disclosure

[0002] High-volume, high-pressure pumps are utilized at wellsites for a variety of pumping operations. Such operations may include drilling, cementing, acidizing, water jet cutting, hydraulic fracturing, and other wellsite operations. In some pumping operations, several pumps may be fluidly connected to a well via various fluid conduits and/or a manifold. During such operations, the fluid conduits and/or the manifold distributes low-pressure fluid from a mixer, a blender, and/or other sources among the pumps and combines pressurized fluid from the pumps for injection into the well. The fluid conduits and/or the manifold may have a large physical size and weight to satisfy intended fluid flow rates and operating pressures generated by the pumps.

[0003] Success of the pumping operations at a wellsite may be affected by many factors, including efficiency, failure rates, and safety related to operation of the pumps and the manifold. High fluid pressures, flow rates, and vibrations generated by the pumps may cause mechanical fatigue, wear, and other damage to the pumps and various downstream equipment, including the manifold and associated fluid sensors, valves, couplings, and conduits. Mechanical fatigue and wear may cause leaks and/or other failures in the pumps and the various downstream equipment.

[0004] To ensure that the wellsite equipment operates as intended, human operators at the wellsite may perform pressure and flow rate calibrations, diagnostics, and other tests before commencing actual downhole pumping operations. To perform such tests and to oversee the actual downhole pumping operations, the operators typically approach the wellsite equipment to visually inspect the fluid sensors and to manually adjust the fluid valves, thus exposing themselves to a potentially dangerous environment. Approaching wellsite equipment during testing or pumping operations may be dangerous, such as because high-pressure fluid within such equipment may escape, which may lead to serious injuries. Also, performing the testing and pumping operations manually may result in inconsistent equipment settings and, thus, inconsistent performance between different operational stages or jobs caused by human error.

Summary of the Disclosure

[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 indispensable features of the claimed subject matter, nor is it intended for use as an aid in limiting the scope of the claimed subject matter.

[0006] The present disclosure introduces a method that includes establishing communication between a cementing unit and a controller operable to control operation of the cementing unit. The controller includes a processor and a memory including computer program code. The method also includes inputting a fluid volume set-point and operating the controller to automatically perform a flow rate calibration of the cementing unit and a cement pumping operation of the cementing unit. The flow rate calibration includes automatically: varying pumping speed of the cementing unit while recording first pumping speeds and corresponding first flow rates generated by the cementing unit; and determining a flow rate ramp relating the recorded first flow rates to the corresponding recorded first pumping speeds. The cement pumping operation includes automatically: (a) increasing pumping speed of the cementing unit while recording: (i) second pumping speeds; (ii) first pressures generated by the cementing unit corresponding to the recorded second pumping speeds; and (iii) second flow rates generated by the cementing unit corresponding to the recorded second pumping speeds and/or first pressures; then (b) maintaining the pumping speed while recording the maintained pumping speed and corresponding second pressures and third flow rates; and then (c) decreasing the pumping speed while recording fourth pumping speeds and corresponding third pressures and fourth flow rates until the cementing unit has stopped pumping cement and a volume of the pumped cement is substantially equal to the fluid volume set-point.

[0007] The present disclosure also introduces a method that includes establishing communication between a cementing unit and a controller operable to control operation of the cementing unit. The cementing unit includes sensors operable to generate information related to operational status of the cementing unit, and the controller includes a processor and a memory including computer program code. The method also includes operating the controller to automatically perform initialization of the cementing unit. The initialization includes automatically: determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and confirming the operational parameters are within corresponding predetermined ranges.

[0008] The present disclosure also introduces a method that includes establishing communication between a cementing unit and a controller operable to control operation of the cementing unit. The controller includes a processor and a memory including computer program code. The method also includes operating the controller to automatically perform a flow rate calibration of the cementing unit. The flow rate calibration includes automatically: varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate generated by the cementing unit; and determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds.

[0009] The present disclosure also introduces a method that includes establishing communication between a cementing unit and a controller operable to control operation of the cementing unit. The controller includes a processor and a memory including computer program code. The method also includes inputting a fluid volume set-point, and operating the controller to automatically perform a cement pumping operation of the cementing unit. The cement pumping operation includes automatically: (1) increasing pumping speed of the cementing unit while recording the pumping speed, pressure generated by the cementing unit and corresponding to the pumping speed, and cement flow rate generated by the cementing unit and corresponding to the pumping speed and/or pressure; then (2) maintaining the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate; and then (3) decreasing the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate until the cementing unit has stopped pumping cement and a volume of the pumped cement is substantially equal to the fluid volume set-point.

[0010] These and additional aspects of the present disclosure are set forth in the description that follows, and/or may be learned by a person having ordinary skill in the art by reading the materials herein and/or practicing the principles described herein. At least some aspects of the present disclosure may be achieved via means recited in the attached claims.

Brief Description of the Drawings

[0011] The present disclosure is understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0012] FIG. 1 is a schematic view of an example implementation of apparatus according to one or more aspects of the present disclosure.

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[0013] FIG. 2 is a schematic view of a portion of an example implementation of the apparatus shown in FIG. 1 according to one or more aspects of the present disclosure.

[0014] FIG. 3 is a perspective view of a portion of an example implementation of the apparatus shown in FIG. 2 according to one or more aspects of the present disclosure.

[0015] FIG. 4 is a sectional view of a portion of the apparatus shown in FIG. 3 according to one or more aspects of the present disclosure.

[0016] FIG. 5 is a schematic view of an example implementation of apparatus according to one or more aspects of the present disclosure.

[0017] FIG. 6 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

[0018] FIG. 7 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

[0019] FIG. 8 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

[0020] FIG. 9 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

Detailed Description

[0021] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for simplicity and clarity, and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0022] FIG. 1 is a schematic view of at least a portion of an example wellsite system 100 according to one or more aspects of the present disclosure. The figure depicts the wellsite system 100 located on a wellsite 102 adjacent a wellbore 104 and a partial sectional view of the subterranean formation 106 penetrated by the wellbore 104 below the wellsite 102. The wellbore 104 may terminate with a wellhead 108 at the wellsite 102. The wellsite system 100 may be operable to transfer various materials and additives from corresponding sources to a destination location for blending or mixing and eventual injection into the wellbore 104 during wellbore cementing operations.

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[0023] The wellsite system 100 may comprise a cement mixing and pumping unit 110 (referred to hereinafter as a "cementing unit") fluidly connected with one or more tanks 112 and an additive container 114. The tanks 112 may contain that which is known in the art as a base fluid, which may be or comprise fresh water, brine, and/or mud. The container 114 may contain liquid or solid chemicals or additives operable to treat the base fluid. The additives may be or comprise accelerators, retarders, fluid-loss additives, dispersants, extenders, weighting agents, lost circulation additives, among other examples. The cementing unit 110 may be operable to receive the base fluid and one or more of the additives via fluid conduits 116, 118, and mix or otherwise combine the base fluid and the additives to form that which is known in the art as a mixed fluid.

[0024] The wellsite system 100 may further comprise a bulk container 120, which may contain a bulk material that is substantially different than the additives contained within the additive container 114. For example, the bulk material may be or comprise a cement powder or bulk cement, among other examples. The cementing unit 110 may be operable to receive the bulk cement from the bulk container 120 via a conduit 122, and mix or otherwise combine the mixed fluid and the bulk cement to form a mixture, which may be or comprise that which is known in the art as a cement slurry. The cementing unit 110 may then discharge or pump the cement slurry into the wellbore 104 via one or more fluid conduits 124 and/or the wellhead 108. The one or more fluid conduits 124 may be or comprise at least a portion of that which is known in the art as a treating line.

[0025] The wellsite system 100 may further comprise a batch mixer 126 operable to receive and mix predetermined quantities of the base fluid, additives, and/or bulk cement to form predetermined quantities or batches of the mixed fluid and/or cement slurry. If utilized to store the mixed fluid, the mixed fluid may be communicated to the cementing unit 110 via a fluid conduit 128 to be mixed with the bulk cement to form the cement slurry. If utilized to store the cement slurry, the cement slurry may be communicated to the cementing unit 110 via the fluid conduit 128 and pumped by the cementing unit 110 into the wellbore 104 via the fluid conduit 124 and/or the wellhead 108.

[0026] The wellsite system 100 may also comprise a control/power center 130, such as may be operable to provide control and/or centralized electric power distribution to one or more pieces of wellsite equipment or portions of the wellsite system 100. The control/power center 130 may be operable to monitor and control at least a portion of the wellsite system 100 during cementing operations. For example, the control/power center 130 may be operable to monitor and control one or more portions of the cementing unit 110 as well as

pumps and/or conveyers (not shown) for moving the fluids, materials, and/or mixtures described above to the cementing unit 110. The control/power center 130 may comprise an engine-generator set, such as a gas turbine generator, an internal combustion engine generator, and/or other sources of electric power. Electric power and/or control signals may be communicated between the control/power center 130 and other wellsite equipment via electric conductors (not shown). However, other means of signal communication, such as wireless communication, are also within the scope of the present disclosure.

[0027] The cementing unit 110, the additive container 114, the bulk container 120, the batch mixer 126, and/or the control/power center 130 may each be disposed on corresponding trucks, trailers, and/or other mobile carriers 111, 115, 121, 127, 131, respectively, such as may permit their transportation to the wellsite 102. However, the cementing unit 110, the additive container 114, the bulk container 120, the batch mixer 126, and/or the control/power center 130 may be skidded or otherwise stationary, and/or may be temporarily or permanently installed at the wellsite 102.

[0028] FIG. 1 depicts the wellsite system 100 as being operable to form fluids and/or mixtures that may be pressurized and individually or collectively injected into the wellbore 104 during wellbore cementing operations. However, it is to be understood that the wellsite system 100 may be operable to mix and/or produce other mixtures and/or fluids that may be mixed by the cementing unit 110 and injected into the wellbore 104 during other oilfield operations, such as drilling, hydraulic fracturing, acidizing, chemical injecting, and/or water jet cutting operations, among other examples.

[0029] FIG. 2 is a schematic view of at least a portion of an example implementation of the cementing unit 110 shown in FIG. 1 according to one or more aspects of the present disclosure, and designated in FIG. 2 by reference numeral 200. The cementing unit 200 may be utilized in various implementations of a wellsite system. However, for the sake of clarity and ease of understanding, the cementing unit 200 is described below in the context of the wellsite system 100 shown in FIG. 1. Thus, the following description refers to FIGS. 1 and 2, collectively.

[0030] The cementing unit 200 comprises a mixer 202 operable to receive and mix or blend the bulk cement and the mixed fluid to form the cement slurry. The mixer 202 may be a vortex type mixer or another mixer operable to mix or blend liquids and solids. For example, the mixer 202 may receive the bulk cement from a container 204, which may temporarily store and/or direct the bulk cement received from the bulk container 120 via the conduit 122. The bulk cement may be transferred to the mixer 202 via a material transfer

conduit 206, which may comprise a volumetric or mass dry metering device (not shown) operable to control the volumetric or mass flow rate of the bulk cement into the mixer 202. The bulk cement metering device may include a metering feeder, a screw feeder, an auger, and/or conveyor, among other examples.

[0031] The mixer 202 may receive the mixed fluid from displacement tanks 210, 212 via a fluid conduit 214. Each of the displacement tanks 210, 212 may receive the additives from the additive container 114 via the conduit 118 and the base fluid from the tanks 112 via the conduit 116. Within each of the displacement tanks 210, 212 a plurality of mixing blades or other agitators 216, 218 may agitate the mixture to uniformly blend the additives with the base fluid. Each of the displacement tanks 210, 212 may be or comprise a continuous flow channel or pathway for communicating or conveying the additives and the base fluid over a period of time sufficient to permit adequate blending to occur. Each displacement tank 210, 212 may have a first-in-first-out (FIFO) mode of operation, and may comprise a vessel-type outer housing enclosing a receptacle having an elongated flow pathway or space operable to store and communicate the contents therethrough. Metering systems (not shown), such as metering pumps and/or metering valves, may control the flow rate at which the additives and the base fluid are introduced into the displacement tanks 210, 212.

[0032] One or more fluid level sensors 211, 213 may be connected or otherwise disposed in association with each of the displacement tanks 210, 212. Each level sensor 211, 213 may be operable to generate signals or information indicative of the amount of base fluid, mixed fluid, or another fluid contained within a corresponding displacement tank 210, 212. Each fluid level sensor 211, 213 may comprise conductive, capacitive, vibrating, electromechanical, ultrasonic, microwave, nucleonic, and/or other level detection means, as well as load cells and/or other types of level sensors.

[0033] The cementing unit 200 may also include one or more devices operable to pump and/or meter the base fluid or mixed fluid from the displacement tanks 210, 212 to the mixer 202 via the fluid conduit 214. For example, the cementing unit 200 may include an injection pump 220 operable to pump the mixed fluid from the displacement tanks 210, 212 to the mixer 202. The injection pump 220 may be a metering pump, such as may be operable to control the flow rate at which the base fluid or mixed fluid is introduced into the mixer 202. The injection pump 220 may also be a centrifugal or another type of fluid pump. A metering valve (not shown) may be disposed along the fluid conduit 214 to further control the flow rate at which the base fluid or mixed fluid is introduced into the mixer 202.

[0034] A controller 410 may be operable to monitor and control one or more operations of the cementing unit 200. The controller 410 may be in communication with the various metering valves, metering pumps, and other metering systems described above to adjust or otherwise control density and solids fraction of the mixed fluid, the cement slurry, and/or other mixtures. For example, the controller 410 may be operable to control the volumetric flow rates at which the base fluid and the additives are introduced into the displacement tanks 210, 210, such as to control the concentration of the mixed fluid. The controller 410 may further control the volumetric flow rates at which the bulk cement and the mixed fluid are introduced into the mixer 202, such as to control density and solids fraction of the cement slurry.

[0035] The cement slurry may be selectively discharged from the mixer 202 and received by a mixing tank 222 wherein a plurality of mixing blades or other agitators 224 may agitate the cement slurry to further blend the base fluid and bulk cement. The mixing tank 222 may be or comprise a continuous flow channel or pathway for communicating or conveying the cement slurry over a period of time sufficient to permit adequate blending to occur, such that the cement slurry may reach a predetermined level viscosity and/or comprise other properties. The mixing tank 222 may have a FIFO mode of operation, and may comprise a vessel-type outer housing enclosing a receptacle having an elongated flow pathway or space operable to store and communicate the cement slurry therethrough.

[0036] A fluid level sensor 215 may be connected or otherwise disposed in association with the mixing tank 222. The level sensor 215 may be operable to generate signals or information indicative of the amount of cement slurry or another fluid contained within the mixing tank 222. The level sensor 215 may comprise the same structure and/or mode of operation as each of the fluid level sensors 211, 213 described above.

[0037] The cement slurry may be selectively recirculated through the mixer 202 via a recirculation flow path 226 comprising one or more fluid conduits. Recirculation of the cement slurry may be conducted, for example, to perform additional blending of the cement slurry and/or to introduce additional base fluid or bulk cement to the cement slurry, such as to change the composition and/or properties of the cement slurry. Flow control valves 229, 230 may be selectively opened to permit the cement slurry to recirculate through the recirculation flow path 226. During the recirculation operations, a pump 228 may be operable to recirculate or otherwise move the cement slurry through the recirculation flow path 226 from the mixing tank 222 to the mixer 202.

[0038] The cementing unit 200 may further comprise one or more high pressure pump units 241, 242 fluidly coupled to receive the fluids from the displacement tanks 210, 212 and the mixing tank 222 and discharge the fluids into the wellbore 104. For example, the pump units 241, 242 may receive the mixed fluid or the cement slurry via inlet conduits 231, 232 fluidly connected with the displacement tanks 210, 212 and the mixing tank 222. A bypass conduit 233 may extend between the displacement tanks 210, 212 and the mixing tank 222, bypassing the pump units 241, 242. The bypass conduit 233 may be fluidly connected with the conduit 128 and the inlet conduits 231, 232, such as may permit the mixed fluid or cement slurry from the batch mixer 126 to be received by the pump units 241, 242. Although the cementing unit 200 is shown comprising two pump units 241, 242, it is to be understood that the cementing unit 200 may include other quantities of pump units within the scope of the present disclosure.

[0039] One or more flow sensors 244, 245 may be disposed along the inlet conduit 231 or otherwise in association with the pump unit 241 in a manner permitting the sensing of a fluid flow rate generated by the pump unit 241. For example, the flow sensors 244, 245 may be fluidly coupled in association with fluid inlets 326 (shown in FIG. 3) of the pump unit 241. Each of the flow sensors 244, 245 may generate a signal or information indicative of a flow rate of the fluid introduced into the pump unit 241 and, thus, facilitate monitoring of the flow rate of the fluid discharged by the pump unit 241. Similarly, one or more flow sensors 246, 247 may be disposed along the inlet conduit 232 or otherwise in association with the fluid inlets 326 of the pump unit 242. Each of the flow sensors 246, 247 may generate a signal or information indicative of a flow rate of the fluid introduced into the pump unit 242 and, thus, facilitate monitoring of the flow rate of the fluid discharged by the pump unit 242.

[0040] An inlet valve 221, 223, 225, 227 may be disposed in association with each corresponding fluid inlet 326 of each pump unit 241, 242, such as to selectively fluidly connect and disconnect each pump unit 241, 242 from the mixing tank 222, the displacement tanks 210, 212, and/or other portions of the cementing unit 200. For example, the inlet valves 221, 223 may be coupled along the inlet conduit 231 on opposing sides of the pump unit 241. Similarly, the inlet valves 225, 227 may be coupled along the inlet conduit 232 on opposing sides of the pump unit 242.

[0041] The cementing unit 200 may further comprise outlet conduits 234, 235, each fluidly connected with a corresponding fluid outlet 335 (shown in FIG. 3) of each pump unit 241, 242. Each outlet conduit 234, 235 may include a corresponding fluid outlet valve 238, 239, which may selectively fluidly connect and disconnect each pump unit 241, 242 from the

wellbore 104 and/or other portions of the cementing unit 200 located downstream from the fluid outlet valves 238, 239. The outlet conduits 234, 235 may be fluidly connected with each other via an intermediate or joining conduit 236. A fluid isolation valve 237 may be disposed along the joining conduit 236 to selectively fluidly connect and disconnect the outlet conduits 234, 235. The output conduits 234, 235 and the joining conduit 236 may be or comprise at least a portion of that which is known in the art as a treating or discharge manifold 250.

[0042] The outlet conduit 234 may be fluidly connected with a fluid conduit 240, which may be or form a portion of the fluid conduit 124 to fluidly couple the pump unit 241, and perhaps the pump unit 242, with the wellbore 104. The fluid conduit 240 may be or comprise at least a portion of that which is known in the art as a cement line 240, which may be utilized to inject the cement slurry into the wellbore 104 during cementing operations. The outlet conduit 235 may be fluidly connected with a fluid conduit 243, which may form a portion of the fluid conduit 124 to fluidly couple the pump unit 242, and perhaps pump unit 241, with the wellbore 104. The fluid conduit 243 may be or comprise at least a portion of that which is known in the art as a kill line 243, which may be utilized to inject the cement slurry into the wellbore 104 during well kill operations. The outlet conduit 234 may be selectively isolated from the cement line 240 by a fluid valve 248, while the outlet conduit 235 may be selectively isolated from the kill line 243 by a fluid valve 249. The discharge manifold 250, the fluid valves 237, 238, 239, 248, 249, the cement line 240, and the kill line 243 may be or comprise that which is known in the art as treating iron or equipment.

[0043] The fluid valves 221, 223, 225, 227, 237, 238, 239, 248, 249 may be or comprise ball valves, globe valves, butterfly valves, and/or other types of fluid valves, such as may be selectively opened and closed to permit and prevent fluid flow. Each fluid valve 221, 223, 225, 227, 237, 238, 239, 248, 249 may be actuated remotely by a corresponding actuator operatively coupled with each of the fluid valves 221, 223, 225, 227, 237, 238, 239, 248, 249. For clarity, just actuator 251 associated with the fluid inlet valve 221 is identified with a numeral in FIG. 2, however each of the other fluid valves 223, 225, 227, 237, 238, 239, 248, 249 may comprise a corresponding actuator having the same or similar structure and/or mode of operation. The actuator 251 may be or comprise an electric actuator, such as a solenoid or motor, or a fluid actuator, such as a pneumatic or hydraulic cylinder or rotary actuator. Each of the fluid valves 221, 223, 225, 227, 237, 238, 239, 248, 249 may also be actuated manually, such as by a lever (not shown).

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[0044] Each fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249 may also include a corresponding position sensor operable to generate a signal or information indicative of an actual position of a corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249. The position sensors may be operable to monitor in-real time the actual position of the fluid valves 221, 223, 225, 227, 237, 237, 238, 239, 248, 249, which may include an open-flow position and a closed-flow position. For clarity, just position sensor 253 associated with the fluid inlet valve 221 is identified with a numeral in FIG. 2, however each of the other fluid valves 223, 225, 227, 237, 238, 239, 248, 249 may comprise a corresponding position sensor having the same or similar structure and/or mode of operation. Furthermore, each position sensor may be disposed in association with the corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249 in a manner permitting sensing of the actual position of the corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249. For example, each position sensor may monitor position, orientation, and/or rotation of a fluid-blocking portion of the corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249 or another moving portion of the corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249, such as a rotating shaft or stem. Each position sensor may be coupled with or disposed adjacent the corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249, or each position sensor may be incorporated as a part of the corresponding fluid valve 221, 223, 225, 227, 237, 237, 238, 239, 248, 249. The position sensors may be or comprise proximity sensors, such as capacitive sensors, inductive sensors, magnetic sensors, Hall effect sensors, and/or reed switches, among other examples. The position sensors may also or instead include linear position sensors, such as linear potentiometers. The position sensors may also or instead include rotary position sensors, such as encoders, rotary potentiometers, synchros, resolvers, and/or rotary variable differential transformers (RVDT), among other examples.

[0045] The discharge manifold 250 may be fluidly connected with an adjustable choke valve 252, such as may be operable to bleed or otherwise relieve fluid pressure from the discharge manifold 250. The choke valve 252 may be operable to progressively open, such as to permit the pressurized fluid within the discharge manifold 250 to relieve or otherwise flow out of the discharge manifold 250 via a relief conduit 254. The relief conduit 254 may fluidly connect the discharge manifold 250 with the displacement tanks 210, 212, such as may permit the pressurized fluid within the discharge manifold 250 to be discharged into the displacement tanks 210, 212. The choke valve 252 may be or comprise a needle valve, a

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metering valve, a butterfly valve, a globe valve, or another valve operable to progressively or gradually open and close to control rate of fluid flow permitted through the choke valve 252.

[0046] The choke valve 252 may be remotely progressively opened and closed by a corresponding actuator 256 operatively coupled with the choke valve 252. The choke valve 252 may also be progressively opened and closed manually via a lever or a wheel 258. The choke valve 252 may also include a corresponding position sensor 260 operable to generate a signal or information indicative of an actual position of the choke valve, such as to monitor in-real time the actual position of the choke valve 252. The actual positions of the choke valve 252 may include a fully-open flow position, a fully-closed flow position, and intermediate or incremental positions between the fully-open flow position and the fully-closed flow positions. Each intermediate position may be indicative of an amount or percentage that the choke valve 252 is open and, thus, indicative of the flow rate through the choke valve 252. The actuator 256 and the position sensor 260 of the choke valve 252 may comprise the same or similar structure and/or mode of operation as the actuator 251 and the position sensor 253 described above. Also, the actuator 256 and the position sensors 260 may be disposed in association with the choke valve 252 in a manner that is similar in which the actuator 251 and the position sensor 253 are disposed in association with the fluid valve 221 described above.

[0047] The cementing unit 200 may further comprise bleed valves 262, 264, fluidly connected in series between the pump units 241, 242 and the choke valve 252. The bleed valves 262, 264 may be disposed along the outlet conduit 235 and may be operable to selectively fluidly connect and disconnect the choke valve 252 from the discharge manifold 250. The bleed valves 262, 264 may be or comprise ball valves, globe valves, butterfly valves, and/or other types of fluid valves, such as may be selectively opened and closed to permit and prevent fluid flow. Each bleed valve 262, 264 may be actuated remotely by a corresponding actuator 266, 268 operatively coupled in association with the bleed valves 262, 264. Each bleed valve 262, 264 may include a corresponding position sensor 272, 274 operatively connected thereto and operable to generate a signal or information indicative of an actual position of the each bleed valve 262, 264, such as to monitor in-real time the actual position of each bleed valve 262, 264. The actual positions of the bleed valves 262, 264 may include an open-flow position and a closed-flow position. The actuators 266, 268 and the position sensors 272, 274 may comprise the same or similar structure and/or mode of operation as the actuator 251 and the position sensor 253 described above. Also, the actuators 266, 268 and the position sensors 272, 274 may be disposed in association with the

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corresponding bleed valves 262, 264 in a manner that is similar in which the actuator 251 and the position sensor 253 are disposed in association with the fluid valve 221.

[0048] The cementing unit 200 may further comprise one or more pressure sensors disposed in association with the pump units 241, 242, the discharge manifold 250, and/or the cement line 240 in a manner permitting the sensing of fluid pressure within the pump units 241, 242, the discharge manifold 250, and/or the cement line 240. Each pressure sensor may be operable to generate an electrical signal and/or information indicative of the fluid pressure within the pump units 241, 242, the discharge manifold 250, and/or cement line 240. For example, a pressure sensor 276 may be disposed in association with the cement line 240, between the wellhead 108 and the fluid valve 248. As shown in FIG. 3, a pressure sensor 317 may also or instead be disposed in association with each pump unit 241, 242 to monitor the fluid pressure within each pump unit 241, 242 and/or at the corresponding fluid outlets 335.

[0049] The controller 410 may be further operable to monitor and control other operations of the cementing unit 200. To facilitate such monitoring and control, the controller 410 may be in communication with the valve actuators 251, 256, 266, 268 to permit the controller 410 to open and close or otherwise control the fluid valves 221, 223, 225, 227, 237, 238, 239, 248, 249, 252, 262, 264. The controller 410 may be in communication with the valve position sensors 253, 260, 272, 274 to permit the controller 410 to receive the feedback signals generated by the position sensors 253, 260, 272, 274 and, thus, verify that the valves 221, 223, 225, 227, 237, 238, 239, 248, 249, 252, 262, 264 transitioned to their intended position. The controller 410 may also be in communication with one or more portions of the pump units 241, 242, such as may permit the controller 410 to activate, deactivate, and control pumping or operating speed of the pump units 241, 242, as well as the flow rate and pressure generated by the pump units 241, 242. The controller 410 may also be in communication with the pressure sensors 276, 317, the flow sensors 244, 245, 246, 247, and the fluid level sensors 211, 213, 215, such as may permit the controller 410 to receive the information indicative of fluid pressure generated by the pump units 241, 242, the flow rate generated by the pump units 241, 242, and the amount of fluid available for pumping by the pump units 241, 242. Accordingly, the controller 410 may be operable to monitor and control one or more portions of the cementing unit 200, such as to control pressure, flow rates, and/or movement of fluids, including the base fluid, the mixed fluid, and the cement slurry, to implement the example methods and/or processes described herein.

[0050] Communication between the controller 410 and the various portions of the cementing unit 200 may be via wired and/or wireless communication means. However, for

clarity and ease of understanding, such communication means are not depicted in FIG. 2, as a person having ordinary skill in the art will appreciate that such communication means are within the scope of the present disclosure. Furthermore, although the controller 410 is shown as being associated with the cementing unit 200, the controller 410 may be implemented as part of the control/power center 130 or otherwise located externally from the cementing unit 200.

[0051] FIG. 3 is a perspective view of a portion of an example implementation of the pump unit 241, 242 shown in FIG. 2 according to one or more aspects of the present disclosure, and designated in FIG. 3 by reference numeral 300. FIG. 4 is a side sectional view of a portion of the pump unit 300 shown in FIG. 3. Portions of the pump unit 300 shown in FIGS. 3 and 4 are shown in phantom lines, such as to prevent obstruction from view of other portions of the pump unit 300. The following description refers to FIGS. 1-4, collectively.

[0052] The pump unit 300 comprises a pump 302 operatively coupled with and actuated by a prime mover 304. The pump 302 includes a power section 308 and a fluid section 310. The fluid section 310 may comprise a pump housing 316 having a plurality of fluid chambers 318. One end of each fluid chamber 318 may be plugged by a cover plate 320, such as may be threadedly engaged with the pump housing 316 while an opposite end of each fluid chamber 318 may contain a reciprocating member 322 slidably disposed therein and operable to displace the fluid within the corresponding fluid chamber 318. Although the reciprocating member 322 is depicted as a plunger, the reciprocating member 322 may also be implemented as a piston, diaphragm, or another reciprocating fluid displacing member.

[0053] Each fluid chamber 318 is fluidly connected with a corresponding one of a plurality of fluid inlet cavities 324 each adapted for communicating fluid from fluid inlets 326 into a corresponding fluid chamber 318. The fluid inlets 326 may be in fluid communication with a corresponding inlet conduit 231, 232. Each fluid inlet cavity 324 may contain an inlet valve 328 operable to control fluid flow from the fluid inlets 326 into the fluid chamber 318. Each inlet valve 328 may be biased toward a closed flow position by a first spring or another biasing member 330, which may be held in place by an inlet valve stop 332. Each inlet valve 328 may be actuated to an open flow position by a selected or predetermined differential pressure between the corresponding fluid inlet cavity 324 and the fluid inlets 326.

[0054] Each fluid chamber 318 is also fluidly connected with a fluid outlet cavity 334 extending through the pump housing 316 transverse to the reciprocating members 322. The

fluid outlet cavity 334 is adapted for communicating pressurized fluid from each fluid chamber 318 into one or more fluid outlets 335 fluidly connected at one or both ends of the fluid outlet cavity 334. The fluid outlets 335 may be in fluid communication with a corresponding outlet conduit 234, 235. The fluid section 310 also contains a plurality of outlet valves 336 each operable to control fluid flow from a corresponding fluid chamber 318 into the fluid outlet cavity 334. Each outlet valve 336 may be biased toward a closed flow position by a spring or another biasing member 338, which may be held in place by an outlet valve stop 340. Each outlet valve 336 may be actuated to an open flow position by a selected or predetermined differential pressure between the corresponding fluid chamber 318 and the fluid outlet cavity 334. The fluid outlet cavity 334 may be plugged by cover plates 342, such as may be threadedly engaged with the pump housing 316.

[0055] During pumping operations, portions of the power section 308 of the pump unit 300 rotate in a manner that generates a reciprocating linear motion to move the reciprocating members 322 longitudinally within the corresponding fluid chambers 318, thereby alternatingly drawing and displacing the fluid within the fluid chambers 318. With regard to each reciprocating member 322, as the reciprocating member 322 moves out of the fluid chamber 318, as indicated by arrow 321, the pressure of the fluid inside the corresponding fluid chamber 318 decreases, thus creating a differential pressure across the corresponding fluid inlet valve 328. The pressure differential operates to compress the biasing member 330, thus actuating the fluid inlet valve 328 to an open flow position to permit the fluid from the fluid inlets 326 to enter the corresponding fluid inlet cavity 324. The fluid then enters the fluid chamber 318 as the reciprocating member 322 continues to move longitudinally out of the fluid chamber 318 until the pressure difference between the fluid inside the fluid chamber 318 and the fluid at the fluid inlets 326 is low enough to permit the biasing member 330 to actuate the fluid inlet valve 328 to the closed flow position. As the reciprocating member 322 begins to move longitudinally back into the fluid chamber 318, as indicated by arrow 323, the pressure of the fluid inside of fluid chamber 318 begins to increase. The fluid pressure inside the fluid chamber 318 continues to increase as the reciprocating member 322 continues to move into the fluid chamber 318 until the pressure of the fluid inside the fluid chamber 318 is high enough to overcome the pressure of the fluid inside the fluid outlet cavity 334 and compress the biasing member 338, thus actuating the fluid outlet valve 336 to the open flow position and permitting the pressurized fluid to move into the fluid outlet cavity 334, the fluid outlets 335, and the corresponding fluid outlet conduit 234, 235.

[0056] The pump unit 300 may further comprise a pressure sensor 317 disposed in association with the fluid section 310 in a manner permitting the sensing of fluid pressure at the fluid outlets 335. For example, the pressure sensor 317 may extend through one or more of the cover plates 342 or other portions of the corresponding pump housing 316 to monitor pressure within the fluid outlet cavity 334 and, thus, the fluid outlets 335 and the corresponding outlet conduits 234, 235.

[0057] The fluid flow rate generated by the pump unit 300 may depend on the physical size of the reciprocating members 322 and fluid chambers 318, as well as the pump unit operating speed, which may be defined by the speed or rate at which the reciprocating members 322 cycle or move within the fluid chambers 318. The pumping speed, such as the speed or the rate at which the reciprocating members 322 move, may be related to the rotational speed of the power section 308 and/or the prime mover 304. Accordingly, the fluid flow rate generated by the pump unit 300 may be controlled by controlling the rotational speed of the power section 308 and/or the prime mover 304.

[0058] The prime mover 304 may comprise an engine, such as a gasoline engine or a diesel engine, an electric motor, such as a synchronous or asynchronous electric motor, including a synchronous permanent magnet motor, a hydraulic motor, or another prime mover operable to drive or otherwise rotate a drive shaft 352 of the power section 308. The drive shaft 352 may be enclosed and maintained in position by a power section housing 354. To prevent relative rotation between the power section housing 354 and the prime mover 304, the power section housing 354 and prime mover 304 may be fixedly coupled together or to a common base, such as a trailer of the mobile carrier 111.

[0059] The prime mover 304 may comprise a rotatable output shaft 356 operatively connected with the drive shaft 352 by a gear train or transmission 362, which may comprise at least one spur gear 358 coupled with the drive shaft 352 and at least one pinion gear 360 coupled with a support shaft 361. The output shaft 356 and the support shaft 361 may be coupled, such as may facilitate transfer of torque from the prime mover 304 to the support shaft 361, the pinion gear 360, the spur gear 358, and the drive shaft 352. For clarity, FIGS. 3 and 4 show the transmission 362 comprising a single spur gear 358 engaging a single pinion gear 360, however, it is to be understood that the transmission 362 may comprise two or more sets of gears, such as may permit the transmission 362 to be shifted between different gear configurations to control the operating speed of the drive shaft 352 and/or torque transferred to the drive shaft 352. Accordingly, the transmission 362 may be shifted to

control the rotational speed of the power section 308 and, thus, the pumping speed of the pump unit 300 to control the fluid flow rate generated by the pump unit 300.

[0060] The drive shaft 352 may be implemented as a crankshaft comprising a plurality of axial journals 364 and offset journals 366. The axial journals 364 may extend along a central axis of rotation of the drive shaft 352, while the offset journals 366 may be offset from the central axis of rotation by a selected or predetermined distance and spaced 120 degrees apart with respect to the axial journals 364. The drive shaft 352 may be supported in position within the power section 308 by the power section housing 354, wherein two of the axial journals 364 may extend through opposing openings in the power section housing 354.

[0061] The power section 308 and the fluid section 310 may be coupled or otherwise connected together. For example, the pump housing 316 may be fastened with the power section housing 354 by a plurality of threaded fasteners 382. The pump 302 may further comprise an access door 398, which may facilitate access to portions of the pump 302 located between the power section 308 and the fluid section 310, such as during assembly and/or maintenance of the pump 302.

[0062] To transform and transmit the rotational motion of the drive shaft 352 to a reciprocating linear motion of the reciprocating members 322, a plurality of crosshead mechanisms 385 may be utilized. For example, each crosshead mechanism 385 may comprise a connecting rod 386 pivotally coupled with a corresponding offset journal 366 at one end and with a pin 388 of a crosshead 390 at an opposing end. During pumping operations, walls and/or interior portions of the power section housing 354 may guide each crosshead 390, such as may reduce or eliminate lateral motion of each crosshead 390. Each crosshead mechanism 385 may further comprise a piston rod 392 coupling the crosshead 390 with the reciprocating member 322. The piston rod 392 may be coupled with the crosshead 390 via a threaded connection 394 and with the reciprocating member 322 via a flexible connection 396.

[0063] The pump unit 300 may further comprise one or more rotary sensors 311 operable to generate a signal or information indicative of rotational position, rotational speed, and/or operating frequency of the pump 302. For example, one or more of the rotary sensors 311 may be operable to convert angular position or motion of the drive shaft 352 or another rotating portion of the power section 308 to an electrical signal indicative of pumping speed of the pump unit 300. The rotary sensor 311 may be mounted in association with an external portion of the drive shaft 352 or other rotating members of the power section 308. The rotary sensor 311 may also or instead be mounted in association of the prime mover 304 to monitor

the rotational position and/or rotational speed of the prime mover 304, which may be utilized to determine the pumping speed of the pump unit 300. The rotary sensor 311 may be or comprise an encoder, a rotary potentiometer, a synchro, a resolver, and/or an RVDT, among other examples.

[0064] The pump unit 300 may also include prime mover power and/or control components, such as a variable speed or frequency drive (VFD) 313 and/or an engine throttle control 315, which may be utilized to facilitate control of the prime mover 304 by the controller 410. The VFD 313/throttle control 315 may be connected with or otherwise in communication with the prime mover 304 via mechanical and/or electrical communication means 314. For example, the VFD 313 may receive control signals from the controller 410 and output corresponding electrical power to control the speed of the prime mover 304 and, thus, control the speed of the pump unit 300. The throttle control 315 may receive control signals from the controller 410 and output a corresponding electrical or mechanical throttle control signal to control the speed of the prime mover 304. Although the VFD 313/throttle control 315 is shown located near or in association with the prime mover 304, the VFD 313/throttle control 315 may be located or disposed at a distance from the prime mover 304. For example, the VFD 313/throttle control 315 may be or form a portion of the control/power center 130. The pump unit 300 may comprise the VFD 313 in implementations in which the prime mover 304 is or comprises an electric motor and the pump unit 300 may comprise the engine throttle control 315 in implementations in which the prime mover 304 is or comprises an engine.

[0065] The prime mover 304 may be cooled and/or lubricated by a lube pump unit 312 operatively coupled with the prime mover 304. The lube pump unit 312 may impart flow of lubricant through portions of the prime mover 304, such as to remove heat from the prime mover 304 and/or lubricate moving portions of the prime mover 304. The lube pump unit 312 may comprise a pump portion (not shown) and an actuator portion (not shown) operable to actuate the pump portion. The actuator portion of the lube pump unit 312 and, thus, the pumping operations of the lube pump unit 312 may be controlled and/or powered by the VFD 313, which may be connected with or otherwise in communication with the lube pump unit 312 via the communication means 314, such as electrical communication means. Functionality or operation of the lube pump unit 312 may be monitored or confirmed by monitoring lubricant pressure and/or lubricant flow rate generated by the lube pump unit 312. For example, the lubricant pressure and flow rate may be monitored by corresponding

pressure and flow rate sensors (not shown) disposed in association with the lube pump unit 312 and in communication with the controller 410.

[0066] The prime mover 304 may also or instead be cooled by a cooling fan assembly or blower unit 305 disposed in association with the prime mover 304. The blower unit 305 may impart air movement, such as to remove heat from the prime mover 304 or otherwise prevent the prime mover 304 from overheating. The blower unit 305 may also remove heat from the lubricant being pumped by the lube pump unit 312. The blower unit 305 may comprise a plurality of blades (not shown) and an actuator portion (not shown) operable to actuate the blades. The actuator portion of the blower unit 305 and, thus, the cooling operations of the blower unit 305 may be controlled and/or powered by the VFD 313. The VFD 313 may be connected with or otherwise in communication with the blower unit 305 via the communication means 314, such as electrical communication means. Functionality or operation of the blower unit 305 may be monitored or confirmed by monitoring air pressure and/or air flow rate generated by the blower unit 305. The air pressure and air flow rate may be monitored by corresponding pressure and flow rate sensors (not shown) disposed in association with the blower unit 305 and in communication with the controller 410.

[0067] A temperature sensor 307, such as a resistance temperature detector (RTD), may be disposed in association with the prime mover 304, such as to generate a signal or information indicative of a temperature of the prime mover 304. For example, the temperature sensor 307 may monitor the temperature within a motor winding, an engine housing, or within another portion of the prime mover 304. The temperature sensor 307 may be in communication with the controller 410, which may shut down the prime mover 304 if the detected temperature level exceeds a predetermined temperature level.

[0068] A moisture sensor 309 may also be disposed in association with the prime mover 304, such as to generate a signal or information indicative of moisture present at or near the prime mover 304. The moisture sensor 309 may be in communication with the controller 410, which may shut down the prime mover 304 if the moisture is detected by the moisture sensor 309.

[0069] Although FIGS. 3 and 4 show the pump unit 300 comprising a triplex reciprocating pump 302, which has three fluid chambers 318 and three reciprocating members 322, implementations within the scope of the present disclosure may include the pump 302 as or comprising a quintuplex reciprocating pump having five fluid chambers 318 and five reciprocating members 322, or a pump having other quantities of fluid chambers 318 and reciprocating members 322. It is further noted that the pump 302 described above and

shown in FIGS. 3 and 4 is merely an example, and that other pumps, such as diaphragm pumps, gear pumps, external circumferential pumps, internal circumferential pumps, lobe pumps, and other positive displacement pumps, are also within the scope of the present disclosure.

[0070] Various portions of the cementing unit 200 described above may collectively form a control system 400, which may be operable to monitor and/or control operations of the cementing unit 200, including the fluid pressure and fluid flow rate generated by the pump units 241, 242. FIG. 5 is a schematic view of a portion of an example implementation of a control system 400 according to one or more aspects of the present disclosure. The following description refers to FIGS. 1-5, collectively.

[0071] The control system 400 may include the controller 410 in communication with the valve actuators 251, 256, 266, 268, the position sensors 253, 260, 272, 274, the flow sensors 244, 245, 246, 247, the pressure sensors 276, 317, the transmission 362, the rotary sensor 311, the temperature sensor 307, the moisture sensor 309, the fluid level sensors 211, 213, 215, and the prime mover 304, the lube pump unit 312, and the blower unit 305 via the VFD 313/throttle control 315. For clarity, these and other components in communication with the controller 410 will be collectively referred to hereinafter as "sensors and controlled components." The controller 410 may be operable to execute example machine-readable instructions to implement at least a portion of one or more of the example methods and/or processes described herein, and/or to implement at least a portion of one or more of the example systems described herein.

[0072] The controller 410 may be or comprise, for example, one or more processors, special-purpose computing devices, servers, personal computers, personal digital assistant (PDA) devices, smartphones, internet appliances, and/or other types of computing devices. The controller 410 may comprise a processor 412, such as a general-purpose programmable processor. The processor 412 may comprise a local memory 414, and may execute coded instructions 432 present in the local memory 414 and/or another memory device. The processor 412 may execute, among other things, machine-readable instructions or programs to implement the example methods and/or processes described herein. The programs stored in the local memory 414 may include program instructions or computer program code that, when executed by an associated processor, facilitate the cementing unit 200 to perform the example methods and/or processes described herein. The processor 412 may be, comprise, or be implemented by one or a plurality of processors of various types suitable to the local application environment, and may include one or more of general-purpose computers,

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special-purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as non-limiting examples. Of course, other processors from other families are also appropriate.

[0073] The processor 412 may be in communication with a main memory 417, such as may include a volatile memory 418 and a non-volatile memory 420, perhaps via a bus 422 and/or other communication means. The volatile memory 418 may be, comprise, or be implemented by random access memory (RAM), static random access memory (SRAM), synchronous dynamic random access memory (SDRAM), dynamic random access memory (DRAM), RAMBUS dynamic random access memory (RDRAM), and/or other types of random access memory devices. The non-volatile memory 420 may be, comprise, or be implemented by read-only memory, flash memory, and/or other types of memory devices. One or more memory controllers (not shown) may control access to the volatile memory 418 and/or non-volatile memory 420. The controller 410 may be operable to store or record information entered by the human operators and/or information generated by the sensors and controlled components on the main memory.

[0074] The controller 410 may also comprise an interface circuit 424. The interface circuit 424 may be, comprise, or be implemented by various types of standard interfaces, such as an Ethernet interface, a universal serial bus (USB), a third generation input/output (3GIO) interface, a wireless interface, and/or a cellular interface, among others. The interface circuit 424 may also comprise a graphics driver card. The interface circuit 424 may also comprise a communication device, such as a modem or network interface card to facilitate exchange of data with external computing devices via a network (*e.g.*, Ethernet connection, digital subscriber line (DSL), telephone line, coaxial cable, cellular telephone system, satellite, *etc.*). One or more of the sensors and controlled components may be connected with the controller 410 via the interface circuit 424, such as may facilitate communication between the sensors and controlled components and the controller 410.

[0075] One or more input devices 426 may also be connected to the interface circuit 424. The input devices 426 may permit the human operators to enter the coded instructions 432, operational set-points, and/or other data into the processor 412. The operational set-points may include, but not limited to, a pressure ramp set-point, a pressure set-point, a pressure duration set-point, flow rate ramp set-point, a flow rate set-point, a fluid volume set-point, pump unit operating speed set-point, among other examples. Additional operational set-points may be described below. The input devices 426 may be, comprise, or be implemented

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by a keyboard, a mouse, a touchscreen, a track-pad, a trackball, an isopoint, and/or a voice recognition system, among other examples. One or more output devices 428 may also be connected to the interface circuit 424. The output devices 428 may be, comprise, or be implemented by display devices (*e.g.*, a liquid crystal display (LCD) or cathode ray tube display (CRT), among others), printers, and/or speakers, among other examples. The controller 410 may also connect with one or more mass storage devices 430 and/or a removable storage medium 434, such as may be or include floppy disk drives, hard drive disks, compact disk (CD) drives, digital versatile disk (DVD) drives, and/or USB and/or other flash drives, among other examples.

[0076] The coded instructions 432, the operational set-points, and/or other data may be stored in the mass storage device 430, the main memory 417, the local memory 414, and/or the removable storage medium 434. Thus, the controller 410 may be implemented in accordance with hardware (perhaps implemented in one or more chips including an integrated circuit, such as an application specific integrated circuit), or may be implemented as software or firmware for execution by the processor 412. In the case of firmware or software, the implementation may be provided as a computer program product including a computer readable medium or storage structure embodying computer program code (*i.e.*, software or firmware) thereon for execution by the processor 412.

[0077] The coded instructions 432 may include program instructions or computer program code that, when executed by the processor 412, may cause the cementing unit 200 to perform methods, processes, and/or routines described herein. For example, the controller 410 may receive and process the operational set-points and/or the signals or information generated by the various sensors described herein. Based on the received operational set-points and sensor information, the controller 410 may cause the cementing unit 200 and/or other portions of the wellsite system 100 to automatically perform and/or undergo one or more operations or routines within the scope of the present disclosure. For example, the controller 410 may cause the cementing unit 200 to perform an initialization of the cementing unit 200, a pressure calibration of the cementing unit 200, a pressure test of the cementing unit 200, a flow rate calibration of the cementing unit 200, a flow rate test of the cementing unit 200, a cement pumping operation of the cementing unit 200, among other examples, substantially without manual control of the various portions of the cementing unit 200 by human operators. The controller 410 may also assess operational health of the cementing unit 200, including the pump units 241, 242, the fluid valves 221, 223, 225, 227, 237, 238, 239, 248, 249, 252, 262, 264, and the discharge manifold 250. Also, if a plurality of

cementing units 200 are utilized at the wellsite 102 to perform a cementing job or operation, the controller 410 may receive information designating which one or more of the plurality of cementing units 200 may perform the operations or routines described herein.

[0078] The pressure and flow rate tests may be performed by the cementing unit 200 before the cement pumping operations. For example, the pressure test may permit an automated verification that the high pressure portions of the cementing unit 200, including the manifold 250 and the fluid valves 237, 238, 239, 248, 249, 252, 262, 264, are properly fastened and that there are no leaks that may cause safety or service quality issues during the cement pumping operation. The pressure test may also validate that the cementing unit 200 is functioning well enough to reach intended high pressures to perform the cement pumping operation. The flow rate test may validate that the cementing unit 200, including the pump units 241, 242, is functioning well enough to reach intended high flow rates that may be utilized during the cement pumping operation. The cement pumping operation may include automated pumping of the cement slurry into the wellbore 104 in a predetermined manner and at a predetermined flow rate and/or pressure.

[0079] The initialization of the cementing unit 200 may be performed before the cement pumping operation to verify that the cementing unit 200 may pump the cement slurry at the intended flow rate and measure the cement flow rate accurately. During or after the initialization, the flow rate calibration of the cementing unit 200 may be performed. The flow rate calibration may include the controller 410 executing the coded instructions 432 or an algorithm to sweep through various prime mover speed settings and/or transmission gear settings to generate a baseline for a database comprising data points correlating a particular operating speed of the cementing unit 200 and a resulting flow rate generated by the cementing unit 200. During flow rate calibration, the coded instructions 432 may cause the controller 410 to increase the output flow rate of the cementing unit 200 to automatically and continuously check for deviations from an expected baseline behavior and utilize feedback, feedforward, and ramping control to update the database with the optimal correlation of the various cementing unit pumping speeds. Accordingly, the flow rate calibration may provide an estimated flow rate ramp indicative of fluid flow rate generated by the cementing unit 200 in response or with respect to the operating or pumping speed of the cementing unit 200. Accordingly, the estimated flow rate ramp may be utilized by the controller 410 to automatically control the pumping speed of the cementing unit 200 by controlling the prime mover 304 and/or transmission 362 to control the flow rate of the cement or other fluid during the cement pumping operation and/or another pumping operation.

[0080] During the initialization of the cementing unit 200, the pressure calibration of the cementing unit 200, the pressure test of the cementing unit 200, the flow rate calibration of the cementing unit 200, the flow rate test of the cementing unit 200, and the cement pumping operation of the cementing unit 200, the cementing unit 200 may utilize the pump units 241, 242 to pump water, brine, mud, the base fluid, the mixed fluid, the cement slurry, and/or other fluids from the mixing tank 222, the displacement tanks 210, 212, and/or other sources, such as the tanks 112, the container 114, and/or the batch mixer 126. Accordingly, unless described otherwise, the one or more fluids being pumped by the pump units 241, 242, may be referred to hereinafter simply as "a fluid."

[0081] FIG. 6 is a flow-chart diagram of at least a portion of an example implementation of a method (500) according to one or more aspects of the present disclosure. The method (500) may be performed utilizing or otherwise in conjunction with at least a portion of one or more implementations of one or more instances of the apparatus shown in one or more of FIGS. 1-5 and/or otherwise within the scope of the present disclosure. For example, the method (500) may be performed and/or caused, at least partially, by the controller 410 executing the coded instructions 432 according to one or more aspects of the present disclosure. Thus, the following description of the method (500) also refers to apparatus shown in one or more of FIGS. 1-5. However, the method (500) may also be performed in conjunction with implementations of apparatus other than those depicted in FIGS. 1-5 that are also within the scope of the present disclosure.

[0082] The method (500) may comprise establishing (505) communication between the cementing unit 200 and the controller 410. As described above, the controller 410 is operable to control operation of the cementing unit 200, such as via operation of the processor 412, the memory 417, and the computer program code 432. The method (500) may further comprise inputting (510) operational set-points, such as may be utilized by the controller 410 to automatically perform a flow rate calibration and/or other operation of the cementing unit 200. Such inputs (510) may be performed by a human operator via the input devices 426 described above, although the controller 410 may also be operable to retrieve the inputs as predetermined values/ranges included in the computer program code 432.

[0083] The method (500) also comprises operating (515) the controller 410 to automatically perform initialization of operation of the cementing unit 200. The initialization may comprise automatically determining (520) operational parameters related to operational status of the cementing unit 200 based on the information generated by the sensors 253, 244, 276, 307, 309, 311, 317, and confirming (525) the operational parameters are within

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corresponding predetermined ranges. The operational parameters may comprise at least one of cementing unit temperature, cementing unit pressure, presence of moisture in association with the cementing unit, cementing unit cooling system pressure, and cementing unit lubrication system pressure, among other examples.

[0084] The determination (520) and confirmation (525) of the operational parameters may be or comprise a pre-calibration parameter condition check performed by the controller 410, such as may include monitoring the operational parameters or signals from the various sensors 253, 244, 276, 307, 309, 311, 317 and confirming that the detected operational parameters are within the corresponding predetermined ranges. If the detected parameters match or are within the predetermined parameters, pre-conditions are met and the initialization may continue. For example, the controller 410 may monitor the temperature sensor 307 to verify that the temperature of the prime mover 304 does not exceed a predetermined threshold. The controller 410 may also monitor the moisture sensor 309 to check if the prime mover 304 is exposed to moisture. If the temperature of the prime mover 304 is greater than, for example, 170 °Celsius (°C) or if the prime mover 304 is exposed to moisture, the initialization (515) may be stopped. The controller 410 may also monitor functionality of the lube pump unit 312 and/or the blower unit 305 by monitoring the lubricant and air pressure and/or flow rate.

[0085] The initialization and/or other portion of the method (500) may also comprise performing (530) the flow rate calibration and/or other operation utilizing the entered (510) operational set-points. The operational set-points may relate to at least one of a fluid volume to be pumped by the cementing unit 200 and a pumping speed of the cementing unit 200 during the performance (530) of the flow rate calibration and/or other operation.

[0086] For example, performing (530) the flow rate calibration may comprise varying (535) pumping speed of the cementing unit 200 while recording the pumping speed and a corresponding flow rate generated by the cementing unit, and estimating or otherwise determining (540) a flow rate ramp relating the flow rate to the pumping speed. The flow rate ramp may relate the recorded fluid flow rate generated by the cementing unit 200 to the recorded pumping speed or operating rate of the cementing unit 200. The flow rate ramp may be utilized as an estimate or projection of an actual fluid flow rate in response to the pumping speed during cement or other pumping operations. The flow rate ramp may be utilized during the cement pumping operations or other pumping operations to control the fluid flow rate by controlling the pumping speed of the cementing unit 200.

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[0087] Varying (535) the pumping speed may comprise increasing (545) the pumping speed of the cementing unit 200 while recording the pumping speed and the corresponding flow rate generated by the cementing unit until a predetermined fluid volume is pumped by the cementing unit 200. Varying (535) the pumping speed may further comprise decreasing (550) the pumping speed of the cementing unit 200 while recording the pumping speed and the corresponding flow rate generated by the cementing unit 200 until the cementing unit 200 stops pumping the fluid. Varying (535) the pumping speed of the cementing unit 200 may be performed by varying the speed of the prime mover 304 via the VFD/engine throttle 313, 315 and/or by shifting between lower and higher speeds or gear ratios of the transmission 362.

[0088] The pumping speed may be increased (545) by a first incremental speed set-point until the predetermined fluid volume is pumped, and the pumping speed may be decreased (550) by a second incremental speed set-point until the cementing unit 200 stops pumping the fluid. In an example implementation, the first and second incremental speed set-points may range between about one and about five revolutions per minute (RPM) for each flow rate and pumping speed reading performed by the controller 410. The predetermined fluid volume may range, for example, between about 50 barrels (BBL) and about 200 BBL of fluid.

[0089] Performing (530) the flow rate calibration may further comprise the controller 410, before varying the pumping speed, confirming that the cementing unit 200 has stopped pumping, confirming that the cementing unit 200 is depressurized, detecting a volume of fluid available for performing the flow rate calibration, and opening (and/or confirming to be open) fluid inlet valves 221, 223, 225, 227 and fluid outlet valves 238, 239 of the cementing unit 200. The controller 410 may confirm that the cementing unit 200 has stopped via the rotary sensors 311. The controller 410 may confirm that the cementing unit 200 is depressurized if the pressure detected by the pressure sensor 317 ranges, for example, between about zero and about 100 pounds per square inch (PSI). Furthermore, the controller 410 may confirm that the fluid volume available for performing the flow rate calibration is sufficient if, for example, the fluid level sensors 211, 213, 215 indicate between about 50 BBL and about 200 BBL of fluid. Also, the controller 410 may confirm that the fluid inlet valves 221, 223, 225, 227 and the fluid outlet valves 238, 239 are open via the valve position sensors 253.

[0090] The method (500) may further comprise operating the controller 410 to automatically confirm (555) that safety parameters are within corresponding predetermined ranges. Safety parameters may include pressure and temperature readings, which if exceeding the predetermined ranges, may cause the controller 410 to shut down the

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initialization. For example, a predetermined threshold of safety related to the prime mover 304 may be a temperature exceeding 170 °C. A predetermined threshold of safety related to the pump units 241, 242 may be a pressure exceeding 20,000 PSI or another pressure exceeding pump unit specifications. A sudden pressure drop detected, for example, within the pump units 241, 242 and/or the manifold 250 may be indicative of a leak or structural failure and may also cause the controller 410 to shut down the initialization. The automatic confirmation (555) that safety parameters are within corresponding predetermined ranges may be perform before, during, and/or after the initialization (515), the flow rate calibration (530), and/or other operations of the cementing unit 200.

[0091] FIG. 7 is a flow-chart diagram of at least a portion of an example implementation of another method (600) according to one or more aspects of the present disclosure. The method (600) may be performed utilizing or otherwise in conjunction with at least a portion of one or more implementations of one or more instances of the apparatus shown in one or more of FIGS. 1-5 and/or otherwise within the scope of the present disclosure. For example, the method (600) may be performed and/or caused, at least partially, by the controller 410 executing the coded instructions 432 according to one or more aspects of the present disclosure. Thus, the following description of the method (600) also refers to apparatus shown in one or more of FIGS. 1-5. However, the method (600) may also be performed in conjunction with implementations of apparatus other than those depicted in FIGS. 1-5 that are also within the scope of the present disclosure.

[0092] The method (600) may comprise establishing (605) communication between the cementing unit 200 and the controller 410. The method (600) also comprises operating (610) the controller 410 to automatically perform a flow rate calibration of the cementing unit 200. Automatically performing (610) the flow rate calibration may include automatically varying (615) the pumping speed of the cementing unit 200 while recording the pumping speed monitored by the rotary sensor 311 and a corresponding flow rate of the cementing unit 200 monitored by the flow sensors 244, 245, 246, 247. The pumping speed may be controlled by controlling the operating speed of the prime mover 304 and/or the gear settings of the transmission 362. A flow rate ramp relating the flow rate to the pumping speed is then estimated or otherwise determined (620) based on the recorded (615) data.

[0093] The method (600) may further include inputting (625) one or more operational set-points, such as a predetermined fluid volume to be pumped by the cementing unit 200. Such inputs (625) may be performed by a human operator via the input devices 426 described above, although the controller 410 may also be operable to retrieve the inputs as

predetermined values/ranges included in the computer program code 432. Varying (615) the pumping speed may comprise increasing (630) the pumping speed while recording the pumping speed and the corresponding flow rate generated by the cementing unit 200 until the predetermined fluid volume or other operational set-point is met, and decreasing (635) the pumping speed of the cementing unit 200 while recording the pumping speed and the corresponding flow rate generated by the cementing unit 200 until the cementing unit 200 stops pumping a fluid. For example, the operational set-point may be a predetermined range of the fluid volume to be pumped by the cementing unit 200, such as between about 20 BBL and about 100 BBL of fluid, and/or between about 20% and about 30% of a fluid volume allocated for the performance (610) of the flow rate calibration.

[0094] The entered (625) set-points may also comprise first and second incremental speed set-points, such that the pumping speed may be increased (630) by the first incremental speed set-point until the operational set-point is met, and the pumping speed may be decreased (635) by the second incremental speed set-point until the cementing unit 200 stops pumping the fluid. For example, the first and second incremental speed set-points may range between about one and about five RPM for each flow rate and pumping speed recording (615) performed by the controller 410.

[0095] The entered (625) set-points may also comprise a first incremental percentage set-point, a second incremental percentage set-point, a fluid flow rate set-point, and a fluid volume set-point. For example, determining (620) the flow rate ramp may include determining a first flow rate ramp based on the data recorded (615) while increasing (630) and decreasing (635) the pumping speed, and varying (615) the pumping speed while recording data may further comprise increasing (640) the pumping speed by a speed corresponding to the first incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp while recording the pumping speed monitored by the rotary sensor 311 and the corresponding flow rate of the cementing unit 200 monitored by the flow sensors 244, 245, 246, 247 until the fluid volume set-point is met. Varying (615) the pumping speed may further comprise decreasing (645) the pumping speed by a speed corresponding to the second incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp while recording the pumping speed monitored by the rotary sensor 311 and a corresponding flow rate of the cementing unit 200 monitored by the flow sensors 244, 245, 246, 247 until the cementing unit stops pumping the fluid. Determining (620) the flow rate ramp(s) may thus also comprise determining a second flow rate ramp relating the flow rate to the pumping speed after the first flow rate ramp was estimated, based

on the data recorded (615) during the second pump speed increase (640) and/or decrease (645) and/or the first flow rate ramp.

[0096] Similarly to the first flow rate ramp, the second flow rate ramp may relate the recorded fluid flow rate to the recorded pumping speed. However, in determining (620) the second flow rate ramp, the controller 410 may cause the cementing unit 200 to increase (640) and then decrease (645) by the first and second incremental percentage set-points of the fluid flow rate set-point. Accordingly, the controller 410 may increase (640) and decrease (645) the flow rate of the cementing unit 200 by the incremental percentage set-points by increasing and decreasing the operating speed of the cementing unit 200 by a speed that corresponds to the incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp.

[0097] In an example implementation, the first and second incremental percentage set-points may each range between about 1% and about 10% of the fluid flow rate set-point. The fluid flow rate set-point may range, for example, between about four BBL per minute (BPM) and about ten BPM. The fluid volume set-point may range between about 50 BBL and about 200 BBL of fluid. The fluid volume set-point may instead range, for example, between about 70% and about 80% of the fluid volume allocated for performance (610) of the flow rate calibration.

[0098] Similarly to as described above with respect to performing (530) the flow rate calibration of the method (500) shown in FIG. 6, performing (610) the flow rate calibration may further comprise, before varying (615) the pumping speed, confirming that the cementing unit 200 has stopped pumping, confirming that the cementing unit 200 is depressurized, detecting a volume of fluid available for the performance (610) of the flow rate calibration, and opening the fluid inlet valves 221, 223, 225, 227 and fluid outlet valves 238, 239 of the cementing unit 200. The method (600) may also comprise operating the controller 410 to automatically confirm (650) that safety parameters are within corresponding predetermined ranges before, during, and/or after the performance (610) of the flow rate calibration, such as before, during, and/or after varying (615) the pumping speed while recording data as described above.

[0099] FIG. 8 is a flow-chart diagram of at least a portion of an example implementation of another method (700) according to one or more aspects of the present disclosure. The method (700) may be performed utilizing or otherwise in conjunction with at least a portion of one or more implementations of one or more instances of the apparatus shown in one or more of FIGS. 1-5 and/or otherwise within the scope of the present disclosure. For example,

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the method (700) may be performed and/or caused, at least partially, by the controller 410 executing the coded instructions 432 according to one or more aspects of the present disclosure. Thus, the following description of the method (700) also refers to apparatus shown in one or more of FIGS. 1-5. However, the method (700) may also be performed in conjunction with implementations of apparatus other than those depicted in FIGS. 1-5 that are also within the scope of the present disclosure.

[00100] The method (700) may comprise establishing (705) communication between the cementing unit 200 and the controller 410. The method (700) may also comprise inputting (710) one or more set-points. For example, an input (710) set-point may be a fluid volume set-point, such as may range between about 50 BBL and about 500 BBL of fluid, although other values/ranges are also within the scope of the present disclosure. The inputs (710) may be performed by a human operator via the input devices 426 described above, although the controller 410 may also be operable to retrieve the inputs as predetermined values/ranges included in the computer program code 432.

[00101] The method also comprises operating (715) the controller 410 to automatically perform a cement pumping operation of the cementing unit 200. Performing (715) the cement pumping operation may comprise automatically increasing (720) pumping speed of the cementing unit 200 while recording the pumping speed, the pressure generated by the cementing unit 200 corresponding to the pumping speed, and the cement flow rate corresponding to the pumping speed and/or pressure. Performing (715) the cement pumping operation may then comprise automatically maintaining (725) the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate, and then decreasing (730) the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate until the cementing unit 200 has stopped pumping cement and the volume of the pumped cement is substantially equal to the fluid volume set-point.

[00102] The input (710) set-points may also comprise a fluid flow rate set-point. For example, the cement pumping operation (715) may comprise increasing (720) pumping speed to reach the flow rate set-point and maintaining (725) the pumping speed to maintain the fluid flow rate set-point. The fluid flow rate set-point may range, for example, between about four BPM and about ten BPM. The fluid flow rate may be increased (720) and decreased (730), for example, at a rate ranging between about 0.50 BPM/minute and about 5 BPM/minute.

[00103] Similarly to as described above with respect to the method (500), operation (715) of the controller 410 for the cementing operation may further comprise, before increasing

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(720), maintaining (725), and decreasing (730) the pumping speed, confirming that the cementing unit 200 has stopped pumping and is depressurized, confirming that a volume of fluid is available for performing the cement pumping operation, and opening (and/or confirming to be open) the fluid inlet valves 221, 223, 225, 227 and fluid outlet valves 238, 239 of the cementing unit 200.

[00104] The method (700) may also comprise operating (750) the controller 410 to initialize the cementing unit 200, as described above with respect to FIG. 6. The method (700) may also comprise confirming (760) that safety parameters are within predetermined ranges, similar to as described above. Such confirmation (760) may be performed before, during, and/or after the initialization (750) and/or the cementing operation (715). For example, such confirmation (760) may be or comprise a pre-calibration parameter condition check performed by the controller 410, such as may include monitoring the operational parameters or signals from the various sensors 253, 244, 276, 307, 309, 311, 317 and confirming that the detected operational parameters are within the corresponding predetermined ranges. If the detected parameters match the predetermined parameters, pre-conditions are met and the cementing operation (715) may continue.

[00105] FIG. 9 is a flow-chart diagram of at least a portion of an example implementation of another method (800) according to one or more aspects of the present disclosure. The method (800) may be performed utilizing or otherwise in conjunction with at least a portion of one or more implementations of one or more instances of the apparatus shown in one or more of FIGS. 1-5 and/or otherwise within the scope of the present disclosure. For example, the method (800) may be performed and/or caused, at least partially, by the controller 410 executing the coded instructions 432 according to one or more aspects of the present disclosure. Thus, the following description of the method (800) also refers to apparatus shown in one or more of FIGS. 1-5. However, the method (800) may also be performed in conjunction with implementations of apparatus other than those depicted in FIGS. 1-5 that are also within the scope of the present disclosure.

[00106] The method (800) may comprise establishing (805) communication between the cementing unit 200 and the controller 410. The method (800) may also comprise inputting (810) one or more set-points. For example, an input (810) set-point may be a fluid volume set-point and/or a flow rate set-point, as described above. The inputs (810) may be performed by a human operator via the input devices 426 described above, although the controller 410 may also be operable to retrieve the inputs as predetermined values/ranges included in the computer program code 432.

[00107] The method (800) also comprises operating the controller 410 to automatically initialize (815) the cementing unit 200 and perform (820) a cementing operation utilizing the cementing unit 200. Initializing (815) the cementing unit 200 may be via the method (500) shown in FIG. 6, or at least portions thereof. Performing (820) the cementing operation may be via the method (700) shown in FIG. 8, or at least portions thereof. The method (800) may also comprise operating the controller 410 to perform (825) a flow rate calibration of the cementing unit 200. The flow rate calibration (825) may be via the method (600) shown in FIG. 7, or at least portions thereof. The method (800) may also comprise confirming (830) that safety parameters are within predetermined ranges, similar to as described above. Other implementations of the method (800) shown in FIG. 9 also within the scope of the present disclosure may comprise other combinations of one or more aspects of two or more of the method (500) shown in FIG. 6, the method (600) shown in FIG. 7, and/or the method (700) shown in FIG. 8.

[00108] In view of the entirety of the present disclosure, including the claims and the figures, a person having ordinary skill in the art will readily recognize that the present disclosure introduces a method comprising: (A) establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the controller comprises a processor and a memory including computer program code; (B) inputting a fluid volume set-point; and (C) operating the controller to automatically perform: (1) a flow rate calibration of the cementing unit, wherein the flow rate calibration comprises automatically: (a) varying pumping speed of the cementing unit while recording first pumping speeds and corresponding first flow rates generated by the cementing unit; and (b) determining a flow rate ramp relating the recorded first flow rates to the corresponding recorded first pumping speeds; and then (2) a cement pumping operation of the cementing unit, wherein the cement pumping operation comprises automatically: (a) increasing pumping speed of the cementing unit while recording: (i) second pumping speeds; (ii) first pressures generated by the cementing unit corresponding to the recorded second pumping speeds; and (iii) second flow rates generated by the cementing unit corresponding to the recorded second pumping speeds and/or first pressures; then (b) maintaining the pumping speed while recording the maintained pumping speed and corresponding second pressures and third flow rates; and then (c) decreasing the pumping speed while recording fourth pumping speeds and corresponding third pressures and fourth flow rates until the cementing unit has stopped pumping cement and a volume of the pumped cement is substantially equal to the fluid volume set-point.

[00109] The method may further comprise inputting an operational set-point, and varying the pumping speed may comprise: increasing pumping speed of the cementing unit while recording the first pumping speeds and the corresponding first flow rates generated by the cementing unit until the operational set-point is met; and decreasing pumping speed of the cementing unit while recording the first pumping speeds and the corresponding first flow rates generated by the cementing unit until the cementing unit stops pumping a fluid. The operational set-point may comprise a predetermined fluid volume to be pumped by the cementing unit. The method may further comprise inputting first and second incremental speed set-points, wherein the pumping speed may be increased during the flow rate calibration by the first incremental speed set-point until the operational set-point is met, and wherein the pumping speed may be decreased during the flow rate calibration by the second incremental speed set-point until the cementing unit stops pumping the fluid.

[00110] The method may further comprise inputting a fluid flow rate set-point, wherein: increasing pumping speed of the cementing unit may comprise increasing pumping speed of the cementing unit to reach the flow rate set-point; and maintaining the pumping speed may comprise maintaining the pumping speed to maintain the fluid flow rate set-point.

[00111] The cementing unit may comprise a plurality of sensors operable to generate information related to operational status of the cementing unit. In such implementations, among others within the scope of the present disclosure, operating the controller may further comprise operating the controller to automatically perform initialization of operation of the cementing unit prior to the flow rate calibration. The initialization may comprise automatically: determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and confirming the operational parameters are within corresponding predetermined ranges.

[00112] The present disclosure also introduces a method comprising: (A) establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the cementing unit comprises a plurality of sensors operable to generate information related to operational status of the cementing unit, and wherein the controller comprises a processor and a memory including computer program code; (B) operating the controller to automatically perform initialization of the cementing unit, wherein the initialization comprises automatically: (1) determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and (2) confirming the operational parameters are within corresponding predetermined ranges.

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[00113] The operational parameters may comprise at least one of cementing unit temperature, cementing unit pressure, presence of moisture in association with the cementing unit, cementing unit cooling system pressure, and cementing unit lubrication system pressure.

[00114] The method may further comprise inputting operational set-points to be utilized by the controller to automatically perform an operation of the cementing unit, wherein the initialization further comprises, after confirming the operational parameters are within the corresponding predetermined ranges, automatically performing a flow rate calibration utilizing the operational set-points. The operational set-points may relate to at least one of a fluid volume to be pumped by the cementing unit and a pumping speed of the cementing unit. The flow rate calibration may comprise: varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate generated by the cementing unit; and determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds. Varying the pumping speed may comprise: increasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until a predetermined fluid volume is pumped by the cementing unit; and decreasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until the cementing unit stops pumping the fluid. The pumping speed may be increased by a first incremental speed set-point until the predetermined fluid volume is pumped, and the pumping speed may be decreased by a second incremental speed set-point until the cementing unit stops pumping the fluid. The flow rate calibration may further comprise, before varying the pumping speed: confirming that the cementing unit is not pumping; confirming that the cementing unit is depressurized; confirming that a sufficient volume of fluid is available for performing the flow rate calibration; and either: (1) opening fluid inlet and outlet valves of the cementing unit; or (2) confirming that the fluid inlet and outlet valves of the cementing unit are open. The flow rate calibration may comprise each of: (1) opening the fluid inlet and outlet valves of the cementing unit; and (2) confirming that the fluid inlet and outlet valves of the cementing unit are open.

[00115] The method may further comprise operating the controller to automatically confirm that safety parameters are within corresponding predetermined ranges during the initialization.

[00116] The present disclosure also introduces a method comprising: (A) establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the controller comprises a processor and a memory including

computer program code; and (B) operating the controller to automatically perform a flow rate calibration of the cementing unit, wherein the flow rate calibration comprises automatically: (1) varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate generated by the cementing unit; and (2) determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds.

[00117] The method may further comprise inputting an operational set-point, and varying the pumping speed may comprise: increasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until the operational set-point is met; and decreasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until the cementing unit stops pumping a fluid. The operational set-point may comprise a predetermined fluid volume to be pumped by the cementing unit. The method may further comprise inputting first and second incremental speed set-points, wherein the pumping speed may be increased by the first incremental speed set-point until the operational set-point is met, and wherein the pumping speed may be decreased by the second incremental speed set-point until the cementing unit stops pumping the fluid. In such implementations, among others within the scope of the present disclosure, the recorded flow rates and corresponding recorded pumping speeds may be first recorded flow rates and first recorded pumping speeds; the flow rate ramp may be a first flow rate ramp; the method may further comprise inputting a first incremental percentage set-point, a second incremental percentage set-point, a fluid flow rate set-point, and a fluid volume set-point; and varying the pumping speed may further comprise, after estimating the first flow rate ramp: (a) increasing the pumping speed of the cementing unit by a speed corresponding to the first incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp while recording second pumping speeds and corresponding second flow rates generated by the cementing unit until the fluid volume set-point is met; (b) decreasing the pumping speed of the cementing unit by a speed corresponding to the second incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp while recording third pumping speeds and corresponding third flow rates generated by the cementing unit until the cementing unit stops pumping the fluid; and (c) determining a second flow rate ramp relating the second and third recorded flow rates to the corresponding second and third recorded pumping speeds.

[00118] The flow rate calibration may further comprise, before varying the pumping speed: (3) confirming that the cementing unit is not pumping; (4) confirming that the

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cementing unit is depressurized; (5) confirming that a sufficient volume of fluid is available for performing the flow rate calibration; and (6) either or both of: (i) opening fluid inlet and outlet valves of the cementing unit; or (ii) confirming that the fluid inlet and outlet valves of the cementing unit are open.

[00119] The method may further comprise operating the controller to automatically confirm that safety parameters are within corresponding predetermined ranges during the flow rate calibration.

[00120] The present disclosure also introduces a method comprising: (A) establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the controller comprises a processor and a memory including computer program code; (B) inputting a fluid volume set-point; and (C) operating the controller to automatically perform a cement pumping operation of the cementing unit, wherein the cement pumping operation comprises automatically: (1) increasing pumping speed of the cementing unit while recording the pumping speed, pressure generated by the cementing unit and corresponding to the pumping speed, and cement flow rate generated by the cementing unit and corresponding to the pumping speed and/or pressure; then (2) maintaining the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate; and then (3) decreasing the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate until the cementing unit has stopped pumping cement and a volume of the pumped cement is substantially equal to the fluid volume set-point.

[00121] The method may further comprise inputting a fluid flow rate set-point, and the cement pumping operation may further comprise: increasing pumping speed of the cementing unit to reach the flow rate set-point; and maintaining the pumping speed to maintain the fluid flow rate set-point.

[00122] The cementing unit may further comprise a plurality of sensors operable to generate information related to operational status of the cementing unit, and the method may further comprise: determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and confirming that the operational parameters are within corresponding predetermined ranges.

[00123] The cement pumping operation may further comprise performing a flow rate calibration of the cementing unit before increasing, maintaining, and decreasing the pumping speed, wherein the flow rate calibration comprises automatically: varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate

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generated by the cementing unit; and determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds. The flow rate calibration may further comprise, before varying the pumping speed: confirming that the cementing unit is not pumping; confirming that the cementing unit is depressurized; confirming that a sufficient volume of fluid is available for performing the flow rate calibration; and either or both of: opening fluid inlet and outlet valves of the cementing unit; or confirming that the fluid inlet and outlet valves of the cementing unit are open.

[00124] The method may further comprise operating the controller to automatically confirm that safety parameters are within corresponding predetermined ranges during the cement pumping operation.

[00125] The present disclosure also introduces apparatus operable to perform: the methods described above; one or more of such methods; one or more aspects of such methods; and/or other methods within the scope of the present disclosure.

[00126] The foregoing outlines features of several embodiments so that a person having ordinary skill in the art may better understand the aspects of the present disclosure. A person having ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. A person having ordinary skill in the art should also realize that such equivalent constructions do not depart from the scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

[00127] The Abstract at the end of this disclosure is provided to comply with 37 C.F.R. §1.72(b) to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

WHAT IS CLAIMED IS:

1. A method comprising:

establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the controller comprises a processor and a memory including computer program code;

inputting a fluid volume set-point; and

operating the controller to automatically perform:

a flow rate calibration of the cementing unit, wherein the flow rate calibration comprises automatically:

varying pumping speed of the cementing unit while recording first pumping speeds and corresponding first flow rates generated by the cementing unit; and

determining a flow rate ramp relating the recorded first flow rates to the corresponding recorded first pumping speeds; and then

a cement pumping operation of the cementing unit, wherein the cement pumping operation comprises automatically:

increasing pumping speed of the cementing unit while recording:

second pumping speeds;

first pressures generated by the cementing unit corresponding to the recorded second pumping speeds; and

second flow rates generated by the cementing unit corresponding to the recorded second pumping speeds and/or first pressures; then

maintaining the pumping speed while recording the maintained pumping speed and corresponding second pressures and third flow rates; and then

decreasing the pumping speed while recording fourth pumping speeds and corresponding third pressures and fourth flow rates until the cementing unit has stopped pumping cement and a volume of the pumped cement is substantially equal to the fluid volume set-point.

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2. The method of claim 1 further comprising inputting an operational set-point, and wherein varying the pumping speed comprises:

increasing pumping speed of the cementing unit while recording the first pumping speeds and the corresponding first flow rates generated by the cementing unit until the operational set-point is met; and

decreasing pumping speed of the cementing unit while recording the first pumping speeds and the corresponding first flow rates generated by the cementing unit until the cementing unit stops pumping a fluid.

3. The method of claim 2 wherein the operational set-point comprises a predetermined fluid volume to be pumped by the cementing unit.

4. The method of claim 2 further comprising inputting first and second incremental speed set-points, wherein the pumping speed is increased during the flow rate calibration by the first incremental speed set-point until the operational set-point is met, and wherein the pumping speed is decreased during the flow rate calibration by the second incremental speed set-point until the cementing unit stops pumping the fluid.

5. The method of claim 1 further comprising inputting a fluid flow rate set-point, wherein:

increasing pumping speed of the cementing unit comprises increasing pumping speed of the cementing unit to reach the flow rate set-point; and

maintaining the pumping speed comprises maintaining the pumping speed to maintain the fluid flow rate set-point.

6. The method of claim 1 wherein:

the cementing unit comprises a plurality of sensors operable to generate information related to operational status of the cementing unit; and

operating the controller further comprises operating the controller to automatically perform initialization of operation of the cementing unit prior to the flow rate calibration, wherein the initialization comprises automatically:

determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and

confirming the operational parameters are within corresponding predetermined ranges.

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7. A method comprising:

establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the cementing unit comprises a plurality of sensors operable to generate information related to operational status of the cementing unit, and wherein the controller comprises a processor and a memory including computer program code;

operating the controller to automatically perform initialization of the cementing unit, wherein the initialization comprises automatically:

determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and

confirming the operational parameters are within corresponding predetermined ranges.

8. The method of claim 7 wherein the operational parameters comprise at least one of cementing unit temperature, cementing unit pressure, presence of moisture in association with the cementing unit, cementing unit cooling system pressure, and cementing unit lubrication system pressure.

9. The method of claim 7 further comprising inputting operational set-points to be utilized by the controller to automatically perform an operation of the cementing unit, wherein the initialization further comprises, after confirming the operational parameters are within the corresponding predetermined ranges, automatically performing a flow rate calibration utilizing the operational set-points.

10. The method of claim 9 wherein the operational set-points relate to at least one of a fluid volume to be pumped by the cementing unit and a pumping speed of the cementing unit.

11. The method of claim 9 wherein the flow rate calibration comprises:

varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate generated by the cementing unit; and

determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds.

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12. The method of claim 11 wherein varying the pumping speed comprises:

increasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until a predetermined fluid volume is pumped by the cementing unit; and

decreasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until the cementing unit stops pumping the fluid.

13. The method of claim 12 wherein the pumping speed is increased by a first incremental speed set-point until the predetermined fluid volume is pumped, and wherein the pumping speed is decreased by a second incremental speed set-point until the cementing unit stops pumping the fluid.

14. The method of claim 11 wherein the flow rate calibration further comprises, before varying the pumping speed:

confirming that the cementing unit is not pumping;

confirming that the cementing unit is depressurized;

confirming that a sufficient volume of fluid is available for performing the flow rate calibration; and

either:

opening fluid inlet and outlet valves of the cementing unit; or

confirming that the fluid inlet and outlet valves of the cementing unit are open.

15. The method of claim 7 further comprising operating the controller to automatically confirm that safety parameters are within corresponding predetermined ranges during the initialization.

16. A method comprising:

establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the controller comprises a processor and a memory including computer program code; and

operating the controller to automatically perform a flow rate calibration of the cementing unit, wherein the flow rate calibration comprises automatically:

varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate generated by the cementing unit; and

determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds.

17. The method of claim 16 further comprising inputting an operational set-point, and wherein varying the pumping speed comprises:

increasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until the operational set-point is met; and

decreasing the pumping speed of the cementing unit while recording the pumping speed and the corresponding flow rate generated by the cementing unit until the cementing unit stops pumping a fluid.

18. The method of claim 17 wherein the operational set-point comprises a predetermined fluid volume to be pumped by the cementing unit.

19. The method of claim 17 further comprising inputting first and second incremental speed set-points, wherein the pumping speed is increased by the first incremental speed set-point until the operational set-point is met, and wherein the pumping speed is decreased by the second incremental speed set-point until the cementing unit stops pumping the fluid.

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20. The method of claim 19 wherein:

the recorded flow rates and corresponding recorded pumping speeds are first recorded flow rates and first recorded pumping speeds;

the flow rate ramp is a first flow rate ramp;

the method further comprises inputting a first incremental percentage set-point, a second incremental percentage set-point, a fluid flow rate set-point, and a fluid volume set-point; and

varying the pumping speed further comprises, after estimating the first flow rate ramp:

increasing the pumping speed of the cementing unit by a speed corresponding to the first incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp while recording second pumping speeds and corresponding second flow rates generated by the cementing unit until the fluid volume set-point is met;

decreasing the pumping speed of the cementing unit by a speed corresponding to the second incremental percentage set-point of the fluid flow rate set-point based on the first flow rate ramp while recording third pumping speeds and corresponding third flow rates generated by the cementing unit until the cementing unit stops pumping the fluid; and

determining a second flow rate ramp relating the second and third recorded flow rates to the corresponding second and third recorded pumping speeds.

21. The method of claim 16 wherein the flow rate calibration further comprises, before varying the pumping speed:

confirming that the cementing unit is not pumping;

confirming that the cementing unit is depressurized;

confirming that a sufficient volume of fluid is available for performing the flow rate calibration; and

either:

opening fluid inlet and outlet valves of the cementing unit; or

confirming that the fluid inlet and outlet valves of the cementing unit are open.

22. The method of claim 16 further comprising operating the controller to automatically confirm that safety parameters are within corresponding predetermined ranges during the flow rate calibration.

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23. A method comprising:

establishing communication between a cementing unit and a controller operable to control operation of the cementing unit, wherein the controller comprises a processor and a memory including computer program code;

inputting a fluid volume set-point; and

operating the controller to automatically perform a cement pumping operation of the cementing unit, wherein the cement pumping operation comprises automatically:

increasing pumping speed of the cementing unit while recording:

the pumping speed;

pressure generated by the cementing unit and corresponding to the pumping speed; and

cement flow rate generated by the cementing unit and corresponding to the pumping speed and/or pressure; then

maintaining the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate; and then

decreasing the pumping speed while recording the pumping speed and the corresponding pressure and cement flow rate until the cementing unit has stopped pumping cement and a volume of the pumped cement is substantially equal to the fluid volume set-point.

24. The method of claim 23 further comprising inputting a fluid flow rate set-point, and wherein the cement pumping operation further comprises:

increasing pumping speed of the cementing unit to reach the flow rate set-point; and

maintaining the pumping speed to maintain the fluid flow rate set-point.

25. The method of claim 23 wherein the cementing unit further comprises a plurality of sensors operable to generate information related to operational status of the cementing unit, and wherein the method further comprises:

determining operational parameters related to the cementing unit operational status based on the information generated by the sensors; and

confirming that the operational parameters are within corresponding predetermined ranges.

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26. The method of claim 23 wherein the cement pumping operation further comprises performing a flow rate calibration of the cementing unit before increasing, maintaining, and decreasing the pumping speed, wherein the flow rate calibration comprises automatically:

varying pumping speed of the cementing unit while recording the pumping speed and a corresponding flow rate generated by the cementing unit; and

determining a flow rate ramp relating the recorded flow rates to the corresponding recorded pumping speeds.

27. The method of claim 26 wherein the flow rate calibration further comprises, before varying the pumping speed:

confirming that the cementing unit is not pumping;

confirming that the cementing unit is depressurized;

confirming that a sufficient volume of fluid is available for performing the flow rate calibration; and

either:

opening fluid inlet and outlet valves of the cementing unit; or

confirming that the fluid inlet and outlet valves of the cementing unit are open.

28. The method of claim 23 further comprising operating the controller to automatically confirm that safety parameters are within corresponding predetermined ranges during the cement pumping operation.

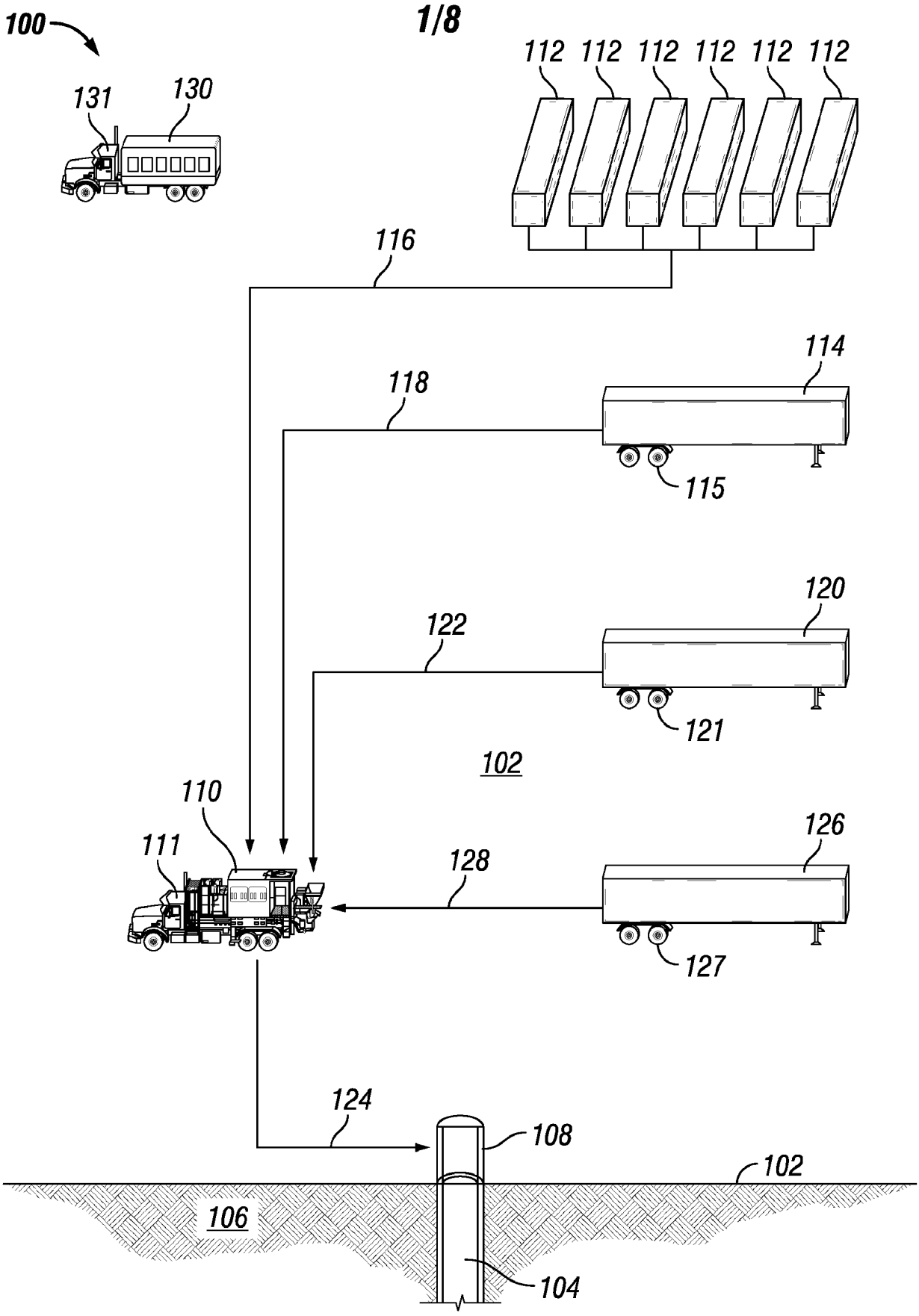

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FIG. 1

SUBSTITUTE SHEET (RULE 26)

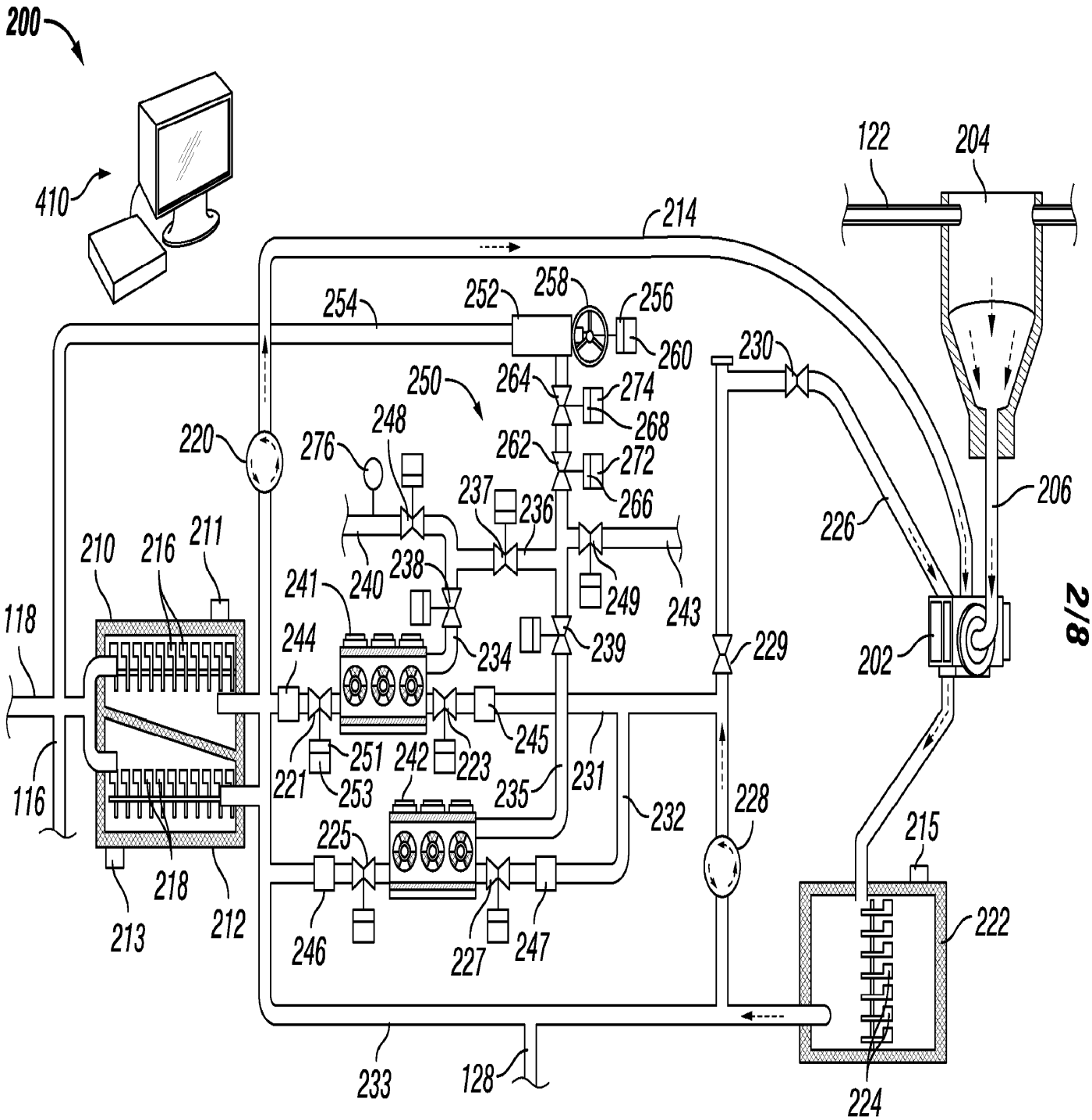


FIG. 2

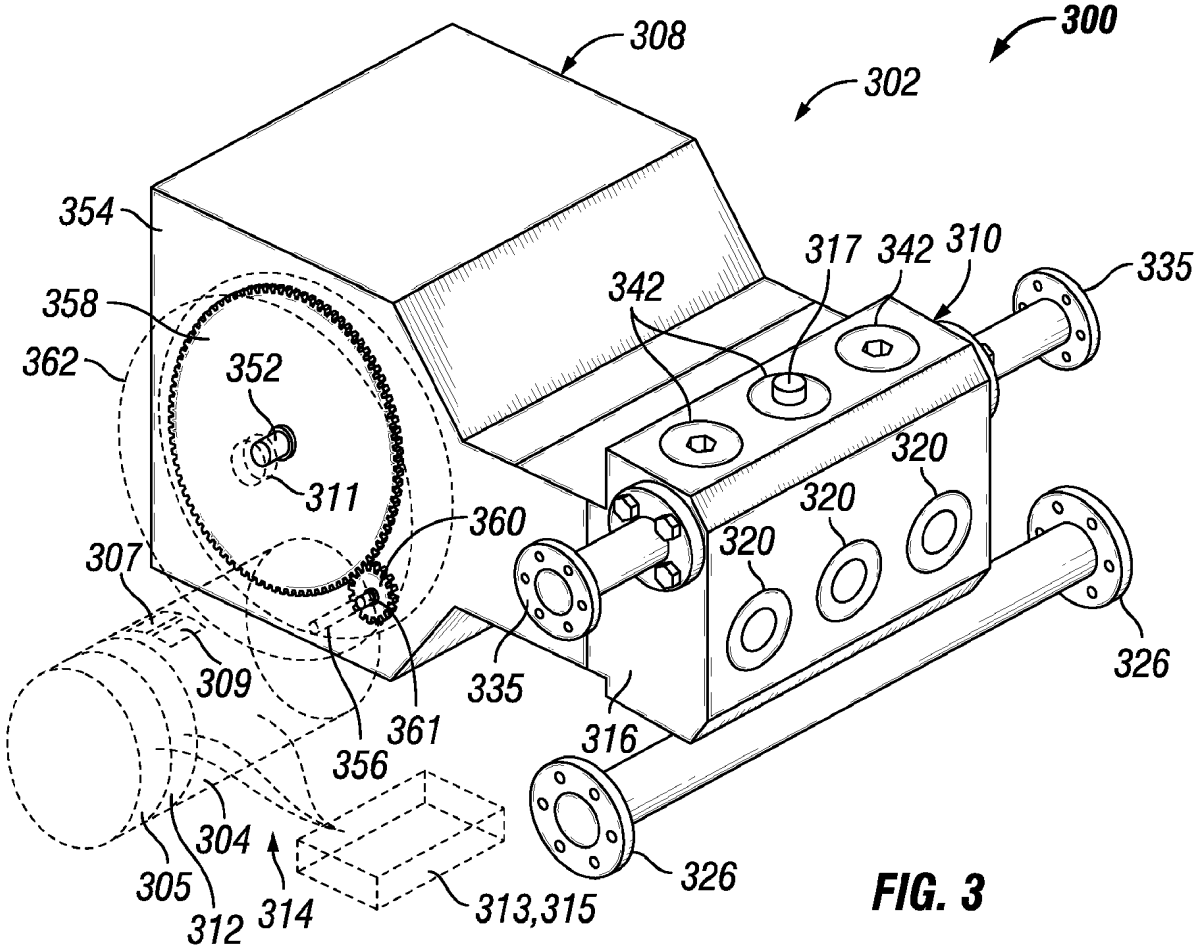

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FIG. 3

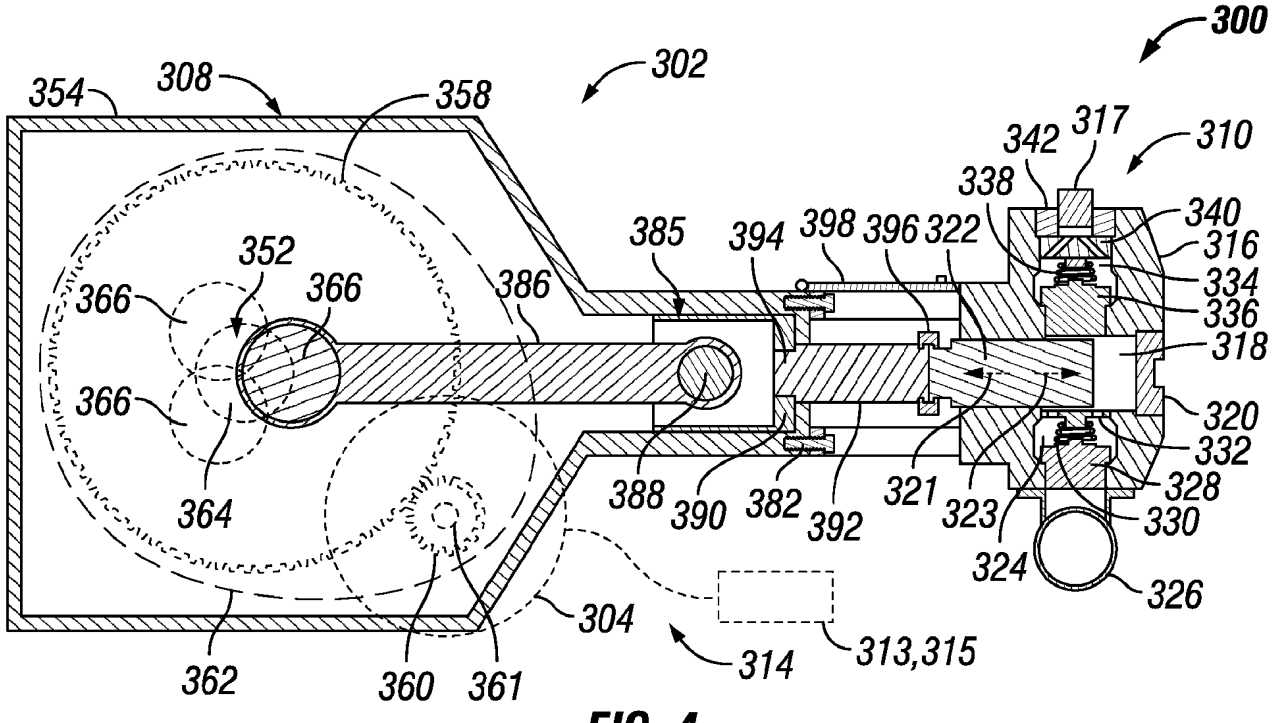

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FIG. 4

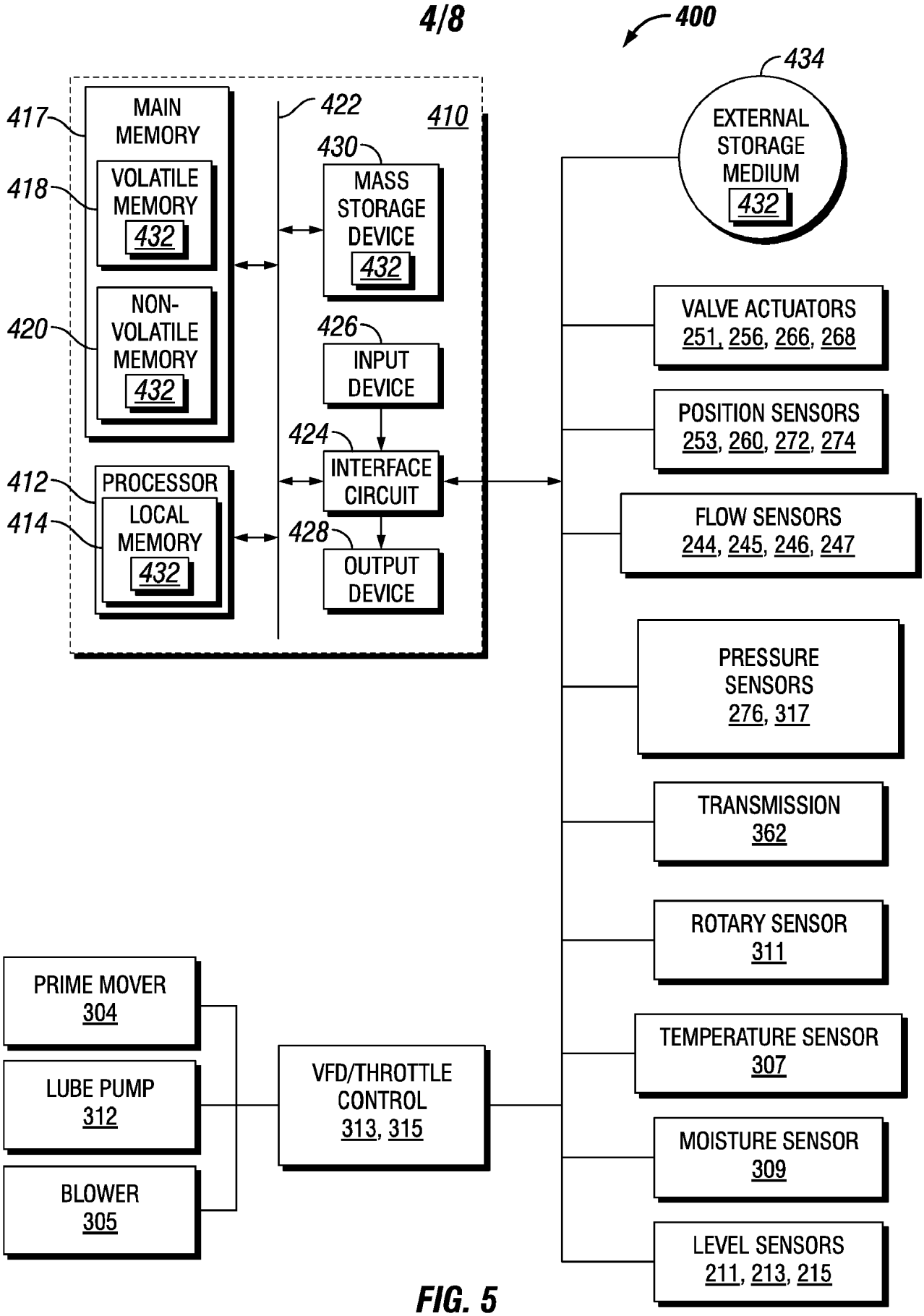

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EXTERNAL STORAGE MEDIUM 432
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MAIN MEMORY
418
VOLATILE MEMORY 432
420
NON-VOLATILE MEMORY 432
412
PROCESSOR
414
LOCAL MEMORY 432
422
410
430
MASS STORAGE DEVICE 432
426
INPUT DEVICE
424
INTERFACE CIRCUIT
428
OUTPUT DEVICE
VALVE ACTUATORS 251, 256, 266, 268
POSITION SENSORS 253, 260, 272, 274
FLOW SENSORS 244, 245, 246, 247
PRESSURE SENSORS 276, 317
TRANSMISSION 362
ROTARY SENSOR 311
TEMPERATURE SENSOR 307
MOISTURE SENSOR 309
LEVEL SENSORS 211, 213, 215
PRIME MOVER 304
LUBE PUMP 312
BLOWER 305
VFD/THROTTLE CONTROL 313, 315

FIG. 5

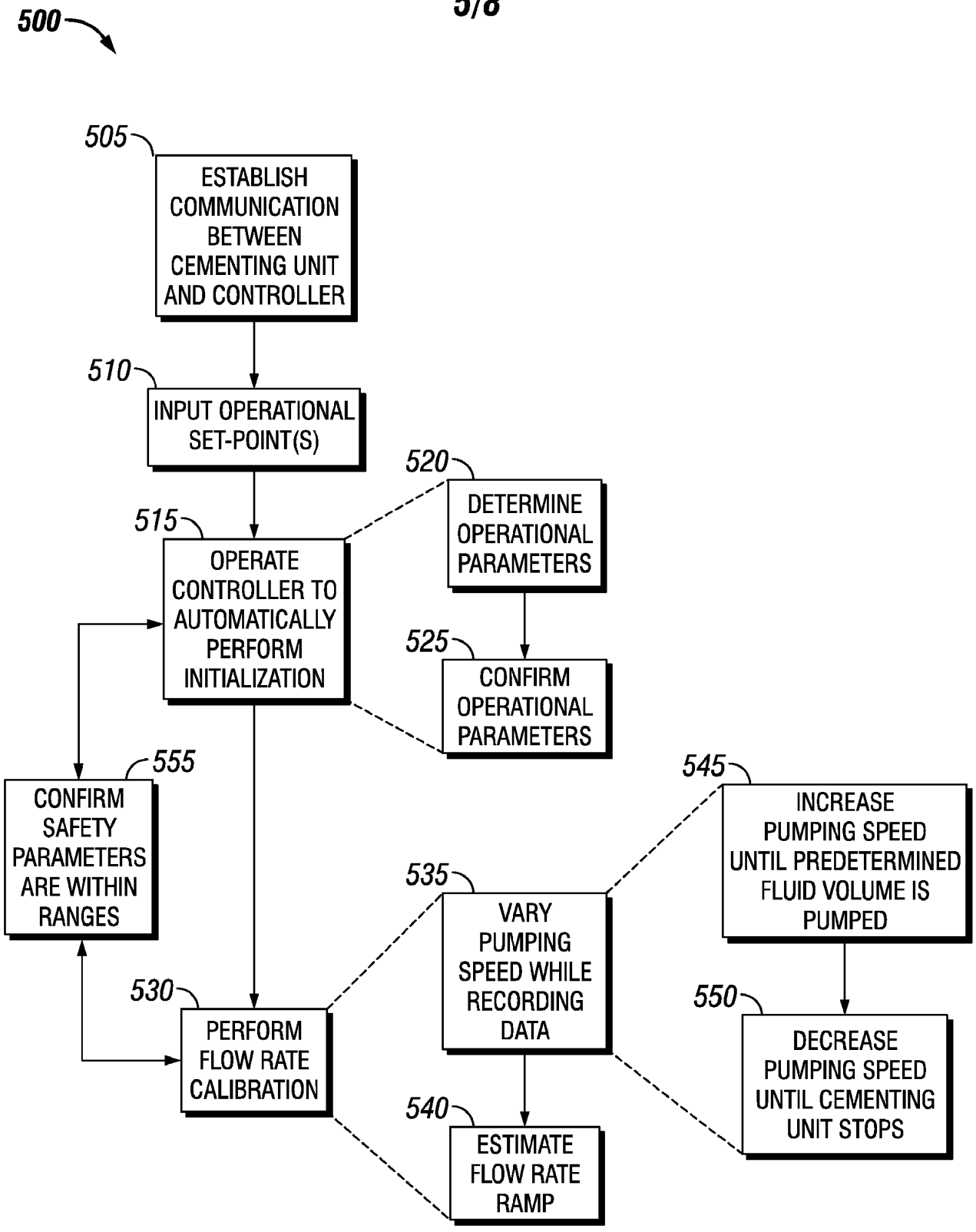

500
505
ESTABLISH COMMUNICATION BETWEEN CEMENTING UNIT AND CONTROLLER
510
INPUT OPERATIONAL SET-POINT(S)
515
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM INITIALIZATION
520
DETERMINE OPERATIONAL PARAMETERS
525
CONFIRM OPERATIONAL PARAMETERS
530
PERFORM FLOW RATE CALIBRATION
535
VARY PUMPING SPEED WHILE RECORDING DATA
540
ESTIMATE FLOW RATE RAMP
545
INCREASE PUMPING SPEED UNTIL PREDETERMINED FLUID VOLUME IS PUMPED
550
DECREASE PUMPING SPEED UNTIL CEMENTING UNIT STOPS
555
CONFIRM SAFETY PARAMETERS ARE WITHIN RANGES

FIG. 6

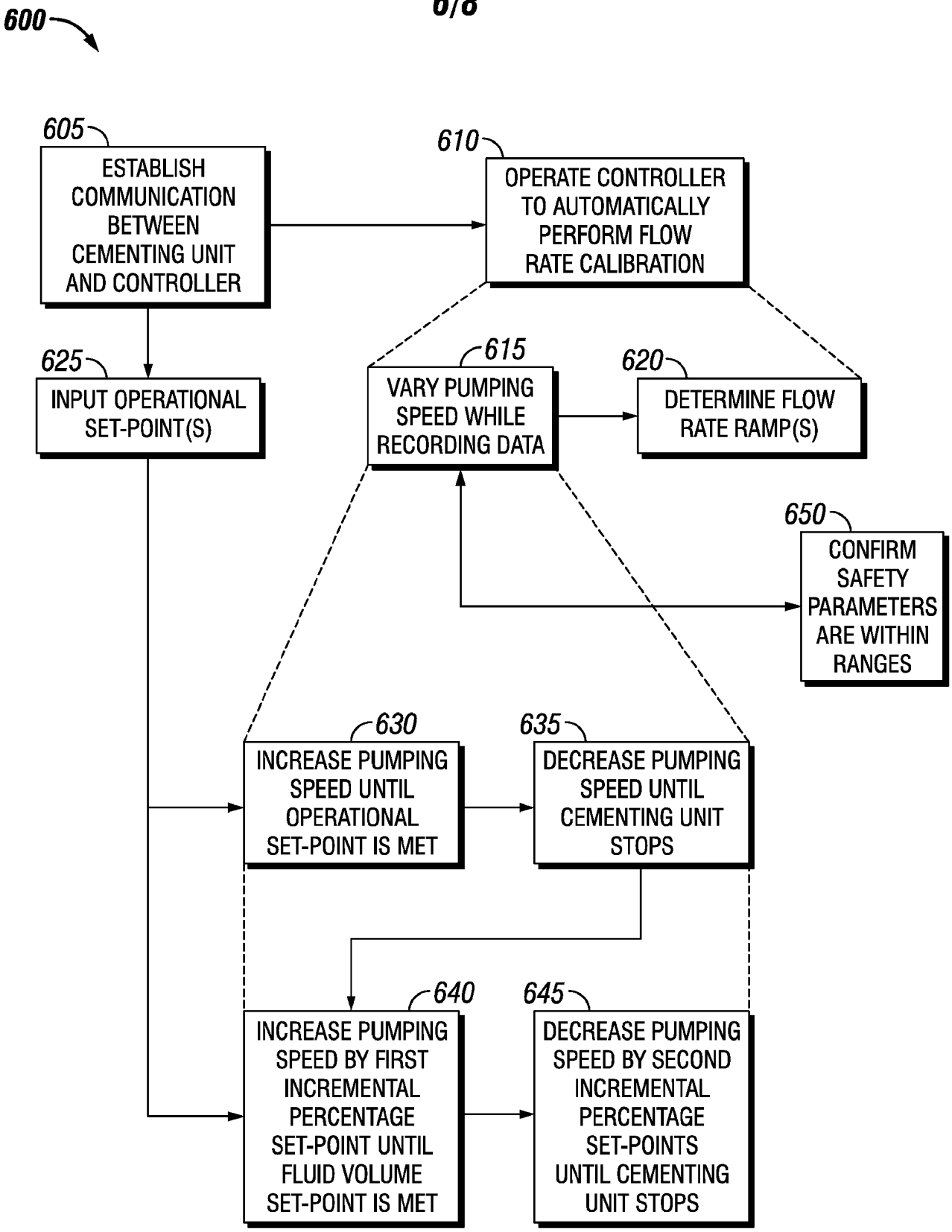

600
605
ESTABLISH COMMUNICATION BETWEEN CEMENTING UNIT AND CONTROLLER
610
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM FLOW RATE CALIBRATION
625
INPUT OPERATIONAL SET-POINT(S)
615
VARY PUMPING SPEED WHILE RECORDING DATA
620
DETERMINE FLOW RATE RAMP(S)
650
CONFIRM SAFETY PARAMETERS ARE WITHIN RANGES
630
INCREASE PUMPING SPEED UNTIL OPERATIONAL SET-POINT IS MET
635
DECREASE PUMPING SPEED UNTIL CEMENTING UNIT STOPS
640
INCREASE PUMPING SPEED BY FIRST INCREMENTAL PERCENTAGE SET-POINT UNTIL FLUID VOLUME SET-POINT IS MET
645
DECREASE PUMPING SPEED BY SECOND INCREMENTAL PERCENTAGE SET-POINTS UNTIL CEMENTING UNIT STOPS

FIG. 7

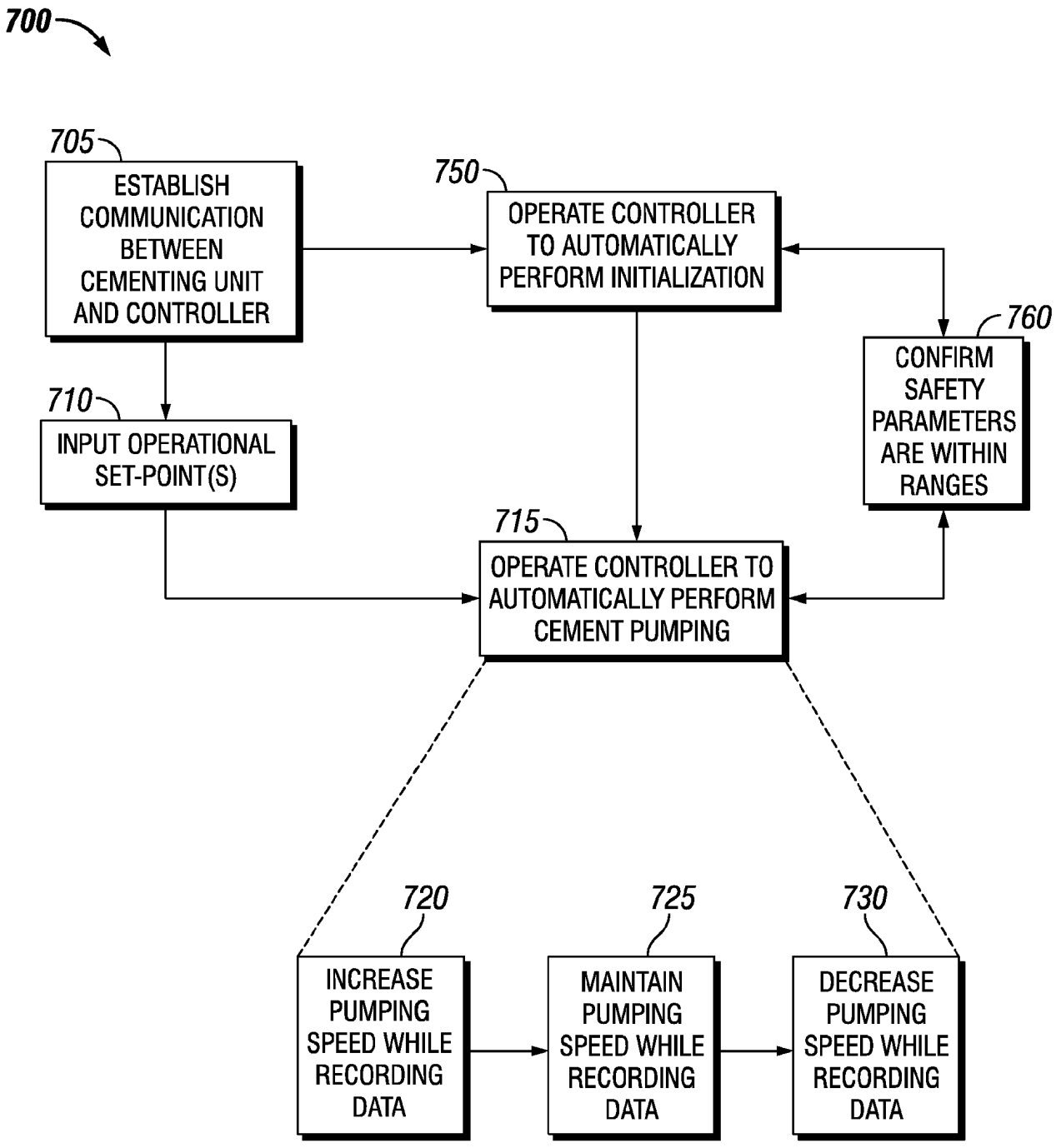

700
705
ESTABLISH COMMUNICATION BETWEEN CEMENTING UNIT AND CONTROLLER
710
INPUT OPERATIONAL SET-POINT(S)
750
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM INITIALIZATION
760
CONFIRM SAFETY PARAMETERS ARE WITHIN RANGES
715
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM CEMENT PUMPING
720
INCREASE PUMPING SPEED WHILE RECORDING DATA
725
MAINTAIN PUMPING SPEED WHILE RECORDING DATA
730
DECREASE PUMPING SPEED WHILE RECORDING DATA

FIG. 8

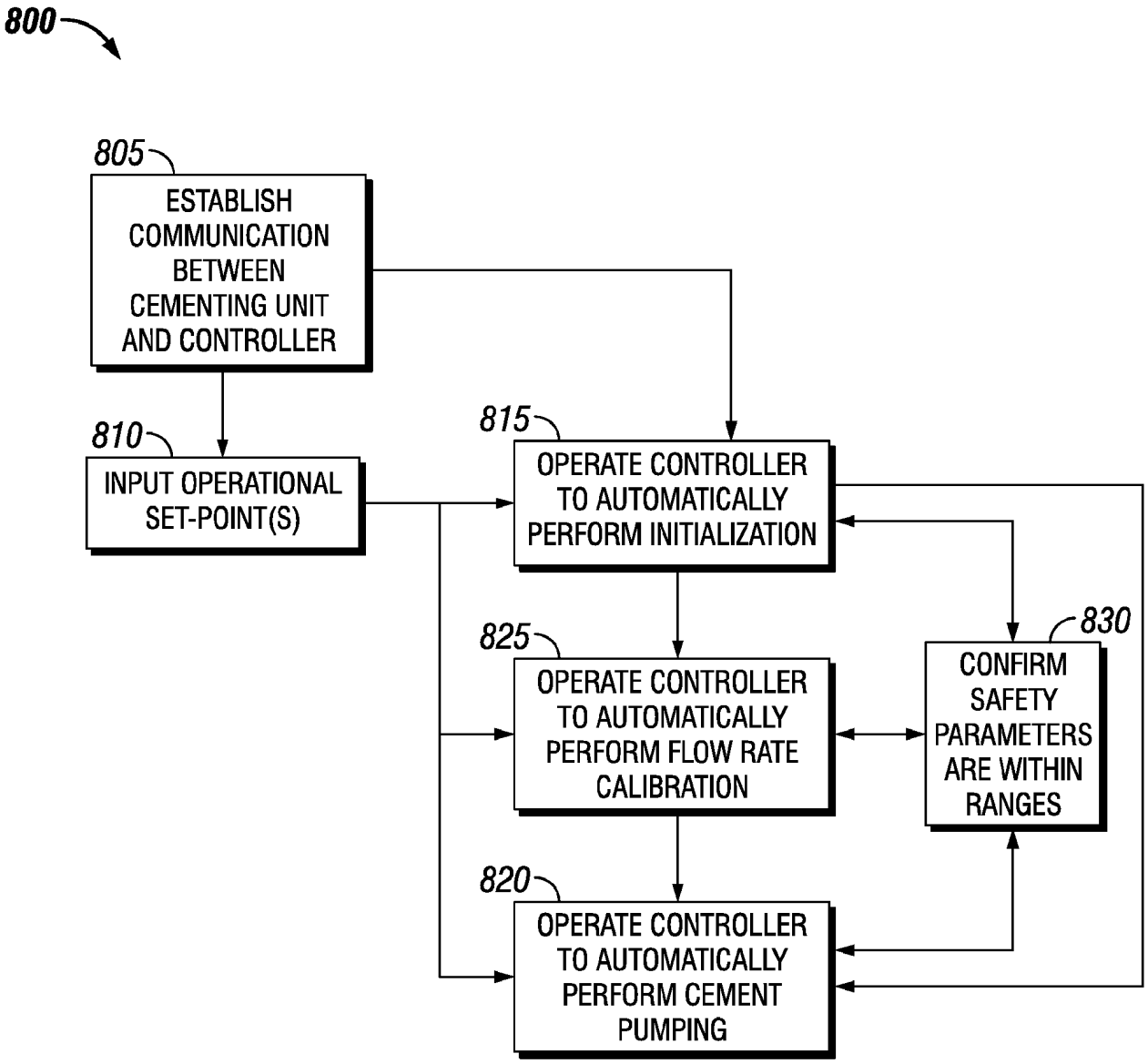

800
805
ESTABLISH COMMUNICATION BETWEEN CEMENTING UNIT AND CONTROLLER
810
INPUT OPERATIONAL SET-POINT(S)
815
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM INITIALIZATION
825
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM FLOW RATE CALIBRATION
830
CONFIRM SAFETY PARAMETERS ARE WITHIN RANGES
820
OPERATE CONTROLLER TO AUTOMATICALLY PERFORM CEMENT PUMPING

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/023856

A. CLASSIFICATION OF SUBJECT MATTER

E21B 33/13(2006.01)i, E21B 33/138(2006.01)i, G05B 19/02(2006.01)i, G06F 19/00(2011.01)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)
E21B 33/13; F04B 49/00; F04D 29/00; F04B 47/02; E21B 33/138; G05B 19/02; G06F 19/00

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: pump, automatically, cementing, flow rate, calibration, speed, ramp, volume, pressure, vary

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004-0120804 A1 (SABINI et al.) 24 June 2004 See paragraphs [0002], [0022]-[0030], [0040]-[0046], [0052], [0060]; and figures 1, 4, 8.	1-28
Y	WO 97-08459 A1 (BAKER HUGHES INCORPORATED et al.) 06 March 1997 See page 36, line 26 - page 37, line 8; page 46, lines 3-15; page 51, lines 5-16; page 63, line 30 - page 64, line 1; and figures 2B, 2D.	1-28
A	US 3705626 A (GLENN, JR. et al.) 12 December 1972 See column 5, line 18 - column 6, line 51; and figures 1-2.	1-28
A	US 2012-0301320 A1 (SEITTER, LARRY E.) 29 November 2012 See paragraphs [0041]-[0070]; and figures 4-7.	1-28
A	US 5006044 A (WALKER, SR. et al.) 09 April 1991 See column 21, line 48 - column 24, line 10; and figure 2.	1-28

☐ 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
26 June 2016 (26.06.2016)	**27 June 2016 (27.06.2016)**

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
PARK, Tae Wook
Telephone No. +82-42-481-3405

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004-0120804 A1	24/06/2004	AU 2003-297991 A1	22/07/2004
		AU 2003-297991 A8	22/07/2004
		CN 100470008 C	18/03/2009
		CN 1777738 A	24/05/2006
		DE 10393946 B4	23/09/2010
		DE 10393946 T5	24/05/2007
		US 7112037 B2	26/09/2006
		WO 2004-059170 A2	15/07/2004
		WO 2004-059170 A3	20/01/2005
WO 97-08459 A1	06/03/1997	AU 2001-57514 A1	20/11/2001
		CA 2230691 A1	06/03/1997
		CA 2230691 C	30/03/2004
		CA 2353164 A1	17/01/2002
		CA 2353164 C	28/12/2004
		CA 2408593 A1	15/11/2001
		GB 2320588 A	24/06/1998
		GB 2320588 B	22/12/1999
		GB 2338801 A	29/12/1999
		GB 2338801 B	01/03/2000
		GB 2369759 A	05/06/2002
		GB 2378106 A	29/01/2003
		NO 324610 B1	26/11/2007
		NO 980882 A	27/04/1998
		US 2001-0032721 A1	25/10/2001
		US 2005-0110655 A1	26/05/2005
		US 6167965 B1	02/01/2001
		US 6586900 B2	01/07/2003
		US 6587037 B1	01/07/2003
		US 6798338 B1	28/09/2004
		US 7248178 B2	24/07/2007
		WO 01-86831 A1	15/11/2001
US 3705626 A	12/12/1972	None	
US 2012-0301320 A1	29/11/2012	EP 2715059 A2	09/04/2014
		EP 2715059 A4	04/11/2015
		US 9121270 B2	01/09/2015
		WO 2012-162528 A2	29/11/2012
		WO 2012-162528 A3	21/03/2013
US 5006044 A	09/04/1991	US 5063775 A	12/11/1991
		US 5222867 A	29/06/1993

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 047158.500029	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 18/54542	International filing date *(day/month/year)* 05 October 2018 (05.10.2018)
Applicant U.S. WELL SERVICES, LLC	

Date of mailing *(day/month/year)* 02 JAN 2019

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ With regard to any protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Lee W. Young Telephone No. PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 047158.500029	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 18/54542	International filing date *(day/month/year)* 05 October 2018 (05.10.2018)	(Earliest) Priority Date *(day/month/year)* 05 October 2017 (05.10.2017)
Applicant U.S. WELL SERVICES, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the drawings to be published with the abstract is Figure No. _____

☐ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☒ none of the figures is to be published with the abstract.

LIBERTY EXHIBIT 1002, Page 1598

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/54542

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 37/06, E21B 45/00, F04B 49/06, F04B 49/20, G01F 1/76,G01N 29/44,G05D 7/06 (2018.01)
CPC - E21B 37/06, E21B 45/00, E21B 47/0007, E21B 49/08, E21B 49/081, E21B 49/087, F04B 49/06, F04B 49/20, F04B 2027/1827, F04B 2027/1831, E21B 2049/085, F04B 2203/1102, F04B 2205/01, F04B 2205/05, G01F 1/76, G01F 25/0007, G01N 29/44, G01N 29/4427, G01N 2030/324, G01N 2291/02836, G05B 23/0294, G05B 2219/32184, G05B 2219/36292, G05B 2219/41303, G05D 7/06, G06F 2201/81, G06F 2209/5022

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)

See Search History Document

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

See Search History Document

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

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y – A	US 2004/0040746 A1 (NIEDERMAYR et al.) 04 March 2004 (04.03.2004), para [0037]-[0040], [0051], [0052], [0066], [0069], [0070], [0090], [0165]-[0170]	1-4, 7, 15-17 – 5, 6, 8-14, 18-20
Y – A	US 2014/0378300 A1 (GHB PTY LTD) 25 December 2014 (25.12.2014), para [0001], [0007]-[0009], [0018], [0027], [0051], [0053], [0068], [0093]-[0103], [0110], [0114], [0151]-[0160]	1-4, 7, 15-17 – 5, 6, 8-14, 18-20
A	WO 2016/144939 A1 (SCHLUMBERGER TECHNOLOGIES CORPORATION) 15 September 2016 (15.09.2016), para [0030], [0036], [0057], [0066], [0067]	5, 6, 8-14, 18-20
A	US 2006/0052903 A1 (BASSETT) 09 March 2006 (09.03.2006), para [0014]-[0016], [0024], [0026], [0043]	5, 6, 8-14, 18-20
A	US 5,006,044 A (WALKER, SR., et al.) 09 April 1991 (09.04.1991), col 2, ln 44-63; col 11, ln 29-50; col 21, ln 48-68; col 31, ln 39-54; col 37, ln 43 to col 38, ln 37	5, 6, 8-14, 18-20

☐ 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
23 November 2018	02 JAN 2019
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	02 JAN 2019
Applicant's or agent's file reference 047158.500029	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 18/54542	05 October 2018 (05.10.2018)	05 October 2017 (05.10.2017)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 37/06, E21B 45/00, F04B 49/06, F04B 49/20, G01F 1/76,G01N 29/44,G05D 7/06 (2018.01)
CPC - E21B 37/06, E21B 45/00, E21B 47/0007, E21B 49/08, E21B 49/081, E21B 49/087, F04B 49/06, F04B 49/20, F04B 2027/1827, F04B 2027/1831, E21B 2049/085, F04B 2203/1102, F04B 2205/01, F04B 2205/05, G01F 1/76, G01F 25/0007, G01N 29/44, G01N 29/4427, G01N 2030/324, G01N 2291/02836, G05B 23/0294, G05B 2219/32184, G05B 2219/36292, G05B 2219/41303, G05D 7/06, G06F 2201/81, G06F 2209/5022

Applicant U.S. WELL SERVICES, LLC

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-6300	23 November 2018	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/54542

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

LIBERTY EXHIBIT 1002, Page 1601

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/54542

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	none	NO
Inventive step (IS)	Claims	5, 6, 8-14, 18-20	YES
	Claims	1-4, 7, 15-17	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	none	NO

2. Citations and explanations:

Claims 1-4, 7, and 15-17 lack an inventive step under PCT Article 33(3) as being obvious over US 2004/0040746 A1 to Niedermayr, et al. (hereinafter 'Niedermayr'), in view of US 2014/0379300 A1 to (GHD Pty Ltd).

Regarding Claim 1, Niedermayr discloses a method for monitoring a fracturing operation (para [0167], [0169]), comprising: positioning a pump (50) at a well site (12) where fracturing operations are being conducted (para [0165], [0170]); arranging one or more sensors (34, 36) at at least one of a pump (para [0038], [0040]), the one or more sensors (34, 36) monitoring a flow rate of a slurry (para [0040], [0066], [0170]); determining an efficiency (para [0050]); and adjusting one or more operating parameters of the pump (50) (para [0051], [0052], [0070]); but does not specifically disclose arranging one or more sensors (34, 36) at at least one of a pump inlet (52) or a pump outlet (54), the one or more sensors (34, 36) monitoring a flow rate of a slurry; receiving flow data from the one or more sensors (34, 36); determining a pump efficiency, based at least in part on the flow data, is below a threshold; and adjusting one or more operating parameters of the pump (50). However, GHD Pty Ltd discloses a method for monitoring a pump (para [0007]-[0009]), comprising arranging one or more sensors (34, 36) at at least one of a pump inlet (52) or a pump outlet (54) (para [0093]-[0103]), the one or more sensors (34, 36) monitoring a flow rate of a liquid (para [0096], [0102], [0156]); receiving flow data from the one or more sensors (34, 36) (para [0114], [0156]); and determining a pump efficiency, based at least in part on the flow data, is below a threshold (para [0158]-[0160]). To a person of ordinary skill in the art, monitoring a pump as taught by GHD Pty Ltd would have been obvious for use in the method for monitoring a fracturing operation as in Niedermayr in order to provide in-situ determination of pump performance so that system operators are alerted to declining performance of a pump proactively (GHD Pty Ltd: para [0001]), because Niedermayr and GHD Pty Ltd are directed towards monitoring flow rate of a pump.

Regarding Claim 2, Niedermayr further discloses the method of claim 1, further comprising: receiving operating data indicative of one or more operating parameters from a second sensor (34, 36) (para [0037], [0040], [0066]); wherein adjusting one or more operating parameters of the pump (50) is based at least in part on the operating data (para [0051], [0052], [0070]).

Regarding Claim 3, Niedermayr further discloses the method of claim 1, further comprising: receiving second flow data from the one or more sensors (34, 36), after the one or more operating parameters are adjusted (para [0069], [0090], continuous operations and control determined in real time.); but does not specifically disclose determining a second pump efficiency. However, GHD Pty Ltd discloses a method for monitoring a pump (para [0007]-[0009]), further comprising determining pump efficiency in real time (para [0018], [0068], [0110]). To a person of ordinary skill in the art, monitoring a pump as taught by GHD Pty Ltd would have been obvious for use in the method for monitoring a fracturing operation as in Niedermayr in order to provide in-situ determination of pump performance so that system operators are alerted to declining performance of a pump proactively (GHD Pty Ltd: para [0001]), because Niedermayr and GHD Pty Ltd are directed towards monitoring flow rate of a pump.

Regarding Claim 4, GHD Pty Ltd further discloses the method of claim 3, further comprising: determining the second pump efficiency is above the threshold (para [0051], [0053], [0151], [0152], pump not taken off line or alert not sent when the efficiency is above a threshold.); and storing the one or more operating parameters of the pump (50) (para [0018], [0027], [0051], pump efficiency stored.).

Regarding Claim 7, Niedermayr further discloses the method of claim 1, wherein the one or more operating parameters of the pump (50) include a speed (para [0040]), a suction pressure, a discharge pressure, or a combination thereof.

Regarding Claim 15, Niedermayr discloses a method for adjusting a pump (50) during a fracturing operation, comprising: receiving first data from a first sensor (34, 36) of the pump (50) (para [0038], [0040]); determining efficiency, based at least in part on the first data (para [0050]-[0052]); and performing an action associated with the pump (50) (para [0051], [0052], [0070]); but does not specifically disclose receiving first data from a first sensor (34, 36) arranged at a suction side (52) of the pump (50); receiving second data from a second sensor (34, 36) arranged a discharge side (54) of the pump (50); determining a pump efficiency, based at least in part on the first data and the second data; comparing the pump efficiency to a threshold, the threshold being a pre-determined value indicative of an operational condition of the pump (50); and determining the pump efficiency is below the threshold. However, GHD Pty Ltd discloses a method for monitoring a pump (para [0007]-[0009]), comprising receiving first data from a first sensor (34, 36) arranged at a suction side (52) of the pump (50) (para [0013], [0016], [0026], [0064]); receiving second data from a second sensor (34, 36) arranged a discharge side (54) of the pump (50) (para [0013], [0016], [0026], [0064]); ... (continued)

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LIBERTY EXHIBIT 1002, Page 1602

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:
Box V.2., Citations and explanations,

(Continued from Box V.2.) ... determining a pump efficiency, based at least in part on the first data and the second data (para [0013], [0016], [0026], [0064]); comparing the pump efficiency to a threshold, the threshold being a pre-determined value indicative of an operational condition of the pump (50) (para [0158]-[0160]); and determining the pump efficiency is below the threshold (para [0020], [0029], [0151]). To a person of ordinary skill in the art, monitoring a pump as taught by GHD Pty Ltd would have been obvious for use in the method for monitoring a fracturing operation as in Niedermayr in order to provide in-situ determination of pump performance so that system operators are alerted to declining performance of a pump proactively (GHD Pty Ltd: para [0001]), because Niedermayr and GHD Pty Ltd are directed towards monitoring flow rate of a pump.

Regarding Claim 16, Niedermayr further discloses the method of claim 15, wherein the action comprises adjusting one or more operating parameters of the pump (50) (para [0040], [0043], [0051], [0052]).

Regarding Claim 17, Niedermayr further discloses the method of claim 15, wherein the action comprises taking the pump (50) offline (para [0010], [0151]).

Claims 5, 6, 8-14, and 18-20 meet the criteria set forth in PCT Article 33(2) and PCT Article 33(3) because the prior art fails to teach or fairly suggest the claimed inventions.

Regarding Claim 5. The method of claim 1, wherein the one or more sensors (34, 36) are non-contact sensors arranged exterior of a tubular (70) transporting the slurry.

Regarding Claim 8. A system for monitoring a hydraulic fracturing operation, comprising:
a pump (50) arranged a well site (12) where hydraulic fracturing is to be performed, the pump (50) being fluidly coupled to a slurry supply (26) at a suction end (52) and to discharge piping (32) at a discharge end (54);
a first sensor (34, 36) arranged at at least one of the suction end (52) or the discharge end (52), the first sensor (34, 36) determining a flow rate of the slurry;
a second sensor (34, 36) arranged proximate the pump (50) to measure one or more operating parameters of the pump (50); and
a controller (56) communicatively coupled to the pump (50), the first sensor (34, 36), and the second sensor (34, 36), wherein the controller (56) adjusts the one or more operating parameters based at least in part on information received from the first sensor (34, 36).

Regarding Claim 18. The method of claim 15, further comprising:
receiving third data from a third sensor (34, 36) measuring one or more operating parameters of the pump (50);
determining the one or more operating parameters associated with the third data are outside of a pre-determined range; and
adjusting the one or more operating parameters.

Regarding Claim 19. The method of claim 15, further comprising:
associating the first data with a damage threshold;
associating the second data with a second damage threshold; and
determining at least one of the first data or the second data exceeds the respective first or second damage thresholds; and
adjusting one or more operating parameters of the pump (50).

Regarding Claim 20. The method of claim 15, wherein the first sensor (34, 36) and the second sensor (34, 36) are arranged proximate the pump (50) such that no intermediate equipment is positioned between the first sensor (34, 36) and a pump inlet and no intermediate equipment is positioned between the second sensor (34, 36) and a pump outlet.

Accordingly, regarding Claims 5, 8, and 18-20, Niedermayr discloses the methods as discussed above and further comprises a range (para [0146]) and an intermediate system (para [0045]); but does not specifically disclose the one or more sensors (34, 36) are non-contact sensors arranged exterior of a tubular (70) transporting the slurry;
a system for monitoring a hydraulic fracturing operation, comprising: a pump (50) arranged a well site (12) where hydraulic fracturing is to be performed, the pump (50) being fluidly coupled to a slurry supply (26) at a suction end (52) and to discharge piping (32) at a discharge end (54); a first sensor (34, 36) arranged at at least one of the suction end (52) or the discharge end (52), the first sensor (34, 36) determining a flow rate of the slurry; a second sensor (34, 36) arranged proximate the pump (50) to measure one or more operating parameters of the pump (50); and a controller (56) communicatively coupled to the pump (50), the first sensor (34, 36), and the second sensor (34, 36), wherein the controller (56) adjusts the one or more operating parameters based at least in part on information received from the first sensor (34, 36);
receiving third data from a third sensor (34, 36) measuring one or more operating parameters of the pump (50); determining the one or more operating parameters associated with the third data are outside of a pre-determined range; and adjusting the one or more operating parameters;
associating the first data with a damage threshold; associating the second data with a second damage threshold; and determining at least one of the first data or the second data exceeds the respective first or second damage thresholds; and adjusting one or more operating parameters of the pump (50); and
the first sensor (34, 36) and the second sensor (34, 36) are arranged proximate the pump (50) such that no intermediate equipment is positioned between the first sensor (34, 36) and a pump inlet and no intermediate equipment is positioned between the second sensor (34, 36) and a pump outlet.

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Box V.2., Citations and explanations,

Accordingly, regarding Claims 3, 5, 8, and 18-20, GHD Pty Ltd discloses the methods as discussed above and further discloses measuring pressure at suction and discharge sides of a pump (Fig. 2; para [0013], [0026], [0113]); but does not specifically disclose the one or more sensors (34, 36) are non-contact sensors arranged exterior of a tubular (70) transporting the slurry;
a system for monitoring a hydraulic fracturing operation, comprising: a pump (50) arranged a well site (12) where hydraulic fracturing is to be performed, the pump (50) being fluidly coupled to a slurry supply (26) at a suction end (52) and to discharge piping (32) at a discharge end (54); a first sensor (34, 36) arranged at at least one of the suction end (52) or the discharge end (52), the first sensor (34, 36) determining a flow rate of the slurry; a second sensor (34, 36) arranged proximate the pump (50) to measure one or more operating parameters of the pump (50); and a controller (56) communicatively coupled to the pump (50), the first sensor (34, 36), and the second sensor (34, 36), wherein the controller (56) adjusts the one or more operating parameters based at least in part on information received from the first sensor (34, 36);
receiving third data from a third sensor (34, 36) measuring one or more operating parameters of the pump (50); determining the one or more operating parameters associated with the third data are outside of a pre-determined range; and adjusting the one or more operating parameters;
associating the first data with a damage threshold; associating the second data with a second damage threshold; and determining at least one of the first data or the second data exceeds the respective first or second damage thresholds; and adjusting one or more operating parameters of the pump (50); and
the first sensor (34, 36) and the second sensor (34, 36) are arranged proximate the pump (50) such that no intermediate equipment is positioned between the first sensor (34, 36) and a pump inlet and no intermediate equipment is positioned between the second sensor (34, 36) and a pump outlet.

Accordingly, regarding Claims 3, 5, 8, and 18-20, WO 2016/144939 A1 (Schlumberger Technology Corporation), Schlumberger Technology Corporation discloses a system for monitoring a hydraulic fracturing operation (para [0030]), comprising: a pump (para [0030]), sensor (para [0036]), controller (para [0057]), a predetermined threshold (para [0066]), a range (para [0067]), and operational parameters (para [0067]); but does not specifically disclose the one or more sensors (34, 36) are non-contact sensors arranged exterior of a tubular (70) transporting the slurry;
a system for monitoring a hydraulic fracturing operation, comprising: a pump (50) arranged a well site (12) where hydraulic fracturing is to be performed, the pump (50) being fluidly coupled to a slurry supply (26) at a suction end (52) and to discharge piping (32) at a discharge end (54); a first sensor (34, 36) arranged at at least one of the suction end (52) or the discharge end (52), the first sensor (34, 36) determining a flow rate of the slurry; a second sensor (34, 36) arranged proximate the pump (50) to measure one or more operating parameters of the pump (50); and a controller (56) communicatively coupled to the pump (50), the first sensor (34, 36), and the second sensor (34, 36), wherein the controller (56) adjusts the one or more operating parameters based at least in part on information received from the first sensor (34, 36);
receiving third data from a third sensor (34, 36) measuring one or more operating parameters of the pump (50); determining the one or more operating parameters associated with the third data are outside of a pre-determined range; and adjusting the one or more operating parameters;
associating the first data with a damage threshold; associating the second data with a second damage threshold; and determining at least one of the first data or the second data exceeds the respective first or second damage thresholds; and adjusting one or more operating parameters of the pump (50); and
the first sensor (34, 36) and the second sensor (34, 36) are arranged proximate the pump (50) such that no intermediate equipment is positioned between the first sensor (34, 36) and a pump inlet and no intermediate equipment is positioned between the second sensor (34, 36) and a pump outlet.

Accordingly, regarding Claims 3, 5, 8, and 18-20, US 2006/0052903 A1 (Bassett), Bassett discloses a system for monitoring a hydraulic fracturing operation (para [0024]), comprising: a pump (para [0024]), sensors (para [0026]), threshold value (para [0043]), predetermined value (para [0014]-[0016]), and operating parameters (para [0026]); but does not specifically disclose the one or more sensors (34, 36) are non-contact sensors arranged exterior of a tubular (70) transporting the slurry;
a system for monitoring a hydraulic fracturing operation, comprising: a pump (50) being fluidly coupled to a slurry supply (26) at a suction end (52) and to discharge piping (32) at a discharge end (54); a first sensor (34, 36) arranged at at least one of the suction end (52) or the discharge end (52), the first sensor (34, 36) determining a flow rate of the slurry; a second sensor (34, 36) arranged proximate the pump (50) to measure one or more operating parameters of the pump (50); and a controller (56) communicatively coupled to the pump (50), the first sensor (34, 36), and the second sensor (34, 36);
receiving third data from a third sensor (34, 36) measuring one or more operating parameters of the pump (50); determining the one or more operating parameters associated with the third data are outside of a pre-determined range; and adjusting the one or more operating parameters;
associating the first data with a damage threshold; associating the second data with a second damage threshold; and determining at least one of the first data or the second data exceeds the respective first or second damage thresholds; and adjusting one or more operating parameters of the pump (50); and
the first sensor (34, 36) and the second sensor (34, 36) are arranged proximate the pump (50) such that no intermediate equipment is positioned between the first sensor (34, 36) and a pump inlet and no intermediate equipment is positioned between the second sensor (34, 36) and a pump outlet.

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In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Box V.2., Citations and explanations,

Accordingly, regarding Claims 3, 5, 8, and 18-20, US 5,006,044 A to Walker, Sr., et al. (hereinafter 'Walker, Sr.'), Walker, Sr. discloses a system for monitoring a hydraulic fracturing operation (col 2, ln 44-63), comprising: a pump (50) arranged a well site (12) where hydraulic fracturing is to be performed (col 11, ln 29-50), comprising a sensor (col 21, ln 48-58), a controller (col 37, ln 43 to col 38, ln 37), and adjusting the one or more operating parameters based at least in part on information received from the first sensor (col 31, ln 39-54); but does not specifically disclose the one or more sensors (34, 36) are non-contact sensors arranged exterior of a tubular (70) transporting the slurry;
a system for monitoring a hydraulic fracturing operation, comprising: a pump (50) being fluidly coupled to a slurry supply (26) at a suction end (52) and to discharge piping (32) at a discharge end (54); a first sensor (34, 36) arranged at at least one of the suction end (52) or the discharge end (52), the first sensor (34, 36) determining a flow rate of the slurry; a second sensor (34, 36) arranged proximate the pump (50) to measure one or more operating parameters of the pump (50); and a controller (56) communicatively coupled to the pump (50), the first sensor (34, 36), and the second sensor (34, 36);
receiving third data from a third sensor (34, 36) measuring one or more operating parameters of the pump (50); determining the one or more operating parameters associated with the third data are outside of a pre-determined range; and adjusting the one or more operating parameters;
associating the first data with a damage threshold; associating the second data with a second damage threshold; and determining at least one of the first data or the second data exceeds the respective first or second damage thresholds; and adjusting one or more operating parameters of the pump (50); and
the first sensor (34, 36) and the second sensor (34, 36) are arranged proximate the pump (50) such that no intermediate equipment is positioned between the first sensor (34, 36) and a pump inlet and no intermediate equipment is positioned between the second sensor (34, 36) and a pump outlet.

Thus, Niedermayr, GHD Pty Ltd, Schlumberger Technology Corporation, Bassett, and Walker, Sr., each individually and in combination fail to teach or fairly suggest the method of Claim 5, the system of Claim 8, and the methods of Claims 18-20.

Regarding Claims 6 and 9-14, these are dependent claims depending from Claims 5 and 8, respectively, and therefore meet the criteria set forth in PCT Article 33(2) and PCT Article 33(3).

Claims 1-20 have industrial applicability as defined by PCT Article 33(4) because the subject matter could be made or used in industry.

SEARCH HISTORY

Application Number	PCT/US 18/54542
Search Conducted By	SRH
Search Approved By	SRH

IPC, CPC, USPC Classifications Searched	IPC(8)- E21B 37/06, E21B 45/00, F04B 49/06, F04B 49/20, G01F 1/76, G01N 29/44, G05D 7/06 (2018.01) CPC- E21B 37/06, E21B 45/00, E21B 47/0007, E21B 49/08, E21B 49/081, E21B 49/087, F04B 49/06, F04B 49/20, F04B 2027/1827, F04B 2027/1831, E21B 2049/085, F04B 2203/1102, F04B 2205/01, F04B 2205/05, G01F 1/76, G01F 25/0007, G01N 29/44, G01N 29/4427, G01N 2030/324, G01N 2291/02836, G05B 23/0294, G05B 2219/32184, G05B 2219/36292, G05B 2219/41303, G05D 7/06, G06F 2201/81, G06F 2209/5022 USPC- 73/198, 73/861.12, 134/22.12, 134/102.1, 134/102.2, 134/166C, 134/169C, 299/1.9, 417/20, 700/282
Date Conducted	23 November 2018

Documentation Searched	Patent Literature and Non-Patent Literature
Search Terms Used	pump, efficiency, performance, sense, flow, rate, monitor, detect, measure, determine, threshold, slurry, wellbore, bore, subterranean, frack, frac, fracturing, drilling, control, adjust, non-contact, sensor, volumeetric, operating, performance, parameter, suction, discharge
Date Conducted	23 November 2018

Electronic Database Searched	Google
Files Searched	Google Patent
Date Conducted	23 November 2018

Search Logic:

(slurry flow rate) (pump efficiency) (monitor OR detect OR measure OR sense) (control OR adjust)
About 108,000 results (0.44 seconds)
(wellbore OR bore OR drilling OR frack OR fracturing) (flow rate) ("pump efficiency"~2) (monitor OR detect OR measure OR sense OR determine) (control OR adjust)
About 2,370 results (0.47 seconds)

(wellbore OR bore OR drilling OR frack OR fracturing) ((flow OR pump) (rate OR speed)) (pump efficiency) (monitor OR detect OR measure OR sense OR determine) (control OR adjust OR parameter)
About 255,000 results (0.75 seconds)
(wellbore OR bore OR drilling OR frack OR fracturing) ((flow OR pump) (rate OR speed OR volumetric)) (pump (efficiency OR performance)) (monitor OR detect OR measure OR sense OR determine) (control OR adjust OR parameter) (suction discharge)
About 77,800 results (0.66 seconds)
(wellbore OR bore OR drilling OR frack OR frac OR fracturing) ((flow OR pump) (rate OR speed OR volumetric OR parameter OR operating)) (pump efficiency) (monitor OR detect OR measure OR sense OR determine) (non contact sensor)
About 130,000 results (0.60 seconds)

Electronic Database Searched	Google
Files Searched	Google Scholar
Date Conducted	23 November 2018

Search Logic:

(slurry flow rate) (pump efficiency) (monitor OR detect OR measure OR sense) (control OR adjust)
About 85,800 results (0.20 sec)
(wellbore OR bore OR drilling OR frack OR fracturing) (flow rate) ("pump efficiency"~2) (monitor OR detect OR measure OR sense OR determine) (control OR adjust)
About 5,560 results (0.26 sec)
(wellbore OR bore OR drilling OR frack OR fracturing) ((flow OR pump) (rate OR speed)) (pump efficiency) (monitor OR detect OR measure OR sense OR determine) (control OR adjust OR parameter)
About 319,000 results (0.19 sec)
(wellbore OR bore OR drilling OR frack OR fracturing) ((flow OR pump) (rate OR speed OR volumetric)) (pump (efficiency OR performance)) (monitor OR detect OR measure OR sense OR determine) (control OR adjust OR parameter) (suction discharge)
About 31,900 results (0.19 sec)
(wellbore OR bore OR drilling OR frack OR frac OR fracturing) ((flow OR pump) (rate OR speed OR volumetric OR parameter OR operating)) (pump efficiency) (monitor OR detect OR measure OR sense OR determine) (non contact sensor)
About 58,600 results (0.22 sec)

Electronic Database Searched	Free Patents Online
Files Searched	(US Pat, PgPub, EPO, JPO, WIPO: classification, keyword)
Date Conducted	23 November 2018

Search Logic:

(slurry flow rate) (pump efficiency) (monitor OR detect OR measure OR sense) (control OR adjust)

Matches 1 - 50 out of 140151
(wellbore OR bore OR drilling OR frack OR fracturing) (flow rate) ("pump efficiency"~2) (monitor OR detect OR measure OR sense OR determine) (control OR adjust)
Matches 1 - 50 out of 2634
(wellbore OR bore OR drilling OR frack OR fracturing) ((flow OR pump) (rate OR speed)) (pump efficiency) (monitor OR detect OR measure OR sense OR determine) (control OR adjust OR parameter)
Matches 1 - 50 out of 256277
(wellbore OR bore OR drilling OR frack OR fracturing) ((flow OR pump) (rate OR speed OR volumetric)) (pump (efficiency OR performance)) (monitor OR detect OR measure OR sense OR determine) (control OR adjust OR parameter) (suction discharge)
Matches 1 - 50 out of 50654
(wellbore OR bore OR drilling OR frack OR frac OR fracturing) ((flow OR pump) (rate OR speed OR volumetric OR parameter OR operating)) (pump efficiency) (monitor OR detect OR measure OR sense OR determine) (non contact sensor)
Matches 1 - 50 out of 72437

Electronic Database Searched	Pat Base
Files Searched	Full-text: AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO Bibliographic: (Europe) AT BA BE BG CH CS CY CZ DD DK EE ES FI GE GR HR HU IE IS IT LT LU LV MC MD MT NL NO PL PT RO RS SE SI SK SM TR UA YU (Asia) EA GC HK ID IL IN KZ MN MY PH RU SG SU TH TJ TW UZ VN (North America) CA CR CU DO GT HN MX NI PA SV TT (South America) AR BR CL CO EC PE UY (Australasia) AU NZ (Africa) AP DZ EG KE MA MW OA ZA ZM ZW
Date Conducted	23 November 2018

Search Logic:

Search 1: IC=(E21B37/06 or E21B45/00 or F04B49/06 or F04B49/20 or G01F1/76 or G01N29/44 or G05D7/06) (Results 39592)
Search 2: CPC=(E21B37/06 or E21B45/00 or E21B47/0007 or E21B49/08 or E21B49/081 or E21B49/087 or F04B49/06 or F04B49/20 or F04B2027/1827 or F04B2027/1831 or E21B2049/085 or F04B2203/1102 or F04B2205/01 or F04B2205/05 or G01F1/76 or G01F25/0007 or G01N29/44 or G01N29/4427 or G01N2030/324 or G01N2291/02836 or G05B23/0294 or G05B2219/32184 or G05B2219/36292 or G05B2219/41303 or G05D7/06 or G06F2201/81 or G06F2209/5022) (Results 15608)
Search 3: UC=(73/198 or 73/861.12 or 134/22.12 or 134/102.1 or 134/102.2 or 134/166C or 134/169C or 299/1.9 or 417/20 or 700/282) (Results 5688)
Search 4: 3 or 2 or 1 (Results 53809)
Search 5: PA=("U.S." or WELL or SERVICES) (Results 217141)
Search 6: INV=(Oehring or Christinzio or Hinderliter) (Results 193)
Search 7: 6 or 5 (Results 217322)
Search 8: SP=(pump* and (effici* or perform*)) (Results 630514)
Search 9: 8 and sens* (Results 115981)
Search 10: 8 and (flow* near rate*) (Results 34495)
Search 11: 8 and (monitor* OR detect* OR measur* OR sens* or determin*) (Results 212253)
Search 12: 8 and threshold* (Results 19154)

Search 13: 12 and 11 and 10 and 9 (Results 1724)
Search 14: 12 and 11 and 10 and 9 and 7 (Results 68)
Search 15: 12 and 11 and 10 and 9 and 4 (Results 196)
Search 16: 8 and slurr* (Results 13213)
Search 17: 8 and (wellbor* or bore* or subterran* or frack* or fracturing*) (Results 35517)
Search 18: 8 and (control* or adjust*) (Results 292944)
Search 19: 18 and 17 and 16 and 12 and 11 and 10 and 9 (Results 7)
Search 20: 18 and 17 and 16 and 12 and 11 and 10 and 7 (Results 4)
Search 21: 18 and 17 and 16 and 12 and 11 and 10 and 4 (Results 5)
Search 22: 18 and 17 and 12 and 11 and 10 and 9 (Results 157)
Search 23: 18 and 17 and 12 and 11 and 10 and 9 and 7 (Results 31)
Search 24: 18 and 17 and 12 and 11 and 10 and 9 and 4 (Results 44)
Search 25: 24 not 23 (Results 34)
Search 26: 8 and (pump* near effic*) (Results 20486)
Search 27: 26 and 18 and 17 and 16 (Results 12)
Search 28: 26 and 18 and 17 and 16 and 10 (Results 6)
Search 29: 26 and 18 and 17 and 10 (Results 66)
Search 30: 26 and 18 and 17 and 10 and 4 (Results 12)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 02 JAN 2019
Applicant's or agent's file reference 047158.500030	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 18/54548	International filing date *(day/month/year)* 05 October 2018 (05.10.2018)
Applicant U.S. WELL SERVICES, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Lee W. Young Telephone No. PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 047158.500030	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 18/54548	International filing date *(day/month/year)* 05 October 2018 (05.10.2018)	(Earliest) Priority Date *(day/month/year)* 05 October 2017 (05.10.2017)
Applicant U.S. WELL SERVICES, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the drawings to be published with the abstract is Figure No. 2

   ☐ as suggested by the applicant.

   ☒ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/54548

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
because they are dependent claims that fail to further describe or clarify the independent claim.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/54548

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044 (2018.01)
CPC - E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044

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)
See Search History Document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/0290114 A1 (US Well Services LLC) 6 October 2016 (06.10.2016) Entire document especially para [0022]-[0026] and fig. 3	1-3, 5-6, 8-10, 12, 16-18, 20
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Y		4, 7, 11, 13-15, 19
Y	US 2015/0211524 A1 (US Well Services LLC) 30 July 2015 (30.07.2015) Entire document especially para [0033], [0044], [0047] and figs. 1-3	4, 11, 19
Y	US 2014/0138079 A1 (US Well Services LLC) 22 May 2014 (22.05.2014) Entire document especially para [0014], [0018], [0022] and fig. 1	7, 13-15
A	US 9,562,420 B2 (Evolution Well Services, LLC) 7 February 2017 (07.02.2017) Entire document	1-20
A	US 2014/0010671 A1 (Cryer et al.) 9 January 2014 (09.01.2014) Entire document	1-20
A	US 2014/0251623 A1 (Prostim Labs, LLC) 11 September 2014 (11.09.2014) Entire document	1-20
A	US 2015/0252661 A1 (Glass) 10 September 2015 (10.09.2015) Entire document	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
21 November 2018	02 JAN 2019
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	02 JAN 2019
Applicant's or agent's file reference 047158.500030	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 18/54548	05 October 2018 (05.10.2018)	05 October 2017 (05.10.2017)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044 (2018.01)
CPC - E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044

Applicant U.S. WELL SERVICES, LLC

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [x] Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	21 November 2018	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/54548

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/54548

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	4, 7, 11, 13-15, 19	YES
	Claims	1-3, 5-6, 8-10, 12, 16-18, 20	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-3, 5-6, 8-10, 12, 16-18 and 20 lack novelty under PCT Article 33(2) as being anticipated by US 2016/0290114 A1 to US Well Services LLC (hereinafter 'Well114')

Regarding Claim 1, Well114 teaches a hydraulic fracturing system (See fig. 3; para [0023]) for fracturing a subterranean formation (64 - "subterranean formation", fig. 3) comprising:
an electric pump (84 - "pump", fig. 3; para [0022]-[0024] - pump is driven by an electric generator 50 and an electric motor 88) fluidly connected to a well (60 - "wellbore", fig. 3) associated with the subterranean formation and powered by at least one electric motor (88 - "electric motor", fig. 3; para [0023]), and configured to pump fluid into a wellbore (60 - "wellbore", fig. 3) associated with the well at a high pressure so that the fluid passes from the wellbore into the subterranean formation (para [0023]) and fractures (62 - "fractures", fig. 3; para [0023]) the subterranean formation;
at least one generator (50 - "generator", fig. 2; para [0022]) electrically coupled (108 - "line", fig. 3; para [0025]) to the electric motor so as to generate electricity for use by the electric pump (para [0025]);
wherein a shaft of the motor (88 - "electric motor", fig. 3) is directly coupled to a crankshaft of the pump (84 - "pump", fig. 3) without an intermediate gear reduction system (para [0023] - " In one example, the connection 90 is a direct coupling between an electric motor 88 and a hydraulic fracturing pump 84.") such that the shaft of the motor rotates at substantially the same speed as the crankshaft of the pump (See fig. 3; para [0023] - a direct coupling between the motor 88 and pump 84 means the speed would be transferred from the shaft of the motor to the crankshaft of the pump).

Regarding Claim 2, Well114 teaches the system of claim 1, further comprising: a coupling device (90 - "connection", fig. 3) connecting the shaft of the motor to the crankshaft (para [0023]).

Regarding Claim 3, Well114 teaches the system of claim 2, wherein the coupling device (90 - "connection", fig. 3) is a flexible coupling device or a rigid coupling device (all couplings must be either rigid or flexible).

Regarding Claim 5, Well114 teaches the system of claim 1, further comprising: a variable frequency drive (91 - "variable frequency drive", fig. 3) connected to the at least one electric motor to control the speed of the at least one electric motor (para [0024]).

Regarding Claim 6, Well114 teaches the system of claim 1, wherein the at least one generator (50 - "generator", fig. 2; para [0022]) comprises one of a turbine generator (44 - "turbine", fig. 2; para [0022]) or a reciprocating engine generator, or a combination thereof.

Regarding Claim 8, Well114 teaches a hydraulic fracturing system (See fig. 3; para [0023]) for fracturing a subterranean formation (64; See fig. 3; para [0023]) comprising:
an electric pump (84 - "pump", fig. 3; para [0022]-[0024] - pump is driven by an electric generator 50 and an electric motor 88) fluidly connected to a well (60 - "wellbore", fig. 3) associated with the subterranean formation and configured to pump fluid into a wellbore (60 - "wellbore", fig. 3) associated with the well at a high pressure so that the fluid passes from the wellbore into the subterranean formation (para [0023]) and fractures (62 - "fractures", fig. 3; para [0023]) the subterranean formation;
at least one electric motor (88 - "electric motor", fig. 3; para [0023]) providing operational energy to the electric pump (para [0023]);
at least one generator (50 - "generator", fig. 2; para [0022]) electrically coupled (108 - "line", fig. 3) to the electric motor so as to generate electricity for use by the electric pump (para [0025]);
a variable frequency drive (91 - "variable frequency drive", fig. 3) connected to the at least one electric motor to control the speed of the at least one electric motor (para [0024]);
wherein a shaft of the motor (88 - "electric motor", fig. 3) is directly coupled (para [0023] - " In one example, the connection 90 is a direct coupling between an electric motor 88 and a hydraulic fracturing pump 84.") to a crankshaft of the pump (84 - "pump", fig. 3) such that the shaft of the motor rotates at substantially the same speed as the crankshaft of the pump (See fig. 3; para [0023] - a direct coupling between the motor 88 and pump 84 means the speed would be transferred from the shaft of the motor to the crankshaft of the pump).

Regarding Claim 9, Well114 teaches the system of claim 8, further comprising: a coupling device (90 - "connection", fig. 3) connecting the shaft of the motor to the crankshaft (para [0023]).

Regarding Claim 10, Well114 teaches the system of claim 9, wherein the coupling device (90 - "connection", fig. 3) is a flexible coupling device or a rigid coupling device (all couplings must be either rigid or flexible).

-*-Continued in Supplemental Box-*-

LIBERTY EXHIBIT 1002, Page 1616

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 16/54548

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claims 12 and 13: The recitations "The system of claim 1" is confusing because claim 1 already has two dependent claims with the exact same wording as claims 12 and 13 (See claims 6 and 7). It appears as though the author of the claims made an error and wrote that claims 12 and 13 were dependent from the wrong independent claim. Accordingly, for purposes of this opinion, the recitations have been interpreted to be "The system of claim 8."

Claim 20: The recitation "The system of claim 1" is confusing because claim 1 already has language and a dependent claim with the exact same wording as claim 20 (See claims 1 and 6). It appears as though the author of the claim made an error and wrote that claim 20 was dependent from the wrong independent claim. Accordingly, for purposes of this opinion, the recitation has been interpreted to be "The system of claim 16."

LIBERTY EXHIBIT 1002, Page 1617

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Regarding Claim 12, Well114 teaches the system of claim 8 (Note: See Box VIII), wherein the at least one generator (50 - "generator", fig. 2; para [0022]) comprises one of a turbine generator (44 - "turbine", fig. 2; para [0022]) or a reciprocating engine generator, or a combination thereof.

Regarding Claim 16, Well114 teaches a hydraulic fracturing system (See fig. 3; para [0023]) for fracturing a subterranean formation (64; See fig. 3; para [0023]) comprising:
an electric pump (84 - "pump", fig. 3; para [0022]-[0024] - pump is driven by an electric generator 50 and an electric motor 88) fluidly connected to a well (60 - "wellbore", fig. 3) associated with the subterranean formation and configured to pump fluid into a wellbore (60 - "wellbore", fig. 3) associated with the well at a high pressure so that the fluid passes from the wellbore into the subterranean formation (para [0023]) and fractures (62 - "fractures", fig. 3; para [0023]) the subterranean formation;
at least one electric motor (88 - "electric motor", fig. 3; para [0023]) providing operational energy to the electric pump (para [0023]);
a variable frequency drive (91 - "variable frequency drive", fig. 3) connected to the at least one electric motor to control the speed of the at least one electric motor (para [0024]);
wherein a shaft (88 - "electric motor", fig. 3) of the motor is directly coupled (para [0023] - " In one example, the connection 90 is a direct coupling between an electric motor 88 and a hydraulic fracturing pump 84.") to a crankshaft of the pump (84 - "pump", fig. 3) such that the shaft of the motor rotates at substantially the same speed as the crankshaft of the pump and a torque output of the at least one electric motor is directly transmitted to the electric pump (See fig. 3; para [0023] - a direct coupling between the motor 88 and pump 84 means the torque would be transferred from the shaft of the motor to the crankshaft of the pump).

Regarding Claim 17, Well114 teaches the system of claim 16, further comprising: a coupling device (90 - "connection", fig. 3) connecting the shaft of the motor to the crankshaft (para [0023]).

Regarding Claim 18, Well114 teaches the system of claim 17, wherein the coupling device (90 - "connection", fig. 3) is a flexible coupling device or a rigid coupling device (all couplings must be either rigid or flexible).

Regarding Claim 20, Well114 teaches the system of claim 16 (Note: See Box VIII), further comprising: at least one generator (50 - "generator", fig. 2; para [0022]) electrically coupled (108 - "line", fig. 3) to the electric motor so as to generate electricity for use by the electric pump (para [0023], [0025]), wherein the at least one generator comprises one of a turbine generator (44 - "turbine", fig. 2; para [0022]) or a reciprocating engine generator, or a combination thereof.

Claims 4, 11 and 19 lack an inventive step under PCT Article 33(3) as being obvious over Well114 in view of US 2015/0211524 A1 to US Well Services LLC (hereinafter 'Well524')

Regarding Claim 4, Well114 teaches the system of claim 2, but does not specifically teach wherein the coupling device is at least one of a beam coupling, a bellows coupling, a chain coupling, a jaw coupling, a diaphragm coupling, a disc coupling, a gear coupling, a grid coupling, an Oldham coupling, a Schmidt coupling, or clamping coupling. Further, Well524 teaches a hydraulic fracturing system (See fig. 1; para [0033]) comprising a coupling device (152 - "torsional coupling", figs. 2A-C; para [0040]) for connecting a shaft of a motor (para [0041] - "motor shaft") to a crankshaft of a pump (para [0041] - "pump shaft") wherein the coupling device is a jaw coupling (para [0045]-[0047]; See fig. 3; see how motor coupling claws 170 are designed to fit within the areas between adjacent elastomeric inserts 164). Accordingly, it would have been obvious to one of ordinary skill in the art to use the coupling device taught by Well524 instead of the coupling device taught by Well114 to directly couple the motor to the pump in order to allow for a misalignment of shafts while still maintaining full torque and speed transfer.

Regarding Claim 11, Well114 teaches the system of claim 9, but does not specifically teach wherein the coupling device is at least one of a beam coupling, a bellows coupling, a chain coupling, a jaw coupling, a diaphragm coupling, a disc coupling, a gear coupling, a grid coupling, an Oldham coupling, a Schmidt coupling, or clamping coupling. Further, Well524 teaches a hydraulic fracturing system (See fig. 1; para [0033]) comprising a coupling device (152 - "torsional coupling", figs. 2A-C; para [0040]) for connecting a shaft of a motor (para [0041] - "motor shaft") to a crankshaft of a pump (para [0041] - "pump shaft") wherein the coupling device is a jaw coupling (para [0045]-[0047]; See fig. 3; see how motor coupling claws 170 are designed to fit within the areas between adjacent elastomeric inserts 164). Accordingly, it would have been obvious to one of ordinary skill in the art to use the coupling device taught by Well524 instead of the coupling device taught by Well114 to directly couple the motor to the pump in order to allow for a misalignment of shafts while still maintaining full torque and speed transfer.

Regarding Claim 19, Well114 teaches the system of claim 17, but does not specifically teach wherein the coupling device is at least one of a beam coupling, a bellows coupling, a chain coupling, a jaw coupling, a diaphragm coupling, a disc coupling, a gear coupling, a grid coupling, an Oldham coupling, a Schmidt coupling, or clamping coupling. Further, Well524 teaches a hydraulic fracturing system (See fig. 1; para [0033]) comprising a coupling device (152 - "torsional coupling", figs. 2A-C; para [0040]) for connecting a shaft of a motor (para [0041] - "motor shaft") to a crankshaft of a pump (para [0041] - "pump shaft") wherein the coupling device is a jaw coupling (para [0045]-[0047]; See fig. 3; see how motor coupling claws 170 are designed to fit within the areas between adjacent elastomeric inserts 164). Accordingly, it would have been obvious to one of ordinary skill in the art to use the coupling device taught by Well524 instead of the coupling device taught by Well114 to directly couple the motor to the pump in order to allow for a misalignment of shafts while still maintaining full torque and speed transfer.

-*-Continued in next Supplemental Box-*-

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Claims 7 and 13-15 lack an inventive step under PCT Article 33(3) as being obvious over Well114 in view of US 2014/0138079 A1 to US Well Services LLC (hereinafter 'Well079')

Regarding Claim 7, Well114 teaches the system of claim 1, but does not specifically teach wherein the electric pump comprises limited gearing. Further, Well079 teaches a hydraulic fracturing system (See fig. 1; para [0018]) comprising an electric motor (14 - "electric motor", fig. 1) for providing operational energy (para [0014]) to a pump (10 - "pump", fig. 1) wherein the pump comprises limited gearing (para [0022]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the limited gearing in the pump taught by Well079 on the pump taught by Well114 in order to allow for the pump to have greater variability in its output despite the same input.

Regarding Claim 13, Well114 teaches the system of claim 8 (Note: See Box VIII), but does not specifically teach wherein the electric pump comprises limited gearing. Further, Well079 teaches a hydraulic fracturing system (See fig. 1; para [0018]) comprising an electric motor (14 - "electric motor", fig. 1) for providing operational energy (para [0014]) to a pump (10 - "pump", fig. 1) wherein the pump comprises limited gearing (para [0022]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the limited gearing in the pump taught by Well079 on the pump taught by Well114 in order to allow for the pump to have greater variability in its output despite the same input.

Regarding Claim 14, Well114, in view of Well079, teaches but does not specifically teach the system of claim 13, wherein the limited gearing is internal to the electric pump. However, using routine experimentation and design principles, it would have been obvious to one of ordinary skill in the art that the limited gearing can only be either internal to the pump or external to the pump. Accordingly, it would have been obvious to one of ordinary skill in the art to place the limited gearing internal to the pump in order to protect it from any other components of the system of from the wellbore.

Regarding Claim 15, Well114, in view of Well079, teaches but does not specifically teach the system of claim 13, wherein the limited gearing is external to the electric pump. However, using routine experimentation and design principles, it would have been obvious to one of ordinary skill in the art that the limited gearing can only be either internal to the pump or external to the pump. Accordingly, it would have been obvious to one of ordinary skill in the art to place the limited gearing external to the pump in order to save room inside the pump and allow for a more modular assembly to aid assembly and disassembly.

Claims 1-20 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used by industry.

SEARCH HISTORY

Application Number	PCT/US 18/54548
Search Conducted By	MFG
Search Approved By	SCL

CPC/IPC Classifications Searched	IPC(8): E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044 (2018.01) CPC: E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044
Date Conducted	21 November 2018 (21.11.2018)

Documentation Searched	IPC(8): E21B 43/26, F04B 47/02, F04B 17/03, F04D 29/044 (2018.01) CPC: (Keyword limited; see below)
Search Terms Used	electric powered hydraulic fracturing system limited gearing US Well Services LLC pump motor wellbore variable frequency drive turbine generator crankshaft coupling
Date Conducted	21 November 2018 (21.11.2018)

Electronic Database Searched	PatBase
Files Searched	Full-text: AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO Bibliographic: (European) AT BA BE BG CH CS CY CZ DD DK EE ES FI GE GR HR HU IE IS IT LT LU LV MC MD MT NL NO PL PT RO RS SE SI SK SM TR UA YU (Asia) EA GC HK ID IL IN KZ MN MY PH RU SG SU TH TJ TW UZ VN (North America) CA CR CU DO GT HN MX NI PA SV TT (South America) AR BR CL CO EC PE UY (Australasia) AU NZ (Africa) AP DZ EG KE MA MW OA ZA ZM ZW
Date Conducted	21 November 2018 (21.11.2018)
Search Logic:	

#	Search query	Results
1	IC=(F04B47/02) OR CPC=(F04B47/02)	5047
2	1 AND FT=(pump* NEAR (gear*))	241
3	2 AND FT=(electric* NEAR motor*)	110
4	IC=(E21B43/26) OR CPC=(E21B43/26)	9654
5	4 AND FT=((electric* NEAR motor*) AND (motor* NEAR pump*))	109
6	IC=(F04B17/03) OR CPC=(F04B17/03)	7904
7	6 AND FT=((electric* NEAR motor*) AND (motor* NEAR pump*))	1417
8	7 AND FT=(coupling* OR (gear* NEAR limited*))	456
9	IC=(F04D29/044) OR CPC=(F04D29/044)	1301
10	9 AND FT=((electric* NEAR motor*) AND (motor* NEAR pump*))	134
11	pn=(US20160290114 OR US20150211524 OR us2014138079)	1
12	CTB 11 OR CTF 11	204
13	12 AND FT=((electric* NEAR motor*) AND (motor* NEAR pump*))	45

Electronic Database Searched	Google
Files Searched	Patents
Date Conducted	21 November 2018 (21.11.2018)

Search Logic:

electric powered hydraulic fracturing system -gear - About 29,900 results
assignee:(US Well Services LLC) - About 42 results
electric powered hydraulic fracturing system limited gearing - About 15,200 results
pump "limited gearing" - 7 results
pump with additional spacing - About 208,000 results
electric fracturing systems with motor and pump - About 131,000 results
coupling for motor shaft and pump crankshaft - About 110,000 results
electric pump and motor for wellbore - About 45,900 results
electric powered hydraulic fracturing with variable frequency drive - About 63,200 results
electric powered hydraulic fracturing with turbine generator - About 199,000 results

Electronic Database Searched	Google
Files Searched	Web

Date Conducted	21 November 2018 (21.11.2018)

Search Logic:

"limited gearing" - About 3,980 results
"limited gearing" pump - About 647 results
electric powered hydraulic fracturing system -gear - About 765,000 results
US Well Services LLC - About 780,000,000 results
electric powered hydraulic fracturing system limited gearing - About 705,000 results
pump with additional spacing - About 7,570,000 results
electric fracturing systems with motor and pump - About 10,900,000 results
coupling for motor shaft and pump crankshaft - About 4,980,000 results
electric powered hydraulic fracturing with variable frequency drive - About 1,300,000 results
electric powered hydraulic fracturing with turbine generator - About 1,020,000 results

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 31 DEC 2018
Applicant's or agent's file reference 047158.500031	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US 18/55913	International filing date *(day/month/year)* 15 October 2018 (15.10.2018)
Applicant U.S. WELL SERVICES, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ With regard to any protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   - ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within 20 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices. In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within 22 months from the priority date, the applicant may request that a supplementary international search be carried out by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Lee W. Young PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 047158.500031	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 18/55913	International filing date *(day/month/year)* 15 October 2018 (15.10.2018)	(Earliest) Priority Date *(day/month/year)* 13 October 2017 (13.10.2017)
Applicant U.S. WELL SERVICES, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 9 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the language, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the title,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the drawings,

   a. the figure of the drawings to be published with the abstract is Figure No. 2

   ☐ as suggested by the applicant.

   ☒ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/55913

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 44/00, E21B 43/26, E21B 43/267 (2018.01)
CPC - E21B 44/00, E21B 43/26, E21B 43/267, E21B 44/005

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)
See Search History Document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2017/0037717 A1 (US Well Services LLC) 9 February 2017 (09.02.2017) Entire document especially para [0022], [0023], [0030] and fig. 1	1-7, 9-13, 17, 19 --- 8, 14-16, 18, 20
Y	US 2017/0226842 A1 (Schlumberger Technology Corporation) 10 August 2017 (10.08.2017) Entire document especially para [0028]-[0030], [0075], [0090], [0094], [0142]-[0143] and figs. 1 and 2	8, 14-16, 18, 20
Y	US 2011/0247878 A1 (Rasheed) 13 October 2011 (13.10.2011) Entire document especially para [0041], [0066], [0076], [0078] and figs. 1 and 3	15
A	US 2016/0230524 A1 (Dumoit et al.) 11 August 2016 (11.08.2016) Entire document	1-20
A	US 2017/0114625 A1 (Lord Corporation) 27 April 2017 (27.04.2017) Entire document	1-20
A	US 2017/0022807 A1 (Landmark Graphics Corporation) 26 January 2017 (26.01.2017) Entire document	1-20
A	US 2017/0030178 A1 (US Well Services LLC) 2 February 2017 (02.02.2017) Entire document	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
5 December 2018	31 DEC 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	31 DEC 2018
Applicant's or agent's file reference 047158.500031	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 18/55913	15 October 2018 (15.10.2018)	13 October 2017 (13.10.2017)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 44/00, E21B 43/26, E21B 43/267 (2018.01)
CPC - E21B 44/00, E21B 43/26, E21B 43/267, E21B 44/005

Applicant U.S. WELL SERVICES, LLC

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability: citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [x] Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	5 December 2018	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/55913

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, this opinion has been established on the basis of a sequence listing:

a. ☐ forming part of the international application as filed:

☐ in the form of an Annex C/ST.25 text file.

☐ on paper or in the form of an image file.

b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/55913

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-8, 11, 13-20	YES
	Claims	9, 10, 12	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	None	NO

2. Citations and explanations:

Claims 9-10 and 12 lack novelty under PCT Article 33(2) as being anticipated by US 2017/0037717 A1 to US Well Services LLC (hereinafter 'Well')

Regarding Claim 9, Well teaches an automated hydraulic fracturing system (10 - "hydraulic fracturing system", fig. 1; para [0022], [0030]), comprising:
a pump system (36 - "fracturing pump", fig. 1) fluidly coupled to a wellhead (41 - "wellhead assembly", fig. 1) at a wellsite to pump a fracturing fluid into the wellhead (para [0022]);
a blender (28 - "blender", fig. 1) configured to mix together proppant and a fluid mixture to form the fracturing fluid (para [0022]);
a proppant storage and delivery system (32 - "proppant source", 34 - "line", fig. 1) configured to provide the proppant for the blender (para [0022]);
a hydration unit (18 - "hydration unit", fig. 1) configured to mix an additive into a fluid to form the fluid mixture and provide the fluid mixture to the blender (para [0022]);
a fluid storage and delivery system (20 - "fluid source", 22 - "line", fig. 1) configured to provide the fluid for the hydration unit (para [0022]);
an additive storage and delivery system (24 - "additive source", 26 - "line", fig. 1) configured to provide the additive to the hydration unit (para [0022]); and
an automated control system (160 - "controller", 154 - "sensors", 156 - "information handling system", 158, 162 - "communication means", fig. 1; para [0022], [0030] - "variable frequency drive") comprising a plurality of sensing devices (154 - "sensors", fig. 1; para [0030]) and a plurality of control devices (160 - "controller", fig. 1; para [0022] - "variable frequency drive") integrated into the pump system (para [0022]), the blender system (para [0030]), the proppant storage and delivery system, the fluid storage and delivery system, and the additive storage and delivery system, the automated control system configured to monitor one or more parameters of the automated hydraulic fracturing system via the plurality of sensing devices and transmit control instructions for one or more of the plurality of control devices to control an aspect of the automated hydraulic fracturing system (para [0030]).

Regarding Claim 10, Well teaches the system of claim 9, further comprising one or more of a plurality of components including a manifold, a manifold trailer, a discharge piping, flow lines conveyance devices, a turbine (44 - "turbine", fig. 1; para [0023]), a motor (39 - "motor", fig. 1), a variable frequency drive, a generator (50 - "generator", fig. 1), or a fuel source, wherein the automated control system (160 - "controller", 154 - "sensors", 156 - "information handling system", 158, 162 - "communication means", fig. 1; para [0022], [0030] - "variable frequency drive") comprises sensors and control devices integrated into the one or more of the plurality of components (para [0030] - sensors 154 can be placed in the power end of the hydraulic fracturing fleet which includes turbine 44 and generator 50).

Regarding Claim 12, Well teaches the system of claim 9, wherein the automated control system (160 - "controller", 154 - "sensors", 156 - "information handling system", 158, 162 - "communication means", fig. 1; para [0022] - "variable frequency drive") comprises processing devices (156 - "information handling system", fig. 1; para [0030]) located at the wellsite (See fig. 1; para [0030]), remote from the website, or both.

-*-Continued in Supplemental Box-*-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/55913

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claim 8: The term "the central processing system" is confusing and lacks proper antecedent basis. The term is properly introduced in claim 7. As written, claim 8 depends from claim 1. Accordingly, for purposes of this opinion, claim 8 has been interpreted to depend from claim 7.

LIBERTY EXHIBIT 1002, Page 1629

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/55913

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Claims 1-7, 11, 13, 17 and 19 lacks an inventive step under PCT Article 33(3) as being obvious over Well

Regarding Claim 1, Well teaches an automated hydraulic fracturing system (10 - "hydraulic fracturing system", fig. 1; para [0022], [0030]), comprising:
a pump system (36 - "fracturing pump", fig. 1) fluidly coupled to a wellhead (41 - "wellhead assembly", fig. 1) to pump a fracturing fluid into the wellhead (para [0022]), wherein the pump is instrumented with a pump controller (para [0022] - variable frequency drive controls motor 39 which controls pump 36);
a blender system (28 - "blender", fig. 1) fluidly coupled to the pump (See fig. 1), the blender mixing together one or more materials to form the fracturing fluid (para [0022]), wherein the blender is instrumented with a blender sensor (para [0030] - "In one example, a sensor is mounted near the blender discharge pump");
a source system (20 - "fluid source", 22 - "line", 32 - "proppant source", 34 - "line", fig. 1) for providing at least one of the one or more materials to the blender (para [0022]); and
a component (53 - "turbine generator", fig. 1; para [0023]), the component instrumented with at least one of a component sensor (para [0030] - sensors 154 can be placed in the power end of the hydraulic fracturing fleet which includes turbine 44 and generator 50) and a component controller,
and a controller (160 - "controller", fig. 1; para [0030]; para [0023] - "variable frequency drive"), wherein the controller controls a aspects of the automated hydraulic fracturing system based at least in part on automated instructions (para [0030]), the automated instructions generated based on measurements received from the at least one of the blender sensor and the component sensor (para [0030] - "controller 160 can be used for sending control commands for operation of the system 10, and thus can utilize vibration information from sensors 154 to adjust control commands.") but does not specifically teach wherein the pump system or the source system have their own sensors; wherein the blender system or the source system each have their own controller; or wherein each controller controls their own respective aspect of the automated hydraulic fracturing system.
However, Well does teach that the sensors (154 - "sensors", fig. 1; para [0030]) can comprise multiple sensors located on multiple parts of the hydraulic fracturing system (para [0030]) and also teaches that the controller is able to control the entire system (para [0030]). The separation and rearrangement of parts falls within the ordinary skill of one in the art using routine experimentation and design principles. Accordingly, it would have been obvious to one of ordinary skill in the art to provide the pump system and the source system with their own sensors and to provide the pump system, the blender system, the component and the source system with their own controllers in order to provide the information handling system with information about all components of the system as well as improving the speed at which the controllers are able to actually control their respective aspect of the system.

Regarding Claim 2, Well teaches the system of claim 1, wherein the pump system (36 - "fracturing pump", fig. 1) comprises a motor (39 - "motor", fig. 1) controlled by the pump controller (para [0023] - "variable frequency drive") based at least in part on the automated instructions (para [0022], [0030]).

Regarding Claim 3, Well teaches the system of claim 1, wherein the blender (28 - "blender", fig. 1) comprises at least one of a chemical pump (para [0022] - "Blender 28 can have an onboard chemical additive system, such as with chemical pumps and augers."), a cooling system, an auger, a blender discharge pump, a valve, or an actuator, the at least one controlled by the blender controller based at least in part on the automated instructions (para [0022], [0030]).

Regarding Claim 4, Well teaches the system of claim 1, wherein the source (20 - "fluid source", 22 - "line", 32 - "proppant source", 34 - "line", fig. 1) comprises at least one of a gate, a valve, an actuator, a delivery belt, a delivery line (22, 34 - "line", fig. 1; para [0023]), or a chemical pump, the at least one controlled by the source controller based at least in part on the automated instructions (para [0022], [0030]).

Regarding Claim 5, Well teaches the system of claim 1, wherein the component (53 - "turbine generator", fig. 1; para [0023]) comprises at least one of a turbine (44 - "turbine", para [0023]), a generator, a hydration unit, a distribution system, a fuel source, or a wellhead.

Regarding Claim 6, Well teaches the system of claim 5, wherein the component sensor (para [0030] - sensors 154 can be placed in the power end of the hydraulic fracturing fleet which includes turbine 44 and generator 50) measures at least one parameter associated with the turbine (44 - "turbine", fig. 1; para [0023], [0030]), the generator, the hydration unit, the distribution system, the fuel source, or the wellhead, and the component controller (para [0030]; see treatment of claim 1) controls at least one aspect of the turbine, the generator, the hydration unit, the distribution system, the fuel source, or the wellhead, based at least in part on the automated instructions (para [0030]).

Regarding Claim 7, Well teaches the system of claim 1, further comprising a central processing system (160 - "controller", 156 - "information handling system", fig. 1) configured to receive the measurements from the pump sensor, the blender sensor, the source sensor, and the component sensor, and generate the automated instructions based on the measurements (para [0030]; see treatment of claim 1).

Regarding Claim 11, Well teaches the system of claim 9, but does not specifically teach wherein the control instructions cause the one or more of the plurality of control devices to automatically adjust one or more of a flow rate, a pressure, power, motor speed, gates, valve, actuators, delivery lines and conveyance devices, pump rates, or cooling systems. Further, Well does teach that the pressure or pump rate of the slurry can be adjusted by the pump system (36 - "pump", fig. 1; para [0022]), that a sensor (154 - "sensor", fig. 1) can be associated with the pump (para [0030]) and that the controller is able to send control commands to operate the system. Accordingly, it would have been obvious to one of ordinary skill in the art that the pressure and flow rate of the pump system could be adjusted using the control instructions in order to allow for automatic adjustment of the pump, thus reducing the chances of user error.

-*-Continued in next Supplemental Box-*-

LIBERTY EXHIBIT 1002, Page 1630

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Regarding Claim 13, Well teaches an automated hydraulic fracturing method (10 - "hydraulic fracturing system", fig. 1; para [0022], [0030]), comprising:
initiating a hydraulic fracturing operation using an automated hydraulic fracturing system (See fig. 1; para [0022]);
providing a first material (para [0022] - "fluid") for a fracturing fluid from a first source (20 - "fluid source", fig. 1) to a blender (28 - "blender", fig. 1);
providing a second material (para [0022] - "additives") for the fracturing fluid from a second source (24 - "additive source", fig. 1) to the blender (para [0022]);
mixing the first material and the second material at the blender to form the fracturing fluid (See fig. 1; para [0022]), the blender comprising a blender sensor (para [0030] - "in one example, a sensor is mounted near the blender discharge pump") for measuring one or more parameters associated with the blender (para [0030]);
providing the fracturing fluid from the blender to a pump (36 - "fracturing pump", fig. 1), the pump comprising a pump controller (para [0022] - variable frequency drive controls motor 39 which controls pump 36) for controlling one or more functions of the pump (para [0022]);
injecting the fracturing fluid from the pump into a wellhead (41 - "wellhead assembly", fig. 1) coupled to a well (12 - "wellbore", fig. 1; para [0022]);
monitoring the one or more parameters via the blender sensor (para [0030]);
generating automated instructions for at least one of a controller (160 - "controller", fig. 1; para [0030]) based at last in part on the one or more parameters (para [0030]); and
controlling at least one of the one or more functions of the first source, the blender, or the pump via the controller or the pump controller, respectively, based at least in part on the automated instructions (para [0030]) but does not specifically teach wherein the first source or the pump each comprise their own sensor for measuring their respective parameters; wherein the first source or the blender have their own controller for controlling their respective functions.
However, Well does teach that the sensors (154 - "sensors", fig. 1; para [0030]) can comprise multiple sensors located on multiple parts of the hydraulic fracturing system (para [0030]) and also teaches that the controller is able to control the entire system (para [0030]). The separation and rearrangement of parts falls within the ordinary skill of one in the art using routine experimentation and design principles. Accordingly, it would have been obvious to one of ordinary skill in the art to provide the pump system and the source system with their own sensors and to provide the pump system, the blender system, the component and the source system with their own controllers in order to provide the information handling system with information about all components of the system as well as improving the speed at which the controllers are able to actually control their respective aspect of the system.
While Well does not explicitly disclose the positive recitation of a method, the device taught by Well is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 17, Well teaches the method of claim 13, further comprising:
transmitting information (para [0030] - "information sensed by sensors") derived from the one or more measured parameters to a remote control center (para [0030] - "the IHS 156 communicates with the World Wide Web to allow for remote reviewing of the information");
receiving control instructions from the remote control center; and automatically controlling at least one aspect of the hydraulic fracturing system based at least in part on the received control instructions (para [0030] - HIS 156 and controller 160 are used to send control commands for the operation of the system which can be done remotely using the world wide web).

Regarding Claim 19, Well teaches the method of claim 13, further comprising:
controlling a pressure or rate at which the fracturing fluid is injected into the wellhead based on the automated instructions (para [0022] - " In an example, the pressure of the slurry in line 38 ranges from around 80 psi to around 100 psi. The pressure of the slurry can be increased up to around 15,000 psi by pump 36."; para [0030] - "controller 160 can be used for sending control commands for operation of the system 10, and thus can utilize vibration information from sensors 154 to adjust control commands.")
While Well does not explicitly disclose the positive recitation of a method, the device taught by Well is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Claims 8, 14, 16, 18 and 20 lack an inventive step under PCT Article 33(3) as being obvious over Well in view of US 2017/0226842 A1 to Schlumberger Technology Corporation (hereinafter 'Schlumberger')

Regarding Claim 8, Well teaches the system of claim 7 (Note: See Box VIII), but does not specifically teach wherein the central processing system is configured to generate alerts or notifications based on the measurements, the alerts or notifications indicating a condition of a certain component or operation. Further, Schlumberger teaches an automatic hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) configured to generate alerts based on measurements indicating a condition of the source system (para [0075], [0090], [0094]). Accordingly, it would have been obvious to one of ordinary skill in the art to incorporate the alert sending function taught in the sensors of Schlumberger into the sensors taught by Well in order to allow operators to quickly identify problem areas and fix said problems to maximize efficiency of the wellsite.

-*-Continued in next Supplemental Box-*-

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Regarding Claim 14, Well teaches the method of claim 13, but does not specifically teach the method further comprising:
detecting that at least one of the one or more parameters is outside of an acceptable threshold; and
automatically stopping or adjusting at least one of the one or more functions in response to the detection.
Further, Schlumberger teaches an automatic hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) for detecting that at least one parameter is outside an acceptable threshold (para [0142], [0143]) and automatically adjusting the a function in response (para [0143] - a parameter is monitored (615, fig. 6), compared to a threshold (625, fig. 6) and an output signal for controlling an additive system component is outputted). Accordingly, it would have been obvious to one of ordinary skill in the art to have the sensor send a signal and the controller read said signal and adjust the system as need be as taught by Schlumberger be incorporated into the sensors and controller taught by Well in order to allow for automatic adjustment of parameters without waiting on operator intervention in order to maximize efficiency at the wellsite.
While Well, in view of Schlumberger, does not explicitly disclose the positive recitation of a method, the device taught by Well, in view of Schlumberger, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well, in view of Schlumberger, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 16, Well teaches the method of claim 13, but does not specifically teach the method further comprising:
detecting that at least one performance issue of the automated hydraulic fracturing system; and
providing troubleshooting codes or alerts indicative of one or more sources of the performance issue.
Further, Schlumberger teaches an automatic hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) configured to detect at least one performance issue of the source system and provide trouble shooting codes or alerts indicative of the performance issue (para [0075], [0090], [0094], [0096]). Accordingly, it would have been obvious to one of ordinary skill in the art to incorporate the alert sending function and troubleshooting codes taught in the sensors of Schlumberger into the sensors taught by Well in order to allow operators to quickly identify problem areas and fix said problems to maximize efficiency of the wellsite.
While Well, in view of Schlumberger, does not explicitly disclose the positive recitation of a method, the device taught by Well, in view of Schlumberger, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well, in view of Schlumberger, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 18, Well teaches the method of claim 13, but does not specifically teach the method further comprising:
automatically starting, stopping, or adjusting the rate of delivery of the first material from the first source to the blender based at least in part on the automated instructions.
Further, Schlumberger teaches an automatic hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) for detecting that at least one parameter is outside an acceptable threshold (para [0142], [0143]) and automatically adjusting the a function in response (para [0143] - a parameter is monitored (615, fig. 6), compared to a threshold (625, fig. 6) and an output signal for controlling an additive system component is outputted). Accordingly, it would have been obvious to one of ordinary skill in the art to have used the teachings of Schlumberger to have the source sensor and the blender sensor taught by Well be used to monitor flow parameters and automatically adjust the flow rate if one of the sensors senses a parameter outside the threshold in order to allow for automatic adjustment of parameters without waiting on operator intervention in order to maximize efficiency at the wellsite.
While Well, in view of Schlumberger, does not explicitly disclose the positive recitation of a method, the device taught by Well, in view of Schlumberger, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well, in view of Schlumberger, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 20, Well teaches the method of claim 13, further comprising:
providing the fracturing fluid from the blender to a plurality of pumps (See fig. 1; para [0022]);
providing the fracturing fluid from the plurality of pumps to a distribution system (42 - "discharge piping", fig. 1; para [0022]);
injecting the fracturing fluid from the distribution system into the wellbore (See fig. 1; para [0022]); but does not specifically teach the method comprising
automatically adjusting individual pressures or pump rates of the plurality of pumps and/or a pressure or pump rate of the distribution system based on the automated instructions.
Further, Schlumberger teaches an automatic hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) for detecting that at least one parameter is outside an acceptable threshold (para [0142], [0143]) and automatically adjusting the a function in response (para [0143] - a parameter is monitored (615, fig. 6), compared to a threshold (625, fig. 6) and an output signal for controlling an additive system component is outputted). Accordingly, it would have been obvious to one of ordinary skill in the art to have used the teachings of Schlumberger to have the pump sensors taught by Well be used to monitor flow parameters and automatically adjust the flow rate of one of the pumps based on the instructions in order to allow for automatic adjustment of parameters without waiting on operator intervention in order to maximize efficiency at the wellsite.
While Well, in view of Schlumberger, does not explicitly disclose the positive recitation of a method, the device taught by Well, in view of Schlumberger, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well, in view of Schlumberger, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

-*-Continued in next Supplemental Box-*-

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Claim 15 lacks an inventive step under PCT Article 33(3) as being obvious over Well in view of Schlumberger in view of US 2011/0247876 A1 to Rasheed

Regarding Claim 15, Well teaches the method of claim 13, but does not specifically teach the method further comprising:
detecting substandard performance in one or more areas of the automated hydraulic fracturing system;
automatically troubleshooting the automated hydraulic fracturing system based on live data from a plurality of sensors or previous data collected by the sensors;
determining one or more causes or suspected causes of the substandard performance; and
automatically adjusting one or more components of the automated hydraulic fracturing system to resolve the substandard performance.
Further, Schlumberger teaches an automatic hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) configured to detect substandard performance of the system (para [0094], [0099]) and allows for trouble shooting based on the data from the sensors (para [0094], [0099]) to determine the cause of the substandard performance and automatically adjusts the system to resolve it (para [0142], [0143]). Accordingly, it would have been obvious to one of ordinary skill in the art to incorporate the alert sending function and troubleshooting codes taught in the sensors of Schlumberger into the sensors taught by Well in order to allow operators to quickly identify problem areas and fix said problems to maximize efficiency of the wellsite.
Further, any combination of the above references fails to teach wherein the troubleshooting is done automatically. However, Rasheed teaches a system (See fig. 1; para [0076]) comprising sensors (76 - "vibration sensor", fig. 3; para [0078]) wherein when the sensor detects substandard performance, the problem is automatically troubleshooted (para [0041], [0066], [0080]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the automatic troubleshooting taught by Rasheed in the system taught by Well, in view of Schlumberger, instead of the manual troubleshooting in order to reduce the need for operator intervention and maximize the efficiency of the wellsite.
While Well, in view of Schlumberger and Rasheed, does not explicitly disclose the positive recitation of a method, the device taught by Well, in view of Schlumberger and Rasheed, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well, in view of Schlumberger and Rasheed, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Claims 1-20 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used by industry.

SEARCH HISTORY

Application Number	PCT/US 18/55913
Search Conducted By	MFG
Search Approved By	SCL

CPC/IPC Classifications Searched	IPC(8): E21B 44/00, E21B 43/26, E21B 43/267 (2018.01) CPC: E21B 44/00, E21B 43/26, E21B 43/267, E21B 44/005
Date Conducted	5 December 2018 (05.12.2018)

Documentation Searched	IPC(8): E21B 44/00, E21B 43/26, E21B 43/267 (2018.01) CPC: (keyword limited; see below)
Search Terms Used	automatic fracturing system and method wellbore US Well Services LLC instructions sensor alerts troubleshooting remote processor additives
Date Conducted	5 December 2018 (05.12.2018)

Electronic Database Searched	PatBase
Files Searched	Full-text: AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO Bibliographic: (European) AT BA BE BG CH CS CY CZ DD DK EE ES FI GE GR HR HU IE IS IT LT LU LV MC MD MT NL NO PL PT RO RS SE SI SK SM TR UA YU (Asia) EA GC HK ID IL IN KZ MN MY PH RU SG SU TH TJ TW UZ VN (North America) CA CR CU DO GT HN MX NI PA SV TT (South America) AR BR CL CO EC PE UY (Australasia) AU NZ (Africa) AP DZ EG KE MA MW OA ZA ZM ZW
Date Conducted	5 December 2018 (05.12.2018)
Search Logic:	

##	Search query	Results
1	pA=(US Well Services LLC)	7
2	IC=(E21B43/267) OR CPC=(E21B43/267)	3359
3	2 AND FT=(sensor* NEAR (alert* OR notif* OR troubleshoot*))	5
4	2 AND FT=(sensor* AND ((troubleshoot* OR trouble shoot*) W3 automatic*))	0
5	2 AND FT=(sensor* AND ((troubleshoot* OR trouble shoot*) NEAR automatic*))	0
6	IC=(E21B44/00) OR CPC=(E21B44/00)	6382
7	6 AND FT=(sensor* AND ((troubleshoot* OR trouble shoot*) W3 automatic*))	2
8	IC=(E21B43/26) OR CPC=(E21B43/26)	9708
9	8 AND FT=(sensor* AND ((troubleshoot* OR trouble shoot*) NEAR automatic*))	1
10	pn=(us2017037717 OR us2017226842 OR us2011247878)	3
11	CTB 10 OR CTF 10	432
12	11 AND TAC=(well*) AND FT=(sensor*)	118
13	TAC=(well* AND fractur*) AND FT=(sensor* AND (controller* OR automat*))	1548
14	13 AND FT=((instruct* OR control*) NEAR (sens*))	717
15	14 AND FT=(pump* AND blender*)	90
16	CPC=(E21B44/005)	466
17	16 AND FT=(sens* NEAR control*)	149

Electronic Database Searched	Google
Files Searched	Patents
Date Conducted	5 December 2018 (05.12.2018)

Search Logic:

automatic fracturing system and method - About 187,000 results
automatic fracturing system and method wellbore - About 41,100 results
inassignee:"Us Well Services Llc" - About 26 results
inassignee:"Us Well Services Llc" sensor - About 17 results
"automated hydraulic fracturing" - 1 result
hydraulic fracturing with automated instructions - About 8,930 results
hydraulic fracturing with automated instructions and alerts - About 10,600 results
hydraulic fracturing with automated instructions for troubleshooting - About 72,600 results

remote processor for hydraulic fracturing - About 13,600 results
remote processor for hydraulic fracturing with additives - About 8,850 results

Electronic Database Searched	Google
Files Searched	Web
Date Conducted	5 December 2018 (05.12.2018)
Search Logic:	

automatic fracturing system and method - About 15,600,000 results
automatic fracturing system and method wellbore - About 703,000 results
"Us Well Services Llc" - About 13,200 results
"Us Well Services Llc" sensor - About 2,860 results
"automated hydraulic fracturing" - About 406 results
hydraulic fracturing with automated instructions - About 524,000 results
hydraulic fracturing with automated instructions and alerts - About 634,000 results
hydraulic fracturing with automated instructions for troubleshooting - About 30,400,000 results
remote processor for hydraulic fracturing - About 442,000 results
remote processor for hydraulic fracturing with additives - About 323,000 results

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 047158.500032	Date of mailing *(day/month/year)* 04 JAN 2019
International application No. PCT/US 18/57539	FOR FURTHER ACTION See paragraphs 1 and 4 below
Applicant U.S. WELL SERVICES, LLC	International filing date *(day/month/year)* 25 October 2018 (25.10.2018)

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Lee W. Young PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 047158.500032	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 18/57539	International filing date *(day/month/year)* 25 October 2018 (25.10.2018)	(Earliest) Priority Date *(day/month/year)* 25 October 2017 (25.10.2017)
Applicant U.S. WELL SERVICES, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the drawings to be published with the abstract is Figure No. 1

☐ as suggested by the applicant.

☒ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/57539

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 44/00, E21B 43/26, E21B 43/267 (2018.01)
CPC - E21B 44/00, E21B 43/26, E21B 43/267

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)
See Search History Document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2017/0037717 A1 (US Well Services LLC) 9 February 2017 (09.02.2017) Entire document especially para [0022], [0024], [0030] and figs. 1-2	1, 3, 7, 14-16 --- 2, 4-6, 8-13, 17-20
Y	WO 2016/160458 A1 (Schlumberger Technology Corporation) 6 October 2016 (06.10.2016) Entire document especially para [0028], [0038], [0039] and figs. 1, 2, 5 and 7	2, 4-6, 8-12, 17-20
Y	US 2016/0032703 A1 (US Well Services LLC) 4 February 2016 (04.02.2016) Entire document especially para [0014], [0023], [0063]-[0064] and fig. 1	9, 10, 13, 20
Y	US 2017/0226842 A1 (Schlumberger Technology Corporation) 10 August 2017 (10.08.2017) Entire document especially para [0028]-[0030], [0075], [0080], [0094], [0119] and fig. 2	12, 13
A	US 2016/0258267 A1 (Stewart & Stevenson, LLC) 8 September 2016 (08.09.2016) Entire document	1-20
A	US 2015/0144336 A1 (Data Automated Water Systems, LLC) 28 May 2015 (28.05.2015) Entire document	1-20
A	US 2016/0208595 A1 (Tang et al.) 21 July 2016 (21.07.2016) Entire document	1-20
A	US 2015/0075778 A1 (Halliburton Energy Services, Inc.) 19 March 2015 (19.03.2015) Entire document	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
12 December 2018	04 JAN 2019

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	04 JAN 2019
Applicant's or agent's file reference 047158.500032	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 18/57539	25 October 2018 (25.10.2018)	25 October 2017 (25.10.2017)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 44/00, E21B 43/26, E21B 43/267 (2018.01)
CPC - E21B 44/00, E21B 43/26, E21B 43/267

Applicant U.S. WELL SERVICES, LLC

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	12 December 2018	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/57539

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, this opinion has been established on the basis of a sequence listing:

a. ☐ forming part of the international application as filed:

☐ in the form of an Annex C/ST.25 text file.

☐ on paper or in the form of an image file.

b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/57539

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	None	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1 20	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1, 3, 7 and 14-16 lack an inventive step under PCT Article 33(3) as being obvious over US 2017/0037717 A1 to US Well Services LLC (hereinafter 'Well717')

Regarding Claim 1, Well717 teaches a hydraulic fracturing system (10 - "hydraulic fracturing system", fig. 1; para [0022], [0030]), comprising:
a plurality of pumps (36 - "fracturing pump", fig. 1; para [0024]; see fig. 2) positioned at a wellsite (12 - "wellbore", fig. 1) and configured to pressurize a fracturing fluid (para [0022]);
a distribution system (38 - "line", 42 - "discharge piping", 76 - "suction manifold", 80 - "discharge manifold", figs. 1 and 2) fluidly coupled to receive and consolidate fracturing fluid from the plurality of pumps for injection (para [0024]) into a wellhead (41 - "wellhead assembly", fig. 1); and
a control system (154 - "sensors", 156 - "information handling system", 160 - "controller", 158, 162 - "communication means", fig. 1; para [0030]) comprising:
a plurality of sensing devices (154 - "sensors", fig. 1) configured to measure one or more parameters (para [0030]);
one or more processing devices (156 - "information handling system", fig. 1) configured to receive and analyze the one or more parameters measured by the plurality of sensing devices and generate control instructions based at least in part on the one or more parameters (para [0030]); and
one or more control devices (160 - "controller", fig. 1) configured to receive the control instructions and control one or more aspects based on the control instructions (para [0030]) but does not specifically teach wherein the control system measures a parameter or controls aspects of the pumps and the distribution system.
However, Well717 does teach that the sensors (154 - "sensors", fig. 1; para [0030]) can comprise multiple sensors located on multiple parts of the hydraulic fracturing system (para [0030]) in order to adjust control commands for the system (para [0030]). Accordingly, it would have been obvious to one of ordinary skill in the art to include sensors on the pumps and distribution system in order to allow for constant monitoring and adjustment of fracturing fluid entering wellhead because the pumps and distribution system are key members of the hydraulic fracturing system.

Regarding Claim 3, Well717 teaches the system of claim 1, wherein the plurality of pumps or the distribution system (38 - "line", 42 - "discharge piping", 76 - "suction manifold", 80 - "discharge manifold", figs. 1 and 2) includes at least one of a gate, valve, actuator, motor, suction pipe, discharge pipe (42 - "discharge piping", fig. 1), engine, transmission, or temperature regulation device, controllable via the one or more control devices (160 - "controller", fig. 1; para [0030] - controller 160 uses measurements from sensors 154 to adjust control commands. Since the pump and distribution system has sensors now, they can be monitored and controlled by the controller 160).

Regarding Claim 7, Well717 teaches a hydraulic fracturing method (10 - "hydraulic fracturing system", fig. 1; para [0022], [0030]), comprising:
providing a fracturing fluid (para [0022] - line 38 provides a fracturing slurry to pumps 36) to a plurality of pumps (36 - "fracturing pump", fig. 1; para [0024]; see fig. 2);
pumping the fracturing fluid (para [0022]) into a distribution system (38 - "line", 42 - "discharge piping", 76 - "suction manifold", 80 - "discharge manifold", figs. 1 and 2);
injecting the fracturing fluid (para [0022]) into a wellhead (41 - "wellhead assembly", fig. 1);
measuring one or more parameters (para [0030]) of the plurality of pumps, the distribution system, or the wellhead via a plurality of sensing devices (154 - "sensors", fig. 1; para [0030]) instrumented thereon (See fig. 1);
generating automated instructions (para [0030] - information handling system 156 generates instructions) for one or more control devices (160 - "controller", fig. 1) based at least in part on the one or more parameters (para [0030]); and
controlling one or more functions of the plurality of pumps, the distribution system, or the wellhead based at least in part on the automated instructions (para [0030] - controller 160 controls the devices based on the instructions of the information handling system which is based on the parameter measurements of sensors 154).
While Well717 does not explicitly disclose the positive recitation of a method, the device taught by Well717 is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717 as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

-*-Continued in Supplemental Box-*-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/67539

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claim 16: The term "the distribution system" is confusing and lacks proper antecedent basis. The term is properly introduced in claim 15. As written, claim 16 depends from claim 17. Accordingly, for purposes of this opinion, claim 16 has been interpreted to be dependent on claim 15.

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Regarding Claim 14, Well717 teaches a hydraulic fracturing method (10 - "hydraulic fracturing system", fig. 1; para [0022], [0030]), comprising:
receiving a first data from a first sensing device (154 - "sensors", fig. 1; para [0030]; see how one sensor 154 is located on the wellhead assembly 41) of a hydraulic fracturing system (10 - "hydraulic fracturing system", fig. 1);
receiving second data from a second sensing device (154 - "sensors", fig. 1; para [0030] - a sensor 154 can be placed near blender discharge pump) of a blender system (28 - "blender", fig. 1) of the hydraulic fracturing system, the blender system mixing together materials to form a fracturing fluid (para [0022] - "fracturing slurry") and delivering the fracturing fluid to a pump system (36 - "pumps", fig. 1; para [0022]), and the second data indicative of a condition of the blender system (para [0030]);
generating automated instructions para [0030] - information handling system 156 generates instructions) for one or more control devices (160 - "controller", fig. 1) of the blender system based at least in part on the first and second data (para [0030]); and
controlling one or more functions of the blender system based at least in part on the automated instructions (para [0030] - controller 160 controls the devices based on the instructions of the information handling system which is based on the parameter measurements of sensors 154) but does not specifically teach wherein the first sensing device measures data indicative of a condition of the pump system. However, Well717 does teach that the sensors (154 - "sensors", fig. 1; para [0030]) can comprise multiple sensors located on multiple parts of the hydraulic fracturing system (para [0030]) in order to adjust control commands for the system (para [0030]). Accordingly, it would have been obvious to one of ordinary skill in the art to include sensors on the pumps for monitoring a condition thereof in order to allow for constant monitoring and adjustment of fracturing fluid entering wellhead because the pumps and distribution system are key members of the hydraulic fracturing system.
While Well717 does not explicitly disclose the positive recitation of a method, the device taught by Well717 is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717 as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 15, Well717 teaches the method of claim 14, wherein the pump system comprises:
one or more pumps (36 - "fracturing pump", fig. 1; para [0024]; see fig. 2); and
a distribution system (38 - "line", 42 - "discharge piping", 76 - "suction manifold", 80 - "discharge manifold", figs. 1 and 2) that receives and consolidates the fracturing fluid from the one or more pumps (para [0024]) for injection into a wellhead (41 - "wellhead assembly", fig. 1).
While Well717 does not explicitly disclose the positive recitation of a method, the device taught by Well717 is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717 as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 16, Well717 teaches the method of claim 15 (Note: See Box VIII), but does not specifically teach the method further comprising:
controlling one or more functions of the distribution system based on the automated instructions.
However, Well717 does teach that the sensors (154 - "sensors", fig. 1; para [0030]) can comprise multiple sensors located on multiple parts of the hydraulic fracturing system (para [0030]) in order to adjust control commands for the system (para [0030]). Accordingly, it would have been obvious to one of ordinary skill in the art to include sensors on the distribution system and allow the controller to control functions based on readings from the sensors in order to allow for constant monitoring and adjustment of fracturing fluid entering wellhead because the pumps and distribution system are key members of the hydraulic fracturing system.
While Well717 does not explicitly disclose the positive recitation of a method, the device taught by Well717 is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717 as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Claims 2, 4-6, 8, 11 and 17-19 lack an inventive step under PCT Article 33(3) as being obvious over Well717 in view of WO 2016/160458 A1 to Schlumberger Technology Corporation (hereinafter 'Schlumberger458')

Regarding Claim 2, Well717 teaches the system of claim 1, wherein the plurality of sensing devices (154 - "sensors", fig. 1) are installed on the plurality of pumps and the distribution system (para [0030]; See treatment of claim 1), but does not specifically teach wherein the sensing devices include at least one of flow sensors, accelerometers, pressure transducer, or tachometers. Further, Schlumberger458 teaches a hydraulic fracturing system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0038]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) in communication with a controller (410 - "controller", fig. 2; para [0049]). Accordingly, it would have been obvious to use the flow sensing devices taught by Schlumberger458 in association with the pumps and controller taught by Well717 in order to allow the control system to quickly identify which pumps are operating efficiently and which may require maintenance.

-*-Continued in next Supplemental Box-*-

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Regarding Claim 4, Weil717 teaches the system of claim 1, further comprising:
a suction line (76 - "suction manifold", fig. 1) through which fracturing fluid is supplied (para [0024]); and
a discharge line (80 - "discharge line", fig. 1) through which fracturing fluid is discharged (para [0024]), but does not specifically teach wherein the plurality of sensing devices includes one or more flow sensors configured to measure flow through the suction line and the discharge line.
Further, Schlumberger458 teaches a hydraulic fracturing system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0038]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) in communication with a controller (410 - "controller", fig. 2; para [0049]). Accordingly, it would have been obvious to use the flow sensing devices taught by Schlumberger458 in association with the pumps, suction line, discharge line and controller taught by Weil717 in order to allow the control system to quickly identify which pumps are operating efficiently and which may require maintenance.

Regarding Claim 5, Weil717 teaches the system of claim 1, further comprising:
one or more blenders (28 - "blender", fig. 1) configured to mix together one or more materials to form the fracturing fluid (para [0022]), wherein the fracturing fluid is provided from the blender to the plurality of pumps via a manifold (38 - "line", fig. 1), but does not specifically teach wherein the plurality of sensing devices includes one or more pressure or flow sensors for measuring flow and/or pressure conditions at the one or more blenders, the manifold, the plurality of pumps, or the distribution system.
Further, Schlumberger458 teaches a hydraulic fracturing system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0038]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) in communication with a controller (410 - "controller", fig. 2; para [0049]). Accordingly, it would have been obvious to use the flow sensing devices taught by Schlumberger458 in association with the pumps and controller taught by Weil717 in order to allow the control system to quickly identify which pumps are operating efficiently and which may require maintenance.

Regarding Claim 6, Weil717, in view of Schlumberger458, teaches the system of claim 5, and Weil717 further teaches that the one or more control device (Weil717: 160 - "controller", fig. 1) is configured to control the one or more blenders, the manifold, the plurality of pumps and the distribution system based on the flow and/or pressure conditions (para [0030] - controller 160 controls the devices based on the instructions of the information handling system which is based on the parameter measurements of sensors 154).

Regarding Claim 8, Weil717 teaches the method of claim 7, but does not specifically teach further comprising:
detecting that a first parameter of the one or more parameters is outside of an acceptable threshold, wherein the first parameter is associated with a first pump of the plurality of pumps; and
automatically adjusting or turning off the first pump.
Further, Schlumberger458 teaches a hydraulic fracturing method (See fig. 5; para [0081]) comprising a system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0036]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) wherein the method comprises detecting that a parameter associated with the plurality of pumps is outside an acceptable threshold (para [0090]) and automatically turning the pump off (para [0090]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the method of shutting off a pump when a parameter is outside an acceptable threshold as taught by Schlumberger458 with the hydraulic fracturing method taught by Weil717 in order to ensure that no faulty pumps continue to operate and create dangerous working conditions at the wellsite.
While Weil717, in view of Schlumberger458, does not explicitly disclose the positive recitation of a method, the device taught by Weil717, in view of Schlumberger458, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Weil717, in view of Schlumberger458, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 11, Weil717 teaches the method of claim 7, but does not specifically teach the method further comprising:
determining that the one or more parameters are indicative of a potential failure condition; and
determining a source of the potential failure condition.
Further, Schlumberger458 teaches a hydraulic fracturing method (700 - "method", fig. 8; para [0099]) comprising a hydraulic fracturing system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0038]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) in communication with a controller (410 - "controller", fig. 2; para [0049]), the method comprising determining that a parameter is indicative of a potential failure condition (para [00104] - "The method (700) may also comprise confirming (760) that safety parameters are within predetermined ranges..") and determining the source of the failure (para [00104] - controller 410 checks through all the sensors to find the issue). Accordingly, it would have been obvious to one of ordinary skill in the art to use the failure condition sensing method as taught by Schlumberger458 with the method taught by Weil717 in order to allow an operator or controller to quickly identify the exact location of the wellsite that requires maintenance.
While Weil717, in view of Schlumberger458, does not explicitly disclose the positive recitation of a method, the device taught by Weil717, in view of Schlumberger458, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Weil717, in view of Schlumberger458, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

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Supplemental Box

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-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Regarding Claim 17, Well717 teaches the method of claim 14, but does not specifically teach wherein the pump system comprises a plurality of pumps, and the first data includes measurements of each of the plurality of pumps. Further, Schlumberger458 teaches a hydraulic fracturing system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0036]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) in communication with a controller (410 - "controller", fig. 2; para [0049]). Accordingly, it would have been obvious to use the flow sensing devices taught by Schlumberger458 in association with each of the pumps and the controller taught by Well717 in order to allow the control system to quickly identify which pumps are operating efficiently and which may require maintenance.
While Well717, in view of Schlumberger458, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 18, Well717, in view of Schlumberger458, teaches the method of claim 17, and Well717 teaches the method further comprising:
controlling one or more of the plurality of pumps (36 - "fracturing pump", fig. 1; para [0024]; see fig. 2) individually based on the automated instructions (para [0030]).
While Well717, in view of Schlumberger458, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 19, Well717, in view of Schlumberger458, teaches the method of claim 18, but does not specifically teach the method further comprising:
detecting that a measurement associated with a first pump of the plurality of pumps is outside of an acceptable threshold; and
automatically taking the first pump offline in response to the detection.
Further, Schlumberger458 teaches a hydraulic fracturing method (See fig. 5; para [0081]) comprising a system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0036]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) wherein the method comprises detecting that a parameter associated with the plurality of pumps is outside an acceptable threshold (para [0090]) and automatically turning the pump off (para [0090]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the method of shutting off a pump when a parameter is outside an acceptable threshold as taught by Schlumberger458 with the hydraulic fracturing method taught by Well717 in order to ensure that no faulty pumps continue to operate and create dangerous working conditions at the wellsite.
While Well717, in view of Schlumberger458, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Claims 9-10 and 20 lack an inventive step under PCT Article 33(3) as being obvious over Well717 in view of Schlumberger458 in view of US 2016/0032703 A1 to US Well Services LLC (hereinafter 'Well703')

Regarding Claim 9, Well717, in view of Schlumberger458, teaches the method of claim 8, but does not specifically teach the method further comprising:
adjusting one or more of the other pumps in the plurality of pumps to compensate for the first pump.
Further, Well703 teaches a hydraulic fracturing system (See fig. 1; para [0014]) comprising a plurality of pumps (10 - "plurality of pumps", fig. 1) comprising a plurality of sensors (para [0023]) associated with a controller (para [0063] - "pump control station") wherein the controller is operable to adjust the flow rates of pumps in order to compensate for a pump with no flow rate (para [0064] - pump control station works to ensure the combined flow rate remains constant, so if one pump were to stop pumping, the pump control station would adjust the other pumps to compensate). Accordingly, it would have been obvious to one of ordinary skill in the art to use the teaching of adjusting pump rates of individual pumps to maintain a total combined flow rate as taught by Well703 on the method taught by Well717, in view of Schlumberger458, in order to allow for automatic, consistent flow into the wellbore during a hydraulic fracturing operation.
While Well717, in view of Schlumberger458 and Well703, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458 and Well703, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458 and Well703, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 10, Well717, in view of Schlumberger458 and Well703, teaches the method of claim 9, but does not specifically teach the method further comprising:
selecting the one or more of the other pumps to adjust based at least in part on the conditions of the other pumps as indicated by one or more of the one or more parameters.
Further, Schlumberger458 teaches a hydraulic fracturing method (See fig. 5; para [0061]) comprising a system (100 - "wellsite system", fig. 1; para [0028]) comprising a plurality of pumps (241, 242 - "high pressure pump units", fig. 2; para [0036]) comprising a plurality of sensing devices (244, 245, 246, 247 - "flow sensors", fig. 1; para [0039]) wherein the method comprises detecting that a parameter associated with the plurality of pumps is outside an acceptable threshold (para [0090]) and automatically turning the pump off (para [0090]).
Further still, Well703 teaches a hydraulic fracturing system (See fig. 1; para [0014]) comprising a plurality of pumps (10 - "plurality of pumps", fig. 1) comprising a plurality of sensors (para [0023]) associated with a controller (para [0063] - "pump control station") wherein the controller is operable to adjust the flow rates of pumps in order to compensate for a pump with no flow rate (para [0064] - pump control station works to ensure the combined flow rate remains constant, so if one pump were to stop pumping, the pump control station would adjust the other pumps to compensate). Accordingly, it would have been obvious to one of ordinary skill in the art that the controller would monitor the flow of each working pump using the flow sensors and determine which pumps are most capable of picking up the slack and adjusting said pumps in order to more evenly balance the flow through each pump so as to avoid exceeding the threshold for shutdown.
While Well717, in view of Schlumberger458 and Well703, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458 and Well703, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458 and Well703, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Regarding Claim 20, Well717, in view of Schlumberger458, teaches the method of claim 19, but does not specifically teach the method further comprising:
adjusting one or more of the other pumps in the plurality of pumps to compensate for taking the first pump offline.
Further, Well703 teaches a hydraulic fracturing system (See fig. 1; para [0014]) comprising a plurality of pumps (10 - "plurality of pumps", fig. 1) comprising a plurality of sensors (para [0023]) associated with a controller (para [0063] - "pump control station") wherein the controller is operable to adjust the flow rates of pumps in order to compensate for a pump with no flow rate (para [0064] - pump control station works to ensure the combined flow rate remains constant, so if one pump were to stop pumping, the pump control station would adjust the other pumps to compensate). Accordingly, it would have been obvious to one of ordinary skill in the art to use the teaching of adjusting pump rates of individual pumps to maintain a total combined flow rate as taught by Well703 on the method taught by Well717, in view of Schlumberger458, in order to allow for automatic, consistent flow into the wellbore during a hydraulic fracturing operation.
While Well717, in view of Schlumberger458 and Well703, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458 and Well703, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458 and Well703, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

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LIBERTY EXHIBIT 1002, Page 1647

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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-*-Supplemental Box - Box V.2 - Citations and Explanations-*-

Claim 12 lacks an inventive step under PCT Article 33(3) as being obvious over Well717 in view of Schlumberger458 in view of US 2017/0226842 A1 to Schlumberger Technology Corporation (hereinafter 'Schlumberger842')

Regarding Claim 12, Well717, in view of Schlumberger458, teaches the method of claim 11, but does not specifically teach the method further comprising:
generating an alert or notification indicative of the potential failure condition and the source.
Further, Schlumberger842 teaches a hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a source system (200 - "additive system", fig. 2; para [0030]) instrumented with a source sensor (204 - "sensor", fig. 2; para [0030]) configured to generate alerts based on measurements indicating a condition of the source system (para [0075], [0090], [0094]). Accordingly, it would have been obvious to one of ordinary skill in the art to incorporate the alert sending function taught in the sensors of Schlumberger842 into the sensors taught by Well717 in order to allow operators to quickly identify problem areas and fix said problems to maximize efficiency of the wellsite.
While Well717, in view of Schlumberger458 and Schlumberger842, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Schlumberger458 and Schlumberger842, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Schlumberger458 and Schlumberger842, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Claim 13 lacks an inventive step under PCT Article 33(3) as being obvious over Well717 in view of Well703 in view of Schlumberger842

Regarding Claim 13, Well717 teaches the method of claim 7, but does not specifically teach the method further comprising:
logging operation data including a number of strokes and pumping hours performed by a pump of the plurality of pumps; and
determining a maintenance schedule based at least in part on the operation data.
Further, Well703 teaches a hydraulic fracturing system (See fig. 1; para [0014]) comprising a plurality of pumps (10 - "plurality of pumps", fig. 1) comprising a plurality of sensors (para [0023]) associated with a controller (para [0063] - "pump control station") wherein the sensor logs operational data including the number of strokes performed by a pump (para [0051]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the sensor for logging operational strokes as taught by Well703 on the system taught by Well717 in order to allow an operator to quickly determine which pumps might most quickly need to be shut down for maintenance.
Any combination of the above references fails to teach wherein the method comprises determining a maintenance schedule based at least in part on the operation data.
However, Schlumberger842 teaches a hydraulic fracturing system (See figs. 1 and 2; para [0028], [0029]) comprising a predictive maintenance tool (565 - "predictive maintenance tool", fig. 5; para [0119]) that determines a maintenance schedule based on logged parameters exceeding thresholds or live parameters exceeding thresholds. Accordingly, it would have been obvious to one of ordinary skill in the art to use the predictive maintenance tool taught by Schlumberger842 on the pumps taught by Well717 in order to allow an operator to perform maintenance on a pump before it fails and hurts the efficiency of the wellsite.
While Well717, in view of Well703 and Schlumberger842, does not explicitly disclose the positive recitation of a method, the device taught by Well717, in view of Well703 and Schlumberger842, is inherently used to perform the claimed method. Accordingly, it would have been obvious to a person having ordinary skill in the art to have utilized the system and teachings of Well717, in view of Well703 and Schlumberger842, as a whole, effectively providing a method of use through enabling the use of an automated hydraulic fracturing system.

Claims 1-20 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used by industry.

SEARCH HISTORY

Application Number	PCT/US 18/57539
Search Conducted By	MFG
Search Approved By	SCL

CPC/IPC Classifications Searched	IPC(8): E21B 44/00, E21B 43/26, E21B 43/267 (2018.01) CPC: E21B 44/00, E21B 43/26, E21B 43/267
Date Conducted	12 December 2018 (12.12.2018)

Documentation Searched	IPC(8): E21B 44/00, E21B 43/26, E21B 43/267 (2018.01) CPC: (keyword limited; see below)
Search Terms Used	Smart fracturing system and method multiple pumps controller and sensors flow US Well Services LLC threshold hydraulic logging pump strokes maintenance schedule
Date Conducted	12 December 2018 (12.12.2018)

Electronic Database Searched	PatBase
Files Searched	Full-text: AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO Bibliographic: (European) AT BA BE BG CH CS CY CZ DD DK EE ES FI GE GR HR HU IE IS IT LT LU LV MC MD MT NL NO PL PT RO RS SE SI SK SM TR UA YU (Asia) EA GC HK ID IL IN KZ MN MY PH RU SG SU TH TJ TW UZ VN (North America) CA CR CU DO GT HN MX NI PA SV TT (South America) AR BR CL CO EC PE UY (Australasia) AU NZ (Africa) AP DZ EG KE MA MW OA ZA ZM ZW
Date Conducted	12 December 2018 (12.12.2018)
Search Logic:	

#	Search query	Results
1	IC=(E21B44/00) OR CPC=(E21B44/00)	6397
2	1 AND FT=(pump* NEAR automat*)	134
3	2 AND FT=(sensor*)	97
4	3 AND FT=((process* OR control*) NEAR pump*)	77
5	4 AND FT=(hydraul* NEAR fractur*)	7
6	5 AND FT=(pump* NEAR flow sens*)	0
7	4 AND FT=(pump* NEAR flow sens*)	2
8	5 AND FT=(flow sens*)	1
9	4 AND FT=(alert* OR troubleshoot* OR failure condition*)	19
10	4 AND FT=((mainten* OR repair*) NEAR pump*)	9
11	IC=(E21B43/26 OR E21B43/267) OR CPC=(E21B43/26 OR E21B43/267)	11494
12	11 AND FT=(pump* NEAR (autom* OR sens*))	348
13	12 AND FT=(mainten* NEAR schedule*)	3
14	pn=(us2017037717 OR us2016032703 OR wo16160458)	2
15	CTB 14 OR CTF 14	214
16	15 AND FT=(pump* NEAR automat*)	16

Electronic Database Searched	Google
Files Searched	Patents
Date Conducted	12 December 2018 (12.12.2018)

Search Logic:

Smart fracturing system and method - About 45,800 results
Smart fracturing system and method multiple pumps- About 20,300 results
automated fracturing system with controller and sensors - About 108,000 results
automated fracturing system with flow sensors - About 106,000 results
"US Well Services LLC" - About 667 results
"US Well Services LLC" hydraulic fracturing automated - About 390 results
controller "hydraulic fracturing" threshold - About 5,100 results
controller "hydraulic fracturing" alert system - About 3,060 results
controller "hydraulic fracturing" logging pump strokes - About 529 results
controller "hydraulic fracturing" "maintenance schedule" - About 23 results

Electronic Database Searched	Google
Files Searched	Web
Date Conducted	12 December 2018 (12.12.2018)

Search Logic:

Smart fracturing system and method - About 10,200,000 results
Smart fracturing system and method multiple pumps- About 4,050,000 results
automated fracturing system with controller and sensors - About 9,950,000 results
automated fracturing system with flow sensors - About 12,600,000 results
"US Well Services LLC" - About 11,400 results
"US Well Services LLC" hydraulic fracturing automated - About 1,120 results
controller "hydraulic fracturing" threshold - About 232,000 results
controller "hydraulic fracturing" alert system - About 352,000 results
controller "hydraulic fracturing" logging pump strokes - About 83,700 results
controller "hydraulic fracturing" "maintenance schedule" - About 282,000 results

Electronic Acknowledgement Receipt

EFS ID:	34926284
Application Number:	16170695
International Application Number:	
Confirmation Number:	6906
Title of Invention:	SMART FRACTURING SYSTEM AND METHOD
First Named Inventor/Applicant Name:	Jared Oehring
Customer Number:	132858
Filer:	Taylor P. Evans/Stephanie McDonough
Filer Authorized By:	Taylor P. Evans
Attorney Docket Number:	047158.100032
Receipt Date:	22-JAN-2019
Filing Date:	25-OCT-2018
Time Stamp:	17:36:04
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	100032_IDS.pdf	1035286 42bac3cadc5b62859a68cae773b2a8e9143d8a27	no	6

Warnings:

Information:					
2	Other Reference-Patent/App/Search documents	100031.pdf	214752 faa678d394f7cde3d00109e900e2ee8a3df7a63f	no	7
Warnings:					
Information:					
3	Foreign Reference	WO2016144939A1.pdf	2806113 872bb70d656a1509be358ed84d26d96df024df95	no	51
Warnings:					
Information:					
4	Foreign Reference	WO2016160458A1.pdf	2943101 c19c0fff680828435 78b747bb7ab73e084460695	no	57
Warnings:					
Information:					
5	Other Reference-Patent/App/Search documents	047158-500029_ISR.pdf	802847 09a6ee9f7678ee3365f1ee4a86703a29c1c6ee60	no	13
Warnings:					
Information:					
6	Other Reference-Patent/App/Search documents	047158-500030_ISR.pdf	665357 36b902d632a1627341950fd2f01f5d30c9ebd86d	no	13
Warnings:					
Information:					
7	Other Reference-Patent/App/Search documents	047158-500031_ISR.pdf	952437 a028f3c3a8360e2f1ae30b8c076ed95c2155e085	no	14
Warnings:					
Information:					
8	Other Reference-Patent/App/Search documents	047158-500032_ISR.pdf	832886 f41c7088830eacd43d5727861d637e53eca5a9fb	no	15
Warnings:					

The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing

Information:	
Total Files Size (in bytes):	10252779

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/170,695	10/25/2018	Jared Oehring	047158.100032	6906

132858 7590 12/13/2018

Hogan Lovells US LLP
609 Main Street
Suite 4200
Houston, TX 77002

EXAMINER	

ART UNIT	PAPER NUMBER
3676	

NOTIFICATION DATE	DELIVERY MODE
12/13/2018	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

hlusdocketing@hoganlovells.com
jennifer.tilley@hoganlovells.com
danny.vara@hoganlovells.com

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Doc Code:
TRACK1.GRANT

Decision Granting Request for Prioritized Examination (Track I or After RCE)	Application No.: 16/170,695

1. THE REQUEST FILED October 25, 2018 IS **GRANTED.**

The above-identified application has met the requirements for prioritized examination
- A. ☒ for an original nonprovisional application (Track I).
- B. ☐ for an application undergoing continued examination (RCE).

2. **The above-identified application will undergo prioritized examination.** The application will be accorded special status throughout its entire course of prosecution until one of the following occurs:

- A. filing a **petition for extension of time** to extend the time period for filing a reply;
- B. filing an **amendment to amend the application to contain more than four independent claims, more than thirty total claims**, or a multiple dependent claim;
- C. filing a **request for continued examination**;
- D. filing a notice of appeal;
- E. filing a request for suspension of action;
- F. mailing of a notice of allowance;
- G. mailing of a final Office action;
- H. completion of examination as defined in 37 CFR 41.102; or
- I. abandonment of the application.

Telephone inquiries with regard to this decision should be directed to Cheryl Gibson-Baylor at (571)272-3213, Office of Petitions. In his/her absence, calls may be directed to Brian W. Brown, (571)272-5338.

Cheryl Gibson-Baylor
/Cheryl Gibson-Baylor/
[*Signature*]

Petitions Paralegal Specialist
(Title)

Office of Petitions: Routing Sheet



Application No. 16170695

This application is being forwarded to your office for further processing. A decision has been rendered on a petition filed in this application, as indicated below. For details of this decision, please see the document PET.OP.DEC filed on the same date as this document.

- [X] **GRANTED**
- [ ] **DISMISSED**
- [ ] **DENIED**

Office of Petitions: Decision Count Sheet

12

Application No. 16170695



For US serial numbers: enter number only, no slashes or commas. Ex: 10123456

For PCT: enter "51+single digit of year of filing+last 5 numbers", Ex. for PCT/US05/12345, enter 51512345

Deciding Official: GIBSON-BAYLOR, C

Count (1) - Palm Credit 16170695

Decision: GRANT

FINANCE WORK NEEDED

☐ Select Check Box for YES



Decision Type: 643 - Track One request



Notes:

Count (2)

Decision: n/a

FINANCE WORK NEEDED

☐ Select Check Box for YES

Decision Type: NONE

Notes:

Count (3)

Decision: n/a

FINANCE WORK NEEDED

☐ Select Check Box for YES

Decision Type: NONE

Notes:

Initials of Approving Official (if required)

Printed on: 12/11/2018

Office of Petitions Internal Document - Ver. 5.0

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/170,695	10/25/2018	3674	1880	047158.100032	20	3

CONFIRMATION NO. 6906

132858
Hogan Lovells US LLP
609 Main Street
Suite 4200
Houston, TX 77002

FILING RECEIPT



Date Mailed: 11/19/2018

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Jared Oehring, Houston, TX;
Alexander James Christinzio, Morgantown, WV;
Brandon N. Hinderliter, Houston, TX;

Applicant(s)

U.S. Well Services, LLC, Houston, TX;

Assignment For Published Patent Application

U.S. Well Services, LLC, Houston, TX

Power of Attorney: The patent practitioners associated with Customer Number 132858

Domestic Priority data as claimed by applicant

This appln claims benefit of 62/577,056 10/25/2017

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 11/15/2018

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/170,695**

Projected Publication Date: 04/25/2019

Non-Publication Request: No

Early Publication Request: No
Title

SMART FRACTURING SYSTEM AND METHOD

Preliminary Class

166

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/170,695

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	300
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	660
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	760
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 100 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 460 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1720

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16170695
Filing Date	2018-10-25
First Named Inventor	Jared Oehring
Art Unit	
Examiner Name	
Attorney Docket Number	047158.100032

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3764233		1973-10-09	Strickland	
	2	5879137		1999-03-09	Yie	
	3	7563076		2009-07-21	Brunet	
	4	7683499		2010-03-23	Saucier	
	5	8083504		2011-12-27	Williams	
	6	3334495		1967-08-08	Jensen	
	7	1671436		1928-05-29	Melott	
	8	2004077		1935-06-04	McCartney	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16170695
	Filing Date	2018-10-25
	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	9	2220622		1940-11-05	Aitken	
	10	3066503		1962-12-04	Fleming	
	11	3837179		1974-09-24	Barth	
	12	4037431		1977-07-26	Sugimoto	
	13	5907970		1999-06-01	Havlovick et al.	
	14	6142878		2000-11-07	Barin	
	15	8789601		2014-07-29	Broussard	
	16	6271637		2001-08-07	Kushion	
	17	6529135		2003-03-04	Bowers et al.	
	18	6931310		2005-08-16	Shimizu et al.	
	19	7755310		2010-07-13	West et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16170695
	Filing Date	2018-10-25
	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	20	8054084		2011-11-08	Schulz et al.	
	21	8310272		2012-11-13	Quarto	
	22	8354817		2013-01-15	Yeh et al.	
	23	8838341		2014-09-16	Kumano	
	24	9018881		2015-04-28	Mao et al.	
	25	2248051		1941-07-08	Armstrong	
	26	3722595		1973-03-27	Kiel	
	27	7312593		2007-12-25	Streicher et al.	
	28	4226299		1980-10-07	Hansen	
	29	4456092		1984-06-26	Kubozuka	
	30	5655361		1997-08-12	Kishi	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16170695
	Filing Date	2018-10-25
	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	31	6254462		2001-07-03	Kelton	
	32	3061039		1962-10-30	Peters	
	33	3773140		1973-11-20	Mahajan	
	34	5548093		1996-08-20	Sato	
	35	6202702		2001-03-20	Ohira	
	36	6802690		2004-10-12	Han	
	37	8534235		2013-09-17	Chandler	
	38	8727068		2014-05-20	Bruin	
	39	9103193		2015-08-11	Coli	
	40	6164910		2000-12-26	Mayleben	
	41	7500642		2009-03-10	Cunningham	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16170695
	Filing Date	2018-10-25
	First Named Inventor	Jared Oehring
	Art Unit	
	Examiner Name	
	Attorney Docket Number	047158.100032

	42	8899940		2014-12-02	Laugemors	
	43	8905056		2004-12-09	Kendrick	
	44	4151575		1979-04-24	Hogue	
	45	5130628		1992-07-14	Owen	
	46	6315523		2001-11-13	Mills	
	47	7336514		2008-02-26	Amarillas	
	48	7525264		1999-04-28	Dodge	
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

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Art Unit	
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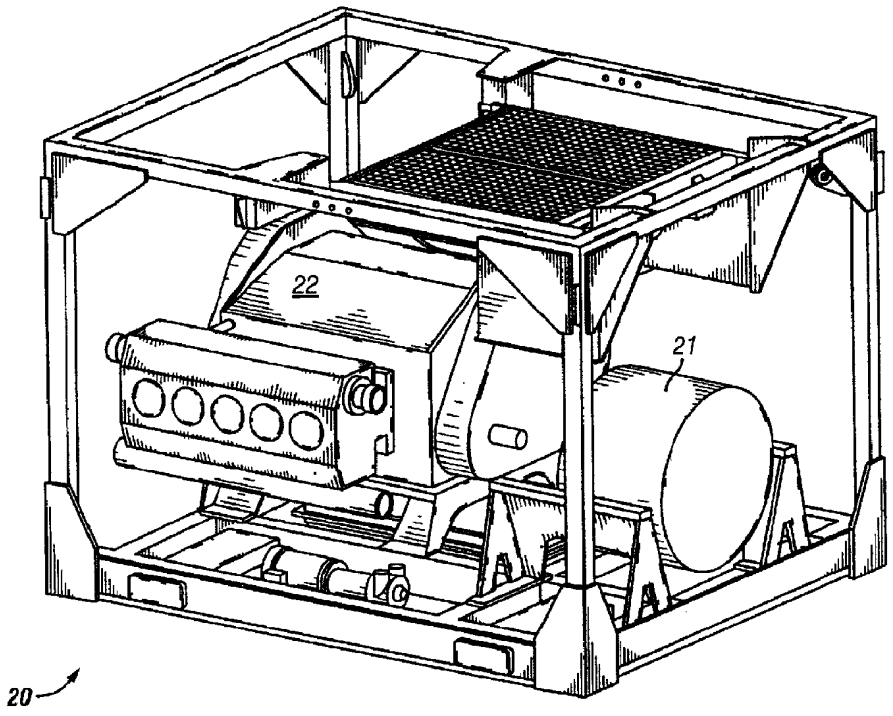
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(54) Titre : SYSTEME ELECTRIQUE MOBILE ET MODULAIRE UTILISE POUR FRACTURER DES FORMATIONS SOUTERRAINES

(54) Title: MOBILE, MODULAR, ELECTRICALLY POWERED SYSTEM FOR USE IN FRACTURING UNDERGROUND FORMATIONS



A

(57) Abrégé/Abstract:
The invetion provides a fracturing module for use in delivering pressurized fluid to a wellbore. The fracturing module includes an AC motor configured to operate in the range of up to 2500 rpm and up to 20,000 ft/lbs of torque during a fracturing operation. A

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(13) A1

(57) Abrégé(suite)/Abstract(continued):
plunger- style fluid pump is coupled to the AC motor. The dimensions of the module are such that it is sized, for example, to fit within the dimensions of an ISO intermodal container.

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ABSTRACT

The invetion provides a fracturing module for use in delivering pressurized fluid to a wellbore. The fracturing module includes an AC motor configured to operate in the range of up to 2500 rpm and up to 20,000 ft/lbs of torque during a fracturing operation. A plunger-style fluid pump is coupled to the AC motor. The dimensions of the module are such that it is sized, for example, to fit within the dimensions of an ISO intermodal container.

MOBILE, MODULAR, ELECTRICALLY POWERED SYSTEM FOR USE IN FRACTURING UNDERGROUND FORMATIONS

[0001] This application is a divisional application of Canadian Patent File No. 2,845,347 which is a divisional application of Canadian Patent File No. 2,773,843, filed on April 10, 2012.

BACKGROUND

2. Field of Invention

[0002] This invention relates generally to hydraulic stimulation of underground hydrocarbon-bearing formations, and more particularly, to the generation and use of electrical power to deliver fracturing fluid to a wellbore.

3. Description of the Related Art

[0003] Over the life cycle of a typical hydrocarbon-producing wellbore, various fluids (along with additives, proppants, gels, cement, etc...) can be delivered to the wellbore under pressure and injected into the wellbore. Surface pumping systems must be able to accommodate these various fluids. Such pumping systems are typically mobilized on skids or tractor-trailers and powered using diesel motors.

[0004] Technological advances have greatly improved the ability to identify and recover unconventional oil and gas resources. Notably, horizontal drilling and multi-stage fracturing have led to the emergence of new opportunities for natural gas production from shale formations. For example, more than twenty

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fractured intervals have been reported in a single horizontal wellbore in a tight natural gas formation. However, significant fracturing operations are required to recover these resources.

[0005] Currently contemplated natural gas recovery opportunities require considerable operational infrastructure, including large investments in fracturing equipment and related personnel. Notably, standard fluid pumps require large volumes of diesel fuel and extensive equipment maintenance programs. Typically, each fluid pump is housed on a dedicated truck and trailer configuration. With average fracturing operations requiring as many as fifty fluid pumps, the on-site area, or "footprint", required to accommodate these fracturing operations is massive. As a result, the operational infrastructure required to support these fracturing operations is extensive. Greater operational efficiencies in the recovery of natural gas would be desirable.

[0006] When planning large fracturing operations, one major logistical concern is the availability of diesel fuel. The excessive volumes of diesel fuel required necessitates constant transportation of diesel tankers to the site, and results in significant carbon dioxide emissions. Others have attempted to decrease fuel consumption and emissions by running large pump engines on "Bi-Fuel", blending natural gas and diesel fuel together, but with limited success. Further, attempts to decrease the number of personnel on-site by implementing remote monitoring and operational control have not been successful, as personnel are still required on-site to transport the equipment and fuel to and from the location.

SUMMARY

[0007] Various illustrative embodiments of a system and method for hydraulic stimulation of underground hydrocarbon-bearing formations are provided herein. In accordance with an aspect of the disclosed subject matter, a method of delivering fracturing fluid to a wellbore is provided. The method can comprise the steps of: providing a dedicated source of electric power at a site containing a wellbore to be fractured; providing one or more electric fracturing modules at the site, each electric fracturing module comprising an electric motor and a coupled fluid pump, each electric motor operatively associated with the dedicated source of electric power; providing a wellbore treatment fluid for pressurized delivery to a wellbore, wherein the wellbore treatment fluid can be continuous with the fluid pump and with the wellbore; and operating the fracturing unit using electric power from the dedicated source to pump the treatment fluid to the wellbore.

[0008] In certain illustrative embodiments, the dedicated source of electrical power is a turbine generator. A source of natural gas can be provided, whereby the natural gas drives the turbine generator in the production of electrical power. For example, natural gas can be provided by pipeline, or natural gas produced on-site. Liquid fuels such as condensate can also be provided to drive the turbine generator.

[0009] In certain illustrative embodiments, the electric motor can be an AC permanent magnet motor and/or a variable speed motor. The electric motor can be capable of operation in the range of up to 1500 rpms and up to 20,000 ft/lbs of torque. The pump can be a triplex or quintiplex plunger style fluid pump.

[0010] In certain illustrative embodiments, the method can further comprise the steps of: providing an electric blender module continuous and/or operatively associated with the fluid pump, the blender module comprising: a fluid source, a fluid additive source, and a centrifugal blender tub, and supplying electric

power from the dedicated source to the blender module to effect blending of the fluid with fluid additives to generate the treatment fluid.

[0011] In accordance with another aspect of the disclosed subject matter, a system for use in delivering pressurized fluid to a wellbore is provided. The system can comprise: a well site comprising a wellbore and a dedicated source of electricity; an electrically powered fracturing module operatively associated with the dedicated source of electricity, the electrically powered fracturing module comprising an electric motor and a fluid pump coupled to the electric motor; a source of treatment fluid, wherein the treatment fluid can be continuous with the fluid pump and with the wellbore; and a control system for regulating the fracturing module in delivery of treatment fluid from the treatment fluid source to the wellbore.

[0012] In certain illustrative embodiments, the source of treatment fluid can comprise an electrically powered blender module operatively associated with the dedicated source of electricity. The system can further comprise a fracturing trailer at the well site for housing one or more fracturing modules. Each fracturing module can be adapted for removable mounting on the trailer. The system can further comprise a replacement pumping module comprising a pump and an electric motor, the replacement pumping module adapted for removable mounting on the trailer. In certain illustrative embodiments, the replacement pumping module can be a nitrogen pumping module, or a carbon dioxide pumping module. The replacement pumping module can be, for example, a high torque, low rate motor or a low torque, high rate motor.

[0013] In accordance with another aspect of the disclosed subject matter, a fracturing module for use in delivering pressurized fluid to a wellbore is provided. The fracturing module can comprise: an AC permanent magnet motor capable of operation in the range of up to 1500 rpms and up to 20,000 ft/lbs of torque; and a plunger-style fluid pump coupled to the motor.

[0014] In accordance with another aspect of the disclosed subject matter, a method of blending a fracturing fluid for delivery to a wellbore to be fractured is provided. A dedicated source of electric power can be provided at a site containing a wellbore to be fractured. At least one electric blender module can be provided at the site. The electric blender module can include a fluid source, a fluid additive source, and a blender tub. Electric power can be supplied from the dedicated source to the electric blender module to effect blending of a fluid from the fluid source with a fluid additive from the fluid additive source to generate the fracturing fluid. The dedicated source of electrical power can be a turbine generator. A source of natural gas can be provided, wherein the natural gas is used to drive the turbine generator in the production of electrical power. The fluid from the fluid source can be blended with the fluid additive from the fluid additive source in the blender tub. The electric blender module can also include at least one electric motor that is operatively associated with the dedicated source of electric power and that effects blending of the fluid from the fluid source with the fluid additive from the fluid additive source.

[0015] In certain illustrative embodiments, the electric blender module can include a first electric motor and a second electric motor, each of which is operatively associated with the dedicated source of electric power. The first electric motor can effect delivery of the fluid from the fluid source to the blending tub. The second electric motor can effect blending of the fluid from the fluid source with the fluid additive from the fluid additive source in the blending tub. In certain illustrative embodiments, an optional third electric motor may also be present, that can also be operatively associated with the dedicated source of electric power. The third electric motor can effect delivery of the fluid additive from the fluid additive source to the blending tub.

[0016] In certain illustrative embodiments, the electric blender module can include a first blender unit and a second blender unit, each disposed adjacent to the other on the blender module and each capable of

independent operation, or collectively capable of cooperative operation, as desired. The first blender unit and the second blender unit can each include a fluid source, a fluid additive source, and a blender tub. The first blender unit and the second blender unit can each have at least one electric motor that is operatively associated with the dedicated source of electric power and that effects blending of the fluid from the fluid source with the fluid additive from the fluid additive source. Alternatively, the first blender unit and the second blender unit can each have a first electric motor and a second electric motor, both operatively associated with the dedicated source of electric power, wherein the first electric motor effects delivery of the fluid from the fluid source to the blending tub and the second electric motor effects blending of the fluid from the fluid source with the fluid additive from the fluid additive source in the blending tub. In certain illustrative embodiments, the first blender unit and the second blender unit can each also have a third electric motor operatively associated with the dedicated source of electric power, wherein the third electric motor effects delivery of the fluid additive from the fluid additive source to the blending tub.

[0017] In accordance with another aspect of the disclosed subject matter, an electric blender module for use in delivering a blended fracturing fluid to a wellbore is provided. The electric blender module can include a first electrically driven blender unit and a first inlet manifold coupled to the first electrically driven blender unit and capable of delivering an unblended fracturing fluid thereto. A first outlet manifold can be coupled to the first electrically driven blender unit and can be capable of delivering the blended fracturing fluid away therefrom. A second electrically driven blender unit can be provided. A second inlet manifold can be coupled to the second electrically driven blender unit and capable of delivering the unblended fracturing fluid thereto. A second outlet manifold can be coupled to the second electrically driven blender unit and can be capable of delivering the blended fracturing fluid away therefrom. An inlet crossing line can be coupled to both the first inlet manifold and the second inlet

manifold and can be capable of delivering the unblended fracturing fluid therebetween. An outlet crossing line can be coupled to both the first outlet manifold and the second outlet manifold and can be capable of delivering the blended fracturing fluid therebetween. A skid can be provided for housing the first electrically driven blender unit, the first inlet manifold, the second electrically driven blender unit, and the second inlet manifold.

[0017a] In one aspect there is provided a fracturing module for use in delivering pressurized fluid to a wellbore, the fracturing module comprising: an AC motor configured to operate in the range of up to 2,500 rpm during a fracturing operation, the AC motor operatively associated with a dedicated source of electricity; and a remotely controllable variable frequency drive electrically coupled to the AC motor, the variable frequency drive configured to control the speed of the electric motor; and a first plunger-style fluid pump coupled to a drive shaft of the AC motor and configured to pump fracturing fluid into a well bore and a second plunger-style fluid pump coupled to the drive shaft of the AC motor and configured to pump fracturing fluid into the well bore at the same time as the first fluid pump; wherein the first and second fluid pumps are axially aligned with the AC motor, further wherein the drive shaft of the AC motor is coupled to the first and second fluid pumps so that the AC motor is capable of concurrently driving both fluid pumps.

[0017b] In another aspect, there is provided a system for use in delivering pressurized fluid to a wellbore, the system comprising: a well site comprising a wellbore and a dedicated source of electricity; a mobile fracturing trailer at the well site for housing an electrically powered fracturing module; the electrically powered fracturing module operatively associated with the dedicated source of electricity, the electrically powered fracturing module comprising the electric motor and a first fluid pump coupled to a drive shaft of the electric motor and configured to pump fracturing fluid into the well bore and a second fluid pump coupled to the drive shaft of the electric motor and configured to pump fracturing fluid into the well bore, wherein the first and second fluid pumps are axially aligned with the electric motor.

[0017c] In another aspect, there is provided A method of blending a fracturing fluid for delivery to a wellbore to be fractured, the method comprising the steps of: providing a dedicated source of electric power for fracturing operations at a site containing a wellbore to be fractured; providing an electric motor and a first electric blender module coupled to a drive shaft of the electric motor and configured to blend fracturing fluid and a second electric blender module coupled to the drive shaft of a second electric motor and configured to blend fracturing fluid, wherein the first and second blender modules are axially aligned; providing for each electric blender module a fluid source, an additive source, and a blender tub; and supplying electric power from the dedicated source of electric power to the electric motor to affect blending of a fluid from the fluid source with an additive from the additive source to generate the fracturing fluid.

[0018] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following detailed description in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] A better understanding of the presently disclosed subject matter can be obtained when the following detailed description is considered in conjunction with the following drawings, wherein:

[0020] Figure 1 is a schematic plan view of a traditional fracturing site;

[0021] Figure 2 is a schematic plan view of a fracturing site in accordance with certain illustrative embodiments described herein;

[0022] Figure 3 is a schematic perspective view of a fracturing trailer in accordance with certain illustrative embodiments described herein;

[0023] Figure 4A is a schematic perspective view of a fracturing module in accordance with certain illustrative embodiments described herein;

[0024] Figure 4B is a schematic perspective view of a fracturing module with maintenance personnel in accordance with certain illustrative embodiments described herein;

[0025] Figure 5A is a schematic side view of a blender module in accordance with certain illustrative embodiments described herein;

[0026] Figure 5B is an end view of the blender module shown in Figure 4A;

[0027] Figure 5C is a schematic top view of a blender module in accordance with certain illustrative embodiments described herein;

[0028] Figure 5D is a schematic side view of the blender module shown in Figure 5C;

[0029] Figure 5E is a schematic perspective view of the blender module shown in Figure 5C;

[0030] Figure 6 is a schematic top view of an inlet manifold for a blender module in accordance with certain illustrative embodiments described herein; and

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[0031] Figure 7 is a schematic top view of an outlet manifold for a blender module in accordance with certain illustrative embodiments described herein.

DETAILED DESCRIPTION

[0032] The presently disclosed subject matter generally relates to an electrically powered fracturing system and a system and method for providing on-site electrical power and delivering fracturing fluid to a wellbore at a fracturing operation.

[0033] In a conventional fracturing operation, a "slurry" of fluids and additives is injected into a hydrocarbon bearing rock formation at a wellbore to propagate fracturing. Low pressure fluids are mixed with chemicals, sand, and, if necessary, acid, and then transferred at medium pressure and high rate to vertical and/or deviated portions of the wellbore via multiple high pressure, plunger style pumps driven by diesel fueled prime movers. The majority of the fluids injected will be flowed back through the wellbore and recovered, while the sand will remain in the newly created fracture, thus "propping" it open and providing a permeable membrane for hydrocarbon fluids and gases to flow through so they may be recovered.

[0034] According to the illustrative embodiments described herein, natural gas (either supplied to the site or produced on-site) can be used to drive a dedicated source of electrical power, such as a turbine generator, for hydrocarbon-producing wellbore completions. A scalable, electrically powered fracturing fleet is provided to deliver pressurized treatment fluid, such as fracturing fluid, to a wellbore in a fracturing operation, obviating the need for a constant supply of diesel fuel to the site and reducing the site footprint and infrastructure required for the fracturing operation, when compared with conventional operations. The treatment fluid provided for pressurized delivery to the wellbore can be continuous with the wellbore and with one or more components of the fracturing fleet, in certain illustrative embodiments. In these embodiments, continuous generally means that downhole hydrodynamics are dependent upon constant flow (rate and pressure) of the delivered fluids, and that there should not be any interruption in fluid flow during delivery to the wellbore if the fracture is to propagate as desired. However, it should not

be interpreted to mean that operations of the fracturing fleet cannot generally be stopped and started, as would be understood by one of ordinary skill in the art.

[0035] With reference to Figure 1, a site plan for a traditional fracturing operation on an onshore site is shown. Multiple trailers 5 are provided, each having at least one diesel tank mounted or otherwise disposed thereon. Each trailer 5 is attached to a truck 6 to permit refueling of the diesel tanks as required. Trucks 6 and trailers 5 are located within region A on the fracturing site. Each truck 6 requires a dedicated operator. One or more prime movers are fueled by the diesel and are used to power the fracturing operation. One or more separate chemical handling skids 7 are provided for housing of blending tanks and related equipment.

[0036] With reference to Figure 2, an illustrative embodiment of a site plan for an electrically powered fracturing operation on a onshore site is shown. The fracturing operation includes one or more trailers 10, each housing one or more fracturing modules 20 (see Figure 3). Trailers 10 are located in region B on the fracturing site. One or more natural gas-powered turbine generators 30 are located in region C on the site, which is located a remote distance D from region B where the trailers 10 and fracturing modules 20 are located, for safety reasons. Turbine generators 30 replace the diesel prime movers utilized in the site plan of Figure 1. Turbine generators 30 provide a dedicated source of electric power on-site. There is preferably a physical separation between the natural gas-based power generation in region C and the fracturing operation and wellbore located in region B. The natural gas-based power generation can require greater safety precautions than the fracturing operation and wellhead. Accordingly, security measures can be taken in region C to limit access to this more hazardous location, while maintaining separate safety standards in region B where the majority of site personnel are typically located. Further, the natural gas powered supply of electricity can be monitored and regulated remotely such that, if desired, no personnel are required to be within region C during operation.

[0037] Notably, the setup of Figure 2 requires significantly less infrastructure than the setup shown in Figure 1, while providing comparable pumping capacity. Fewer trailers 10 are present in region B of Figure 2 than the trucks 6 and trailers 5 in region A of Figure 1, due to the lack of need for a constant diesel fuel supply. Further, each trailer 10 in Figure 2 does not need a dedicated truck 6 and operator as in Figure 1. Fewer chemical handling skids 7 are required in region B of Figure 2 than in region A of Figure 1, as the skids 7 in Figure 2 can be electrically powered. Also, by removing diesel prime movers, all associated machinery necessary for power transfer can be eliminated, such as the transmission, torque converter, clutch, drive shaft, hydraulic system, etc ...., and the need for cooling systems, including circulating pumps and fluids, is significantly reduced. In an illustrative embodiment, the physical footprint of the on-site area in region B of Figure 2 is about 80% less than the footprint for the conventional system in region A of Figure 1.

[0038] With reference to the illustrative embodiments of Figure 3, trailer 10 for housing one or more fracturing modules 20 is shown. Trailer 10 can also be a skid, in certain illustrative embodiments. Each fracturing module 20 can include an electric motor 21 and a fluid pump 22 coupled thereto. During fracturing, fracturing module 20 is operatively associated with turbine generator 30 to receive electric power therefrom. In certain illustrative embodiments, a plurality of electric motors 21 and pumps 22 can be transported on a single trailer 10. In the illustrative embodiments of Figure 3, four electric motors 21 and pumps 22 are transported on a single trailer 10. Each electric motor 21 is paired to a pump 22 as a single fracturing module 20. Each fracturing module 20 can be removably mounted to trailer 10 to facilitate ease of replacement as necessary. Fracturing modules 20 utilize electric power from turbine generator 30 to pump the fracturing fluid directly to the wellbore.

[0039] Electrical Power Generation

[0040] The use of a turbine to directly drive a pump has been previously explored. In such systems, a transmission is used to regulate turbine power to the pump to allow for speed and torque control. In the present operation, natural gas is instead used to drive a dedicated power source in the production of electricity. In illustrative embodiments, the dedicated power source is an on-site turbine generator. The need for a transmission is eliminated, and generated electricity can be used to power the fracturing modules, blenders, and other on-site operations as necessary.

[0041] Grid power may be accessible on-site in certain fracturing operations, but the use of a dedicated power source is preferred. During startup of a fracturing operation, massive amounts of power are required such that the use of grid power would be impractical. Natural gas powered generators are more suitable for this application based on the likely availability of natural gas on-site and the capacity of natural gas generators for producing large amounts of power. Notably, the potential for very large instantaneous adjustments in power drawn from the grid during a fracturing operation could jeopardize the stability and reliability of the grid power system. Accordingly, a site-generated and dedicated source of electricity provides a more feasible solution in powering an electric fracturing system. In addition, a dedicated on-site operation can be used to provide power to operate other local equipment, including coiled tubing systems, service rigs, etc...

[0042] In an illustrative embodiment, a single natural gas powered turbine generator 30, as housed in a restricted area C of Figure 2, can generate sufficient power (for example 31 MW at 13,800 volts AC power) to supply several electric motors 21 and pumps 22, avoiding the current need to deliver and operate each fluid pump from a separate diesel-powered truck. A turbine suitable for this purpose is a TM2500+ turbine generator sold by General Electric. Other generation packages could be supplied by Pratt & Whitney or Kawasaki for example. Multiple options are available for turbine power generation,

depending on the amount of electricity required. In an illustrative embodiment, liquid fuels such as condensate can also be provided to drive turbine generator 30 instead of, or in addition to, natural gas. Condensate is less expensive than diesel fuels, thus reducing operational costs.

[0043] Fracturing Module

[0044] With reference to Figures 4A and 4B, an illustrative embodiment of fracturing module 20 is provided. Fracturing module 20 can include an electric motor 21 coupled to one or more electric pumps 22, in certain illustrative embodiments. A suitable pump is a quintiplex or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc.

[0045] Electric motor 21 is operatively associated with turbine generator 30, in certain embodiments. Typically, each fracturing module 20 will be associated with a drive housing for controlling electric motor 21 and pumps 22, as well as an electrical transformer and drive unit 50 (see Figure 3) to step down the voltage of the power from turbine generator 30 to a voltage appropriate for electric motor 21. The electrical transformer and drive unit 50 can be provided as an independent unit for association with fracturing module 20, or can be permanently fixed to the trailer 10, in various embodiments. If permanently fixed, then transformer and drive unit 50 can be scalable to allow addition or subtraction of pumps 22 or other components to accommodate any operational requirements.

[0046] Each pump 22 and electric motor 21 are modular in nature so as to simplify removal and replacement from fracturing module 20 for maintenance purposes. Removal of a single fracturing module 20 from trailer 10 is also simplified. For example, any fracturing module 20 can be unplugged and unpinned from trailer 10 and removed, and another fracturing module 20 can be installed in its place in a matter of minutes.

[0047] In the illustrative embodiment of Figure 3, trailer 10 can house four fracturing modules 20, along with a transformer and drive unit 50. In this particular configuration, each single trailer 10 provides more

pumping capacity than four of the traditional diesel powered fracturing trailers 5 of Figure 1, as parasitic losses are minimal in the electric fracturing system compared to the parasitic losses typical of diesel fueled systems. For example, a conventional diesel powered fluid pump is rated for 2250 hp. However, due to parasitic losses in the transmission, torque converter and cooling systems, diesel fueled systems typically only provide 1800 hp to the pumps. In contrast, the present system can deliver a true 2500 hp directly to each pump 22 because pump 22 is directly coupled to electric motor 21. Further, the nominal weight of a conventional fluid pump is up to 120,000 lbs. In the present operation, each fracturing module 20 weighs approximately 28,000 lbs., thus allowing for placement of four pumps 22 in the same physical dimension (size and weight) as the spacing needed for a single pump in conventional diesel systems, as well as allowing for up to 10,000 hp total to the pumps. In other embodiments, more or fewer fracturing modules 20 may be located on trailer 10 as desired or required for operational purposes.

[0048] In certain illustrative embodiments, fracturing module 20 can include a electric motor 21 that is an AC permanent magnet motor capable of operation in the range of up to 1500 rpms and up to 20,000 ft/lbs of torque. Fracturing module 20 can also include a pump 22 that is a plunger-style fluid pump coupled to electric motor 21. In certain illustrative embodiments, fracturing module 20 can have dimensions of approximately 136" width x 108" length x 100" height. These dimensions would allow fracturing module 20 to be easily portable and fit with a ISO intermodal container for shipping purposes without the need for disassembly. Standard sized ISO container lengths are typically 20' , 40' or 53'. In certain illustrative embodiments, fracturing module 20 can have dimensions of no greater than 136" width x 108" length x 100" height. These dimensions for fracturing module 20 would also allow crew members to easily fit within the confines of fracturing module 20 to make repairs, as illustrated in Figure 4b. In certain illustrative embodiments, fracturing module 20 can have a width of no greater than 102" to fall within shipping configurations and road restrictions. In a specific embodiment, fracturing module 20 is

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capable of operating at 2500 hp while still having the above specified dimensions and meeting the above mentioned specifications for rpms and ft/lbs of torque.

[0049] Electric Motor

[0050] With reference to the illustrative embodiments of Figures 2 and 3, a medium low voltage AC permanent magnet electric motor 21 receives electric power from turbine generator 30, and is coupled directly to pump 22. In order to ensure suitability for use in fracturing, electric motor 21 should be capable of operation up to 1,500 rpm with a torque of up to 20,000 ft/lbs, in certain illustrative embodiments. A motor suitable for this purpose is sold under the trademark TeraTorq® and is available from Comprehensive Power, Inc. of Marlborough, Massachusetts. A compact motor of sufficient torque will allow the number of fracturing modules 20 placed on each trailer 10 to be maximized.

[0051] Blender

[0052] For greater efficiency, conventional diesel powered blenders and chemical addition units can be replaced with electrically powered blender units. In certain illustrative embodiments as described herein, the electrically powered blender units can be modular in nature for housing on trailer 10 in place of fracturing module 20, or housed independently for association with each trailer 10. An electric blending operation permits greater accuracy and control of fracturing fluid additives. Further, the centrifugal blender tubs typically used with blending trailers to blend fluids with proppant, sand, chemicals, acid, etc... prior to delivery to the wellbore are a common source of maintenance costs in traditional fracturing operations.

[0053] With reference to Figures 5A-5E and Figures 6-7, illustrative embodiments of a blender module 40 and components thereof are provided. Blender module 40 can be operatively associated with turbine generator 30 and capable of providing fractioning fluid to pump 22 for delivery to the wellbore. In certain embodiments, blender module 40 can include at least one fluid additive source 44, at least one fluid

source 48, and at least one centrifugal blender tub 46. Electric power can be supplied from turbine generator 30 to blender module 40 to effect blending of a fluid from fluid source 48 with a fluid additive from fluid additive source 44 to generate the fracturing fluid. In certain embodiments, the fluid from fluid source 48 can be, for example, water, oils or methanol blends, and the fluid additive from fluid additive source 44 can be, for example, friction reducers, gellents, gellent breakers or biocides.

[0054] In certain illustrative embodiments, blender module 40 can have a dual configuration, with a first blender unit 47a and a second blender unit 47b positioned adjacent to each other. This dual configuration is designed to provide redundancy and to facilitate access for maintenance and replacement of components as needed. In certain embodiments, each blender unit 47a and 47b can have its own electrically-powered suction and tub motors disposed thereon, and optionally, other electrically-powered motors can be utilized for chemical additional and/or other ancillary operational functions, as discussed further herein.

[0055] For example, in certain illustrative embodiments, first blender unit 47a can have a plurality of electric motors including a first electric motor 43a and a second electric motor 41a that are used to drive various components of blender module 40. Electric motors 41a and 43a can be powered by turbine generator 30. Fluid can be pumped into blender module 40 through an inlet manifold 48a by first electric motor 43a and added to tub 46a. Thus, first electric motor 43a acts as a suction motor. Second electric motor 41a can drive the centrifugal blending process in tub 46a. Second electric motor 41a can also drive the delivery of blended fluid out of blender module 40 and to the wellbore via an outlet manifold 49a. Thus, second electric motor 41a acts as a tub motor and a discharge motor. In certain illustrative embodiments, a third electric motor 42a can also be provided. Third electric motor 42a can also be powered by turbine generator 30, and can power delivery of fluid additives to blender 46a. For example,

proppant from a hopper 44a can be delivered to a blender tub 46a, for example, a centrifugal blender tub, by an auger 45a, which is powered by third electric motor 42a.

[0056] Similarly, in certain illustrative embodiments, second blender unit 47b can have a plurality of electric motors including a first electric motor 43b and a second electric motor 41b that are used to drive various components of blender module 40. Electric motors 41b and 43b can be powered by turbine generator 30. Fluid can be pumped into blender module 40 through an inlet manifold 48b by first electric motor 43b and added to tub 46b. Thus, second electric motor 43a acts as a suction motor. Second electric motor 41b can drive the centrifugal blending process in tub 46b. Second electric motor 41b can also drive the delivery of blended fluid out of blender module 40 and to the wellbore via an outlet manifold 49b. Thus, second electric motor 41b acts as a tub motor and a discharge motor. In certain illustrative embodiments, a third electric motor 42b can also be provided. Third electric motor 42b can also be powered by turbine generator 30, and can power delivery of fluid additives to blender 46b. For example, proppant from a hopper 44b can be delivered to a blender tub 46b, for example, a centrifugal blender tub, by an auger 45b, which is powered by third electric motor 42b.

[0057] Blender module 40 can also include a control cabin 53 for housing equipment controls for first blender unit 47a and second blender unit 47b, and can further include appropriate drives and coolers as required.

[0058] Conventional blenders powered by a diesel hydraulic system are typically housed on a forty-five foot tractor trailer and are capable of approximately 100 bbl/min. In contrast, the dual configuration of blender module 40 having first blender unit 47a and second blender unit 47b can provide a total output capability of 240 bbl/min in the same physical footprint as a conventional blender, without the need for a separate backup unit in case of failure.

[0059] Redundant system blenders have been tried in the past with limited success, mostly due to problems with balancing weights of the trailers while still delivering the appropriate amount of power. Typically, two separate engines, each approximately 650 hp, have been mounted side by side on the nose of the trailer. In order to run all of the necessary systems, each engine must drive a mixing tub via a transmission, drop box and extended drive shaft. A large hydraulic system is also fitted to each engine to run all auxiliary systems such as chemical additions and suction pumps. Parasitic power losses are very large and the hosing and wiring is complex.

[0060] In contrast, the electric powered blender module 40 described in certain illustrative embodiments herein can relieve the parasitic power losses of conventional systems by direct driving each piece of critical equipment with a dedicated electric motor. Further, the electric powered blender module 40 described in certain illustrative embodiments herein allows for plumbing routes that are unavailable in conventional applications. For example, in certain illustrative embodiments, the fluid source can be an inlet manifold 48 that can have one or more inlet crossing lines 50 (see Figure 7) that connect the section of inlet manifold 48 dedicated to delivering fluid to first blender unit 47a with the section of inlet manifold 48 dedicated to delivering fluid to second blender unit 47b. Similarly, in certain illustrative embodiments, outlet manifold 49 can have one or more outlet crossing lines 51 (see Fig 6) that connect the section of outlet manifold 49 dedicated to delivering fluid from first blender unit 47a with the section of outlet manifold 49 dedicated to delivering fluid from second blender unit 47b. Crossing lines 50 and 51 allow flow to be routed or diverted between first blender unit 47a and second blender unit 47b. Thus, blender module 40 can mix from either side, or both sides, and/or discharge to either side, or both sides, if necessary. As a result, the attainable rates for the electric powered blender module 40 are much larger that of a conventional blender. In certain illustrative embodiments, each side (i.e., first blender unit 47a and second blender unit 47b) of blender module 40 is capable of approximately 120 bbl/min. Also, each

side (i.e., first blender unit 47a and second blender unit 47b) can move approximately 15 t/min of sand, at least in part because the length of auger 45 is shorter (approximately 6') as compared to conventional units (approximately 12').

[0061] In certain illustrative embodiments, blender module 40 can be scaled down or "downsized" to a single, compact module comparable in size and dimensions to fracturing module 20 described herein. For smaller fracturing or treatment jobs requiring fewer than four fracturing modules 20, a downsized blender module 40 can replace one of the fracturing modules 20 on trailer 10, thus reducing operational costs and improving transportability of the system.

[0062] Control System

[0063] A control system can be provided for regulating various equipment and systems within the electric powered fractioning operation. For example, in certain illustrative embodiments, the control system can regulate fracturing module 20 in delivery of treatment fluid from blender module 30 to pumps 22 for delivery to the wellbore. Controls for the electric-powered operation described herein are a significant improvement over that of conventional diesel powered systems. Because electric motors are controlled by variable frequency drives, absolute control of all equipment on location can be maintained from one central point. When the system operator sets a maximum pressure for the treatment, the control software and variable frequency drives calculate a maximum current available to the motors. Variable frequency drives essentially "tell" the motors what they are allowed to do.

[0064] Electric motors controlled via variable frequency drive are far safer and easier to control than conventional diesel powered equipment. For example, conventional fleets with diesel powered pumps utilize an electronically controlled transmission and engine on the unit. There can be up to fourteen different parameters that need to be monitored and controlled for proper operation. These signals are typically sent via hardwired cable to an operator console controlled by the pump driver. The signals are

converted from digital to analog so the inputs can be made via switches and control knobs. The inputs are then converted from analog back to digital and sent back to the unit. The control module on the unit then tells the engine or transmission to perform the required task and the signal is converted to a mechanical operation. This process takes time.

[0065] Accidental over-pressures are quite common in these conventional operations, as the signal must travel to the console, back to the unit and then perform a mechanical function. Over-pressures can occur in milliseconds due to the nature of the operations. These are usually due to human error, and can be as simple as a single operator failing to react to a command. They are often due to a valve being closed, which accidentally creates a "deadhead" situation.

[0066] For example, in January of 2011, a large scale fractioning operation was taking place in the Horn River Basin of north-eastern British Columbia, Canada. A leak occurred in one of the lines and a shutdown order was given. The master valve on the wellhead was then closed remotely. Unfortunately, multiple pumps were still rolling and a system over-pressure ensued. Treating iron rated for 10,000 psi was taken to well over 15,000 psi. A line attached to the well also separated, causing it to whip around. The incident caused a shutdown interruption to the entire operation for over a week while investigation and damage assessment were performed.

[0067] The control system provided according to the present illustrative embodiments, being electrically powered, virtually eliminates these types of scenarios from occurring. A maximum pressure value set at the beginning of the operation is the maximum amount of power that can be sent to electric motor 21 for pump 22. By extrapolating a maximum current value from this input, electric motor 21 does not have the available power to exceed its operating pressure. Also, because there are virtually no mechanical systems between pump 22 and electric motor 21, there is far less "moment of inertia" of gears and clutches to deal with. A near instantaneous stop of electric motor 21 results in a near instantaneous stop of pump 22.

[0068] An electrically powered and controlled system as described herein greatly increases the ease in which all equipment can be synced or slaved to each other. This means a change at one single point will be carried out by all pieces of equipment, unlike with diesel equipment. For example, in conventional diesel powered operations, the blender typically supplies all the necessary fluids to the entire system. In order to perform a rate change to the operation, the blender must change rate prior to the pumps changing rates. This can often result in accidental overflow of the blender tubs and/or cavitation of the pumps due to the time lag of each piece of equipment being given manual commands.

[0069] In contrast, the present operation utilizes a single point control that is not linked solely to blender operations, in certain illustrative embodiments. All operation parameters can be input prior to beginning the fractioning. If a rate change is required, the system will increase the rate of the entire system with a single command. This means that if pumps 22 are told to increase rate, then blender module 40 along with the chemical units and even ancillary equipment like sand belts will increase rates to compensate automatically.

[0070] Suitable controls and computer monitoring for the entire fracturing operation can take place at a single central location, which facilitates adherence to pre-set safety parameters. For example, a control center 40 is indicated in Figure 2 from which operations can be managed via communications link 41. Examples of operations that can be controlled and monitored remotely from control center 40 via communications link 41 can be the power generation function in Area B, or the delivery of treatment fluid from blender module 40 to pumps 22 for delivery to the wellbore.

[0071] Comparison Example

[0072] Table 1, shown below, compares and contrasts the operational costs and manpower requirements for a conventional diesel powered operation (such as shown in Figure 1) with those of a electric powered operation (such as shown in Figure 2).

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[0073] Table 1

[0074] Comparison of Conventional Diesel Powered Operation vs. Electric Powered Operation

Diesel Powered Operation	Electric Powered Operation
Total fuel cost (diesel) - about $80,000 per day	Total fuel cost (natural gas) - about $2,300 per day
Service interval for diesel engines - about every 200-300 hours	Service interval for electric motor - about every 50,000 hours
Dedicated crew size - about 40 people	Dedicated crew size - about 10 people

[0075] In Table 1, the "Diesel Powered Operation" utilizes at least 24 pumps and 2 blenders, and requires at least 54,000 hp to execute the fracturing program on that location. Each pump burns approximately 300-400 liters per hour of operation, and the blender units burn a comparable amount of diesel fuel. Because of the fuel consumption and fuel capacity of this conventional unit, it requires refueling during operation, which is extremely dangerous and presents a fire hazard. Further, each piece of conventional equipment needs a dedicated tractor to move it and a driver/operator to run it. The crew size required to operate and maintain a conventional operation such as the one in Figure 1 represents a direct cost for the site operator.

[0076] In contrast, the electric powered operation as described herein utilizes a turbine that only consumes about 6mm scf of natural gas per 24 hours. At current market rates (approximately $2.50 per mmbtu), this equates to a reduction in direct cost to the site operator of over $77,000 per day compared to

the diesel powered operation. Also, the service interval on electric motors is about 50,000 hours, which allows the majority of reliability and maintainability costs to disappear. Further, the need for multiple drivers/operators is reduced significantly, and electric powered operation means that a single operator can run the entire system from a central location. Crew size can be reduced by around 75%, as only about 10 people are needed on the same location to accomplish the same tasks as conventional operations, with the 10 people including off-site personnel maintenance personnel. Further, crew size does not change with the amount of equipment used. Thus, the electric powered operation is significantly more economical.

[0077] Modular Design and Alternate Embodiments

[0078] As discussed above, the modular nature of the electric powered fracturing operation described herein provides significant operational advantages and efficiencies over traditional fracturing systems. Each fracturing module 20 sits on trailer 10 which houses the necessary mounts and manifold systems for low pressure suctions and high pressure discharges. Each fracturing module 20 can be removed from service and replaced without shutting down or compromising the fractioning spread. For instance, pump 22 can be isolated from trailer 10, removed and replaced by a new pump 22 in just a few minutes. If fracturing module 20 requires service, it can be isolated from the fluid lines, unplugged, un-pinned and removed by a forklift. Another fracturing module 20 can be then re-inserted in the same fashion, realizing a drastic time savings. In addition, the removed fracturing module 20 can be repaired or serviced in the field. In contrast, if one of the pumps in a conventional diesel powered system goes down or requires service, the tractor/trailer combination needs to be disconnected from the manifold system and driven out of the location. A replacement unit must then be backed into the line and reconnected. Maneuvering these units in these tight confines is difficult and dangerous.

[0079] The presently described electric powered fracturing operation can be easily adapted to accommodate additional types of pumping capabilities as needed. For example, a replacement pumping

module can be provided that is adapted for removable mounting on trailer 10. Replacement pumping module can be utilized for pumping liquid nitrogen, carbon dioxide, or other chemicals or fluids as needed, to increase the versatility of the system and broaden operational range and capacity. In a conventional system, if a nitrogen pump is required, a separate unit truck/trailer unit must be brought to the site and tied into the fractioning spread. In contrast, the presently described operation allows for a replacement nitrogen module with generally the same dimensions as fractioning module 20, so that the replacement module can fit into the same slot on the trailer as fractioning module 20 would. Trailer 10 can contain all the necessary electrical power distributions as required for a nitrogen pump module so no modifications are required. The same concept would apply to carbon dioxide pump modules or any other pieces of equipment that would be required. Instead of another truck/trailer, a specialized replacement module can instead be utilized.

[0080] Natural gas is considered to be the cleanest, most efficient fuel source available. By designing and constructing "fit for purpose equipment" that is powered by natural gas, it is expected that the fracturing footprint, manpower, and maintenance requirements can each be reduced by over 60% when compared with traditional diesel-powered operations.

[0081] In addition, the presently described electric powered fracturing operation resolves or mitigates environmental impacts of traditional diesel-powered operations. For example, the presently described natural gas powered operation can provide a significant reduction in carbon dioxide emissions as compared to diesel-powered operations. In an illustrative embodiment, a fractioning site utilizing the presently described natural gas powered operation would have a carbon dioxide emissions level of about 2200 kg/hr, depending upon the quality of the fuel gas, which represents an approximately 200% reduction from carbon dioxide emissions of diesel-powered operations. Also, in an illustrative embodiment, the presently described natural gas powered operation would produces no greater than about

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80 decibels of sound with a silencer package utilized on turbine 30, which meets OSHA requirements for noise emissions. By comparison, a conventional diesel-powered fractioning pump running at full rpm emits about 105 decibels of sound. When multiple diesel-powered fractioning pumps are running simultaneously, noise is a significant hazard associated with conventional operations.

[0082] In certain illustrative embodiments, the electric-powered fractioning operation described herein can also be utilized for offshore oil and gas applications, for example, fracturing of a wellbore at an offshore site. Conventional offshore operations already possess the capacity to generate electric power on-site. These vessels are typically diesel over electric, which means that the diesel powerplant on the vessel generates electricity to meet all power requirements including propulsion. Conversion of offshore pumping services to run from an electrical power supply will allow transported diesel fuel to be used in power generation rather than to drive the fracturing operation, thus reducing diesel fuel consumption. The electric power generated from the offshore vessel's power plant (which is not needed during station keeping) can be utilized to power one or more fracturing modules 10. This is far cleaner, safer and more efficient than using diesel powered equipment. Fracturing modules 10 are also smaller and lighter than the equipment typically used on the deck of offshore vessels, thus removing some of the current ballast issues and allowing more equipment or raw materials to be transported by the offshore vessels.

[0083] In a deck layout for a conventional offshore stimulation vessel, skid based, diesel powered pumping equipment and storage facilities on the deck of the vessel create ballast issues. Too much heavy equipment on the deck of the vessel causes the vessel to have higher center of gravity. Also, fuel lines must be run to each piece of equipment greatly increasing the risk of fuel spills. In illustrative embodiments of a deck layout for an offshore vessel utilizing electric-powered fractioning operations as described herein, the physical footprint of the equipment layout is reduced significantly when compared to the conventional layout. More free space is available on deck, and the weight of equipment is

dramatically decreased, thus eliminating most of the ballast issues. A vessel already designed as diesel-electric can be utilized. When the vessel is on station at a platform and in station keeping mode, the vast majority of the power that the ship's engines are generating can be run up to the deck to power modules. The storage facilities on the vessel can be placed below deck, further lowering the center of gravity, while additional equipment, for instance, a 3-phase separator, or coiled tubing unit, can be provided on deck, which is difficult in existing diesel-powered vessels. These benefits, coupled with the electronic control system, give a far greater advantage over conventional vessels.

[0084] While the present description has specifically contemplated a fracturing system, the system can be used to power pumps for other purposes, or to power other oilfield equipment. For example, high rate and pressure pumping equipment, hydraulic fracturing equipment, well stimulation pumping equipment and/or well servicing equipment could also be powered using the present system. In addition, the system can be adapted for use in other art fields requiring high torque or high rate pumping operations, such as pipeline cleaning or dewatering mines.

[0085] It is to be understood that the subject matter herein is not limited to the exact details of construction, operation, exact materials, or illustrative embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. Accordingly, the subject matter is therefore to be limited only by the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A fracturing module for use in delivering pressurized fluid to a wellbore, the fracturing module comprising:

an AC motor configured to operate in the range of up to 2,500 rpm during a fracturing operation, the AC motor operatively associated with a dedicated source of electricity; and

a remotely controllable variable frequency drive electrically coupled to the AC motor, the variable frequency drive configured to control the speed of the electric motor; and

a first plunger-style fluid pump coupled to a drive shaft of the AC motor and configured to pump fracturing fluid into a well bore and a second plunger-style fluid pump coupled to the drive shaft of the AC motor and configured to pump fracturing fluid into the well bore at the same time as the first fluid pump;

wherein the first and second fluid pumps are axially aligned with the AC motor, further wherein the drive shaft of the AC motor is coupled to the first and second fluid pumps so that the AC motor is capable of concurrently driving both fluid pumps.

2. The fracturing module of claim 1, wherein the fracturing module has dimensions of no greater than 136" width x 108" length x 100" height.

3. The fracturing module of claim 1, wherein the module is sized to fit within the dimensions of an ISO intermodal carrier.

4. The fracturing module of claim 1, wherein the module is disposed on a mobile fracturing trailer.

5. The fracturing module of claim 4 wherein the module is adapted for removable mounting on the mobile fracturing trailer.

6. The fracturing module of claim 1 further comprising an electrical transformer and drive unit.

7. A system for delivering pressurized fluid into a wellbore comprising the fracturing module of claim 1 and a natural gas powered turbine generator configured to power said motor, the system operating at a sound of no greater than 80 decibels.

8. A system for use in delivering pressurized fluid to a wellbore, the system comprising: a well site comprising a wellbore and a dedicated source of electricity;

a mobile fracturing trailer at the well site for housing an electrically powered fracturing module;

the electrically powered fracturing module operatively associated with the dedicated source of electricity, the electrically powered fracturing module comprising the electric motor and a first fluid pump coupled to a drive shaft of the electric motor and configured to pump fracturing fluid into the well bore and a second fluid pump coupled to the drive shaft of the electric motor and configured to pump fracturing fluid into the well bore, wherein the first and second fluid pumps are axially aligned with the electric motor.

9. The system of claim 8 wherein the first and second fluid pumps are configured to pump fracturing fluid into the well bore at the same time.

10. The system of claim 8 wherein the electrically powered fracturing module is adapted for removable mounting on the mobile fracturing trailer.

11. The system of claim 8 further comprising a first plunger-style fluid pump coupled to a drive shaft of the electric motor and configured to pump fracturing fluid into a well bore and a second plunger-style fluid pump coupled to the drive shaft of the electric motor and configured to pump fracturing fluid into the well bore at the same time as the first fluid pump.

12. The system of claim 8 further wherein the electrically powered fracturing module is sized to fit within the dimensions of an ISO intermodal carrier.

13. The system of claim 8 wherein the electrically powered fracturing module has dimensions of no greater than 136" width x l08" length x 100" height.

14. The system of claim 8 wherein the electrically powered fracturing module further comprises an electrical transformer and drive unit.

15. A method of blending a fracturing fluid for delivery to a wellbore to be fractured, the method comprising the steps of:

providing a dedicated source of electric power for fracturing operations at a site containing a wellbore to be fractured;

providing an electric motor and a first electric blender module coupled to a drive shaft of the electric motor and configured to blend fracturing fluid and a second electric blender module coupled to the drive shaft of a second electric motor and configured to blend fracturing fluid, wherein the first and second blender modules are axially aligned;

providing for each electric blender module a fluid source, an additive source, and a blender tub; and

supplying electric power from the dedicated source of electric power to the electric motor to affect blending of a fluid from the fluid source with an additive from the additive source to generate the fracturing fluid.

16. The method of claim 15, further comprising providing a source of natural gas, wherein the dedicated source of electric power is a turbine generator, and wherein the natural gas is used to drive the turbine generator for the production of electric power.

17. The method of claim 15, wherein the fluid from the fluid source is blended with the additive from the additive source in the blender tub.

18. The method of claim 15, wherein the electrically powered blender module is operatively associated with a control cabin adapted to:

sync the first and second blender modules with one or more fluid pumps that pump the fracturing fluid within the wellbore; and automatically compensate a change in flow rate of the first and second blender modules based upon a change in flow rate of the one or more fluid pumps instructed by a command generated from a central control for fracturing operations.

19. The method of claim 15, wherein the electrically powered blender module is operatively coupled to a control cabin that is adapted to drive the first and second electric blending modules.

20. The method of claim 15, wherein the first electric blender module is a dual configuration blender module that comprises a first blender unit and a second blender unit that are both mounted on a trailer, wherein the first blender unit and the second blender unit each comprise the fluid source, the additive source, and the blender tub

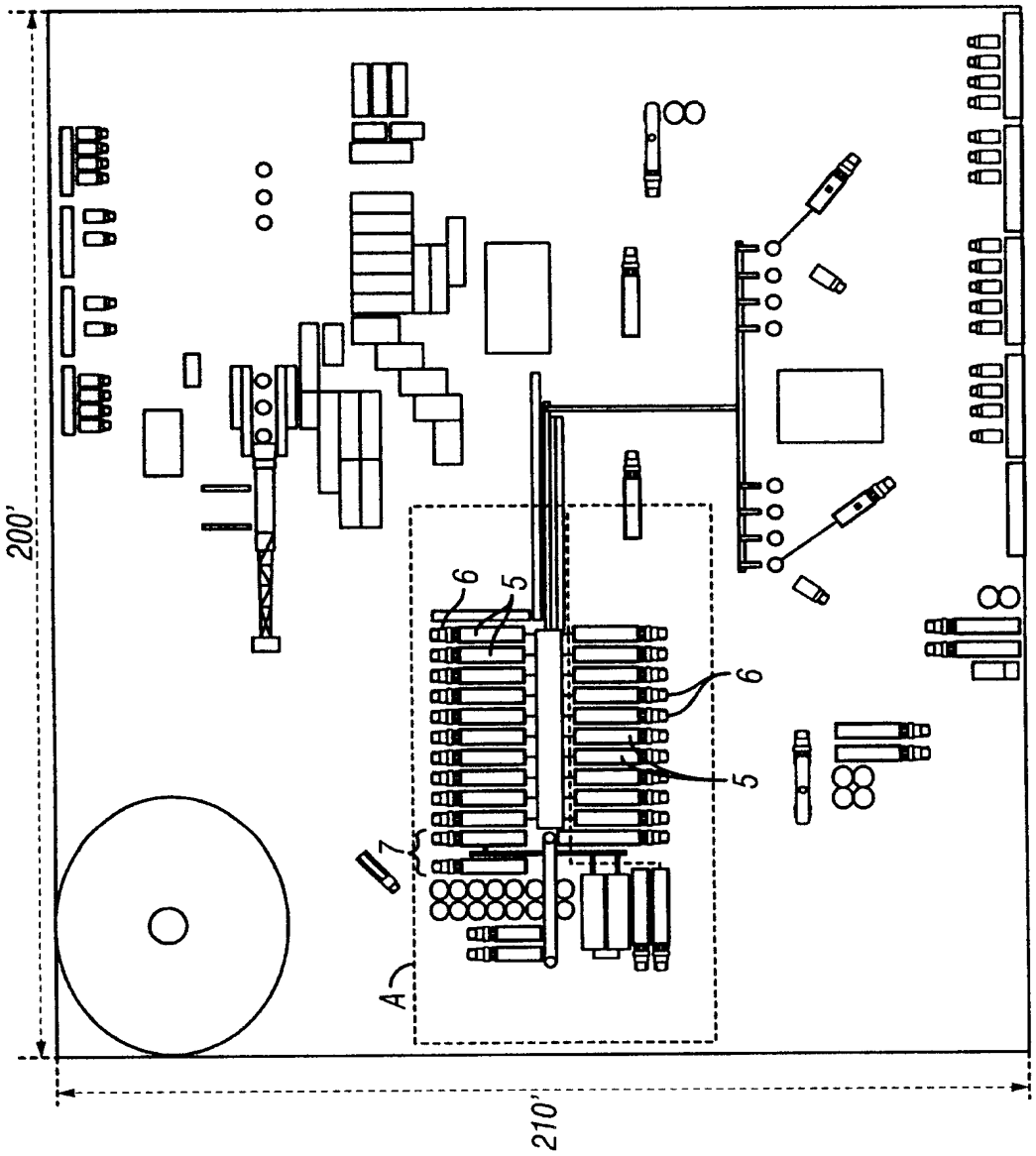


FIG. 1
(Prior Art)

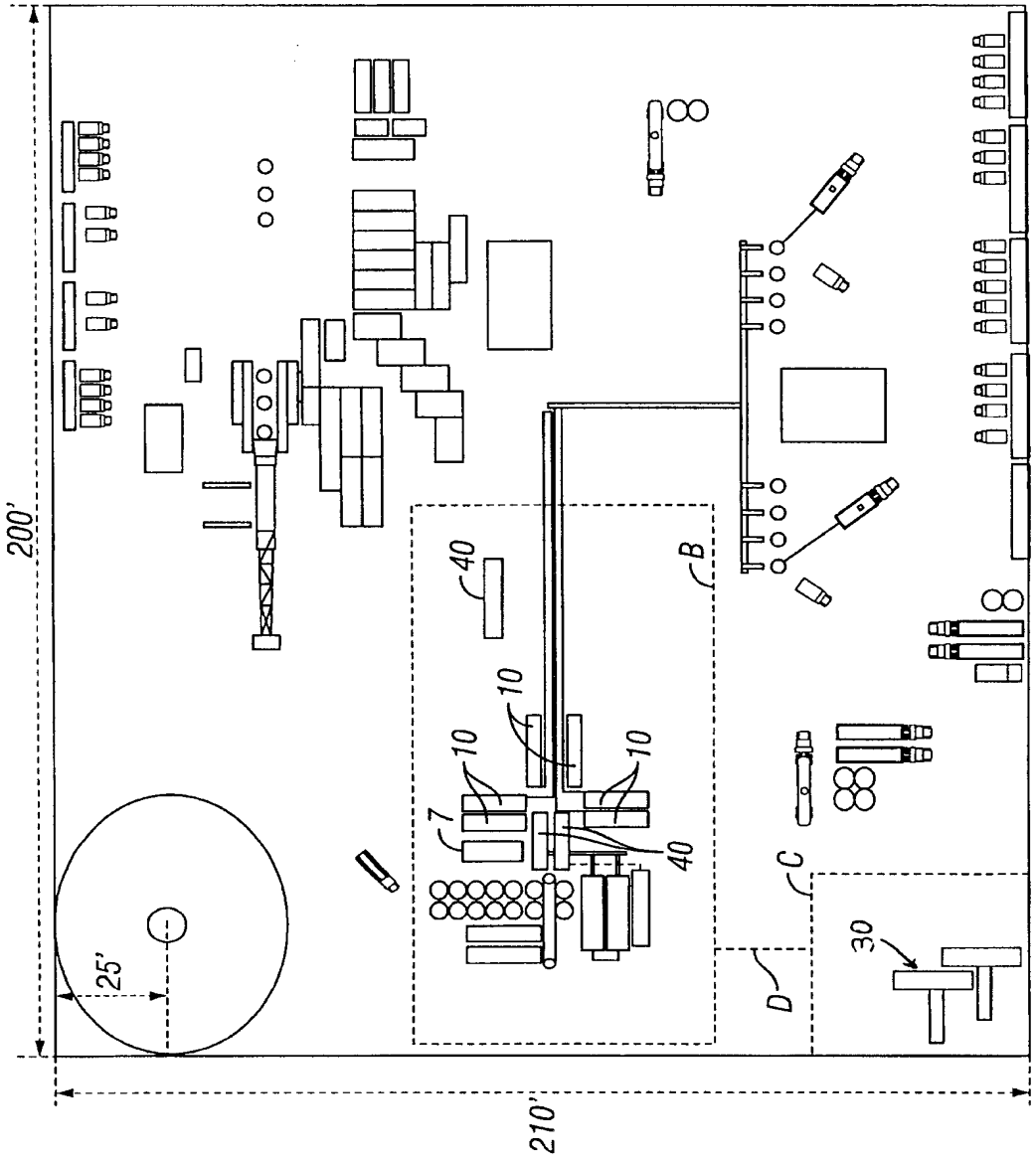


FIG. 2

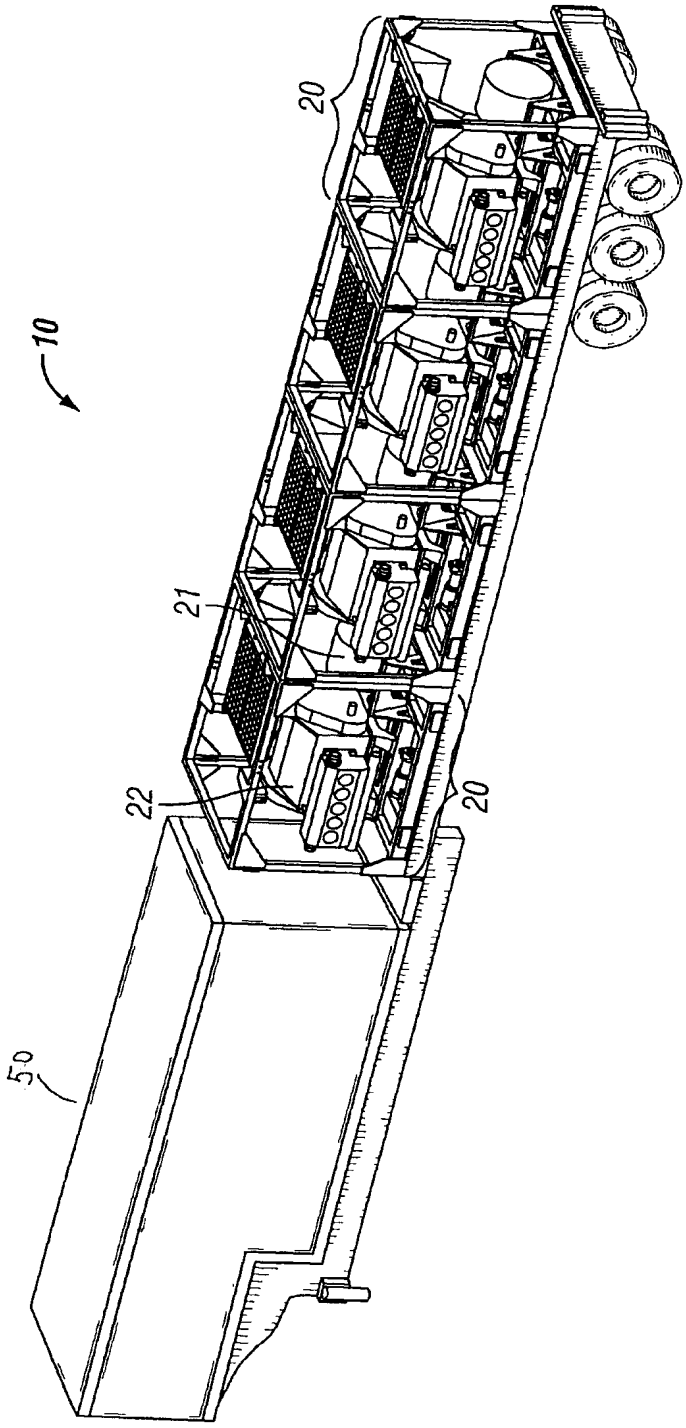


FIG. 3

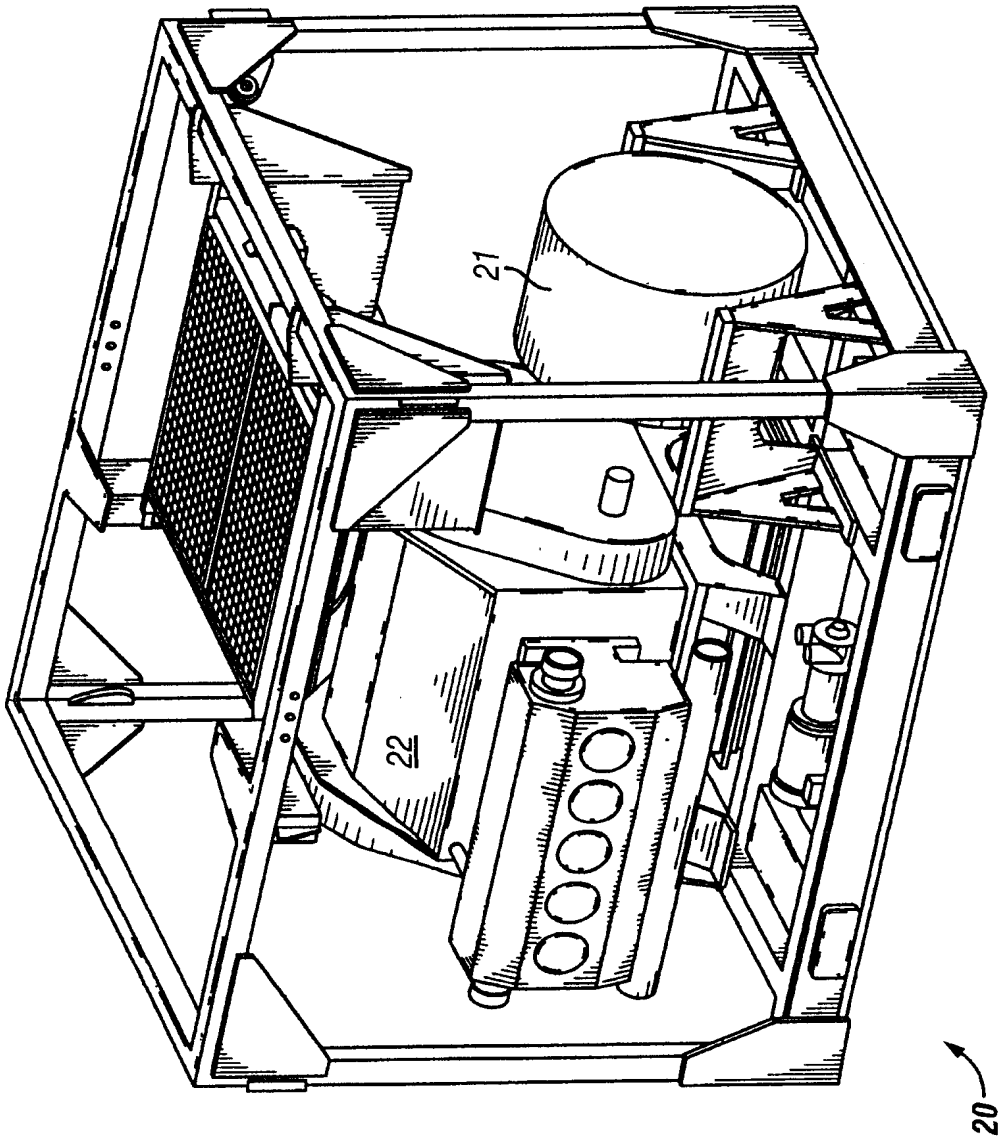


FIG. 4A

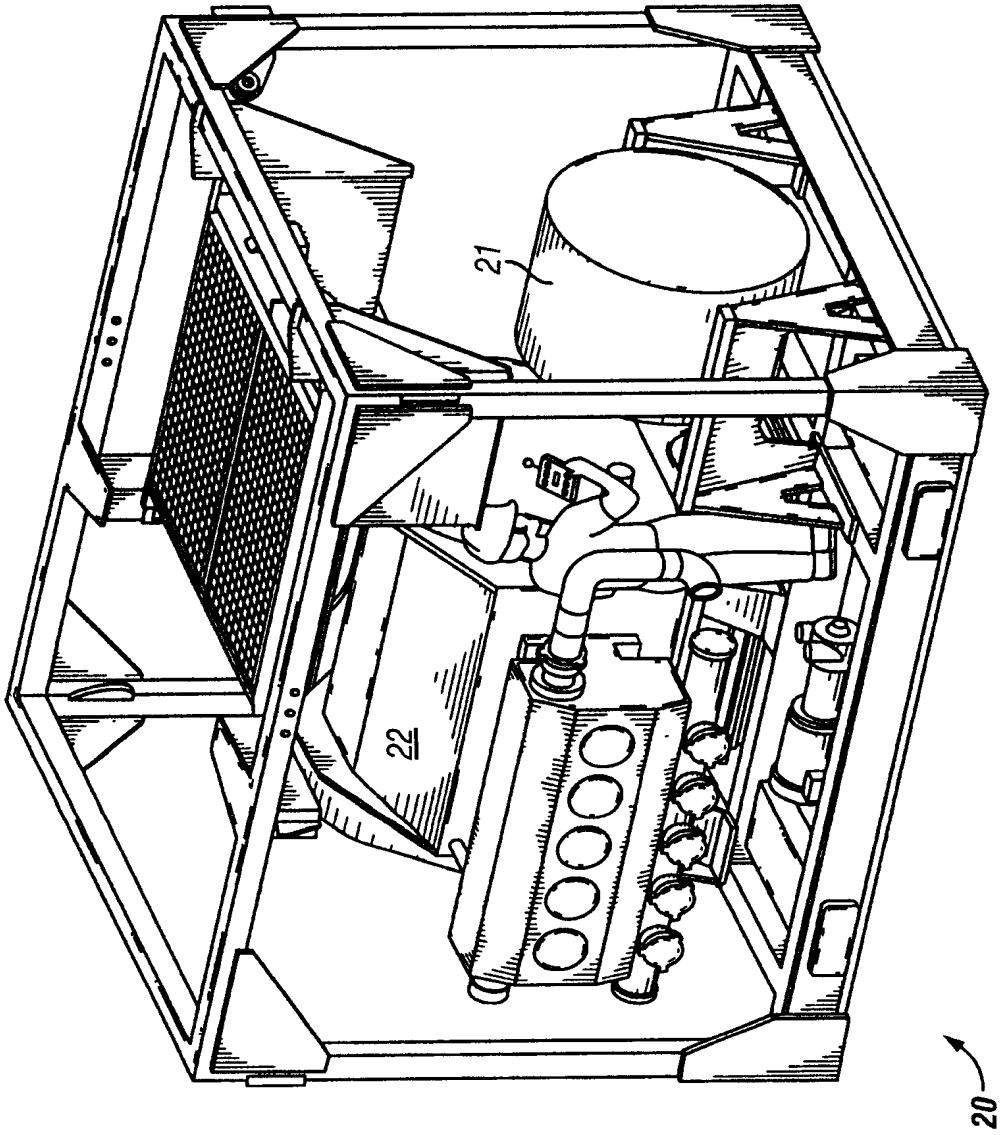


FIG. 4B

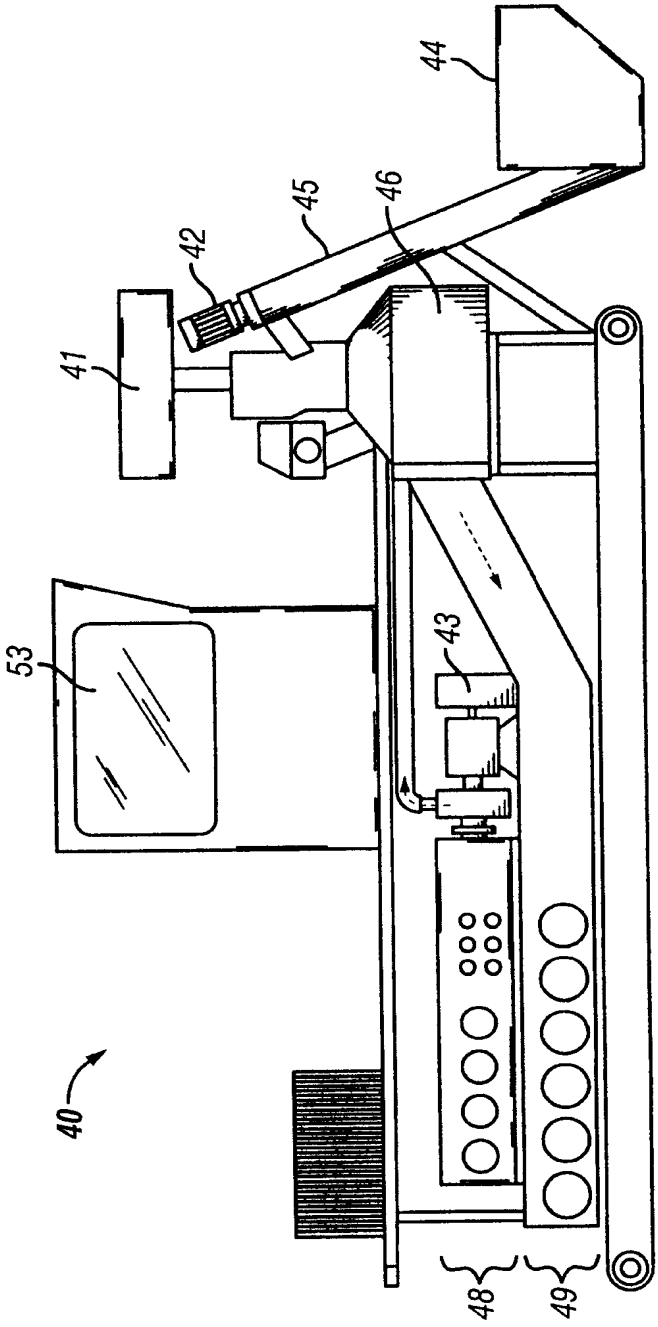


FIG. 5A

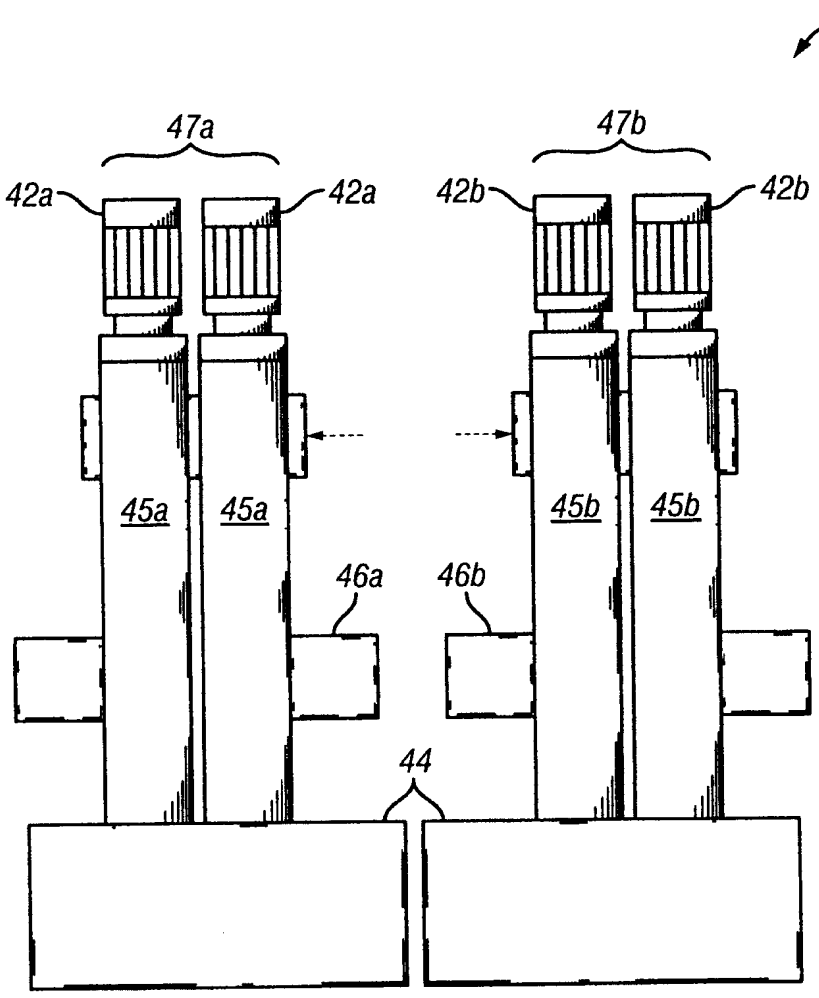


FIG. 5B

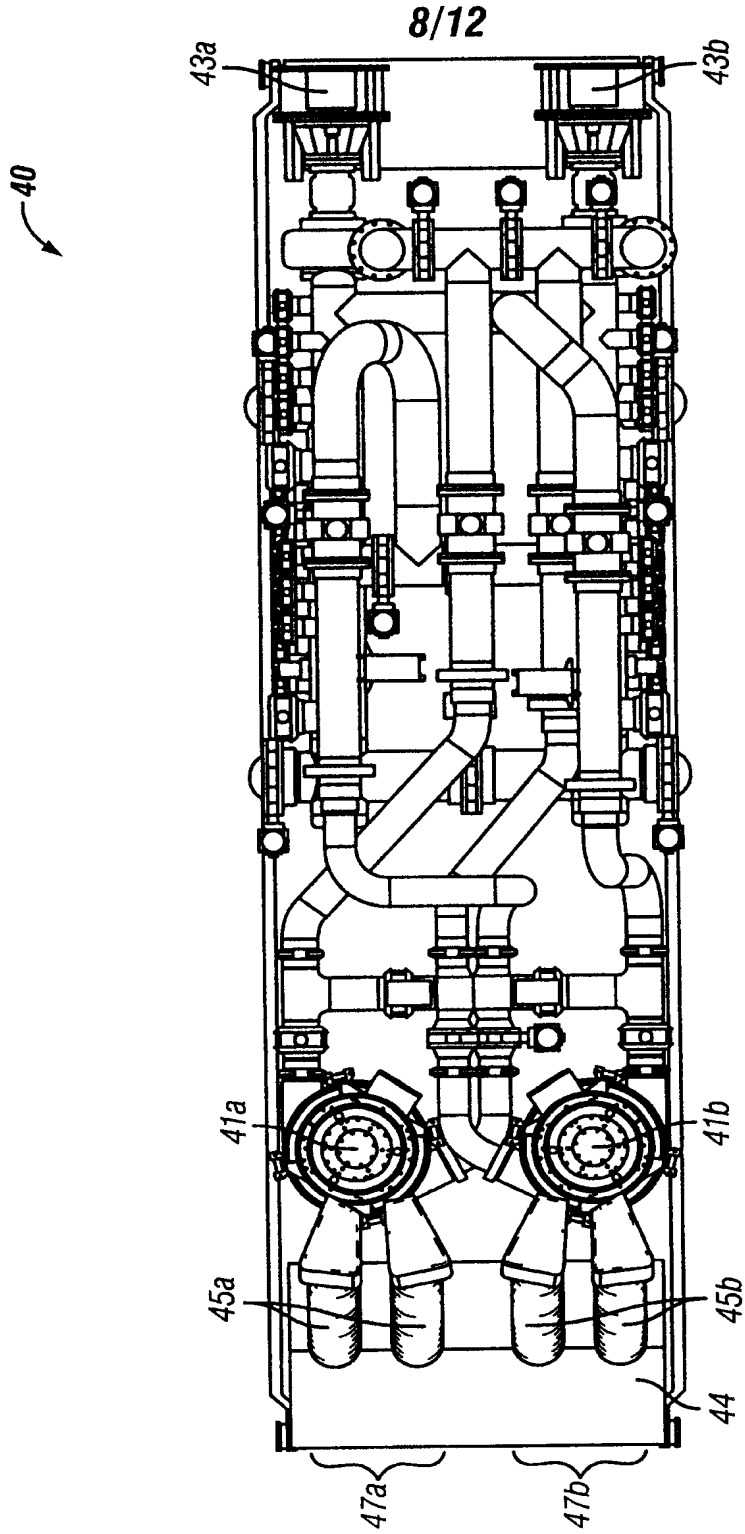


FIG. 5C

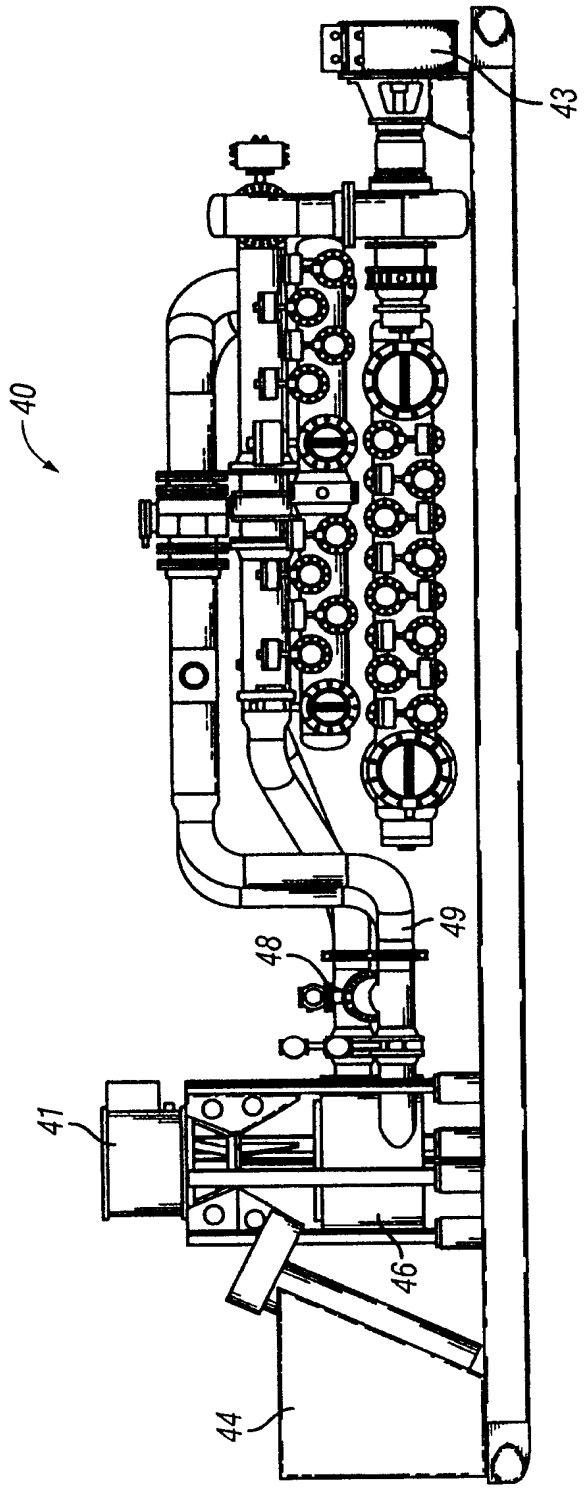


FIG. 5D

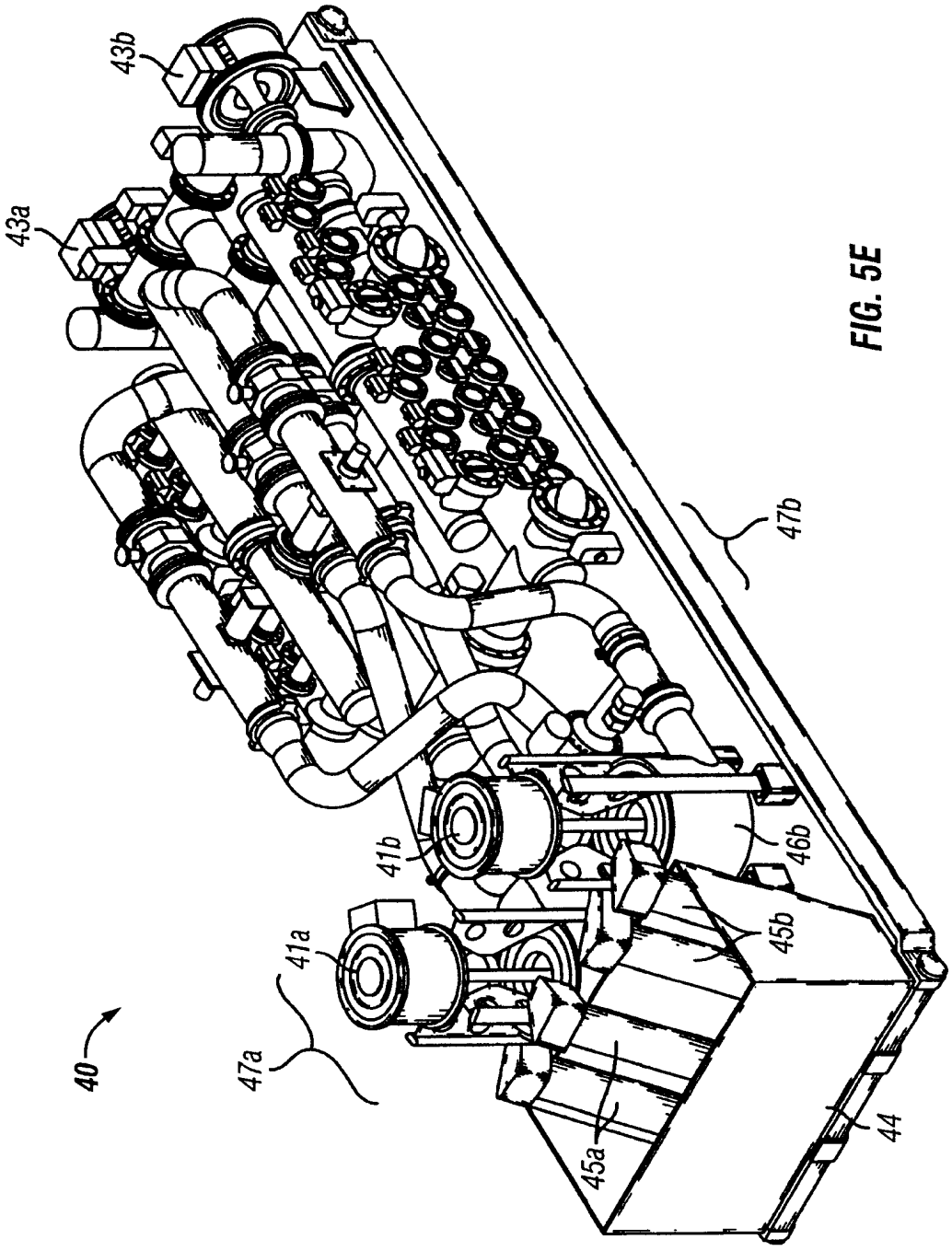


FIG. 5E

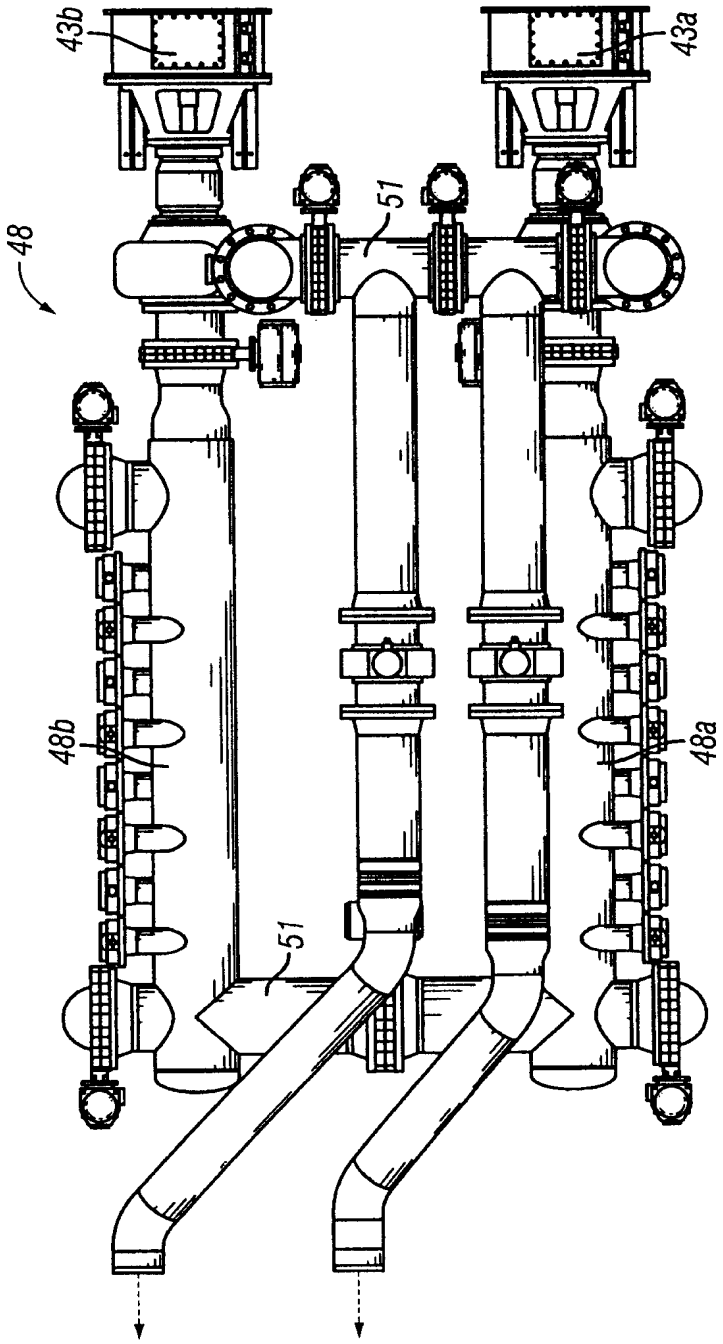


FIG. 6

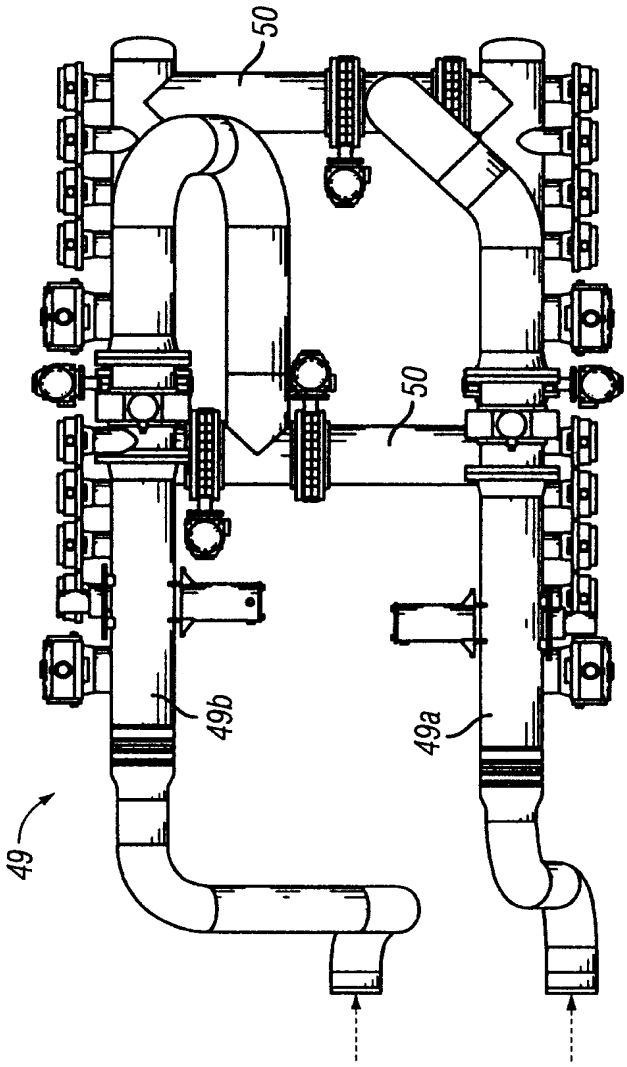
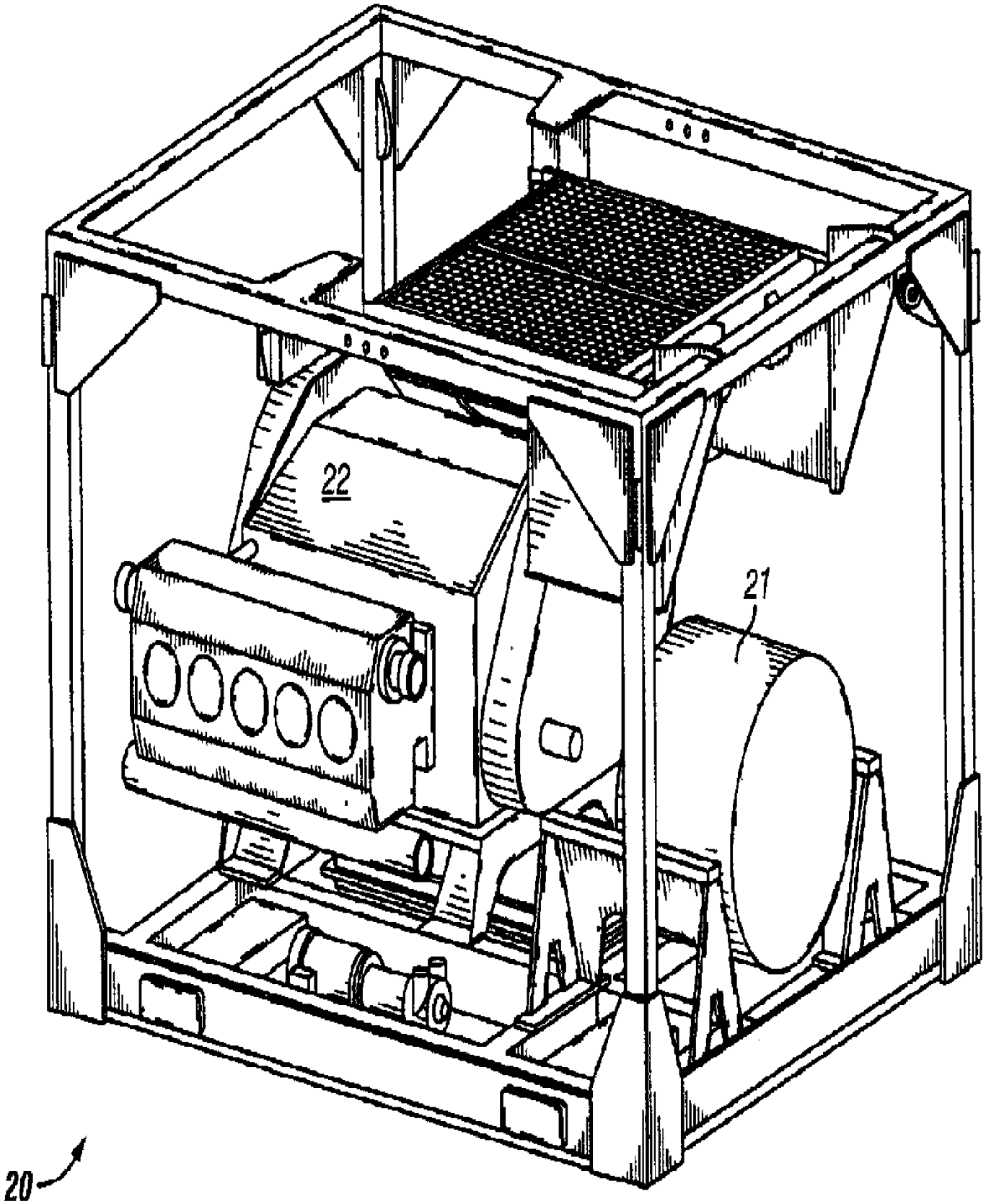


FIG. 7



A

Espacenet

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Singlechip-based induction motor variable frequency speed regulation control system

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Abstract of CN101977016 (A)

The invention discloses a singlechip-based induction motor variable frequency speed regulation control system. The system comprises a main circuit, an auxiliary power circuit, an inverter circuit, a control part, an over-current protection circuit, a rotation speed detection circuit and other peripheral circuits. A 16-bit high-performance signal controller dsPIC30F4011 which is produced by the Microchip Company is used as a control core by the system to perform speed regulation based on vector control motor excitation. A digital signal controller dsPIC30F4011 of the America Microchip Technology Company is used as a chip special for motor control, a digital signal processor (DSP) inner core is embedded, and the chip has quick data processing capacity and is provided with abundant input and output equipment and interface circuits; an intelligent power module (IPM) IRAMSIOUP 60A of the IR Company is an inverter switching device, so that the variable frequency speed regulation control system of an asynchronous motor is constructed; and the system has the characteristics that the system is simple to drive and easy to realize.

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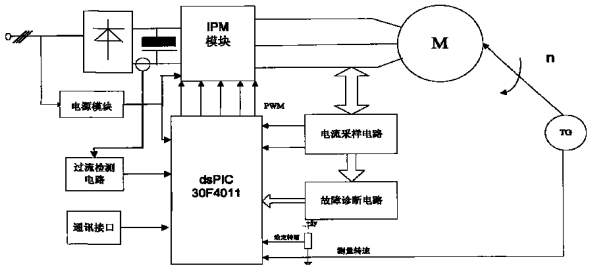
权利要求书 1 页 说明书 8 页 附图 4 页

(54)发明名称

一种基于单片机的感应电机变频调速控制系统

(57)摘要

一种基于单片机的感应电机变频调速控制系统。该系统包括主电路、辅助电源电路、逆变电路、控制部分，过流保护电路、转速检测电路以及其他外围电路。该系统以微芯公司生产的16位高性能信号控制器dsPIC30F4011为控制核心，基于矢量控制电机励磁，进行调速。美国MicrochipTechnology公司的数字信号控制器dsPIC30F4011是电机控制的专用芯片，内嵌DSP内核，具有相当快的数据处理能力和丰富的输入输出设备及接口电路；IR公司的智能功率模块(IPM)IRAMSIOUP60A为逆变开关器件，构建了异步电动机的变频调速控制系统，具有驱动简单、易于实现的特点。



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1. 一种基于单片机的感应电机变频调速控制系统，其特征在于，该系统包括主电路、辅助电源电路、控制部分，电流检测电路、转速检测电路以及其他外围电路，具体组成如下：

主电路：以 220V 交流供电，经过单相桥式不可控整流电路和电容滤波，得到平滑的直流电压供给 IPM 模块和辅助电源电路使用；

IPM 模块：逆变部分变频控制最主要的部分之一，它的主要作用是将直流中间电路输出的直流电压换为所需频率的交流电压，给异步电动机供电；

逆变部分：由六个开关器件组成，与开关器件并联的快速恢复二极管用于处理无功电流，称为续流二极管；逆变部分 IGBT 位于逆变桥上，其输入端与电解电容并联，起到缓冲波动和干扰的作用，考虑到经济性安全系数不必取得太大；

控制部分：以 dsPIC30F4011 芯片为核心，外加相电流检测电路、速度检测电路、串口通讯电路、按键和故障保护电路；逆变电路是由 dsPIC30F4011 输出六路 PWM 脉冲信号用于控制 IPM 模块，得到三相可控交流电供给异步电动机；dsPIC30F4011 芯片内集成了一款专用电机控制模块叫 MCPWM 模块，这一设置大大简化了产生 PWM 波形的控制软件和外部硬件，通过编程可产生独立的、具有相同频率和工作方式的三相 6 路 PWM 波形，并由 RE 口直接输出 6 路 PWM 信号给逆变电路，且三相互补不重叠；

故障保护电路：将故障综合后的故障信号送入控制部分，任何一个故障发生，控制部分便关闭 PWM；

电流检测电路：在直流母线上串一个功率电阻，通过该功率电阻把电流信号转换成电压信号，然后再通过运算放大器对信号进行放大后送入控制部分；在主电路进行电流检测时，一旦检测到主电路的电流过流，应该立即封锁控制信号输出，通知控制部分关闭 PWM 并报警；

转速检测电路：是通过电机自带的测速发电机来实现的。

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一种基于单片机的感应电机变频调速控制系统

【技术领域】：

[0001] 本发明属于电机控制、电力电子和微机原理的交叉技术领域，具体涉及以微芯公司生产的 16 位高性能信号控制器 dsPIC30F4011 为控制核心，设计感应电机的变频调速控制系统。

【背景技术】：

[0002] 近年来随着电力电子技术、数字控制技术、控制理论的发展，特别是一些先进控制技术的发明，交流变频调速的发展也越来越快，使交流调速得到越来越广泛的应用，其调速性能也不断提高，克服了许多直流调速难以克服的缺点。第一代变频器采用的是恒压频比控制方式，它根据异步电动机等效电路确定的线性进行变频调速。电压是指基波的有效值，改变 U/f 只能调节电动机的稳态磁通和转矩，谈不上动态控制。第二代变频器的主要特征是采用矢量控制方式，它参照直流电动机的控制方式，将异步电动机的定子电流空间矢量分解为转子励磁分量和转矩分量。此控制方法的主要缺点是需要复杂的坐标变换运算，以及需检测转速信号。因此，进一步提出无速度传感器矢量控制的方法，它根据异步电动机实际运行的相电压和相电流，以及定转子绕组参数推算出转速观测值，以实现磁场定向的矢量控制。由于转速观测值的精度受到所用计算参数与电动机实际运行参数之间偏差大小的影响，所以无速度传感器矢量控制的调速精度和范围，均低于带速度编码器的矢量控制方案。一般前者的调速精度为 1%，输出额定转矩时的最低频率只能达到 1Hz 左右，而后者调速精度为 0.01%，最低频率为 0.1Hz。与矢量控制并行发展的还有直接转矩控制方式，它以异步电动机的转矩作为被控量，强调转矩的直接控制效果，并不刻意追求输出电流为正弦波形。异步电动机的直接转矩控制是直接在定子坐标上计算磁链的幅值和转矩的大小，对其进行直接跟踪调节，以获得迅速的动态响应，其响应速度可小到 1 ～ 2ms。从转矩调控要求看，磁链有点误差，并不会对转矩控制性能产生重大影响。这种控制方式的优点是对电动机参数变化不敏感。

[0003] 近几年来，不依赖电动机模型的模糊自寻优控制、人工神经网络等智能化控制方法开始引入到交流调速系统中，成为交流调速控制理论、控制技术新的研究发展方向。

[0004] 逆变器从采用晶闸管半控器件到采用 GTR 全控器件，其输出波形从交流方波发展为脉宽调制 (PWM) 波形，大大减小了谐波分量，拓宽了异步电动机变频调速范围，并减小了转矩的脉动幅度。然而，GTR 工作频率一般在 2kHz 以下，载波频率和最小脉宽都受到限制，难以得到较为理想的正弦波脉宽调制波形，使异步电动机在变频调速时产生噪声。IGBT 的工作频率可在 10 ～ 20kHz 之间，与 GTR 相比，不仅工作频率高出一个数量级，而且在电压和电流指标均已超出 GTR。由于逆变器载波频率的提高，以及可以构成特定的 PWM 波形，异步电动机变频调速控制器的谐波噪声大为降低。智能功率模块 (IPM) 是以 IGBT 为开关器件，同时含有驱动电路和保护电路的一种功率集成器件 (PIC)。IPM 的保护功能有过电流、短路、欠电压、过电压和过热等，还可以实现再生制动。由 IPM 组成的逆变器只需对桥臂上各个 IGBT 提供隔离的 PWM 信号即可。简单的外部电路和控制电路的集成化，使变频器体积

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大为减小。还有，由于功率开关器件的故障检测和保护电路接近故障点，故可以抑制故障扩大，保证装置可靠运行。

[0005] 数字化使得控制器对信息的处理能力大幅度提高，许多难以实现的复杂控制，采用微机控制器后便都解决了。高性能的矢量控制系统，如果没有微机的支持是不可能真正实现的。此外，微机控制技术给交流调速系统增加了多方面的功能，特别是故障诊断技术得到了完全的实现。

[0006] 微机控制技术及大规模集成电路的应用提高了交流调速系统的可靠性，操作、设置的多样性和灵活性，降低了变频器调速装置的成本和体积。实践表明，调速控制装置中所采用的微处理器的性能将直接影响到装置性能。

【发明内容】：

[0007] 本发明目的是克服现有调速系统的不足，提供一种基于单片机的感应电机变频调速控制系统。

[0008] 本发明采用高性能微处理器可以简化装置结构、完善装置功能、实现复杂有效的控制策略以及提高控制装置的可靠性。美国 MicrochipTechnology 公司的数字信号控制器 dsPIC30F4011 是电机控制的专用芯片，内嵌 DSP 内核，具有相当快的数据处理能力和丰富的输入输出设备及接口电路，因而本发明选用它作为核心控制器件来构成控制回路。在主回路中，采用 IR 公司的智能功率模块 (IPM) IRAMSIOUP60A[40] 为逆变开关器件，构建了异步电动机的变频调速控制系统。

[0009] 本发明的技术方案 ：

[0010] 本发明提供的基于单片机的感应电机变频调速控制系统是一个典型的交一直一交变压变频结构，整个控制系统以 dsPIC30F4011 芯片为核心，包括主电路、辅助电源电路，控制部分，过电流保护电路，转速检测电路以及其他外围电路，具体组成如下 ：

[0011] 主电路 ：以 220V 交流供电，经过单相桥式不可控整流电路和电容滤波，得到平滑的直流电压供给 IPM 模块和辅助电源电路使用 ；

[0012] IPM 模块 ：逆变电路是变频控制最主要的部分之一，它的主要作用是将直流中间电路输出的直流电压 (电流) 转换为所需频率的交流电压 (电流)，给异步电动机供电。逆变电路由六个开关器件组成，与开关器件并联的快速恢复二极管用于处理无功电流，称为续流二极管。逆变部分 IGBT 位于逆变桥上，其输入端与电解电容并联，起到缓冲波动和干扰的作用，考虑到经济性安全系数不必取得太大。IR 公司生产的智能模块 (IPM) IRAMSIOUP60A[40]，它的耐压值为 600V，额定电流为 10A。它是向第四代器件功率集成电路 (PIC) 的过渡产品，是微电子技术和电力电子技术相结合的产物。IPM 具有以下特点 ：(1) 开关速度快，驱动电流小，控制驱动更为简单 ；(2) 采用了隔离技术，散热更加均匀，体积更加紧凑 ；(3) 集成度高，它在片内集成了驱动电路、保护电路、甚至光耦，大大缩短开发时间 ；(4) 内含电流传感器，可以高效迅速地检测出过电流和短路电流，能对功率芯片给予足够的保护，故障率大大降低 ；(5) 保护功能丰富，如电流保护、电压保护、温度保护等一应俱全，实现了信号处理、故障诊断、自我保护等多种智能功能，既减小了体积、减轻了重量，又提高了可靠性 ；(6) 由于在器件内部电源电路和驱动电路的配线设计上做到优化，所以浪涌电压，门极振荡，噪声引起的干扰等问题能得到有效的控制 ；(7) 很高的性价比，IPM 的售价已

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经逐渐接近 IGBT，而采用 IPM 后的开关电源容量、驱动功率容量的减小和器件的节省以及综合性能的提高等因素使得 IPM 构成的变频器性价比已经高于 IGBT 构成的变频器，有很好的经济性。

[0013] 控制部分：以 dsPIC30F4011 芯片为核心，外加相电流检测电路、速度检测电路、串口通讯电路、按键和故障保护电路；由 dsPIC30F4011 芯片输出六路 PWM 脉冲信号用于控制 IPM 模块逆变部分，得到三相可控交流电供给异步电动机；

[0014] dsPIC30F4011 芯片内集成了一款专用电机控制模块叫 MCPWM 模块，这一设置大大简化了产生 PWM 波形的控制软件和外部硬件，通过编程可产生独立的、具有相同频率和工作方式的三相 6 路 PWM 波形，并由 RE 口直接输出 6 路 PWM 信号给逆变器，且三相互补不重叠。我们只需定义各个寄存器值便可以产生理想的 PWM 信号，同时为防止同一桥臂上两个功率管发生直通造成短路，该发生器还可通过编程设置死区互锁时间。

[0015] 故障保护电路：将故障综合后的故障信号送入控制部分，任何一个故障发生，控制部分便关闭 PWM 脉冲信号。

[0016] 电流检测电路：在直流母线上串一个很小的功率电阻，通过该功率电阻把电流信号转换成电压信号，然后再通过运算放大器对信号进行放大后送入控制部分；过流是引起功率驱动器被烧坏和损坏的主要原因之一。在主电路进行电流检测时，一旦检测到主电路的电流过流，应该立即封锁控制信号输出，通知控制部分关闭 PWM 并报警。

[0017] 转速检测电路：是电机自带的测速发电机来实现的。

[0018] 整流电路一般分为可控整流和不控整流，其中可控整流又分为全控整流和半控整流。在全控整流电路中，整流器件全部有晶闸管或其他可控器件组成，半控整流电路则由二极管和晶闸管混合组成；不可控整流电路全部由整流二极管组成。本发明的整流部分全部应用整流二极管进行单相不可控桥式整流，这样可有效抑制可控整流中因相控角的变化而引起的谐波，同时也能提高调速装置的功率因数。

[0019] 装置中 dsPIC30F4011 芯片需要 +5V 供电电源，而智能模块 IPM 需要 +15V 电源，所以设计辅助电源来满足此要求，选用了 ST 公司生产的 VIPER12A 芯片，它可以把约 300V 的直流电转换为 +15V 直流电，然后再用 LM7805 把 +15V 转换为 +5V 电源，以提供给各个芯片。

[0020] 本发明的优点和积极效果：

[0021] 本发明以微芯公司生产的 16 位高性能信号控制器 dsPIC30F4011 为控制核心，基于矢量控制电机励磁，进行调速。

[0022] 采用美国 MicrochipTechnology 公司的数字信号控制器 dsPIC30F4011 是电机控制的专用芯片，内嵌 DSP 内核，具有相当快的数据处理能力和丰富的输入输出设备及接口电路。所说的 DsPIC30F4011 内集成了一款专用电机控制模块叫 MCPWM 模块，这一设置大大简化了产生 PWM 波形的控制软件和外部硬件，通过编程可产生独立的、具有相同频率和工作方式的三相 6 路 PWM 波形，并由 RE 口直接输出 6 路 PWM 信号给逆变器，且三相互补不重叠。只需定义各个寄存器值便可以产生理想的 PWM 信号，同时为防止同一桥臂上两个功率管发生直通造成短路，该发生器还可通过编程设置死区互锁时间。

[0023] 采用 IR 公司的智能功率模块 (IPM) IRAMSIOUP60A 为逆变开关器件，构建了异步电动机的变频调速控制器，具有以下特点：(1) 开关速度快，驱动电流小，控制驱动更为简单；(2) 采用了隔离技术，散热更加均匀，体积更加紧凑；(3) 集成度高，它在片内集成了驱动电

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路、保护电路、甚至光耦，大大缩短开发时间；(4) 内含电流传感器，可以高效迅速地检测出过电流和短路电流，能对功率芯片给予足够的保护，故障率大大降低；(5) 保护功能丰富，如电流保护、电压保护、温度保护等一应俱全，实现了信号处理、故障诊断、自我保护等多种智能功能，既减小了体积、减轻了重量，又提高了可靠性；(6) 由于在器件内部电源电路和驱动电路的配线设计上做到优化，所以浪涌电压，门极振荡，噪声引起的干扰等问题能得到有效的控制；(7) 很高的性价比，IPM 的售价已经逐渐接近 IGBT，而采用 IPM 后的开关电源容量、驱动功率容量的减小和器件的节省以及综合性能的提高等因素使得 IPM 构成的变频器性价比已经高于 IGBT 构成的变频器，有很好的经济性。

【附图说明】：

[0024] 图 1 为控制系统总体结构；

[0025] 图 2 为 dsPIS30F4011 结构框图；

[0026] 图 3 为逆变电路 IPM 内部结构和外部连接图；

[0027] 图 4 为转速检测硬件电路图。

[0028] 图 5 为整流电路结构图；

[0029] 图 6 为用 VIPER12A 组建的整个辅助电源电路；

[0030] 图 7 为电流采样电路；

[0031] 图 8 为电流检测电路。

【具体实施方式】：

[0032] 实施例 1：

[0033] 下面结合附图对本设计做进一步描述：控制系统总体结构如图 1 所示，主电路以 220V 交流供电，经过单相桥式不可控整流、电容滤波，得到平滑的直流电压供给 IPM 模块和辅助电源电路使用。

[0034] 逆变电路部分，是由 dsPIC30F4011 输出六路 PWM 脉冲信号控制 IPM 模块，得到三相可控交流电供给异步电动机。

[0035] 控制部分，是以 dsPIC30F4011 芯片为核心，外加相电流检测电路、速度检测电路、串口通讯电路、按键和故障保护电路。

[0036] 故障保护电路将故障综合后的故障信号送入控制部分，任何一个故障发生，便关闭 PWM。

[0037] 过电流检测电路是通过电阻把电流信号转换成电压信号，然后再通过运算放大器对信号进行放大后送入控制芯片。

[0038] 转速检测电路是通过电机自带的测速发电机来实现的。

[0039] 如图 2 为 dsPIC30F4011 结构框图。dsPIC30F 系列 CPU 模块采用 16 位改进型哈佛结构，并带有增强型指令集，包含对 DSP 的有力支持。CPU 指令宽度 24 位，PC 宽度为 23 位，可寻址高达 24X4M 位程序空间。共有 16 个 16 位工作寄存器，每个寄存器都可作为数据、地址或地址偏移寄存器。该系列数字信号控制器具有丰富的指令集，包括多种寻方式，且大多为单周期指令，大大加快了单片机的运行速度。指令主要分为 MCU 类型和 DSP 类型两大类，这两类指令可以有机地集合到构架中，并在同一个执行单元中执行。它还支持 C 语言编译

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器编程，易于开发。dsPIC30F 系列 CPU 内部自带存储容量大，RAM 最高可达 64KB。数据空间可作为 32K 字或 64K 字节寻址，并分为两块：X 和 Y 数据存储器。每个存储器块有各自的地址发生单元 (AGU)。MCU 类指令只能通过 X 存储器 AGU 进行操作，可将整个存储器空间作为一个线性空间访问。某些带双操作数的 DSP 类型指令通过 X 和 Y 的 AGU 读两个操作数。另外，可将数据存储器空间的高 32KB 映射到 8 位程序空间可视性页面 (PSVPAG)。DsPIC30F4011 内集成了一款专用电机控制模块 - 电机控制脉宽调制 (CPwM) 模块，这一设置大大简化了产生 PWM 波形的控制软件和外部硬件，通过编程可产生独立的、具有相同频率和工作方式的三相 6 路 PWM 波形，并由 RE 口直接输出 6 路 PWM 信号给逆变器，且三相互补不重叠。我们只需定义各个寄存器值便可以产生理想的 PWM 信号，同时为防止同一桥臂上两个功率管发生直通造成短路，该发生器还可通过编程设置死区互锁时间。

[0040] 如图 3 所示：逆变电路是变频控制最主要的部分之一，主要作用是将直流中间电路输出的直流电压（电流）转换为所需频率的交流电压（电流），给异步电动机供电。逆变部分由六个开关器件组成，与开关器件并联的快速恢复二极管用于处理无功电流，称为续流二极管。逆变部分 IGBT 的电压选择与整流二极管最大的不同是，整流二极管的输入直接与电网相连，电网易受到外界的干扰，因此选择的安全系数口较大；而 IGBT 位于逆变桥上，其输入端与电解电容并联，起到缓冲波动和干扰的作用，考虑到经济性安全系数不必取得太大，IGBT 的额定电压 U 可以按式 (3) 来选择：

[0041] $U \geqslant (U_{DC} \times 1.15+150) \times a$

[0042] 式中 U_{DC} 是直流侧电压；1.15 是过电压系数；150 是由 $L\frac{di}{dt}$ 引起允许的尖峰电压；a 是安全系数，一般取 1.1。对单相交流 220V 输入电压，U_{DC} = 311V，这样得 IGBT 的额定电压 U ≥ 558V。额定电流值 I_C，可按式 (4) 选择：

[0043] $$I_C = \frac{\sqrt{2} \times 1.5 \times 1.4}{0.9} \times I_N \qquad (4)$$

[0044] 其中，0.9 为电网电压向下的波动系数；1.5 为过载 50％允许运行 1 分钟的系数，1.4 为温度的影响系数。由电机铭牌得到 I = 2.5A，选用 IR 公司生产的智能模块 (IPM) IRAMSIOUP60A[40]，它的耐压值为 600V，额定电流为 IOA。它是向第四代器件功率集成电路 (PIC) 的过渡产品，是微电子技术和电力电子技术相结合的产物。它不但提供一定的功率输出能力，而且具有逻辑、控制、传感、检测、保护和自诊断等功能。

[0045] 图 3 为逆变电路 IPM 模块的内部结构和外部连接图，单电源 +15V 驱动，dsPIC30F4011 发出的 PWM 脉冲控制六个 IGBTN 极的开通和关断。P+ 为整流后的直流输入，N- 为接地端。VDD 为芯片的工作电压。输入的方波信号经驱动 IC 来控制逆变桥 IGBT 的通断。当 T/Itrip 输入高电平时内部驱动就会停止工作，从而达到保护芯片的作用。选用的 IR 公司生产的智能模块 (IPM) IRAMSIOUP60A[40]，它的耐压值为 600V，额定电流为 IOA。它是向第四代器件功率集成电路 (PIC) 的过渡产品，是微电子技术和电力电子技术相结合的产物。它不但提供一定的功率输出能力，而且具有逻辑、控制、传感、检测、保护和自诊断等功能。IPM 具有以下特点：

[0046] (1) 开关速度快，驱动电流小，控制驱动更为简单；

[0047] (2) 采用了隔离技术，散热更加均匀，体积更加紧凑；

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[0048] (3) 集成度高，它在片内集成了驱动电路、保护电路、甚至光耦，大大缩短开发时间；

[0049] (4) 内含电流传感器，可以高效迅速地检测出过电流和短路电流，能对功率芯片给予足够的保护，故障率大大降低；

[0050] (5) 保护功能丰富，如电流保护、电压保护、温度保护等一应俱全，实现了信号处理、故障诊断、自我保护等多种智能功能，既减小了体积、减轻了重量，又提高了可靠性；

[0051] (6) 由于在器件内部电源电路和驱动电路的配线设计上做到优化，所以浪涌电压，门极振荡，噪声引起的干扰等问题能得到有效的控制；

[0052] (7) 很高的性价比，IPM 的售价已经逐渐接近 IGBT，而采用 IPM 后的开关电源容量、驱动功率容量的减小和器件的节省以及综合性能的提高等因素使得 IPM 构成的变频器性价比已经高于 IGBT 构成的变频器，有很好的经济性。IRAMS10UP60A 使用参数见表：

[0053]

参数	描述	最大值	单位
Vbus	最大直流母线电压	450	V
Vces	最大 IGBT 导通电压	600	V
Io@Tc = 25℃	相电流均方值	10	A
Io@Tc = 100	相电流均方值	4.5	A
Ipk	最大相电流峰值	15	A
Fp	最大 PWM 载波频率	20	KHz
Pd	每相最大功耗	10	W
Rthj-c	每个 IGBT 热阻	4.5	℃ /W
Viso	绝缘电压	2000	Vrms
Tc	工作壳温	-20-+100	℃
Tj	工作壳温	-20-+150	℃
T	安装扭矩范围	0.8-1.0	Nm

[0054] 图 4 所示：转速检测硬件电路。电机自身带有测速发电机，电机每转一圈，都会送出 8 个触发脉冲，测速发电机输出八个脉，通过计算脉冲的时间便可以得到转速。电机每转一圈，这个电路可以输出的脉冲进行整形，输出标准方波。再送入芯片中测出其速度。通过上拉电阻把其电压值进行提升，然后通过两级低通滤波器滤除高频干扰，在这里选用 RC 低通滤波器。此处采用了 LM393 等组成的滞回比较器把正弦波转换为方波，由于它是 OC 门输

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出，所以需要对其进行上拉，此信号便可以送入芯片端口了。

[0055] 如图 5 所示：本设计中的整流部分全部应用整流二极管进行单相不可控桥式整流，这样可有效抑制可控整流中因相控角的变化而引起的谐波，同时也能提高调速系统的功率因数。其为单相不可控桥式电路，其中整流二极管的选择是比较关键的问题，耐压按式 (1) 选择：

[0056] $$U_{RPM}=U_{AC}\times\sqrt{2}\times1.1a \quad (1)$$

[0057] 其中 U_{AC} 为电网电压，考虑到其峰值的波动、闪电雷击等因素，取波动系数为 1.1，安全系数 a = 2，在交流电网电压为 220V 时，U_{RPM} = 684V，所以取二极管的耐压等级为 800V。整流二极管的额定电流按式 (2) 确定：

[0058] $$I \geq 2\sqrt{2}I_N \quad (2)$$

[0059] 式中 I_N 为电机的额定电流值。由电机铭牌得到 I_N = 2A，I = 2.5A. 而整流模块 KBJ1508 的电压电流限度为 800V，15A，根据以上的计算选用整流模块 KBJ1508。

[0060] 滤波电路由一个滤波电容构成，这个电容容量足够大，从逆变器向整流电路全波整流后的直流电源看过去电源内阻很小，近似恒压源，保证直流电压稳定。当系统接入 220 交流电，整流后电压的峰值为 311V，考虑电网电压的波动范围 ±10％，电容的耐压应大于 $1.1\sqrt{2}U=342V$，电容应满足 RC = (3-5)T/2 的条件，C = 285-476Uf。故我们选择 470uF/450V 的滤波电容。

[0061] 如图 6 所示：系统中 dsPIC30F4011 需要 +5V 供电电源，而智能模块 IPM 需要 +15V 电源，所以我们设计辅助电源来满足此要求。这里选用了 ST 公司生产的 VIPER12A 芯片，它可以把约 300V 的直流电转换为 +15V 直流电，然后再用 LM7805 把 +15V 转换为 +5V 电源，以提供给各个芯片。用 VIPER12A 构成的整个辅助电源电路，此电路中稳压元件采用 LM7805，D9 采用 IN4148，D6、D7 采用 STTH1L06U，以满足高频低耗的需要，L1 为高频滤波电感，在这里选用 1.8mH/500mA 电感。D9、C43 为缓冲回路，C47 用来对 15V 直流电滤波，正常工作后芯片由自激绕组供电。电路的工作过程是输入的直流电压使芯片启动，功率 MOSFET 工作，直流电经功率 MOSFE 进入 S，给电感 L1 充电，稳压管两端的电压经 D6，D8 反馈至 FB，当稳压管两端电压大于 0.23V 时就会触发过流比较器，关断功率 MOSFET。然后 VIPER12A 就会被再启动再关断，如此就把整流后的直流电转换成不同脉冲宽度的矩形波，经电感电容滤波后输出稳定的 15V 直流电压。15V 再经过 LM7805 得到 5V 电压，C48 是对 5V 电压进行滤波，并且通过点亮指示灯来显示是否辅助电源工作正常。

[0062] 如图 7 所示为电流采样电路。在 U、V、W 的接地端接高精度小阻值电阻，把电流信号转换成电压信号，然后电压信号经过运算放大器 LM258 后得到放大，送入 CPU 进行处理。通过实验和计算，可以得到各参数如下：R_o 为 10KΩ，R_2 为 100KΩ，R_3 为 20KΩ，则放大倍数为 $(R_2+R_3)/R_3$ = 6。

[0063] 如图 8 所示为电流检测电路。电流的过流检测是在直流母线上串一个很小的功率电阻，把电流信号转换成电压信号送给电压比较器，电压比较器平时输出高电平 FLTA，比较器输出的是低电平，三极管 3904 不会动作。当过流发生时，比较器输出高电平，T/ITRIP 就会得到高电压，会使逆变器驱动芯片停止工作，同时使三极管导通，输出低电平给芯片故障

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引脚信号，CPU 产生过流保护。相电流 I_S 通过电阻 R_1 转换成电压信号，这个电阻精度必须比较高，在这里采用精度为 0.5%，阻值为 0.06Ω 的检测电阻，电容 C_1 选用 0.1uF(104) 对其进行滤波。R_2 和 R_3 通过对 5V 进行分压，提供过流阀值，经过实验分析选用 R_2 为 10KΩ，R_3 为 2KQ，当检测的电压大于 0.18V 时，即电流超过 3A 时认为过流，比较器 LM393 会输出一个低电平，芯片检测到此信号触发故障中断子程序，关闭 PWM 输出，同时 PWM 驱动电路也会关闭。电流不超过 3A 则正常运行。

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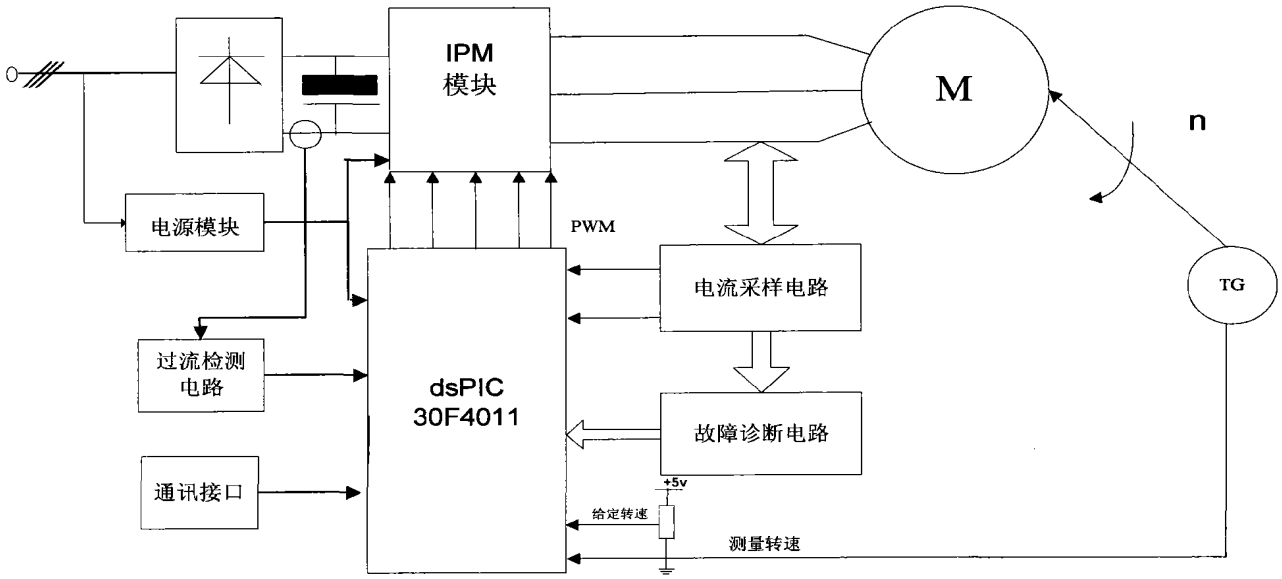


图 1

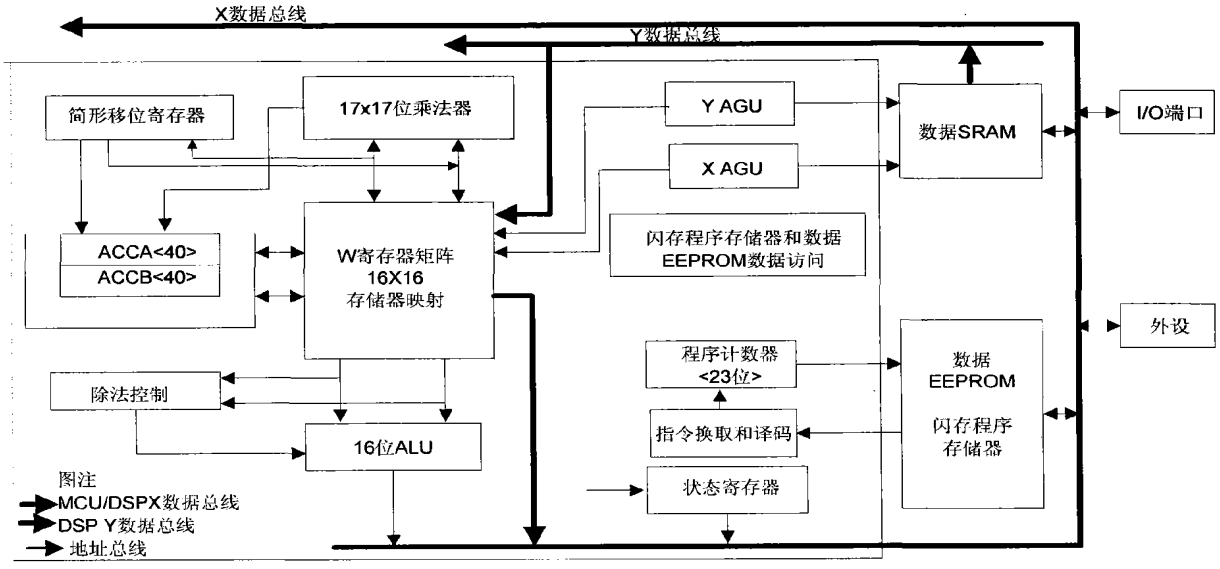


图 2

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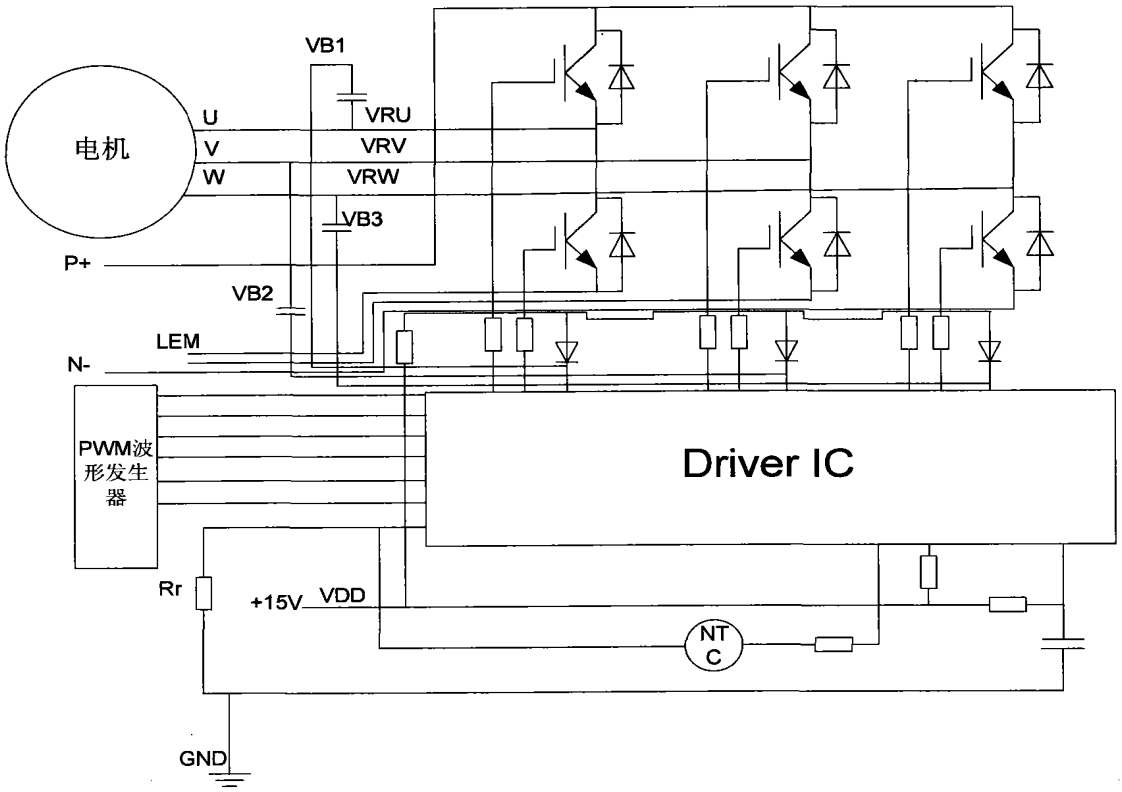


图 3

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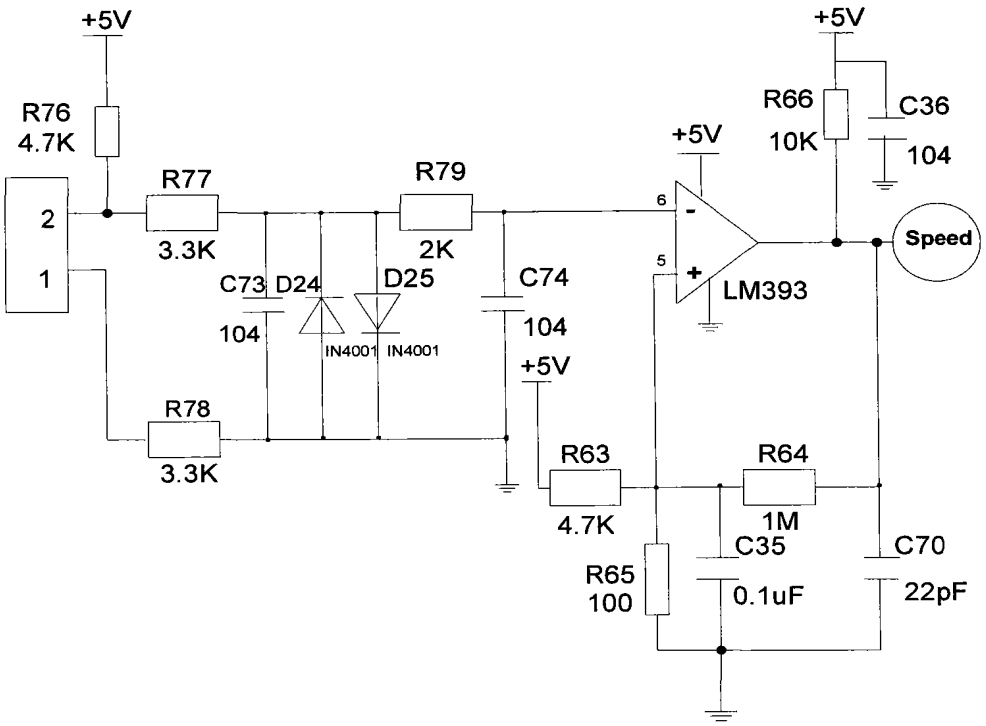


图 4

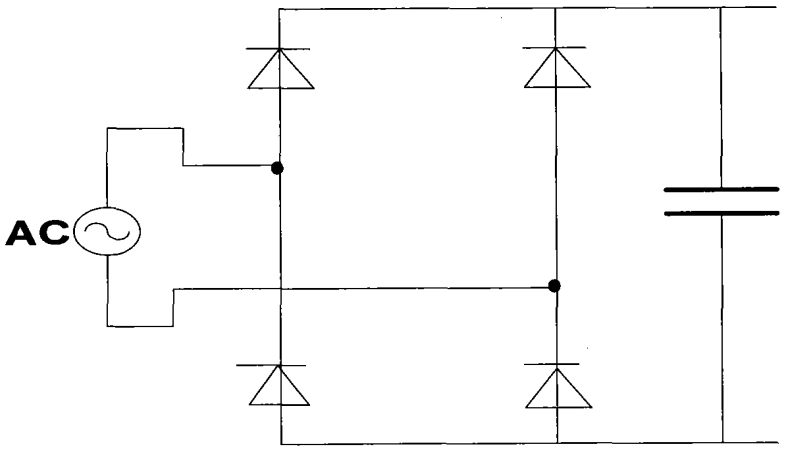


图 5

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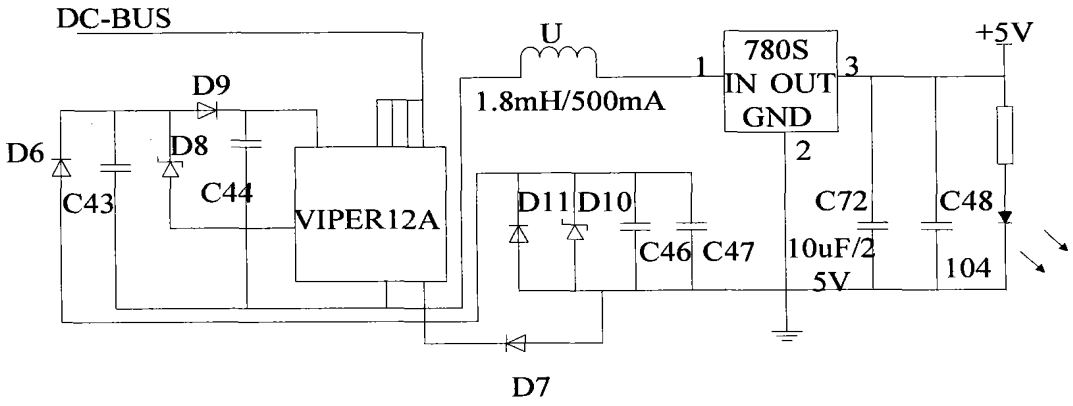


图 6

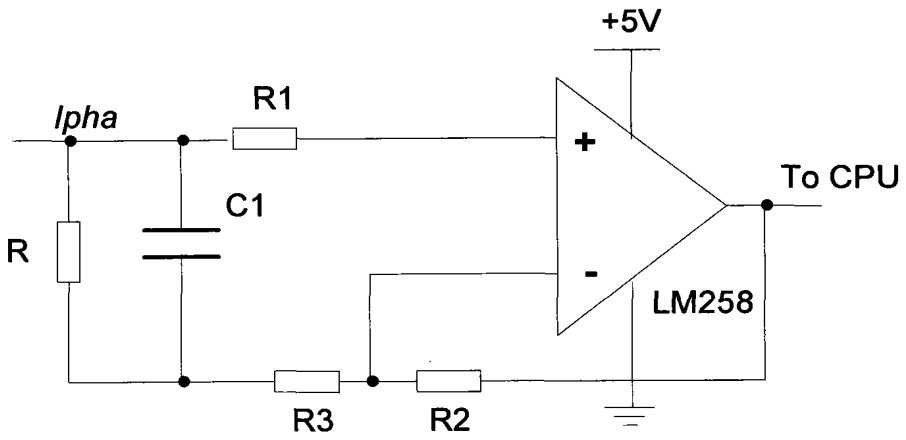


图 7

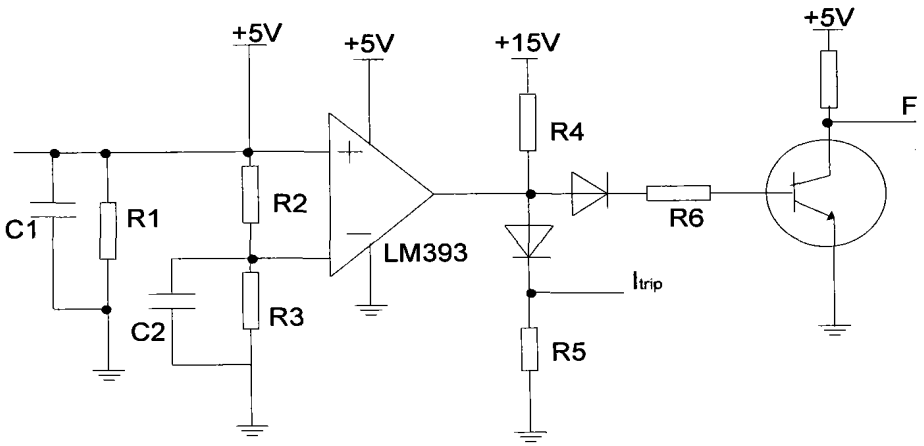


图 8

LIBERTY EXHIBIT 1002, Page 1756

DERWENT-ACC-NO: 2004-659178

DERWENT-WEEK: 200554

Copyright ©2015 Thomson Reuters

TITLE: Noise reducing wall member for e.g. engine or electrical machinery enclosure, has each of sound absorption and sound insulation walls comprising of alternating thin and thick part

INVENTOR: MORIKAWA Y

PATENT-ASSIGNEE: TOSHIBA KK[TOKE]

PRIORITY-DATA: 2003JP-054684 (February 28, 2003)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE
JP 2004264589 A	September 24, 2004	JA
JP 3680061 B2	August 10, 2005	JA

APPLICATION-DATA:

PUB-NO	APPL-DESCRIPTOR	APPL-NO	APPL-DATE
JP2004264589A	N/A	2003JP-054684	February 28, 2003
JP 3680061B2	Previous Publ	2003JP-054684	February 28, 2003

INT-CL-CURRENT:

TYPE	IPC DATE	
CIPP	E01 F 8/00	20060101
CIPS	E04 B 1/86	20060101
CIPS	G10 K 11/16	20060101
CIPS	G10 K 11/172	20060101

ABSTRACTED-PUB-NO: JP 2004264589 A

BASIC-ABSTRACT:

NOVELTY - Each of sound absorption and sound insulation walls (20,30) comprises of alternating thin parts (21,31) and thick parts (22,32). Particle velocity of the sound passing the thick part of the sound absorption wall (20) is greater than a reference velocity. The pressure level of the sound passing the thick part of the sound insulation wall (30) is greater than a sound pressure reference value.

USE - For e.g. engine or electrical machinery enclosure.

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ADVANTAGE - Optimizes thickness of structural member according to mode of sound to be reduced. Achieves weight reduction.

DESCRIPTION OF DRAWING(S) - Figure is a perspective view of a noise reducing wall member.

Sound absorption wall (20)

Thin parts (21,31)

Thick parts (22,32)

Sound insulation wall (30)

CHOSEN-DRAWING: Dwg.1/4

TITLE-TERMS: NOISE REDUCE WALL MEMBER ENGINE ELECTRIC MACHINE ENCLOSE SOUND ABSORB INSULATE COMPRISE ALTERNATE THIN THICK PART

DERWENT-CLASS: P86 Q41 Q43

SECONDARY-ACC-NO:

Non-CPI Secondary Accession Numbers: 2004-522009

LIBERTY EXHIBIT 1002, Page 1758

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2004-264589
(P2004-264589A)
(43)公開日　平成16年9月24日(2004.9.24)

(51) Int.Cl.[7]		F I			テーマコード（参考）
G10K	11/172	G10K	11/16	E	2D001
E01F	8/00	E01F	8/00		2E001
E04B	1/86	E04B	1/86	N	5D061

審査請求 有　請求項の数 1　OL　（全 6 頁）

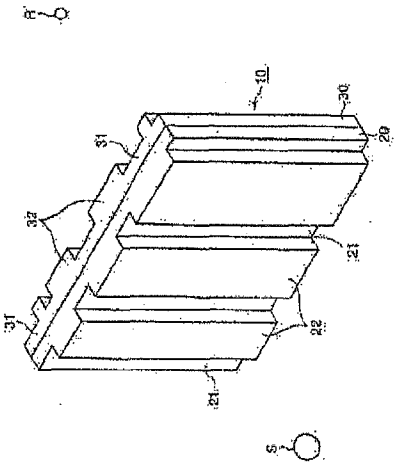
(21) 出願番号　特願2003-54684 (P2003-54684)
(22) 出願日　平成15年2月28日 (2003.2.28)

(71) 出願人　000003078
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(74) 代理人　100088683
弁理士　中村　誠
(74) 代理人　100108855
弁理士　蔵田　昌俊
(74) 代理人　100084618
弁理士　村松　貞男
(74) 代理人　100092196
弁理士　橋本　良郎

最終頁に続く

(54)【発明の名称】壁部材

(57)【要約】
【課題】構造部材の厚さを低減対象音の音響モードにしたがって最適化することで、容積を最小とし軽量とすることが可能な壁部材を提供すること。
【解決手段】積層して配置された吸音壁２０と遮音壁３０とを備え、吸音壁２０は、薄肉部２１と厚肉部２２とを備え、遮音壁３０は、薄肉部３１と厚肉部３２とを備え、低減対象音の音響モードに基づいて、粒子速度が速度基準値よりも大きい部分に対応して厚肉部２２を配置するとともに、音圧レベルが音圧基準値よりも大きい部分に対応して厚肉部３２を配置する。
【選択図】　図１



LIBERTY EXHIBIT 1002, Page 1759

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 047158.500026	Date of mailing *(day/month/year)* 19 SEP 2018 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2018/040683	International filing date *(day/month/year)* 03 July 2018
Applicant U.S. WELL SERVICES, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   - ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Within 22 months from the priority date, the applicant may request that a supplementary international search be carried out by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver Telephone No. PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2017)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 047158.500026	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2018/040683	International filing date *(day/month/year)* 03 July 2018	(Earliest) Priority Date *(day/month/year)* 07 July 2017
Applicant U.S. WELL SERVICES, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the language, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I.

2. ☒ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the title,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the drawings,

   a. the figure of the drawings to be published with the abstract is Figure No. 1

   ☐ as suggested by the applicant.

   ☒ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

LIBERTY EXHIBIT 1002, Page 1761

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/040683

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 5-9, 13, 14
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/040683

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 43/26; E21B 41/00; E21B 43/16; F01D 15/10; F02C 7/32 (2018.01)

CPC - E21B 43/26; E21B 41/00; E21B 41/0085; E21B 43/16; F01D 15/10; F02C 7/32; F05D 2220/76 (2018.08)

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)

See Search History document

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

USPC - 166/66.4; 166/177.5; 166/308.1 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/0348479 A1 (US WELL SERVICES LLC) 01 December 2016 (01.12.2016) entire document	1-4, 10-12, 15
A	US 2017/0104389 A1 (EVOLUTION WELL SERVICES, LLC) 13 April 2017 (13.04.2017) entire document	1-4, 10-12, 15
A	US 2015/0252661 A1 (GLASS) 10 September 2015 (10.09.2015) entire document	1-4, 10-12, 15
A	US 2016/0186531 A1 (HARKLESS et al) 30 June 2016 (30.06.2016) entire document	1-4, 10-12, 15

☐ 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
22 August 2018	19 SEP 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)* 19 SEP 2018

Applicant's or agent's file reference
047158.500026

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2018/040683	03 July 2018	07 July 2017

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 43/26; E21B 41/00; E21B 43/16; F01D 15/10; F02C 7/32 (2018.01)
CPC - E21B 43/26; E21B 41/00; E21B 41/0085; E21B 43/16; F01D 15/10; F02C 7/32; F05D 2220/76 (2018.08)

Applicant U.S. WELL SERVICES, LLC

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☒ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	22 August 2018	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/040683

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/040683

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application.

☒ claims Nos. 5-9, 13, 14

because:

☐ the said international application, or the said claims Nos. _____ relate to the following subject matter which does not require an international search *(specify)*:

☒ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. 5-9, 13, 14 are so unclear that no meaningful opinion could be formed *(specify)*:

Claims 5-9, 13, 14 are improper multiple dependent claims not drafted in accordance with the second and third sentences of Rule 6.4(a).

☐ the claims, or said claims Nos. _____ are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no international search report has been established for said claims Nos. 5-9, 13, 14

☐ a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

- ☐ furnish a sequence listing in the form of an Annex C/ST.25 text file, and such listing was not available to the International Searching Authority in the form and manner acceptable to it; or the sequence listing furnished did not comply with the standard provided for in Annex C of the Administrative Instructions.
- ☐ furnish a sequence listing on paper or in the form of an image file complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in the form and manner acceptable to it; or the sequence listing furnished did not comply with the standard provided for in Annex C of the Administrative Instructions.
- ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13*ter*.1(a) or (b).

☐ See Supplemental Box for further details.

LIBERTY EXHIBIT 1002, Page 1766

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/040663

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	None	YES
	Claims	1-4, 10-12, 15	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-4, 10-12, 15	NO
Industrial applicability (IA)	Claims	1-4, 10-12, 15	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-4, 10-12, and 15 lack novelty under PCT Article 33(2) as being anticipated by US Well Services LLC (hereinafter US Well).

Regarding Claim 1, US Well discloses a hydraulic fracturing system for fracturing a subterranean formation (wireline power supply during electric powered fracturing operations; title) characterized by: an electric pump fluidly connected to a well associated with the subterranean formation, and configured to pump fluid into a wellbore associated with the well at a high pressure so that the fluid passes from the wellbore into the subterranean formation and fractures the subterranean formation (Paragraph [0051] describes electric powered fracking pumps.); one or more ancillary units associated with the fluid pumped into the wellbore (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125.); a first motor electrically coupled to the electric pump to operate the electric pump (Paragraph [0051] describes fracking pumps being powered by electric motors.); and one or more second motors, each of the one or more second motors electrically coupled to at least one of the one or more ancillary units to operate the at least one of the one or more ancillary units (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125 all being powered by electricity, presumably electric motors.).

Regarding Claim 2, US Well discloses the system of claim 1, further characterized by: an electric generator (Paragraph [0036] describes an electric power generator.), wherein the first motor is electrically coupled to the electric pump via the electric generator to generate electricity for use by the electric pump (Paragraph [0035] describes a generator providing power to electric fracking pumps.).

Regarding Claim 3, US Well discloses the system of claim 1 or 2, wherein the one or more second motor comprises an electric motor (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125 all being powered by electricity, presumably electric motors.).

Regarding Claim 4, US Well discloses the system of claim 3, wherein the electric motor is selected from the group consisting of any of a single-phase AC motor, a three-phase motor (Paragraph [0045] describes the use of three phase electrical power on the wireline equipment.), and a DC motor.

Regarding Claim 10, US Well discloses a hydraulic fracturing system for fracturing a subterranean formation (wireline power supply during electric powered fracturing operations; title) characterized by: an electric pump fluidly connected to a well associated with the subterranean formation, and configured to pump fluid into a wellbore associated with the well at a high pressure so that the fluid passes from the wellbore into the subterranean formation and fractures the subterranean formation (Paragraph [0051] describes electric powered fracking pumps.); one or more ancillary units associated with the fluid pumped into the wellbore (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125.); a first motor electrically coupled to the electric pump to operate the electric pump (Paragraph [0051] describes fracking pumps being powered by electric motors.); one or more second motors, the one or more second motors characterized by an electric motor (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125 all being powered by electricity, presumably electric motors.), and each of the one or more second motors electrically coupled to at least one of the one or more ancillary units to operate the at least one of the one or more ancillary units; and a plurality of variable-frequency drives (VFD), each VFD connected to at least one of the first motor or the one or more second motors to control the speed of the first motor or the one or more second motors (Paragraph [0048] describes blender discharge motor connected to a VFD and paragraph [0049] describes fracking pumps being connected to a VFD.).

Regarding Claim 11, US Well discloses the system of claim 10, wherein the electric motor is selected from the group consisting of any of a single-phase AC motor, a three-phase motor (Paragraph [0045] describes the use of three phase electrical power on the wireline equipment.), and a DC motor.

Regarding Claim 12, US Well discloses the system of claim 10 or 11, wherein each VFD frequently performs electric motor diagnostics to prevent damage to the first motor or the one or more second motors (Claim 2 describes the VFD frequently performing electric motor diagnostics to prevent damage to at least one electrical motor.).

International application No.
PCT/US2018/040683

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Regarding Claim 15, US Well discloses a method for powering one or more ancillary units associated with a hydraulic fracturing system (wireline power supply during electric powered fracturing operations; title; the method being inherent in the description), the method characterized by: fluidly connecting an electric pump to a well associated with a subterranean formation, the electric pump configured to pump fluid into a wellbore associated with the well at a high pressure so that the fluid passes from the wellbore into the subterranean formation and fractures the subterranean formation (Paragraph [0051] describes electric powered fracking pumps.); fluidly connecting the one or more ancillary units with the fluid pumped into the wellbore (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125.); electrically coupling a first motor to the electric pump to operate the electric pump (Paragraph [0051] describes fracking pumps being powered by electric motors.); electrically coupling one or more second motors to each of the one or more ancillary units to operate the one or more ancillary units, the one or more second motors characterized by an electric motor (Paragraph [0037] describes sand equipment 121, hydration unit 123, and blender 125 all being powered by electricity, presumably electric motors.); and connecting each of a plurality of variable-frequency drives (VFD) to at least one of the first motor or the one or more second motors to control the speed of the first motor or the one or more second motors (Paragraph [0048] describes blender discharge motor connected to a VFD and paragraph [0049] describes fracking pumps being connected to a VFD.).

Claims 1-4, 10-12, and 15 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

Electronic Acknowledgement Receipt

EFS ID:	34215797
Application Number:	16170695
International Application Number:	
Confirmation Number:	6906
Title of Invention:	SMART FRACTURING SYSTEM AND METHOD
First Named Inventor/Applicant Name:	Jared Oehring
Customer Number:	132858
Filer:	Taylor P. Evans/Stephanie McDonough
Filer Authorized By:	Taylor P. Evans
Attorney Docket Number:	047158.100032
Receipt Date:	05-NOV-2018
Filing Date:	
Time Stamp:	17:14:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	047158-100032_IDS.pdf	1050010 d1a0b543239beb70b1d2aad78497182821 3a467a	no	30

Warnings:

Information:					
2	Foreign Reference	CA2966672A1.pdf	1602814 3916dee8828ea600e633dcb1ae8ad73eea34a2c9	no	48
Warnings:					
The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing					
Information:					
3	Foreign Reference	CN101977016A.pdf	803676 a93454bfde78b83d915b1b930ac57dadee6da00d	no	16
Warnings:					
Information:					
4	Foreign Reference	JP2004264589.pdf	137203 3a0163b419c7e66f230ee0fd5cafea5b97ea883f	no	3
Warnings:					
Information:					
5	Non Patent Literature	NPL-1.pdf	265555 591acdd0884e7418b119f5770a99b349ff7fdd1b	no	2
Warnings:					
Information:					
6	Other Reference-Patent/App/Search documents	NPL-2.pdf	377602 6c3ca36dd3d3730875498a46d1f7a93d6fd1aae2	no	10
Warnings:					
Information:					
7	Other Reference-Patent/App/Search documents	NPL-3.pdf	560119 cef1f1e4f121c4a16d01235ac830673dceb2c2f0	no	16
Warnings:					
Information:					
8	Other Reference-Patent/App/Search documents	NPL-4.pdf	278422 1d8c019e2f420d0d46213cfb4484dd327b5b0085	no	8
Warnings:					

Information:					
9	Other Reference-Patent/App/Search documents	NPL-5.pdf	304832 7da318b8d7c0533e296468dd97b36a063f6c4089	no	9
Warnings:					
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10	Other Reference-Patent/App/Search documents	NPL-6.pdf	355149 b32a6d81523770df5cfcc9cb8ef202414fc81a87	no	5
Warnings:					
Information:					
11	Other Reference-Patent/App/Search documents	NPL-7.pdf	648364 5e56a90c3a32fce4679d876656e6c13fbb454243	no	13
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12	Other Reference-Patent/App/Search documents	NPL-8.pdf	416252 6bff86b8d8538e105e9d4f3205c49e50baaf3eee	no	15
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14	Other Reference-Patent/App/Search documents	NPL-10.pdf	347182 dbf2cca04164a6581210560525f81149f20ef398	no	10
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Information:					
15	Other Reference-Patent/App/Search documents	NPL-11.pdf	319654 1ee46a247454ff0dd9d92bed6222456ebcec32d2	no	9
Warnings:					
Information:					

16	Other Reference-Patent/App/Search documents	NPL-12.pdf	340896 57fa5ec905f2dff11900bae08fe2c1ae7d586cd0	no	11
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17	Other Reference-Patent/App/Search documents	NPL-13.pdf	259841 5f66125dc394653d57c51b94ba84af54feb7372d	no	7
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19	Other Reference-Patent/App/Search documents	NPL-15.pdf	323644 5c824a3955835c2a142fff6c8e89cfe093966fb8	no	10
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22	Other Reference-Patent/App/Search documents	NPL-18.pdf	1060055 7ce3425ddf68db8e6fc813b084b87082f754a370	no	29
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26	Other Reference-Patent/App/Search documents	NPL-22.pdf	914315 f1ed304e2641d5e0dc060dfcf0f9f3d42ae38736	no	26
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27	Other Reference-Patent/App/Search documents	NPL-23.pdf	477768 9097bec4a06bf1a58255709a299ccf572669a5e2	no	14
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29	Other Reference-Patent/App/Search documents	NPL-25.pdf	377985 237e2c85af09d19cf7cb543c47313c5a45ddb5ad	no	7
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Information:					

30	Other Reference-Patent/App/Search documents	NPL-26.pdf	1183912 7e1a6ae1483129df3319e86782490d171adcddd6	no	4
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31	Other Reference-Patent/App/Search documents	NPL-27.pdf	513370 613846c97d5a97f394676e8db875d38ebbc6a14c	no	14
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34	Other Reference-Patent/App/Search documents	NPL-30.PDF	1720052 4521f83d51ace785df9c8c36491647 4f6a0636a2	no	6
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35	Other Reference-Patent/App/Search documents	NPL-31.pdf	1075045 57b28c6bfb3d0fa629280b4b1901d26504cc2573	no	4
Warnings:					
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36	Other Reference-Patent/App/Search documents	NPL-32.pdf	219467 aaf00dcfa34bf6fe5e9894a1b1ced293f1b2bbc6	no	7
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37	Other Reference-Patent/App/Search documents	NPL-33.pdf	304155 03f600617bb97ec2d345ef87af05ffe83a1f4e55	no	9
Warnings:					
Information:					
38	Other Reference-Patent/App/Search documents	NPL-34.pdf	414424 e98d69001209ae5ac3a6b2472c1e0c3447c49857	no	9
Warnings:					
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Information:					
39	Other Reference-Patent/App/Search documents	NPL-35.pdf	176576 9d704329cec304ab4ecf65ec3669ed96e4e65e2d	no	3
Warnings:					
Information:					
			Total Files Size (in bytes):	22366600	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/AIA/80 (07-17)
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POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

[X] Practitioners associated with Customer Number: 132858

OR

[ ] Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

[X] The address associated with Customer Number: 132858

OR

[ ]

Firm or individual name		
Address		
City	State	Zip
Country		
Telephone	Email	

Assignee name and address: U.S. Well Services, LLC
770 Post Oak Lane #405
Houston, TX 77056

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature	Date 7/31/2017
Name Jared Oehring	Telephone 281-685-7529
Title Vice President of Technology	

This collection of information is required by 37 CFR 1.31, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public, which is to update (and by the USPTO to process) the file of a patent or reexamination proceeding. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 18 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/96 (08-12)
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STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: U.S. Well Services, LLC

Application No./Patent No.: 16/170,695 Filed/Issue Date: 10/25/2018

Titled: SMART FRACTURING SYSTEM AND METHOD

U.S. Well Services, LLC, a corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

   1. From: _____ To: _____

      The document was recorded in the United States Patent and Trademark Office at

      Reel _____, Frame _____, or for which a copy thereof is attached.

   2. From: _____ To: _____

      The document was recorded in the United States Patent and Trademark Office at

      Reel _____, Frame _____, or for which a copy thereof is attached.

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

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4. From: _____ To: _____

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The document was recorded in the United States Patent and Trademark Office at

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6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☑ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Taylor P. Evans/	2018-10-31
Signature	Date
Taylor P. Evans	60506
Printed or Typed Name	Title or Registration Number

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Docket No. 047158.100032

ASSIGNMENT

WHEREAS, we, Jared Oehring, Alexander James Christinzio, and Brandon N. Hinderliter, citizens of the United States of America, are the inventors of AUTOMATED FRACTURING PUMP SYSTEM for which an application for United States Letters Patent was filed on October 25, 2017 as Application Serial No. 62/577,056; and

WHEREAS, U.S. Well Services, LLC, a Texas Corporation, with a business address of 770 South Post Oak Lane, Suite 405, Houston, Texas 77056, USA, hereafter "Assignee," is desirous of acquiring the entire right, title, and interest in and to the aforesaid invention throughout the world, and all right, title, and interest in, to and under any and all Letters Patent of the United States and all other countries throughout the world;

NOW, THEREFORE, be it known that, for good and valuable consideration, the adequacy, receipt, and legal sufficiency of which from Assignee are each hereby acknowledged, we, as Assignor, sells, assigns, transfers, and sets over to Assignee, all right, title, and interest in and to said invention throughout the world, and said application for U.S. Letters Patent, and any and all divisions, continuations, continuations-in-part, reissues, extensions, reexaminations, post-grant proceeding, or other inter-parties review proceedings thereof, and any and all Letters Patent of the United States and foreign countries which may be granted therefor, the same to be held and enjoyed by them for their own use and benefit, and for the use and benefit of their successors, assigns, or other legal representatives, to the end of the term or terms for which said Letters Patent of the United States or foreign countries are or may be granted, reexamined, or reissued, as fully and entirely as the same would have been held and enjoyed by we if this assignment and sale had not been made.

And we hereby authorize and request the Commissioner of Patents and Trademarks to issue any and all Letters Patent of the United States and any foreign patent offices on said invention or resulting from said application and from any and all divisions, continuations, continuations-in-part, reissues, extensions, reexaminations, post-grant proceeding, or other inter-parties review proceedings thereof, to Assignee, as assignee of the entire interest, and hereby covenant that we have the full right to convey the entire interest herein assigned, and that we have not executed and will not execute any agreement in conflict herewith.

And we further hereby covenant and agree that we will, at any time, upon request, execute and deliver any and all papers that may be necessary or desirable to perfect the title of said invention and to such Letters Patent as may be granted therefor, to Assignee or its successors, assigns, or other legal representatives and that if Assignee or its successors, assigns, or other legal representatives shall desire to file any divisional or continuation applications or to secure a reexamination or reissue of such Letters Patent, or to file a disclaimer relating thereto, will, upon request, sign all papers, make all rightful oaths, and do all lawful acts requisite for the filing of such divisional or continuation application, or such application for reissue and the procuring thereof, and for the filing of such disclaimer, without further compensation but at the expense of Assignee or its successors, assigns, or other legal representatives.

And we do further covenant and agree that we will, at any time upon request, communicate to Assignee or its successors, assigns, or other legal representatives, such facts relating to said invention and Letters Patent or the file history thereof as may be known to me, and testify as to the same in any interference, litigation, or other proceeding when requested so to do, without further compensation but at the expense of Assignee or its successors, assigns, or other legal representatives.

Signature: _____ Date: 1/2/2018

Inventor Name: Jared Oehring

Signature: _____ Date: _____

Inventor Name: Alexander James Christinzio

Signature: _____ Date: 1/2/2018

Inventor Name: Brandon N. Hinderliter

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Signature: _____ Date: _____
Inventor Name: Jared Oehring

Signature: Alexander James Christinzio Date: 1/2/2018
Inventor Name: Alexander James Christinzio

Signature: _____ Date: _____
Inventor Name: Brandon N. Hinderliter

Electronic Acknowledgement Receipt

EFS ID:	34183070
Application Number:	16170695
International Application Number:	
Confirmation Number:	6906
Title of Invention:	SMART FRACTURING SYSTEM AND METHOD
First Named Inventor/Applicant Name:	Jared Oehring
Customer Number:	132858
Filer:	Taylor P. Evans/Stephanie McDonough
Filer Authorized By:	Taylor P. Evans
Attorney Docket Number:	047158.100032
Receipt Date:	01-NOV-2018
Filing Date:	
Time Stamp:	11:52:16
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	Smart_Frac_Alexander.pdf	1294620 3f9c3b98b5b2616b1f03cddc7d2b018af945dd73	no	2

Warnings:

Information:					
2	Oath or Declaration filed	Smart_Frac-Brandon.pdf	79097 bc53cd98c081b7112754ec9d50cc6d9e1a7121d9	no	2
Warnings:					
Information:					
3	Oath or Declaration filed	Smart_Frac-Jared.pdf	76430 1181ca18a93042ca5ef07799e6d4138d05a49e32	no	2
Warnings:					
Information:					
4	Power of Attorney	POA-USWS.pdf	67856 a5f40aac95c5e9004ef5ef4e1227f739b4ba2670	no	2
Warnings:					
Information:					
5	Assignee showing of ownership per 37 CFR 3.73	Statement_USWS.pdf	362774 9ee65e6e77c9bbf6d0a512d77f5e361e630f2135	no	6
Warnings:					
Information:					
		Total Files Size (in bytes):	1880777		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SMART FRACTURING SYSTEM AND METHOD

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 16/170,695

filed on 10/25/2018.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Alexander James Christinzio Date (Optional): _____

Signature: Alexander James Christinzio

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
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The above-identified application was made or authorized to be made by me.

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LEGAL NAME OF INVENTOR

Inventor: Brandon N. Hinderliter Date (Optional): 10/30/18

Signature: [signature]

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

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LEGAL NAME OF INVENTOR

Inventor: Jared Oehring Date (Optional) :

Signature:

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Doc Code: TRACK1.REQ
Document Description: TrackOne Request

PTO/AIA/424 (04-14)

CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION UNDER 37 CFR 1.102(e) (Page 1 of 1)

First Named Inventor:	Jared Oehring	Nonprovisional Application Number (if known):	
Title of Invention:	SMART FRACTURING SYSTEM AND METHOD		

APPLICANT HEREBY CERTIFIES THE FOLLOWING AND REQUESTS PRIORITIZED EXAMINATION FOR THE ABOVE-IDENTIFIED APPLICATION.

1. The processing fee set forth in 37 CFR 1.17(i)(1) and the prioritized examination fee set forth in 37 CFR 1.17(c) have been filed with the request. The publication fee requirement is met because that fee, set forth in 37 CFR 1.18(d), is currently $0. The basic filing fee, search fee, and examination fee are filed with the request or have been already been paid. I understand that any required excess claims fees or application size fee must be paid for the application.

2. I understand that the application may not contain, or be amended to contain, more than four independent claims, more than thirty total claims, or any multiple dependent claims, and that any request for an extension of time will cause an outstanding Track I request to be dismissed.

3. The applicable box is checked below:

I. ☑ Original Application (Track One) - Prioritized Examination under § 1.102(e)(1)

i. (a) The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a). This certification and request is being filed with the utility application via EFS-Web.

---OR---

(b) The application is an original nonprovisional plant application filed under 35 U.S.C. 111(a). This certification and request is being filed with the plant application in paper.

ii. An executed inventor's oath or declaration under 37 CFR 1.63 or 37 CFR 1.64 for each inventor, **or** the application data sheet meeting the conditions specified in 37 CFR 1.53(f)(3)(i) is filed with the application.

II. ☐ Request for Continued Examination - Prioritized Examination under § 1.102(e)(2)

i. A request for continued examination has been filed with, or prior to, this form.
ii. If the application is a utility application, this certification and request is being filed via EFS-Web.
iii. The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a), or is a national stage entry under 35 U.S.C. 371.
iv. This certification and request is being filed prior to the mailing of a first Office action responsive to the request for continued examination.
v. No prior request for continued examination has been granted prioritized examination status under 37 CFR 1.102(e)(2).

Signature /Taylor P. Evans/	Date 2018-10-25
Name (Print/Typed) Taylor P. Evans	Practitioner Registration Number 60506

Note: *This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. Submit multiple forms if more than one signature is required.**

☑ *Total of 1 forms are submitted.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

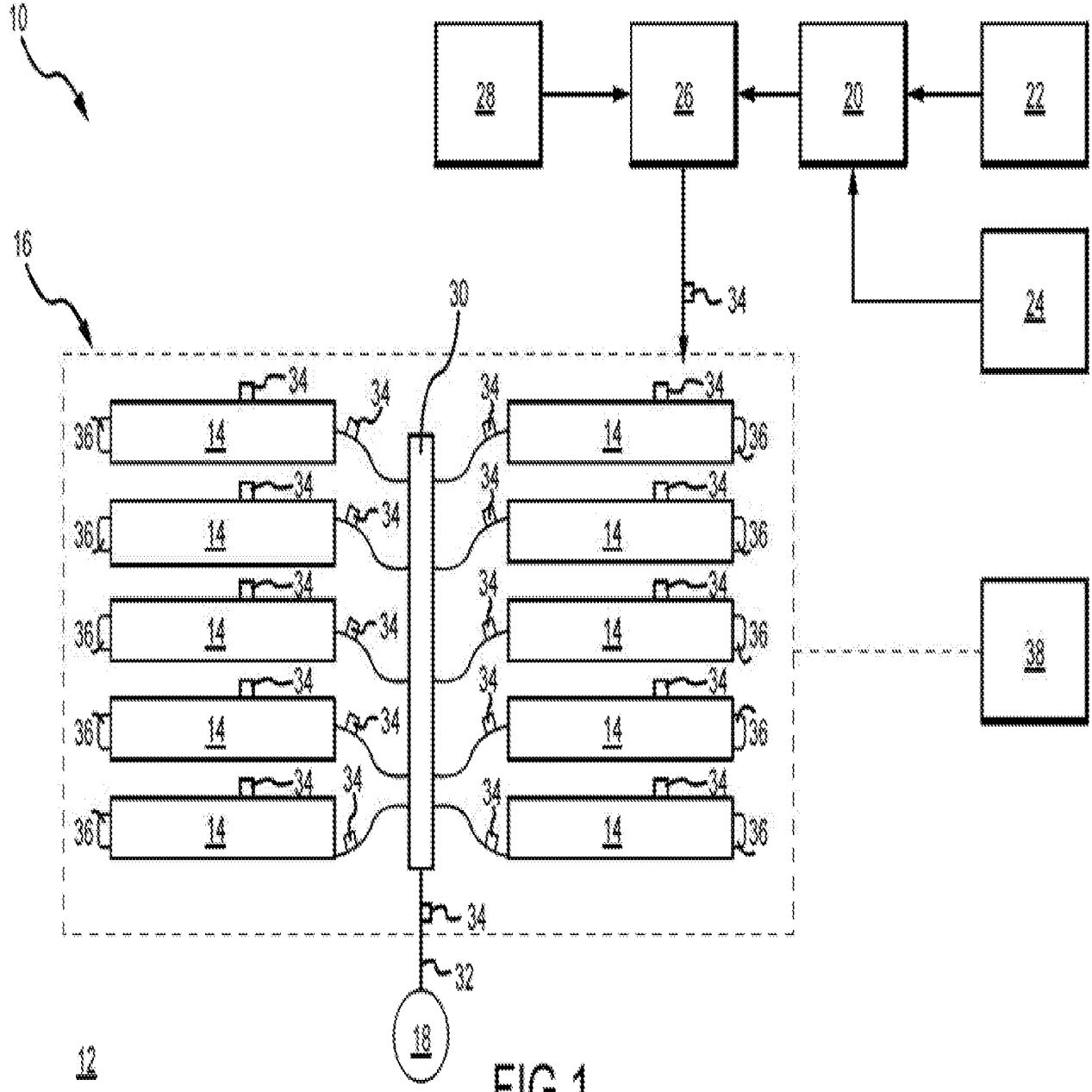


FIG.1

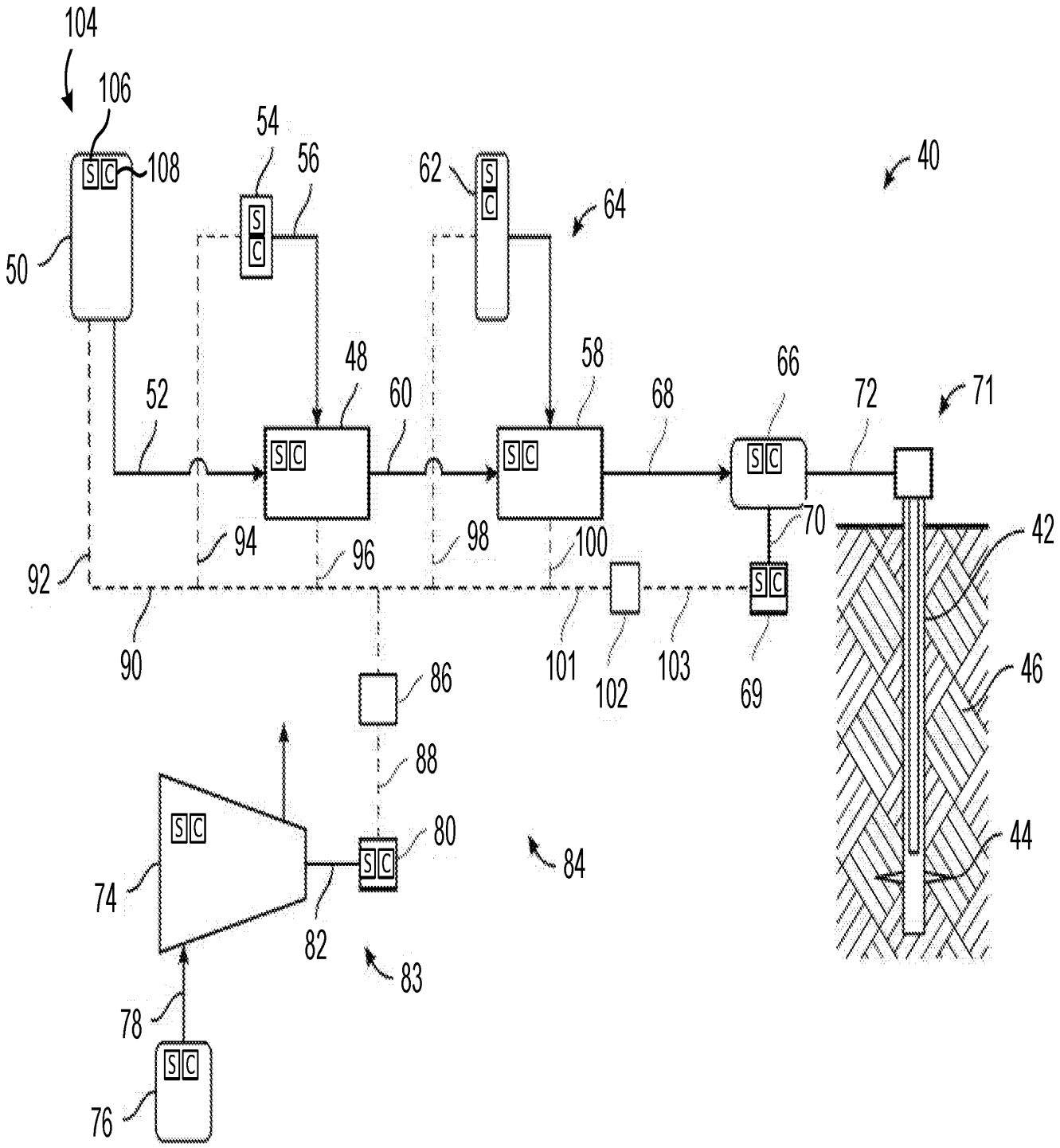

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FIG.2

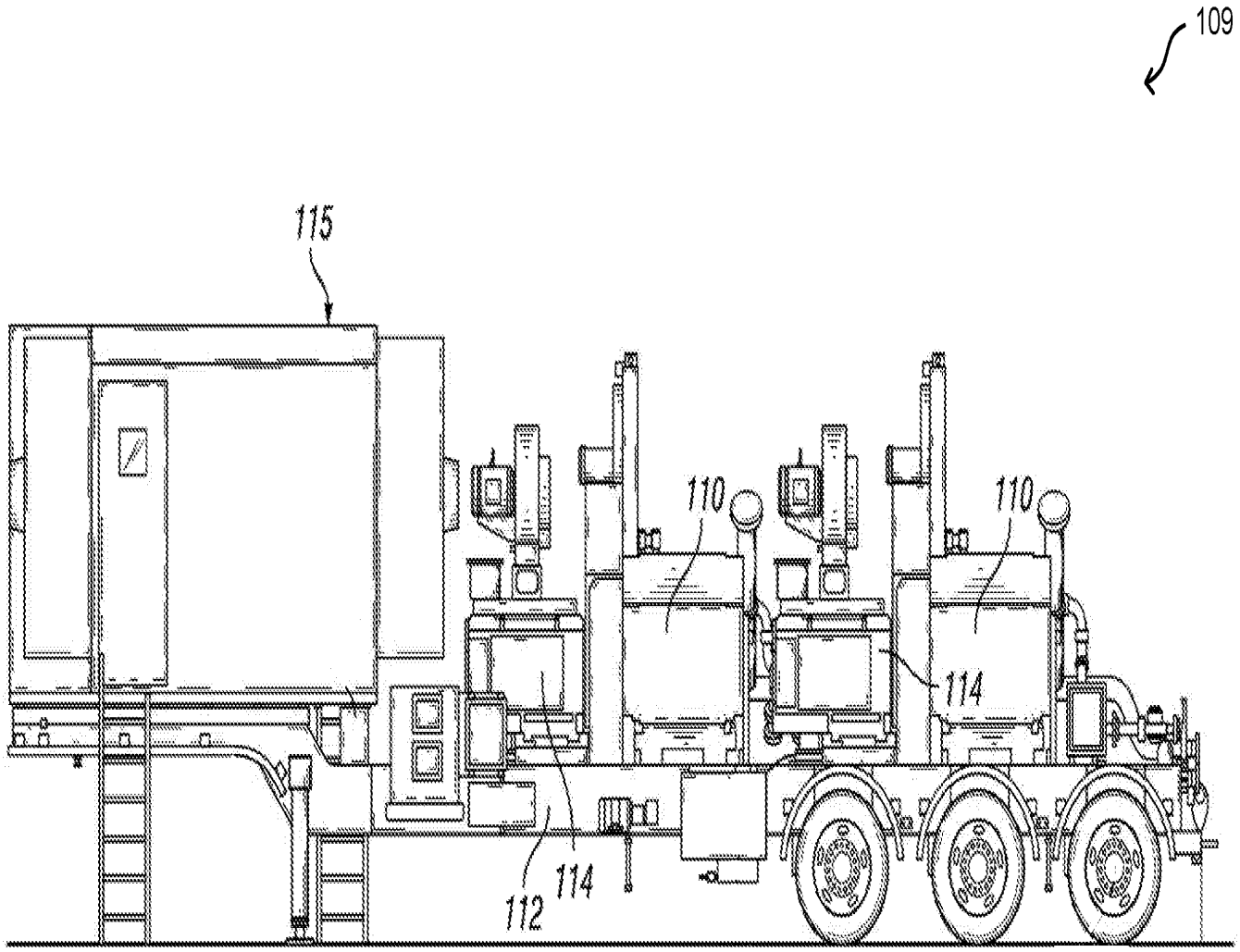


FIG.3

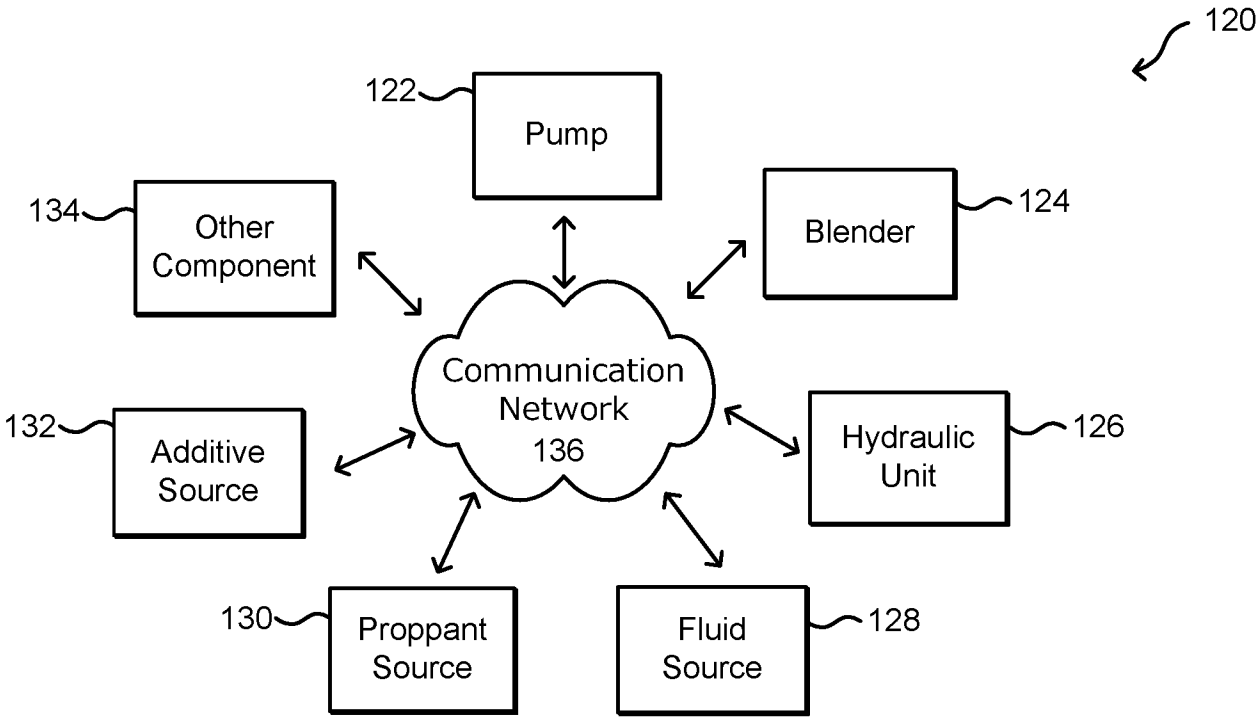

120
122
Pump
134
Other Component
Blender
124
Communication Network 136
132
Additive Source
Hydraulic Unit
126
130
Proppant Source
Fluid Source
128

FIG.4

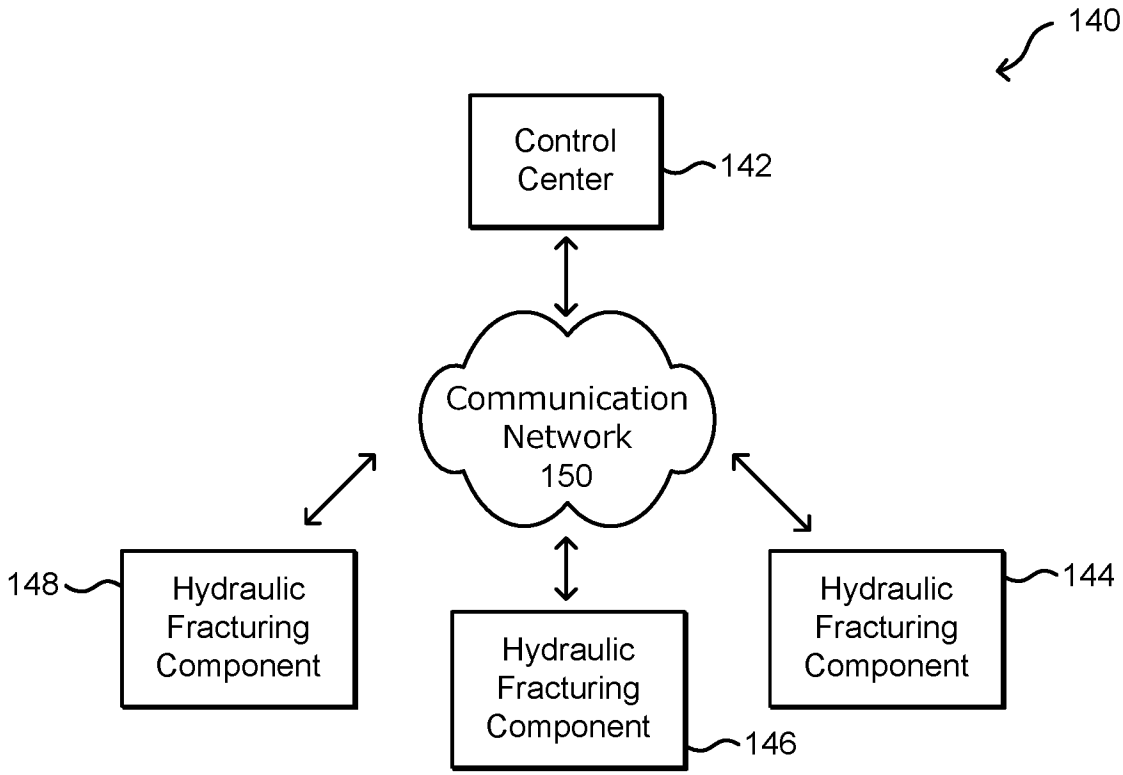

140
Control Center
142
Communication Network 150
148
Hydraulic Fracturing Component
Hydraulic Fracturing Component
144
Hydraulic Fracturing Component
146

FIG.5

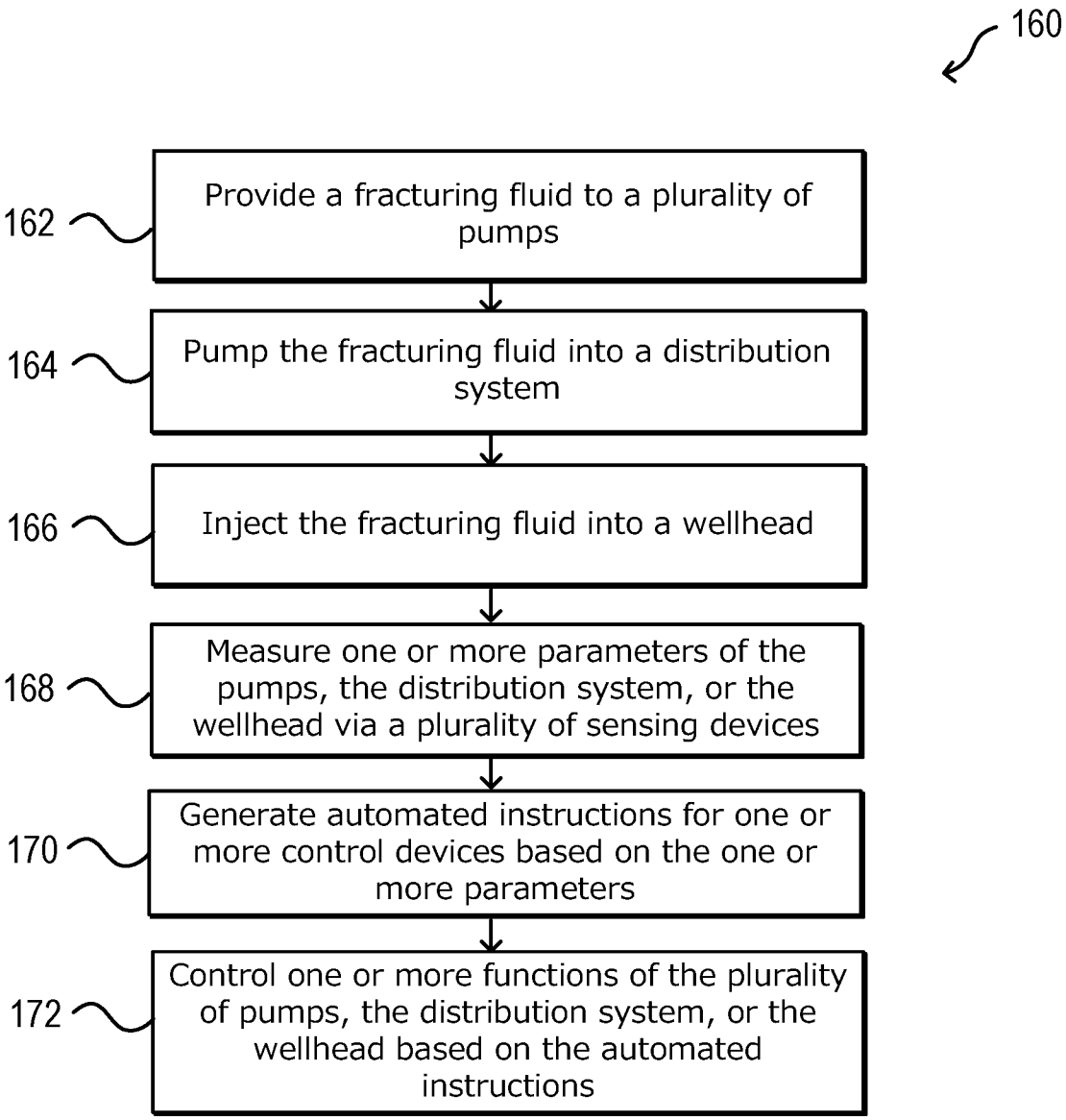

160
162
Provide a fracturing fluid to a plurality of pumps
164
Pump the fracturing fluid into a distribution system
166
Inject the fracturing fluid into a wellhead
168
Measure one or more parameters of the pumps, the distribution system, or the wellhead via a plurality of sensing devices
170
Generate automated instructions for one or more control devices based on the one or more parameters
172
Control one or more functions of the plurality of pumps, the distribution system, or the wellhead based on the automated instructions

FIG.6

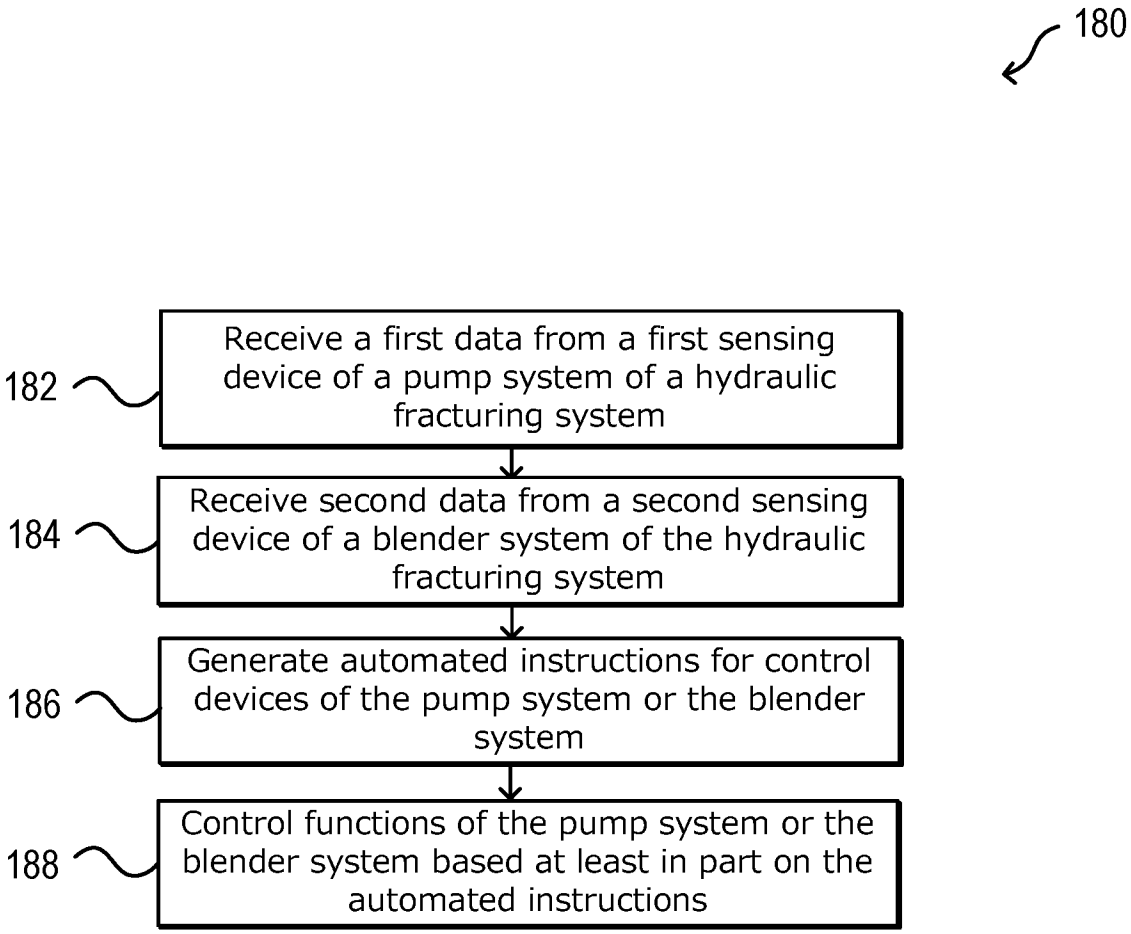

180
182
Receive a first data from a first sensing device of a pump system of a hydraulic fracturing system
184
Receive second data from a second sensing device of a blender system of the hydraulic fracturing system
186
Generate automated instructions for control devices of the pump system or the blender system
188
Control functions of the pump system or the blender system based at least in part on the automated instructions

FIG.7

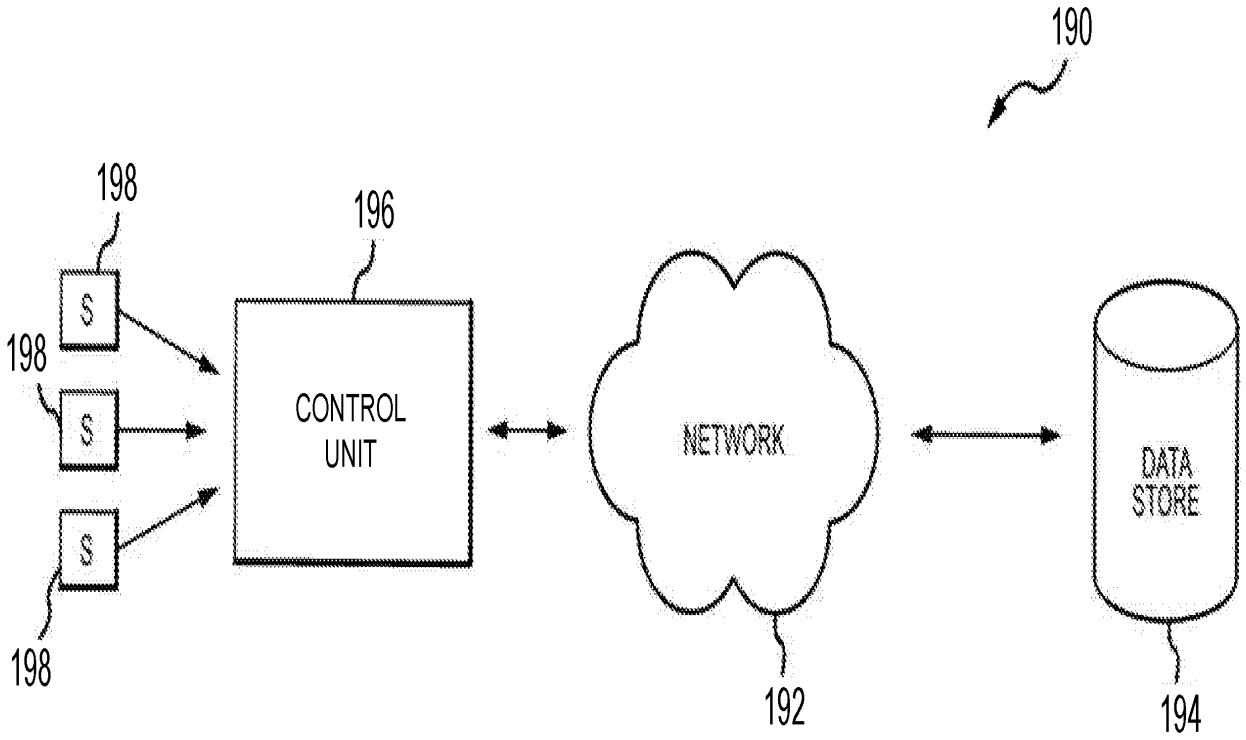

190
198
196
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198
S
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S
CONTROL UNIT
NETWORK
DATA STORE
192
194

FIG.8

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	SMART FRACTURING SYSTEM AND METHOD
First Named Inventor/Applicant Name:	Jared Oehring
Filer:	Taylor P. Evans/Stephanie McDonough
Attorney Docket Number:	047158.100032

Filed as Large Entity

Filing Fees for Track I Prioritized Examination - Nonprovisional Application under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY APPLICATION FILING	1011	1	300	300
UTILITY SEARCH FEE	1111	1	660	660
UTILITY EXAMINATION FEE	1311	1	760	760
REQUEST FOR PRIORITIZED EXAMINATION	1817	1	4000	4000
Pages:				
Claims:				
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
PROCESSING FEE, EXCEPT PROV. APPLS.	1830	1	140	140

Petition:	
Patent-Appeals-and-Interference:	
Post-Allowance-and-Post-Issuance:	
Extension-of-Time:	
Miscellaneous:	
Total in USD ($)	**5860**

Electronic Acknowledgement Receipt

EFS ID:	34099306
Application Number:	16170695
International Application Number:	
Confirmation Number:	6906
Title of Invention:	SMART FRACTURING SYSTEM AND METHOD
First Named Inventor/Applicant Name:	Jared Oehring
Customer Number:	132858
Filer:	Taylor P. Evans/Stephanie McDonough
Filer Authorized By:	Taylor P. Evans
Attorney Docket Number:	047158.100032
Receipt Date:	25-OCT-2018
Filing Date:	
Time Stamp:	15:31:24
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$5860
RAM confirmation Number	102618INTEFSW00002074501349
Deposit Account	501349
Authorized User	Stephanie McDonough

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.19 (Document supply fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	WebADS.pdf	136326 96dc48e61e5fec372793d7ea89861ce3a21a3642	no	8
Warnings:					
Information:					
2		047158-100032_Specification.pdf	139675 6cf56d32fa1a9d1b70ccc0a977cb42765152a901	yes	29

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Abstract	29	29
	Claims	23	28
	Specification	1	22

Warnings:					
Information:					
3	TrackOne Request	047158-100032_Track_One.pdf	124635 81289888e9befa0fc7bf82ca6e48630c7ba1a467	no	2
Warnings:					
Information:					
4	Drawings-only black and white line drawings	047158-100032_Figures.pdf	631420 f2c1385df0c9e40892a976052d5b338e13a27cf2	no	7
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	40250 5dbcf942d9a47c212ca28995838c9d590acde71e	no	2

Warnings:	
Information:	
Total Files Size (in bytes):	1072306

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Jared		Oehring	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Houston	State/Province	TX	Country of Residence i	US

Mailing Address of Inventor:

Address 1	c/o U.S. Well Services, LLC		
Address 2	770 South Post Oak Lane, Suite 405		
City	Houston	State/Province	TX
Postal Code	77056	Country i	US

Inventor 2

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Alexander	James	Christinzio	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Morgantown	State/Province	WV	Country of Residence i	US

Mailing Address of Inventor:

Address 1	c/o U.S. Well Services, LLC		
Address 2	770 South Post Oak Lane, Suite 405		
City	Houston	State/Province	TX
Postal Code	77056	Country i	US

Inventor 3

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Brandon	N.	Hinderliter	

PTO/AIA/14 (08-15)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

Residence Information (Select One)	◉ US Residency	○ Non US Residency	○ Active US Military Service

City	Houston	**State/Province**	TX	**Country of Residence** i	US

Mailing Address of Inventor:

Address 1	c/o U.S. Well Services, LLC		
Address 2	770 South Post Oak Lane, Suite 405		
City	Houston	**State/Province**	TX
Postal Code	77056	**Country** i	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	132858		
Email Address	hlusdocketing@hoganlovells.com	Add Email	Remove Email

Application Information:

Title of the Invention	SMART FRACTURING SYSTEM AND METHOD		
Attorney Docket Number	047158.100032	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	7	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country i

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	132858		

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	Remove
Registration Number					
Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	Remove
Registration Number					

Additional Representative Information blocks may be generated within this form by selecting the **Add** button.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Claims benefit of provisional	62577056	2017-10-25

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

PTO/AIA/14 (08-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:	

If the Applicant is an Organization check here. ☒

Organization Name	U.S. Well Services, LLC

Mailing Address Information For Applicant:

Address 1	770 South Post Oak Lane		
Address 2	Suite 405		
City	Houston	**State/Province**	TX
Country[i]	US	Postal Code	77056
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button.

PTO/AIA/14 (08-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
	Application Number	
Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☒

Organization Name	U.S. Well Services, LLC

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1	770 South Post Oak Lane		
Address 2	Suite 405		
City	Houston	**State/Province**	TX
Country i	US	Postal Code	77056
Phone Number		Fax Number	
Email Address			

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	047158.100032
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Title of Invention	SMART FRACTURING SYSTEM AND METHOD	

Signature:

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Signature	/Taylor P. Evans/			Date (YYYY-MM-DD)	
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ABSTRACT

A hydraulic fracturing system includes a plurality of pumps positioned at a wellsite and configured to pressurize a fracturing fluid, a distribution system fluidly coupled to receive and consolidate fracturing fluid from the plurality of pumps for injection into a wellhead. The hydraulic fracturing system further includes a control system, which includes a plurality of sensing devices configured to measure one or more parameters of the plurality of pumps and the distribution system, one or more processing device configured to receive and analyze the one or more parameters measured by the plurality of sensing devices and generate control instructions based at least in part on the one or more parameters, and one or more control device configured 110 to receive the control instructions and control one or more aspects of the plurality of pumps or the distribution system based on the control instructions.

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CLAIMS

1. A hydraulic fracturing system, comprising:

a plurality of pumps positioned at a wellsite and configured to pressurize a fracturing fluid;

a distribution system fluidly coupled to receive and consolidate fracturing fluid from the plurality of pumps for injection into a wellhead; and

a control system comprising:

a plurality of sensing devices configured to measure one or more parameters of the plurality of pumps and the distribution system;

one or more processing devices configured to receive and analyze the one or more parameters measured by the plurality of sensing devices and generate control instructions based at least in part on the one or more parameters; and

one or more control devices configured to receive the control instructions and control one or more aspects of the plurality of pumps or the distribution system based on the control instructions.

2. The system of claim 1, wherein the plurality of sensing devices are installed on the plurality of pumps and the distribution system, and include at least one of flow sensors, accelerometers, pressure transducer, or tachometers.

3. The system of claim 1, wherein the plurality of pumps or the distribution system includes at least one of a gate, valve, actuator, motor, suction pipe, discharge pipe, engine, transmission, or temperature regulation device, controllable via the one or more control devices.

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4. The system of claim 1, further comprising:

a suction line through which fracturing fluid is supplied; and

a discharge line through which fracturing fluid is discharged, wherein the plurality of sensing devices includes one or more flow sensors configured to measure flow through the suction line and the discharge line.

5. The system of claim 1, further comprising:

one or more blenders configured to mix together one or more materials to form the fracturing fluid, wherein the fracturing fluid is provided from the blender to the plurality of pumps via a manifold, wherein the plurality of sensing devices includes one or more pressure or flow sensors for measuring flow and/or pressure conditions at the one or more blenders, the manifold, the plurality of pumps, or the distribution system.

6. The system of claim 5, wherein the one or more control device is configured to control the one or more blenders, the manifold, the plurality of pumps and the distribution system based on the flow and/or pressure conditions.

7. A hydraulic fracturing method, comprising:

providing a fracturing fluid to a plurality of pumps;

pumping the fracturing fluid into a distribution system;

injecting the fracturing fluid into a wellhead;

measuring one or more parameters of the plurality of pumps, the distribution system, or the wellhead via a plurality of sensing devices instrumented thereon;

generating automated instructions for one or more control devices based at least in part on the one or more parameters; and

controlling one or more functions of the plurality of pumps, the distribution system, or the wellhead based at least in part on the automated instructions.

8. The method of claim 7, further comprising:

detecting that a first parameter of the one or more parameters is outside of an acceptable threshold, wherein the first parameter is associated with a first pump of the plurality of pumps; and

automatically adjusting or turning off the first pump.

9. The method of claim 8, further comprising:

adjusting one or more of the other pumps in the plurality of pumps to compensate for the first pump.

10. The method of claim 9, further comprising:

selecting the one or more of the other pumps to adjust based at least in part on the conditions of the other pumps as indicated by one or more of the one or more parameters.

11. The method of claim 7, further comprising:

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determining that the one or more parameters are indicative of a potential failure condition; and

determining a source of the potential failure condition.

12. The method of claim 11, further comprising:

generating an alert or notification indicative of the potential failure condition and the source.

13. The method of claim 7, further comprising:

logging operation data including a number of strokes and pumping hours performed by a pump of the plurality of pumps; and

determining a maintenance schedule based at least in part on the operation data.

14. A hydraulic fracturing method, comprising:

receiving a first data from a first sensing device of a pump system of a hydraulic fracturing system, the first data indicative of a condition of the pump system;

receiving second data from a second sensing device of a blender system of the hydraulic fracturing system, the blender system mixing together materials to form a fracturing fluid and delivering the fracturing fluid to the pump system, and the second data indicative of a condition of the blender system;

generating automated instructions for one or more control devices of the pump system or the blender system based at least in part on the first and second data; and

controlling one or more functions of the pump system or the blender system based at least in part on the automated instructions.

15. The method of claim 14, wherein the pump system comprises:

one or more pumps; and

a distribution system that receives and consolidates the fracturing fluid from the one or more pumps for injection into a wellhead.

16. The method of claim 17, further comprising:

controlling one or more functions of the distribution system based on the automated instructions.

17. The method of claim 14, wherein the pump system comprises a plurality of pumps, and the first data includes measurements of each of the plurality of pumps.

18. The method of claim 17, further comprising:

controlling one or more of the plurality of pumps individually based on the automated instructions.

19. The method of claim 18, further comprising:

detecting that a measurement associated with a first pump of the plurality of pumps is outside of an acceptable threshold; and

automatically taking the first pump offline in response to the detection.

20. The method of claim 19, further comprising:

adjusting one or more of the other pumps in the plurality of pumps to compensate for taking the first pump offline.

NON-PROVISIONAL PATENT APPLICATION

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SMART FRACTURING SYSTEM AND METHOD

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SMART FRACTURING SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of co-pending U.S. Provisional Application Serial No. 62/577,056 filed October 25, 2017 titled "AUTOMATED FRACTURING PUMP SYSTEM" the full disclosure of which is hereby incorporated herein by reference in its entirety for all purposes.

BACKGROUND

[0002] With advancements in technology over the past few decades, the ability to reach unconventional sources of hydrocarbons has tremendously increased. Horizontal drilling and hydraulic fracturing are two such ways that new developments in technology have led to hydrocarbon production from previously unreachable shale formations. Hydraulic fracturing (fracturing) operations typically require powering numerous components in order to recover oil and gas resources from the ground. For example, hydraulic fracturing usually includes pumps that inject fracturing fluid down the wellbore, blenders that mix proppant into the fluid, cranes, wireline units, and many other components that all must perform different functions to carry out fracturing operations.

[0003] Conventionally, these components or systems of components are generally independent systems that are individually controlled by operators. Furthermore, in some cases, operators are also responsible for taking measurements, interpreting raw data, making calculations, and the like. Thus, a large amount of operator intervention to diagnose, interpret, respond to, adjust, and otherwise control operating conditions of the various components.

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SUMMARY

[0004] Applicant recognized the problems noted above herein and conceived and developed embodiments of systems and methods, according to the present disclosure, for assessing flow rates in hydraulic fracturing systems.

[0005] In an embodiment, a hydraulic fracturing system includes a plurality of pumps positioned at a wellsite and configured to pressurize a fracturing fluid, a distribution system fluidly coupled to receive and consolidate fracturing fluid from the plurality of pumps for injection into a wellhead. The hydraulic fracturing system further includes a control system, which includes a plurality of sensing devices configured to measure one or more parameters of the plurality of pumps and the distribution system. The control system also includes one or more processing device configured to receive and analyze the one or more parameters measured by the plurality of sensing devices and generate control instructions based at least in part on the one or more parameters. The control system further includes one or more control device configured to receive the control instructions and control one or more aspects of the plurality of pumps or the distribution system based on the control instructions.

[0006] In an embodiment, a hydraulic fracturing method includes providing a fracturing fluid to a plurality of pumps, pumping the fracturing fluid into a distribution system, injecting the fracturing fluid into a well via a wellhead, and measuring one or more parameters of the plurality of pumps, the distribution system, or the wellhead via a plurality of sensing devices instrumented thereon. The method also includes generating automated instructions for one or more control devices based at least in part on the one or more parameters, and controlling one or more functions of the plurality of pumps, the distribution system, or the wellhead based at least in part on the automated instructions.

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[0007] In an embodiment, a hydraulic fracturing method includes receiving a first data from a first sensing device of a pump system of a hydraulic fracturing system, the first data indicative of a condition of the pump system, and receiving second data from a second sensing device of a blender system of the hydraulic fracturing system, the blender system mixing together materials to form a fracturing fluid and delivering the fracturing fluid to the pump system, and the second data indicative of a condition of the blender system. The method also includes generating automated instructions for one or more control devices of the pump system or the blender system based at least in part on the first and second data, and controlling one or more functions of the plurality of the pump system or the blender system based at least in part on the automated instructions.

BRIEF DESCRIPTION OF DRAWINGS

[0008] The foregoing aspects, features, and advantage of embodiments of the present disclosure will further be appreciated when considered with reference to the following description of embodiments and accompanying drawings. In describing embodiments of the disclosure illustrated in the appended drawings, specific terminology will be used for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.

[0009] FIG. 1 is a schematic plan view of an embodiment of an automated hydraulic fracturing operation, in accordance with embodiments of the present disclosure.

[0010] FIG. 2 is a schematic diagram of an embodiment of an automated hydraulic fracturing system, in accordance with embodiments of the present disclosure.

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[0011] FIG. 3 illustrates an instrumented fracturing pump system, in accordance with embodiments of the present disclosure.

[0012] FIG. 4 is a diagram of communicative components of an automated hydraulic fracturing system, in accordance with embodiments of the present disclosure.

[0013] FIG. 5 is a diagram of communicative components of an automated hydraulic fracturing system with a central control center, in accordance with embodiments of the present disclosure.

[0014] FIG. 6 is a flow chart of an embodiment of an automated hydraulic fracturing method, in accordance with embodiments of the present disclosure.

[0015] FIG. 7 is a flow chart of an embodiment of a method of controlling an automated hydraulic fracturing system, in accordance with embodiments of the present disclosure.

[0016] FIG. 8 is a block diagram of an embodiment of a control system of an automated hydraulic fracturing system, in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

[0017] The foregoing aspects, features, and advantages of the present disclosure will be further appreciated when considered with reference to the following description of embodiments and accompanying drawings. In describing the embodiments of the disclosure illustrated in the appended drawings, specific terminology will be used for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.

[0018] When introducing elements of various embodiments of the present disclosure, the articles "a", "an", "the", and "said" are intended to mean that there are one or more of the elements. The terms "comprising", "including", and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Any examples of operating parameters and/or environmental conditions are not exclusive of other parameters/conditions of the disclosed embodiments. Additionally, it should be understood that references to "one embodiment", "an embodiment", "certain embodiments", or "other embodiments" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Furthermore, reference to terms such as "above", "below", "upper", "lower", "side", "front", "back", or other terms regarding orientation or direction are made with reference to the illustrated embodiments and are not intended to be limiting or exclude other orientations or directions. Additionally, recitations of steps of a method should be understood as being capable of being performed in any order unless specifically stated otherwise. Furthermore, the steps may be performed in series or in parallel unless specifically stated otherwise.

[0019] FIG. 1 is a schematic representation of an embodiment of a hydraulic fracturing system 10 positioned at a well site 12. In the illustrated embodiment, pump trucks 14, which make up a pumping system 16, are used to pressurize a fracturing fluid solution for injection into a wellhead 18. A hydration unit 20 receives fluid from a fluid source 22 via a line, such as a tubular, and also receives additives from an additive source 24. In an embodiment, the fluid is water and the additives are mixed together and transferred to a blender unit 26 where proppant from a proppant source 28 may be added to form the fracturing fluid solution (e.g., fracturing fluid) which is transferred to the pumping system 16. The pump trucks 14 may receive the fracturing fluid

solution at a first pressure (e.g., 80 psi to 100 psi) and boost the pressure to around 15,000 psi for injection into the wellhead 18. In certain embodiments, the pump trucks 14 are powered by electric motors.

[0020] After being discharged from the pump system 16, a distribution system 30, such as a missile, receives the fracturing fluid solution for injection into the wellhead 18. The distribution system 30 consolidates the fracturing fluid solution from each of the pump trucks 14 (for example, via common manifold for distribution of fluid to the pumps) and includes discharge piping 32 (which may be a series of discharge lines or a single discharge line) coupled to the wellhead 18. In this manner, pressurized solution for hydraulic fracturing may be injected into the wellhead 18. In the illustrated embodiment, one or more sensors 34, 36 are arranged throughout the hydraulic fracturing system 10. In embodiments, the sensors 34 transmit flow data to a data van 38 for collection and analysis, among other things.

[0021] Figure 2 is a detailed schematic representation of an automated hydraulic fracturing system 40, that can be used for pressurizing a wellbore 42 to create fractures 44 in a subterranean formation 46 that surrounds the wellbore 42. Included with the system 40 is a hydration unit 48 that receives fluid from a fluid source 50 via line 52, and also selectively receives additives from an additive source 54 via line 56. Additive source 54 can be separate from the hydration unit 48 as a stand-alone unit, or can be included as part of the same unit as the hydration unit 48. The fluid, which in one example is water, is mixed inside of the hydration unit 48 with the additives. In an embodiment, the fluid and additives are mixed over a period of time, to allow for uniform distribution of the additives within the fluid. In the example of Figure 2, the fluid and additive mixture is transferred to a blender unit 58 via line 60. A proppant source 62 contains proppant, which is delivered to the blender unit 58 as represented by line 64, where line 64 can be a

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conveyer. Inside the blender unit 58, the proppant and fluid/additive mixture are combined to form a fracturing fluid, which is then transferred to a fracturing pump system 66 via line 68; thus fluid in line 68 includes the discharge of blender unit 58 which is the suction (or boost) for the fracturing pump system 66.

[0022] Blender unit 58 can have an onboard chemical additive system, such as with chemical pumps and augers. Optionally, additive source 54 can provide chemicals to blender unit 58; or a separate and standalone chemical additive system (not shown) can be provided for delivering chemicals to the blender unit 58. In an example, the pressure of the fracturing fluid in line 68 ranges from around 80 psi to around 100 psi. The pressure of the fracturing fluid can be increased up to around 15,000 psi by pump system 66. A motor 69, which connects to pump system 66 via connection 40, drives pump system 66 so that it can pressurize the fracturing fluid. In one example, the motor 69 is controlled by a variable frequency drive ("VFD").

[0023] After being discharged from pump system 66, fracturing fluid is pumped into a wellhead assembly 71. Discharge piping 42 connects discharge of pump system 66 with wellhead assembly 71 and provides a conduit for the fracturing fluid between the pump system 66 and the wellhead assembly 71. In an alternative, hoses or other connections can be used to provide a conduit for the fracturing fluid between the pump system 66 and the wellhead assembly 71. Optionally, any type of fluid can be pressurized by the fracturing pump system 66 to form injection fracturing fluid that is then pumped into the wellbore 42 for fracturing the formation 44, and is not limited to fluids having chemicals or proppant.

[0024] An example of a turbine 74 is provided in the example of Figure 1. The turbine 74can be gas powered, receiving a combustible fuel from a fuel source 76 via a feed line 78. In one

example, the combustible fuel is natural gas, and the fuel source 76 can be a container of natural gas or a well (not shown) proximate the turbine 74. Combustion of the fuel in the turbine 74 in turn powers a generator 80 that produces electricity. Shaft 82 connects generator 80 to turbine 74. The combination of the turbine 74, generator 80, and shaft 82 define a turbine generator 83. In another example, gearing can also be used to connect the turbine 74 and generator 80.

[0025] An example of a micro-grid 84 is further illustrated in Figure 2, and which distributes electricity generated by the turbine generator 83. Included with the micro-grid 84 is a transformer 86 for stepping down voltage of the electricity generated by the generator 80 to a voltage more compatible for use by electrically powered devices in the hydraulic fracturing system 40. In another example, the power generated by the turbine generator and the power utilized by the electrically powered devices in the hydraulic fracturing system 10 are of the same voltage, such as 4160 V, so that main power transformers are not needed. In one embodiment, multiple 3500 kVA dry cast coil transformers are utilized. Electricity generated in generator 80 is conveyed to transformer 86 via line 88. In one example, transformer 86 steps the voltage down from 13.8 kV to around 600 V. Other step down voltages can include 4,160 V, 480 V, or other voltages.

[0026] The output or low voltage side of the transformer 56 connects to a power bus 90, lines 92, 94, 96, 98, 100, and 101 connect to power bus 90 and deliver electricity to electrically powered components of the system 40. More specifically, line 92 connects fluid source 20 to bus 90, line 94 connects additive source 24 to bus 90, line 96 connects hydration unit 18 to bus 90, line 98 connects proppant source 62 to bus 90, line 100 connects blender unit 28 to bus 90, and line 101 connects bus 90 to an optional variable frequency drive ("VFD") 102. Line 103 connects VFD

102 to motor 69. In one example, VFD 102 can be used to control operation of motor 69, and thus also operation of pump 66.

[0027] In an example, additive source 54 contains ten or more chemical pumps for supplementing the existing chemical pumps on the hydration unit 48 and blender unit 58. Chemicals from the additive source 54 can be delivered via lines 56 to either the hydration unit 48 and/or the blender unit 58. In one embodiment, the elements of the system 40 are mobile and can be readily transported to a wellsite adjacent the wellbore 42, such as on trailers or other platforms equipped with wheels or tracks.

[0028] In the illustrated embodiment, one or more instrumentation devices 104 such as various types of sensors 106 and controllers 108 are arranged throughout the hydraulic fracturing system 40 and coupled to one or more of the aforementioned components, including any of the wellhead assembly 71, pump 66, blender unit 58, proppant source 62, hydration unit 48, additive source 54, fluid source 50, generator 80, turbine 74, fuel source 76, any deliveries lines, and various other equipment used in the hydraulic fracturing system 40, not all of which are explicitly described herein for sake of brevity. The instrumentation 104 may include various sensors, actuators, and/or controllers, which may be different for different components. For example, the instrumentation devices 104 may include hardware features such as, low pressure transducer (low and high frequency), high pressure transducers (low and high frequency), low frequency accelerometers, high frequency accelerometers, temperature sensors, external mounted flow meters such as doppler and sonar sensors, magnetic flow meters, turbine flow meters, proximity probes and sensors, speed sensors, tachometers, capacitive, doppler, inductive, optical, radar, ultrasonic, fiber optic, and hall effect sensors, transmitters and receivers, stroke counters, GPS

location monitoring, fuel consumption, load cells, PLCs, and timers. In some embodiments, the instrumentation devices may be installed on the components and dispersed in various locations.

[0029] The components may also include communication means that enable all the sensor packages, actuation devices, and equipment components to communicate with each other allowing for real time conditional monitoring. This would allow equipment to adjust rates, pressure, operating conditions such as engine, transmission, power ends RPMs, sand storage compartment gates, valves, and actuators, sand delivery belts and shoots, water storage compartments gates, valves, and actuators, water delivery lines and hoses, individual fracture pump's rates as well as collective system rates, blender hydraulics such as chemical pumps, liquid and dry, fan motors for cooling packages, blender discharge pumps, electric and variable frequency powered chemical pumps and auger screws, suction and discharge manifold meters, valves, and actuators. Equipment can prevent failures, reduce continual damage, and control when it is allowed and not allowed to continue to operate based on live and continuous data readings. Each component may be able to provide troubleshooting codes and alerts that more specifically narrow down the potential causes of issues. This allows technicians to more effectively service equipment, or for troubleshooting or other processes to be initialized automatically. Conditional monitoring will identify changes in system components and will be able to direct, divert, and manage all components so that each is performing its job the most efficiently

[0030] In some embodiments, the sensors may transmit data to a data van 38 for collection and analysis, among other things. In some embodiment, the sensors may transmit data to other components, to the central processing unit, or to devices and control units remote from the site. The communications between components, sensors, and control devices may be wired, wireless,

or a combination of both. Communication means may include fiber optics, electrical cables, WiFi, Bluetooth, radio frequency, and other cellular, nearfield, Internet-based, or other networked communication means.

[0031] The features of the present disclosure may allow for remote monitoring and control from diverse location, not solely the data van 68. Fracturing control may be integrated in with the sensor and monitoring packages 104 to allow for automated action to be taken when/if needed. Equipment may be able to determine issues or failures on its own, then relay that message with a specified code and alarm. Equipment may also be in control to shut itself down to prevent failures from occurring. Equipment may monitor itself as well as communicate with the system as a whole. This may allow whole system to control equipment and processes so that each and every component is running at its highest efficiency, sand, water, chemical, blenders, pumps, and low and high pressure flow lines. Features of the present disclosure may capture, display, and store data, which may be visible locally and remotely. The data may be accessible live during the data collection and historical data may also be available. Each component to this system can be tested individually with simulation as well as physical function testing.

[0032] Operating efficiencies for each individual component and the system 40 may be greatly improved. For example, sand storage and delivery to the blender can be monitored with load cells, sonar sensors and tachometers to determine storage amounts, hopper levels, auger delivery to the tub. Pump efficiencies may be monitored with flow sensors, accelerometers, pressure transducer and tachometers to optimize boost and rate while minimizing harmful conditions such as cavitation or over rating. Failure modes such as wash outs, cutting, valve and/or seat failures, packing issues and supply blockage can be captured and then prevented. Flow lines, both suction supply and discharge can be monitored with flow meters to distribute and optimize flow rates

and velocities while preventing over pumping scenarios. Feedback loops of readings from blender to supply manifolds and to pumps can work with each other to optimize pressure and flow. Dropping out of an individual pump may occur preventing further failures, when this occurs the system as a whole may automatically select the best pumps to make up that needed rate. These changes and abilities solve equipment issues and prevent down time as well as provide a means to deliver a consistent job.

[0033] In some embodiments, instrumentation devices 104 (any of the above described, among others) can be imbedded, mounted, located in various locations such as in line with flow vessels like hoses, piping, manifolds, placed one pump components such as fluid ends, power ends, transmission, engines, and any component within these individual pieces, mounted external to piping and flow vessels, mounted on under or above sand and water storage containers. Blender hoppers could be duel equipped with hopper proximity level sensors as well as a load cell to determine amount of sand in the hopper at any given time.

[0034] FIG. 3 illustrates an example fracturing pump system 109, in accordance with example embodiments. As illustrated, the fracturing pump system 109 includes instrumented components, including motors 114, a transmission, a variable frequency drive (VFD) 115, pumps 110, a power end, and a fluid end. The fluid end may further include instrumented components such as packings, valves, seats, stay rod bolts, suction manifold, suction hoses, and discharge flow iron. These components may include embedded or retrofitted hardware devices which are configured to sense various conditions and states associated with the components. Example hardware devices include low pressure transducer (low and high frequency), high pressure transducers (low and high frequency), low frequency accelerometers, high frequency accelerometers, temperature sensors, external mounted flow meters such as doppler and sonar sensors, magnetic

flow meters, turbine flow meters, proximity probes and sensors, speed sensors, tachometers, capacitive, doppler, inductive, optical, radar, ultrasonic, fiber optic, and hall effect sensors, transmitters and receivers, stroke counters, gps location monitoring, fuel consumption, PLCs, and timers. The system may be attached to a trailer 112 or a skid.

[0035] The fracturing pump components may also include various types of communications devices such as transmitters, receivers, or transceivers, using various communication protocols. This enables components of the fracturing pump components to communicate amongst each other or with a central control unit or remote device so monitor conditions, ensuring that the pumping process is completed effectively and consistently. Communication between the equipment can be both wired and/or wireless, such as through Ethernet, WiFi, Bluetooth, cellular, among other options. Data captured by the hardware can be displayed live locally, stored locally, displayed live remotely, or stored remotely. Such data may be accessed in real-time as well as stored and retrieved at a later time as historical data. In some embodiments, data from one component can be used to determine real time actions to be taken by another component to ensure proper functionality of each component. Specifically, this may allow equipment to adjust rates, pressure, operating conditions such as engine, transmission, power end rotations per minute (RPMs), valves, actuators, individual fracturing pump rates as well as collective system rates, fan motors for cooling packages, electric and variable frequency drive (VFD) powered electric motors for pumps, suction and discharge manifold meters, valves, and actuators. Equipment can prevent failures, reduce continual damage, and control operation based on live and continuous data readings.

[0036] Additionally, each component may be able to provide troubleshooting codes and alerts that more specifically provides information regarding the potential causes of issues or current

conditions. This information may allow technicians to more effectively service equipment. Conditional monitoring can be used to identify changes in system components and can direct, divert, and manage all components such that each component performs its function with optimal efficiency and/or effectiveness. Failures may be reduced because of the ability to automatically shut down equipment based on continuous real-time readings from various sensors. The components can monitor themselves as well as communicate with the system as a whole.

[0037] Present systems and techniques may improve the operating efficiencies for each individual component and the system as a whole. For example, pump efficiencies can be monitored with flow sensors, accelerometers, pressure transducer and tachometers to optimize boost and rate while minimizing harmful conditions such as cavitation or over rating. Failure modes such as wash outs, cutting, valve failures, seat failures, packing issues and supply blockage, can be captured and then prevented. Flow lines, both suction supply and discharge can be monitored with flow meters to distribute and optimize flow rates and velocities while preventing over pumping scenarios. In some embodiments, feedback loops of readings from blender to supply manifolds and to pumps can work with each other to optimize pressure and flow.

[0038] In various embodiments, for example, an individual pump may be dropped from operation to prevent further failures. When this occurs, the system as a whole may automatically select the best pump(s) to make up for the dropped pump. Power ends (pumps) may keep track of stroke counts and pumping hours. This data may be accompanied with maintenance logs which may help determine schedules and maintenance procedures. In some embodiments, transmissions may be monitored for each individual gear, duration and load may be logged as well as temperature. If any of these various components were to indicate an alarm that would be

detrimental to the equipment, the signal from that sensor may relay the message to shut the entire pump down.

[0039] FIG. 4 includes a diagram 120 illustrating a connected automated fracturing system, in accordance with various embodiments. In this example, one or more components 42 of a fracturing system, such as a pump 122, blender 124, hydration unit 126, fluid source 128, proppant source 130, additive source 132, and one or more other components 134, may include communication devices for transmitting and receiving data with each other over a communication network 136. In some embodiments, at least some of the components include processors that analyze the data received from one or more of the other components and automatically controls one or more aspects of that component. The communication network 120 may include various types of wired or wireless communication protocols, or a combination of wired and wireless communications. In some embodiments, the connected automated fracturing system further includes one or more of a plurality of components including a manifold, a manifold trailer, a discharge piping, flow lines, conveyance devices, a turbine, a motor, a variable frequency drive, a generator, or a fuel source. Sensors and control devices may be integrated into the one or more of these components, allowing these components to communicate with the rest of the system.

[0040] FIG. 5 includes a diagram 140 illustrating a communications network of the automated fracturing system, in accordance with various embodiments. In this example, one or more hydraulic fracturing components 148, such as, and not limited to, any of those mentioned above, may be communicative with each other via a communication network 150 such as described above with respect to FIG. 4. The components 148 may also be communicative with a control center 142 over the communication network 150. The control center 142 may be instrumented

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into the hydraulic fracturing system or a component. The control center 142 may be onsite, in a data van, or located remotely. The control center 142 may receive data from any of the components 148, analyze the received data, and generate control instructions for one or more of the components based at least in part on the data. For example, the control center 142 may control an aspect of one component based on a condition of another component. In some embodiments, the control center 142 may also include a user interface, including a display for displaying data and conditions of the hydraulic fracturing system. The user interface may also enable an operator to input control instructions for the components 144. The control center 142 may also transmit data to other locations and generate alerts and notification at the control center 150 or to be received at user device remote from the control center 142.

[0041] In some embodiments, a hydraulic fracturing system includes a plurality of pumps positioned at a wellsite and configured to pressurize a fracturing fluid, a distribution system fluidly coupled to receive and consolidate fracturing fluid from the plurality of pumps for injection into a wellhead. The hydraulic fracturing system further includes a control system, which includes a plurality of sensing devices configured to measure one or more parameters of the plurality of pumps and the distribution system. The control system also includes one or more processing device configured to receive and analyze the one or more parameters measured by the plurality of sensing devices and generate control instructions based at least in part on the one or more parameters. The control system further includes one or more control device configured to receive the control instructions and control one or more aspects of the plurality of pumps or the distribution system based on the control instructions.

[0042] In some embodiments, the one or more sensing device are installed on the plurality of pumps and the distribution system, and include at least one of flow sensors, accelerometers,

pressure transducer, or tachometers. The plurality of pumps or the distribution system may include at least one of a gate, valve, actuator, motor, suction pipe, discharge pipe, engine, transmission, or temperature regulation device, controllable via the one or more control device. In some embodiments, the system further includes a suction line through which fracturing fluid is supplied and a discharge line through which fracturing fluid is discharged, and the plurality of sensing devices includes one or more flow sensors configured to measure flow through the suction line and the discharge line.

[0043] The system may also include one or more blenders configured to mix together one or more materials to form the fracturing fluid, wherein the fracturing fluid is provided from the blender to the plurality of pumps via a manifold, wherein the plurality of sensing devices includes one or more pressure or flow sensors for measuring flow and/or pressure conditions at the one or more blenders, the manifold, the plurality of pumps and the distribution system. In some embodiments, the one or more control device is configured to control the one or more blenders, the manifold, the plurality of pumps and the distribution system based on the flow and/or pressure conditions.

[0044] FIG. 6 is a flow chart of an embodiment of an automated hydraulic fracturing method 160, in accordance with example embodiments. It should be noted that the method may include additional steps, fewer steps, and differently ordered steps than illustrated in this example. In this example, a fracturing fluid is provided 162 to a plurality of pumps, and the fracturing fluid is pumped 164 into a distribution system. The fracturing fluid is then injected 166 into a well via a wellhead. One or more parameters of the plurality of pumps, the distribution system, or the wellhead is measured 168 via a plurality of sensing devices instrumented thereon. Automated instructions are then generated for one or more control devices based at least in part on the one or

more parameters, and one or more functions of the plurality of pumps, the distribution system, or the wellhead can be controlled based at least in part on the automated instructions.

[0045] In some embodiments, the method 160 also includes detecting that a first parameter of the one or more parameters is outside of an acceptable threshold, in which the first parameter is associated with a first pump of the plurality of pumps, and automatically adjusting or turning off the first pump. In some embodiments, the method 160 also includes adjusting one or more of the other pumps in the plurality of pumps to compensate for the first pump. In some embodiments, the method 160 also includes selecting the one or more of the other pumps to adjust based at least in part on the conditions of the other pumps as indicated by one or more of the one or more parameters. In one or more embodiments, the method 160 also includes determining that the one or more parameters are indicative of a potential failure condition; and determining a source of the potential failure condition. In some embodiments, the method 160 also includes generating an alert or notification indicative of the potential failure condition and the source. In some embodiments, the method 160 also includes logging operation data including a number of strokes and pumping hours performed by a pump of the plurality of pumps, and determining a maintenance schedule based at least in part on the operation data.

[0046] The hydraulic fracturing system may include other components, such as a turbine, a generator, a hydration unit, a distribution system, a fuel source, or a wellhead, among others. These components may also be instrumented with sensors that measures at least one parameter associated with the turbine, the generator, the hydration unit, the distribution system, the fuel source, or the wellhead. These components may also include controllers, which control at least one aspect of the turbine, the generator, the hydration unit, the distribution system, the fuel source, or the wellhead, based at least in part on the automated instructions. In some

embodiments, the hydraulic fracturing system includes a plurality of pumps and a distribution system, in which fracturing fluid is provided from the blender to the plurality of pumps, the fracturing fluid is provided from the plurality of pumps to the distribution system, and the fracturing fluid is injected from the distribution system into the wellbore. The individual pressure at each pump may be automatically adjusted based on the automated instructions. The combined or overall pump rate of the plurality of pumps may also be controlled, and the rate at the distribution system may also be controlled via the automated instructions.

[0047] FIG. 7 illustrates a method 180 of controlling an automated fracturing system, in accordance with various embodiments. In this embodiment, a first data is received 182 from a first sensing device of a pump system of a hydraulic fracturing system. The first data may be indicative of a condition of the pump system, such as a flow rate, pump efficiency, temperature, pressure, among others. Second data may be received 184 from a second sensing device of a blender system of the hydraulic fracturing system. The blender system mixes together materials such as proppant and a fluid to form a fracturing fluid and delivers the fracturing fluid to the pump system. The second data may be indicative of a condition of the blender system. Automated instructions for one or more control devices of the pump system or the blender system is generated based at least in part on the first and second data. one or more functions of the plurality of the pump system or the blender system is controlled based at least in part on the automated instructions.

[0048] In some embodiments, the pump system includes one or more pumps and a distribution system that receives and consolidates the fracturing fluid from the one or more pumps for injection into a wellhead. In some embodiments, the method 180 also includes controlling one or more functions of the distribution system based on the automated instructions. In some

embodiments, the pump system includes a plurality of pumps, and the first data includes measurements of each of the plurality of pumps. The method 180 may also include controlling one or more of the plurality of pumps individually based on the automated instructions. The method 180 may further include detecting that a measurement associated with a first pump of the plurality of pumps is outside of an acceptable threshold, and automatically taking the first pump offline in response to the detection. The method may further include adjusting one or more of the other pumps in the plurality of pumps to compensate for taking the first pump offline.

[0049] FIG. 8 is a block diagram of an embodiment of a control system 190 for receiving, analyzing, and storing information from the well site. As described above, sensors 198 are arranged at the well site and may transmit data to a control unit 196 for evaluation and potential adjustments to operating parameters of equipment at the well site. The control unit 196 may be communicatively coupled to a network 192, such as the Internet, that can access a data store 194, such as a cloud storage server. Accordingly, in embodiments, data from the sensors 198 is transmitted to the control unit 196 (which may be located on a component, within a data van, or remotely) and is stored locally. However, the control unit 196 may upload the data from the sensors 198 along with other data, to the data store 194 via the network 192. Accordingly, data from previous pumping operations or different sensors may be utilized to adjust various aspects of the hydraulic fracturing operation as needed. For example, the flow data from the sensor 198 may be coupled with information from the sensors 198 (such as the vibration sensor, gear sensors, RPM sensors, pressure sensors, etc.) to provide diagnostics with information from the data store 194. For example, previous data may be used as training data for a machine learning model for predicting various control parameters of a present operation.

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[0050] In embodiments, the data store 194 includes information of the equipment used at the well site. It should be appreciated that, in various embodiments, information from the data store 194 may be stored in local storage, for example in storage within a data can, and as a result, communication over the network 192 to the remote data store 194 may not be used. For example, in various embodiments, drilling operations may be conducted at remote locations where Internet data transmission may be slow or unreliable. As a result, information from the data store 194 may be downloaded and stored locally at the data van before the operation, thereby providing access to the information for evaluation of operation conditions at the well site.

[0051] The foregoing disclosure and description of the disclosed embodiments is illustrative and explanatory of the embodiments of the invention. Various changes in the details of the illustrated embodiments can be made within the scope of the appended claims without departing from the true spirit of the disclosure. The embodiments of the present disclosure should only be limited by the following claims and their legal equivalents.

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