PTO/SB/08a (02-18)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16728359
Filing Date	2019-12-27
First Named Inventor	Jared Oehring
Art Unit	3679
Examiner Name	Aaron Lloyd Lembo
Attorney Docket Number	047158.100066

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	9119326		2015-08-25	McDonnell	
	2	5050673		1991-09-24	Baldridge	
	3	7308933		2007-12-18	Mayfield	
	4	6273193		2001-08-14	Hermann	
	5	5366324		1994-11-22	Arlt	
	6	8646521		2014-02-11	Bowen	
	7	4759674		1988-07-26	Schroder	
	8	1656861		1928-01-17	Leonard	

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	9	10227854		2019-03-12	Glass	
	10	9932799		2018-04-03	Symchuk	
	11	6936947		2005-08-30	Leijon	
	12	7835140		2010-11-16	Mori	
	13	10393108		2019-08-27	Chong	
	14	10378326		2019-08-13	Morris	
	15	10371012		2019-08-06	Davis	
	16	3302069		1967-01-31	Webster	
	17	9728354		2017-08-08	Skolozdra	
	18	10436026		2019-10-08	Ounadjela	
	19	10246984		2019-04-02	Payne	

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	20	10287873		2019-05-14	Filas	
	21	8800652		2014-08-12	Bartko	
	22	9915128		2018-03-13	Hunter	
	23	10196878		2019-02-05	Hunter	
	24	9963961		2018-05-08	Hardin	
	25	10260327		2019-04-16	Kajaria	
	26	7926562		2011-04-19	Poitzsch	
	27	7082993		2006-08-01	Ayoub	
	28	8096354		2012-01-17	Poitzsch	
	29	9976351		2018-05-22	Randall	
	30	10309205		2019-06-04	Randall	

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	31	10407990		2019-09-10	Oehring	
	32	2407796		1946-09-17	Page	
	33	2416848		1947-03-04	Rothery	
	34	7894757		2011-07-26	Keast	
	35	1656861		1928-01-17	Leonard	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

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	20150354322		2015-12-10	Vicknair	
	2	20170016433		2017-01-19	Chong	
	3	20050061548		2005-03-24	Hooper	
	4	20150053426		2015-02-26	Smith	

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	Attorney Docket Number	047158.100066

	5	20120247783		2012-10-04	Berner, Jr.	
	6	20120222865		2012-09-06	Larson	
	7	20090145611		2009-06-11	Pallini Jr.	
	8	20080041596		2008-02-21	Blount	
	9	20170036872		2017-02-09	Wallace	
	10	20180363437		2018-12-20	Coli	
	11	20080017369		2008-01-24	Sarada	
	12	20190203572		2019-07-04	Morris	
	13	20180245428		2018-08-30	Richards	
	14	20190316447		2019-10-17	Oehring	
	15	20190226317		2019-07-25	Payne	

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	16	20190100989		2019-04-04	Stewart	
	17	20190178057		2019-06-13	Hunter	
	18	20180216455		2018-08-02	Andreychuk	
	19	20190203567		2019-07-04	Ross	
	20	20170146189		2017-05-25	Herman	
	21	20190292891		2019-09-26	Kajaria	
	22	20190292866		2019-09-26	Ross	
	23	20190128080		2019-05-02	Ross	
	24	20180363437		2019-12-20	Coli	
	25	20170030177		2017-02-02	Oehring	
	26	20080017369		2008-01-24	Sarada	

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	27	20170036872		2017-02-09	Wallace	
	28	20150300336		2015-10-22	Hernandez	
	29	20170314979		2017-11-02	Ye	
	30	20140379300		2014-12-25	Devine	
	31	20170226842		2017-08-10	Omont	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	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	2787814	CA		2014-02-21	Pawlick		☓
	2	2978706	CA		2016-09-09	Payne		☒
	3	2945579	CA		2019-10-08	Oehring		☒
	4	2944980	CA		2017-02-12	Oehring		☒

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	Attorney Docket Number	047158.100066

	5	2849825	CA		2018-07-17	Bartko		☒
	6	3000322	CA		2013-04-18	Bartko		☒
	7	2797081	CA		2019-09-10	Hunter		☒
	8	3050131	CA		2011-11-03	Hunter		☒
	9	3018485	CA		2017-08-10	Herman		☒
	10	2482943	CA		2011-05-24	Ayoub		☒
	11	2919649	CA		2019-02-26	Randall		☒
	12	2919666	CA		2019-07-16	Randall		☒
	13	3006422	CA		2017-06-01	Green		☒
	14	2406801	CA		2001-11-01	Demetrius		☒

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16728359
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	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

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	International Search Report and Written Opinion mailed January 2, 2020 in related PCT Application No. PCT/US19/55325	☒
	2	Notice of Allowance mailed January 9, 2020 in related U.S. Patent Application No. 16/570,331	☒
	3	Non-Final Office Action mailed December 23, 2019 in related U.S. Patent Application No. 16/597,008	☒
	4	Non-Final Office Action mailed January 10, 2020 in related U.S. Patent Application No. 16/597,014	☒
	5	Non-Final Office Action mailed December 6, 2019 in related U.S. Patent Application No. 16/564,186	☒
	6	International Search Report and Written Opinion mailed November 26, 2019 in related PCT Application No. PCT/US19/51018	☒
	7	International Search Report and Written Opinion mailed February 11, 2020 in related PCT Application No. PCT/US2019/055323	☒
	8	Final Office Action mailed March 31, 2020 in related U.S. Patent Application No. 15/356,436	☒
	9	Non-Final Office Action mailed March 3, 2020 in related U.S. Patent Application No. 16/152,695	☒

If you wish to add additional non-patent literature document citation information please click the Add button Add

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EXAMINER SIGNATURE			
Examiner Signature		Date Considered	

*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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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)	2020-06-17
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.**

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 the Freedom of Information Act requires disclosure of these record s.

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 inspections 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.

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)* 19 SEP 2018
Applicant's or agent's file reference 047158.500026	**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 PCT Helpdesk: 571-272-4300 Telephone No. 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.

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.

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/040683

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 [0061] 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 [0061] 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.).

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.

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 047158.500029	**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	

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 047158.500029	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.

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 2014/0379300 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], [0025], [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 48-58; 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

LIBERTY EXHIBIT 1056, Page 613

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:

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 Niedermeyr, 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 1056, Page 616

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/54542

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], [0161]). 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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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, 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 56,600 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 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 047158.500030	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], [0016], [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
21 November 2018

Date of mailing of the international search report
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

LIBERTY EXHIBIT 1056, Page 627

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-*-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 18/54548

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."

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.

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-*-

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 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 18/57539	International filing date *(day/month/year)* 25 October 2018 (25.10.2018)
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 047158.500032	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], [0090], [0094], [0119] and fig. 2	12, 13
A	US 2016/0256267 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:

- [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	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 16/57539

Box No. I Basis of this opinion

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

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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

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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.
Continuation of:
-*-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 (26 - "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, Well717 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 [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 the pumps, suction line, discharge line 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.

Regarding Claim 5, Well717 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 [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 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.

Regarding Claim 6, Well717, in view of Schlumberger458, teaches the system of claim 5, and Well717 further teaches that the one or more control device (Well717: 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, Well717 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 [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]). 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.

Regarding Claim 11, Well717 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 [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]), 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 Well717 in order to allow an operator or controller to quickly identify the exact location of the wellsite that requires 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.

-*-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 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 [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 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 [0038]) 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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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 'Schlumberger642')

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, Schlumberger642 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 Schlumberger642 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 Schlumberger642, 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

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)*	15 FEB 2019
Applicant's or agent's file reference: 047158.500036	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No.: PCT/US2018/063977	International filing date *(day/month/year)*: 05 December 2018
Applicant: U.S. WELL SERVICES, INC.	

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 PCT Helpdesk: 571-272-4300 Telephone No. 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 047158.500036	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2018/063977	International filing date *(day/month/year)* 05 December 2018	(Earliest) Priority Date *(day/month/year)* 05 December 2017
Applicant U.S. WELL SERVICES, INC.		

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/US2018/063977

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 43/12; E21B 43/26; B60P 3/00; B62D 63/06; E21B 33/068; F04B 15/00 (2019.01)
CPC - E21B 43/12; E21B 43/26; B60P 3/00; B62D 63/06; F04B 47/02; F04B 49/06 (2019.01)

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; 166/250.1; 166/271; 166/308.1; 417/410.1 (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 2016/0177675 A1 (EVOLUTION WELL SERVICES, LLC) 23 June 2016 (23.06.2016) entire document	1-20
A	US 2007/0277982 A1 (SHAMPINE et al) 06 December 2007 (06.12.2007) entire document	1-20
A	US 2016/0258267 A1 (STEWART & STEVENSON, LLC) 08 September 2016 (08.09.2016) entire document	1-20
A	US 2014/0138079 A1 (US WELL SERVICES LLC) 22 May 2014 (22.05.2014) 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
24 January 2019	15 FEB 2019
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)* 15 FEB 2019
Applicant's or agent's file reference 047158.500036	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2018/063977	05 December 2018	05 December 2017

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 43/12; E21B 43/26; B60P 3/00; B62D 63/06; E21B 33/068; F04B 15/00 (2019.01)
CPC - E21B 43/12; E21B 43/26; B60P 3/00; B62D 63/06; F04B 47/02; F04B 49/06 (2019.01)

Applicant U.S. WELL SERVICES, INC.

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
- [ ] 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	24 January 2019	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/US2018/063977

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/US2018/063977

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	1-20	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 1-20 lack novelty under PCT Article 33(2) as being anticipated by Evolution Well Services, Llc.

Regarding Claim 1, Evolution Well Services, Llc discloses a hydraulic fracturing system for fracturing a subterranean formation (a system for pumping and pressurizing fracturing fluid, Para. [0008]), comprising: an electric pump, arranged on a first support structure (fracturing pump transport 108 (first support structure) includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2), the electric pump coupled to a well associated with the subterranean formation and powered by at least one electric motor (a plurality of fracturing pump transports 108 that deliver fracturing fluid through wellhead 101 to subsurface geological formations, Para. [0043] & Fig. 2), 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 (a mobile fracturing system 103 may be moved onto the well site 100 to perform fracturing operations that force relatively high pressure fracturing fluid through wellhead 101 into subsurface geological formations to create fissures and cracks within the rock, Para. [0041] & Fig. 1); and support equipment, arranged on a second support structure, electrically coupled to the electric pump (auxiliary power transport 106 integral with drive power transports 104 (second support structure) may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, Para. [0044] & Fig. 2), wherein the support equipment includes at least a transformer for distributing power to the electric pump (auxiliary power transport 106 integral with drive power transports 104 may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, Para. [0044] & Fig. 2, and, drive power transports 104 may be configured to monitor and control one or more electrical motors located on the fracturing pump transports 106 via a plurality of connections, such as electrical connections (e.g., copper wires), fiber optics, wireless, and/or combinations thereof, Para. [0045] & Fig. 2), the power being received from at least one generator at a voltage higher than an operating voltage of the electric pump (mobile fracturing system comprises an auxiliary gas turbine generator transport 206, Para. [0050] & Fig. 2, and, auxiliary power transport 106 may receive the 13.8 KV electrical connection and step down the voltage to 4.6 KV, which is provided to other fracturing equipment, such as the fracturing pump transport 108, Para. [0044] & Fig. 2).

Regarding Claim 2, Evolution Well Services, Llc discloses the system of claim 1, wherein the second support structure is separated from and distinct from the first support structure (auxiliary power transport 106 integral with drive power transports 104 (second support structure) separate from fracturing pump transport 108 (first support structure), Fig. 2).

Regarding Claim 3, Evolution Well Services, Llc discloses the system of claim 1, wherein the first support structure and the second support structure are at least one of a trailer, a skid, a pad, a truck bed, or a combination thereof (the term "transport" refers to any transportation assembly, including, but not limited to, a trailer, truck, skid, and/or barge used to transport relatively heavy structures, such as fracturing equipment, Para. [0032]).

Regarding Claim 4, Evolution Well Services, Llc discloses the system of claim 1, further comprising: a variable frequency drive connected to the at least one electric motor to control the speed of the at least one electric motor (one or more electrical motors located on the fracturing pump transports 108, one or more variable frequency drives (VFDs) used to monitor and control the prime movers on the fracturing pump transports 108, Para. [0045] & Fig. 2).

Regarding Claim 5, Evolution Well Services, Llc discloses the system of 4, wherein the variable frequency drive is mounted on the second support structure (each of the drive power transports 104 comprise one or more variable frequency drives (VFDs) integral with auxiliary power transport 106(second support structure), Para. [0045] & Fig. 2).

Regarding Claim 6, Evolution Well Services, Llc discloses the system of claim 1, wherein the first support structure includes a plurality of electric pumps (fracturing pump transport 108 may receive the electric power received from the drive power transport 104 to power a prime mover, the prime mover converts electric power to mechanical power for driving one or more pumps, Para. [0046] & Fig. 2), the plurality of electric pumps having a combined horsepower of between 5,000 and 6,000 horsepower (a fracturing pump transport that comprises a dual shaft electric motor configured to drive at least two pumps, each of the pumps may be configured to operate within a desired mechanical power range, such as about 1,500 HP to about 5,000 HP, to discharge fracturing fluid at relatively high pressures, Para. [0039]).

Regarding Claim 7, Evolution Well Services, Llc discloses the system of claim 1, further comprising: a switch gear (switch gear transport 112, Fig. 2) positioned separate from the second support structure and between the at least one generator and the transformer (switch gear transport 112 located between auxiliary gas turbine generator transport 206 and auxiliary power transport 106 integral with drive power transports 104 (second support structure), Fig. 2).

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2018/063977

Supplemental Box

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

Regarding Claim 8, Evolution Well Services, Llc discloses a hydraulic fracturing system for fracturing a subterranean formation (a system for pumping and pressurizing fracturing fluid, Para. [0006]), comprising: a first support structure, forming a pumping trailer (fracturing pump transport 108 (first support structure) includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2), comprising: 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 (fracturing pump transport 108 (first support structure) includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2, and, a mobile fracturing system 103 may be moved onto the well site 100 to perform fracturing operations that force relatively high pressure fracturing fluid through wellhead 101 into subsurface geological formations to create fissures and cracks within the rock, Para. [0041] & Fig. 1); at least one electric motor providing operational energy to the electric pump (a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2); and a first support component, the first support component regulating operation of the electric pump (drive power transports 104 (first support) may be configured to monitor and control one or more electrical motors located on the fracturing pump transports 108 via a plurality of connections, such as electrical connections (e.g., copper wires), fiber optics, wireless, and/or combinations thereof, Para. [0045] & Fig. 2); and a second support structure, forming a support trailer (auxiliary power transport 106 (second support), Para. [0044] & Fig. 2, and, the term "transport" refers to any transportation assembly, including, but not limited to, a trailer, truck, skid, and/or barge used to transport relatively heavy structures, such as fracturing equipment, Para. [0032]), comprising: a second support component, the second support component regulating electric power transmission to the electric pump (auxiliary power transport 106 may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, Para. [0044] & Fig. 2).

Regarding Claim 9, Evolution Well Services, Llc discloses the system of claim 8, wherein the second support component comprises at least one of a transformer, a variable frequency drive, or a motor control center (auxiliary power transport 106 may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, Para. [0044] & Fig. 2).

Regarding Claim 10, Evolution Well Services, Llc discloses the system of claim 8, wherein the first support structure and the second support structure are separate components arranged remote from and not in contact with one another (drive power transports 104 (first support) and auxiliary power transport 106 (second support) located separate from one another, Fig. 2).

Regarding Claim 11, Evolution Well Services, Llc discloses the system of claim 8, wherein the first support structure and the second support structure are at least one of a trailer, a skid, a pad, a truck bed, or a combination thereof (drive power transports 104 (first support) and auxiliary power transport 106 (second support), Fig. 2, and, the term "transport" refers to any transportation assembly, including, but not limited to, a trailer, truck, skid, and/or barge used to transport relatively heavy structures, such as fracturing equipment, Para. [0032]).

Regarding Claim 12, Evolution Well Services, Llc discloses the system of claim 8, wherein the second support component is a transformer for distributing power to the electric pump (auxiliary power transport 106 may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, Para. [0044] & Fig. 2), the power being received from at least one generator at a voltage higher than an operating voltage of the electric pump (mobile fracturing system comprises an auxiliary gas turbine generator transport 206, Para. [0050] & Fig. 2, and, auxiliary power transport 106 may receive the 13.8 KV electrical connection and step down the voltage to 4.8 KV, which is provided to other fracturing equipment, such as the fracturing pump transport 108, Para. [0044] & Fig. 2).

Regarding Claim 13, Evolution Well Services, Llc discloses the system of claim 8, wherein the first support structure includes a plurality of electric pumps (fracturing pump transport 108 (first support structure) includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2), the plurality of electric pumps having a combined horsepower of between 5,000 and 6,000 horsepower (a fracturing pump transport that comprises a dual shaft electric motor configured to drive at least two pumps, each of the pumps may be configured to operate within a desired mechanical power range, such as about 1,500 HP to about 5,000 HP, to discharge fracturing fluid at relatively high pressures, Para. [0039]).

Regarding Claim 14, Evolution Well Services, Llc discloses the system of claim 8, wherein the electric pump has a horsepower rating of between approximately 1,750 and approximately 3,000 (each of the pumps may be configured to operate within a desired mechanical power range, such as about 1,500 HP to about 5,000 HP, Para. [0039]).

Regarding Claim 15, Evolution Well Services, Llc discloses the system of claim 8, further comprising a plurality of pumping trailers and a plurality of support trailers arranged at well site (plural fracturing pump transports 108, drive power transports 104 (first support) and auxiliary power transports 106 (second support), Fig. 2, and, the term "transport" refers to any transportation assembly, including, but not limited to, a trailer, truck, skid, and/or barge used to transport relatively heavy structures, such as fracturing equipment, Para. [0032]), wherein a combined horsepower of the respective electric pumps of the plurality of pumping trailers is approximately 30,000 (fracturing pump transport 108 includes prime mover may be a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2, and, each dual shaft electric motor may be an electric motor configured to operate within a desired mechanical power range, such as about 1,500 horsepower (HP) to about 10,000 HP, Para. [0039] & Fig. 2).

Regarding Claim 16, Evolution Well Services, Llc discloses the system of claim 8, wherein the first support component comprises at least one of a transformer, a variable frequency drive, or a motor control center (drive power transports 104 (first support) may be configured to monitor and control one or more electrical motors (motor control center) located on the fracturing pump transports 108 via a plurality of connections, such as electrical connections (e.g., copper wires), fiber optics, wireless, and/or combinations thereof, Para. [0045] & Fig. 2).

Supplemental Box

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

Regarding Claim 17, Evolution Well Services, Llc discloses a hydraulic fracturing system for fracturing a subterranean formation (a system for pumping and pressurizing fracturing fluid, Para. [0006]), comprising: at least one generator (turbine generator transport 206, Para. [0050] & Fig. 2); at least one switch gear receiving electrical power from the generator (switch gear transport 112 may receive the electricity generated from the mobile source of electric power via one or more electrical connections, Para. [0043] & Fig. 1 and 2); an electric pump, arranged on a first support structure (fracturing pump transport 106 (first support structure) includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2), the electric pump coupled to a well associated with the subterranean formation and powered by at least one electric motor arranged on the first support structure (fracturing pump transport 106 (first support structure) associated with wellhead 101 includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2), 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 (fracturing pump transport 106 (first support structure) associated with wellhead 101 includes a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2, and, mobile fracturing system 103 may be moved onto the well site 100 to perform fracturing operations that force relatively high pressure fracturing fluid through wellhead 101 into subsurface geological formations to create fissures and cracks within the rock, Para. [0041] & Fig. 1 and 2); and a transformer, arranged on a second support structure (auxiliary power transport 106 (second support structure) may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, Para. [0044] & Fig. 2), positioned between the switch gear and at least one electric motor (auxiliary power transport 106 (second support structure) positioned between switch gear transport 112 and fracturing pump transport 108 including a dual shaft electric motor that drives two different pumps, Para. [0046] & Fig. 2), the transformer reducing a voltage output from the at least one switch gear (auxiliary power transport 106 (second support structure) may comprise a transformer and a control system to control, monitor, and provide power to the electrically connected fracturing equipment, auxiliary power transport 106 may receive the 13.8 KV electrical connection and step down the voltage to 4.8 KV, which is provided to other fracturing equipment, such as the fracturing pump transport 108, Para. [0044] & Fig. 2).

Regarding Claim 18, Evolution Well Services, Llc discloses the system of claim 17, wherein the first support structure and the second support structure are separate components arranged remote from and not in contact with one another (drive power transports 104 (first support) and auxiliary power transport 106 (second support) located separate from one another, Fig. 2).

Regarding Claim 19, see claim 3.

Regarding Claim 20, see claim 6.

Claims 1-20 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.

Search History:

Limited Classification Search

The Patent Analyst performed a limited classification search within the following US, IPC, CPC, ECLA, or F-Term classification areas:

CPC Class/Subclass(es): E21B 43/12; E21B 43/26; B60P 3/00; B62D 63/06; F04B 47/02; F04B 49/06 (2019.01)

IPC (8) Class/Subclass(es): E21B 43/12; E21B 43/26; B60P 3/00; B62D 63/06; E21B 33/068; F04B 15/00; F04B 17/03; F04B 47/02; F04B 49/06; F04D 13/06 (2019.01)

U.S. Class/Subclass(es): 166/66.4; 166/177.5; 166/250.1; 166/271; 166/308.1; 417/410.1

See Global Search Results.

Global Patent Literature Text Search

The Patent Analyst performed the following global text search, which was not limited by classification but may or may not have been limited by other criteria:

Minesoft PatBase: https//www.patbase.com

#	Search query	Results
1	INV=(OEHRING, JARED)	7
2	PN=(US10020711 BB OR US10036238 BB OR US10107086 BB OR US10119381 BB OR US2017028368 AA OR US9650879 BB OR US9745840 BB OR US9840901 BB OR US9893500 BB OR US9970278 BB OR US9995218 BB OR US9650871 BB)	2
3	INV=(HINDERLITER, BRANDON)	6
4	INV=(ROBINSON, LON)	11
5	PA=(US WELL SERVICES)	8
6	PN=(US20120255734)	1
7	UC=(166/177.5)	304
8	UC=(166/308.1)	1405
9	UC=(166/308.1) and (support structure or trailer or skid or pad or truck bed)	312
10	9 not 7	261
11	UC=(166/308.1) and transformer% and variable frequency drive%	9
12	UC=(166/308.1) and generator and (switch gear or switchgear)	3
13	UC=(166/308.1) and voltage and pump	43
14	13 not (9 or 7)	23
15	UC=(166/66.4)	470

16	UC=(166/66.4) and (fracturing or fracking)	28
17	UC=(166/271)	409
18	UC=(166/271) and pump%	170
19	18 not (13 or 9 or 7)	157
20	UC=(166/250.1)	392
21	UC=(166/250.1) and pump%	234
22	21 not (18 or 13 or 9 or 7)	180
23	UC=(417/410.1)	1545
24	UC=(417/410.1) and (fracturing or fracking)	4
25	IC=(E21B43/26)	9399
26	IC=(E21B43/26) and (support structure or trailer or skid or pad or truck bed) and electr* and pump%	548
27	26 not (21 or 18 or 13 or 9 or 7)	397
28	IC=(E21B43/26) and (support structure or trailer or skid or pad or truck bed) and transformer% and variable frequency drive%	19
29	IC=(E21B43/26) and (support structure or trailer or skid or pad or truck bed) and generator and (switch gear or switchgear)	10
30	IC=(E21B43/26) and electr* and pump% and motor and high pressure	309
31	30 not (26 or 21 or 18 or 13 or 9 or 7)	113
32	IC=(E21B43/26) and (generator w10 voltage)	47
33	32 not (30 or 26 or 21 or 18 or 13 or 9 or 7)	26
34	IC=(E21B43/12)	9614
35	IC=(E21B43/12) and (fracturing or fracking) and transformer% and variable frequency drive% and pump%	8
36	IC=(E21B43/12) and (fracturing or fracking) and generator and (switch gear or switchgear) and pump%	3
37	IC=(E21B43/12) and (fracturing or fracking) and (support structure or trailer or skid or pad or truck bed) and electr* and pump%	81
38	37 not (32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	48
39	IC=(E21B33/068)	963
40	IC=(E21B33/068) and (fracturing or fracking)	235
41	40 not (37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	192
42	IC=(F04B15/00)	4818
43	IC=(F04B15/00) and (fracturing or fracking)	21
44	IC=(F04B17/03)	7519
45	IC=(F04B17/03) and (fracturing or fracking)	44

46	45 not (43 or 40 or 37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	27
47	IC=(F04B47/02)	4535
48	IC=(F04B47/02) and (fracturing or fracking)	32
49	IC=(F04B49/06)	18587
50	IC=(F04B49/06) and (fracturing or fracking)	78
51	50 not (45 or 43 or 40 or 37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	53
52	IC=(F04B49/06) and ((support structure or trailer or skid or pad or truck bed) w10 remote)	10
53	IC=(F04D13/06)	17197
54	IC=(F04D13/06) and (fracturing or fracking)	18
55	IC=(B62D63/06)	6299
56	IC=(B62D63/06) and (fracturing or fracking)	13
57	IC=(B60P3/00)	17890
58	IC=(B60P3/00) and (fracturing or fracking)	63
59	58 not (50 or 45 or 43 or 40 or 37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	55
60	CPC=(E21B43/26)	4421
61	CPC=(E21B43/26) and (support structure or trailer or skid or pad or truck bed)	799
62	61 not (58 or 50 or 45 or 43 or 40 or 37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	272
63	CPC=(E21B43/26) and electr* and pump% and transformer% and variable frequency drive% and generator and (switch gear or switchgear)	8
64	CPC=(E21B43/26) and (generator w10 voltage)	32
65	CPC=(E21B43/26) and transformer% and variable frequency drive% and (remote or wireless)	13
66	CPC=(E21B43/12)	1952
67	CPC=(E21B43/12) and (fracturing or fracking) and (support structure or trailer or skid or pad or truck bed)	38
68	CPC=(F04B49/06)	3514
69	CPC=(F04B49/06) and (fracturing or fracking) and (support structure or trailer or skid or pad or truck bed) and electr* and pump%	13
70	CPC=(F04B49/06) and electr* and pump% and transformer% and variable frequency drive% and generator and (switch gear or switchgear)	2
71	CPC=(F04B47/02)	1601
72	CPC=(F04B47/02) and (fracturing or fracking) and electr* and pump%	41
73	72 not (61 or 58 or 50 or 45 or 43 or 40 or 37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	14

74	CPC=(B62D63/06)	807
75	CPC=(B62D63/06) and (fracturing or fracking)	4
76	CPC=(B60P3/00)	2073
77	CPC=(B60P3/00) and (fracturing or fracking)	13
78	RF=(18_63977)	22
79	ctb=78 or ctf=78	1068
80	79 not (78 or 72 or 61 or 58 or 50 or 45 or 43 or 40 or 37 or 32 or 30 or 26 or 21 or 18 or 13 or 9 or 7)	887
81	80 and (fracturing or fracking)	191

Google Patents: https://patents.google.com

#	Search query	Results
1	hydraulic fracturing electric pump support equipment (trailer OR skid OR pad OR truck bed)	3783
2	fracturing electric pump motor transformer generator voltage	664
3	fracturing electric pump motor remote trailer power source	436
4	fracturing transformer variable frequency drive trailer	121
5	hydraulic fracking pumps electric motors	1466
6	hydrofracturing modular pumps electric drive	599
7	hydraulic fracturing independent skids	1635

Computer Accessed Text Databases Searched

The Patent Analyst searched the following computer accessed text databases:

Google: https://www.google.com/

#	Search query	Results
1	US WELL SERVICES hydraulic fracturing support equipment structure	31900000
2	hydraulic fracturing electric pump support equipment skids	784000

Google Scholar: https://scholar.google.com/

#	Search query	Results
1	US WELL SERVICES hydraulic fracturing support equipment structure	32500

YouTube: https://youtube.com

#	Search query	Results
1	US WELL SERVICES hydraulic fracturing support equipment structure	N/A

Date search was completed: 24 January 2019

RP/SS

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Taylor P. Evans
Hogan Lovells US LLP
609 Main Street, Suite 4200
Houston, TX 77002
United States of America

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 047168.500035	Date of mailing *(day/month/year)* 05 MAR 2019 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US18/63970	International filing date *(day/month/year)* 05 December 2018 (05.12.2018)
Applicant U.S. Well Services, Inc.	

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 Shane Thomas 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 047158.500035	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US18/63970	International filing date *(day/month/year)* 05 December 2018 (05.12.2018)	(Earliest) Priority Date *(day/month/year)* 05 December 2017 (05.12.2017)
Applicant U.S. Well Services, Inc.		

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. 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/US18/63970

A. CLASSIFICATION OF SUBJECT MATTER
IPC - E21B 43/20, 43/26, 37/00; F04B 49/20, 15/02, 47/02, 17/03; F16H 39/02 (2019.01)
CPC - E21B 43/20, 43/26, 37/00; F04B 49/20, 15/02, 47/02, 17/03, 53/006, 9/045; F04D 25/028; F16H 39/02

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	US 2017/0051732 A1 (BAKER HUGHES INCORPORATED) 23 February 2017; Figures 1-5; Paragraphs [0016] and [0021]	1-20
Y	US 4,100,822 A (ROSMAN, A) 18 July 1978; Figures 3-5; Column 4, Lines 57-59	1-20
Y	US 8,851,860 B1 (MAIL., J) 07 October 2014; Figure 1; Column 1, Lines 29-33, 39-48, 53-64, 64-67 and Column 2, Lines 1-3	4-5, 14 and 18
Y	US 2016/0258267 A1 (STEWART & STEVENSON, LLC) 08 September 2016; Figure 6; Paragraph [0062]	8-14 and 19-20
A	US 2016/0341281 A1 (ONESUBSEA IP UK LIMITED) 24 November 2016; Figure 5; entire document	1-20
A	US 2005/0274508 A1 (FOLK, R et al.) 15 December 2005; Figure 1; entire document	1-20
A	US 2007/0131410 A1 (HILL, F et al.) 14 June 2007; Figure 9; 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
26 January 2019 (26.01.2019)	05 MAR 2019
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas 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
United States of America

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)* 05 MAR 2019

Applicant's or agent's file reference
047158.500035

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US18/63970	05 December 2018 (05.12.2018)	05 December 2017 (05.12.2017)

International Patent Classification (IPC) or both national classification and IPC
IPC - E21B 43/20, 43/26, 37/00; F04B 49/20, 15/02, 47/02, 17/03; F16H 39/02 (2019.01)
CPC - E21B 43/20, 43/26, 37/00; F04B 49/20, 15/02, 47/02, 17/03, 53/006, 9/045; F04D 25/028; F16H 39/02

Applicant U.S. Well Services, Inc.

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	26 January 2019 (26.01.2019)	Shane Thomas 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/US16/63970

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/US16/63970

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	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, 6-7 and 15-17 lack an inventive step under PCT Article 33(3) as being obvious over US 2017/0051732 A1 to BAKER HUGHES INCORPORATED, hereinafter "BAKER", in view of US 4,100,822 A (ROSMAN).

As per claim 1, Baker discloses a hydraulic fracturing system for fracturing a subterranean formation (pump system 10 for hydraulic fracturing of a borehole in an adjacent earthen formation (subterranean); Figure 1; Paragraph [0016] and [0021]) comprising: a multi-plunger hydraulic fracturing pump fluidly connected to a well associated with the subterranean formation (pump 50 for hydraulic fracturing of a borehole in an adjacent earthen formation (subterranean), which may be a quintuplex pump having five pistons 146 (plungers); Figure 3; Paragraphs [0016] and [0021]), the multi-plunger pump (50) 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 (pump 50 for pumping pressurized fluid into a borehole (wellbore) in an adjacent earthen formation (subterranean) for hydraulic fracturing; Figure 3; Paragraphs [0016] and [0021]); a plurality of motors positioned to power the multi-plunger pump (motors 34, 58 positioned to power the pump 50 (multi-plunger pump); Figure 1); and a planetary gear train having an input pinion gear in rotational contact with the plurality of motors (planetary gear system 170 having a input pinion sun gear 174 in rotational contact with motor 58 through drive shaft 60 and motor 34 through gear train 62 to drive shaft 52; Figures 1 and 4; Paragraph [0024]), wherein a gear ratio of the planetary gear train and a speed at which the plurality of motors operate are selected so as to limit a maximum pump speed associated with the multi-plunger pump (the gear ratio of planetary gear system 170 allows for gear reduction, allowing for the rotational speed of the drive shaft 60 to convert to a slower rotational speed on the drive shaft 52 of the pump 50 (thereby limiting maximum pump speed); Figures 1 and 4; Paragraph [0024]). Baker fails to disclose a plurality of input pinion gears in rotational contact with each of the plurality of motors. Rosman discloses a plurality of motors and a plurality of input pinion gears in rotational contact with each of the plurality of motors (see Figures 3-5 wherein pinions 23 having gear teeth 34 are connected rotationally to hydraulic drive motors 21). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the planetary gearing of Baker by having a motor for each associated planet gear as taught by Rosman for the purpose of having smaller motors wherein there is an advantage that the system is less expensive with respect to initial capitalization and maintenance (Rosman; Column 4, Lines 57-59).

As per claim 2, Baker as modified by Rosman discloses the system of claim 1. Baker fails to disclose the system further comprising a plurality of speed reduction gearboxes positioned between the plurality of input pinion gears and the plurality of motors so as to achieve a desired pump rate. Rosman discloses a plurality of speed reduction gearboxes positioned between a plurality of input pinion gears and a plurality of motors (gear boxes 22 are positioned between a plurality of pinions 23 having gear teeth 23 and a plurality of hydraulic drive motors 21; gear boxes are designed to increase torque while reducing speed of the output shaft; Figures 3-5; Column 4, Lines 46-62). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the gearing of Baker by having a motor for each associated planet gear as well as gear boxes as taught by Rosman resulting in a desired pump rate for the purpose of having smaller motors wherein there is an advantage that the system is less expensive with respect to initial capitalization and maintenance (Rosman; Column 4, Lines 57-59) and developing the amount of torque necessary to rotate ring members with high loads (Rosman; Column 4, Lines 60-62)).

As per claim 3, Baker as modified by Rosman discloses the system of claim 1. Baker fails to disclose wherein a plurality of motors comprises one of a plurality of electric motors or a plurality of hydraulic motors. Rosman discloses wherein a plurality of motors comprises one of a plurality of electric motors or a plurality of hydraulic motors (hydraulic drive motors 21; Figure 4). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the motor of Baker with the plurality of hydraulic motors as taught by Rosman for the purpose of utilizing a motor which can generate high torques without excessive size.

As per claim 6, Baker as modified by Rosman discloses the system of claim 1. Baker further discloses wherein the hydraulic pump comprises an odd number of plungers greater than or equal to five plungers (pump 50 for hydraulic fracturing of a borehole in an adjacent earthen formation (subterranean) with five pistons 146 (plungers); Figure 3; Paragraphs [0016] and [0021]).

As per claim 7, Baker as modified by Rosman discloses the system of claim 6, wherein a stroke length of each of the plungers associated with the hydraulic pump is selected to inversely relate to a pump speed associated with the hydraulic pump so as to achieve a predetermined flow rate (see Figure 3 wherein the distance the crosshead 148 travels (stroke length) of the piston 146 (plunger) associated with the pump system 10 would be in a inversely related relation to pump speed since the longer the stroke length is, the lower the pump speed required to achieve a given flow rate; Figures 3-5; Paragraphs [0026] and [0019]).

-***-Continued Within the Next Supplemental Box-***-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US18/63970

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 4-10, 14 and 18-20 are objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claims 4-10, 14 and 18-20 are indefinite for the following reason: Claims 4-10, 14 and 18-20 refer to "the plurality of hydraulic pumps". There is a lack of antecedent basis for "the plurality of hydraulic pumps". For the purpose of this opinion, as best understood, the claim is interpreted to read "the hydraulic pump".

Claim 11 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claim 11 is indefinite for the following reason: Claim 11 refers to "the plurality of electric motors" in line 8. There is a lack of antecedent basis for "electric motors". For the purpose of this opinion, as best understood, the claim is interpreted to read "the plurality of motors".

Claim 20 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claim 20 is indefinite for the following reason: Claim 20 refers to "the plurality of VFDs" in line 3. There is a lack of antecedent basis for "the plurality of VFDs". For the purpose of this opinion, as best understood, the claim is interpreted to read "the VFD".

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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-***-Continued from Box V: Citations and Explanations-***-
As per claim 15, Baker discloses a method for pumping fluid into a wellbore associated with a subterranean formation (pump system 10 for hydraulic (fluid) fracturing of a borehole in an adjacent earthen formation (subterranean); Figure 1; Paragraph [0016] and [0021]), the method comprising: fluidly connecting a multi-plunger hydraulic fracturing pump to a well associated with the subterranean formation (pump 50 is fluidly connected to a borehole and is used for hydraulic fracturing of a borehole in an adjacent earthen formation (subterranean), which may be a quintuplex pump having five pistons 146 (plungers); Figure 3; Paragraphs [0016] and [0021]) such that the multi-plunger pump pumps fluid into the wellbore at a high pressure so that fluid passes from the wellbore into the subterranean formation and fractures the subterranean formation (pump 50 for pumping pressurized fluid into a borehole (wellbore) in an adjacent earthen formation (subterranean) for hydraulic fracturing; Figure 3; Paragraphs [0016] and [0021]); powering the multi-plunger pump with a plurality of motors (motors 34, 58 positioned to power the pump 50 (multi-plunger pump); Figure 1); and a planetary gear train having an input pinion gear in rotational contact with the plurality of motors (planetary gear system 170 having a input pinion sun gear 174 in rotational contact with motor 58 through drive shaft 60 and motor 34 through gear train 62 to drive shaft 52; Figure 4; Paragraph [0024]) so as to translate power from the plurality of motors into a desired pump rate of the multi-plunger pump (planetary gear system 170, allows for gear reduction of the power coming from motor 34, allowing for the rotational speed of the drive shaft 60 connected to motor 58, to convert to a slower rotational speed on the drive shaft 52 of the pump 50 (desired pump rate); Figures 1 and 4; Paragraph [0024]). Baker fails to disclose a plurality of input pinion gears in rotational contact with each of the plurality of motors. Rosman discloses a plurality of motors and a plurality of input pinion gears in rotational contact with each of the plurality of motors (see Figures 3-5 wherein pinions 23 having gear teeth 34 are connected rotationally to hydraulic drive motors 21). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the planetary gearing of Baker by having a motor for each associated planet gear as taught by Rosman for the purpose of having smaller motors wherein there is an advantage that the system is less expensive with respect to initial capitalization and maintenance (Rosman; Column 4, Lines 57-59).

As per claim 16, Baker as modified by Rosman discloses the method of claim 15. Baker fails to disclose further comprising: positioning a plurality of speed reduction gearboxes between the plurality of input pinion gears and the plurality of motors so as to achieve the desired pump rate. Rosman discloses positioning a plurality of speed reduction gearboxes between a plurality of input pinion gears and a plurality of motors (gear boxes 22 are positioned between a plurality of pinions 23 having gear teeth 23 and a plurality of hydraulic drive motors 21; gear boxes are designed to increase torque while reducing speed of the output shaft; Figures 3-5; Column 4, Lines 46-62). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the gearing of Baker by having a motor for each associated planet gear as well as gear boxes as taught by Rosman resulting in a desired pump rate for the purpose of having smaller motors wherein there is an advantage that the system is less expensive with respect to initial capitalization and maintenance (Rosman; Column 4, Lines 57-59) and developing the amount of torque necessary to rotate ring members with high loads (Rosman; Column 4, Lines 60-62)).

As per claim 17, Baker as modified by Rosman discloses the method of claim 15. Baker fails to disclose wherein a plurality of motors comprises one of a plurality of electric motors or a plurality of hydraulic motors. Rosman discloses wherein a plurality of motors comprises one of a plurality of electric motors or a plurality of hydraulic motors (hydraulic drive motors 21; Figure 4). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the motor of Baker with the plurality of hydraulic motors as taught by Rosman for the purpose of utilizing a motor which can generate high torques without excessive size.

Claims 4-5 and 18 lack an inventive step under PCT Article 33(3) as being obvious over BAKER in view of ROSMAN further in view of US 8,851,860 B1 (MAIL).

As per claim 4, Baker as modified by Rosman discloses the system of claim 1. Baker fails to disclose wherein the maximum pump speed correlates to a critical plunger speed associated with the hydraulic pump. Mail discloses wherein a maximum pump speed correlates to a critical plunger speed associated with a hydraulic pump (mainstream methods of subsurface downhole pumping (hydraulic pump) include mounted reciprocating mechanisms (plunger) in a casing tube; optimal speeds of up and down strokes can be defined as maximum speeds that will not cause overstressing of pump rod (critical plunger speed); therefore maximum pumping speed correlates to an operation at optimal up and down stroke speed (critical plunger speed) associated with the hydraulic pump; Column 1, Lines 29-33, 39-48, 53-54, 64-67 and Column 2, Lines 1-3). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the maximum pump speed of Baker by correlating it to the critical plunger speed as taught by Mail for the purpose of avoiding overstressing of structural parts and premature damage (Baker; Column 1, Lines 64-67 and Column 2, Lines 1-3).

As per claim 5, Baker as modified by Rosman discloses the system of claim 1. Baker fails to disclose wherein the maximum pump speed is 5% or less over a critical plunger speed associated with hydraulic pump. Mail discloses wherein the maximum pump speed is 5% or less over a critical plunger speed associated with hydraulic pump (mainstream methods of subsurface downhole pumping (hydraulic pump) include mounted reciprocating mechanisms (plunger) in a casing tube; optimal speeds of up and down strokes can be defined as maximum speeds that will not cause overstressing of pump rod (critical plunger speed); therefore maximum pumping speed would equate (less than 5%) to an operation at optimal up and down stroke speed (critical plunger speed) associated with the hydraulic pump; Column 1, Lines 29-33, 39-48, 53-54, 63-67 and Column 2, Lines 1-3). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the maximum pump speed of Baker by equating it to the critical plunger speed as taught by Mail for the purpose of avoiding overstressing of structural parts and premature damage (Baker; Column 1, Lines 63-67 and Column 2, Lines 1-3).

-***-Continued Within the Next Supplemental Box-***-

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As per claim 18, Baker as modified by Rosman discloses the method of claim 15. Baker fails to disclose wherein the maximum pump speed correlates to a critical plunger speed associated with the hydraulic pump. Mail discloses wherein a maximum pump speed correlates to a critical plunger speed associated with a hydraulic pump (mainstream methods of subsurface downhole pumping (hydraulic pump) include mounted reciprocating mechanisms (plunger) in a casing tube; optimal speeds of up and down strokes can be defined as maximum speeds that will not cause overstressing of pump rod (critical plunger speed); therefore maximum pumping speed correlates to an operation at optimal up and down stroke speed (critical plunger speed) associated with the hydraulic pump; Column 1, Lines 29-33, 39-48, 53-64, 64-67 and Column 2, Lines 1-3). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the maximum pump speed of Baker by correlating it to the critical plunger speed as taught by Mail for the purpose of avoiding overstressing of structural parts and premature damage (Baker; Column 1, Lines 64-67 and Column 2, Lines 1-3).

Claims 8-13 and 19-20 lack an inventive step under PCT Article 33(3) as being obvious over BAKER in view of ROSMAN further in view of US 2016/0258267 A1 to STEWART & STEVENSON, LLC, hereinafter "STEWART".

As per claim 8, Baker as modified by Rosman discloses the system of claim 1. Baker discloses further comprising: a variable frequency drive (VFD) connected to a motor to control the speed of the motor, wherein the VFD is positioned to accelerate or decelerate pump rotational speeds associated with the hydraulic pump (variable frequency drive (VFD) 76 connected to motor 34 to control the speed thereof, wherein the VFD is positioned to adjust operating speeds of pump 50; Figure 2; Paragraph [0019-0020]). Baker fails to disclose a variable frequency drive (VFD) connected to a plurality of motors. Stewart discloses a variable frequency drive (VFD) connected to a plurality of motors (controlling, using one or more variable frequency drives (VFDs), a plurality of electrical motors to drive at least one fluid pump of the at least one hydraulic fracturing pump unit; Claim 31). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the other motor of Baker to be connected to the VFD as taught by Stewart for the purpose of utilizing the benefits of a VFD to the other motors in the system, the benefits including contributing to energy savings, increasing the efficiency and life of the motor, reducing mechanical wear upon the motor and thus the need for repair (Baker; Paragraph [0019]).

As per claim 9, Baker as modified by Rosman and Stewart discloses the system of claim 8. Baker further discloses a variable frequency drive (VFD), wherein the VFD is positioned to accelerate or decelerate pump rotational speeds associated with the hydraulic pump (variable frequency drive (VFD) 76 connected to motor 34 to control the speed thereof, wherein the VFD is positioned to adjust operating speeds of pump 50; Figure 2; Paragraph [0019-0020]). Baker fails to disclose wherein the VFD comprises a plurality of VFDs connected to a plurality of motors, wherein the plurality of VFDs are configured to share a load required to power the hydraulic pump. Stewart discloses wherein the VFD comprises a plurality of VFDs connected to a plurality of motors, wherein the plurality of VFDs are configured to share a load required to power the hydraulic pump (controlling, using one or more (plurality) variable frequency drives (VFDs), a plurality of electrical motors to drive at least one fluid pump of the at least one hydraulic fracturing pump unit (sharing the load); Claim 31). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the other motor of Baker to have a VFD for the purpose utilizing the benefits of a VFD to the other motors in the system, the benefits including contributing to energy savings, increasing the efficiency and life of the motor, reducing mechanical wear upon the motor and thus the need for repair (Baker; Paragraph [0019]).

As per claim 10, Baker as modified by Rosman and Stewart discloses the system of claim 9. Baker fails to disclose wherein a plurality of VFDs are configured to automatically shut off in the event of an overpressure event with respect to the plurality of hydraulic pumps. Stewart discloses wherein a plurality of VFDs are configured to automatically shut off in the event of an overpressure event with respect to a hydraulic pump (a RUN/STOP will control the fracturing pump unit 700 a in which an e-stop will be supplied to stop the entire fracturing pump unit 700 a, shutting down frac VFDs 410 a, 410 b of motors 411 a, 411 b; the RUN/STOP is initiated when frac VFD 410 a detects the discharge pressure exceeds a overpressure setpoint with respect to hydraulic fracturing pump 710 a, it stops the frac motor 411 as it activates a shutdown; Figures 3 and 6; Paragraphs [0054] and [0062]). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the VFD of Baker to automatically shut down during an overpressure event as taught by Stewart for the purpose of avoiding catastrophic failure in the system.

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As per claim 11, Baker discloses a hydraulic fracturing system for fracturing a subterranean formation (pump system 10 for hydraulic fracturing of a borehole in an adjacent earthen formation (subterranean); Figure 1; Paragraph [0016] and [0021]) comprising: a multi-plunger hydraulic fracturing pump fluidly connected to a well associated with the subterranean formation (pump 50 for hydraulic fracturing of a borehole in an adjacent earthen formation (subterranean), which may be a quintuplex pump having five pistons 146 (plungers); Figure 3; Paragraphs [0016] and [0021]), the multi-plunger 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 (pump 50 for pumping pressurized fluid into a borehole (wellbore) in an adjacent earthen formation (subterranean) for hydraulic fracturing; Figure 3; Paragraphs [0016] and [0021]); a plurality of motors positioned to power the multi-plunger pump (motors 34, 58 positioned to power the pump 50 (multi-plunger pump); Figure 1); a variable frequency drive connected to a motor to control the speeds of the motor (variable frequency drive (VFD) 76 connected to motor 34 to control the speed thereof, wherein the VFD is positioned to adjust operating speeds of pump 50; Figure 2; Paragraph [0019-0020]); and a planetary gear train having an input pinion gear in rotational contact with the plurality of motors (planetary gear system 170 having a input pinion sun gear 174 in rotational contact with motor 58 through drive shaft 60 and motor 34 through gear train 62 to drive shaft 52; Figure 4; Paragraph [0024]), wherein a gear ratio of the planetary gear train and a speed at which the plurality of motors operates are selected so as to limit a maximum pump speed associated with the multi-plunger pump (the gear ratio of planetary gear system 170 allows for gear reduction, allowing for the rotational speed of the drive shaft 60 to convert to a slower rotational speed on the drive shaft 52 of the pump 50 (thereby limiting maximum pump speed); Figures 1 and 4; Paragraph [0024]). Baker fails to disclose a plurality of input pinion gears in rotational contact with each of the plurality of motors. Baker also fails to disclose a variable frequency drive (VFD) connected to a plurality of motors. Rosman discloses a plurality of motors and a plurality of input pinion gears in rotational contact with each of the plurality of motors (see Figures 3-5 wherein pinions 23 having gear teeth 34 are connected rotationally to hydraulic drive motors 21). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the planetary gearing of Baker by having a motor for each associated planet gear as taught by Rosman for the purpose of having smaller motors wherein there is an advantage that the system is less expensive with respect to initial capitalization and maintenance (Rosman; Column 4, Lines 57-59). Stewart discloses a variable frequency drive (VFD) connected to a plurality of motors (controlling, using one or more variable frequency drives (VFDs), a plurality of electrical motors to drive at least one fluid pump of the at least one hydraulic fracturing pump unit; Claim 31). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the other motor of Baker to be connected to the VFD as taught by Stewart for the purpose of utilizing the benefits of a VFD to the other motors in the system, the benefits including contributing to energy savings, increasing the efficiency and life of the motor, reducing mechanical wear upon the motor and thus the need for repair (Baker; Paragraph [0019]).

As per claim 12, Baker as modified by Rosman and Stewart discloses the system of claim 11. Baker fails to disclose the system further comprising a plurality of speed reduction gearboxes positioned between the plurality of input pinion gears and the plurality of motors so as to achieve a desired pump rate. Rosman discloses a plurality of speed reduction gearboxes positioned between a plurality of input pinion gears and a plurality of motors (gear boxes 22 are positioned between a plurality of pinions 23 having gear teeth 23 and a plurality of hydraulic drive motors 21; gear boxes are designed to increase torque while reducing speed of the output shaft; Figures 3-5; Column 4, Lines 46-62). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the gearing of Baker by having a motor for each associated planet gear as well as gear boxes as taught by Rosman resulting in a desired pump rate for the purpose of having smaller motors wherein there is an advantage that the system is less expensive with respect to initial capitalization and maintenance (Rosman; Column 4, Lines 57-59) and developing the amount of torque necessary to rotate ring members with high loads (Rosman; Column 4, Lines 60-62)).

As per claim 13, Baker as modified by Rosman and Stewart discloses the system of claim 11. Baker fails to disclose wherein a plurality of motors comprises one of a plurality of electric motors or a plurality of hydraulic motors. Rosman discloses wherein a plurality of motors comprises one of a plurality of electric motors or a plurality of hydraulic motors (hydraulic drive motors 21; Figure 4). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the motor of Baker with the plurality of hydraulic motors as taught by Rosman for the purpose for the purpose of utilizing a motor which can generate high torques without excessive size.

As per claim 19, Baker as modified by Rosman discloses the method of claim 15. Baker discloses further comprising: connecting a variable frequency drive (VFD) to the motor so as to control the speed of the motor, wherein the VFD is positioned to accelerate or decelerate pump rotational speeds associated with each of the hydraulic pump (variable frequency drive (VFD) 76 connected to motor 34 to control the speed thereof, wherein the VFD is positioned to adjust operating speeds of pump 50; Figure 2; Paragraph [0019-0020]). Baker fails to disclose a variable frequency drive (VFD) connected to a plurality of motors. Stewart discloses a variable frequency drive (VFD) connected to a plurality of motors (controlling, using one or more variable frequency drives (VFDs), a plurality of electrical motors to drive at least one fluid pump of the at least one hydraulic fracturing pump unit; Claim 31). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the other motor of Baker to be connected to the VFD as taught by Stewart for the purpose of utilizing the benefits of a VFD to the other motors in the system, the benefits including contributing to energy savings, increasing the efficiency and life of the motor, reducing mechanical wear upon the motor and thus the need for repair (Baker; Paragraph [0019]).

As per claim 20, Baker as modified by Rosman and Stewart discloses the method of claim 19. Baker fails to disclose detecting an overpressure event with respect to the hydraulic pump; and automatically shutting off the VFD. Stewart discloses wherein a VFD is configured to automatically shut off in the event of an overpressure event with respect to a hydraulic pump (when frac VFD 410 detects the discharge pressure exceeds a overpressure setpoint with respect to hydraulic fracturing pump 710 a, it stops the frac motor 411 as it activates a shutdown; Figure 6; Paragraph [0062]). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the VFD of Baker to automatically shut down during an overpressure event as taught by Stewart for the purpose of avoiding catastrophic failure in the system.

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In case the space in any of the preceding boxes is not sufficient.
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-***-Continued from Previous Supplemental Box-***-
Claim 14 lacks an inventive step under PCT Article 33(3) as being obvious over BAKER in view of ROSMAN further in view of STEWART further in view of MAIL.

As per claim 14, Baker as modified by Rosman and Stewart discloses the system of claim 11. Baker fails to disclose wherein the maximum pump speed correlates to a critical plunger speed associated with each of the plurality of hydraulic pumps. Mail discloses wherein a maximum pump speed correlates to a critical plunger speed associated with a hydraulic pump (mainstream methods of subsurface downhole pumping (hydraulic pump) include mounted reciprocating mechanisms (plunger) in a casing tube; optimal speeds of up and down strokes can be defined as maximum speeds that will not cause overstressing of pump rod (critical plunger speed), therefore maximum pumping speed correlates to an operation at optimal up and down stroke speed (critical plunger speed) associated with the hydraulic pump; Column 1, Lines 29-33, 39-48, 53-54, 64-67 and Column 2, Lines 1-3). It would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the maximum pump speed of Baker by correlating it to the critical plunger speed as taught by Mail for the purpose of avoiding overstressing of structural parts and premature damage (Baker; Column 1, Lines 64-67 and Column 2, Lines 1-3).

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

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)* 10 APR 2019
Applicant's or agent's file reference 047158.500037	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2019/016635	International filing date *(day/month/year)* 05 February 2019
Applicant U.S. WELL SERVICES, INC.	

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, Fac**simile** 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 PCT Helpdesk: 571-272-4300 Telephone No. 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 047158.500037	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2019/016635	International filing date *(day/month/year)* 05 February 2019	(Earliest) Priority Date *(day/month/year)* 05 February 2018
Applicant U.S. WELL SERVICES, INC.		

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. 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/US2019/016635

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.01)
CPC - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.02)

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 - 700/295; 166/305.1, 166/308.1; 700/293 (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 2016/0105022 A1 (US WELL SERVICES LLC) 14 April 2016 (14.04.2016) entire document	1-4, 15, 19, 20
---		---
Y		5, 7-12, 14, 16, 18
Y	US 2010/0019574 A1 (BALDASSARRE et al) 28 January 2010 (28.01.2010) entire document	5
Y	CA 2 964 593 A1 (US WELL SERVICES LLC) 15 October 2017 (15.10.2017) entire document	7-12, 14, 16, 18
A	US 2016/0369609 A1 (EVOLUTION WELL SERVICES, LLC) 22 December 2016 (22.12.2016) 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
25 March 2019	10 APR 2019
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)*	10 APR 2019
Applicant's or agent's file reference 047158.500037	FOR FURTHER ACTION See paragraph 2 **below**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/016635	05 February 2019	05 February 2018

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.01)
CPC - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.02)

Applicant U.S. WELL SERVICES, INC.

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	25 March 2019	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/US2019/016635

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/US2019/016635

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	5-14, 16-18	YES
	Claims	1-4, 15, 19, 20	NO
Inventive step (IS)	Claims	6, 13, 17	YES
	Claims	1-5, 7-12, 14-16, 18-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-4, 15, 19, and 20 lack novelty under PCT Article 33(2) as being anticipated by US Well Services LLC (hereinafter USWell**022**).

Regarding Claim 1, USWell022 discloses a system for completing a well (a hydraulic fracturing operation can be carried out according to the following process... The fracturing fluid can be pumped into the wellbore at a high enough pressure that the fracturing fluid cracks the formation, para 0042), the system comprising: a generator (generators 222A, 222B, para 0045; also see Fig. 5); a plurality of electric load components, each electric load component powered by the generator (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5); and a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of electric load components to reduce the electric load (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if one of the turbines loses power,... [in prior art] the ability to shed load, such as by shutting down power to non-critical parts of the system, is limited. The power draw from all of the units overloads the turbines, para 0006; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).

Regarding Claim 2, USWell022 discloses the system of claim 1, further comprising: a switch gear positioned between the generator and the plurality of electric load components to distribute power between the generator and the plurality of electric load components (The power from the generators 222A of group A goes to switchgear 235A. From switchgear 235A, the power goes to the transformers 223A, and to the auxiliary trailer 225A, which can have a transformer, as well as a VFD and softstarts for the blender and hydration units. Power can then go to one or more of the following: the primary blender 234A, the primary hydration unit 232A, the primary data van 227A, and/or the primary sand equipment 229A. Power from the transformers 223A also goes to pumps 210A., para 0050; also see Fig. 5).

Regarding Claim 3, USWell022 discloses the system of claim 1, wherein the generator is a natural gas turbine generator, a natural gas generator, or a diesel generator (the electric generators 22 can be powered by natural gas., para 0027).

Regarding Claim 4, USWell022 discloses the system of claim 1, wherein the electric load components are selected from the group consisting of electric hydraulic fracturing pumps, a blender, sand equipment, a hydration unit, and a data van (Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B, as well as separate and distinct auxiliary trailers 225A, 225B, each including its own ancillary equipment, such as, for example, data vans 227A, 227B, sand equipment 229A, 229B, blenders 234A, 234B, and hydration units 232A, 232B, para 0045; also see Fig. 5).

Regarding Claim 15, USWell022 discloses a method of completing a well (a hydraulic fracturing operation can be carried out according to the following process... The fracturing fluid can be pumped into the wellbore at a high enough pressure that the fracturing fluid cracks the formation, para 0042), the method comprising the steps of: a) powering a plurality of hydraulic fracturing equipment components with a generator (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5); b) monitoring the generator to determine when the generator loses functionality; c) when the generator loses functionality, selectively deactivating one or more of the plurality of hydraulic fracturing equipment components to decrease the load (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if one of the turbines loses power,... [in prior art] the ability to shed load, such as by shutting down power to non-critical parts of the system, is limited. The power draw from all of the units overloads the turbines, para 0006; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).

Regarding Claim 19, USWell022 discloses the method of claim 15, further comprising: distributing power between the generator and the plurality of hydraulic fracturing equipment components with a switchgear (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5)

Supplemental Box

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

Regarding Claim 20, USWell022 discloses the method of claim 15, wherein step c) is carried out by a load shedding control panel that monitors the generator to determine when the generator loses functionality (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).

Claim 5 lacks an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter USWell022) in view of Baldassarre et al. (hereinafter Baldassarre).

Regarding Claim 5, USWell022 fails to disclose the system of claim 4, wherein the load shedding panel prioritizes the order in which the plurality of electric load components will be deactivated. Baldassarre is in the field of energy management systems (para 0002) and teaches wherein the load shedding panel prioritizes the order in which the plurality of electric load components will be deactivated (loads are shed in the predetermined sequence established by a user and/or as defined by a user in real-time via a user interactive device until the total current is less than the predetermined peak total or until the system has detected a stable current situation, para 0058; the control system can store this information and statistically translate it to determine the priority of each sensed load, and subsequently create a priority list to be implemented by an auxiliary power source in the instance when the utility power source fails, para 0076). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of Baldassarre for the purpose of shedding lower priority loads based on predetermined priority or real-time decisions made by the user so as to ensure that the vital loads remain connected and active while the auxiliary or generator power source remains below a threshold value (see Baldassarre, para 0130).

Claims 7-12, 14, 16, and 18 lack an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter USWell022) in view of US Well Services LLC (hereinafter USWell593).

Regarding Claim 7, USWell022 fails to disclose the system of claim 1, wherein the generator is in selective electrical communication with a power grid.
USWell593 is in the field of hydraulic fracturing (para 0002) and teaches wherein the generator is in selective electrical communication with a power grid (FIG. 14 illustrates an example 1400 of a configuration for load sharing with a utility grid, according to an embodiment, para 0085; enable the switchgear units -B+- 1425-b and "C+- 1425-c to load share between the generator sets 1405-a, 1405-b, 1405-c, 1405- d and the utility grid. For example, if the utility grid is transmitting power at 69 kV, the transformer 1445 can step down the 69kV voltage to 13.8 kV for use by the microgrid. In this configuration, power can be either provided to the grid or supplemented from the utility grid during times of peak power demand, para 0086). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of allowing for power transfer to and from the grid as needed (see USWell593, para 0086).

Regarding Claim 8, USWell022 discloses a system for completing a well (a hydraulic fracturing operation can be carried out according to the following process... The fracturing fluid can be pumped into the wellbore at a high enough pressure that the fracturing fluid cracks the formation, para 0042), the system comprising: a generator (generators 222A, 222B, para 0045; also see Fig. 5); a plurality of hydraulic fracturing equipment components, each of the plurality of hydraulic fracturing equipment components powered by the generator (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B, as well as separate and distinct auxiliary trailers 225A, 225B, each including its own ancillary equipment, such as, for example, data vans 227A, 227B, sand equipment 229A, 229B, blenders 234A, 234B, and hydration units 232A, 232B [hydraulic fracturing components], para 0045; also see Fig. 5); an electric equipment, the electric equipment powered by the generator; and a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of hydraulic fracturing equipment components or the electric equipment to reduce the electric load (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if one of the turbines loses power,... [in prior art] the ability to shed load, such as by shutting down power to non-critical parts of the system, is limited. The power draw from all of the units overloads the turbines, para 0006; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).
USWell022 does not disclose wherein the electric equipment is an electric drilling rig. USWell593 discloses wherein the electric equipment is an electric drilling rig (The power generation equipment can be used to supply any oilfield equipment including... drilling rigs, para 0044). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of providing power for oilfield equipment that doe not have access to a utility provided power grid or that has a dynamic power load or low power factor(see USWell593, para 008644).

Supplemental Box

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

Regarding Claim 9, modified USWell022 discloses the system of claim 8, further comprising: a switch gear positioned between the generator and the plurality of hydraulic fracturing equipment components, and between the generator and the electric equipment, to distribute power between the generator and the plurality of hydraulic fracturing equipment components, and between the generator and the electric equipment (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5).
USWell022 does not disclose wherein the electric equipment is an electric drilling rig. USWell593 discloses wherein the electric equipment is an electric drilling rig (The power generation equipment can be used to supply any oilfield equipment including... drilling rigs, para 0044) It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of providing power for oilfield equipment that doe not have access to a utility provided power grid or that has a dynamic power load or low power factor(see USWell593, para 008644).

Regarding Claim 10, modified USWell022 discloses the system of claim 8, wherein the generator is a natural gas turbine generator, a natural gas generator, or a diesel generator (the electric generators 22 can be powered by natural gas., para 0027).

Regarding Claim 11, modified USWell022 discloses the system of claim 8, wherein the hydraulic fracturing equipment components are selected from the group consisting of electric hydraulic fracturing pumps, a blender, sand equipment, a hydration unit, and a data van (Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B, as well as separate and distinct auxiliary trailers 225A, 225B, each including its own ancillary equipment, such as, for example, data vans 227A, 227B, sand equipment 229A, 229B, blenders 234A, 234B, and hydration units 232A, 232B, para 0045; also see Fig. 5).

Regarding Claim 12, modified USWell022 fails to disclose the system of claim 11, wherein the load shedding panel prioritizes the order in which the plurality of hydraulic fracturing equipment components and the electric drilling rig will be deactivated. USWell593 teaches wherein the load shedding panel prioritizes the order in which the plurality of hydraulic fracturing equipment components and electric equipment will be deactivated (loads are shed in the predetermined sequence established by a user and/or as defined by a user in real-time via a user interactive device until the total current is less than the predetermined peak total or until the system has detected a stable current situation, para 0058; the control system can store this information and statistically translate it to determine the priority of each sensed load, and subsequently create a priority list to be implemented by an auxiliary power source in the instance when the utility power source fails, para 0076). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of Baldassarre for the purpose of shedding lower priority loads based on predetermined priority or real-time decisions made by the user so as to ensure that the vital loads remain connected and active while the auxiliary or generator power source remains below a threshold value (see Baldassarre, para 0130)

Regarding Claim 14, modified USWell022 fails to disclose the system of claim 8, wherein the generator is in selective electrical communication with a power grid. USWell593 teaches wherein the generator is in selective electrical communication with a power grid (FIG. 14 illustrates an example 1400 of a configuration for load sharing with a utility grid, according to an embodiment, para 0085; enable the switchgear units -B+- 1425-b and "C+- 1425-c to load share between the generator sets 1405-a, 1405-b, 1405-c, 1405-d and the utility grid. For example, if the utility grid is transmitting power at 69 kV, the transformer 1445 can step down the 69kV voltage to 13.8 kV for use by the microgrid. In this configuration, power can be either provided to the grid or supplemented from the utility grid during times of peak power demand, para 0086). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of allowing for power transfer to and from the grid as needed (see USWell593, para 0086).

Regarding Claim 16, USWell022 fails to explicitly disclose the method of claim 15, further comprising: powering an electric drilling rig with the generator. USWell593 discloses wherein the electric equipment is an electric drilling rig (The power generation equipment can be used to supply any oilfield equipment including... drilling rigs, para 0044) It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of providing power for oilfield equipment that doe not have access to a utility provided power grid or that has a dynamic power load or low power factor(see USWell593, para 008644).

Regarding Claim 18, USWell022 fails to discloses the method of claim 15, further comprising: distributing power from the generator to a power grid. USWell593 teaches distributing power from the generator to a power grid (FIG. 14 illustrates an example 1400 of a configuration for load sharing with a utility grid, according to an embodiment, para 0085; enable the switchgear units -B+- 1425-b and "C +- 1425-c to load share between the generator sets 1405-a, 1405-b, 1405-c, 1405- d and the utility grid. For example, if the utility grid is transmitting power at 69 kV, the transformer 1445 can step down the 69kV voltage to 13.8 kV for use by the microgrid. In this configuration, power can be either provided to the grid or supplemented from the utility grid during times of peak power demand, para 0086). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of allowing for extra power generated to be fed to the grid (see USWell593, paras 0086 and 0088).

Claims 6, 13, and 17 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest:

Regarding claim 6, the prior art of record, individually or in combination, does not teach or fairly suggest the system of claim 5, wherein the load shedding panel is programmed to deactivate the blender after other electric load components are deactivated.

Regarding claim 13, the prior art of record, individually or in combination, does not teach or fairly suggest the system of claim 12, wherein the load shedding panel is programmed to deactivate the blender after other hydraulic fracturing equipment components are deactivated.

LIBERTY EXHIBIT 1056, Page 697

Supplemental Box

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

Regarding claim 17, the prior art of record, individually or in combination, does not teach or fairly suggest the method of claim 15, wherein the plurality of hydraulic fracturing equipment includes at least one blender, the method further comprising: prioritizing the deactivation of the plurality of hydraulic fracturing equipment components so that the at least one blender is deactivated only after other hydraulic fracturing equipment is deactivated.

Claims 1-20 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.

Search History:

Limited Classification Search

The Patent Analyst performed a limited classification search within the following US, IPC, CPC, ECLA, or F-Term classification areas:

CPC Class/Subclass(es): H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.02)

IPC (8) Class/Subclass(es): H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.01)

U.S. Class/Subclass(es): 700/295; 166/305.1; 166/308.1; 700/293

See Global Search Results.

Global Patent Literature Text Search

The Patent Analyst performed the following global text search, which was not limited by classification but may or may not have been limited by other criteria:

Questel Orbit: **https://www.orbit.com**

#	Search query	Results
1	((BRANDON 2D HINDERLITER)/IN/OIN/INH/INV)	24
2	((JARED 2D OEHRING)/IN/OIN/INH/INV)	34
3	((WELL W SERVICES)/PA/OPA)	214
4	(1 OR 2) AND 3	35
5	1 OR 2 OR 3	214
6	5 AND (LOAD W SHED+)/TX	5
7	5 AND (LOAD W SHED+)/TX AND RIG/TX	2
8	(HYDRAULIC AND FRACTUR+ AND (LOAD W SHED+) AND (DRILLING W RIG))/TX	7
9	5 AND ((LOAD W SHED+) AND (CONTROL W PANEL))/TX	1
10	5 AND (PRIORITIZ+)/TX	0
11	(HYDRAULIC AND FRACTUR+ AND BLENDER AND (LOAD W SHED+))/TX	6
12	(CA2964593)/XPN	1
13	(LOAD W SHED+)/TI/AB	1126
14	(700295)/PCL	1333
15	(700293)/PCL	390
16	(166308100)/PCL	1261
17	(166305100)/PCL	1957
18	14 OR 15 OR 16 OR 17	4711

19	18 AND (HYDRAULIC AND FRACTURING)/TX	1567
20	18 AND (HYDRAULIC AND FRACTURING AND SHED+)/TX	10
21	(E21B-043/26)/CPC	5467
22	(E21B-043/26)/IPC	9814
23	(F04D-013/06)/IPC	12913
24	(F04D-013/06)/CPC	5242
25	(H02J-003/14)/CPC	4245
26	(H02J-003/14)/IPC	5368
27	(H02J-003/12)/IPC	3841
28	(H02J-003/12)/CPC	1026
29	21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28	34106
30	29 AND (LOAD W SHED+)/TX	963
31	29 AND (HYDRAULIC AND FRACTUR+ AND (LOAD W SHED+))/TX	7
32	29 AND (HYDRAULIC AND DRILL+ AND (LOAD W SHED+))/TX	4

Google Patents: **https://patents.google.com**

#	Search query	Results
1	hydraulic fracturing generator control	100+
2	hydraulic fracturing generator control load shedding	100+
3	MICROGRID ELECTRICAL LOAD MANAGEMENT for hydraulic fracturing	100+
4	hydraulic fracturing generator load shedding prioritize	100+
5	drilling generator load shedding prioritize	100+
6	generator load control prioritize	100+
7	generator load control prioritize blender drilling	100+
8	hydraulic fracturing blender turned off last	100+
9	generator powered earth equipment blender turned off last	100+

Computer Accessed Text Databases Searched

The Patent Analyst searched the following computer accessed text databases:

Google **Scholar: https**://scholar.**google**.com/

#	Search query	Results
1	hydraulic fracturing generator control	100+
2	hydraulic fracturing generator control load shedding	100+

3	MICROGRID ELECTRICAL LOAD MANAGEMENT for hydraulic fracturing	100+
4	drilling generator load shedding prioritize	100+
5	generator load control prioritize	100+
6	generator load control prioritize blender drilling	100+
7	hydraulic fracturing blender turned off last	100+
8	generator powered earth equipment blender turned off last	100+

Date search was completed: 25 March 2019

SV/CC

Electronic Acknowledgement Receipt

EFS ID:	39747156
Application Number:	16728359
International Application Number:	
Confirmation Number:	6981
Title of Invention:	SYSTEM AND METHOD FOR INTEGRATED FLOW SUPPLY LINE
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:	047158.100066
Receipt Date:	17-JUN-2020
Filing Date:	27-DEC-2019
Time Stamp:	14:44:46
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)	100066_IDS_3.pdf	1036834 2a56d796524b6dcfd49e437902343a42e5cc0e57	no	12

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2	Other Reference-Patent/App/Search documents	NPL-11.pdf	319654 1ee46a247454ff0dd9d92bed6222456ebcec32d2	no	9
Warnings:					
Information:					
3	Other Reference-Patent/App/Search documents	NPL-12.pdf	340896 57fa5ec905f2dff11900bae08fe2c1ae7d586cd0	no	11
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4	Other Reference-Patent/App/Search documents	NPL-13.pdf	259841 5f66125dc394653d57c51b94ba84af54feb7372d	no	7
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5	Other Reference-Patent/App/Search documents	NPL-14.pdf	262664 9c0c180fcc9b33718242d725da4cc0206ab0e2cf	no	8
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Information:					
6	Other Reference-Patent/App/Search documents	NPL-15.pdf	323644 5c824a3955835c2a142fff6c8e89cfe093966fb8	no	10
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7	Other Reference-Patent/App/Search documents	NPL-16.pdf	409079 517bae45b327c03f1344ada3b1defb6f3e1dba36	no	10
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8	Other Reference-Patent/App/Search documents	NPL-17.pdf	1086569 5d7f47f6f6428d775a89ea76cf6492dfdd7874c7	no	23
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9	Other Reference-Patent/App/Search documents	NPL-18.pdf	1060055 7ce3425ddf68db8e6fc813b084b87082f754a370	no	29
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14	Other Reference-Patent/App/Search documents	NPL-23.pdf	477768 9097bec4a06bf1a58255709a299ccf572669a5e2	no	14
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16	Other Reference-Patent/App/Search documents	NPL-25.pdf	377985 237e2**c85af09d19cf7cb543c47313c5**a45dd**b5ad**	no	7
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18	Other Reference-Patent/App/Search documents	NPL-27.pdf	513370 61384**6c97d5a97f394676e8db875d3**8ebbc**6a14c**	no	14
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19	Other Reference-Patent/App/Search documents	NPL-28.pdf	259116 a14d6**a19e09f39b424e07487c378c1**ff22b9**eaab**	no	8
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20	Other Reference-Patent/App/Search documents	NPL-29.pdf	246974 90f86**007da0c8c3e09c6f313efbbd81**65e8b**46c7**	no	7
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Information:					

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27	Other Reference-Patent/App/Search documents	NPL-36.pdf	214752 faa678d394f7cde3d00109e900e2ee8a3df7a63f	no	7
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29	Other Reference-Patent/App/Search documents	NPL-38.pdf	665357 36b902d632a1627341950fd2f01f5d30c9ebd86d	no	13
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35	Other Reference-Patent/App/Search documents	NPL44.pdf	291386 db0150c7b78b89c53eba87ae7e9409c801c88419	no	9
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Information:					
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National Stage of an International Application under 35 U.S.C. 371

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PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16728359
Filing Date	2019-12-27
First Named Inventor	Jared Oehring
Art Unit	3679
Examiner Name	Aaron Lloyd Lembo
Attorney Docket Number	047158.100066

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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	10280724		2019-05-07	Hinderliter	
	2	10254732		2019-04-09	Oehring	
	3	10232332		2019-03-19	Oehring	
	4	5172009		1992-12-15	Mohan	
	5	6484490		2002-11-26	Olsen	
	6	7581379		2009-09-01	Yoshida	
	7	8616005		2013-12-31	Cousino	
	8	10008880		2018-06-26	Vicknair	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

	9	5755096		1998-05-26	Holleyman	
	10	2407796		1946-09-17	Page	
	11	2416848		1947-03-04	Rothery	
	12	7984757		2011-07-26	Keast	
	13	10407990		2019-09-10	Oehring	

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	1	20170218727		2017-08-03	Oehring	
	2	20150136043		2015-05-21	Shaaban	
	3	20160105022		2016-04-14	Oehring	
	4	20160265457		2016-09-15	Stephenson	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16728359
	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

	5	20140219824		2014-08-07	Burnette	
	6	20160281484		2016-09-29	Lestz	
	7	20190010793		2019-01-10	Hinderliter	
	8	20150211512		2015-07-30	Wiegman	
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	10	20120049625		2012-03-01	Hopwood	
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	14	20170218727		2017-08-03	Oehring	
	15	20150136043		2015-05-21	Shaaban	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

	16	20190112910		2019-04-18	Oehring	
	17	20170096885		2017-04-06	Oehring	
	18	20100045109		2010-02-25	Arnold	
	19	20030056514		2003-03-27	Lohn	
	20	20080264625		2008-10-30	Ochoa	
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	23	20160290563		2016-10-06	Diggins	
	24	20170159570		2017-06-08	Bickert	
	25	20140255214		2014-09-11	Burnette	
	26	20190245348		2019-08-08	Hinderliter	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16728359
	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

	27	20190211661		2019-07-11	Reckels	
	28	20190169971		2019-06-06	Oehring	
	29	20100038907		2010-02-18	Hunt	
	30	20190162061		2019-05-30	Stepheson	
	31	20190178235		2019-06-13	Coskrey	
	32	20190063309		2019-02-28	Davis	
	33	20040167738		2004-08-26	Miller	

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	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	2707269	CA		2010-12-09	Kidd		X

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16728359
	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

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	Non-Final Office Action issued in corresponding Application No. 16/170,695 dated June 7, 2019	☒
	2	Non-Final Office Action issued in corresponding Application No. 16/268,030 dated May 10, 2019	☒
	3	Final Office Action issued in corresponding Application No. 16/210,749 dated June 11, 2019	☒
	4	Canadian Office Action mailed May 30, 2019 in corresponding CA Application No. 2,833,711	☒
	5	Canadian Office Action mailed June 20, 2019 in corresponding CA Application No. 2,964,597	☒
	6	International Search Report and Written Opinion mailed July 9, 2019 in related PCT Application No. PCT/US2019/027584	☒
	7	Office Action mailed June 7, 2019 in related U.S. Application No. 16/268,030	☒
	8	International Search Report and Written Opinion mailed September 11, 2019 in related PCT Application No. PCT/US2019/037493	☒
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	Application Number	16728359
	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

	11	Office Action mailed September 11, 2019 in related U.S. Patent Application No. 16/268,030	☒
	12	Office Action mailed October 11, 2019 in related U.S. Patent Application No. 16/385,070	☒
	13	Office Action mailed September 3, 2019 in related U.S. Patent Application No. 15/994,772	☒
	14	Office Action mailed September 20, 2019 in related U.S. Patent Application No. 16/443,273	☒
	15	Canadian Office Action mailed October 1, 2019 in related Canadian Patent Application No. 2,936,997	☒
	16	International Search Report and Written Opinion mailed November 26, 2019 in related PCT Application No. PCT/US19/51018	☒
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	Application Number	16728359
	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

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).

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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)	2020-06-17
Name/Print	Taylor P. Evans	Registration Number	60506

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609 MAIN STREET, SUITE 4200
HOUSTON, TX 77002

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(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 09 JUL 2019
Applicant's or agent's file reference 047158.500040	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2019/027584	International filing date *(day/month/year)* 16 April 2019
Applicant U.S. WELL SERVICES, INC.	

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 PCT Helpdesk: 571-272-4300 Telephone No. 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 047158.500040	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2019/027584	International filing date *(day/month/year)* 16 April 2019	(Earliest) Priority Date *(day/month/year)* 16 April 2018
Applicant U.S. WELL SERVICES, INC.		

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.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/027584

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - **E21B 41/00; E21B 21/06; E21B 43/12**; E21B 44/00; F04B 17/03; **F04B 17/05 (2019.01)**

CPC - **E21B 41/0092**; E21B 21/06; E21B 41/00; E21B 41/0085; E21B **43/12**; **E21B 44/00**; F04B 17/03; **F04B 17/05**; F04B 17/06 (2019.05)

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 - 166/53; 166/65.1; 166/66.4; 166/177.5; 166/250.1; 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 2016/0105022 A1 (US WELL SERVICES LLC) 14 April 2016 (14.04.2016) entire document	1, 2, 4, 5, 9-11, 13, 14
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Y		3, 6-8, 12
Y	US 2016/0265457 A1 (HALLIBURTON ENERGY SERVICES, INC.) 15 September 2016 (15.09.2016) entire document	3, 12
Y	US 2016/0369609 A1 (EVOLUTION WELL SERVICES, LLC) 22 December 2016 (22.12.2016) entire document	6, 7
Y	US 4,432,064 A (BARKER et al) 14 February 1984 (14.02.1984) entire document	8
A	US 2014/0290768 A1 (FTS INTERNATIONAL SERVICES, LLC) 02 October 2014 (02.10.2014) entire document	1-14

☐ 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
10 June 2019	09 JUL 2019
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)*	09 JUL 2019

Applicant's or agent's file reference	FOR FURTHER ACTION
047158.500040	See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/027584	16 April 2019	16 April 2018

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 41/00; E21B 21/06; E21B 43/12; E21B 44/00; F04B 17/03; F04B 17/05 (2019.01)
CPC - E21B 41/0092; E21B 21/06; E21B 41/00; E21B 41/0085; E21B 43/12; E21B 44/00; F04B 17/03; F04B 17/05; F04B 17/06 (2019.05)

Applicant U.S. WELL SERVICES, INC.

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
- [ ] 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	10 June 2019	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/US2019/027584

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/US2019/027584

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	3, 6-8, 12	YES
	Claims	1, 2, 4, 5, 9-11, 13, 14	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-14	NO
Industrial applicability (IA)	Claims	1-14	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1, 2, 4, 5, 9-11, 13, and 14 lack novelty under PCT Article 33(2) as being anticipated by US Well Services LLC (hereinafter US Well Services).

Regarding Claim 1, US Well Services discloses a hydraulic fracturing fleet (Figs. 1-5, Para. [0019] regarding a hydraulic fracturing operation having a plurality of pumps mounted to vehicles), characterized by: a datavan (data vans 227A, 227B, Fig. 5, data vans 227A, 227B, Para. [0045]) for engaging an interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]), the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]) characterized by at least one back-up component that is either or both of diesel-powered (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and electric-powered; a controller (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031]) executing a software module (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031], inherent that the programmable logic controller with touchscreen interface would have a software module) for determining a type (conventional diesel or bi-fuel powered frack system . . . the electric system, Para. [0052]) of a connected component (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B) to the datavan (data vans 227A, 227B), the type (conventional diesel or bi-fuel powered frack system . . . the electric system, Para. [0052]) associated with the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]); and switching components (a transfer switch could be used to switch, Para. [0052]) associated with the datavan (data vans 227A, 227B) for switching (a transfer switch could be used to switch, Para. [0052]) between the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]) upon determination, by the controller (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031]), of the type (conventional diesel or bi-fuel powered frack system . . . the electric system, Para. [0052]) of the connected component (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B).

Regarding Claim 2, US Well Services discloses the hydraulic fracturing fleet of claim 1, further characterized by: multi-pump controls (the hydraulic fracturing pumps can be split evenly between the banks, Para. [0049], an A/C console that controls the VFD 15, and thus the speed of the electric motor 14 and the pump 16, other pump control and data monitoring equipment can include pump throttles, Para. [0031]) in the datavan (data vans 227A, 227B, Fig. 5) for controlling a diesel (at pumps 210A, 210B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) or an electric pump (at pumps 210A, 210B, Fig. 5, the electric system, Para. [0052]) in the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]).

Supplemental Box

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

Regarding Claim 4, US Well Services discloses the hydraulic fracturing fleet of claim 1, further characterized by: electric (at blenders 234A, 234B, Fig. 5, the electric system, Para. [0052]) and diesel blenders (at blenders 234A, 234B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) in the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]), the electric (at blenders 234A, 234B, Fig. 5, the electric system, Para. [0052]) and the diesel blenders (at blenders 234A, 234B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) further being associated with back-up counterpart blenders (at blenders 234A, 234B, Fig. 5, in addition, although two groups A, B are shown in FIG. 5, more than two groups can be used . . . a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052]).

Regarding Claim 5, US Well Services discloses the hydraulic fracturing fleet of claim 1, further characterized by: a pump operator station (at data vans 227A, 227B, Fig. 5, communicating with an operator via one or more user interfaces, Para. [0024]) comprised in the datavan (data vans 227A, 227B) for enabling operator control (provide information to an operator, and to allow the operator to control different parameters of the fracturing operation, Para. [0031]) of the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]) or with back-up (kept separate to create redundancy and backup capabilities in the system, Para. [0048]) counterpart components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, in addition, although two groups A, B are shown in FIG. 5, more than two groups can be used, Para. [0052]) that are either diesel powered (a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) or electric-powered (the electric system, Para. [0052]).

Regarding Claim 9, US Well Services discloses the hydraulic fracturing fleet of claim 1, further characterized by: a redundant diesel or electric power (generators 222A, 222B, Fig. 5, two or more generators 222A, 222B grouped into two or more banks of power, which are kept separate to create redundancy and backup capabilities in the system, Para. [0048], electric power generation, Para. [0046]) to power the datavan (data vans 227A, 227B) from the hydraulic fracturing fleet (as shown in Fig. 5) or a remote station

Regarding Claim 10, US Well Services discloses a method of operating a hydraulic fracturing fleet (Figs. 1-5; Para. [0019] regarding a hydraulic fracturing operation having a plurality of pumps mounted to vehicles), characterized by: engaging, using a datavan (data vans 227A, 227B, Fig. 5, data vans 227A, 227B, Para. [0045]), an interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]), the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]) characterized by at least one back-up component that is either or both of diesel-powered (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and electric-powered; determining, by a software module (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031], inherent that the programmable logic controller with touchscreen interface would have a software module) executing on a controller (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031]), a type (conventional diesel or bi-fuel powered frack system . . . the electric system, Para. [0052]) of a connected component (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B) to the datavan (data vans 227A, 227B), the type (conventional diesel or bi-fuel powered frack system . . . the electric system, Para. [0052]) associated with the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]); and switching, by switching components (a transfer switch could be used to switch, Para. [0052]) associated with the datavan (data vans 227A, 227B), between the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]) upon determination by the controller (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031]) of the type (conventional diesel or bi-fuel powered frack system . . . the electric system, Para. [0052]) of the connected component (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B).

Supplemental Box

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

Regarding Claim 11, US Well Services discloses the method of claim 10, further characterized by: controlling, by multi-pump controls (the hydraulic fracturing pumps can be split evenly between the banks, Para. [0049], an A/C console that controls the VFD 15, and thus the speed of the electric motor 14 and the pump 10, other pump control and data monitoring equipment can include pump throttles, Para. [0031]) in the datavan (data vans 227A, 227B, Fig. 5), a diesel (at pumps 210A, 210B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) or an electric pump (at pumps 210A, 210B, Fig. 5, the electric system, Para. [0052]) in the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]).

Regarding Claim 13, US Well Services discloses the method of claim 10, further characterized by: electric (at blenders 234A, 234B, Fig. 5, the electric system, Para. [0052]) and diesel blenders (at blenders 234A, 234B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) in the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]), the electric (at blenders 234A, 234B, Fig. 5, the electric system, Para. [0052]) and the diesel blenders (at blenders 234A, 234B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) further being associated with back-up counterpart blenders (at blenders 234A, 234B, Fig. 5, in addition, although two groups A, B are shown in FIG. 5, more than two groups can be used . . . a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052]).

Regarding Claim 14, US Well Services discloses the method of claim 10, further characterized by: enabling, from a pump operator station (at data vans 227A, 227B, Fig. 5, communicating with an operator via one or more user interfaces, Para. [0024]) comprised in the datavan (data vans 227A, 227B), operator control (provide information to an operator, and to allow the operator to control different parameters of the fracturing operation, Para. [0031]) of the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para. [0052]) or the back-up (kept separate to create redundancy and backup capabilities in the system, Para. [0048]) counterpart components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B) that are either diesel powered (a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) or electric-powered (the electric system, Para. [0052])

Claims 3 and 12 lack an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter US Well Services) in view of Halliburton Energy Services, Inc. (hereinafter Halliburton Energy Services).

Regarding Claim 3, US Well Services discloses the hydraulic fracturing fleet of claim 1, further characterized by: the switching components (a transfer switch could be used to switch, Para. [0052]) configured to communicate with the software module (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031], inherent that the programmable logic controller with touchscreen interface would have a software module) and to receive frequency levels (other pump control and data monitoring equipment can include pump throttles, a VFD fault indicator with a reset, Para. [0031], a variable frequency drive (VFD) 15, Para. [0021]) for a variable frequency drive (as well as a VFD, Para. [0050], each electric motor 14 can be equipped with a variable frequency drive (VFD) 15, and an A/C console, that controls the speed of the electric motor 14, and hence the speed of the pump 10, Para. [0021]) of an electric pump (at pumps 210A, 210B, Fig. 5, the electric system, Para. [0052]).
US Well Services fails to explicitly disclose wherein the configured to receive includes configured to receive control gear levels for a diesel engine.
Halliburton Energy Services is in the art of diesel fuel consumption at a well site operation (Para. [0014]) and teaches wherein configured to receive includes configured to receive control gear levels (engine parameters . . . operating gear . . . into a diesel consumption model, Para. [0026]) for a diesel engine (a diesel consumption value for a dual-fuel engine configuration, Para. [0026]).
It would have been obvious to one of ordinary skill in the art at the time of the invention to modify US Well Services with the teaching of Halliburton Energy Services for the purpose of providing a diesel consumption model at a well site to adjust engine parameters and thereby ensure that operators can refine and optimize fuel consumption (Halliburton Energy Services, Para. [0015]).

Supplemental Box

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

Regarding Claim 12, US Well Services discloses the method of claim 10, further characterized by: communicating with the software module (a programmable logic controller for local control, and a graphics panel, the graphics panel can include, for example, a touchscreen interface, Para. [0031], inherent that the programmable logic controller with touchscreen interface would have a software module) to receive instructions for frequency (other pump control and data monitoring equipment can include pump throttles, a VFD fault indicator with a reset, Para. [0031], a variable frequency drive (VFD) 15, Para. [0021]) and/or voltage levels for a variable frequency drive (as well as a VFD, Para. [0050], each electric motor 14 can be equipped with a variable frequency drive (VFD) 15, and an A/C console, that controls the speed of the electric motor 14, and hence the speed of the pump 10, Para. [0021]) of an electric pump (at pumps 210A, 210B, Fig. 5, the electric system, Para. [0052]); and controlling the frequency levels (other pump control and data monitoring equipment can include pump throttles, a VFD fault indicator with a reset, Para. [0031], a variable frequency drive (VFD) 15, Para. [0021]) based at least in part on requirements of the hydraulic fracturing fleet (as shown in Fig. 5).
US Well Services fails to explicitly disclose wherein to receive instructions includes to receive instructions for gear levels and engine revolutions per minute (RPM) for a diesel engine; and controlling the gear levels.
Halliburton Energy Services is in the art of diesel fuel consumption at a well site operation (Para. [0014]) and teaches wherein to receive instructions includes to receive instructions for gear levels (engine parameters . . . operating gear . . . into a diesel consumption model, Para. [0025]) and engine revolutions per minute (RPM) (engine parameters . . . engine speed . . . into a diesel consumption model, Para. [0026]) for a diesel engine (a diesel consumption value for a dual-fuel engine configuration, Para. [0025]); and controlling the gear levels (engine parameters . . . operating gear . . . into a diesel consumption model, Para. [0026], computer control to change engine parameters, Para. [0032]).
It would have been obvious to one of ordinary skill in the art at the time of the invention to modify US Well Services with the teaching of Halliburton Energy Services for the purpose of providing a diesel consumption model at a well site to adjust engine parameters and thereby ensure that operators can refine and optimize fuel consumption (Halliburton Energy Services, Para. [0015]).

Claims 6 and 7 lack an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter US Well Services) in view of Evolution Well Services, LLC (hereinafter Evolution Well Services).

Regarding Claim 6, US Well Services discloses the hydraulic fracturing fleet of claim 1, further characterized by: a pump down station (a fracturing fluid, which is pumped down the well by the electric-powered pumps, Para. [0042]) configured to operate concurrently with the interchangeable combination (conventional diesel . . . so that conventional means could be used to power the system if the electric system becomes incapacitated, Para. [0052]) of the diesel-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, a conventional diesel or bi-fuel powered frack system could be tied into the system as a backup, Para. [0052], diesel powered . . . by a discrete diesel engine, Para. [0005]) and the electric-powered components (at pumps 210A, 210B, sand equipment 229A, 229B, blenders 234A, 234B, hydration units 232A, 232B, Fig. 5, the electric system, Para [0052]) being in operation with a first well (the wellbore, Para. [0044]).
US Well Services fails to explicitly disclose wherein the pump down station is a pump down station configured to operate with a second well.
Evolution Well Services is in the art of a system for pumping and pressurizing fracturing fluid (Para. [0005]) and teaches wherein a pump down station is a pump down station (at fracturing pump transports 108, Fig. 1) configured to operate with a second well (Fig. 3 showing two wellheads 101; FIG. 3 is a schematic diagram an embodiment of a well site 300 that includes two wellheads 101 and two data vans 114, Para. [0054]).
It would have been obvious to one of ordinary skill in the art at the time of the invention to modify US Well Services with the teaching of Evolution Well Services for the purpose of providing fracturing at a second wellhead and thereby ensure that a well site can operate two wellheads simultaneously (Evolution Well Services, Para. [0054]).

Regarding Claim 7, US Well Services discloses the hydraulic fracturing fleet of claim 1.
US Well Services fails to explicitly disclose further characterized by: a data network coupled to the datavan for transmitting on-site data associated with the hydraulic fracturing fleet to a remote station and for transmitting remote data from the remote station to the datavan.
Evolution Well Services is in the art of a system for pumping and pressurizing fracturing fluid (Para. [0005]) and teaches further characterized by: a data network (a control network system . . . configured to operate remotely using a network topology, such as an Ethernet ring topology network, Para. [0041]) coupled to a datavan (a data van, Para. [0041]) for transmitting on-site data (a control network system that monitors and controls one or more hydraulic fracturing equipment, Para. [0041]) associated with a hydraulic fracturing fleet (the hydraulic fracturing equipment, Para. [0041]) to a remote station (a remote location, Para. [0041]) and for transmitting remote data (controls one or more hydraulic fracturing equipment remotely, Para. [0041]) from the remote station (a remote location, Para. [0041]) to the datavan (a data van, Para. [0041]).
It would have been obvious to one of ordinary skill in the art at the time of the invention to modify US Well Services with the teaching of Evolution Well Services for the purpose of providing a control network system that can monitor and control equipment remotely and thereby ensure that implementing control stations can be located away from the vicinity of the fracturing equipment (Evolution Well Services, Para. [0041]).

Supplemental Box

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

Claim 8 lacks an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter US Well Services) in view of Barker et al. (hereinafter Barker).

Regarding Claim 8, US Well Services discloses the hydraulic fracturing fleet of claim 1.
US Well Services fails to explicitly disclose further characterized by: waterproof covers provided in the datavan for safeguarding the switching components of the datavan.
Barker is in the art of microcomputer-based systems for monitoring a plurality of operations on an offshore drilling rig (Col. 1, Lns. 5-9) and teaches further characterized by: waterproof covers (electrical service is protected through a breaker box preferably located near the door 120, all switches for overhead lighting are preferably waterproof, Col. 7, Lns. 56-60) provided in a datavan (at housing 112 of skid 114, Fig. 2) for safeguarding switching components (all switches for overhead lighting are preferably waterproof, Col. 7, Lns. 56-60) of the datavan (at housing 112 of skid 114).
It would have been obvious to one of ordinary skill in the art at the time of the invention to modify US Well Services with the teaching of Barker for the purpose of having the switches of the enclosure be waterproof and thereby ensure that the equipment is maintained throughout the housing (Barker, Col. 7, Lns. 48-60).

Claims 1-14 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.

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)* 11 SEP 2019
Applicant's or agent's file reference 047158.500042	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2019/037493	International filing date *(day/month/year)* 17 June 2019
Applicant U.S. WELL SERVICES, INC.	

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 PCT Helpdesk: 571-272-4300 Telephone No. 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 047158.500042	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2019/037493	International filing date *(day/month/year)* 17 June 2019	(Earliest) Priority Date *(day/month/year)* 15 June 2018
Applicant U.S. WELL SERVICES, INC.		

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. 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/US2019/037493

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 43/26; E21B 41/00; E21B 43/00; E21B 44/00 (2019.01)
CPC - E21B 43/26; E21B 41/00; E21B 43/00; E21B 44/00 (2019.08)

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 - 166/308.1; 166/244.1; 166/305.1 (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 2018/0156210 A1 (US WELL SERVICES, LLC) 07 June 2018 (07.06.2018) entire document	1-4, 9, 10, 12
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Y		5-8, 13-15
Y	US 2017/0222409 A1 (US WELL SERVICES LLC) 03 August 2017 (03.08.2017) entire document	5, 7, 13, 14
Y	US 2010/0045109 A1 (ARNOLD) 25 February 2010 (25.02.2010) entire document	8, 15
A	US 5,172,009 A (MOHAN) 15 December 1992 (15.12.1992) entire document	1-15

☐ 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
26 August 2019	11 SEP 2019
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)*	11 SEP 2019
Applicant's or agent's file reference 047158.500042	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/037493	17 June 2019	15 June 2018

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - E21B 43/26; E21B 41/00; E21B 43/00; E21B 44/00 (2019.01)
CPC - E21B 43/26; E21B 41/00; E21B 43/00; E21B 44/00 (2019.08)

Applicant U.S. WELL SERVICES, INC.

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	26 August 2019	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/US2019/037493

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/US2019/037493

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	5-8, 11, 13-15	YES
	Claims	1-4, 9, 10, 12	NO
Inventive step (IS)	Claims	5, 11	YES
	Claims	1-4, 6-10, 12-15	NO
Industrial applicability (IA)	Claims	1-15	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-4, 9, 10, and 12 lack novelty under PCT Article 33(2) as being anticipated by U.S. Well Services, LLC (hereinafter USWell).

Regarding Claim 1, USWell discloses a system comprising: a mobile unit (power distribution system... the turbine generator 52 may be mounted on the trailer 58 [mobile unit] within a housing 60 mounted on the trailer, para 0028); at least one generator (the turbine generator 52, para 0028); and at least one switch gear (the switch gear 64 is mounted on a trailer 58 and includes the housing 60, para 0029), the at least one generator coupled to the at least one switch gear on the mobile unit (Power cables 62 from the turbines 52 can be connected to the switch gear 64 on a side, para 0029), the mobile unit configured to provide power generated by the at least one generator in electrical buses for at least one load on one or more external mobile units (direct power transmission from the switch gear units 64 to the equipment, such as the auxiliary unit 66 and the pumps 74, para 0039; The embodiment illustrated in FIG. 2 further includes an auxiliary unit 66, which in the illustrated embodiments is mounted on a trailer 58...The hydraulic fracturing pumps may be on a single common trailer, or broken up with various associated equipment on different trailers [all loads on external mobile units/trailers], para 0030; also see Fig. 4).

Regarding Claim 2, USWell discloses the system of claim 1, further comprising: at least one fracturing pump (FP) mobile unit of the one or more external mobile units, the at least one FP mobile unit physically external relative to the mobile unit (The hydraulic fracturing pumps may be on a single common trailer, or broken up with various associated equipment on different trailers [external mobile units], para 0030; also see Fig. 4); and at least one transformer provided between the at least one FP mobile unit and the at least one switch gear to condition the power supplied to the at least one FP mobile unit (the transformer 70... may be used to condition power for auxiliary equipment. For example, the transformer 70 may be a 3500 kVA transformer that converts three AC 13.8 kV electricity to three phase AC 600 V electricity. Cable connections may be arranged along the transformer 70 receive power output from the generators 52, the switch gear 64, or a combination thereof... transformer 70 may be advantageous to supply power to secondary equipment, para 0032).

Regarding Claim 3, USWell discloses the system of claim 1, further comprising: a predetermined number of FP mobile unitscomprised in the one or more external mobile units, the predetermined number of FP mobile units determined by a maximum of the power available from the at least one generator and handled by the at least one switch gear (in the illustrated embodiment includes twin fracturing pumps 74. it should be appreciated that while the illustrated embodiment includes dual pumps 74, other embodiments may include one, three, four, five, or any reasonable number of fracturing pumps 74. In the illustrated embodiment, each pump 74 is capable of consuming up to 1.2 MW of electricity. Therefore, the illustrated twin fracturing pumps 74 can draw about 2.5 MW of electricity [total available power] under full load conditions, para 0031).

Regarding Claim 4, USWell discloses the system of claim 1, further comprising: a predetermined number of generators comprising the at least one generator, the predetermined number of generators having individual power output values that is lesser than a power output of an isolated single generator occupying all available space in an independent mobile unit physically external to the mobile unit (other embodiments may have any reasonable number of generators 52 and/or switch gear units 64, as well as other equipment, based on operating conditions at the well site. , para 0044; arious auxiliary trailers may be utilized to selected equipment at the well site and various configurations may be implemented to enable different designs and configurations to be utilized based on costs, space constraints, para 0030).

Regarding Claim 9, USWell discloses a method comprising: providing a mobile unit with at least one generator and at least one switchgear (the turbine generator 52 may be mounted on the trailer 58 [mobile unit] within a housing 60 mounted on the trailer, para 0028; the switch gear 64 is mounted on a trailer 58 and includes the housing 60, para 0029), the at least one generator coupled to the at least one switch gear on the mobile unit (Power cables 62 from the turbines 52 can be connected to the switch gear 64 on a side, para 0029); generating power from the at least one generator; providing the power in electrical buses for at least one load in one or more external mobile units (direct power transmission from the switch gear units 64 to the equipment, such as the auxiliary unit 66 and the pumps 74, para 0039; The embodiment illustrated in FIG. 2 further includes an auxiliary unit 66, which in the illustrated embodiments is mounted on a trailer 58...The hydraulic fracturing pumps may be on a single common trailer, or broken up with various associated equipment on different trailers [all loads on external mobile units/trailers], para 0030; also see Fig. 4).

Supplemental Box

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

Regarding Claim 10, USWell discloses the method of claim 9, further comprising: providing at least one fracturing pump (FP) mobile unit of the one or more external mobile units that is physically external relative to the mobile unit (The hydraulic fracturing pumps may be on a single common trailer, or broken up with various associated equipment on different trailers [external mobile units], para 0030; also see Fig. 4); and conditioning the power supplied to the at least one FP mobile unit using at least one transformer provided between the at least one FP mobile unit and the at least one switch gear (the transformer 70... may be used to condition power for auxiliary equipment. For example, the transformer 70 may be a 3500 kVA transformer that converts three AC 13.8 kV electricity to three phase AC 600 V electricity. Cable connections may be arranged along the transformer 70 receive power output from the generators 52, the switch gear 64, or a combination thereof... transformer 70 may be advantageous to supply power to secondary equipment, para 0032).

Regarding Claim 12, USWell discloses the method of claim 9, further comprising: providing at least one Variable Frequency Drive (VFD); and providing at least one Motor Control Center (MCC), the VFD and the MCC being on individual ones of the one or more external mobile units that is physically external relative to the mobile unit (The VFD 68 may be referred to as a VFD house and may include an independent VFD for each pump coupled to the VFD and/or VFD house 68, para 0030; a variable frequency drive connected to the motor to control the speed of the motor, claim 6; also see Fig. 5 [separate trailers for each VFD]).

Claims 6, 7, 13, and 14 lack an inventive step under PCT Article 33(3) as being obvious over U.S. Well Services, LLC (hereinafter USWell) in view of US Well Services LLC (hereinafter USWell409).

Regarding Claim 6, USWell discloses the system of claim 1, further comprising: one or more power cable interconnects configured to couple the mobile unit with a second mobile unit of the one or more external mobile units, the second mobile unit having at least one second generator and at least one second switch gear (power and communications cables 62 can extend between associated equipment, such as switch gear units 64... one or more generators can be provided in each housing 60 and/or be mounted on each skid 56 and/or trailer 58, para 0028; also see Fig. 2). USWell fails to explicitly disclose the one or more power cable interconnects to transmit power in support of redundancy or load sharing between the mobile unit and the second mobile unit.
USWell409 is in the field of hydraulic fracturing (Abstract) and teaches the one or more power cable interconnects to transmit power in support of redundancy or load sharing between the mobile unit and the second mobile unit (the power transmission network is broken into two banks with direct communication between generator sets 805-a, 805-b and switchgear "B" 825-b-1 in the first bank 807-a, and generator sets 805-c, 805-d and switchgear "B" 825-b-2 in the second bank 807-b, para 0062; Splitting the microgrid into two banks 807-a, 807-b can build redundancy into the system. If a single generator set fails during peak power demand, any other generator set on the same circuit can share the load., para 0063). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell with the teaching of USWell409 for the purpose of building redundancy into the system, thus if a single generator set fails during peak power demand, any other generator set on the same circuit can share the load (see USWell409, para 0063).

Regarding Claim 7, USWell discloses the system of claim 1, further comprising an optional datavan in the one or more external mobile units for control of the at least one load sharing FP mobile unit, the optional datavan offering the control of the at least one load sharing FP mobile unit instead of a second control available from within the mobile unit (Controls for operating the electric hydraulic fracturing system may be provided in the housing 60 of the electric data van 76, as well as devices for monitoring conditions and operational parameters of components of the electric hydraulic fracturing system, para 0035). USWell fails to explicitly disclose at least one load sharing FP mobile unit coupled to share the at least one load of a second FP mobile unit of the one or more external mobile units.
USWell409 teaches at least one load sharing FP mobile unit coupled to share the at least one load of a second FP mobile unit of the one or more external mobile units (the power transmission network is broken into two banks with direct communication between generator sets 805-a, 805-b and switchgear "B" 825-b-1 in the first bank 807-a, and generator sets 805-c, 805-d and switchgear "B" 825-b-2 in the second bank 807-b, para 0062; Splitting the microgrid into two banks 807-a, 807-b can build redundancy into the system. If a single generator set fails during peak power demand, any other generator set on the same circuit can share the load., para 0063). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell with the teaching of USWell409 for the purpose of building redundancy into the system, thus if a single generator set fails during peak power demand, any other generator set on the same circuit can share the load (see USWell409, para 0063).

Regarding Claim 13, USWell discloses the method of claim 9, further comprising: coupling the mobile unit with a second mobile unit of the one or more external mobile units using one or more power cable interconnects, the second mobile unit having at least one second generator and at least one second switch gear (power and communications cables 62 can extend between associated equipment, such as switch gear units 64... one or more generators can be provided in each housing 60 and/or be mounted on each skid 56 and/or trailer 58, para 0028; also see Fig. 2). USWell fails to explicitly disclose the one or more power cable interconnects to transmit power in support of redundancy or load sharing between the mobile unit and the second mobile unit.
USWell409 teaches the one or more power cable interconnects to transmit power in support of redundancy or load sharing between the mobile unit and the second mobile unit (the power transmission network is broken into two banks with direct communication between generator sets 805-a, 805-b and switchgear "B" 825-b-1 in the first bank 807-a, and generator sets 805-c, 805-d and switchgear "B" 825-b-2 in the second bank 807-b, para 0062; Splitting the microgrid into two banks 807-a, 807-b can build redundancy into the system. If a single generator set fails during peak power demand, any other generator set on the same circuit can share the load., para 0063). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell with the teaching of USWell409 for the purpose of building redundancy into the system, thus if a single generator set fails during peak power demand, any other generator set on the same circuit can share the load (see USWell409, para 0063).

Supplemental Box

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

Regarding Claim 14, USWell discloses the method of claim 12, further comprising: controlling, via an optional datavan in the one or more external mobile units, the at least one FP mobile unit, the optional datavan offering the control of the at least one FP mobile unit instead of a second control (Controls for operating the electric hydraulic fracturing system may be provided in the housing 60 of the electric data van 76, as well as devices for monitoring conditions and operational parameters of components of the electric hydraulic fracturing system, para 0035)
USWell fails to explicitly disclose coupling at least one load sharing FP mobile unit to share the at least one load of a second FP mobile unit of the one or more external mobile units. USWell409 teaches coupling at least one load sharing FP mobile unit to share the at least one load of a second FP mobile unit of the one or more external mobile units (the power transmission network is broken into two banks with direct communication between generator sets 805-a, 805-b and switchgear "B" 825-b-1 in the first bank 807-a, and generator sets 805-c, 805-d and switchgear "B" 825-b-2 in the second bank 807-b, para 0062; Splitting the microgrid into two banks 807-a, 807-b can build redundancy into the system. If a single generator set fails during peak power demand, any other generator set on the same circuit can share the load., para 0063). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell with the teaching of USWell409 for the purpose of building redundancy into the system, thus if a single generator set fails during peak power demand, any other generator set on the same circuit can share the load (see USWell409, para 0063).

Claims 8 and 15 lack an inventive step under PCT Article 33(3) as being obvious over U.S. Well Services, LLC (hereinafter USWell) in view of Arnold.

Regarding Claim 8, USWell fails to disclose the system of claim 1, further comprising: an isolation transformer in one of the one or more external mobile units, the isolation transformer being physically external relative to the mobile unit and being configured for filtering harmonics between the at least one generator and the at least one load in the one or more external mobile units. Arnold is in the field of an AC power distribution unit (Abstract) and teaches an isolation transformer configured for filtering harmonics between the at least one generator and the at least one load (A power input feed 62 is coupled to an optional isolating transformer 63 connected to harmonic filter... isolating transformer 63 may attenuate noise energy propagating through the point-of-use unit and reduce the harmonic current distortion at the third harmonic frequency, para 0031). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell with the teaching of Arnold for the purpose of reducing malfunctions of sensitive electronics (see Arnold, para 0005).

Regarding Claim 15, USWell fails to disclose the method of claim 9, further comprising: filtering harmonics between the at least one generator and the at least one load in the one or more external mobile units using an isolation transformer that is in one of the one or more external mobile units, the isolation transformer being physically external relative to the mobile unit. Arnold teaches filtering harmonics between the at least one generator and the at least one load using an isolation transforme (A power input feed 62 is coupled to an optional isolating transformer 63 connected to harmonic filter... isolating transformer 63 may attenuate noise energy propagating through the point-of-use unit and reduce the harmonic current distortion at the third harmonic frequency, para 0031). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell with the teaching of Arnold for the purpose of reducing malfunctions of sensitive electronics (see Arnold, para 0005).

Claims 5 and 11 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest:

Regarding claim 5, the prior art of record, individually or in combination, does not teach or fairly suggest the system of claim 1, further comprising: the at least one switchgear being physically arranged to replace an electronic equipment room (EER) of at least one mobile unit of the one or more external mobile units that is designed to comprise the EER.

Regarding claim 11, the prior art of record, individually or in combination, does not teach or fairly suggest the method of claim 9, further comprising: physically arranging the at least one switch gear to replace an electronic equipment room (EER) of at least one mobile unit of the one or more external mobile units that is designed to comprise the EER.

Claims 1-15 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.

LIBERTY EXHIBIT 1056, Page 736

Search History:

Limited Classification Search

The Patent Analyst performed a limited classification search within the following US, IPC, CPC, ECLA, or F-Term classification areas:

CPC Class/Subclass(es): E21B 43/26; E21B 41/00; E21B 43/00; E21B 44/00 (2019.08)

IPC (8) Class/Subclass(es): E21B 43/26; E21B 41/00; E21B 43/00; E21B 44/00 (2019.01)

U.S. Class/Subclass(es): 166/308.1; 166/244.1; 166/305.1

See Global Search Results.

Global Patent Literature Text Search

The Patent Analyst performed the following global text search, which was not limited by classification but may or may not have been limited by other criteria:

Questel Orbit: https://www.orbit.com

#	Search query	Results
1	((WELL W SERVICE+)/PA/OPA)	390
2	((HINDERLITER 2D BRANDON)/IN/OIN/INH/INV)	30
3	2 AND BUSES/TX	0
4	2 AND BUS+/TX	20
5	2 AND (REPLAC+ S ROOM)/TX	0
6	2 AND (MOBILE W UNITS)/TX	0
7	..CITB NOSOURCE SS 2 6 RANKED	0
8	(US4100822)/XPN	1
9	(WO2019152981)/XPN	1
10	..CITB NOSOURCE SS 9 1 RANKED	0
11	..SIMILARITY SS 9 RANKED 1	29861
12	(US20160105022)/XPN	1
13	2 AND (GENERATOR+ AND SWITCHGEAR)/TX	16
14	2 AND (GENERATOR+ AND (SWITCH W GEAR))/TX	14
15	13 OR 14	20
16	(REPLAC+ S ELECTRONIC S EQUIPMENT S ROOM)/TI/AB/CLMS/TX	374
17	((REPLAC+ S ELECTRONIC S EQUIPMENT S ROOM) AND SWITCHGEAR)/TI/AB/CLMS/TX	9
18	2 AND EER/TX	13

19	(E21B-043/26)/CPC	5843
20	(E21B-043/26)/IPC	10299
21	(E21B-043/00)/IPC	21446
22	(E21B-043/00)/CPC	2949
23	(E21B-044/00)/CPC	2766
24	(E21B-044/00)/IPC	6407
25	(E21B-041/00)/IPC	8347
26	(E21B-041/00)/CPC	6311
27	19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26	45741
28	27 AND (GENERATOR+ AND (SWITCH W GEAR))/TX	28
29	27 AND (GENERATOR+ AND (SWITCHGEAR))/TX	47
30	166308100/PCL	1259
31	166305100/PCL	1955
32	166244100/PCL	247
33	30 OR 31 OR 32	3254
34	33 AND (GENERATOR+ AND (SWITCHGEAR))/TX	6
35	33 AND (FRACTUR+)/TX	2350
36	33 AND (FRACTUR+ AND MOBILE)/TX	336
37	33 AND (FRACTUR+ AND TRAILER+)/TX	92

Google Patents: https://patents.google.com

#	Search query	Results
1	INTEGRATED MOBILE POWER UNIT FOR HYDRAULIC FRACTURING	100+
2	integrated generator and switchgear for fracturing	100+
3	hydraulic fracturing mobile units switchgear generators	100+
4	generator and switchgear on a transport unit	100+
5	generator and switchgear on a transport unit hydraulic fractruing	100+

Computer Accessed Text Databases Searched

The Patent Analyst searched the following computer accessed text databases:

Google Scholar: https://scholar.google.com/

#	Search query	Results
1	INTEGRATED MOBILE POWER UNIT FOR HYDRAULIC FRACTURING	100+

2	integrated generator and switchgear for fracturing	100+
3	hydraulic fracturing mobile units switchgear generators	100+
4	generator and switchgear on a transport unit	100+
5	generator and switchgear on a transport unit hydraulic fractruing	100+

Date search was completed: 26 August 2019

SV/CC

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Taylor P. Evans
Hogan Lovells US LLP
609 Main Street, Suite 4200
Houston, TX 77002
United States of America

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)* 26 NOV 2019
Applicant's or agent's file reference 047158.500046	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US19/51018	International filing date *(day/month/year)* 13 September 2019 (13.09.2019)
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 preferably through ePCT, or on paper to:
   The International Bureau of WIPO, 34, chemin des Colombettes, 1211 Geneva 20, Switzerland
   (Facsimile No.: +41 22 338 82 70)

   For more detailed instructions, see the *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 Shane Thomas Telephone No. PCT Helpdesk: 571-272-4300

Form PCT/ISA/220 (revised January 2019)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference		FOR FURTHER ACTION
047158.500046		see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US19/51018	13 September 2019 (13.09.2019)	14 September 2018 (14.09.2018)
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. 3

☐ 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/US19/51018

A. CLASSIFICATION OF SUBJECT MATTER

IPC - B66F 3/24; E21B 17/01, 17/08, 19/00, 19/06 (2019.01)

CPC - B66F 3/24, 3/247; E21B 17/01, 17/085; 19/004, 19/06

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 --- A	US 2,407,796 A (PAGE H E) 17 September 1946; figure 1; column 1, lines 1-5; column 3, lines 1-10; column 4, lines 20-30	1, 3-6, 9, 12-14 --- 10, 15
X --- A	US 2,416,848 A (ROTHERY J S) 4 March 1947; figure 1; column 1, lines 1-5; column 2, lines 35-40; column 3, lines 5-40	1-2, 6-9, 11 --- 10, 15
A	US 7,984,757 B1 (KEAST L G et al) 26 July 2011; figures 5A, 6, 7B; column 7, lines 10-20; column 8, lines 45-50; column 9, lines 10-30	10, 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
"D" document cited by the applicant in the international application
"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
06 November 2019 (06.11.2019)	26 NOV 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 Shane Thomas Telephone No. PCT Helpdesk: 571-272-4300

Form PCT/ISA/210 (second sheet) (July 2019)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: Taylor P. Evans
Hogan Lovells US LLP
609 Main Street, Suite 4200
Houston, TX 77002
United States of America

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)* 26 NOV 2019

Applicant's or agent's file reference
047158.500046

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US19/51018	13 September 2019 (13.09.2019)	14 September 2018 (14.09.2018)

International Patent Classification (IPC) or both national classification and IPC
IPC - B66F 3/24; E21B 17/01, 17/08, 19/00, 19/06 (2019.01)
CPC - B66F 3/24, 3/247; E21B 17/01, 17/085; 19/004, 19/06

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	06 November 2019 (06.11.2019)	Shane Thomas PCT Help Desk Telephone No. 571-272-4300

Form PCT/ISA/237 (cover sheet) (revised January 2019)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US19/51018

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(b)).

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/US19/51018

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	10, 15	YES
	Claims	1-9, 11-14	NO
Inventive step (IS)	Claims	10, 15	YES
	Claims	1-9, 11-14	NO
Industrial applicability (IA)	Claims	1-15	YES
	Claims	NONE	NO

2. Citations and explanations:

Claims 1, 3-6, 9, and 12-14 lack novelty under PCT Article 33(2) as being anticipated by US 2,407,796 A (PAGE).

As per claim 1, Page discloses an apparatus for performing hoisting functions (jack used for raising loads; figure 1; column 1, lines 1-5), the apparatus characterized by: a first elongated member (5, 25, 30, collectively forming a member which is vertically elongated) including a provision for a first external mechanical coupling at a distal location on the first elongated member (provided with sleeve 35 and extension screw 39 (provision), which are capable of providing an external mechanical coupling at an upper location as shown; figure 1; column 4, lines 20-30); a second elongated member (82) mechanically coupled to the first elongated member at proximal locations on the first elongated member and the second elongated member (a lower end (proximal location) of tube 82 is coupled to a lower end (proximal location) of body 30 via base 5 as shown; figure 1); a third member (86, 87, collectively) mechanically coupled to a first portion of the first elongated member (connected to arm 88 of body 30 (first portion) via pin 89 as shown; figure 1; column 3, lines 1-10), the first portion including a damping system (30, 50, collectively – see claim 3 of the instant application, where the hydraulic cylinder of the damping system forms part of the first elongated member); the third member including a fourth member (86), the fourth member configured to move through at least a second portion of a length of the second elongated member (piston 86 reciprocates within at least a lower portion (second portion of a length) of the piston chamber 85 within tube 82 (second elongated member); figure 1; column 3, lines 1-10); and at least one mechanical coupler (100) associated with the second elongated member (as shown) for a second external mechanical coupling of the apparatus to a riser (tube 100 is capable of being used to couple the tube 82 of the jack (apparatus) to a riser, rather than coupling to valve 101; figure 1).

As per claim 3, Page discloses the apparatus of claim 1, and further discloses further characterized by: a hydraulic cylinder (body 30, which defines cylinders 32 and 33; figure 1) fixed within or forming part of (forms a part of as shown) the first elongated member (5, 25, 30, collectively), the hydraulic cylinder forming part of the damping system (30, 50, collectively) of the first portion (30) of the first elongated member (5, 25, 30, collectively), and the hydraulic cylinder including a first hinge (89) for mechanically coupling with the third member (86, 87, collectively, as shown).

As per claim 4, Page discloses the apparatus of claim 3, and further discloses wherein the hydraulic cylinder (30; figure 1) is within the first elongated member (these limitations are considered optional in accordance with claim 3) to move the third member in an angle around the first hinge (creating pressure that lifts body 30, which as lifted will also lift and cause piston 86 with rod 87 (third member, collectively) to pivot its angle about pin 89 (hinge); figure 1; column 2, lines 40-50; column 3, lines 5-15 and 65-75).

As per claim 5, Page discloses the apparatus of claim 4, and further discloses further characterized by: an adjusting mechanism (130; figure 1) for the hydraulic cylinder (30) to control the angle and/or to control a speed with which the third member is moved (screw 130 may be employed to relieve pressure to control the rate of descent (speed) of the body 30 and thereby the piston 86 and rod 87 (third member, collectively) since they are pivotally connected by pin 89; figure 1; column 3, lines 5-15 and 65-75; column 5, lines 1-20).

As per claim 6, Page discloses the apparatus of claim 1, and further discloses further characterized by: the second portion of the second elongated member being a hollow area (piston 86 reciprocates within at least a lower hollow portion (second portion of a length) of the piston chamber 85 within tube 82 (second elongated member); figure 1; column 3, lines 1-10); and the fourth member included within the hollow area of the second elongated member (piston 86 reciprocates within at least a lower hollow portion (second portion of a length) of the piston chamber 85 within tube 82 (second elongated member); figure 1; column 3, lines 1-10).

-***-Continued Within the Next Supplemental Box-***-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US19/51018

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 1 and 9 are objected to under PCT Rule 66.2(a)(iii) as containing the following defect in the form or contents thereof: in claims 1 and 9, the phrase "the fourth member to move" should be written as "the fourth member configured to move".
Claim 3 is objected to under PCT Rule 66.2(a)(iii) as containing the following defect in the form or contents thereof: in claim 3, the phrase "for mechanical coupling" should be written as "for mechanically coupling".
Claim 5 is objected to under PCT Rule 66.2(a)(iii) as containing the following defect in the form or contents thereof: claim 5 depends upon itself, and is instead interpreted as being dependent on claim 4.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US19/51018

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 7 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claim 7 is indefinite for the following reason(s): Claim 7 refers to "the wellhead". There is a lack of antecedent basis for these limitations in the claim. For the purpose of this opinion, as best understood, the claim is interpreted to read "a wellhead".

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US19/51018

Supplemental Box

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

-***-Continued from Box V: Citations and Explanations-***-

As per claim 9, Page discloses a method for lifting a riser associated with a wellhead (a jack is used for raising loads to substantial heights, and so would be capable of raising a riser associated with a wellhead; figure 1; column 1, lines 1-5), the method characterized by: providing an apparatus (jack; figure 1) with a first elongated member (5, 25, 30, collectively forming a member which is vertically elongated) including a provision for an external mechanical coupling at a distal location (provided with sleeve 35 and extension screw 39 (provision), which are capable of providing an external mechanical coupling at an upper location as shown; figure 1; column 4, lines 20-30); mechanically hinging (via pivot pin 83) a second elongated member (82) to the first elongated member at proximal locations on the first elongated member and the second elongated member (a lower location (proximal location) of tube 82 is pivotally connected to boss 80 (proximal location) of base 5 (of the first elongated member) via pivot pin 83; figure 1; column 3, lines 1-10); mechanically hinging (via pivot pin 89) a third member (86, 87, collectively) to a first portion (30) of the first elongated member (5, 25, 30, collectively, as shown; figure 1; column 3, lines 5-15), the first portion including a damping system (30, 50, collectively - see claim 12 of the instant application, where the hydraulic cylinder of the damping system forms part of the first elongated member); providing the third member with a fourth member (86), the fourth member configured to move through at least a first portion of a length of the second elongated member (piston 86 reciprocates within at least a lower portion (first portion of a length) of the piston chamber 85 within tube 82 (second elongated member); figure 1; column 3, lines 1-10); and enabling mechanical coupling for the apparatus to the riser using at least one mechanical coupler on the second elongated member (tube 100 is capable of being used to couple the tube 82 of the jack (apparatus) to a riser, rather than coupling to valve 101; figure 1).

As per claim 12, Page discloses the method of claim 9, and further discloses further characterized by: providing a hydraulic cylinder (body 30, which defines the cylinders 32 and 33; figure 1) as part of the damping system (30, 50, collectively), within or as part (forms a part of as shown) of the first elongated member (5, 25, 30, collectively, as shown), the hydraulic cylinder including the first portion of the first elongated member mechanically hinged to the third member (body 30 defines the cylinders 32 and 33 and is also pivotally connected to rod 87 (of the third member) via pivot pin 89; figure 1; column 3, lines 5-10; column 3, lines 1-10).

As per claim 13, Page discloses the method of claim 12, and further discloses further characterized by: moving, by the hydraulic cylinder that is the part of or that is within the first elongated member, the third member in an angle about a hinge affixed between the first elongated member and the third member (creating pressure that lifts body 30, which as lifted will also lift and cause piston 86 with rod 87 (third member, collectively) to pivot its angle about pin 89 (hinge); figure 1; column 2, lines 40-50; column 3, lines 5-15 and 65-75).

As per claim 14, Page discloses the method of claim 13, and further discloses further characterized by: adjusting a mechanism (130; figure 1) for the hydraulic cylinder to control the angle and/or to control a speed with which the third member is moved (screw 130 may be employed to relieve pressure to control the rate of descent (speed) of the body 30 and thereby the piston 86 and rod 87 (third member, collectively) since they are pivotally connected by pin 89; figure 1; column 3, lines 5-15 and 65-75; column 5, lines 1-20).

Claims 1-2, 6-9, and 11 lack novelty under PCT Article 33(2) as being anticipated by US 2,416,848 A (ROTHERY).

As per claim 1, Rothery discloses an apparatus for performing hoisting functions (jack for lifting loads; figure 1; column 1, lines 1-5), the apparatus characterized by: a first elongated member (1) including a provision (middle foot 10) for a first external mechanical coupling at a distal location on the first elongated member (middle foot 10 is capable of being used for mechanically coupling a lower location (distal location) of body 1 (first elongated member) to another component; figure 1; column 2, lines 50-55); a second elongated member (18) mechanically coupled to the first elongated member at proximal locations on the first elongated member and the second elongated member (upper locations (proximal locations) on body 1 (first elongated member) and outer tubular part 18 (second elongated member) are coupled via hinge butts 3; figure 1; column 2, lines 35-45; column 3, lines 5-15); a third member (left strut 11, tubular part 19, collectively) mechanically coupled to a first portion of the first elongated member (left strut 11 (of the third member) is coupled to a lower portion (first portion) of body 1 (first elongated member) as shown; figure 1), the first portion including a damping system (27); the third member including a fourth member (19), the fourth member configured to move through at least a second portion of a length of the second elongated member (inner tubular part 19 (fourth member) is slidable within the lower portion (second portion) of the outer tubular part 18 (second elongated member); figure 1; column 3, lines 5-15); and at least one mechanical coupler (28) associated with the second elongated member for a second external mechanical coupling of the apparatus to a riser (lug 28 is capable of being used for mechanically coupling the outer tubular part 18 (second elongated member) of the jack (apparatus) to a riser; figure 1; column 3, lines 35-40).

As per claim 2, Rothery discloses the apparatus of claim 1, and further discloses wherein the first elongated member (1; figure 1) and the second elongated member (18) are hollow tubular members (body 1 is a cylindrical liquid reservoir, i.e., a hollow tubular member, and outer part 18 is tubular; figures 1-2; column 2, lines 35-40; column 3, lines 5-10).

As per claim 6, Rothery discloses the apparatus of claim 1, and further discloses further characterized by: the second portion of the second elongated member being a hollow area (inner tubular part 19 (fourth member) is slidable within a hollow area of the lower portion (second portion) of the outer tubular part 18 (second elongated member); figure 1; column 3, lines 5-15); and the fourth member included within the hollow area of the second elongated member (inner tubular part 19 (fourth member) is slidable within a hollow area of the lower portion (second portion) of the outer tubular part 18 (second elongated member); figure 1; column 3, lines 5-15).

As per claim 7, Rothery discloses the apparatus of claim 1, and further discloses further characterized by: the at least one mechanical coupler having a latching system for latching to the riser of a wellhead to form the second external mechanical coupling of the apparatus to the riser (a pin 20 (latching system) is passed through a hole in the lug 28 (mechanical coupler) and a hole in lug 29 in order to lock the tubular member 18 to the body 1, and so together the pin 20 and lug 28 are capable of being used for locking the outer tubular part 18 (second elongated member) of the jack (apparatus) to a riser of a wellhead; figure 1; column 3, lines 30-40).

-***-Continued Within the Next Supplemental Box-***-

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US19/51018

Supplemental Box

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

-***-Continued from Previous Supplemental Box-***-

As per claim 8, Rothery discloses the apparatus of claim 1, and further discloses further characterized by: the second elongated member being hinged with a second hinge to the first elongated member (outer tubular part 18 (second elongated member) and body 1 (first elongated member) are coupled via hinge butts 3 (second hinge); figure 1; column 2, lines 35-45; column 3, lines 5-15).

As per claim 9, Rothery discloses a method for lifting a riser associated with a wellhead (jack for lifting loads, capable of being used to lift a riser associated with a wellhead; figure 1; column 1, lines 1-5), the method characterized by: providing an apparatus (jack; figure 1) with a first elongated member (1) including a provision (middle foot 10) for an external mechanical coupling at a distal location (middle foot 10 is capable of being used for mechanically coupling a lower location (distal location) of body 1 (first elongated member) to another component; figure 1; column 2, lines 50-55); mechanically hinging (via hinge butts 3) a second elongated member (18) to the first elongated member at proximal locations on the first elongated member and the second elongated member (upper locations (proximal locations) on body 1 (first elongated member) and outer tubular part 18 (second elongated member) are coupled via hinge butts 3; figure 1; column 2, lines 35-45; column 3, lines 5-15); mechanically hinging (via pivot pin 12) a third member (left strut 11, tubular part 19, collectively) to a first portion of the first elongated member (left strut 11 (of the third member) is pivotally coupled to a lower portion (first portion) of body 1 via pivot pin 12; figure 1; column 2, lines 50-55), the first portion including a damping system (the lower portion (first portion) of body 1 comprises a release valve 27 (damping system); figure 1; column 3, lines 25-35); providing the third member with a fourth member (19), the fourth member configured to move through at least a first portion of a length of the second elongated member (inner tubular part 19 (fourth member) is slidable within the lower portion (first portion) of the outer tubular part 18 (second elongated member); figure 1; column 3, lines 5-15); and enabling mechanical coupling for the apparatus to the riser using at least one mechanical coupler on the second elongated member (lug 28 is capable of being used for mechanically coupling the outer tubular part 18 (second elongated member) of the jack (apparatus) to a riser; figure 1; column 3, lines 35-40).

As per claim 11, Rothery discloses the method of claim 9, and further discloses wherein the first elongated member (1; figure 1) and the second elongated member (18) are hollow tubular members (body 1 is a cylindrical liquid reservoir, i.e., a hollow tubular member, and outer part 18 is tubular; figures 1-2; column 2, lines 35-40; column 3, lines 5-10).

Claim 10 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest a motivation to combine the disparate references.

PAGE discloses mechanically coupling the apparatus at the second elongated member (as shown, the tube 100 couples (coupling components of the apparatus together) the tube 82 of the jack to the valve 101; figure 1).

ROTHERY discloses mechanically coupling the apparatus at the second elongated member (pin 20 is passed through a hole in the lug 28 (mechanical coupler) and a hole in lug 29 in order to lock (coupling components of the apparatus together) the tubular member 18 to the body 1; figure 1; column 3, lines 30-40).

US 7,984,757 B1 (KEAST) discloses mechanically coupling the apparatus (58, 86, 129, collectively; figures 5A, 6, 7B) to the riser (116; head 114 of torque wrench assembly 86 (of the apparatus) engages to grip the tubular 116 (riser); figures 6, 7B; column 9, lines 10-30) at the second elongated member (86); mechanically coupling the external mechanical coupling to a hoist (link 58 (first elongated member) is connected via the external coupling mechanism at its lower end as shown to elevator 60 (hoist); figures 5A, 6, 7B; column 7, lines 1-10); and hoisting the riser into position with the wellhead (the elevator 60 (hoist) is used for grabbing and elevating (into position) the tubular 116 extending through the rig floor 90 and rig floor sub 91 in the well bore 8; figures 5A, 6, 7B; column 7, lines 10-20; column 8, lines 45-50).

Nonetheless, it would not have been obvious to one of ordinary skill in the art at the time of the invention to modify Page or Rothery's apparatus to be used for hoisting Keast's riser into position with the wellhead because Page and Rothery disclose tripod type lifts for lifting a load with a central member which only moves linearly in one direction to lift a load that is completely on top of the jack, which one of ordinary skill in the art would not use for hoisting a riser into position with a wellhead, since additional structural features would need to be provided in order to attach Page or Rothery's apparatus to a riser for hoisting purposes. Furthermore, the prior art fails to disclose an apparatus for hoisting as recited in claim 9 that is used for hoisting a riser into position with a wellhead, therefore creating the claimed apparatus and using it to hoist a riser into position with a wellhead would require more than routine skill in the art and impermissible hindsight. Finally, Keast fails to disclose all of the recited components of claim 9, specifically a first member hinged to a third member and the third member having a fourth member that moves through the second elongated member, and modifying Keast to function this way would not have been obvious because it would require restructuring the connection between link 54, link 58, the torque wrench assembly 86, and the hydraulic drive unit 129, which would require more than routine skill in the art and impermissible hindsight.

-***-Continued Within the Next Supplemental Box-***-

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US19/51018

Supplemental Box

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

-***-Continued from Previous Supplemental Box-***-

Claim 15 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest a motivation to combine the disparate references.

PAGE discloses the second elongated member (82; figure 1).

ROTHERY discloses latching, using a latching system, the second elongated member (pin 20 (latching system) is passed through a hole in the lug 28 (mechanical coupler) and a hole in lug 29 in order to lock the tubular member 18 to the body 1, and so together the pin 20 and lug 28 are capable of being used for locking the outer tubular part 18 (second elongated member) of the jack (apparatus) to a riser of a wellhead; figure 1; column 3, lines 30-40).

KEAST discloses latching, using a latching system, the second elongated member to the riser for hoisting the riser into position with the wellhead (a wrench head 114 (latching system) is provided at the lower end of torque wrench assembly 86 (second elongated member) to engage and grip (latch) the tubular 116 (riser), enabling the elevator 60 (hoist) to be used for elevating (into position) the tubular 116 (riser) extending through the rig floor 90 and rig floor sub 91 in the well bore 8; figures 5A, 6, 7B; column 7, lines 10-20; column 8, lines 45-50; column 9, lines 10-30).

Nonetheless, it would not have been obvious to one of ordinary skill in the art at the time of the invention to modify Page or Rothery's apparatus to be used for hoisting Keast's riser into position with the wellhead because Page and Rothery disclose tripod type lifts for lifting a load with a central member which only moves linearly in one direction to lift a load that is completely on top of the jack, which one of ordinary skill in the art would not use for hoisting a riser into position with a wellhead, since additional structural features would need to be provided in order to attach Page or Rothery's apparatus to a riser for hoisting purposes. Furthermore, the prior art fails to disclose an apparatus for hoisting as recited in claim 9 that is used for hoisting a riser into position with a wellhead with the latching system, therefore creating the claimed apparatus and using it to latch to and hoist a riser into position with a wellhead would require more than routine skill in the art and impermissible hindsight. Finally, Keast fails to disclose all of the recited components of claim 9, specifically a first member hinged to a third member and the third member having a fourth member that moves through the second elongated member, and modifying Keast to function this way would not have been obvious because it would require restructuring the connection between link 54, link 58, the torque wrench assembly 86, and the hydraulic drive unit 129, which would require more than routine skill in the art and impermissible hindsight.

Claims 1-15 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TEXAS 77002
UNITED STATES OF AMERICA

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)* 11 FEB 2020
Applicant's or agent's file reference 047158.500047	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US2019/055323	International filing date *(day/month/year)* 09 October 2019 (09.10.2019)
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 preferably through ePCT, or on paper to: The International Bureau of WIPO, 34 chemin des Colombettes, 1211 Geneva 20, Switzerland (Facsimile No.: +41 22 338 82 70)

   For more detailed instructions, see the *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 90bis.1 and 90bis.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 45bis.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 COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA	Authorized officer HARRY C. KIM
Facsimile No. (571)273-8300	Telephone No. 571-272-4300

Form PCT/ISA/220 (revised January 2019)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 047158.500047	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2019/055323	International filing date *(day/month/year)* 09 October 2019 (09.10.2019)	(Earliest) Priority Date *(day/month/year)* 09 October 2018 (09.10.2018)
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/US2019/055323

A. CLASSIFICATION OF SUBJECT MATTER

IPC: E21B 43/26; F04B 1/00, 15/02, 17/03; H01F 38/14; B01D 39/14, 46/00
CPC: E21B 43/26; F04B 1/00, 15/02, 17/03; H01F 38/14; B01D 39/14, 46/00

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)

CPC: CPC: E21B 43/26; F04B 1/00, 15/02, 17/03; H01F 38/14; B01D 39/14, 46/00/IPC: E21B 43/26;F04B 1/00, 15/02, 17/03;H01F 38/14;B01D 39/14, 46/00

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

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

US-PGPUB, USPAT, USOCR: fracturing, variable, slide, WITH, sliding, frequency, pump, trailer, transformer, slides, OR, platform, switchgear, SAME, stand, electric, support, ADJ, out, vehicle, humans, operator, ladders, rollers, horizontal, roller, rails, vertical, rail, stand, operators, ladder, standing, angle, sarada, in, generator, turbine, angle, human, pump, out

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2018/0363437 A1 (COLI ET AL.) 20 December 2018 (20.12.2018), See entire documents.	1-4, 6-12, and 14-16
Y	US 2017/0030177 A1 (OEHRING ET AL.) 02 February 2017 (02.02.2017), See entire documents.	1-4, 6-12, and 14-19
Y	US 2008/0017369 A1 (SARADA) 24 January 2008 (24.01.2008), See entire documents.	2, and 10-12
Y	US 2017/0036872 A1 (WALLACE ET AL.) 09 February 2017 (09.02.2017), See entire documents.	3, 4, 7-12, and 14-19
Y	US 1,656,861 A (A. J. LEONARD) 17 January 1928 (17.01.1928), See entire documents.	16

☐ 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
"D" document cited by the applicant in the international application
"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
06 February 2020 (06.02.2020)	11 FEB 2020
Name and mailing address of the ISA/US COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA Facsimile No. (571)273-8300	Authorized officer HARRY C. KIM Telephone No. 571-272-4300

Form PCT/ISA/210 (second sheet) (July 2019)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
TAYLOR P. EVANS
HOGAN LOVELLS US LLP
609 MAIN STREET, SUITE 4200
HOUSTON, TEXAS 77002
UNITED STATES OF AMERICA

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	11 FEB 2020
Applicant's or agent's file reference: 047158.500047	FOR FURTHER ACTION: See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/055323	09 October 2019 (09.10.2019)	09 October 2018 (09.10.2018)

International Patent Classification (IPC) or both national classification and IPC
IPC: E21B 43/26; F04B 1/00, 15/02, 17/03; H01F 38/14; B01D 39/14, 46/00
CPC: E21B 43/26; F04B 1/00, 15/02, 17/03; H01F 38/14; B01D 39/14, 46/00

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
COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA	06 February 2020 (06.02.2020)	HARRY C. KIM
Facsimile No. (571)273-8300		Telephone No. 571-272-4300

Form PCT/ISA/237 (Cover sheet) (revised January 2019)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/055323

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
   - [x] 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(b)).

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/US2019/055323

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	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	5, 13, and 20	YES
	Claims	1-4, 6-12, and 14-19	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

---------- EXPLANATION ----------

Claims **1, and 6 lacks** an inventive step under PCT Article 33(3) as being obvious over Coli et al. (US 2018/0363437) in view of Oehring et al. (US 2017/0030177).

In reference to claim 1, Coli discloses a hydraulic fracturing system for fracturing a subterranean formation, comprising:

a support structure 10 having a first area (Fig. 3, occupied by left most pump module 20), a second area (Fig. 3, within enclosure 50), a third area (Fig. 3, within enclosure 50), and a fourth area (Fig. 3, any of the other pump modules 20) arranged adjacent one another (see Fig. 3);

an electric powered, multi-plunger pump 22 (par. 0038) with up to 15 plungers (note that the term "up to 15 plungers" is interpreted as any pump having between 1 and 15 plungers; Coli discloses quintiplex and triplex pumps, par. 0044), arranged in the first area, the electric powered pump 22 coupled to a well associated with the subterranean formation and powered by at least one electric motor 21, also arranged in the first area (see Fig. 3), the electric powered pump 22 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 (par. 0038);

a variable frequency drive (VFD) (pars. 0063 and 0064, located within "transformer and drive unit 50 (see Fig. 3)"), arranged in the second area proximate the first area, connected to the at least one electric motor to control the speed of the at least one electric motor;

a transformer (par. 0045, located within "transformer and drive unit 50 (see Fig. 3)", arranged in the third area proximate the second area (Coli doesn't explicitly show how the transformer and VFD are oriented within the enclosure 50, but anything located within the enclosure is both proximate to other features located within the enclosure and proximate to the first area), the transformer positioned within an enclosure 50, the transformer distributing power to the electric pump 22, the power being received from at least one generator 30 (par. 0034, "turbine generator") at a voltage higher than an operating voltage of the electric pump (par. 0045).

Coli fails to disclose a slide out platform integrated into the first area, the slide out platform being driven between a retracted position and a deployed position, wherein the deployed position provides a work area proximate the electric pump extending outward from the electric pump.

Oehring discloses a slide out platform 30 (see Figs. 1-3, two separate slide out platforms 30_1 and 30_2 are shown) integrated into a first area comprising an electric pump 12, the slide out platform 30 being driven between a retracted position (see Fig. 3) and a deployed position (see Fig. 2), wherein the deployed position provides a work area proximate the electric pump 12 extending outward from the electric pump 12 (see Fig. 2). It would have been obvious to a person having ordinary skill in the art at the time of the invention to provide a slide out platform integrated into the first area so that human operators can access the electric pump for operation or maintenance.

In reference to claim 6, Oehring discloses a pump platform 94, the pump platform 94 supporting both the electric powered pump 12 and the platform 30, the platform 30 arranged axially lower than the electric

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

powered pump 12 (see Figs. 2 and 3, par. 0023 describes pump platform as "the trailer frame", implying that it supports everything attached to the trailer, including the pump 12).

Claim 2 lack an inventive step under PCT Article 33(3) as being obvious over Coli et al. (US 2018/0363437) in view of Oehring et al. (US 2017/0030177) in the prior art as applied in the immediately preceding paragraph and further in view of Sarada (US 2008/0017369).

In reference to claim 2, Coli and Oehring fail to disclose a filtration trailer fluidly coupled to a turbine coupled to the at least one generator, the filtration trailer receiving an inlet flow of gas, from the well site, and removing one or more components of the gas before directing the gas to the turbine.

Sarada discloses a filtration means 10 (par. 0026) fluidly coupled to a turbine 16 (par. 0027) coupled to the at least one generator (par. 0027), the filtration means receiving an inlet flow of gas, from the well site (see Figure), and removing one or more components of the gas before directing the gas to the turbine 16 (par. 0026).

Further, while Sarada fails to disclose that the filtration means is located on a trailer, Coli and Oehring both disclose transporting well equipment on a trailer (see above).

It would have been obvious to a person having ordinary skill in the art at the time of the invention to provide a filtration trailer so that natural gas can be separated from other materials produced from the well prior to being directed to power the generator.

Claims 3, 4, 7, and 8 lacks an inventive step under PCT Article 33(3) as being obvious over Coli et al. (US 2018/0363437) in view of Oehring et al. (US 2017/0030177) in the prior art as applied in the immediately preceding paragraph and further in view of Wallace et al. (US 2017/0036872).

In reference to claim 3, Coli and Oehring fail to disclose an actuator, coupled to the slide out platform, the actuator driving movement of the platform between the retracted position and the deployed position.

Wallace discloses an actuator 140 (par. 0034), coupled to the slide out platform 82, the actuator 140 driving movement of the platform between the retracted position and the deployed position (par. 0035). It would have been obvious to a person having ordinary skill in the art at the time of the invention to include a slide out platform with an actuator in place of the slide out platform of Oehring as the actuator would prevent the need for a human operator to manually slide the platform into position.

In reference to claim 4, Wallace discloses that the actuator 140 is a "electromechanical linear" (par. 0036) actuator forming at least a portion of a drive system, the drive system comprising:

a pair of guide rails (not numbered, see Fig. 4, the rails connected to platform 82 that bear against rollers 96), coupled to the platform 82 (see Fig. 4);

brackets 90 and 92, supporting the guide rails (see Fig. 4); and

a plurality of wheels 96 engaging the guide rails (see Fig. 4), the wheels restricting movement of the guide rails in at least two directions (see Fig. 4, the wheels prevent lateral movement in either direction against brackets 92).

In reference to claim 7, Coli and Oehring fail to disclose that movement of the platform is driven by an actuator powered by a DC motor.

Wallace discloses driving movement of a platform 82 with a DC motor (par. 0017, it runs on "reduced DC power"). It would have been obvious to a person having ordinary skill in the art at the time of the invention to include a slide out platform with an actuator in place of the slide out platform of Oehring as the actuator would prevent the need for a human operator to manually slide the platform into position.

In reference to claim 8, Wallace discloses a controller 50 (par. 0015), electrically coupled to the platform 82, the controller 50 configured to regulate operation of the platform 82 between the retracted position and the deployed position (par. 0036).

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**

Claims **9, 14, and 15 lacks** an inventive step under PCT Article 33(3) as being obvious over Oehring et al. (US 2017/0030177) in view of Coli et al. (US 2018/0363437) in the prior art as applied in the immediately preceding paragraph and further in view of Wallace et al. (US 2017/0036872).

In reference to claim 9, Oehring discloses a hydraulic fracturing system 110 for fracturing a subterranean formation 116 (par. 0025), comprising:

at least one generator 150;

at least one switchgear receiving electrical power from the generator (par. 0027);

an electric powered pump 12 (Fig. 1, either of the pumps 12_1 or 12_2), arranged on a support structure 14, the electric powered pump 12 coupled to a well associated with the subterranean formation 116 and powered by at least one electric motor 18, the electric powered pump 12 configured to pump fluid into a wellbore 112 associated with the well at a high pressure so that the fluid passes from the wellbore 112 into the subterranean formation 116 and fractures the subterranean formation 116 (see Fig. 5);

a variable frequency drive (VFD) 139, connected to the at least one electric motor 18 to control the speed of the at least one electric motor 18;

a transformer 156, distributing power to the electric powered pump 12, the power being received from the least one generator 150 at a voltage higher than an operating voltage of the electric powered pump (par. 0026); and

a slide out platform 30, arranged on the support structure 14, the slide out platform being driven between a retracted position (Fig. 2) and a deployed position (Fig. 3), wherein the deployed position provides a work area proximate the electric powered pump 12 extending outward from the electric powered pump 12 substantially perpendicular to a longitudinal axis of the support structure 14 (see Fig. 2), the platform 30 being at least partially coupled to a pump platform 94 supporting the electric powered pump 12 (see Fig. 2).

Oehring fails to disclose that the VFD and the transformer are arranged on the support structure; and that the slide out platform is electrically controlled.

Coli discloses an "electrical transformer and drive unit 50 (see Fig. 3)" (par. 0045) that includes a variable frequency drive (par. 0063) that is located on the same support structure 10 as an electric motor 21 and an electric pump 22. It would have been obvious to a person having ordinary skill in the art at the time of the invention to arrange the VFD and the transformer on the support structure so that they do not have to be transported separately from the pump and motor.

Wallace discloses an electrically controlled (par. 0036, "electromechanical linear actuator controlled") slide out platform 82 (see Fig. 1). It would have been obvious to a person having ordinary skill in the art to include an electrically controlled slide out platform in place of the slide out platform of Oehring as the electrical control would prevent the need for a human operator to manually slide the platform into position.

In reference to claim 14, Wallace discloses a controller 50 (par. 0015), electrically coupled to the platform 82, the controller 50 configured to regulate operation of the platform 82 between the retracted position and the deployed position (par. 0036).

In reference to claim 15, Oehring discloses that the platform 30 comprises:

a handrail 38 (see Fig. 2); and

a ladder 46 (see Fig. 2).

Claims **10-12 lacks** an inventive step under PCT Article 33(3) as being obvious over Oehring et al. (US 2017/0030177) in view of Coli et al. (US 2018/0363437) and Wallace et al. (US 2017/0036872) in the prior art as applied in the immediately preceding paragraph and further in view of Sarada (US 2008/0017369).

In reference to claim 10, Coli and Oehring fail to disclose a filtration trailer fluidly coupled to a turbine coupled to the at least one generator, the filtration trailer receiving an inlet flow of gas, from the well site, and removing one or more components of the gas before directing the gas to the turbine.

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

Sarada discloses a filtration means 10 (par. 0026) fluidly coupled to a turbine 16 (par. 0027) coupled to the at least one generator (par. 0027), the filtration means receiving an inlet flow of gas, from the well site (see Figure), and removing one or more components of the gas before directing the gas to the turbine 16 (par. 0026).

Further, while Sarada fails to disclose that the filtration means is located on a trailer, Coli and Oehring both disclose transporting well equipment on a trailer.

It would have been obvious to a person having ordinary skill in the art at the time of the invention to provide a filtration trailer so that natural gas can be separated from other materials produced from the well can be used to power the generator.

In reference to claim 11, Wallace discloses an actuator 140, coupled to the slide out platform 82, the actuator 140 driving movement of the platform between the retracted position and the deployed position 140 (par. 0036), the actuator being driven by a DC motor (par. 0017, it runs on "reduced DC power").

In reference to claim 12, Wallace discloses that Wallace discloses that the actuator 140 is a "electromechanical linear" (par. 0036) actuator forming at least a portion of a drive system, the drive system comprising:

a pair of guide rails (not numbered, see Fig. 4, the rails connected to platform 82 that bear against rollers 96), coupled to the platform 82 (see Fig. 4);

brackets 90 and 92, supporting the guide rails (see Fig. 4); and a plurality of wheels 96 engaging the guide rails (see Fig. 4), the wheels restricting movement of the guide rails in at least two directions (see Fig. 4, the wheels prevent lateral movement in either direction against brackets 92).

Claims 16 lack an inventive step under PCT Article 33(3) as being obvious over Oehring et al. (US 2017/0030177) in view of Coli et al. (US 2018/0363437) and Wallace et al. (US 2017/0036872) in the prior art as applied in the immediately preceding paragraph and further in view of Leonard (US 1,656,861).

In reference to claim 16, Oehring fails to disclose that the ladder is arranged at an angle relative to the platform, the angle being obtuse. Leonard discloses ladder 72 (page 3, line 40) arranged at an obtuse angle relative to a platform 56. It would have been obvious to a person having ordinary skill in the art at the time of the invention to dispose a ladder at an obtuse angle so that the climb up the ladder is less steep.

Claims 17-19 lacks an inventive step under PCT Article 33(3) as being obvious over Oehring et al. (US 2017/0030177) in view of Wallace et al. (US 2017/0036872).

In reference to claim 17, Oehring discloses a slide out platform 30 coupled to a trailer 14 including one or more components for hydraulic fracturing (see Fig. 1), comprising:

a pair of guide rails 70 and 72 (par. 0022, Figs. 2 and 3), coupled to the platform 30, the guiderails 70 and 72 extending perpendicular to an axis of the trailer 14 and engaging at least a portion of a pump platform 94 (see Figs. 2 and 3); and

brackets 76 and 77 (par. 0022, Figs. 2 and 3) supporting the guide rails 70 and 72.

Oehring fails to disclose an actuator for driving movement of the platform between a retracted position and a deployed position, the actuator being coupled to a lower area of a standing portion of the platform; and a plurality of wheels engaging the guide rails, the wheels restricting movement of the guide rails in at least two directions.

Wallace discloses an electrically driven (par. 0036, "electromechanical linear actuator controlled") slide out platform 82 comprising an actuator 140 for driving movement of the platform 82 between a retracted position and a deployed position (par. 0035), the actuator 140 being coupled to a lower area of a standing portion of the platform 82 (see Fig. 3); and a plurality of wheels 96 engaging the guide rails (see Fig. 4), the wheels 96 restricting movement of the guide rails in at least two directions (see Fig. 4).

It would have been obvious to a person having ordinary skill in the art at the time of the invention to include an electrically driven slide out platform in place of the slide out platform of Oehring as the

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**

electrical control would prevent the need for a human operator to manually slide the platform into position.

Further, it would have been obvious to a person having ordinary skill in the art at the time of the invention to include wheels with the guide rails to reduce friction between the guide rails and the brackets to reduce friction between the two while the platform is being driven.

In reference to claim 18, Wallace discloses that the actuator 140 is powered by a DC motor (par. 0017, it runs on "reduced DC power"), the DC motor being powered by a battery 140 that is recharged by at least one motor 34 (par. 0015). As Oehring discloses a motor 18 that is a hydraulic fracturing component, it would have been obvious to charge the battery with the motor as failing to do so would require an additional motor to be provided.

In reference to claim 19, Oehring discloses:

a handrail 38, arranged along a length of the platform 30 (see Figs. 1 and 2);

a retention rail 50 (see Fig. 2), the retention rail being rotatable about an axis (see Figs. 2-4); and

a ladder 46 (see Fig. 2).

Claims 5, 13, and 20 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the claims limitations.

Claims 5, 13, and 20 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the claims limitations.

Claims 1-20 meets 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.

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/055323

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 6 is objected to under PCT Article 6 as lacking clarity because claim 6 indefinite for the following reason(s): **for the failing to particularly point out and distinctly claim the subject matter which the inventor or joint inventor, the applicant regards as the invention**

"the platform arranged axially lower than the electric powered pump". Claim 6, prior to the above limitation, also recites the limitation "a pump platform". Claim 6 depends from claim 1 which recites "a slide out platform". As there are multiple platforms claimed, it is unclear which platform must be arranged axially lower than the electric powered pump.

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 2020
Applicant's or agent's file reference 047158.500048	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 19/55325	International filing date *(day/month/year)* 09 October 2019 (09.10.2019)
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 preferably through ePCT, or on paper to:
   The International Bureau of WIPO, 34, chemin des Colombettes, 1211 Geneva 20, Switzerland
   (Facsimile No.: +41 22 338 82 70)

   For more detailed instructions, see the *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 Young Telephone No. PCT Helpdesk: 571-272-4300

Form PCT/ISA/220 (revised January 2019)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference		FOR FURTHER ACTION
047158.500048		see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US 19/55325	09 October 2019 (09.10.2019)	09 October 2018 (09.10.2018)
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. 4

   ☐ 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 19/55325

A. CLASSIFICATION OF SUBJECT MATTER
IPC - E21B 43/26 (2019.01)
CPC - E21B 43/26

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 --- A	US 2018/0258746 A1 (U.S. Well Services, LLC) 13 September 2018 (13.09.2018) Entire document especially para [0006]-[0007], [0014]-[0015], [0024], [0030] and figs. 1 and 3	9, 13, 15 ----- 1-2, 6, 8, 12 ----- 3-5, 7, 10-11, 14
Y --- A	US 2016/0177675 A1 (Evolution Well Services, LLC) 23 June 2016 (23.06.2016) Entire document especially para [0076]-[0077] and figs. 7A-B	12 ----- 5
Y --- A	US 2015/0354322 A1 (Vicknair et al.) 10 December 2015 (10.12.2015) Entire document especially para [0013] and figs. 1A-D	1-2, 6, 8 ----- 3-5, 7
Y --- A	CA 2787814 A1 (Pawlick) 21 February 2014 (21.02.2014) Entire document especially para [0001]-[0002], [0022], [0026] and figs. 1 and 2	1-2, 6, 8 ----- 3-5, 7
A	US 2016/0105022 A1 (US Well Services, LLC) 14 April 2016 (14.04.2016) Entire document especially para [0040]-[0041] and fig. 3	7, 14
A	US 9,893,500 B2 (US Well Services, LLC) 13 February 2018 (13.02.2018) Entire document	1-15
A	US 2015/0252661 A1 (Glass) 10 September 2015 (10.09.2015) Entire document	1-15

☒ 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
"D" document cited by the applicant in the international application
"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
19 November 2019	02 JAN 2020
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 Young Telephone No. PCT Helpdesk: 571-272-4300

Form PCT/ISA/210 (second sheet) (July 2019)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 19/55325

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0010671 A1 (Cryer et al.) 9 January 2014 (09.01.2014) Entire document	1-15
A	US 2017/0016433 A1 (Schlumberger Technology Corporation) 19 January 2017 (19.01.2017) Entire document	1-15
A	US 9,119,326 B2 (McDonnell et al.) 25 August 2015 (25.08.2015) Entire document	1-15

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 2020
Applicant's or agent's file reference 047158.500048	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 19/55325	09 October 2019 (09.10.2019)	09 October 2018 (09.10.2018)

International Patent Classification (IPC) or both national classification and IPC
IPC - E21B 43/26 (2019.01)
CPC - E21B 43/26

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
- [ ] 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	19 November 2019	Lee Young PCT Help Desk Telephone No. 571-272-4300

Form PCT/ISA/237 (cover sheet) (revised January 2019)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 19/55325

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(b)).

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 19/55325

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	1-8, 10-12, 14-15	YES
	Claims	9, 13	NO
Inventive step (IS)	Claims	3-5, 7, 10-11, 14	YES
	Claims	1-2, 6, 8-9, 12, 13, 15	NO
Industrial applicability (IA)	Claims	1-15	YES
	Claims	None	NO

2. Citations and explanations:

Claims 9 and 13 lack novelty under PCT Article 33(2) as being anticipated by US 2018/0258746 A1 to U.S. Well Services, LLC (hereinafter 'US746')

Regarding Claim 9, US746 teaches a hydraulic fracturing system (See figs. 1 and 3; para [0014]) for fracturing a subterranean formation (para [0006]-[0007], [0014]), comprising:
at least one generator (22 - "generators", fig. 1; para [0020]);
at least one switchgear (47 - "switchgear", fig. 3) receiving electrical power from the generator (See fig. 3; para [0034]);
an electric powered pump (10 - "pump", fig. 1; para [0018] - "plungers"), arranged on a support structure (collectively 12 - "pump trailers", fig. 1; includes pump trailers 12 that support pumps 10 as well as the trailers that are not labeled but support generators 22), the electric powered pump coupled to a well (16 - "wellhead", fig. 1) associated with the subterranean formation (See fig. 1; para [0014]) and powered by at least one electric motor (14 - "electric motor", fig. 1), the electric powered pump configured to pump fluid into a wellbore associated with the well at a high pressure (para [0006], [0035]) so that the fluid passes from the wellbore into the subterranean formation and fractures the subterranean formation (para [0006]-[0008], [0014]);
a variable frequency drive (VFD) (para [0015] - "variable frequency drive"), arranged on the support structure proximate the electric powered pump (See fig. 1; para [0015] - connected to the motor 14 and the pump 10 so it must be on one of the trailers 12), connected to the at least one electric motor to control the speed of the at least one electric motor (para [0015]);
a transformer (para [0024] - "transformers"), arranged on the support structure proximate the VFD (See fig. 1; para [0024, [0030] - transformer must be located on either trailer 12 or on one of the pump trailers that supports generators 22 since the transformer is designed to step down voltage between the generator and the pump), the transformer distributing power to the electric powered pump, the power being received from the least one generator (22 - "generator", fig. 1) at a voltage higher than an operating voltage of the electric powered pump (para [0024] - transformers are designed to reduce voltage between components); and
a cooling system (para [0015] - "air conditioning unit"), arranged on the support structure proximate the transformer (See fig. 1; para [0015] - in order to cool the VFD, the air conditioning unit must be on a trailer), the cooling system providing a cooling fluid to at least the VFD (para [0015] - "air").

Regarding Claim 13, US746 teaches the system of claim 9, wherein the support structure is at least one of a trailer (collectively 12 - "pump trailers", fig. 1; includes pump trailers 12 that support pumps 10 as well as the trailers that are not labeled but support generators 22), a skid, a pad, a truck bed, or a combination thereof.

Claim 15 lacks an inventive step under PCT Article 33(3) as being obvious over US746

Regarding Claim 15, US746 teaches the system of claim 9, but does not specifically teach wherein the cooling system comprises a radiator that utilizes a water/glycol mixture. Further, Pawlick teaches a hydraulic fracturing system (See figs. 1 and 2; para [0001]-[0002], [0022]) comprising a cooling system (20 - "radiator", figs. 1 and 2) for providing a cooling fluid via one or more headers (41, 42 - "top and bottom headers", fig. 6; para [0026]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the cooling system taught by Pawlick to cool the VFD in place of the cooling system taught by US in order to ensure the VFD is sufficiently cooled to continue safe operation of the hydraulic fracturing system. Any combination of the above references fails to teach wherein the radiator utilizes a water/glycol mixture. However, the use of water/glycol in radiators are ubiquitous and well-known to the general population. Accordingly, it would have been obvious to one of ordinary skill in the art to use a water/glycol mixture in the radiator in order to keep material costs low for the radiator.

-*-Continued in 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 12 lacks an inventive step under PCT Article 33(3) as being obvious over US746 in view of US 2016/0177675 A1 to Evolution Well Services, LLC (hereinafter 'Evolution')

Regarding Claim 12, US746 teaches the system of claim 9, but does not specifically teach the system further comprising:
a transformer service platform that provides access to the transformer, the transformer service platform positioned at a higher elevation than at least a portion of a base of the electric powered pump.
Further, Evolution teaches a hydraulic fracturing system (See figs. 7A-B; para [0076]) comprising a support structure (710 - "trailer", fig. 7B) comprising a transformer service platform (See fig. 7B; see elevated portion of trailer 710 that supports power and control systems 708; para [0077]), the transformer service platform positioned at a higher elevation (See fig. 7B) than at least a portion of a base of the electric powered pump (702A-B - "pumps", fig. 7B). Accordingly, it would have been obvious to one of ordinary skill in the art to elevate the portion of the support structure containing the transformer in order to provide operators with better access to the components of the transformer during maintenance.

Claims 1-2, 6 and 8 lack an inventive step under PCT Article 33(3) as being obvious over US746 in view of US 2015/0354322 A1 to Vicknair et al. (hereinafter 'Vicknair') in view of CA 2787814 A1 to Pawlick (hereinafter 'Pawlick')

Regarding Claim 1, US746 teaches a hydraulic fracturing system (See figs. 1 and 3; para [0014]) for fracturing a subterranean formation (para [0006]-[0007], [0014]), comprising:
a support structure (collectively 12 - "pump trailers", fig. 1; includes pump trailers 12 that support pumps 10 as well as the trailers that are not labeled but support generators 22) having a first area (See fig. 1; see portion of trailer 12 occupied by pump 10), a second area (See fig. 1; para [0015] - second area is not shown but is the portion of trailer 12 occupied by the variable frequency drive), a third area (See fig. 1; para [0024, [0030] - transformer must be located on either trailer 12 or on one of the pump trailers that supports generators 22 since the transformer is designed to step down voltage between the generator and the pump), and a fourth area (See fig. 1; fourth area is not shown but it is the portion of trailer 12 with the air conditioning unit) arranged adjacent one another (See fig. 1);
an electric powered, multi-plunger pump (10 - "pump", fig. 1; para [0018] - "plungers"), arranged in the first area (See fig. 1; see portion of trailer 12 occupied by pump 10), the electric powered pump coupled to a well (16 - "wellhead", fig. 1) associated with the subterranean formation (See fig. 1; para [0014]) and powered by at least one electric motor (14 - "electric motor", fig. 1), also arranged in the first area (See fig. 1; see pump 10 and motor 14 adjacent to one another one trailer 12), the electric powered pump configured to pump fluid into a wellbore (para [0006], [0035]) 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 (para [0006]-[0008], [0014]);
a variable frequency drive (VFD) (para [0015] - "variable frequency drive"), arranged in the second area (See fig. 1; para [0015] - second area is not shown but is the portion of trailer 12 occupied by the variable frequency drive) proximate the first area, connected to the at least one electric motor to control the speed of the at least one electric motor (para [0015]);
a transformer (para [0024] - "transformers"), arranged in the third area (See fig. 1; para [0024, [0030] - transformer must be located on either trailer 12 or on one of the pump trailers that supports generators 22 since the transformer is designed to step down voltage between the generator and the pump) proximate the second area (See fig. 1; see how trailers of generator 22 are adjacent the trailers 12), the transformer distributing power to the electric pump (para [0030] - describes the embodiment of fig. 2, but the transformer is used in the same way in the embodiment of fig. 1), the power being received from at least one generator (22 - "generators", fig. 1) at a voltage higher than an operating voltage of the electric pump (para [0024] - transformers are designed to reduce voltage between components); and
a cooling system (para [0015] - "air conditioning unit"), arranged in the fourth area (See fig. 1; fourth area is not shown but it is the portion of trailer 12 with the air conditioning unit) proximate the third area (See fig. 1; see how vehicle 42 is adjacent the trailers 12), but does not specifically teach wherein the pump has up to 15 plungers, wherein the transformer is positioned within an enclosure or wherein the cooling system providing a cooling fluid to the VFD via one or more headers.
Design decisions regarding the number of plungers for a pump fall within the ordinary skill in the art of one designing hydraulic fracturing system. Accordingly, it would have been obvious to one of ordinary skill in the art to have utilized routine experimentation and design choices in order to have chosen an appropriate number of plungers for the pumps as claimed thereby allowing for sufficient pressure buildup in the wellbore to initiate a fracturing operation.
Further, Vicknair teaches a hydraulic fracturing system (See figs. 1A-D; para [0013]) comprising a transformer (6 - "transformer", fig. 1A), wherein the transformer is positioned within an enclosure (4 - "substation", fig. 1A). Accordingly, it would have been obvious to one of ordinary skill in the art to use the enclosure taught by Vicknair to enclose the transformer taught by US746 in order to ensure the transformer is not damaged by the ambient environment during hydraulic fracturing operations.
Further still, Pawlick teaches a hydraulic fracturing system (See figs. 1 and 2; para [0001]-[0002], [0022]) comprising a cooling system (20 - "radiator", figs. 1 and 2) for providing a cooling fluid via one or more headers (41, 42 - "top and bottom headers", fig. 6; para [0026]). Accordingly, it would have been obvious to one of ordinary skill in the art to use the cooling system taught by Pawlick to cool the VFD in place of the cooling system taught by US746 in order to ensure the VFD is sufficiently cooled to continue safe operation of the hydraulic fracturing system.

Regarding Claim 2, the modified US746 teaches the system of claim 1, further comprising:
a control system (40 - "control data van", fig. 1), the control system including one or more operating parameters of the electric pump, VFD, transformer, or cooling system (para [0023]) but the does not specifically teach wherein the control system is arranged in the fourth area. However, the rearrangement of parts is obvious to one of ordinary skill in the art so long as it does not modify the operation of the system. Accordingly, it would have been obvious to one of ordinary skill in the art, practicing routine experimentation and design methods, to have the control system be in the fourth area in order to consolidate the control system and the cooling system to help reduce stray parts, or otherwise as desired or necessary to meet the requirements of a particular application.

-*-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 6, the modified US746 teaches the system of claim 1, wherein the support structure is at least one of a trailer (collectively 12 - "pump trailers", fig. 1; includes pump trailers 12 that support pumps 10 as well as the trailers that are not labeled but support generators 22), a skid, a pad, a truck bed, or a combination thereof.

Regarding Claim 8, the modified US746 teaches the system of claim 1, wherein the cooling system (Pawlick: 20 - "radiator", figs. 1 and 2) comprises a radiator (Pawlick: 20 - "radiator", figs. 1 and 2) but does not specifically teach wherein the radiator utilizes a water/glycol mixture. However, the use of water/glycol in radiators are ubiquitous and well-known to the general population. Accordingly, it would have been obvious to one of ordinary skill in the art to use a water/glycol mixture in the radiator in order to keep material costs low for the radiator.

Claims 3-5, 7, 10-11 and 14 meet the criteria of PCT Article 33(2) & 33(3) because, as will be shown, the prior art does not teach, nor does it fairly suggest, the claimed limitations.

The prior art is exemplified by (1) US746, (2) Vicknair, (3) Pawlick, (4) Evolution and (5) US 2016/0108022 A1 to US Well Services, LLC (hereinafter 'US022')

(1) US746 teaches a hydraulic fracturing system (See figs. 1 and 3; para [0014]) for fracturing a subterranean formation (para [0006]-[0007], [0014]), comprising:
at least one generator (22 - "generators", fig. 1; para [0020]);
at least one switchgear (47 - "switchgear", fig. 3) receiving electrical power from the generator (See fig. 3; para [0034]);
an electric powered pump (10 - "pump", fig. 1; para [0018] - "plungers"), arranged on a support structure (collectively 12 - "pump trailers", fig. 1; includes pump trailers 12 that support pumps 10 as well as the trailers that are not labeled but support generators 22), the electric powered pump coupled to a well (16 - "wellhead", fig. 1) associated with the subterranean formation (See fig. 1; para [0014]) and powered by at least one electric motor (14 - "electric motor", fig. 1), the electric powered pump configured to pump fluid into a wellbore associated with the well at a high pressure (para [0006], [0035]) so that the fluid passes from the wellbore into the subterranean formation and fractures the subterranean formation (para [0006]-[0008], [0014]);
a variable frequency drive (VFD) (para [0015] - "variable frequency drive"), arranged on the support structure proximate the electric powered pump (See fig. 1; para [0015] - connected to the motor 14 and the pump 10 so it must be on one of the trailers 12), connected to the at least one electric motor to control the speed of the at least one electric motor (para [0015]);
a transformer (para [0024] - "transformers"), arranged on the support structure proximate the VFD (See fig. 1; para [0024, [0030] - transformer must be located on either trailer 12 or on one of the pump trailers that supports generators 22 since the transformer is designed to step down voltage between the generator and the pump), the transformer distributing power to the electric powered pump, the power being received from the least one generator (22 - "generator", fig. 1) at a voltage higher than an operating voltage of the electric powered pump (para [0024] - transformers are designed to reduce voltage between components); and
a cooling system (para [0015] - "air conditioning unit"), arranged on the support structure proximate the transformer (See fig. 1; para [0015] - in order to cool the VFD, the air conditioning unit must be on a trailer), the cooling system providing a cooling fluid to at least the VFD (para [0015] - "air").

(2) Vicknair teaches a hydraulic fracturing system (See figs. 1A-D; para [0013]) comprising a transformer (6 - "transformer", fig. 1A), wherein the transformer is positioned within an enclosure (4 - "substation", fig. 1A).

(3) Pawlick teaches a hydraulic fracturing system (See figs. 1 and 2; para [0001]-[0002], [0022]) comprising a cooling system (20 - "radiator", figs. 1 and 2) for providing a cooling fluid via one or more headers (41, 42 - "top and bottom headers", fig. 6; para [0026]).

(4) Evolution teaches a hydraulic fracturing system (See figs. 7A-B; para [0076]) comprising a support structure (710 - "trailer", fig. 7B) comprising a transformer service platform (See fig. 7B; see elevated portion of trailer 710 that supports power and control systems 708; para [0077]), the transformer service platform positioned at a higher elevation (See fig. 7B) than at least a portion of a base of the electric powered pump (702A-B - "pumps", fig. 7B).

(5) US022 teaches a hydraulic fracturing system (See fig. 3; para [0040]) comprising cable trays (para [0041] - "cable trays").

Regarding Claim 3, the modified US746 teaches the system of claim 1, further comprising:
a switchgear subassembly (47 - "switchgear", fig. 3; para [0034]), but the prior art does not specifically teach or fairly suggest individually or in combination wherein the switchgear subassembly has integrated core units configured to operate in a connected position, an open position, or a grounded position.

Regarding Claim 4, the prior art does not specifically teach or fairly suggest individually or in combination the system as claimed since it is dependent on claim 3.

-*-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 5, the modified US746 teaches the system of claim 1, but does not specifically teach wherein the fourth section is arranged at a higher elevation than the first section, the fourth section associated with a gooseneck portion of a trailer. Further, Evolution teaches a hydraulic fracturing system (See figs. 7A-B; para [0076]) comprising a support structure (710 - "trailer", fig. 7B) with a first area (See fig. 7B; all of transport 700 except power and control systems 708) and a second area (7-8 - "power and control systems", fig. 7B), wherein the second section is arranged at a higher elevation than the first section (See fig. 7B), the fourth section associated with a gooseneck portion of a trailer (See portion of trailer 71 that juts upward around power and control systems 708). However, the second area, which is elevated, as taught by Evolution comprises a control system, not a cooling system like the fourth area of the system taught by the modified US746. Accordingly, there is no motivation to elevate the fourth area of the modified US746 with respect to the first area. Accordingly, the prior art does not specifically teach or fairly suggest individually or in combination the system as claimed.

Regarding Claim 7, the modified US746 teaches the system of claim 1, but does not specifically teach the system further comprising: cable trays positioned below a walking surface of the fourth section, the cable channels being covered by a hinged cover that pivots to provide access to the cable channels.
Further, US022 teaches a hydraulic fracturing system (See fig. 3; para [0040]) comprising cable trays (para [0041] - "cable trays").
However, any combination of the above references fails to teach wherein the cable trays are positioned below a walking surface of the fourth section or wherein the cable channels are covered by a hinged cover. Accordingly, the prior art does not specifically teach or fairly suggest individually or in combination the system as claimed.

Regarding Claim 10, US746 teaches the system of claim 9, but the prior art does not specifically teach or fairly suggest individually or in combination wherein the at least one switchgear comprises integrated core units configured to operate in a connected position, an open position, or a grounded position.

Regarding Claim 11, the prior art does not specifically teach or fairly suggest individually or in combination the system as claimed since it is dependent on claim 10.

Regarding Claim 14, US746 teaches the system of claim 9, but does not specifically teach the system further comprising:
cable trays positioned below a walking surface of the support structure, the cable channels being covered by a hinged cover that pivots to provide access to the cable channels.
Further, US022 teaches a hydraulic fracturing system (See fig. 3; para [0040]) comprising cable trays (para [0041] - "cable trays").
However, any combination of the above references fails to teach wherein the cable trays are positioned below a walking surface of the support structure or wherein the cable channels are covered by a hinged cover. Accordingly, the prior art does not specifically teach or fairly suggest individually or in combination the system as claimed.

Claims 1-15 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used by industry.

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)* 10 APR 2019
Applicant's or agent's file reference 047158.500037	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2019/016635	International filing date *(day/month/year)* 05 February 2019
Applicant U.S. WELL SERVICES, INC.	

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, Fac**simile** 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 PCT Helpdesk: 571-272-4300 Telephone No. 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 047158.500037	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2019/016635	International filing date *(day/month/year)* 05 February 2019	(Earliest) Priority Date *(day/month/year)* 05 February 2018
Applicant U.S. WELL SERVICES, INC.		

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. 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/US2019/016635

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.01)
CPC - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.02)

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 - 700/295; 166/305.1, 166/308.1; 700/293 (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 2016/0105022 A1 (US WELL SERVICES LLC) 14 April 2016 (14.04.2016) entire document	1-4, 15, 19, 20
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Y		5, 7-12, 14, 16, 18
Y	US 2010/0019574 A1 (BALDASSARRE et al) 28 January 2010 (28.01.2010) entire document	5
Y	CA 2 964 593 A1 (US WELL SERVICES LLC) 15 October 2017 (15.10.2017) entire document	7-12, 14, 16, 18
A	US 2016/0369609 A1 (EVOLUTION WELL SERVICES, LLC) 22 December 2016 (22.12.2016) 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
25 March 2019	10 APR 2019
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)* 10 APR 2019

Applicant's or agent's file reference
047158.500037

FOR FURTHER ACTION
See paragraph 2 **below**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/016635	05 February 2019	05 February 2018

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.01)
CPC - H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.02)

Applicant U.S. WELL SERVICES, INC.

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	25 March 2019	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/US2019/016635

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/US2019/016635

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	5-14, 16-18	YES
	Claims	1-4, 15, 19, 20	NO
Inventive step (IS)	Claims	6, 13, 17	YES
	Claims	1-5, 7-12, 14-16, 18-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-4, 15, 19, and 20 lack novelty under PCT Article 33(2) as being anticipated by US Well Services LLC (hereinafter USWell**022**).

Regarding Claim 1, USWell022 discloses a system for completing a well (a hydraulic fracturing operation can be carried out according to the following process... The fracturing fluid can be pumped into the wellbore at a high enough pressure that the fracturing fluid cracks the formation, para 0042), the system comprising: a generator (generators 222A, 222B, para 0045; also see Fig. 5); a plurality of electric load components, each electric load component powered by the generator (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5); and a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of electric load components to reduce the electric load (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if one of the turbines loses power,... [in prior art] the ability to shed load, such as by shutting down power to non-critical parts of the system, is limited. The power draw from all of the units overloads the turbines, para 0006; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).

Regarding Claim 2, USWell022 discloses the system of claim 1, further comprising: a switch gear positioned between the generator and the plurality of electric load components to distribute power between the generator and the plurality of electric load components (The power from the generators 222A of group A goes to switchgear 235A. From switchgear 235A, the power goes to the transformers 223A, and to the auxiliary trailer 225A, which can have a transformer, as well as a VFD and softstarts for the blender and hydration units. Power can then go to one or more of the following: the primary blender 234A, the primary hydration unit 232A, the primary data van 227A, and/or the primary sand equipment 229A. Power from the transformers 223A also goes to pumps 210A., para 0050; also see Fig. 5).

Regarding Claim 3, USWell022 discloses the system of claim 1, wherein the generator is a natural gas turbine generator, a natural gas generator, or a diesel generator (the electric generators 22 can be powered by natural gas., para 0027).

Regarding Claim 4, USWell022 discloses the system of claim 1, wherein the electric load components are selected from the group consisting of electric hydraulic fracturing pumps, a blender, sand equipment, a hydration unit, and a data van (Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B, as well as separate and distinct auxiliary trailers 225A, 225B, each including its own ancillary equipment, such as, for example, data vans 227A, 227B, sand equipment 229A, 229B, blenders 234A, 234B, and hydration units 232A, 232B, para 0045; also see Fig. 5).

Regarding Claim 15, USWell022 discloses a method of completing a well (a hydraulic fracturing operation can be carried out according to the following process... The fracturing fluid can be pumped into the wellbore at a high enough pressure that the fracturing fluid cracks the formation, para 0042), the method comprising the steps of: a) powering a plurality of hydraulic fracturing equipment components with a generator (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5); b) monitoring the generator to determine when the generator loses functionality; c) when the generator loses functionality, selectively deactivating one or more of the plurality of hydraulic fracturing equipment components to decrease the load (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if one of the turbines loses power,... [in prior art] the ability to shed load, such as by shutting down power to non-critical parts of the system, is limited. The power draw from all of the units overloads the turbines, para 0006; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).

Regarding Claim 19, USWell022 discloses the method of claim 15, further comprising: distributing power between the generator and the plurality of hydraulic fracturing equipment components with a switchgear (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5)

Supplemental Box

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

Regarding Claim 20, USWell022 discloses the method of claim 15, wherein step c) is carried out by a load shedding control panel that monitors the generator to determine when the generator loses functionality (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).

Claim 5 lacks an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter USWell022) in view of Baldassarre et al. (hereinafter Baldassarre).

Regarding Claim 5, USWell022 fails to disclose the system of claim 4, wherein the load shedding panel prioritizes the order in which the plurality of electric load components will be deactivated. Baldassarre is in the field of energy management systems (para 0002) and teaches wherein the load shedding panel prioritizes the order in which the plurality of electric load components will be deactivated (loads are shed in the predetermined sequence established by a user and/or as defined by a user in real-time via a user interactive device until the total current is less than the predetermined peak total or until the system has detected a stable current situation, para 0058; the control system can store this information and statistically translate it to determine the priority of each sensed load, and subsequently create a priority list to be implemented by an auxiliary power source in the instance when the utility power source fails, para 0076). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of Baldassarre for the purpose of shedding lower priority loads based on predetermined priority or real-time decisions made by the user so as to ensure that the vital loads remain connected and active while the auxiliary or generator power source remains below a threshold value (see Baldassarre, para 0130).

Claims 7-12, 14, 16, and 18 lack an inventive step under PCT Article 33(3) as being obvious over US Well Services LLC (hereinafter USWell022) in view of US Well Services LLC (hereinafter USWell593).

Regarding Claim 7, USWell022 fails to disclose the system of claim 1, wherein the generator is in selective electrical communication with a power grid.
USWell593 is in the field of hydraulic fracturing (para 0002) and teaches wherein the generator is in selective electrical communication with a power grid (FIG. 14 illustrates an example 1400 of a configuration for load sharing with a utility grid, according to an embodiment, para 0085; enable the switchgear units -B+- 1425-b and "C+- 1425-c to load share between the generator sets 1405-a, 1405-b, 1405-c, 1405- d and the utility grid. For example, if the utility grid is transmitting power at 69 kV, the transformer 1445 can step down the 69kV voltage to 13.8 kV for use by the microgrid. In this configuration, power can be either provided to the grid or supplemented from the utility grid during times of peak power demand, para 0086). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of allowing for power transfer to and from the grid as needed (see USWell593, para 0086).

Regarding Claim 8, USWell022 discloses a system for completing a well (a hydraulic fracturing operation can be carried out according to the following process... The fracturing fluid can be pumped into the wellbore at a high enough pressure that the fracturing fluid cracks the formation, para 0042), the system comprising: a generator (generators 222A, 222B, para 0045; also see Fig. 5); a plurality of hydraulic fracturing equipment components, each of the plurality of hydraulic fracturing equipment components powered by the generator (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B, as well as separate and distinct auxiliary trailers 225A, 225B, each including its own ancillary equipment, such as, for example, data vans 227A, 227B, sand equipment 229A, 229B, blenders 234A, 234B, and hydration units 232A, 232B [hydraulic fracturing components], para 0045; also see Fig. 5); an electric equipment, the electric equipment powered by the generator; and a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of hydraulic fracturing equipment components or the electric equipment to reduce the electric load (The turbine generators 122 can be connected to the electric motors 114 [of the pumps/loads] via power distribution panels, para 0036; The load shed system of the embodiment of FIG. 5 can monitor when power draw will overload the system (i.e., when demand is higher than supply), and it will send a signal to open a breaker 233A, 233B to cut certain pumps 210A, 210B, thereby reducing power before the entire bank is overloaded para 0047; if one of the turbines loses power,... [in prior art] the ability to shed load, such as by shutting down power to non-critical parts of the system, is limited. The power draw from all of the units overloads the turbines, para 0006; if the at least one first generator loses the ability to generate electricity, the at least one second generator can continue to generate electricity, para 0007).
USWell022 does not disclose wherein the electric equipment is an electric drilling rig. USWell593 discloses wherein the electric equipment is an electric drilling rig (The power generation equipment can be used to supply any oilfield equipment including... drilling rigs, para 0044). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of providing power for oilfield equipment that doe not have access to a utility provided power grid or that has a dynamic power load or low power factor(see USWell593, para 008644).

Supplemental Box

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

Regarding Claim 9, modified USWell022 discloses the system of claim 8, further comprising: a switch gear positioned between the generator and the plurality of hydraulic fracturing equipment components, and between the generator and the electric equipment, to distribute power between the generator and the plurality of hydraulic fracturing equipment components, and between the generator and the electric equipment (at least one first generator in electrical communication with a first switchgear for providing power to primary components of a hydraulic fracturing operation;, claim 1; Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B [load components], para 0045; also see Fig. 5). USWell022 does not disclose wherein the electric equipment is an electric drilling rig. USWell593 discloses wherein the electric equipment is an electric drilling rig (The power generation equipment can be used to supply any oilfield equipment including... drilling rigs, para 0044) It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of providing power for oilfield equipment that doe not have access to a utility provided power grid or that has a dynamic power load or low power factor(see USWell593, para 008644).

Regarding Claim 10, modified USWell022 discloses the system of claim 8, wherein the generator is a natural gas turbine generator, a natural gas generator, or a diesel generator (the electric generators 22 can be powered by natural gas., para 0027).

Regarding Claim 11, modified USWell022 discloses the system of claim 8, wherein the hydraulic fracturing equipment components are selected from the group consisting of electric hydraulic fracturing pumps, a blender, sand equipment, a hydration unit, and a data van (Each group A, B of generators 222A, 222B is connected in turn to separate and distinct groups of transformers 223A, 223B and pumps 210A, 210B, as well as separate and distinct auxiliary trailers 225A, 225B, each including its own ancillary equipment, such as, for example, data vans 227A, 227B, sand equipment 229A, 229B, blenders 234A, 234B, and hydration units 232A, 232B, para 0045; also see Fig. 5).

Regarding Claim 12, modified USWell022 fails to disclose the system of claim 11, wherein the load shedding panel prioritizes the order in which the plurality of hydraulic fracturing equipment components and the electric drilling rig will be deactivated. USWell593 teaches wherein the load shedding panel prioritizes the order in which the plurality of hydraulic fracturing equipment components and electric equipment will be deactivated (loads are shed in the predetermined sequence established by a user and/or as defined by a user in real-time via a user interactive device until the total current is less than the predetermined peak total or until the system has detected a stable current situation, para 0058; the control system can store this information and statistically translate it to determine the priority of each sensed load, and subsequently create a priority list to be implemented by an auxiliary power source in the instance when the utility power source fails, para 0076). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of Baldassarre for the purpose of shedding lower priority loads based on predetermined priority or real-time decisions made by the user so as to ensure that the vital loads remain connected and active while the auxiliary or generator power source remains below a threshold value (see Baldassarre, para 0130)

Regarding Claim 14, modified USWell022 fails to disclose the system of claim 8, wherein the generator is in selective electrical communication with a power grid. USWell593 teaches wherein the generator is in selective electrical communication with a power grid (FIG. 14 illustrates an example 1400 of a configuration for load sharing with a utility grid, according to an embodiment, para 0085; enable the switchgear units -B+- 1425-b and "C+- 1425-c to load share between the generator sets 1405-a, 1405-b, 1405-c, 1405-d and the utility grid. For example, if the utility grid is transmitting power at 69 kV, the transformer 1445 can step down the 69kV voltage to 13.8 kV for use by the microgrid. In this configuration, power can be either provided to the grid or supplemented from the utility grid during times of peak power demand, para 0086). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of allowing for power transfer to and from the grid as needed (see USWell593, para 0086).

Regarding Claim 16, USWell022 fails to explicitly disclose the method of claim 15, further comprising: powering an electric drilling rig with the generator. USWell593 discloses wherein the electric equipment is an electric drilling rig (The power generation equipment can be used to supply any oilfield equipment including... drilling rigs, para 0044) It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of providing power for oilfield equipment that doe not have access to a utility provided power grid or that has a dynamic power load or low power factor(see USWell593, para 008644).

Regarding Claim 18, USWell022 fails to discloses the method of claim 15, further comprising: distributing power from the generator to a power grid. USWell593 teaches distributing power from the generator to a power grid (FIG. 14 illustrates an example 1400 of a configuration for load sharing with a utility grid, according to an embodiment, para 0085; enable the switchgear units -B+- 1425-b and "C +- 1425-c to load share between the generator sets 1405-a, 1405-b, 1405-c, 1405- d and the utility grid. For example, if the utility grid is transmitting power at 69 kV, the transformer 1445 can step down the 69kV voltage to 13.8 kV for use by the microgrid. In this configuration, power can be either provided to the grid or supplemented from the utility grid during times of peak power demand, para 0086). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify USWell022 with the teaching of USWell593 for the purpose of allowing for extra power generated to be fed to the grid (see USWell593, paras 0086 and 0088).

Claims 6, 13, and 17 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest:

Regarding claim 6, the prior art of record, individually or in combination, does not teach or fairly suggest the system of claim 5, wherein the load shedding panel is programmed to deactivate the blender after other electric load components are deactivated.

Regarding claim 13, the prior art of record, individually or in combination, does not teach or fairly suggest the system of claim 12, wherein the load shedding panel is programmed to deactivate the blender after other hydraulic fracturing equipment components are deactivated.

Supplemental Box

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

Regarding claim 17, the prior art of record, individually or in combination, does not teach or fairly suggest the method of claim 15, wherein the plurality of hydraulic fracturing equipment includes at least one blender, the method further comprising: prioritizing the deactivation of the plurality of hydraulic fracturing equipment components so that the at least one blender is deactivated only after other hydraulic fracturing equipment is deactivated.

Claims 1-20 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.

Search History:

Limited Classification Search

The Patent Analyst performed a limited classification search within the following US, IPC, CPC, ECLA, or F-Term classification areas:

CPC Class/Subclass(es): H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.02)

IPC (8) Class/Subclass(es): H02J 3/14; E21B 43/26; F04D 13/06; H02J 3/12 (2019.01)

U.S. Class/Subclass(es): 700/295; 166/305.1; 166/308.1; 700/293

See Global Search Results.

Global Patent Literature Text Search

The Patent Analyst performed the following global text search, which was not limited by classification but may or may not have been limited by other criteria:

Questel Orbit: **https:**//www.orbit.com

#	Search query	Results
1	((BRANDON 2D HINDERLITER)/IN/OIN/INH/INV)	24
2	((JARED 2D OEHRING)/IN/OIN/INH/INV)	34
3	((WELL W SERVICES)/PA/OPA)	214
4	(1 OR 2) AND 3	35
5	1 OR 2 OR 3	214
6	5 AND (LOAD W SHED+)/TX	5
7	5 AND (LOAD W SHED+)/TX AND RIG/TX	2
8	(HYDRAULIC AND FRACTUR+ AND (LOAD W SHED+) AND (DRILLING W RIG))/TX	7
9	5 AND ((LOAD W SHED+) AND (CONTROL W PANEL))/TX	1
10	5 AND (PRIORITIZ+)/TX	0
11	(HYDRAULIC AND FRACTUR+ AND BLENDER AND (LOAD W SHED+))/TX	6
12	(CA2964593)/XPN	1
13	(LOAD W SHED+)/TI/AB	1126
14	(700295)/PCL	1333
15	(700293)/PCL	390
16	(166308100)/PCL	1261
17	(166305100)/PCL	1957
18	14 OR 15 OR 16 OR 17	4711

19	18 AND (HYDRAULIC AND FRACTURING)/TX	1567
20	18 AND (HYDRAULIC AND FRACTURING AND SHED+)/TX	10
21	(E21B-043/26)/CPC	5467
22	(E21B-043/26)/IPC	9814
23	(F04D-013/06)/IPC	12913
24	(F04D-013/06)/CPC	5242
25	(H02J-003/14)/CPC	4245
26	(H02J-003/14)/IPC	5368
27	(H02J-003/12)/IPC	3841
28	(H02J-003/12)/CPC	1026
29	21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28	34106
30	29 AND (LOAD W SHED+)/TX	963
31	29 AND (HYDRAULIC AND FRACTUR+ AND (LOAD W SHED+))/TX	7
32	29 AND (HYDRAULIC AND DRILL+ AND (LOAD W SHED+))/TX	4

Google Patents: **https://patents.google.com**

#	Search query	Results
1	hydraulic fracturing generator control	100+
2	hydraulic fracturing generator control load shedding	100+
3	MICROGRID ELECTRICAL LOAD MANAGEMENT for hydraulic fracturing	100+
4	hydraulic fracturing generator load shedding prioritize	100+
5	drilling generator load shedding prioritize	100+
6	generator load control prioritize	100+
7	generator load control prioritize blender drilling	100+
8	hydraulic fracturing blender turned off last	100+
9	generator powered earth equipment blender turned off last	100+

Computer Accessed Text Databases Searched

The Patent Analyst searched the following computer accessed text databases:

Google **Scholar: https**://scholar.**google**.com/

#	Search query	Results
1	hydraulic fracturing generator control	100+
2	hydraulic fracturing generator control load shedding	100+

3	MICROGRID ELECTRICAL LOAD MANAGEMENT for hydraulic fracturing	100+
4	drilling generator load shedding prioritize	100+
5	generator load control prioritize	100+
6	generator load control prioritize blender drilling	100+
7	hydraulic fracturing blender turned off last	100+
8	generator powered earth equipment blender turned off last	100+

Date search was completed: 25 March 2019

SV/CC

Electronic Acknowledgement Receipt

EFS ID:	39746901
Application Number:	16728359
International Application Number:	
Confirmation Number:	6981
Title of Invention:	SYSTEM AND METHOD FOR INTEGRATED FLOW SUPPLY LINE
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:	047158.100066
Receipt Date:	17-JUN-2020
Filing Date:	27-DEC-2019
Time Stamp:	14:34:49
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)	100066_IDS_2.pdf	1036223 1ce488887044d48743dbbbd910027b1bcd4bdcf13	no	9

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2	Other Reference-Patent/App/Search documents	100004_FOA.pdf	835009 9a2b607645daedc63b33783e683ca57924d76779	no	21
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6	Other Reference-Patent/App/Search documents	100048_NFOA_1-10-2020.pdf	426422 697dd19f949f67bf61f892dcc172c3fc0c122 e87	no	12
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7	Other Reference-Patent/App/Search documents	100063_NFOA_12-6-2019.pdf	339700 970ada9ad386e6440793e1bb058678705e 9985d1	no	10
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8	Other Reference-Patent/App/Search documents	500040_ISR.pdf	578182 966b85f87c03a86b8fac975469bf19159f62 cd49	no	10
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9	Other Reference-Patent/App/Search documents	500042_ISR.pdf	551837 e36f52fe4cd688e3def60e909808fe7624d0cbdd	no	11
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15	Other Reference-Patent/App/Search documents	16152732_OA.pdf	474139 46bd**3842f2368cd060a4dfa5893632**e0a5e**b82e3**	no	11
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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.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16728359
Filing Date	2019-12-27
First Named Inventor	Jared Oehring
Art Unit	3679
Examiner Name	Aaron Lloyd Lembo
Attorney Docket Number	047158.100066

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	
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	6	3334495		1967-08-08	Jensen	
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	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

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	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

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	36	Office Action dated December 12, 2018 in related U.S. Patent Application No. 16/160,708	☒
	37	International Search Report and Written Opinion dated January 2, 2019 in related PCT Patent Application No. PCT/US18/54542	☒
	38	International Search Report and Written Opinion dated January 2, 2019 in related PCT Patent Application No. PCT/US18/54548	☒
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	40	International Search Report and Written Opinion dated January 4, 2019 in related PCT Patent Application No. PCT/US18/57539	☒
	41	Non-Final Office Action issued February 12, 2019 in related U.S. Patent Application No. 16/170,695	☒
	42	International Search Report and Written Opinion dated February 15, 2019 in related PCT Patent Application No. PCT/US18/63977	☒
	43	International Search Report and Written Opinion dated March 5, 2019 in related PCT Patent Application No. PCT/US18/63970	☒
	44	Non-Final Office Action issued February 25, 2019 in related U.S. Patent Application No. 16/210,749	☒
	45	Non-Final Office Action issued March 6, 2019 in related U.S. Patent Application No. 15/183,387	☒
	46	Office Action mailed January 30, 2019 in related Canadian Patent Application No. 2,936,997	☒

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16728359
	Filing Date	2019-12-27
	First Named Inventor	Jared Oehring
	Art Unit	3679
	Examiner Name	Aaron Lloyd Lembo
	Attorney Docket Number	047158.100066

	47	Office Action mailed March 1, 2019 in related Canadian Patent Application No. 2,943,275	☒
	48	International Search Report and Written Opinion mailed April 10, 2019 in corresponding PCT Application No. PCT/US2019/016635	☒
	49	Notice of Allowance mailed April 23, 2019 in corresponding U.S. Patent Application No. 15/635,028	☒
	50	International Search Report and Written Opinion mailed July 9, 2019 in corresponding PCT Application No. PCT/US2019/027584	☒

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

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(11) Application No. AU 2007340913 A1

(19) AUSTRALIAN PATENT OFFICE

(54) Title
Pump integrity monitoring

(51)[6] International Patent Classification(s)
F04B 51/00 (2006.01) 0BHEP F04D
F04D 15/00 (2006.01) 15/00
F04B 51/00 20060101ALI2008071
20060101AFI2008071 0BHEP
PCT/IB2007/054995

(21) Application No: 2007340913 (22) Application Date: 2007.12.10

(87) WIPO No: WO08/081368

(30) Priority Data

(31) Number	(32) Date	(33) Country
11/617,338	2006.12.28	US

(43) Publication Date : 2008.07.10

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 July 2008 (10.07.2008)

PCT

(10) International Publication Number
WO 2008/081368 A1

(51) International Patent Classification:
F04B 51/00 (2006.01) ***F04D 15/00*** (2006.01)

(21) International Application Number:
PCT/IB2007/054995

(22) International Filing Date:
10 December 2007 (10.12.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/617,338 28 December 2006 (28.12.2006) US

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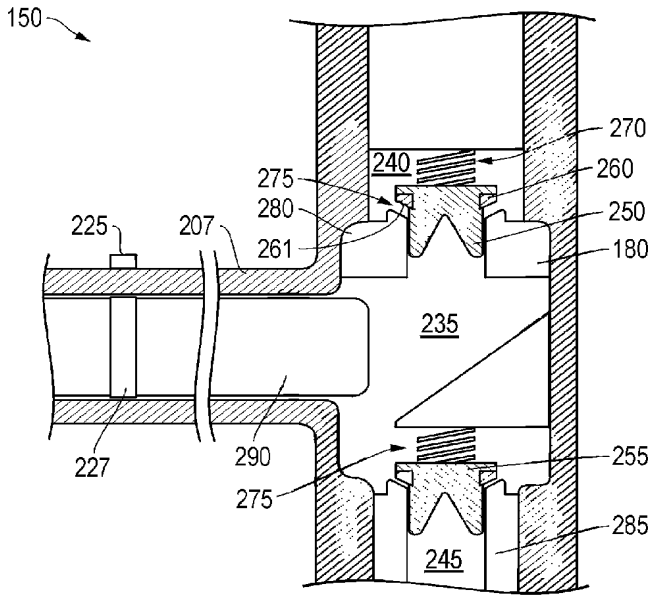
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[Continued on next page]

(54) Title: PUMP INTEGRITY MONITORING



(57) Abstract: A method of monitoring integrity of a pump. The method may include recording timing information of the pump during operation while simultaneously sampling acoustic data with a high speed equidistant acquisition mechanism or at a rate based on the speed of the pump in operation. The acquisition of acoustic data is followed by evaluation thereof. Such techniques may improve resolution of acquired data while substantially increasing processor capacity for evaluation. A pump integrity monitor for carrying out such techniques is also described.

WO 2008/081368 A1

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, 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, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

PUMP INTEGRITY MONITORING

BACKGROUND

[0001] Embodiments described relate to the monitoring of pumps in use. In particular, embodiments of oilfield pumps and techniques for their monitoring with a pump integrity monitor are described.

BACKGROUND OF THE RELATED ART

[0002] Large oilfield operations generally involve any of a variety of positive displacement or centrifugal pumps. Such pumps may be employed in applications for accessing underground hydrocarbon reservoirs. For example, positive displacement pumps are often employed in large scale high pressure applications directed at a borehole leading to a hydrocarbon reservoir. Such applications may include cementing, coiled tubing, water jet cutting, or hydraulic fracturing of underground rock.

[0003] A positive displacement pump such as those described above may be a fairly massive piece of equipment with associated engine, transmission, crankshaft and other parts, operating at between about 200 Hp and about 4,000 Hp. A large plunger is driven by the crankshaft toward and away from a chamber in the pump to dramatically effect a high or low pressure thereat. This makes it a good choice for high pressure applications. Indeed, where fluid pressure exceeding a few thousand pounds per square inch (PSI) is to be generated, a positive displacement pump is generally employed. Hydraulic fracturing of underground rock, for example, often takes place at pressures of 10,000 to 20,000 PSI or more to direct an abrasive containing fluid through a borehole such as that noted above to release oil and gas from rock pores for extraction.

[0004] Whether a positive displacement pump as described above, a centrifugal pump, or some other form of pump for large scale or ongoing operations, regular pump

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monitoring and maintenance may be sought to help ensure uptime and increase efficiency of operations. That is, like any other form of industrial equipment a pump is susceptible to natural wear that could affect uptime or efficiency. This may be of considerable significance in the case of pumps for large scale oilfield operations as they may be employed at a production site on a near round the clock basis. For example, in the case of hydraulic fracturing applications, a positive displacement pump may be employed at a production site and intended to operate for six to twelve hours per day for more than a week.

[0005] Wear on pump components during operation may present in a variety of forms. For example, internal valve seals of a pump may be prone to failure, especially where abrasive fluids are directed through the pump during an application. Issues with other pump components may develop during operation such as plunger wear, loosening engine mounts, deteriorating crankshaft bearings, and transmission breakdown in such forms as a slipping clutch or broken gear teeth. Thus, as indicated above, regular pump monitoring and maintenance of pump health may be an important part of ongoing pump operations.

[0006] Issues with wearing pump components such as those indicated above may be accompanied by certain vibrations particular to the type of wear taking place. Therefore, it is not uncommon to monitor the health of a pump during operation by taking into account such acoustic or vibration information. For example, a positive displacement pump may be evaluated during operation by employing an acoustic sensor coupled to the pump. The acoustic sensor may be a conventional sonic transmitter used to detect high-frequency vibrations particular to a leak or incomplete seal within the chamber of the positive displacement pump, such a leak being a common precursor to pump failure. By employing an acoustic sensor in this manner,

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the costly and somewhat unreliable alternative of regularly timed interruption of pump operation for manual seal inspection and replacement may be avoided. Similar acoustic monitoring of the health of the pump may be employed for the detection of other types of potential pump component wearing as well.

[0007] The above described technique of monitoring the health of the pump via detection of acoustic information during pump operation faces several practical challenges in implementation. For example, pump operations often employ several pumps and associated equipment simultaneously at a production site. In fact, in a multi-pump operation several pumps may be in fluid communication with one another through a common manifold. Therefore, even the detection of a given unhealthy pump condition may not be indicative of the particular pump having the unhealthy condition.

[0008] In order to distinguish the source of unhealthy acoustic data in a multi-pump operation as described above each pump of the multi-pump operation may be operated at a distinct RPM. That is, each pump of a multi-pump operation may operate at its own unique RPM with its own acoustically detectable timing. In this manner, occurrences of unhealthy acoustic data may be correlated to a particular pump operating at a given RPM. However, as a practical matter, operating a host of different pumps at a variety of RPM's for an operation may be near impossible to implement as indicated below.

[0009] The vast majority of oilfield pumps are only able to operate at a limited number of speeds making the above manner of operation potentially very difficult to achieve depending on the particular level of total output called for in a given operation. In fact, even if achievable, the operating of pumps at a variety of RPM's for an operation leads to uneven stress on the pumps with significantly greater loads applied to certain pumps. As a result, there is a greater likelihood of pump failure during the

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operation. Furthermore, regardless of the RPM assigned to a particular pump of a multi-pump operation, natural inconsistencies in behavior of pump components may require data collection over a period of operating time before any reliable acoustic analysis may take place. This delays diagnosis of unhealthy conditions and increases computational complexity of such monitoring, thus requiring significant processing capacity to carry out. Thus, addressing pump health over the long haul remains primarily addressed through regular manual intervention or acoustic monitoring techniques of limited diagnostic effectiveness.

SUMMARY

[0010] An embodiment of monitoring a pump assembly is disclosed wherein the pump assembly is operated and timing information relative thereto is recorded. Sampling of acoustic data then occurs with a high speed acquisition mechanism followed by an evaluation of the acoustic data in light of the timing information. Sampling of acoustic data may also take place based on a speed of the operating pump assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a side partially sectional view of a pump assembly employing an embodiment of a pump integrity monitor.

[0012] Fig. 2 is a cross-sectional view of a portion of the pump assembly of Fig. 1.

[0013] Fig. 3 is a perspective partially sectional view of an embodiment of employing the pump assembly of Fig. 1 in a multi-pump operation.

[0014] Fig. 4 is a chart depicting data obtained by employing an embodiment of the pump integrity monitor and pump assembly of Fig. 1.

[0015] Fig. 5A is a graph depicting data obtained from employing an embodiment of the pump integrity monitor and pump assembly of Fig. 1.

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[0016] Fig. 5B is a graph depicting data obtained from employing another embodiment of the pump integrity monitor and the pump assembly of Fig. 1.

[0017] Fig. 6 is a flow-chart summarizing an embodiment of employing the pump integrity monitor and pump assembly of Fig. 1.

DETAILED DESCRIPTION

[0018] Embodiments are described with reference to certain positive displacement pump assemblies for fracturing operations. However, other types of pumps may be employed for a variety of operations. Regardless, embodiments described herein include a pump assembly 100 that incorporates a pump integrity monitor 101 having particular capabilities. For example, the pump integrity monitor 101 may employ particularly located sensors in conjunction with a high speed data acquisition board that takes up acoustic data from the pump assembly 100 a rate algorithmically adjusted to minimize the effect of noise from neighboring equipment, including noise from equipment and pumps that are in fluid coupling with the pump assembly 100. Furthermore, the pump integrity monitor 101 may acquire data at a lower non-uniform sampling rate based on operating speed of equipment of the pump assembly 100, thereby drastically increasing processing capacity. In a particular example, the pump integrity monitor 101 may acquire acoustic data based on the speed of a pump 150 and thus, plot data in line with positioning characteristics of the pump 150 with less computational complexity.

[0019] Referring specifically now to Fig. 1, an embodiment of a pump assembly 100 is shown equipped with a pump integrity monitor 101. In the embodiment shown, the pump assembly 100 includes a pump 150. The pump 150 shown is a positive displacement pump that may be of a triplex configuration and for use in a fracturing

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operation. However, other types of pumps, including centrifugal pumps, may be employed for a variety of applications according to embodiments described herein.

[0020] The above-described pump assembly 100 includes a variety of equipment with a multitude of parts susceptible to natural wearing and deterioration during operation. In the embodiment shown, this equipment includes a pump 150 with a fluid housing 157 in which a fluid is pressurized for distribution to a fluid pipe 165 and ultimately to a common fluid line 175 as described further herein. The pressurization of the fluid within the fluid housing 157 is created by plungers as directed by a rotating crankshaft 155 of the pump 150. With the fracturing pump 150 of the embodiment shown, pressurization of up to about 20,000 PSI may be achieved in this manner. Alternatively, other degrees of pressurization may be achieved for other applications. For example, where the pump 150 is to be employed in a cementing application, up to about 5,000 PSI may be generated as indicated. Additionally, embodiments of the pump 150 may be employed for coiled tubing or water jet cutting applications.

[0021] The crankshaft 155 is driven by a driveline mechanism 180, itself, driven by an engine 125 as directed through a transmission 140. The engine 125 may be a 200 Hp to 5,000 Hp prime mover. In the embodiment shown, all of this equipment is accommodated at the same platform 130 for placement and use at a production site, such as the well fracturing site 300 shown in Fig. 3. The platform 130 may be a skid for dropping in tact at the production site, part of a conventional trailer, or other form of delivery mechanism.

[0022] With added reference to Fig. 2, all of the above described equipment and components thereof, are subject to natural wear during operation as indicated. Therefore, the pump integrity monitor 101 is provided at the platform 130. In the embodiment shown, the pump integrity monitor 101 may include several circuit boards

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within a control box for sampling and analyzing a host of acoustic and other information. The pump integrity monitor 101 may also include a variety of sensors 120, 110, 179, 225 for obtaining such information during operation of the pump assembly 100 (see also Fig. 2). In particular, as shown in Fig. 1, the information may relate to harmonics of the pump assembly 100 in operation as detected by an acoustic sensor 110 or a pressure transducer 179. Additionally, as detailed further below, operational timing information such as the position of a driveline or crankshaft may be detected by a proximity switch 120 or an index sensor 225, respectively.

[0023] Similar to the embodiment described above, an index sensor may be coupled to a flywheel housing to obtain engine timing information. The engine timing sensor may be employ a magnetic pickup that senses position of a location on a rotating part coupled to the engine 125 such as its flywheel. In this sense, the information is obtained similar to information obtained by the index sensor 225 as described further below. This information may be analyzed by the pump integrity monitor 101 in conjunction with acoustic data obtained from an acoustic sensor coupled to the engine 125 or transmission 140 for establishing a condition thereof as described below. In an embodiment where the pump 150 is electrically driven, the sensors described here may be modified and located to acquire data regarding electrical current input.

[0024] Continuing with reference to Fig. 1, a circuit board of the pump integrity monitor 101 may be provided in the form of a high speed acquisition board which may include no microcontroller or processing capacity. Rather, the high speed acquisition board may be dedicated to sampling acoustic, vibration, or pressure sensor data at a rate of between about 100 to about 600,000 samples per second or more. The high speed acquisition board may be dedicated to obtaining data from the acoustic sensor 110 and/or the pressure transducer 179 as indicated above. These sensors 110, 179 may be

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specifically positioned to acquire acoustic vibration data from the pump assembly 100 during its operation. In an embodiment where the pump 150 is hydraulic in nature, such sensors 110, 179 may be positioned and equipped to acquire hydraulic pressure data in place of acoustic data as described herein. Regardless, the acquired data may be analyzed by the pump integrity monitor 101 in order to provide a recognizable pattern of pump health or integrity information so as to alert an operator of an unhealthy condition of the pump assembly 100 should one arise. Furthermore, it is not required that the pump flow rate remain constant in order to employ techniques described further below.

[0025] Continuing with reference to Figs. 1 and 2, an example of an acoustically detectable unhealthy condition in the pump assembly 100 is described in detail. That is, while a host of harmonic or vibration data is provided by an operating pump assembly 100, certain data may be indicative of a variety of unhealthy conditions. Acoustic profiles of common unhealthy conditions may be pre-loaded on a processor of the pump integrity monitor 101 to allow analysis. With respect to the embodiments described herein, these unhealthy conditions may include plunger wear, loosening engine mounts, piston issues, deteriorating crankshaft bearings, and transmission breakdown in such forms as a slipping clutch or broken gear teeth to name a few. Another such example includes the unhealthy condition of a failing pump valve seal 260 as shown in Fig. 2. This type of failure may be prone to occur in circumstances where abrasive fluids are directed through a pump 150 such as during a fracturing application.

[0026] With particular reference to Fig. 2, the pump 150 includes a plunger 290 for reciprocating within a plunger housing 207 toward and away from a chamber 235. In this manner, the plunger 290 effects high and low pressures on the chamber 235. For

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example, as the plunger 290 is thrust toward the chamber 235, the pressure within the chamber 235 is increased. At some point, the pressure increase will be enough to effect an opening of a discharge valve 250 to allow the release of fluid and pressure within the chamber 235. The amount of pressure required to open the discharge valve 250 as described may be determined by a discharge mechanism 270 such as valve spring which keeps the discharge valve 250 in a closed position until the requisite pressure is achieved in the chamber 235. In an embodiment where the pump 150 is to be employed in a fracturing operation pressures may be achieved in the manner described pressures of up to about 20,000 PSI may be achieved in the manner described here.

[0027] The plunger 290 may also effect a low pressure on the chamber 235. That is, as the plunger 290 retreats away from its advanced discharge position near the chamber 235, the pressure therein will decrease. As the pressure within the chamber 235 decreases, the discharge valve 250 will close returning the chamber 235 to a sealed state. As the plunger 290 continues to move away from the chamber 235 the pressure therein will continue to drop, and eventually a low or negative pressure will be achieved within the chamber 235. Similar to the action of the discharge valve 250 described above, the pressure decrease will eventually be enough to effect an opening of an intake valve 255. The opening of the intake valve 255 allows the uptake of fluid into the chamber 235 from a fluid channel 245 adjacent thereto. The amount of pressure required to open the intake valve 255 as described may be determined by an intake mechanism 275 such as spring which keeps the intake valve 255 in a closed position until the requisite low pressure is achieved in the chamber 235.

[0028] As described above, and with added reference to Fig. 1, a reciprocating or cycling motion of the plunger 290 toward and away from the chamber 235 within the pump 150 controls pressure therein. The valves 250, 255 respond accordingly in order

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to dispense fluid from the chamber 235 through a dispensing channel 240 and ultimately to a fluid pipe 165 at high pressure. That fluid is then replaced with fluid from within a fluid channel 245. All of the movements of the various parts of the pump 150 as described may resonate to a degree throughout the pump 150 including to its non-moving portions, such as at the fluid housing 157 within which the chamber 235 is located. Thus, as indicated above, an acoustic sensor 110 may be secured thereto for sensing such resonating vibrations.

[0029] As noted, certain vibrations detected by the acoustic sensor 110 of Fig. 1 may be indicative of an unhealthy valve seal 260 of the pump 150. For example, upon closer inspection of Fig. 2 it is apparent that the discharge valve 250 includes a conformable valve seal 260 for sealing off of the chamber 235. The conformable nature of such a valve seal 260 is conducive to the pumping of abrasive containing fluids through the pump 150 as is often called for in the case of fracturing operations. For example, the abrasive fluid may include a proppant such as sand, ceramic material or bauxite mixed therein. The conformable nature of the valve seal 260 allows it to conform about any proppant present at the interface 275 of the discharge valve 250 and seat 280. Unfortunately, the conformable nature of the valve seal 260 also leaves it susceptible to the unhealthy circumstance of degradation by such abrasive fluids.

[0030] A conformable valve insert 260 of urethane or other conventional polymers employed in a conventional fracturing operation as described above may degrade completely in about one to six weeks of substantially continuous use. As this degradation begins to occur a completed seal fails to form between the valve 250 and the valve seat 280. Thus, as noted above, an acoustic vibration indicative of an unhealthy condition of the operating pump 150 may then persist that is attributable to a growing leak between the chamber 235 and the dispensing channel 240.

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[0031] Continuing now with reference to Figs. 1-3, the above described unhealthy condition of a failing pump valve seal 260 may be acoustically detectable by the acoustic sensor 110 as indicated. However, as shown in Fig. 3, the pump 150 may be part of but one pump assembly 100 of a multi-pump assembly 300 at a production site 375. Therefore, embodiments described herein include techniques for discerning acoustic data emanating from other assemblies 302, 303, 304, 305, 306 and equipment from the acoustic data of the pump assembly 100 such as that indicative of the unhealthy condition of the valve seal 260 as indicated.

[0032] As shown in Fig. 3, and indicated above, multiple pump assemblies 302, 303, 304, 305, 306 are provided at the production site 375 in addition to the pump assembly 100 of Fig. 1. Each of the assemblies 302, 303, 304, 305, 306, and 100 may be no more than 10-12 feet from one another, with each operating at 1,500 Hp to 5,000 Hp to propel an abrasive fluid 310 into a well 325. The abrasive fluid 310 may be directed into the well 325 and directed to fracturable rock 315 or other earth material as is the nature of a convention fracturing operation.

[0033] Apart from the acoustics emanating from the pump assembly 100 of Fig. 1, a considerable amount of noise is generated in the above described fracturing operation of Fig. 3. In fact, in continuing with reference to Fig 3, added equipment such as a blender 307 may be provided on site adding noise to the operation. Furthermore, each assembly 302, 303, 304, 305, 306, and 100 may generate up to about 20,000 PSI for directing the abrasive fluid 310 through a common manifold 375 and to a well head 350 coupled to the well 325. That is, all of the assemblies 100, 302, 303, 304, 305, 306 may be in fluid communication with one another. As a result of such communication, the ability of acoustics emanating from a single pump assembly to resonate at an adjacent pump assembly is enhanced. Thus, referring back to Fig. 1, the ability of the

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pump integrity monitor 101 to decipher the source of acoustics for establishing the condition of its associated pump assembly 100 in particular, may be of significant benefit.

[0034] Continuing with reference to Figs. 1-3, in spite of the above described fluid communication among pump assemblies 100, 302, 303, 304, 305, 306 during conventional operations such as fracturing, the pump integrity monitor 101 is configured for use in a manner that allows deciphering and favoring the acquisition of acoustic information relative to its own particular pump assembly 100. This may be achieved by the pump integrity monitor 101 employing both the above noted high speed acquisition board in combination with one or both of two sensors 110, 179 positioned to enhance the sensing of acoustic information from the pump assembly 100 of Fig. 1 in particular. That is, as indicated, the high speed acquisition board may be dedicated to sampling sensor data at a rate of between about 100 to about 300,000 samples per second or more. Thus, as detailed further below, the acquisition of acoustic data from the pump assembly 100 of Fig. 1 may be enhanced by use of the sensors 110, 179 positioned as indicated above whereas the resolution of this acoustic data may be enhanced by use of such a high speed acquisition board.

[0035] Continuing with reference to Figs. 1-3, the pump integrity monitor 101 may be directly wired to one or both of two sensors 110, 179 positioned to enhance the sensing of acoustic information from the pump assembly 100 of Fig. 1 in particular. For example, the first sensor, the above described acoustic sensor 110, is positioned directly on the fluid housing 157 of the pump 150. The second sensor, the above noted pressure transducer 179, may be positioned within the common fluid line 175 to the manifold 375. While positioned in a common fluid area, the pressure transducer 179 is located to the pump side of choke 177 that briefly cuts down the inner diameter of the

line 175 (e.g. about in half). This contributes to the attenuation of acoustics emanating from outside of the pump assembly 100 of Fig. 1. Thus, the sensing of acoustic information from the pump assembly 100 of Fig. 1 by the pressure transducer 179 is still enhanced. In fact, the location of the choke 177 also aids in dampening of acoustics from the pump assembly 100 of Fig. 1 to other assemblies 302, 303, 304, 305, 306 such as those of Fig. 3.

[0036] In addition to the enhanced acquisition of acoustic data from the pump assembly 100 of interest, the enhanced resolution of data as indicated renders noise from other sources of little significance. A speed sensor such as a proximity switch 120 may be provided to the pump integrity monitor 101 and coupled to a rotating driveline mechanism 180 for monitoring speed of the operating assembly 100, thus, allowing the processor to confirm outside noise as out of sync from the assembly 100. Therefore, with added reference to Fig. 3, such a high rate of acoustic sampling by the pump integrity monitor 101, the need to operate separate assemblies 100, 302, 303, 304, 305, 306 of a multi-pump operation at significantly different and/or constant speeds is substantially obviated. Rather, distinction between noise emanating from outside sources, out of time from the associated assembly, may readily be deciphered by a processor of the pump integrity monitor 101 with such a vast amount of acoustic data at its disposal.

[0037] As described above, the pump integrity monitor 101 may be employed to diagnose an unhealthy condition such as a leaking pump valve seal 260 in spite of surrounding noise at a production site 375. Furthermore, all other assemblies 302, 303, 304, 305, 306 of a multi-pump operation such as that shown in Fig. 3 may be equipped with individual pump integrity monitors for diagnosis of unhealthy conditions of the associated pump assembly 302, 303, 304, 305, 306. Again, such unhealthy conditions

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may include leaking pump seals, plunger wear, valve spring wear, loosening engine mounts, pump mounts, piston issues, deteriorating crankshaft bearings, crossheads, pony rods, transmission breakdowns such as clutch slippage or broken gear teeth and any other conditions presenting acoustic abnormalities.

[0038] While the above described techniques of employing the pump integrity monitor 101 provide detection of the health of a given assembly 100 regardless of surrounding noise, acoustic data indicative of equipment health or integrity may also be employed in a manner drastically reducing the amount of processor capacity required for establishing equipment health. That is, rather than sampling the above noted acoustic data at a constant rate (i.e. equidistant sampling) and performing an FFT to plot the information, acoustic data may be sampled at a rate based on the speed of the operating equipment (i.e. non-uniform or angular sampling). In this manner the need for a discrete FFT conversion may be eliminated or transferred to the angular domain, also referred to herein as the "order" space. The pump integrity monitor 101 may be provided with the capability to detect and analyze much higher frequencies. For example, frequencies substantially beyond 25KHz, more preferably beyond 100KHz may be analyzed by a processor of the pump integrity monitor 101. As a result, leaks or other acoustically detectable problems encountered by the pump assembly 100 may be detected much earlier on, when presenting at such higher frequencies. In fact, in an alternate embodiment, a very limited Fourier analysis may be performed over a small frequency range in order to increase spectral resolution. Nevertheless, the signal detection may be obtained earlier on at higher frequencies.

[0039] For example, with reference to Figs. 1-3 above, the pump integrity monitor 101 may sample acoustic data at a rate of between about 50 and 5,000 samples per revolution of the crankshaft 155. Thus, positioning information relative to cycling of

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the pump 150 may automatically be provided without any need to perform FFT conversions. In order to regulate the sampling of acoustic data in this manner, a sensor may be provided to monitor or track the timing of a moving part of the pump 150 and thus, its speed. For example, as shown in Fig. 2, an index sensor 225 is provided adjacent a plunger 290 that is driven by the noted crankshaft 155 of Fig. 1. The plunger is equipped with a collar 227 detectable by the index sensor 225 such that timing information may be transmitted to the pump integrity monitor 101. In this manner, the processor of the pump integrity monitor 101 need only keep time of the operating pump 150 in acquiring and plotting acoustically obtained data relative thereto.

[0040] Referring now to Fig. 4, with added reference to Figs. 1-3, acoustic data acquired by the pump integrity monitor 101 via techniques described above is plotted on a chart. The chart shown plots acoustic data that has been obtained from a pump assembly 100 having a pump 150 with a leaking valve seal 260 as shown in Fig. 2. In the embodiment shown, between about 500 and about 5,000 samples of acoustic data have been obtained for a given revolution of the crankshaft 155 of the pump 150. Thus, given timing information from the index sensor 225 acoustic data has been plotted without the requirement of FFT conversions, thereby saving substantial processor capacity of the pump integrity monitor 101.

[0041] Continuing with reference to Fig. 4, timing information from the index sensor 225 allows for the plotting of an acoustic profile of the angular position of the cycling pump 150 based on three plunger reciprocation areas 1, 2, 3. That is, in the embodiments described herein, the pump 150 is of a positive displacement triplex configuration. Thus, three separate plungers, such as the plunger 190 of Fig. 2, reciprocate in any given cycle of the pump 150. A variety of acoustic data 400, 401, 402, 403, 475 may be plotted in accordance therewith.

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[0042] The chart of Fig. 4 reveals that certain acoustic data is persistent throughout an entire cycling of the pump 150. This persistent acoustic data 475 may be the expected acoustics of the operating pump 150 and other equipment of the assembly 100. Due to the improved resolution and enhanced detection provided by the pump integrity monitor 101 as detailed above, the probability of an overwhelming amount of persistent acoustic data 475 emanating from another assembly (i.e. 302, 303, 304, 305, 306 of Fig. 3), is minimized. Regardless, such data fails to be indicative of an unhealthy condition of the pump 150 associated with the pump integrity monitor 101 being employed.

[0043] The chart of Fig. 4 is depicted in a logarithmic scale as alluded to above, with a maximum frequency detectable at half the sampling frequency (i.e. Fs/2). With respect to particular plunger reciprocation areas 1, 2, 3 of the chart, each includes strike data 401, 402, 403, revealing two valve strikes per plunger reciprocation, resonating at between about 1/64 and about 3/8 of the sampling frequency (Fs). This would be expected as described in detail above with respect to Fig. 2 where valves 250, 255 strike valve seats 280, 285 as described above. Again, this particular acoustic data fails to be indicative of any unhealthy condition of the pump assembly 100.

[0044] Unfortunately, upon close examination of the first plunger reciprocation area 1 an unhealthy condition of the pump assembly 100 is revealed. That is, recalling the leaking valve seal 260 of Fig. 2, unhealthy acoustic data indicative of this leak presents in the form of leak data 400 in the first plunger reciprocation area 1. The leak data 400 presents immediately after the striking of a valve (i.e. 250) as shown by the strike data 401. As described with reference to Fig. 2, it is at this time that a completed seal fails to form between the valve 250 and the valve seat 280. Thus, an acoustic vibration, depicted here as leak data 400, resonates as fluid leaks between the chamber

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235 and the dispensing channel 240. An unhealthy condition of the pump assembly 100 is thereby detected and displayed.

[0045] In Fig. 4 detailed above, leak data 400 is depicted in a chart that reflects the angular position of a cycling pump 150 such as that of Fig. 1. The depiction of acoustic leak data 400 in this manner provides some insight into the condition of pump parts driven by a rotating mechanism such as the crankshaft 155. However, with reference to Fig. 1, a variety of other equipment such as an engine 125, transmission 140 or driveline mechanism 180 may also be subject to wear and breakdown. Similarly, the health of such equipment may be detected and monitored according to techniques described above. That is, the above-described techniques may be employed for analyzing both pump and engine data. For example, acoustic data corresponding to a gear ratio employed by the transmission 140 may be indicative of a problem prior to the driveline mechanism 180. Similarly, as described below, unexpected acoustic data corresponding to the rpm of the engine 125 may be indicative of engine side issues such as with engine mounts or piston reciprocation. Additionally, it may be of benefit to examine the acoustics of such equipment in terms other than angular positioning. For example, the amplitude or power (or power spectral density), as shown in Fig. 5A, may provide insight into the condition of operating equipment in other frequency ranges as detailed further below.

[0046] Referring now to Fig. 5A, with added reference to Fig. 1, a graph is shown depicting an acoustic profile of acoustic data acquired from a pump assembly 100 having a four stroke 12 cylinder engine 125 that is running at about 2,400 rpm's. This may be the same pump assembly 100 as that depicting the acoustic data of Fig. 4. However, by way of comparison, the acoustic data of Fig. 4 presents at frequencies higher than the chart of Fig. 5A extends. However, an extension of Fig. 5A in terms of

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frequency would reveal the acoustic pump related data depicted in Fig. 4. Another distinction from Fig. 4 is that in Fig. 5A, rather than depicting the acoustic frequency data against angular positioning, the graph of Fig. 5A depicts acoustic data against power as described further below.

[0047] With added reference to Fig. 1, Fig. 5A depicts acoustic data relative to an engine 125 operating at about 2,400 rpm as indicated. Such an engine 125 would generate a frequency of about 40 Hz by definition. Thus, an examination of the chart of Fig. 5A at about 40 Hz reveals acoustic engine rpm data 560. In fact, the greatest amount of power revealed for the frequency range depicted in Fig. 5A is revealed in the form of the acoustic engine rpm data 560. Other acoustic data is revealed such as camshaft data 551 at about 20 Hz and piston data 580 at about 240 Hz. Again, given a conventional 12 cylinder engine 125 running at about 2,400 rpm, the location of camshaft data 551 at half that of the engine rpm data 560 and the location of the piston data 580 is to be expected. However, abnormalities in such data may be telling. For example, an abnormality in the camshaft data 551 may be indicative of misfiring whereas an abnormality in rpm data 560 may be indicative of engine imbalance, misalignment, abnormal torque reaction, or a weak foundation of the engine 125.

[0048] While the location of the acoustic data 551, 560, 580 reflects the expected operating acoustics of a 12 cylinder engine 125 operating at 2,400 rpm, additional acoustic information is presented in the graph of Fig. 5A. Namely, engine rpm data 560 presents with a peak 565 that breaks into a smooth portion 562 and a smaller rough portion 567 by comparison. Similarly, the piston data 580 includes a smooth portion 582 and a rough portion 587. Thus, it is apparent that a problem has arisen in the firing or operating of at least one of the pistons of the engine. That is, rather than acoustic leak data 400 apparent in Fig. 4, rough portions 567, 587 of data present in Fig. 5A

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revealing an unhealthy condition in the pump assembly 100 outside of the pump 150. Fortunately, however, with particular reference to the z-axis of the chart of Fig. 5A, it does not appear that the problem is increasing over the period of time shown. Therefore, an operator may have time to intervene before failure of the operating pump assembly 100 due to the problem shown.

[0049] In addition to the acoustic data depicted in Fig. 5A 551, 560, 580, additional data relative to the condition of the engine 125 may be obtained. For example, in such an engine 125 as described above, cylinder combustion peaks at about 60 Hz, 100 Hz, 140 Hz, and 180 Hz might be expected along with peaks representing harmonics of crankshaft speed at about 80 Hz, 120 Hz, 160 Hz, and 200 Hz. Such acoustic data may again be analyzed to determine a condition of the engine 125. For example, a peak representing crankshaft harmonics at about 80 Hz that is significantly higher than other crankshaft harmonic peaks may be indicative of a problem such as vibration damper failure relative to a position of the rotating crankshaft.

[0050] Referring now to Fig. 5B, again with added reference to Fig. 1, a graph is shown similar to that of 5A, but with reference now to pump acoustics (i.e. as opposed to engine acoustics). For the embodiment shown and described below, the pump 150 is a positive displacement pump 150 of a triplex configuration. The pump 150 includes a crankshaft 155 rotating at a frequency of about 4 Hz where an initial peak is depicted. In a circumstance of an unhealthy pump condition correlating to the timing of the crankshaft rotation, the peak depicted at about 4 Hz may rise or present otherwise abnormally. Such pump failures may include a valve leak, broken valve spring, loose plunger, loose pump mount, or crank bearing failure.

[0051] Given that the pump 150 employs three plungers 290 as indicated above, each reciprocating with every rotation of the crankshaft 155, the peak at about 12 Hz is

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to be expected. Furthermore, a peak is noted at about 24 Hz which reflects a reduction ration of about six that is provided by gearing between the transmission 140 and the crankshaft 155. For the embodiment shown, a high peak at about 24 Hz would be indicative of problems such as with the transmission 140, driveline 180, or related parts. Similarly, where a bull gear of the described gearing is equipped with say 108 teeth, a harmonic peak at about 432 Hz would be expected as shown. Abnormalities in this peak would be indicative of degradation or other problems with gearing teeth for the depicted embodiment.

[0052] Referring now to Fig. 6, an embodiment of employing a pump integrity monitor is summarized in the form of a flow chart. The monitor is employed as a part of a pump assembly that is in operation as indicated at 620. As noted above, the pump assembly may be operated in conjunction with a host of other equipment, including other pump assemblies in fluid communication therewith. Nevertheless, as indicated, the pump integrity monitor may be employed to decipher the health or integrity that is particular to the pump assembly.

[0053] Deciphering the health of the pump assembly may be achieved in part by employing the pump integrity monitor to record timing information of the pump assembly as indicated at 635 (e.g. perhaps with a proximity switch). With timing information in mind, a vast amount of acoustic data may be sampled with a high speed acquisition mechanism, perhaps at between about 100,000 and 300,000 samples per second as indicated at 650. With properly located sensors to obtain such samples, a fairly high resolution of the acoustics of the operating assembly may be obtained for evaluation as indicated at 680. Additionally, the acoustic data may be sampled based on the speed of the pump as noted at 660 such that an FFT conversion of such data may

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be entirely avoided saving significant processing capacity of the pump integrity monitor.

[0054] Embodiments described herein include a method of monitoring pump integrity with a pump integrity monitor in a manner that distinguishes outside noise from acoustics related to the pump. In fact, even where surrounding noise emanates from other pumps fluidly coupled to the pump of interest, the pump integrity monitor is operated so as to distinguish outside noise without requiring that other pumps be operated at substantially different speeds or constant rates of speed. Thus, there is no need to place undue loads on certain pumps of a multi-pump operation in order to acoustically monitor the operating health of each pump. Furthermore, the pump integrity monitor is operated in such a manner so as to dramatically increase processing capacity by elimination of FFT conversion requirements and to shorten time for diagnosis of the health of the pump. Thus, the practical effectiveness of acoustic diagnostics of an operating pump assembly may be significantly improved.

[0055] Although exemplary embodiments describe particular techniques for monitoring pump assemblies such as positive displacement pumps for fracturing applications, additional embodiments are possible. For example, several pump integrity monitors may be coupled to a central host or one another over a network for analysis of operational conditions at a variety of pumps or even multiple operation sites. Additionally, analysis techniques described above may be further and more particularly tailored based on program configuration. In one example, spectrum averaging bound to timing positions (i.e. stacking) may be employed to reduce noise and improve resolution irrespective of steady or repeatable conditions. Cepstral analysis may also be employed for multiple harmonics originating from a variety of mechanical parts. Joint time-frequency analysis may even be employed to handle time-

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varying frequency content through patter recognition in two dimensional time-frequency space wherein a Bayesian-based pattern classification technique is employed with an embedded database of vibration signatures.

[0056] In addition to that above, methods may be employed tailored to the pump integrity monitor electronics employed. In this regard, interleaved virtual sub-devices may be integrated into a single firmware frame, re-programmable virtual devices may be employed with functionality based on a particular frequency range of interest while still within a single frame, and portable device implementation may be employed.

[0057] Further additional features may be provided for employing the pump integrity monitor described herein such as pre-programming of the pump integrity monitor with a variety of vibration signatures to enhance pattern recognition for the types of problems likely to be acoustically detected during pump operation. In fact, to enhance such recognition, applications may be run that tend to avoid natural operating frequencies that may overlap with frequencies otherwise reflective of an unhealthy pump condition. Furthermore, many other changes, modifications, and substitutions may be made without departing from the scope of the described embodiments.

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CLAIMS

We Claim:

1. A method of monitoring integrity of a pump assembly, the method comprising:

operating the pump assembly;

recording timing information relative to said operating;

sampling acoustic data with a high speed acquisition mechanism of the pump assembly; and

evaluating the acoustic data in light of the timing information.

2. The method of claim 1 wherein said sampling occurs at a rate of more than about 100,000 samples of the acoustic data per second.

3. The method of claim 2 wherein the high speed acquisition mechanism is a high speed acquisition board of a pump integrity monitor for said recording, said sampling and said evaluating.

4. The method of claim 1 wherein said evaluating further comprises distinguishing acoustic data that represents a healthy pump assembly condition from acoustic data that represents an unhealthy pump assembly condition.

5. The method of claim 4 wherein the unhealthy condition is a condition of one of pump mounts, a plunger, crankshaft bearings, a transmission, a pump valve seal, valve spring, crossheads, pony rods, and piston operation of the pump assembly.

6. The method of claim 4 wherein said distinguishing is achieved with reference to a vibration signature pre-programmed into a processor of the pump integrity monitor.

7. The method of claim 1 wherein said recording further comprises monitoring a position of a moving part of the pump assembly.

8. The method of claim 7 wherein said monitoring is achieved with a speed sensor coupled to a driveline mechanism of the pump assembly.

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9. The method of claim 1 wherein said operating of the pump assembly is at a given speed, said sampling occurring at a rate based on the given speed.

10. A method of monitoring integrity of a pump assembly, the method comprising:

operating the pump assembly;

monitoring a speed of said operating;

sampling acoustic data from the pump assembly at a rate based on the speed; and

evaluating the acoustic data for distinguishing acoustic data that represents a healthy pump assembly condition from acoustic data that represents an unhealthy pump assembly condition.

11. The method of claim 10 wherein the unhealthy condition is a condition of one of pump mounts, a plunger, crankshaft bearings, a transmission, a pump valve seal, valve spring, crossheads, ponyrods, and piston operation of the pump assembly.

12. The method of claim 10 wherein said pump assembly includes a crankshaft for rotation during said operating, said sampling occurring at a rate of between about 50 and about 5,000 samples of the acoustic data per rotation.

13. The method of claim 10 wherein said monitoring further comprises tracking a position of a moving part of the pump assembly.

14. The method of claim 13 wherein the pump assembly is a positive displacement pump assembly and the moving part is a plunger, said monitoring achieved with an index sensor coupled to a plunger housing of the pump assembly, the plunger housing to accommodate the plunger, the plunger having a collar detectable by the index sensor.

15. The method of claim 10 wherein said evaluating occurs without performing a discrete Fourier Transform conversion.

16. The method of claim 10 wherein said evaluating further comprises analyzing acoustic data in frequencies between about 100 Hz and about 600 KHz.

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17. The method of claim 10 wherein said evaluating occurs as the speed varies.

18. The method of claim 10 wherein the distinguishing is achieved with reference to a vibration signature loaded into a processor of a pump integrity monitor for said monitoring, said sampling and said evaluating.

19. The method of claim 10 wherein the distinguishing of data that represents a healthy pump assembly condition includes recognizing noise based on the speed.

20. The method of claim 10 wherein said sampling occurs at a rate of more than about 100,000 samples of the acoustic data per second.

21. The method of claim 10 wherein said sampling takes place at one of a constant sampling rate and a variable sampling rate.

22. A pump integrity monitor comprising:

a processor;

a speed sensor coupled to said processor for monitoring a speed of an operating pump assembly; and

a data sensor coupled to said processor for sampling harmonic data from the pump assembly at a rate based upon the speed.

23. The pump integrity monitor of claim 22 wherein said speed sensor is one of an index sensor and a proximity switch for tracking a position of a moving part of the pump assembly.

24. A pump assembly comprising:

a pump;

a pump integrity monitor having a speed sensor coupled to said pump for monitoring a speed thereof during operation thereof; and

an acoustic sensor coupled to said pump integrity monitor for sampling acoustic data at a rate based upon the speed.

25. A multi-pump assembly comprising:

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a first pump assembly having a first pump integrity monitor with a speed sensor coupled to a pump of said first pump assembly for monitoring a speed thereof and an acoustic sensor for sampling acoustic data at a rate based on the speed;

a second pump assembly having a second pump integrity monitor with a speed sensor coupled to a pump of said second pump assembly for monitoring a speed thereof and an acoustic sensor for sampling acoustic data at a rate based on the speed; and

a common manifold in fluid communication with said first pump assembly and said second pump assembly.

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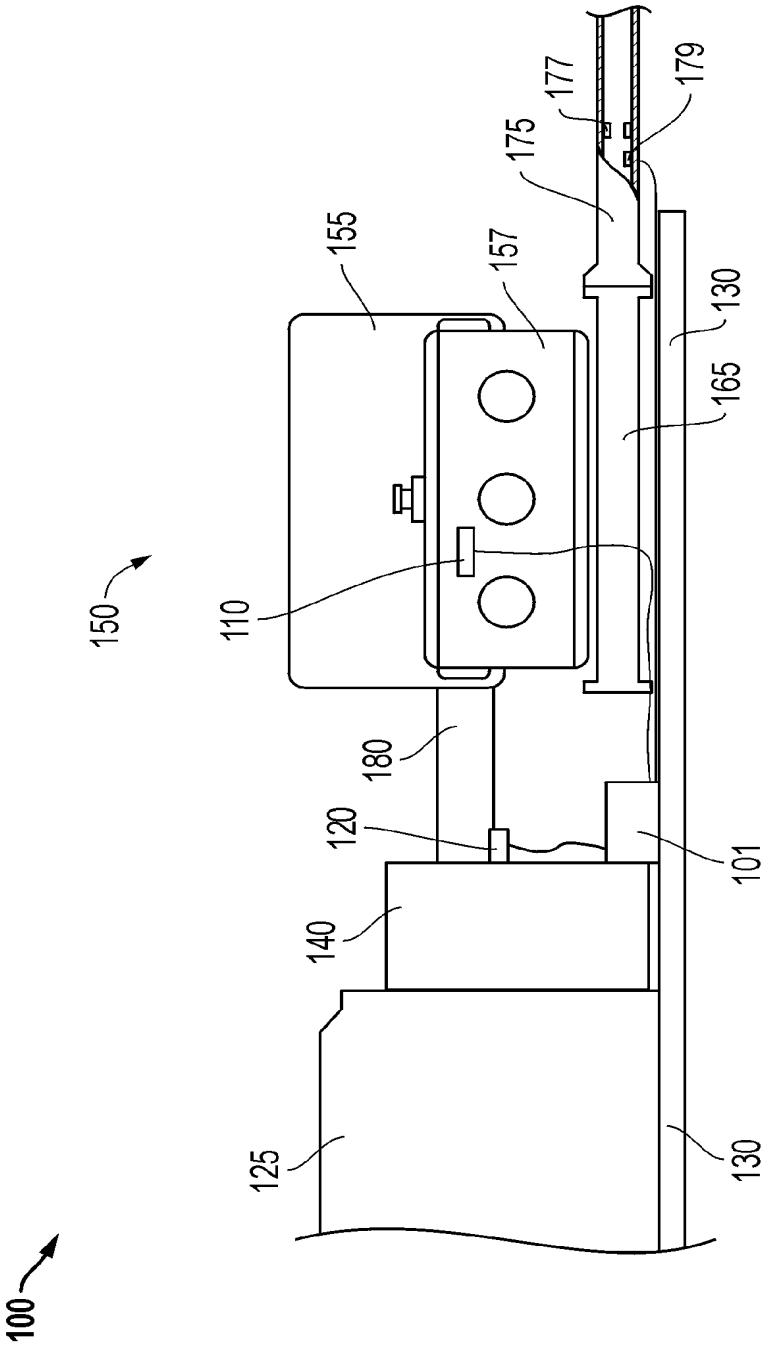


FIG. 1

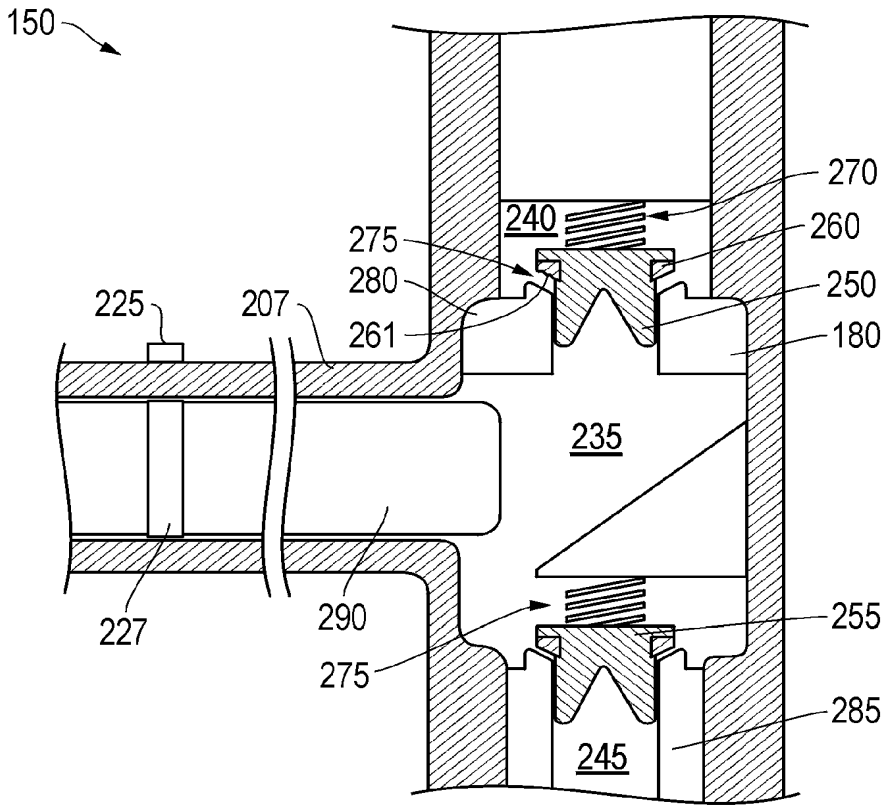

150
270
240
260
275
280
250
225
207
261
180
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275
285
245

FIG. 2

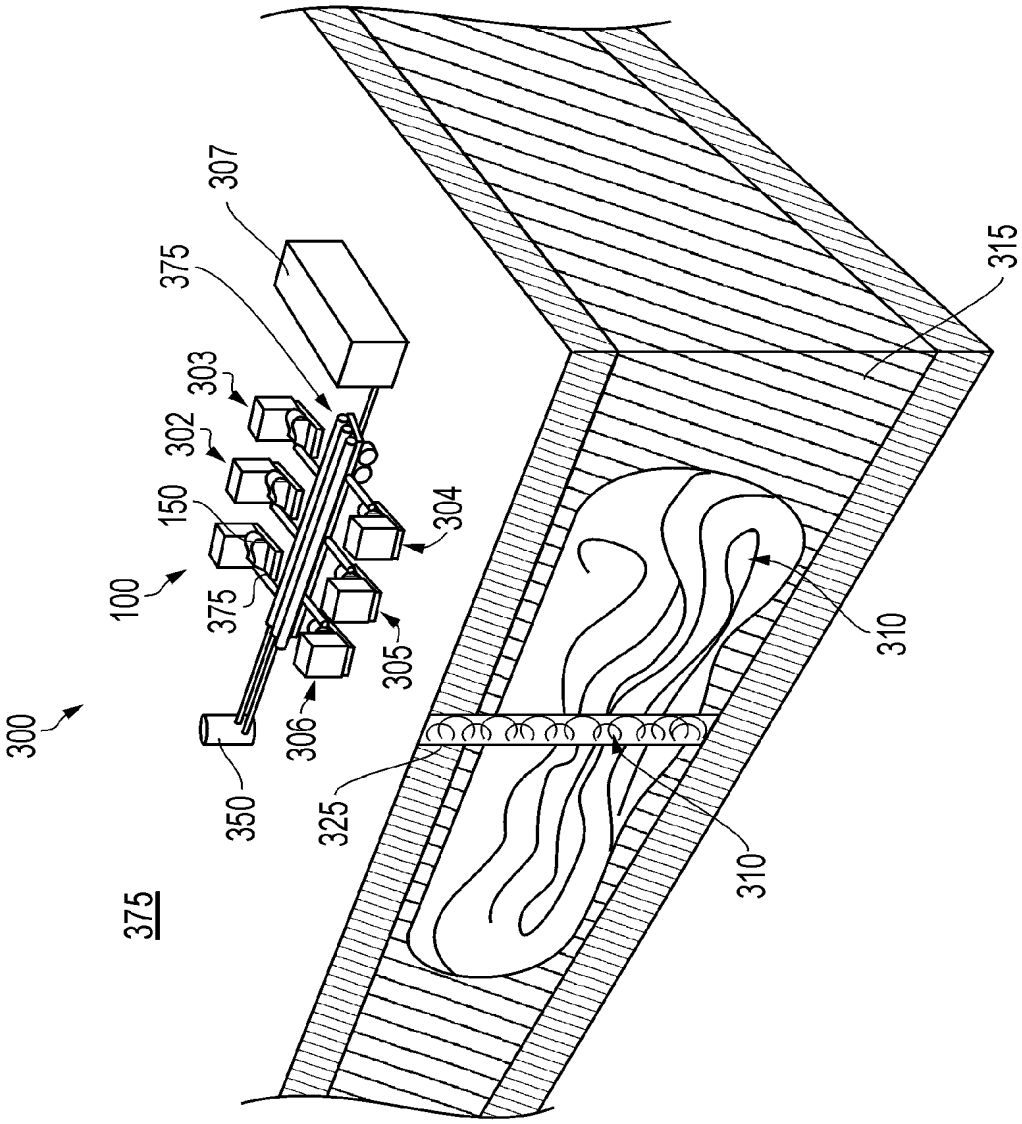

300
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150
302
303
304
305
306
307
315
310
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325
350
375
375
375

FIG. 3

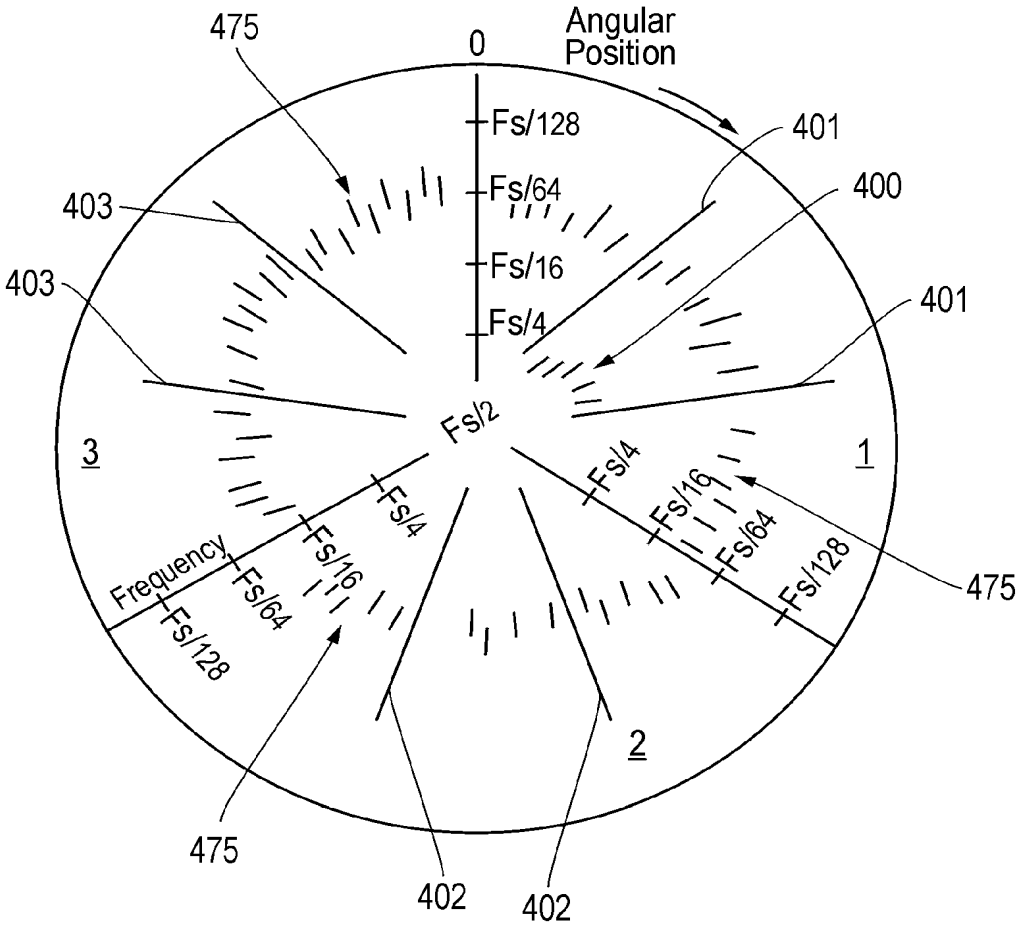

475
0
Angular
Position
401
400
403
403
401
Fs/128
Fs/64
Fs/16
Fs/4
Fs/2
3
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Fs/4
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2
475
402
402

FIG. 4

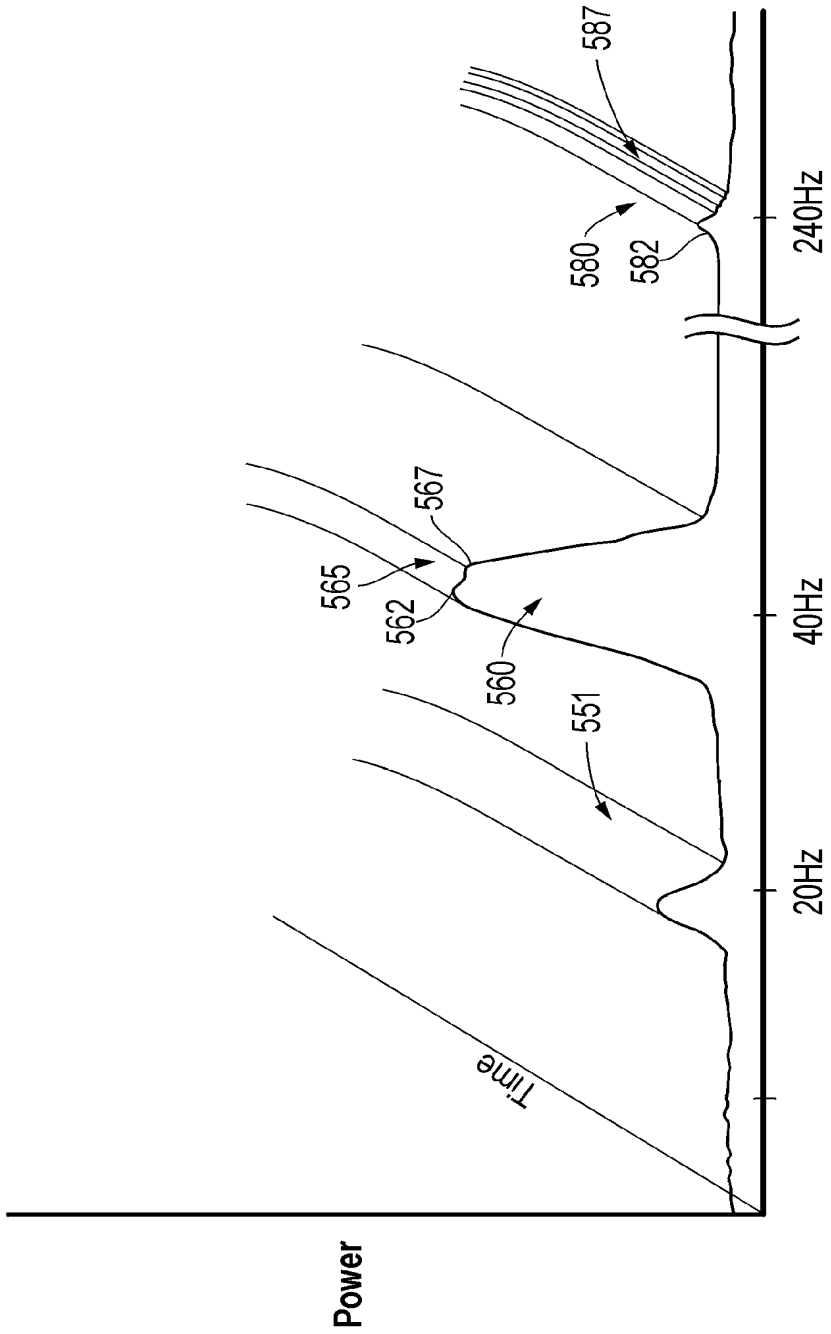

Power
Time
Frequency
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40Hz
240Hz
551
560
562
565
567
580
582
587

FIG. 5A

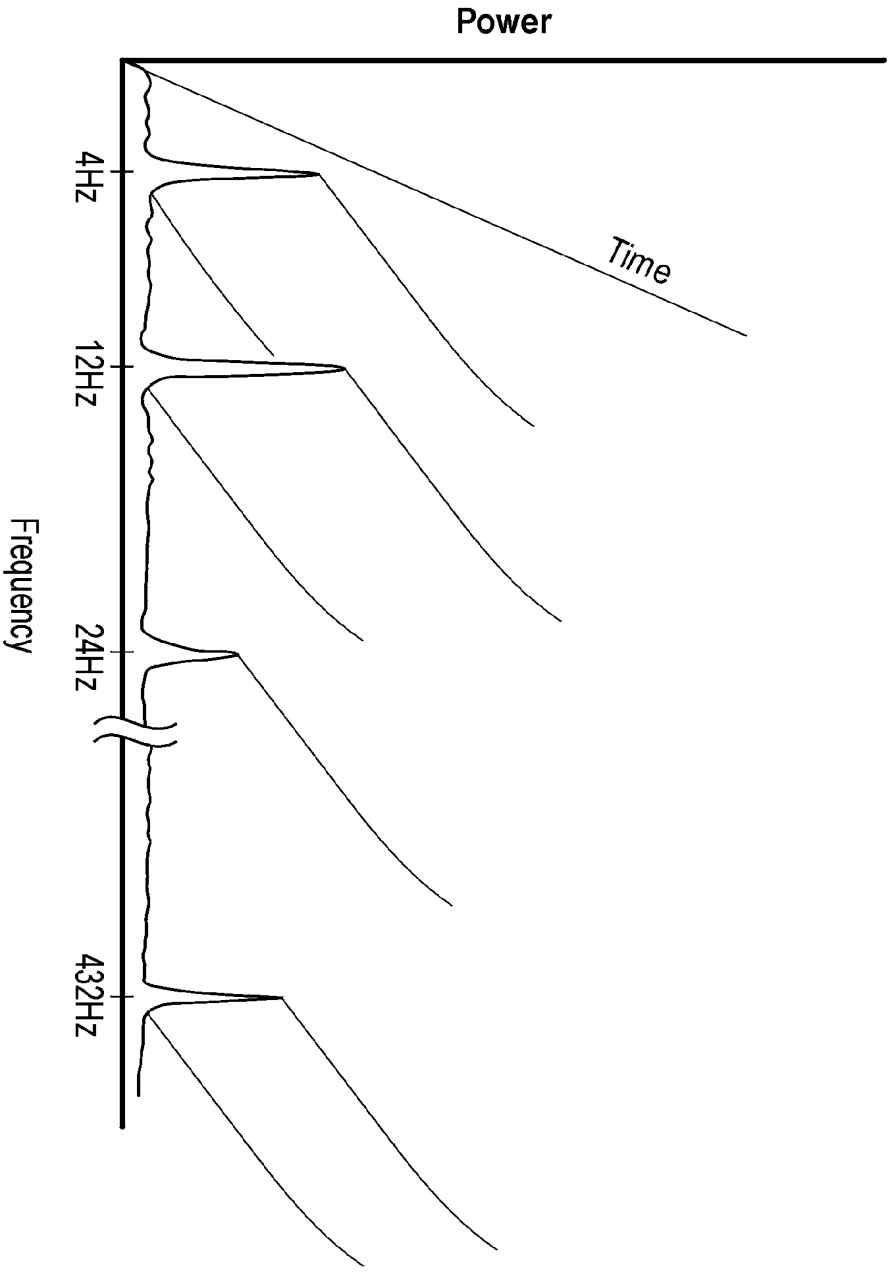


FIG. 5B

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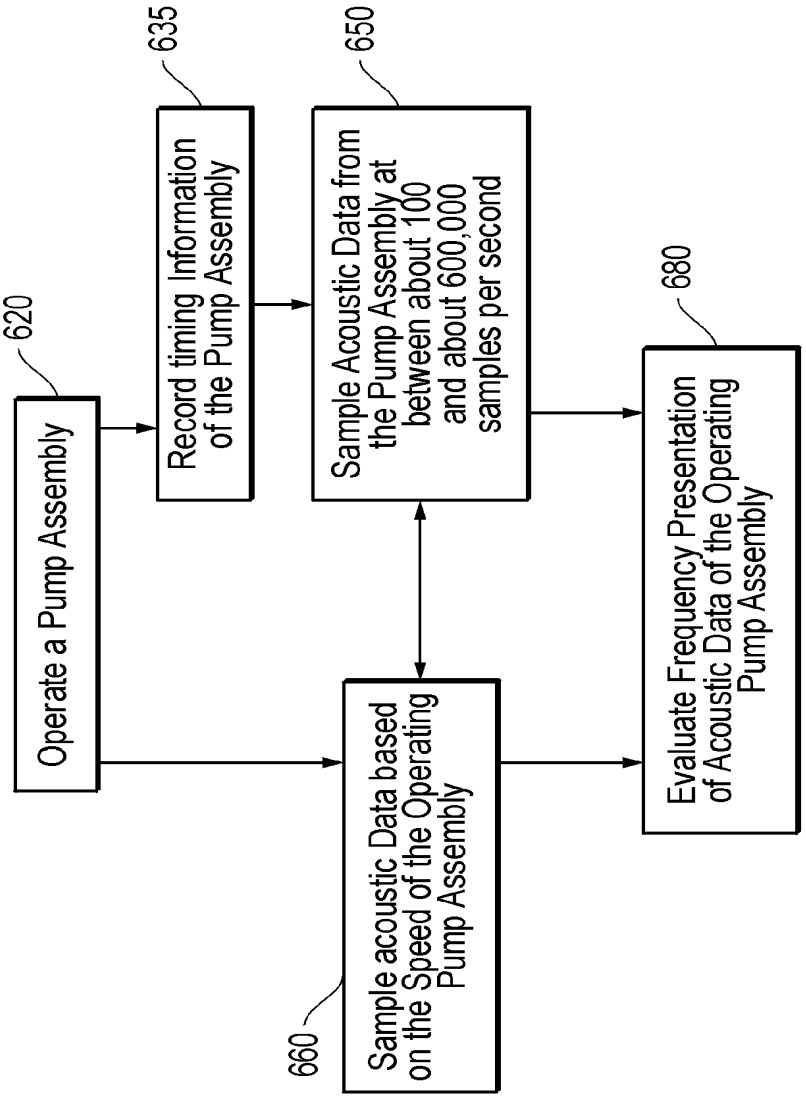

620
Operate a Pump Assembly
635
Record timing Information of the Pump Assembly
650
Sample Acoustic Data from the Pump Assembly at between about 100 and about 600,000 samples per second
660
Sample acoustic Data based on the Speed of the Operating Pump Assembly
680
Evaluate Frequency Presentation of Acoustic Data of the Operating Pump Assembly

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/054995

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04B51/00 F04D15/00

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)
F04B F04D G01M

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 351 714 B1 (BIRCHMEIER JOHN R [US]) 26 February 2002 (2002-02-26) the whole document	1-25
Y	US 2004/230384 A1 (HAYNES HOWARD D [US] ET AL) 18 November 2004 (2004-11-18) the whole document	1-25
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2008	20/05/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel: (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Ingelbrecht, Peter

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2007/054995

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(19) Canadian Intellectual Property Office
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Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

(11) **CA 2 406 801** (13) **A1**

(40) **01.11.2001**
(43) **01.11.2001**

(12)

(21) **2 406 801**

(22) **26.04.2001**

(51) Int. Cl. [7]: **E21B 47/00**, E21B 49/00, E21B 47/02, E21B 43/26

(85) **21.10.2002**

(86) **PCT/US01/13594**

(87) **WO01/081724**

(30) **60/199,779 US 26.04.2000**

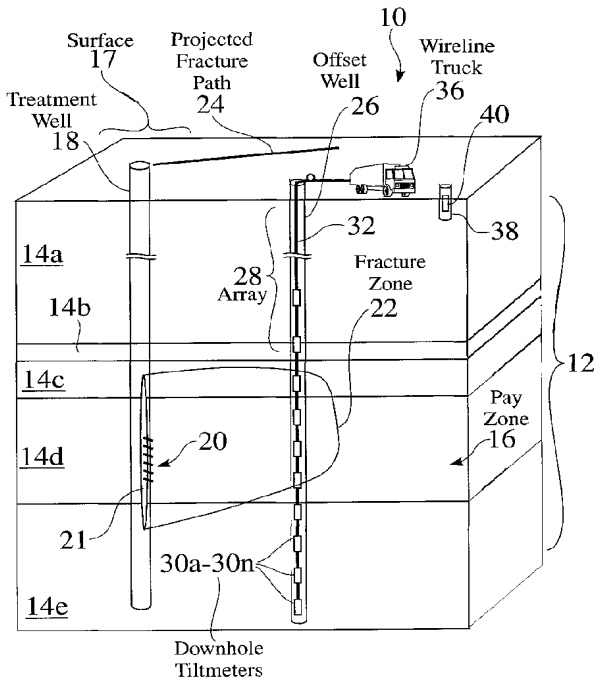
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(54) SYSTEME DE CLINOMETRE POUR PUITS EN COURS DE TRAITEMENT
(54) TREATMENT WELL TILTMETER SYSTEM

(57)
The treatment well tiltmeter system comprises one or more tiltmeter assemblies which are located within an active treatment well. The treatment well tiltmeter system provides data from the downhole tiltmeters, and can be used to map hydraulic fracture growth or other subsurface processes from the collected downhole tilt data versus time. The system provides tilt data inversion of data from each of the treatment well tiltmeter assemblies, and provides isolation of data signals from noise associated with the treatment well environment. As well, the treatment well tiltmeter system provides geomechanical modeling for treatment well processes.



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Canadian Intellectual Property Office
An agency of Industry Canada

CA 2406801 A1 2001/11/01

(21) 2 406 801

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2001/04/26
(87) Date publication PCT/PCT Publication Date: 2001/11/01
(85) Entrée phase nationale/National Entry: 2002/10/21
(86) N° demande PCT/PCT Application No.: US 2001/013594
(87) N° publication PCT/PCT Publication No.: 2001/081724
(30) Priorité/Priority: 2000/04/26 (60/199,779) US

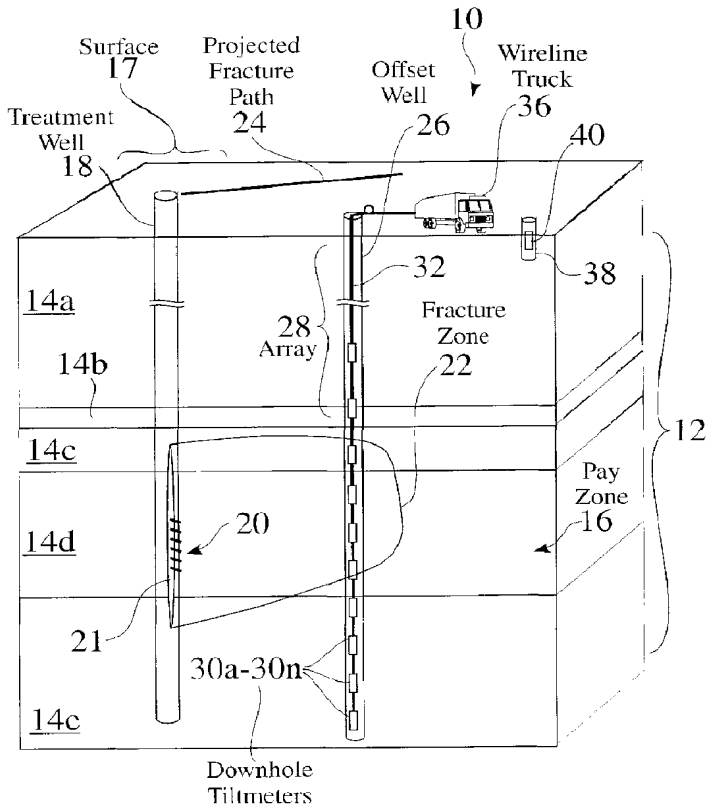
(51) Cl.Int.^{7}/Int.Cl.^{7} E21B 43/26, E21B 47/02, E21B 49/00

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(54) Titre : SYSTEME DE CLINOMETRE POUR PUITS EN COURS DE TRAITEMENT
(54) Title: TREATMENT WELL TILTMETER SYSTEM



(57) Abrégé/Abstract:
The treatment well tiltmeter system comprises one or more tiltmeter assemblies which are located within an active treatment well. The treatment well tiltmeter system provides data from the downhole tiltmeters, and can be used to map hydraulic fracture growth or other subsurface processes from the collected downhole tilt data versus time. The system provides tilt data inversion

(21) 2 406 801

(13) A1

(57) **Abrégé(suite)/Abstract(continued)**:
of data from each of the treatment well tiltmeter assemblies, and provides isolation of data signals from noise associated with the treatment well environment. As well, the treatment well tiltmeter system provides geomechanical modeling for treatment well processes.

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 November 2001 (01.11.2001)

PCT

(10) International Publication Number
WO 01/81724 A1

(51) International Patent Classification[7]: E21B 43/26, 47/02, 49/00

(21) International Application Number: PCT/US01/13594

(22) International Filing Date: 26 April 2001 (26.04.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/199,779 26 April 2000 (26.04.2000) US

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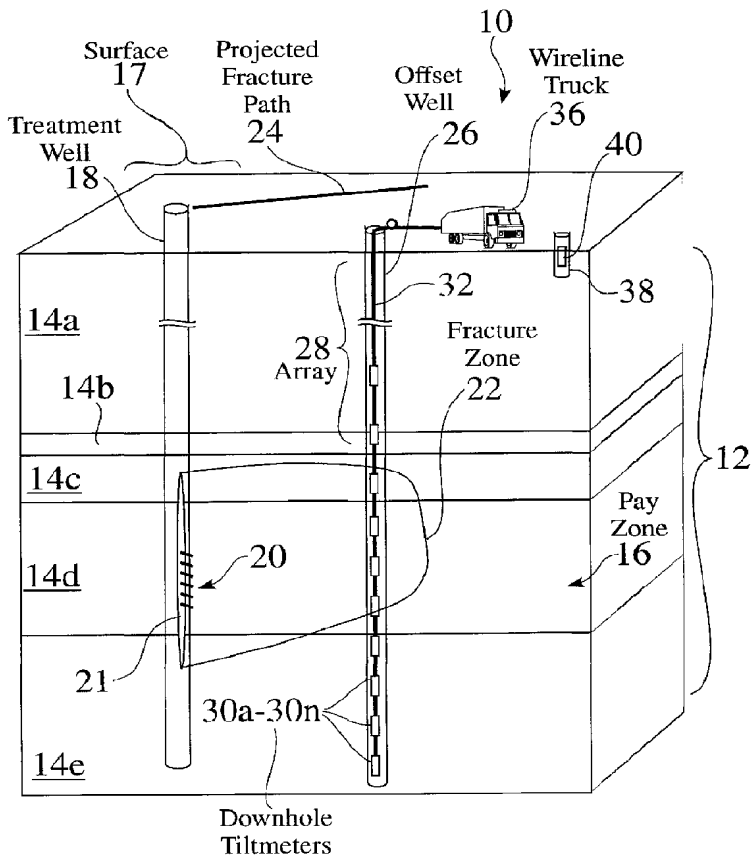
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(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK,

[Continued on next page]

(54) Title: TREATMENT WELL TILTMETER SYSTEM



(57) Abstract: The treatment well tiltmeter system comprises one or more tiltmeter assemblies which are located within an active treatment well. The treatment well tiltmeter system provides data from the downhole tiltmeters, and can be used to map hydraulic fracture growth or other subsurface processes from the collected downhole tilt data versus time. The system provides tilt data inversion of data from each of the treatment well tiltmeter assemblies, and provides isolation of data signals from noise associated with the treatment well environment. As well, the treatment well tiltmeter system provides geomechanical modeling for treatment well processes.

WO 01/81724 A1

WO 01/81724 A1

DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TREATMENT WELL TILTMETER SYSTEM

FIELD OF THE INVENTION

The invention relates to the field of tiltmeter systems and instrumentation in wellbore systems. More particularly, the invention relates to tiltmeter and instrumentation systems for treatment wells.

BACKGROUND OF THE INVENTION

For a variety of applications, fluids are injected into the earth, such as for hydraulic fracture stimulation, waste injection, produced water re-injection, or for enhanced oil recovery processes like water flooding, steam flooding, or CO_2 flooding. In other applications, fluids are produced, *i.e.* removed, from the earth, such as for oil and gas production, geothermal steam production, or for waste clean-up.

Hydraulic fracturing is a worldwide multi-billion dollar industry, and is often used to increase the production of oil or gas from a well. The subsurface injection of pressurized fluid results in a deformation to the subsurface strata. This deformation may be in the form of a large planar parting of the rock, in the case of hydraulic fracture stimulation, or other processes where injection is above formation parting pressure. The resultant deformation may also be more complex, such as in cases where no fracturing is occurring, wherein the subsurface strata (rock layers) compact or swell, due to the poroelastic effects from altering the fluid pressure within the various rock layers.

The preparation of a new well for hydraulic fracturing typically comprises the steps of drilling a well, cementing a casing into the well to seal the well from the rock, and creating perforations at a desired target interval. Perforations are small holes through the casing, which are formed with an explosive device. The target interval is the desired depth within the well, which typically is at the level of a pay zone of oil and/or gas. A bridge plug is then inserted below the perforated interval, to seal off the lower region of the well.

Hydraulic fracturing within a prepared wellbore comprises the pumping of fluid, under high pressure, down the well. The only place that the fluid can escape is through the formed perforations, and into the target zone. The pressure created by the fluid is greater than the in situ stress on the rock, so fractures (cracks, fissures) are created. Proppant (usually sand) is then pumped into the prepared well, so that when the fluid

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leaks off into the rock (via natural porosity), the proppant creates a conductive path for the oil/gas to flow into the well bore. Creation of a hydraulic fracture, therefore, involves parting of the rock, and displacing the fracture faces, to create fracture width. As a result of hydraulic fracturing, the induced deformation field radiates in all directions.

Surface and offset well tiltmeter fracture mapping has been used to estimate and model the geometry of formed hydraulic fractures, by measuring fracture-induced rock deformation.

Surface tilt mapping typically requires a large number of tiltmeters, each located in a near-surface offset bore, which surround an active treatment well that is to be mapped. For example, surface tilt mapping installations often comprise approximately 12 to 30 surface tiltmeters. Tilt data collected from the array of tiltmeters from hydraulic fracturing is then used to estimate the direction, *i.e.* the orientation, of a fracture which is created in the active well.

G. Holzhausen, *Analysis of Earth Tilts Resulting from Formation of Six Hydraulic Fractures*, Crack'r Frac, March 27-28 1979, describes early development in tilt data analysis.

M. Wood, *Method of Determining Change in Subsurface Structure due to Application of Fluid Pressure to the Earth*, U.S. Patent No. 4,271,696, issued 09 June 1981, describes "a method of determination of the change in subsurface structure of the earth resulting from the application of fluid pressure at a selected point, at a selected depth, in the earth, by measuring at least one physical parameter of the contour of the subsurface of the earth above the point of application of fluid pressure. The method involves positioning a plurality of tiltmeters on the earth above the point of application of fluid pressure arranged in a known array, and measuring the change in angle of tilt of the earth's surface at the point of placement of each sensor while varying the pressure and flow rate of fluid into the earth at the selected point."

M. Wood, *Method of Determining the Azimuth and Length of a Deep Vertical Fracture in the Earth*, U.S. Patent No. 4,353,244, issued 12 October 1982, describes "a method of determination of the change in subsurface structure of the earth resulting from the application of fluid pressure at a selected point, at a selected depth, in the earth, by measuring at least one physical parameter of the contour of the surface of the earth above the point of application of fluid pressure. The method involves positioning a plurality of tiltmeters on the earth above the point of application of fluid pressure arranged in a known array, and measuring the change in angle of tilt of the earth's surface

at the point of placement of each sensor while varying the pressure and flow rate of fluid into the earth at the selected point. This invention further teaches how the individual values of incremental tilt at selected points on the earth's surface can be processed to provide indication of the azimuth of the vertical fracture in the earth, and an estimate of length of the fracture."

However, in addition to the direction of a fracture, other details of the formed fracture are important, such as the length and the height of the fracture region. Surface measurements do not accurately reflect the magnitude and dimensions of a formed fracture, due primarily to the relative isolation of the surface tiltmeters from the fracture area. For example, surface tiltemeters are typically installed within ten to fifty feet of the surface, whereas fractures are commonly formed much deeper into the strata.

Recently, downhole offset tilt mapping has been developed, comprising an array of tiltmeters located in a well which is offset from the active treatment well. Offset tiltmeter arrays often comprise a string of seven to thirteen tiltmeters. The plurality of offset tiltmeters are usually located at depths which are comparable to the fracture region, *e.g.* such as within the fracture zone, as well as above and/or below the fracture zone. For example, for a fracture at a depth of 5,000 feet, with an estimated fracture height of 300 feet, and array having a plurality of offset tiltmeters, having a span larger than 300 feet, *e.g.* such as an 800 foot string array, may be located in an offset hole near the active well. The use of a larger number of offset tiltmeters, located above, within, and below a fracture zone, which aids in estimating the extent of the formed fracture zone.

The distance between an active well and an offset well in which an array of offset tiltmeters is located is often dependent on the location of existing wells, and the permeability of the local strata. For example, in existing oil well fields in many locations in California, the surrounding strata has low fluid mobility, which requires that wells are often located relatively close together, *e.g.* such as a 200 ft. spacing. In contrast to closely spaced wells in California, for gas well fields in many locations in Texas, the surrounding strata has higher fluid mobility, which allows gas wells to be located relatively far apart, *e.g.* such as a 1,000-5,000 ft. spacing.

P. Davis, *Surface Deformation Associated with a Dipping Hydrofracture,* Journal of Geophysical Research, Vol. 88, No. B7, Pages 5826-5834, 10 July 1983, describes the modeling of crustal deformations associated with hydrofractures.

C. Wright, *Tiltmeter Fracture Mapping: From the Surface, and Now Downhole*, Hart's Petroleum International, January 1998, describes the use of surface and downhole offset tiltmeters for fracture mapping.

C. Wright, E. Davis, W. Minner, J. Ward, L. Weijers, E. Schell, and S. Hunter, *Surface Tiltmeter Fracture Mapping reaches New Depths – 10,000 Feet, and Beyond?,* SPE 39919, Society of Petroleum Engineers Rocky Mountain Regional Conference, May 1998, Denver, CO, describe surface tilt measurement and mapping techniques for resolution of fracture induced tilts.

C. Wright, E. Davis, G. Golich, J. Ward, S. Demetrius, W. Minner, and L. Weijers, *Downhole Tiltmeter Fracture: Finally Measuring Hydraulic Fracture Dimensions,* SPE 46194, Society of Petroleum Engineers Western Regional Conference, May 10-13 1998, Bakersfield, CA, describe downhole tiltmeter fracture mapping for offset wells.

P. Perri, M. Emanuele, W. Fong, M. Morea, *Lost Hills CO2 Pilot: Evaluation, Injectivity Test Results, and Implementation,* SPE 62526, Society of Petroleum Engineers Western Regional Conference, June 19-23 2000, Long Beach, CA, describe the evaluation, design, and implementation of a CO_2 pilot project and mapping of CO_2 migration.

E. Davis, C. Wright, S. Demetrius, J. Choi, and G. Craley, *Precise Tiltmeter Subsidence Monitoring Enhances Reservoir Management,* SPE 62577, Society of Petroleum Engineers Western Regional Conference, June 19-23 2000, Long Beach, CA, describe tiltmeter-based long term reservoir compaction and dilation due to fluid withdrawal and injection.

L. Griffin, C. Wright, E. Davis, S. Wolhart, and Z. Moschovidis, *Surface and Downhole Tiltmeter Mapping: An effective Tool for Monitoring Downhole Drill Cuttings Disposal,* SPE 63032, 2000 Society of Petroleum Engineers Annual Technical Conference, October 1-4 2000, Dallas TX, describe the use of both surface tiltmeters and offset downhole tiltmeters for drill cuttings disposal monitoring applications.

N. Warpinski, T. Steinfort, P. Branigan, and R. Wilmer, *Apparatus and Method for Monitoring Underground Fracturing*, U.S. Patent Number 5,934,373, Issued 10 August, 1999, describe "an apparatus and method for measuring deformation of a rock mass around the vicinity of a fracture, commonly induced by hydraulic fracturing is provided. To this end, a well is drilled offset from the proposed fracture region, if no existing well is present. Once the well is formed to a depth approximately equal or exceeding the

depth of the proposed fracture, a plurality of inclinometers, for example tiltmeters, are inserted downhole in the well. The inclinometers are located both above and below the approximate depth of the proposed fracture. The plurality of inclinometers may be arranged on a wireline that may be retrieved from the downhole portion of the well and used again or, alternatively, the inclinometers may be cemented in place. In either event, the inclinometers are used to measure the deformation of the rock around the induced fracture."

The disclosed prior art systems and methodologies thus provide tiltmeter assemblies and systems for surface and offset tilt mapping. However, the prior art systems and methodologies fail to provide tiltmeter assemblies and systems within active wells, nor do they provide structures which can be used in an active well environment.

C. Wright, E. Davis, J. Ward, L. Griffin, M. Fisher, L. Lehman, D. Fulton, and J. Podowski, *Real-Time Fracture Mapping from the Live Treatment Well*, Abstract No. SPE71648, submitted December 2000 to Society of Petroleum Engineers for Annual Technical Conference, September 30 – October 3, 2001, describes early development in hydraulic fracture mapping from within a treatment well.

It would be advantageous to provide a system for mapping an active wellbore which does not require either an offset wellbore or the installation of surface tilt arrays. It would be advantageous to construct a measurement device that could be placed into and survive within in an active treatment well, particularly during the pumping of a hydraulic fracture treatment. Furthermore, it would be advantageous to provide a tiltmeter in which induced motion of the subsurface strata is discernable from the induced motion from active fluid flow in the borehole. It would also be advantageous to provide a system for mapping an active wellbore which operates in a wider range of environments and provides a high resolution of fracture width and/or rock deformation pattern data across the subsurface rock strata. Furthermore, it would be advantageous to provide a system for mapping an active wellbore which can be deployed and survive in the hostile treatment well environment.

SUMMARY OF THE INVENTION

The treatment well tiltmeter system comprises one or more tiltmeter assemblies which are located within an active treatment well. The treatment well tiltmeter system provides data from the downhole tiltmeters, which is used to map hydraulic fracture growth or other subsurface processes from the collected downhole tilt data versus time. The system provides data from each of the treatment well tiltmeter assemblies, and provides isolation of data signals from noise associated with the treatment well environment. As well, the treatment well tiltmeter system provides geomechanical modeling for treatment well processes, based upon the treatment well data.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an offset well tiltmeter system;

Figure 2 is a perspective view of fracture-induced deformation;

Figure 3 is a view of a fracture-induced deformation having vertically confined growth;

Figure 4 is a view of a fracture-induced deformation having out of zone growth;

Figure 5 shows fracture-induced deformation having upward fracture growth;

Figure 6 is a view of a fracture-induced deformation having twisting fractures;

Figure 7 is a view of a fracture-induced deformation having poor fluid diversion;

Figure 8 is a simplified view of a fracture-induced deformation having multiple fractures which dip from vertical;

Figure 9 is a simplified view of a fracture-induced deformation having horizontal fractures;

Figure 10 is a view of a fracture-induced deformation having T-shaped fractures;

Figure 11 is a plan view of optimized water/steam flood injection in a well field;

Figure 12 is a plan view of non-optimal water/steam flood injection in a well field;

Figure 13 is a plan view showing the placement of an infill well in a well field;

Figure 14 is a plan view showing non-optimal placement of an infill well in a well field;

Figure 15 is a plan view of fracture-induced deformation which crosses natural fractures;

Figure 16 is a plan view of fracture-induced deformation which is substantially aligned with natural fractures;

Figure 17 is a simplified view of fracture-induced deformation which is located within and substantially accesses the vertical extent of a pay zone;

Figure 18 is a simplified view of fracture-induced deformations which incompletely access the vertical extent of a pay zone region;

Figure 19 is a simplified view of fracture-induced deformation which is substantially located within and extends well into a pay zone;

Figure 20 is a view of a fracture-induced deformation which extends vertically above and below pay zone, in which the deformation length is relatively small;

Figure 21 is a view of fracture-induced deformation as a function of time, in which the deformation continues to extend into a pay zone region;

Figure 22 is a view of fracture-induced deformation as a function of time, in which the deformation extends vertically beyond a pay zone;

Figure 23 is a view of multi-zone coverage fracture-induced deformation, in which the deformations are substantially located within and extend well into each of a plurality of pay zones;

Figure 24 is a view of multi-zone coverage fracture-induced deformation, in which the deformations are do not extend into each of a plurality of pay zones;

Figure 25 is a view of fracture-induced deformation for a substantially horizontal well, in which the deformations extend generally across the vertical extent of the pay zone strata;

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Figure 26 is a view of fracture-induced deformation for a substantially horizontal well, in which the deformations are not substantially centered across the vertical extent of the pay zone strata;

Figure 27 is a view of fracture-induced deformation, in which the formed perforation region for the well is aligned with and extends across the pay zone strata;

Figure 28 is a view of fracture-induced deformation, in which one or more formed perforation regions are misaligned with the pay zone;

Figure 29 is a schematic view of a treatment well tiltmeter system;

Figure 30 is a simplified schematic view of a self-leveling tiltmeter assembly;

Figure 31 is a graph which compares tilt data between non-leveling and self-leveling tiltmeter assemblies;

Figure 32 is a graph which compares tilt data output between different tiltmeter sensor electronics;

Figure 33 is a schematic block diagram of tiltmeter electronics for one or more tiltmeters in a daisy-chain tiltmeter system;

Figure 34 is a partial cutaway view of a treatment well tiltmeter system, in which the tiltmeters are permanently attached to the outside of a well casing;

Figure 35 is a detailed cutaway view of a tiltmeter which is permanently attached to the outside of a well casing;

Figure 36 is an end view of a tiltmeter which is permanently attached to the outside of a well casing;

Figure 37 is a partial cutaway view of a horizontal treatment well tiltmeter system, in which the tiltmeters are permanently attached to the outside of a well casing;

Figure 38 is a partial cutaway view of a treatment well tiltmeter system, in which the tiltmeters are mechanically stabilized within a well casing;

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Figure 39 is a detailed cutaway view of a tiltmeter which is mechanically stabilized within the outside of a well casing;

Figure 40 is an end view of a tiltmeter which is mechanically stabilized within a well casing;

Figure 41 is a partial cutaway view of a horizontal treatment well tiltmeter system, in which the tiltmeters are mechanically stabilized within a well casing;

Figure 42 is a partial cutaway view of a treatment well tiltmeter system, in which the tiltmeters are magnetically attached to a well casing;

Figure 43 is a detailed cutaway view of a tiltmeter which is magnetically attached to a well casing;

Figure 44 is an end view of a tiltmeter which is magnetically attached within the well casing;

Figure 45 is a partial cutaway view of a horizontal treatment well tiltmeter system, in which the tiltmeters are magnetically attached to the well casing;

Figure 46 is a partial cutaway view of a self-leveling tiltmeter assembly;

Figure 47 is a simplified expanded view of a self-leveling tiltmeter housing assembly;

Figure 48 is a simplified assembly view of a self-leveling treatment well tiltmeter housing having cablehead wireline attachments;

Figure 49 is a partial cutaway assembly view of a treatment well tiltmeter tool;

Figure 50 is a detailed partial cutaway assembly view of a treatment well tiltmeter tool;

Figure 51 is a partial cutaway assembly view of a re-zero mechanism within a treatment well tiltmeter tool;

Figure 52 is a detailed partial cutaway assembly view of a re-zero mechanism within a treatment well tiltmeter tool;

Figure 53 is a detailed partial cutaway assembly view of a reed switch within a treatment well tiltmeter tool;

Figure 54 is a top view of a tiltmeter reed switch assembly;

Figure 55 is a side view of a tiltmeter bottom end cap;

Figure 56 is a first end view of a tiltmeter bottom end cap;

Figure 57 is a partial cross-sectional side view of a tiltmeter bottom end cap;

Figure 58 is a side view of a tiltmeter tool body;

Figure 59 is a detailed side view of the end of a tiltmeter tool body;

Figure 60 is a partial cross-sectional detailed side view of the end of a tiltmeter tool body;

Figure 61 is a front view of a tiltmeter Y-channel sensor holder;

Figure 62 is a side view of a tiltmeter Y-channel sensor holder;

Figure 63 is an end view of a tiltmeter Y-channel sensor holder;

Figure 64 is a front view of a tiltmeter X-channel sensor holder;

Figure 65 is a side view of a tiltmeter X-channel sensor holder;

Figure 66 is a side view of a tiltmeter X-channel shaft;

Figure 67 is an end view of a tiltmeter X-channel shaft;

Figure 68 is a side view of a tiltmeter drive shaft;

Figure 69 is an end view of a tiltmeter drive shaft;

Figure 70 is a front view of a tiltmeter Y-channel gear;

Figure 71 is a side view of a tiltmeter Y-channel gear;

Figure 72 is a front view of a tiltmeter reed switch holder;

Figure 73 is a side view of a tiltmeter reed switch holder;

Figure 74 is a side view of a tiltmeter re-zero mechanism body;

Figure 75 is a bottom view of a tiltmeter re-zero mechanism body;

Figure 76 is a first cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 77 is a second cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 78 is a third cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 79 is a fourth cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 80 is a fifth cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 81 is a sixth cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 82 is a seventh cross-sectional view of a tiltmeter re-zero mechanism body;

Figure 83 is a side view of a tiltmeter re-zero mechanism top bearing shaft;

Figure 84 is a side cross-sectional view of a tiltmeter re-zero mechanism top bearing shaft;

Figure 85 is an end view of a tiltmeter re-zero mechanism top bearing shaft;

Figure 86 is a side view of a tiltmeter re-zero mechanism bottom bearing shaft;

Figure 87 is a side cross-sectional view of a tiltmeter re-zero mechanism bottom bearing shaft;

Figure 88 is a first view of a first end of a tiltmeter re-zero mechanism bottom bearing shaft;

Figure 89 is a second view of a first end of a tiltmeter re-zero mechanism bottom bearing shaft;

Figure 90 is a first view of a second end of a tiltmeter re-zero mechanism bottom bearing shaft;

Figure 91 is a second view of a second end of a tiltmeter re-zero mechanism bottom bearing shaft;

Figure 92 is a first front view of a tiltmeter motor mounting disk;

Figure 93 is a side view of a tiltmeter motor mounting disk;

Figure 94 is a side cross sectional view of a tiltmeter motor mounting disk;

Figure 95 is a second front view of a tiltmeter motor mounting disk;

Figure 96 is a side view of a tiltmeter motor holder;

Figure 97 is a side cross-sectional view of a tiltmeter motor holder;

Figure 98 is a first view of a first end of a tiltmeter motor holder;

Figure 99 is a second view of a first end of a tiltmeter motor holder;

Figure 100 shows the second end of a tiltmeter motor holder;

Figure 101 is a front view of a tiltmeter X-channel gear;

Figure 102 is a side view of a tiltmeter X-channel gear;

Figure 103 is a front view of a tiltmeter bearing holder;

Figure 104 is a side view of a tiltmeter bearing holder;

Figure 105 is a front view of a tiltmeter fluoropolymer ring;

Figure 106 is a side view of a tiltmeter fluoropolymer ring;

Figure 107 is a side cross-sectional view of a tiltmeter fluoropolymer ring;

Figure 108 is a top view of a tiltmeter accelerometer mount;

Figure 109 is a front view of a tiltmeter accelerometer mount;

Figure 110 is a side view of a first end of a tiltmeter accelerometer mount;

Figure 111 is a side view of a second end of a tiltmeter accelerometer mount;

Figure 112 is a top view of a tiltmeter Z-axis accelerometer board;

Figure 113 is a top view of a tiltmeter X and Y axis accelerometer board;

Figure 114 is a front view of a tiltmeter tensioner;

Figure 115 is a top view of a tiltmeter tensioner;

Figure 116 is a first side view of a tiltmeter tensioner;

Figure 117 is a second side view of a tiltmeter tensioner;

Figure 118 is a bottom view of a tiltmeter tensioner;

Figure 119 is a front view of a tiltmeter tensioner;

Figure 120 is a top view of a tiltmeter tensioner;

Figure 121 is a first cross-sectional view of a tiltmeter tensioner;

Figure 122 is a side view of a tiltmeter tensioner;

Figure 123 is a second cross-sectional view of a tiltmeter tensioner;

Figure 124 is a bottom view of a tiltmeter tensioner;

Figure 125 is a side view of a tiltmeter spring pole;

Figure 126 is an end view of a tiltmeter spring pole;

Figure 127 is a side view of a tiltmeter tensioner shaft;

Figure 128 is a side view of a tiltmeter power supply board solenoid mount;

Figure 129 is a top view of a tiltmeter power supply board solenoid mount;

Figure 130 is an end view of a tiltmeter power supply board solenoid mount;

Figure 131 is a top view of a tiltmeter reed switch board;

Figure 132 is a detailed plan view of a tiltmeter power supply board;

Figure 133 shows a tiltmeter accelerometer assembly;

Figure 134 is a detailed plan view of a tiltmeter analog board;

Figure 135 is a detailed plan view of a tiltmeter modem board;

Figure 136 is a simplified flow chart of treatment well tiltmeter data acquisition, data analysis, and real-time data display;

Figure 137 is a chart of treatment well tilt response to applied surface pressure for a plurality of tiltmeters;

Figure 138 is a graph which represents fracture-induced deformation for a well, based upon the measured tilt mapping data from a plurality of treatment well tiltmeters;

Figure 139 shows a plan view of measured and projected tilt for a plurality of surface tiltmeters;

Figure 140 is a partial cutaway view of a treatment well tiltmeter system, in which the tiltmeters are magnetically attached to a well casing, in an annular region formed between the casing and an inner tube;

Figure 141 is a detailed cutaway view of a tiltmeter which is magnetically attached to a well casing in an annular region formed between the casing and an inner tube;

Figure 142 is an end view of a tiltmeter which is magnetically attached to well casing in an annular region formed between the casing and an inner tube; and

Figure 143 is a partial cutaway view of a horizontal treatment well tiltmeter system, in which the tiltmeters are magnetically attached to the well casing in an annular region formed between the casing and an inner tube.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 is a partial cutaway view 10 showing a treatment well 18 which extends downward into strata 12, through one or more geological layers 14a-14e. A fracture zone 22 is formed within a previously formed perforation region 20 in the treatment well 18, such as to extend into one or more pay zones 16 within the strata 12. A fracture process is typically designed to coincide with a desired projected fracture path 24, such as to extend into a pay zone 16.

Surface tilt meters 40 are often placed in shallow surface bores 38, to record the tilt of the surface region at one or more locations surrounding the treatment well 18. The surface bores 38 have a typical depth of ten to forty feet. Tilt data collected from the surface tilt meters 40 from a treatment well fracture process is used to estimate the orientation of the formed fracture zone 22.

As seen in Figure 1, an array 28 of offset well tilt meters 30a-30n are placed in an offset wellbore 26, to record data from each of the tiltmeters 30a-30n at different depths within the offset well 26, during a fracture process within the treatment well 18. The array 28 of offset well tilt meters 30a-30n further comprises a wireline 32, which extends to the surface, as well as between each of the offset well tiltmeters 30a-30n. The wireline 32 is typically provided by a wireline truck 36. Tilt data collected from the offset well tilt meters 30a-30n from a treatment well fracture process can be used to estimate the extent, *i.e.* the height, length and width, of the formed fracture zone 22.

Figure 2 is a schematic view of a fracture-induced deformation field 42, as seen both downhole, by an offset tiltmeter array 28, and at the surface 17, by a plurality of tiltmeters 40a-40i. A fracture 22 is induced within a treatment well 18, at a desired depth 15. One or more surface tiltmeters 40a-40i record surface tilt data 48a-48i at surface locations near the treatment well 18. As seen in Figure 2, the surface tilt data 48a-48i indicates the presence of a surface trough 44 formed by a vertical fracture 22. Surface tiltmeters 40 which are located close to the formed trough 44 point downhill, towards the trough 44, while surface tiltmeters further away point away from the fracture zone 22.

One or more offset well tiltmeters 30a-30n record offset well tilt data 46a-46n at different depths within the offset well 26, during a fracture process within the treatment well 18. As seen in Figure 2, the offset well tilt data 46a-46n indicates the depth 15 and magnitude of the fracture 22. The measured deformation field at the surface 17, with a two-dimensional array 40a-40i, gives a very different view of the deformation field than a one-dimensional (linear array) 30a-30n downhole in an offset wellbore 26.

While induced fractures 22 are typically intended to extend along a projected fracture path 24 (FIG. 1), at a controlled depth 15, the actual wellbore 18 and strata 12 conditions commonly yield a variety of actual fracture results.

Figure 3 is a view 50 of a fracture-induced deformation 22 extending from a treatment well 18 having vertically confined growth, at a depth 15 which corresponds with a pay zone 16. The vertical extent 54 of the fracture extends substantially across the pay zone 16, and the length 54 of the fracture 22 extends well within the pay zone 16.

Figure 4 is a view 56 of a fracture-induced deformation having out of zone growth. While the fracture 22 has vertically confined growth, the vertical extent 54 of the fracture extends beyond the pay zone 16, and the length 54 of the fracture extends only a short distance into the pay zone 16.

Figure 5 shows fracture-induced deformation 22 having upward fracture growth 58. While the upper fracture 22 has vertically confined growth, the vertical extent 54 of the fracture 22 extends upward beyond the pay zone 16, and fails to extend substantially across the lower region of the pay zone 16.

Figure 6 is a view of a fracture-induced deformation 22 having twisting fractures 62. While the fracture 22 has vertically confined growth, the vertical extent 54 of the fracture is twisted axially within the pay zone 16.

Figure 7 is a view of a fracture-induced deformation 64 having poor fluid diversion across one or more of a plurality of pay zones 16a-16c. While the upper fracture 22 has vertically confined growth, the vertical extent 54 of the fracture extends beyond the pay zone 16a. The fracture 22 generally located in the lowest pay zone 16c fails to extend substantially across the lowest pay zone 16c, and there is no fracture 22 that is generally formed into the middle pay zone 16b.

Figure 8 is a simplified view 66 of a fracture-induced deformation having multiple fractures 68 which dip from vertical. While the fractures 22 generally extend into the

strata 12 in the pay zone region, the fractures 22 are not substantially aligned with a vertically aligned well bore 18.

Figure 9 is a simplified view 70 of a fracture-induced deformation having horizontal fractures 72. While the fractures 22 generally extend into the strata 12 in the pay zone region 16, the horizontal fractures 72 are not substantially aligned with either the treatment well 18 or the vertically aligned pay zone 16. Figure 10 is a view of a fracture-induced deformation 74 having T-shaped fractures 22,72, in which a combination of fractures 22 having different alignments are formed, and do not necessarily extend across the pay zone 16.

Filed Development Optimization. While the knowledge of fracture induced deformations 22 for a single well are often beneficial, the overall knowledge of the strata and fracture growth obtained through one or more tilt-mapped fractures from a plurality of boreholes can also yield a wealth of information for full field development.

Figure 11 is a plan view 76 of an optimized water/steam flood injection well pattern in a field. Water and/or steam injection is often used to enhance hydrocarbon recovery. In Figure 11, Water and or steam is injected through injector well bores 80, and producer wells 78 are used to obtain product, *e.g.* oil and/or gas. For strata 12 in which induced fractures 22 are generally aligned to coincide with the injector lines 81 of injector well bores 80 and the producer line of producer wells 78, the injected enhancement fluid 82 substantially increases the flow of product across the strata 12 toward the fracture zones 22 of the producer wells 78.

Figure 12 is a plan view of non-optimal water/steam flood injection in a well field. As seen in Figure 12, the induced fractures 22 are not generally aligned to coincide with the injector lines 81 of injector well bores 80 and the producer line of producer wells 78. Therefore, injected enhancement fluid 82 may not substantially increase the flow of product across the strata 12 toward the fracture zones 22 of the producer wells 78.

In field development, it is often desirable to add a new well 18 to an existing field, such as to access a pay zone region 16 which is not efficiently accessed by existing wells 18. Figure 13 is a plan view showing the placement 86 of an infill well 90 in a well field of existing wells 88a-88d. The infill well accesses a region 92 that is not previously accessed by the fracture regions 22 of the existing wells 88a-88d. Figure 14 is a plan view showing non-optimal placement of an infill well 90 in a field of existing wells 88a-88d. In Figure 14, the fracture regions 22 of the infill well 90 access a region 96 which is generally aligned with and is accessed by the existing fracture regions 22 of existing

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wells 88a-88d. While the plan view of existing well heads 88a-88d in Figure 13 and Figure 14 are similar, the existing strata 12 and fracture regions 22 are different. Field development for infill wells 90 can therefore be improved, based upon accurate data acquisition and analysis of the natural and formed structures.

Figure 15 is a plan view 98 of fracture-induced deformation 22 which crosses natural frac structures 100. The fracture region 22 accesses a large portion of the natural frac structure 100. Figure 16 is a plan view 102 of fracture-induced deformation 22 which is substantially aligned with natural fractures. The fracture region 22 in Figure 16 accesses a limited portion of the natural frac structure 100. Treatment well fracturing is often enhanced by the controlled establishment of a perforation zone 20 and fracture structure 22 which accesses a large portion of a surrounding natural frac structure 100.

Fracture Treatment Optimization. Figure 17 is a simplified view of fracture-induced deformation 104 which is located within and substantially covers the vertical height 106 of a pay zone 16. Figure 18 is a simplified view of fracture-induced deformations 108 which incompletely access the vertical height 106 of a pay zone region 16.

Figure 19 is a simplified view of fracture geometry 110 which is substantially located within and extends 52 well into a pay zone 16. Figure 20 is a view of a fracture geometry 112 which extends vertically above and below pay zone 16, in which the fracture length 52 is relatively small.

Figure 21 is a view 114 of fracture-induced deformation geometry as a function of time, in which the deformations 22a, 22b, 22c, 22d continue to extend within a pay zone region 16. Figure 22 is a view 116 of fracture-induced deformation geometry as a function of time, in which the deformation 22a, 22b, 22c, 22d tends to extend vertically beyond a pay zone 16.

Figure 23 is a view 118 of multi-zone coverage fracture-induced deformation, in which the deformations are substantially located within and extend well into each of a plurality of pay zones 16a, 16b, 16c. Figure 24 is a view 120 of multi-zone coverage fracture-induced deformation, in which the deformations do not extend into each of a plurality of pay zones 16a, 16b, 16c.

Figure 25 is a view 122 of fracture-induced deformation geometry for a substantially horizontal well 18h, in which the deformations extend generally across the pay zone strata 16. Figure 26 is a view 124 of fracture-induced deformation geometry for a

substantially horizontal well 18h, in which the deformations are not substantially centered across the pay zone strata 16.

Figure 27 is a view 128 of fracture-induced deformation, in which the formed perforation region 21 for the well 18 is aligned with and extends across the pay zone strata 16. Figure 28 is a view 130 of fracture-induced deformation, in which one or more formed perforation regions 21 are misaligned aligned with the pay zone 16.

Treatment Well Tiltmeter System. Figure 29 is a schematic view of a treatment well tiltmeter system 132. One or more tiltmeters 134a-134n are located at different depths 15 within a treatment well 18. Interconnection cable lines 136, each typically having a length of approximately 20 to 100 feet, interconnect each of the tiltmeters 134 within a treatment well tiltmeter array 135. A main wireline 137 extends from the tiltmeter system 132 to the surface, and is typically provided by a wireline truck 36. The tiltmeters 134a-134n are preferably installed over a depth range approximating one or more depths 15 where fluid outflow or inflow is occurring.

Each of the tiltmeters 134a-134n further comprises means 138 for fixedly positioning the tiltmeter in position, either within the active flowstream, or with in a "quiet" annular region 554 (FIG. 140) between the casing 214a and an inner tubing 214b. As seen in the tiltmeter embodiment 134 in Figure 29, one or more centralizers 138a are located on each tiltmeter 134, and position the tiltmeters 134a-134n within the casing 214. In alternate embodiments, the tiltmeters 134a-134n are attached either permanently or removably to the treatment well structure 18, such as within or external to the casing 214.

The treatment well 18 typically comprises a well head BOP 140. The main wireline passes through a lubricator 148, which allows the tiltmeter array 135 to be removed from an active wellbore 18 under pressure. A bridge plug is typically located in the treatment well 18, below the tiltmeter system, and below the estimated pay zone 16.

The tiltmeters 134a-134n are preferably placed such that one or more tiltmeters 134 are located above, below, and/or within an estimated pay zone region 16, in which a perforation zone 20 is formed. For example, in Figure 29, tiltmeter 134a is located above a perforation zone 20, tiltmeters 134b,134c, and 134d are located within the perforation zone region 20, and tiltmeter 134n is located below the perforation zone region 20.

A frac pump supply line 142 is connected to the well head 140 for a fracturing operation, whereby a fracturing fluid 143 is controllably applied to the treatment well. The treatment may also comprise a blast joint 146 and blast joint fluid diversion 152.

The tiltmeter array 135 collects continuous data 213 of the induced earth deformation versus time, and transmits this data 213 back to the surface via wireline 136,137, via permanent cabling, or via memory storage, if or when the tiltmeters 134 are returned to the surface. The time-series deformation (tilt) data 213 is analyzed over various time intervals, to determine the pattern of subsurface deformation. The geophysical inverse process is then solved, to estimate the nature of the subsurface fluid flow and fracture growth which is responsible for the observed deformation.

The treatment well tiltmeter system 132 provides mapping for subsurface injection processes, such as for hydraulic fracture stimulation, subsurface waste disposal, produced water re-injection, or for other processes where fluid injection is occurring below fracturing pressure. The processing of tilt data also provides monitoring for fluid production related phenomenon, such as for formation compaction, poroelastic swelling, and thermoelastic deformation, which can be used to determine inflow and outflow rates or patterns from various subsurface strata for long-term reservoir monitoring.

The treatment well tiltmeter system 132 preferably provides data acquisition and analysis systems, to map the fracture height growth in real-time on mini-frac pumping treatments, *i.e.* pumping jobs run without proppant. Additionally, possible results of analysis of the data include interpretation of fracture width and length, as well as enhanced resolution of fracture closure stress, net fracture pressure and fracture fluid efficiency.

The treatment well tiltmeter system 132 is designed to withstand the hostile treatment well environment, which often comprises high temperatures, in which high pressure fluid is usually applied to the treatment well 18, such as for a fracturing process. Therefore, preferred embodiments of the treatment well tiltmeter assemblies 134a-134n are designed to withstand these high temperatures and pressures, and are packaged in a small diameter housing, to promote the flow of working fluid 143 and/or proppant within the treatment wellbore 18. While tiltmeter assemblies 134 can be coupled to the wellbore in a manner similar to that of an offset wellbore tiltmeter system, the treatment well tiltmeter assemblies 134a-134n are preferably coupled to the treatment well bore 18 to minimize the flow resistance from working fluids 143 and proppants.

Treatment Well Tiltmeter Assembly. Figure 30 is a simplified schematic view of a self-leveling tiltmeter assembly 134, such as a Series 5000 Tiltmeter, by Pinnacle Technologies, Inc., of San Francisco, CA. The tiltmeter housing assembly 152 comprises an outer housing tube 154, and upper housing end cap 156, and a lower housing end cap 158. In one embodiment of the tiltmeter assembly 134, the exterior housing is an aluminum cylinder roughly 107 cm (42 in.) long and 7 cm (2.5 in.) in diameter. O-ring seals protect the internal components from splash and dust intrusion. Other casing materials, such as stainless steel, titanium, or INCONEL™, are preferably used in corrosive environments.

The tiltmeter assembly 134 comprises a plurality of tilt sensors 150, which preferably comprise orthogonally deposed sensor bubbles 150. Tilt sensors 150 operate on the same principle as a carpenter's level. The orthogonal bubble levels 150 have a precise curvature. Electrodes detect minute movements of the gas bubble within a conductive liquid, as the liquid seeks the lowest spot in the sensor 150. In one embodiment of the tiltmeter assembly 134, the tilt sensors 150 can resolve tilt as little as one billionth of a radian (0.00000005 degrees).

The tiltmeter assembly 134 preferably comprises a tilt sensor leveling assembly 160, by which the tilt sensors 150 are leveled before a fracture operation in the treatment well 18. The tilt sensor leveling assembly 160 provides a simple installation for deep, narrow boreholes. Once the tiltmeter 134 is in place, motors 160 automatically bring the two sensors 150 very close to level, and continue to keep the sensors 150 in their operating range, even if large disturbances move the tiltmeter 134.

Besides tilt, the tiltmeter 134 internally records relevant information such as location, orientation, supply voltage, and sensor temperature. In some embodiments of the treatment well tiltmeter 134, a solid state magnetic compass or gyroscope 162 provides tool orientation, so tilt direction can be accurately determined. On-board looped memory provides up to 8 months of data storage which is easily uploaded via a serial port connection at the surface, typically through a direct cable connection to another computer 210. Communication protocols support communication through up to 8,000 m (25,000 ft) of wireline cable 136,137. Alternate communication protocols support wireless communication through a transceiver and radio links, or through a cell phone interface.

For some tiltmeter applications, the tiltmeter assemblies 134a-134n are programmable, to periodically transmit data signals 213 to the external computer 210, or alternately to a radio or cell phone device, such as to conserve internal battery power. Memory is

preferably retained within each of the tiltmeter assemblies 134a-134n, in the event power to the tiltmeter assemblies 134a-134n is lost.

For some tiltmeter applications, such as for surface tilt measurement, the tiltmeter 134 is powered by a small battery and solar panel combination at the surface. In a preferred embodiment of the treatment well tiltmeter system, power is supplied to each of the tiltmeters 134a-134n, from an external power supply 208 (FIG. 33), through wirelines 136,137. The wirelines 136,137 are typically comprised of a braided steel cable, which further comprises an electrically insulated power and signal conductor. Power is typically provided to each to the tiltmeters 134a-134n through the wirelines 136,137, and is preferably routed through successive tiltmeter assemblies 134 in a daisy-chain configuration.

Within each tiltmeter assembly 134, sensor signals are processed through the analog board 164, which measures and amplifies the tilt signal from the two sensors 150. The analog electronics 164 provide low noise levels and low power consumption, and have 4 gain levels, which can be changed remotely for mapping tilt signals for a wide range of magnitudes. The operating range of one embodiment of the tiltmeter electronics is from –40 °C to 85 °C (-40 °F to 185 °F). In an alternate embodiment of the tiltmeter assembly, the upper temperature limit is approximately 125 °C (260 °F). In another alternate embodiment of the tiltmeter assembly, the upper temperature limit is approximately 150 °C (300 °F).

The tiltmeter assembly 134 also comprises a digital storage and communication module 166. The digital storage and communication module 166 comprises high precision 16 bit or 24 bit A/D converters which are connected to the output of the analog amplifiers 164. Digital communication prevents signal noise during the data transmission 213 to the surface 17. In some embodiments of the treatment well tiltmeter system 132, data is stored within the tiltmeters 134. In a basic embodiment of the treatment well tiltmeter system 132, analog signals are sent up the wireline cable 137 to the recording device 210 (FIG. 33). For applications in which analog signal loss and/or noise occur, the tiltmeter provides digital signal communication. In alternate embodiments of the treatment well tiltmeter system 132, a data signal 213 (FIG. 33) is transferred from each of the tiltmeters 134a-134n, through wire lines 136,137.

Figure 31 is a graph 170 which shows raw tilt data 176, 178 between non-leveling and self-leveling tiltmeter assemblies, respectively, for a period of six days. Figure 32 is a graph 182 which shows tilt data 184, 184 between non-leveling and self-leveling tiltmeter assemblies, respectively, for the two hour period 179 shown in Figure 31. The

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data is plotted in tilt 172 as a function of time 174. The non-leveling tilt meter data 176 shows large (about 1000 nanoradian) daily swings, resulting from near-surface thermal strains.

The Raw data 176 rises sharply when the sun rises in the morning, and declines rapidly at sunset. This level of background motion is insignificant when mapping a shallow fracture treatment, but can be significant when fracture-induced surface tilts are only a few nanoradians. The raw data 178 from the self-leveling tiltmeter 134 over the same six-day period shows only the very smooth (and predictable) background of earth tides that swing roughly 100 nanoradians twice per 24-hour period.

Figure 33 is a schematic block diagram of tiltmeter electronics 188 for one or more tiltmeters in a tiltmeter system 132. Each tiltmeter assembly 134 shown in Figure 33 comprises a power supply board 190, and modem board 192, a processor board 194, an analog board 196, and a sensor subsystem 198. The sensor subsystem 198 comprises a tilt sensor assembly 200, a leveling system assembly 202, an accelerometer or geophone assembly 204, and a limit switch assembly 206. The tilt sensor assembly comprises single axis sensors 150, which provide tilt resolution of better than 1 uR, range of +/- 15 degrees at the sensor 150. The leveling re-zero system 202 provides pre-fracture event alignment of tilt sensors 150. For example, in a deviated well 18, the leveling system 202 typically aligns one sensor 150, *e.g.* 150a, with the wellbore 18, and aligns a second tilt sensor 150, *e.g.* 150b, at a right orthogonal angle to the well bore 18. The leveling system 202 typically provides tool orientation data 213, which is either stored or is sent uphole to the external data acquisition device 210. The accelerometer system 204 preferably comprises an integrated tri-axial accelerometer or geophone 256, which provides information needed for re-zeroing, and provides back-up sensor function, with 300 uR sensitivity. The tiltmeter electronics 188 are highly modularized, and each of the electronics boards 190, 192, 194, 164, as well as the sensor assembly 198, fit within the small inner diameter of treatment well tiltmeter housing 154.

As described above, a main wireline 137 extends to the array 135 of one or more tiltmeter assemblies 134a-134n, and a similar wireline connector cable 136 is located between tiltmeter assemblies 134a-134n. An external power supply 208 provides power 209 to the tiltmeters 134a-134n, through the wirelines 137,136. A computer 210, such as a portable laptop computer 210, provides input signals 211 to and receives output signals 213 from the tiltmeter assemblies 134a-134n, through a surface modem connection 212.

The processor board 194 provides A/D conversion, data storage and all command functions for the tiltmeter assembly 134. Each tiltmeter 134 preferably includes a unique tool ID, which is hardwired into the processor board 194, and is read at power up. The processor board 194 has flash RAM memory, with a static RAM buffer, which allows permanent data storage with no battery, and code memory, which allows software upgrades without opening the tiltmeter assembly 134. The processor board 194 also includes one or more 1 F capacitors, which provide approximately two weeks of clock function for a tiltmeter assembly 134 which has no external connection. Leveling circuitry, associated with the leveling system 202, includes 16 bit A/D conversion, which provides continuous level calibration. Accelerometer circuitry, associated with the accelerometer system 204, includes 10-bit A/D conversion, while system voltage and temperature circuitry includes 8-bit system monitor A/D conversion. A motor control circuit levels sensors, using the accelerometers and limit switches for guidance.

System software, which operates between an external computer 210 and each of the tiltmeter assemblies 134a-134n, comprises a communication protocol which provides fast and reliable communications 211, 213, as well as error detection. The external computer 210 automatically determines the order of tiltmeters 134, which are installed as a treatment tiltmeter array 135, within a treatment well 18.

A flexible data format allows easy modification of data from each of the tiltmeters 134a-134n. For example, pressure and/or temperature data 213 from each tiltmeter 134, *e.g.* such as from tiltmeter 134a, preferably has a unique coding or format, whereby data 213 that is sent to the external computer 210 through wireline 136,137 is associated with the correct tiltmeter assembly 134.

During the startup process, each treatment tiltmeter 134a-134n preferably goes through an internal start up and self-diagnosis procedure, and then performs a handshaking operation with the external computer 210. During the handshaking procedure, each of the treatment well tiltmeters 134a-134n automatically detects the system baud rate for input signals 211and for output signals 213.

Treatment Well Tiltmeter System Configurations. Figure 34 is a partial cutaway view 210 of a treatment well tiltmeter system 132a, in which the tiltmeters 134a-134n are permanently attached to the outside of the well casing 214. Figure 35 is a detailed cutaway view 220 of a tiltmeter 134 which is permanently attached to the outside of the well casing 214, in the casing region 214 of a treatment wellbore 18. Figure 36 is an end view 222 of a tiltmeter 134 which is permanently attached to the outside of the well casing 214. Figure 37 is a partial cutaway view 224 of a treatment well tiltmeter system

132a for a generally horizontal well 18h, in which the tiltmeters 134a-134n are permanently attached to the outside of the well casing 214. In the treatment well tiltmeter system 132a, each tiltmeter 134 is attached to the casing 214, with one or more strap connectors 216. The treatment well tiltmeter system 132a shown in Figure 34 further comprises a secondary sensor device 218, which is also fixedly attached to the casing 214 with one or more strap connectors 216. The secondary sensor device 218 can be used to provide general sensor information for the array, such as pressure and temperature data. The treatment well tiltmeter system 132a can be used for data acquisition before, during, and after a fracture operation, and does not interfere with a working fluid 143 or proppant.

Figure 38 is a partial cutaway view 226 of a treatment well tiltmeter system 132b, in which the tiltmeters 134a-134n are mechanically stabilized within the well casing 214. Figure 39 is a detailed cutaway view 230 of a tiltmeter 134 which is mechanically stabilized, *i.e.* centralized, within the well casing 214, with one or more bowspring stabilizers 228. Figure 40 is an end view 232 of a tiltmeter 134 which is mechanically stabilized within the well casing 214. Figure 41 is a partial cutaway view 234 of a treatment well tiltmeter system 132b for a generally horizontal well 18h, in which the tiltmeters are mechanically centralized within the well casing. In the treatment well tiltmeter system 132b, each tiltmeter 134 and/or secondary device 218 is attached within the casing 214, with one or more bowspring stabilizers 228. In the centralized treatment well tiltmeter system 132b, fluid 143 is diverted around the periphery of the tiltmeters 134a-134n. The centralized treatment well tiltmeter system 132b is readily used in embodiments having relatively large wellbore sizes and/or relatively low injection rates of fluid 143.

The mechanically stabilized treatment well tiltmeter system 132b is often used as a retrievable tiltmeter system 132, wherein an array 135 of treatment well tiltmeters 134a-134n, interconnected with wirelines 136, is attached through the top-most tiltmeter 134, *e.g.* 134a, to a large spool of wireline 137, provided by wireline truck 36. The array 135 is then controllably lowered into the treatment well 18. As the array 135 is lowered, the bow springs 228 contact the pipe casing 214, and the weight of the array 135 and main wireline 137 provides the force necessary to lower the system into place. Once the system is properly installed within the wellbore 18, which includes signal handshaking with the surface computer 210 and rezeroing tilt sensors 150, as necessary, the treatment well 18 is pumped to produce or expand a fracture 22. The tiltmeter data 213 from the tiltmeters 134a-134n is processed (which preferably includes isolating the signal data 213 from ambient conditions, such as working fluid noise), and the tilt map data is acquired. When the mapping is completed, the array 135 is usually removed

from the treatment wellbore 18, by rewinding the main wireline. The treatment well tiltmeter system 12 is then ready to be reused.

Figure 42 is a partial cutaway view 236 of a treatment well tiltmeter system 132c, in which the tiltmeters 134a-134n are magnetically attached 238 to the inner wall of the well casing 214. Figure 43 is a detailed cutaway view 240 of a tiltmeter 134, which is magnetically attached 238 to the well casing 214. Figure 44 is an end view 242 of a tiltmeter 134, which is magnetically attached within the well casing 214. Figure 45 is a partial cutaway view 246 of a treatment well tiltmeter system 132c for a generally horizontal well 18h, in which the tiltmeters are magnetically attached 238 to the well casing. In the treatment well tiltmeter system 132c, each tiltmeter 134 and/or secondary device 218 is attached within the casing 214, with one or more magnets 238. In the magnetically attached treatment well tiltmeter system 132c, magnets 238 provide a decentralized attachment within the borehole 18, which allows a high injection rate of fluids 143 which are often used in hydraulic fracturing, and reduces flow-induced noise on the collected tilt data. The tiltmeter assembly shown in Figure 43 has permanent magnet assemblies 239 located at both the top and bottom of the tiltmeter housing 152, wherein each permanent magnet assembly 239 comprises one or more magnets 238.

Tiltmeter Assembly Details. Figure 46 is a partial cutaway view 250 of a self-leveling tiltmeter housing assembly 134, which comprises an X direction tilt sensor 150a within a latitude directional sensor assembly 254a, and a Y direction tilt sensor 150b within a longitude directional sensor assembly 254b. The level adjustment of the X direction tilt sensor 150a is controlled by a latitude leveling motor 160a. The level adjustment of the Y direction tilt sensor 150b is controlled by a longitude leveling motor 160b.

The self-leveling tiltmeter housing assembly 134 shown in Figure 46 also comprises a three-axis accelerometer assembly 256, which provides orientation data for the tiltmeter assembly within a wellbore 18. As well, the accelerometer assembly 256 can provide supplementary tilt data for the tiltmeter housing assembly 134.

As seen in Figure 33 and Figure 46 the treatment well tiltmeter assembly comprises four electronics modules, comprising the power supply board 190, the modem board 192, the processor board 194, and the analog conditioning board 164. The electronics modules are typically rated to 300 F, or run at reduced power and tested to 300 F. In a preferred embodiment of the treatment well tiltmeter assembly 134, the electrical boards 190,192,194,164 are laid back to back, to reduce the overall tool length.

Figure 47 is a simplified expanded view 260 of a self-leveling tiltmeter housing assembly 152. Figure 48 is a simplified assembly view 280 of a self-leveling tiltmeter housing assembly 152. A tube body 154 is connected to both an upper end connector 266 and a lower end connector 264, which are each respectively connected to housing end assemblies, comprising a retaining collar 268, a fishing head sleeve 272, an anti-rotation collar 276, and a fishing head cablehead 262. Locking blocks 270 are attached to the retaining collars 268, and collar stops 274 are used to position the anti-rotation collars 276.

Figure 49 is a partial cutaway assembly view 282 of a self-leveling treatment well tiltmeter assembly 134. Figure 50 is a detailed partial cutaway assembly view 284 of a self-leveling treatment well tiltmeter assembly 134. The self-leveling treatment well tiltmeter assembly 134 shown in Figure 49 and Figure 50 preferably has a relatively small diameter, e.g. such as a 1.563 inch outer diameter, whereby the tiltmeters 134a-134n are readily mounted within the treatment well bore 18, while minimizing the effect on the flow of working fluid. The modular electronics within the treatment well tiltmeter assembly 134 shown in Figure 49 and Figure 50 are functional to 150° C (300° F). Each treatment well tiltmeter assembly 134 preferably comprises a daisy-chain architecture for power 211, for control input signals 211, and for data output signals 213. Therefore, each treatment well tiltmeter assembly 134 can be placed anywhere within a tiltmeter array 132, *i.e.* the tiltmeter assemblies 134 are interchangeable. As well, each treatment well tiltmeter assembly 134 preferably includes self-diagnostic software and associated fault-tolerant hardware, whereby problems are quickly isolated.

The external housing 154 for the treatment well tiltmeter assembly 134 is preferably comprised of a corrosion-resistant material, such as stainless steel or INCONEL™. In one embodiment, the external housing 154 is gun drilled and centerless ground. In other production embodiments, the external housings are cast to size and ground. Both ends of the treatment well tiltmeter assembly 134 are sealed with an endcap 320 (FIG. 55, FIG. 56, FIG. 57), which are comprised of titanium in on embodiment of the tiltmeter assembly 134. The external housing 154 shown in Figure 49 and Figure 50 has no external threads, to increase strength, and to minimize assembly problems. The treatment well tiltmeter assembly 134 incorporates a sealed design, which keeps the internal componentry dry, even if the cablehead 262 (FIG. 47, FIG. 48) leaks.

Raw tilt data 213 in an active well 18 often has background "noise" which is induced from the flow of fluid 143 within the same active well bore 18. Such noise is minimized my minimizing the cross-sectional diameter of the external housing 154, whereby the flow drag for the working fluid 143 is minimized. Typical inner diameters for wellbores 18 that

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are used for hydraulic fracture stimulation and oil & gas production are anywhere from 2.5" to 6" in diameter, with 4" to 5" currently being the most common I.D. size. In a preferred embodiment of the treatment well tiltmeter 134, the outer diameter of the tiltmeter is 1 9/16". In another embodiment, the outer diameter of the tiltmeter is 2 7/8" diameter.

Re-Zero Mechanism Assembly Details. Figure 51 is a partial cutaway assembly view 286 of a re-zero mechanism 288 within a self-leveling treatment well tiltmeter assembly 134. The re-zero mechanism 288 comprises one or more internal motors and associated pivot mechanisms, which allow the internal tilt sensors 150 to rotate, so that they are on-scale and are able to measure minute tilts in any possible borehole orientation. The treatment well tiltmeters 134a-134n can therefore be used in vertical wells, deviated wells, or even in horizontal wells. The re-zero mechanism 288 can alternately be used in other tiltmeter assemblies, such as for offset or surface tiltmeters, or in a wide variety of other instrumentation and data acquisition systems.

The re-zero mechanism 288 is mounted to a bottom bearing shaft 306 and a top bearing shaft 308, between bearings 287. Figure 52 is a detailed partial cutaway assembly view 292 of a re-zero mechanism 288 within a self-leveling treatment well tiltmeter assembly 134. The re-zero mechanism 288 comprises a rezero-mechanism body 290, with which tiltmeter subassemblies 254a,254b are housed. The X sensor 150a is mounted in relation to an X channel gear 296, and the Y sensor 150b is mounted in relation to an y channel gear 294. The rezero-mechanism assembly also comprises a drive mechanism, having a drive chain 295, which is engageable contact with drive cog 300. The drive cog 300 is affixed to drive ring gear 290, which is driven by motor pinion gear 304. An idler cog 302 is preferably used to adjust the tension in the drive chain 295. The re-zero mechanism allows a treatment well tiltmeter assembly to be functional at any angle and/or orientation

Figure 53 is a detailed partial cutaway assembly view 310 of a reed switch 312 within a rezero-mechanism assembly 288. As seen in Figure 53, a cam means 315 is axially fixed to the X channel gear 296. A magnet 315 is moved by the cam means 315, when the X channel gear 296 is moved. When the magnet 314 moves a specified distance in relation to the reed switch 312, the reed switch 312 is activated, such that leveling motion of the X channel sensor 150a may be controllably limited. The leveling motion of the Y channel sensor 150a is similarly limited. Figure 54 is a top view 318 of a tiltmeter reed switch 312 and reed switch board 316.

Figure 55 is a side view of a tiltmeter bottom end cap 320. Figure 56 is a first end view 321 of a tiltmeter bottom end cap 320. Figure 57 is a partial cross-sectional side view 322 of a tiltmeter bottom end cap 320. A cable connector shaft 324 is located within the tiltmeter bottom end cap 320. The cable connector shaft 324 is electrically connected to wirelines 136,137, such as between tiltmeter assemblies 134, or between the topmost tiltmeter 134a and the surface wireline truck 36 (FIG. 1, FIG. 29). The cable connector shaft 324 is supported by shaft seals 326,328. The shaft seals also provide power and signal insulation between the cable connector shaft 324 and the tiltmeter bottom end cap 320.

Figure 58 is a side view 330 of a tiltmeter tool body 154. Figure 59 is a detailed side view 332 of the end of a tiltmeter tool body 154. Figure 60 is a partial cross-sectional detailed side view 334 of the end of a tiltmeter tool body 154.

Figure 61 is a front view of a tiltmeter Y-channel sensor holder 336. Figure 62 is a side view 338 of a tiltmeter Y-channel sensor holder 336. Figure 63 is an end view 340 of a tiltmeter Y-channel sensor holder 336. Figure 64 is a front view of a tiltmeter X-channel sensor holder 342. Figure 65 is a side view 344 of a tiltmeter X-channel sensor holder 342. Figure 66 is a front view of a tiltmeter X-channel shaft 346. Figure 67 is a side view 348 of a tiltmeter X-channel shaft 346. Figure 68 is a front view of a tiltmeter drive shaft 350. Figure 69 is a side view 352 of a tiltmeter drive shaft 350. Figure 70 is a front view 354 of a tiltmeter Y-channel gear 294. Figure 71 is a side view 356 of a tiltmeter Y-channel gear 294. Figure 72 is a front view of a tiltmeter reed switch holder 358. Figure 73 is a side view 360 of a tiltmeter reed switch holder 358.

Figure 74 is a side view 362 of a tiltmeter re-zero mechanism body 290. Figure 75 is a bottom view 364 of a tiltmeter re-zero mechanism body 290. Figure 76 is a first cross-sectional view 366 of a tiltmeter re-zero mechanism body 290. Figure 77 is a second cross-sectional view 368 of a tiltmeter re-zero mechanism body 290. Figure 78 is a third cross-sectional view 370 of a tiltmeter re-zero mechanism body 290. Figure 79 is a fourth cross-sectional view 372 of a tiltmeter re-zero mechanism body 290. Figure 80 is a fifth cross-sectional view 374 of a tiltmeter re-zero mechanism body 290. Figure 81 is a sixth cross-sectional view 376 of a tiltmeter re-zero mechanism body 290. Figure 82 is a seventh cross-sectional view 378 of a tiltmeter re-zero mechanism body 290.

Figure 83 is a side view 380 of a tiltmeter re-zero mechanism top bearing shaft 306. Figure 85 is an end view 306 of a tiltmeter re-zero mechanism top bearing shaft 306. Figure 84 is a side cross-sectional view 382 of a tiltmeter re-zero mechanism top bearing shaft 306.

Figure 86 is a side view 386 of a tiltmeter re-zero mechanism bottom bearing shaft 308. Figure 87 is a side cross-sectional view 388 of a tiltmeter re-zero mechanism bottom bearing shaft 308. Figure 88 is a first view 390 of a first end of a tiltmeter re-zero mechanism bottom bearing shaft 308. Figure 89 is a second view 392 of a first end of a tiltmeter re-zero mechanism bottom bearing shaft 308. Figure 90 is a first view 394 of a second end of a tiltmeter re-zero mechanism bottom bearing shaft 308. Figure 91 is a second view 396 of a second end of a tiltmeter re-zero mechanism bottom bearing shaft 308.

Figure 92 is a front view of a tiltmeter motor mounting disk 398. Figure 93 is a side view 400 of a tiltmeter motor mounting disk 398. Figure 94 is a side cross sectional view 402 of a tiltmeter motor mounting disk 398. Figure 95 is an alternate front view 402 of a tiltmeter motor mounting disk 398.

Figure 96 is a side view of a tiltmeter motor holder 406. Figure 97 is a side cross-sectional view 408 of a tiltmeter motor holder 406. Figure 98 is a first view 410 of a first end of a tiltmeter motor holder 406. Figure 99 is a second view 412 of a first end of a tiltmeter motor holder 406. Figure 100 shows the second end 414 of a tiltmeter motor holder 406.

Figure 101 is a front view 416 of a tiltmeter X-channel gear 296. Figure 102 is a side view 418 of a tiltmeter X-channel gear 296.

Figure 103 is a front view of a tiltmeter bearing holder 420. Figure 104 is a side cross-sectional view 422 of a tiltmeter bearing holder 420.

Figure 105 is a front view of a tiltmeter bearing fluoropolymer ring 424. Figure 106 is a side view 426 of a tiltmeter bearing fluoropolymer ring 424. Figure 107 is a side cross-sectional view 428 of a tiltmeter bearing fluoropolymer ring 424.

Figure 108 is a top view of a tiltmeter accelerometer mount 430. Figure 109 is a front view 432 of a tiltmeter accelerometer mount 430. Figure 110 is a side view 434 of a first end of a tiltmeter accelerometer mount 430. Figure 111 is a side view 436 of a second end of a tiltmeter accelerometer mount 430.

Figure 112 is a top view of a tiltmeter Z-axis accelerometer board 438. Figure 113 is a top view of a tiltmeter X and Y axis accelerometer board 440.

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Figure 114 is a front view of a tiltmeter tensioner 442. Figure 115 is a top view 444 of a tiltmeter tensioner 442. Figure 116 is a first side view 446 of a tiltmeter tensioner 442. Figure 117 is a second side view 448 of a tiltmeter tensioner 442. Figure 118 is a bottom view 450 of a tiltmeter tensioner 442.

Figure 119 is a front view of a tensioner 452. Figure 120 is a top view 454 of a tensioner 452. Figure 121 is a first cross-sectional view 456 of a tensioner 452. Figure 122 is a side view 458 of a tensioner 452. Figure 123 is a second cross-sectional view 460 of a tiltmeter 452. Figure 124 is a bottom view 462 of a tensioner 452. Figure 125 is a side view of a tiltmeter spring pole 464. Figure 126 is an end view 466 of a tiltmeter spring pole 464. Figure 127 is a side view of a tiltmeter tensioner shaft 468.

Figure 128 is a side view of a tiltmeter power supply board solenoid mount 470. Figure 129 is a top view 472 of a tiltmeter power supply board solenoid mount 470. Figure 130 is an end view 474 of a tiltmeter power supply board solenoid mount. Figure 131 is a top view of a tiltmeter reed switch board 476.

Figure 132 is a detailed plan view 478 of a tiltmeter power supply board 194. The power supply board 194 provides power to all electronics within a treatment well tiltmeter assembly 134, and has a plurality of DC voltage outputs, comprising 3.3 volts, 5 volts, 12 volts, and –5 volts power. As well, the power supply board 194 provides switchable 5 volt "high current" supply for motors (100 mA). The total current draw for a treatment well tiltmeter assembly 134 is approximately 50 mA, without motor operation. The tiltmeter power supply board 194 is presently designed for an input voltage of 13-35 volts. A solid state relay provides power to next treatment well tiltmeter assembly 134 in a daisy-chain array 132, which allows diagnosis of shorts and opens in the wireline array, and provides fault tolerant operation. The power supply board 194 comprises one or more switching power supplies, which are used for efficiency, and to reduce heat generation. The power supply board 194 has less than 1% ripple noise on all voltage supplies.

Figure 133 is a perspective view 480 of a tiltmeter accelerometer assembly 252. Figure 134 is a detailed plan view 482 of a tiltmeter analog board 164, which provides fixed gain signal amplification, since treatment well signals are of predictable, consistent magnitude. In alternate embodiments of the tiltmeter analog board 164, the gain settings are variable. Figure 135 is a detailed plan view 490 of a tiltmeter modem board 192. The tiltmeter modem board 192 provides communication for each of the treatment well tiltmeters 134a-134n. The modem board 192 receives input signals 211 and sends output signals 213, through the connected wireline 136,137, which typically

comprises an insulated conductor within a stranded steel cable. The input signals 211 and the output signals 213 are typically sent along the same conductive path as the supply power 209. The modem board 192 plugs onto the back of power supply board 190. If an external surface modem 212 is not present, the tiltmeter assembly 134 expects input and output communication through an RS-232 cable and port.

Figure 136 is a simplified flow chart 500 of treatment well tiltmeter data acquisition, data analysis, and real-time data display. At step 502, downhole tilt data is recorded by one or more treatment well tiltmeters 134a-134n, wherein the tiltmeters are typically located at different depths within a treatment well 18. At step 504, the data is transmitted uphole from the tiltmeter assemblies 134a-134n.

At step 506, the flow induced deformation is extracted from the raw data 213. Raw tilt data 213 in an active well 18 often has background "noise" which is induced from the flow of fluid 143 within the same active well bore 18. Therefore, the raw data is processed, to isolate the deformation "signals" from distinguished flow noise, as well as from transient events that correlate with changes in the injection flow rate. "Signals" from the deformation of the rock strata are not high frequency and they are quasi-static deformations that occur over time, as a function of the volume of injected (or produced) fluid 143.

After isolation of the deformation-induced signals at each treatment well instrument 134 versus time, the next step is to perform a geophysical inversion to yield a "map" or description of the subsurface rock deformation that must be occurring. Surface and offset-well tilt mapping employ either simplified dislocation or more detailed finite element models of various deformation fields in the far-field. Active (treatment) well mapping is not a far-field solution, but instead is a near-interface or internal view of the deformation process. Models designed for this particular view are employed to invert the observed deformation data. This varies from very sophisticated models of particular fracture opening profiles as a function depth within strata, to a very simplified "On-Off" view of the existence of a fracture. For example, a certain tilt "threshold" can be set to demarcate whether there is fracture growth at a specified depth or not. An array 135 of tiltmeters 134a-134n can then be evaluated, to determine if hydraulic fracture growth is occurring at the depth of that particular tool 134 or not. This simplified analysis allows an "alarm system" for monitoring upward (or downward) fracture growth for a hydraulic fracture, such as for monitoring waste disposal injections.

At step 508, geomechanical modeling of the strata 12 is performed, and is compared to the observed strata deformation. At step 510, the process determines if the

geomechanical model provides a good fit to the observed strata deformation. If the model provides a good fit 514, the results are displayed 516 in real time. If the model fails 512 to provide an acceptable fit to the observed strata deformation, the model is adjusted, and the process returns to comparison step 508.

Figure 137 is a chart 520 of treatment well tilt response 172 to applied surface pressure 524 for a plurality of tiltmeters 134, as a function of time. The applied pressure 522 is shown before, during and after the pumping/ fracture operation. Tilt data 526a, 526e, 526j is shown during the chart interval. The applied pumping interval 528 is separated into three pumping intervals 530a, 530, 530c. Figure 138 represents the determined fracture-induced deformation 540 for the treatment well 18, based upon the measured tilt mapping data from a plurality of treatment well tiltmeters 134 shown in Figure 137. The determined deformation during the first pumping interval 530a is shown as region 542a. The determined deformation during the second pumping interval 530b is shown as region 542b. The determined deformation during the third pumping interval 530c is shown as region 542c. The induced downhole tilt profiles 526a, 526e, 526j are quite different in the treatment well 18, as compared to a tilt mapping profile which is measured in an offset well 26, or at the surface 38, and requires different analysis methods, to map fracture growth and other processes from the measurement of treatment well tilt data, as a function of depth and time. During the processing of raw tilt data 213, motion noise introduced from the flow of a working fluid 143 within the treatment wellbore 18 is isolated from the motion due to earth movement, *i.e.* the tilt data. Figure 138 shows a plan view which compares measured and projected tilt for a plurality of surface tiltmeters 134. The treatment well tilt system 132 yields tilt mapping results where the "signal" of rock deformation is clearly distinguishable from the "noise" of active fluid-flow past the downhole tools 134a-134n.

The treatment well tiltmeter system 132 therefore allows mapping without an offset wellbore or with installed surface tilt arrays. Utilization of the active wellbore allows mapping in a much wider range of environments, and provides an accurate resolution of the fracture width and rock deformation pattern versus depth across the subsurface rock strata.

Alternate Treatment Well Tiltmeter Systems. Figure 140 is a partial cutaway view 552 of a treatment well tiltmeter system 132d, in which the tiltmeters 134 are magnetically attached 238 to a well casing 214a, in an annular region 554 formed between the casing 214a and an inner tubing 214b, wherein a movable fluid 143 or proppant is located within the inner tubing 214b. Figure 141 is a detailed cutaway view 560 of a tiltmeter 134 which is magnetically attached 238 to a well casing 214a in an

annular region 554 formed between the casing 214a and a hollow inner tubing 214b. Figure 142 is an end view 562 of a tiltmeter 134 which is magnetically attached 238 to well casing 214a within an annular region 554 formed between the casing 214a and an inner tubing 214b. Figure 143 is a partial cutaway view of a horizontal treatment well tiltmeter system 132b, in which the tiltmeters 134 are magnetically attached 238 to the well casing 214a in an annular region 554 formed between the casing 214a and an inner tubing 214b. The magnetic attachment 238, typically comprises one or more regions 239 of magnets 238. The treatment well tiltmeter system 132d preferably includes means for mechanical isolation 556 between the tiltmeters 134 and the inner tubing, such as one or more springs or dampeners. The tiltmeters 134 are therefore linked to the strata 12, and are mechanically isolated from the inner tubing 214b, which typically carries a working fluid 143 or proppant.

Although the treatment well tiltmeter system and its methods of use are described herein in connection with treatment wells, the apparatus and techniques can be implemented for a wide variety of wellbore systems, such as for offset wells or surface wells, or any combination thereof, as desired. As well, the treatment well tiltmeter system can be used in conjunction with a wide variety of wellbore systems, such as offset well instrumentation and tiltmeters or surface well instrumentation and tiltmeters, or any combination thereof, as desired.

Accordingly, although the invention has been described in detail with reference to a particular preferred embodiment, persons possessing ordinary skill in the art to which this invention pertains will appreciate that various modifications and enhancements may be made without departing from the spirit and scope of the claims that follow.

CLAIMS

1. A treatment well tiltmeter system for monitoring fluid motion in subsurface strata from an active well, comprising a bore hole extending from a surface into the strata, the treatment well tiltmeter system comprising:

a tiltmeter array located within the bore hole of the active well, the tiltmeter array comprising at least one tiltmeter assembly, each of the at least one tiltmeter assembly comprising at least one tiltmeter sensor; and

means for communication between the tiltmeter array and the surface.

2. The treatment well tiltmeter system of Claim 1, wherein the means for communication is a wireline extending from the surface to the tiltmeter array.

3. The treatment well tiltmeter system of Claim 2, wherein the wireline is retrievable.

4. The treatment well tiltmeter system of Claim 2, further comprising:

an external power supply electrically connected to the wireline.

5. The treatment well tiltmeter system of Claim 2, further comprising:

an external computer connected to the wireline.

6. The treatment well tiltmeter system of Claim 2, wherein the wireline comprises:

an electrically conductive cable; and

a secondary conductor electrically insulated from the electrically conductive cable.

7. The treatment well tiltmeter system of Claim 1, wherein the means for communication is wireless link.

8. The treatment well tiltmeter system of Claim 1, wherein the means for communication comprises a retrievable memory within the tiltmeter array.

9. The treatment well tiltmeter system of Claim 1, further comprising:

a movable fluid within the bore hole.

10. The treatment well tiltmeter system of Claim 1, further comprising:
means for injecting a movable fluid from the surface into the bore hole.

11. The treatment well tiltmeter system of Claim 1, wherein the tiltmeter array comprises a plurality of tiltmeter assemblies, the treatment well tiltmeter system further comprising:
an interconnect wireline between each of the plurality of tiltmeter assemblies.

12. The treatment well tiltmeter system of Claim 1, wherein the tiltmeter array comprises a plurality of tiltmeter assemblies, the treatment well tiltmeter system further comprising:
a wireless connection between at least two of the plurality of tiltmeter assemblies.

13. The treatment well tiltmeter system of Claim 1, wherein the active well comprises a casing having a hollow bore, and wherein the tiltmeter array is located within the hollow bore.

14. The treatment well tiltmeter system of Claim 13, wherein each of the at least one tiltmeter assembly further comprises means for holding each of the at least one tiltmeter assembly within the hollow bore.

15. The treatment well tiltmeter system of Claim 14, wherein the means for holding the at least one tiltmeter assembly within the hollow bore comprises a bowspring connector in contact with the hollow bore.

16. The treatment well tiltmeter system of Claim 14, wherein the means for holding the at least one tiltmeter assembly within the hollow bore comprises at least one magnet.

17. The treatment well tiltmeter system of Claim 1, wherein the active well comprises a casing having a hollow bore located within the bore hole, wherein the tiltmeter array is located between the casing and the strata.

18. The treatment well tiltmeter system of Claim 17, wherein each of the at least one tiltmeter assembly is cemented on the casing.

19. The treatment well tiltmeter system of Claim 17, wherein each of the at least one tiltmeter assembly is strapped to the outer surface of the casing.

20. The treatment well tiltmeter system of Claim 1, wherein the active well comprises a casing having a hollow bore located within the bore hole, an inner tubing having a hollow bore located within the hollow bore of the casing, wherein an annular region is defined

between the inner tubing and the casing, and wherein the tiltmeter array is located within the annular region.

21. The treatment well tiltmeter system of Claim 20, wherein each of the at least one tiltmeter assembly is magnetically attached to the casing.

22. The treatment well tiltmeter system of Claim 21, further comprising:

means for mechanical isolation between each of the at least one tiltmeter assembly and the inner tubing.

23. The treatment well tiltmeter system of Claim 22, wherein means for mechanical isolation between each of the at least one tiltmeter assembly and the inner tubing comprises a spring.

24. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises means for leveling the at least one tiltmeter sensor.

25. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises an accelerometer.

26. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises a geophone.

27. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises a temperature sensor.

28. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises a pressure sensor.

29. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises a gyroscope.

30. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises means for storing data from the at least one tiltmeter sensor.

31. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises means for sending data from the at least one tiltmeter sensor to the surface.

32. The treatment well tiltmeter system of Claim 1, wherein each of the at least one tiltmeter assembly further comprises an internal power source.

33. The treatment well tiltmeter system of Claim 1, further comprising:
an external computer having a wireless connection with at least one of the at least one tiltmeter assembly.

34. An apparatus, comprising:
an active well comprising a borehole extending from a surface into a strata;
a movable fluid located within the bore hole; and
a tiltmeter array located within the bore hole, the tiltmeter array comprising at least one tiltmeter assembly, each of the at least one tiltmeter assembly comprising at least one tiltmeter sensor for measuring the effect of the movable fluid on the strata.

35. The apparatus of Claim 34, further comprising:
a wireline extending from the surface to the tiltmeter array.

36. The apparatus of Claim 35, wherein the wireline is retrievable.

37. The apparatus of Claim 35, further comprising:
an external power supply electrically connected to the wireline.

38. The apparatus of Claim 35, further comprising:
an external computer connected to the wireline.

39. The apparatus of Claim 35, wherein the wireline comprises:
an electrically conductive cable; and
a secondary conductor electrically insulated from the electrically conductive cable.

40. The apparatus of Claim 34, further comprising:
a wireless communication link between the tiltmeter array and the surface.

41. The apparatus of Claim 34, further comprising:
a retrievable memory within the tiltmeter array.

42. The apparatus of Claim 34, further comprising:
means for injecting the movable fluid from the surface into the bore hole.

43. The apparatus of Claim 34, wherein the tiltmeter array comprises a plurality of tiltmeter assemblies, the apparatus further comprising:

an interconnect wireline between each of the plurality of tiltmeter assemblies.

44. The apparatus of Claim 34, wherein the tiltmeter array comprises a plurality of tiltmeter assemblies, the apparatus further comprising:

a wireless connection between at least two of the plurality of tiltmeter assemblies.

45. The apparatus of Claim 34, wherein the active well comprises a casing having a hollow bore, and wherein the tiltmeter array is located within the hollow bore.

46. The apparatus of Claim 45, wherein each of the at least one tiltmeter assembly further comprises means for holding each of the at least one tiltmeter assembly within the hollow bore.

47. The apparatus of Claim 46, wherein the means for holding the at least one tiltmeter assembly within the hollow bore comprises a bowspring connector in contact with the hollow bore.

48. The apparatus of Claim 46, wherein the means for holding the at least one tiltmeter assembly within the hollow bore comprises at least one magnet.

49. The apparatus of Claim 34, wherein the active well comprises a casing having a hollow bore located within the bore hole, wherein the tiltmeter array is located between the casing and the strata.

50. The apparatus of Claim 49, wherein each of the at least one tiltmeter assembly is cemented on the casing.

51. The apparatus of Claim 49, wherein each of the at least one tiltmeter assembly is strapped to the casing.

52. The apparatus of Claim 34, wherein the active well comprises a casing having a hollow bore located within the bore hole, an inner tubing having a hollow bore located within the hollow bore of the casing, wherein an annular region is defined between the inner tubing and the casing, and wherein the tiltmeter array is located within the annular region.

53. The apparatus of Claim 52, wherein each of the at least one tiltmeter assembly is magnetically attached to the casing.

54. The apparatus of Claim 53, further comprising:

means for mechanical isolation between each of the at least one tiltmeter assembly and the inner tubing.

55. The apparatus of Claim 54, wherein means for mechanical isolation between each of the at least one tiltmeter assembly and the inner tubing comprises a spring.

56. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises means for leveling the at least one tiltmeter sensor.

57. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises an accelerometer.

58. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises a geophone.

59. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises a temperature sensor.

60. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises a pressure sensor.

61. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises a gyroscope.

62. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises means for storing data from the at least one tiltmeter sensor.

63. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises means for sending data from the at least one tiltmeter sensor to the surface.

64. The apparatus of Claim 34, wherein each of the at least one tiltmeter assembly further comprises an internal power source.

65. The apparatus of Claim 34, further comprising:

an external computer having a wireless connection with at least one of the at least one tiltmeter assembly.

66. A process, comprising:
providing a well extending from a surface into a strata, the well having a bore hole;
providing a tiltmeter array comprising at least one tiltmeter assembly, each of the at least one tiltmeter assembly comprising at least one tiltmeter sensor;
installing the tiltmeter array within the bore hole; and
measuring the effect of fluid motion through the bore hole and strata on the strata with the tiltmeter array.

67. The process of Claim 66, further comprising the step of:
providing a wireline between the tiltmeter array and the surface.

68. The process of Claim 67, wherein the wireline is retrievable.

69. The process of Claim 67, further comprising:
connecting an external power supply electrically to the wireline.

70. The process of Claim 67, further comprising:
connecting an external computer to the wireline.

71. The process of Claim 67, wherein the wireline comprises:
an electrically conductive cable; and
a secondary conductor electrically insulated from the electrically conductive cable.

72. The process of Claim 66, further comprising the step of:
providing a communication link between the tiltmeter array and the surface.

73. The process of Claim 72, wherein the communication link is a wireline.

74. The process of Claim 72, wherein the communication link is a wireless link.

75. The process of Claim 66, further comprising the step of:
providing a retrievable memory within the tiltmeter array.

76. The process of Claim 66, further comprising the step of:
providing means for injecting the fluid from the surface into the bore hole.

77. The process of Claim 66, wherein the tiltmeter array comprises a plurality of tiltmeter assemblies, the process further comprising the step of:
providing an interconnect wireline between each of the plurality of tiltmeter assemblies.

78. The process of Claim 66, wherein the tiltmeter array comprises a plurality of tiltmeter assemblies, the process further comprising the step of:
providing a wireless connection between at least two of the plurality of tiltmeter assemblies.

79. The process of Claim 66, wherein the active well comprises a casing having a hollow bore, and wherein the tiltmeter array is located within the hollow bore.

80. The process of Claim 79, wherein each of the at least one tiltmeter assembly further comprises means for holding each of the at least one tiltmeter assembly within the hollow bore.

81. The process of Claim 80, wherein the means for holding the at least one tiltmeter assembly within the hollow bore comprises a bowspring connector in contact with the hollow bore.

82. The process of Claim 80, wherein the means for holding the at least one tiltmeter assembly within the hollow bore comprises at least one magnet.

83. The process of Claim 66, wherein the active well comprises a casing having a hollow bore located within the bore hole, and wherein the tiltmeter array is located between the casing and the strata.

84. The process of Claim 83, wherein each of the at least one tiltmeter assembly is cemented on the casing.

85. The process of Claim 83, wherein each of the at least one tiltmeter assembly is strapped to the casing.

86. The process of Claim 66, wherein the active well comprises a casing having a hollow bore located within the bore hole, an inner tubing having a hollow bore located within the hollow bore of the casing, wherein an annular region is defined between the inner tubing and the casing, and wherein the tiltmeter array is located within the annular region.

87. The process of Claim 86, wherein each of the at least one tiltmeter assembly is magnetically attached to the casing.

88. The process of Claim 87, further comprising the step of:

providing means for mechanical isolation between each of the at least one tiltmeter assembly and the inner tubing.

89. The process of Claim 88, wherein the provided means for mechanical isolation between each of the at least one tiltmeter assembly and the inner tubing comprises a spring.

90. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises means for leveling the at least one tiltmeter sensor.

91. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises an accelerometer.

92. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises a geophone.

93. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises a temperature sensor.

94. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises a pressure sensor.

95. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises a gyroscope.

96. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises means for storing data from the at least one tiltmeter sensor.

97. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises means for sending data from the at least one tiltmeter sensor to the surface.

98. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises an internal power source.

99. The process of Claim 66, further comprising the step of:
establishing a wireless connection between an external computer and at least one of the at least one tiltmeter assembly.

100. The process of Claim 66, further comprising the step of:
sending data from the tiltmeter array to the surface.

101. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises means for storing data from the at least one tiltmeter sensor.

102. The process of Claim 66, wherein each of the at least one tiltmeter assembly further comprises means for sending data from the at least one tiltmeter sensor to the surface.

103. The process of Claim 66, further comprising the step of:
recording tilt data with at least one of the at least one tiltmeter assembly.

104. The process of Claim 103, further comprising the step of:
transferring the tilt data to the surface.

105. The process of Claim 104, further comprising the step of:

extracting strata deformation information from the transferred tilt data.

106. The process of Claim 105, further comprising the step of:
running a geomechanical model of strata deformation.

107. The process of Claim 106, further comprising the step of:
comparing the geomechanical model to the extracted strata deformation information.

108. The process of Claim 107, further comprising the step of:
iteratively running the geomechanical model based on the comparison of the geomechanical model to the extracted strata deformation information.

109. The process of Claim 107, further comprising the step of:
displaying the extracted strata deformation information.

110. The process of Claim 107, further comprising the step of:
displaying the geomechanical model.

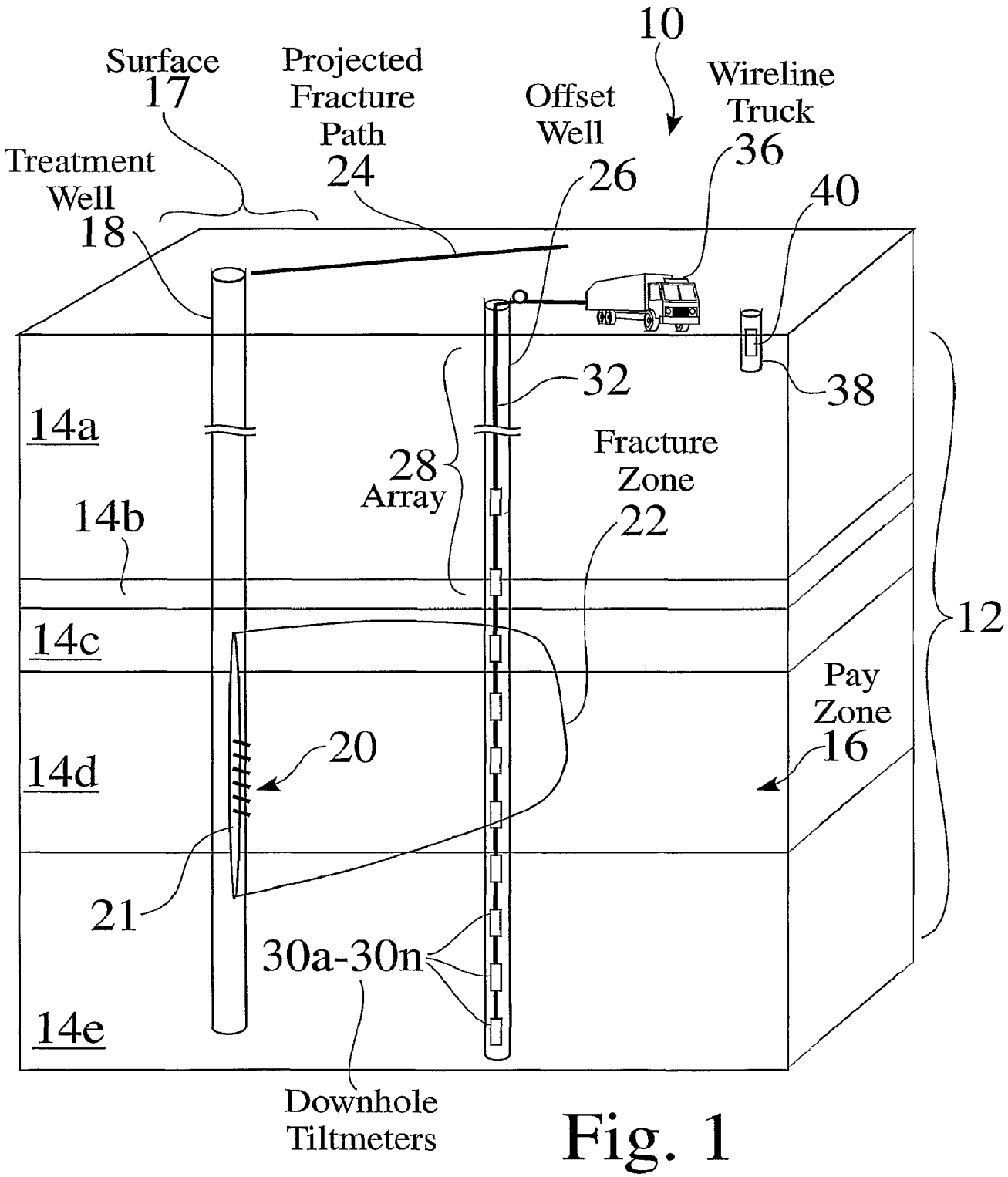

10
Surface
17
Projected
Fracture
Path
24
Offset
Well
26
Wireline
Truck
36
40
Treatment
Well
18
32
38
14a
28
Array
Fracture
Zone
22
14b
12
14c
Pay
Zone
16
20
14d
21
30a-30n
14e
Downhole
Tiltmeters

Fig. 1

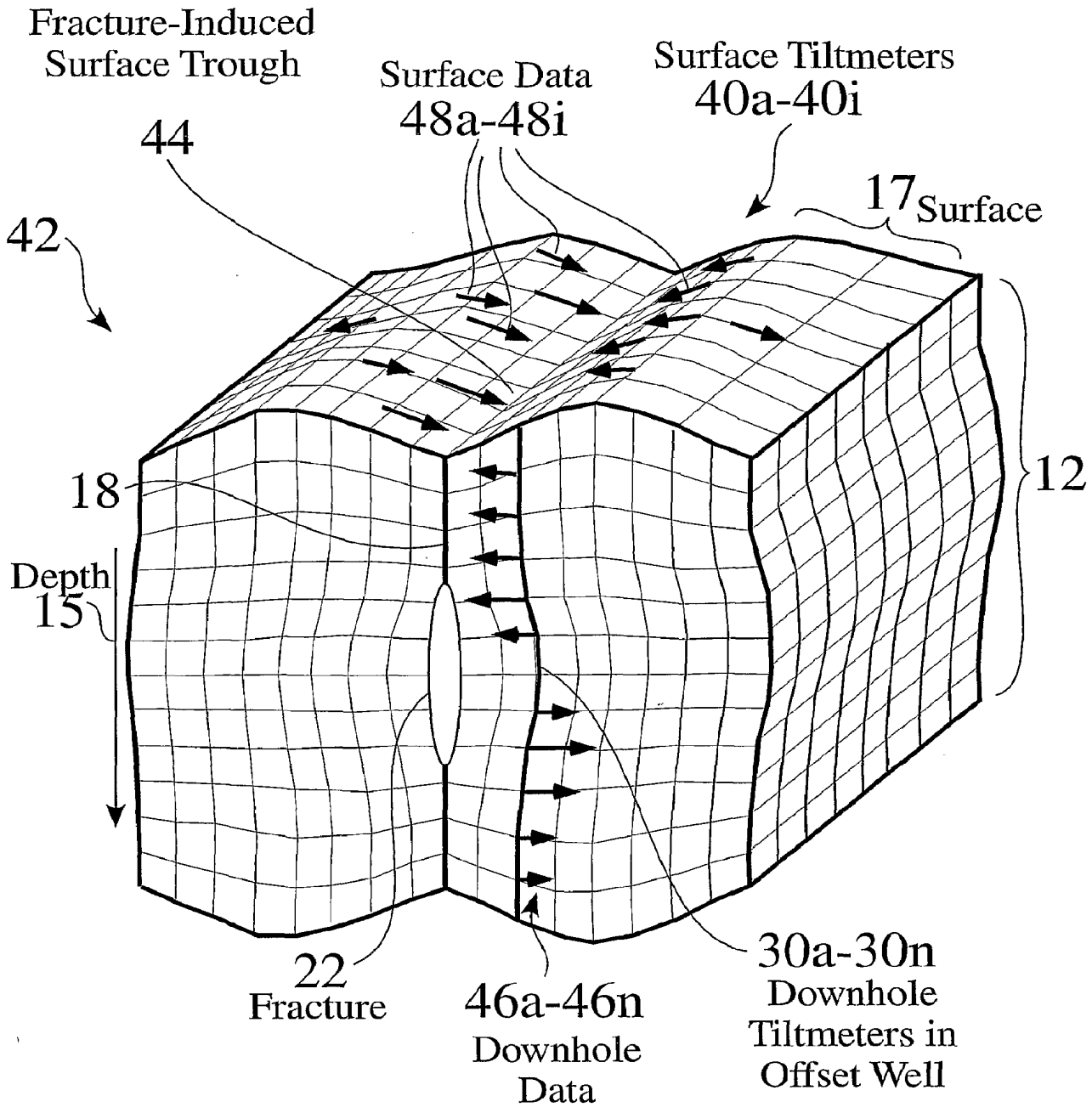

Fracture-Induced
Surface Trough
44
Surface Data
48a-48i
Surface Tiltmeters
40a-40i
17 Surface
42
18
12
Depth
15
22
Fracture
46a-46n
Downhole
Data
30a-30n
Downhole
Tiltmeters in
Offset Well

Fig. 2

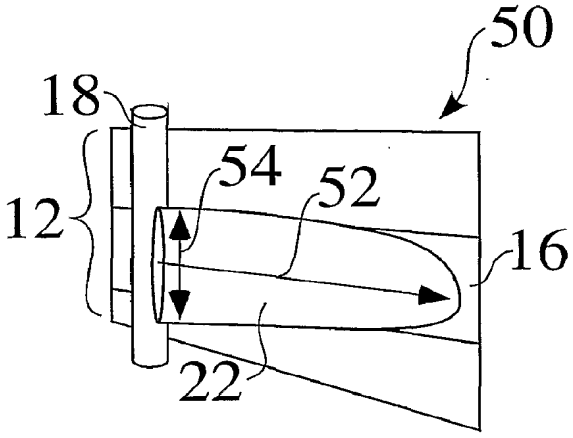


Fig. 3

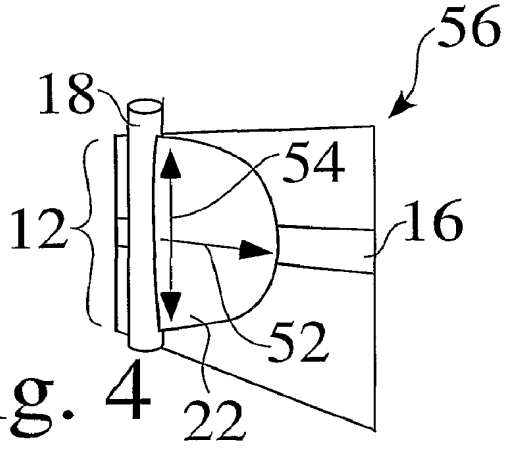


Fig. 4

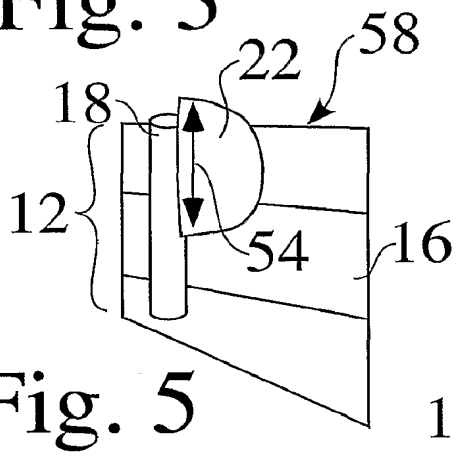


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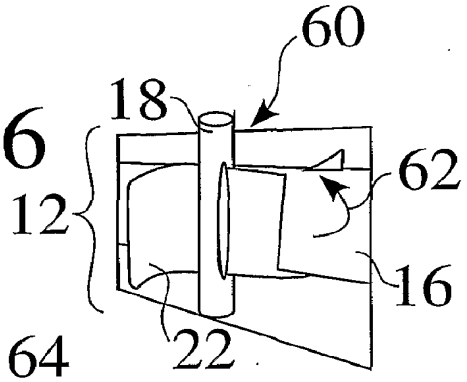


Fig. 6

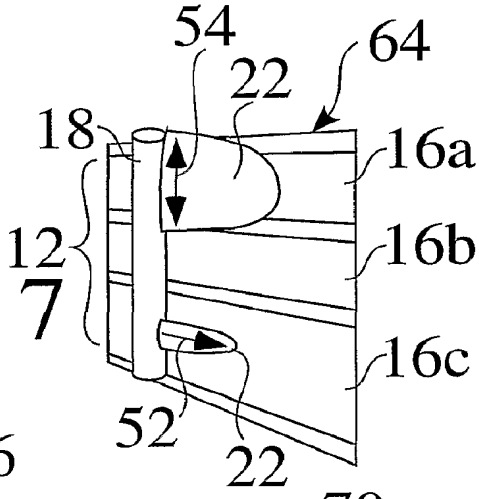
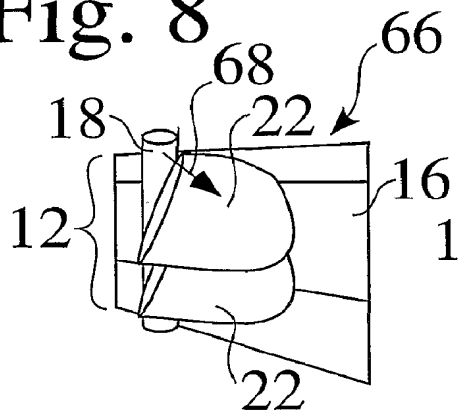


Fig. 7

Fig. 8



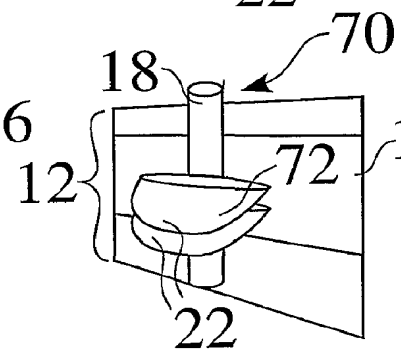


Fig. 9

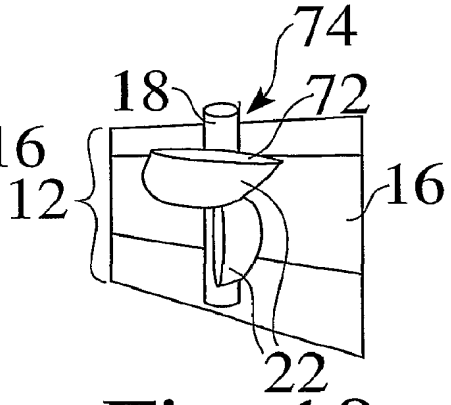


Fig. 10

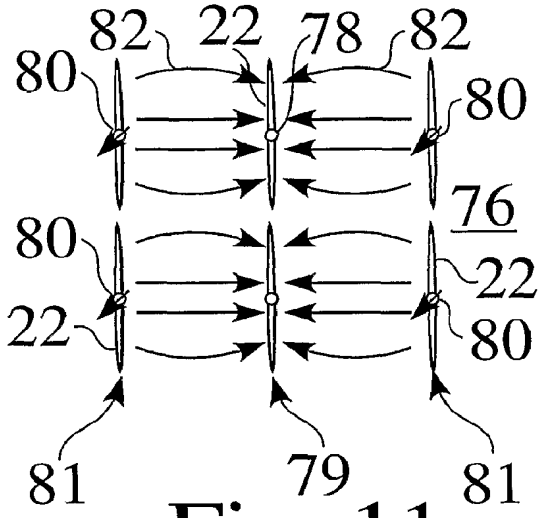


Fig. 11

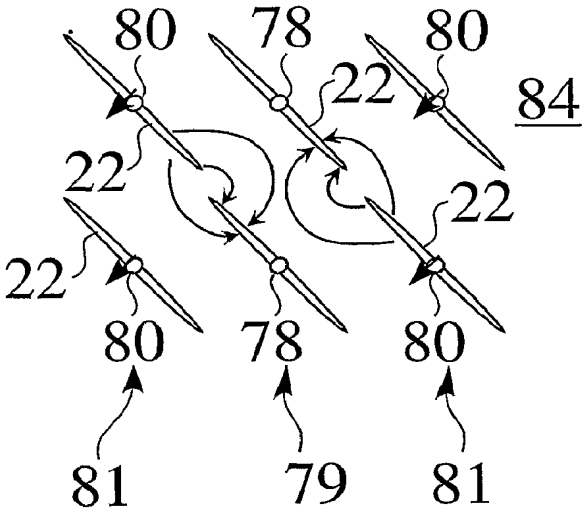


Fig. 12

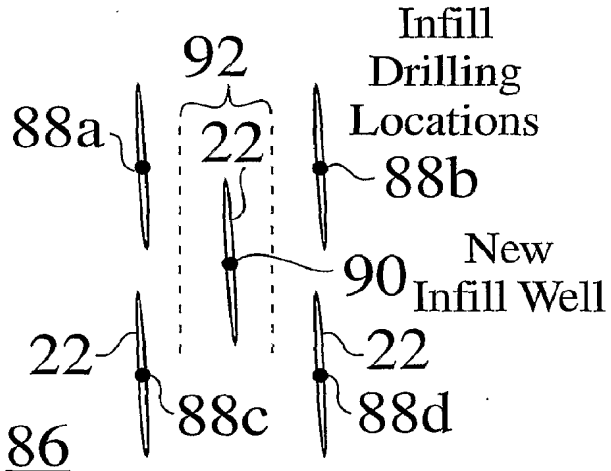


Fig. 13

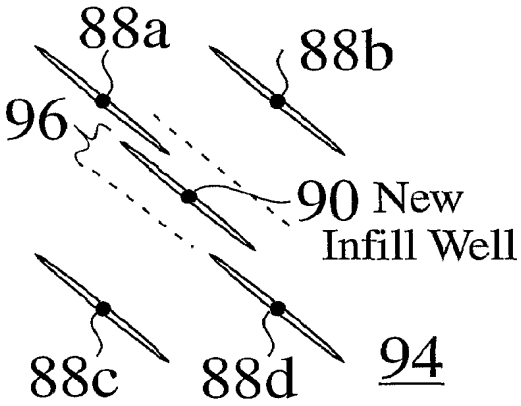


Fig. 14

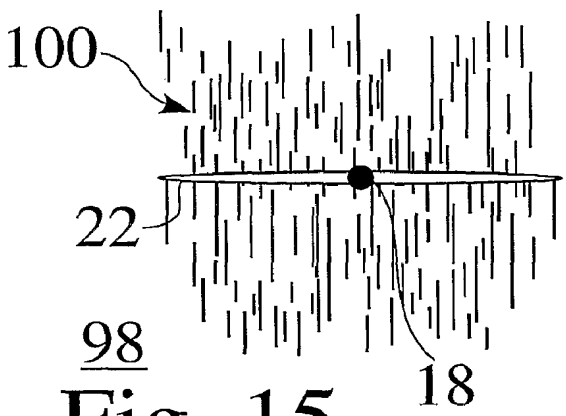


Fig. 15

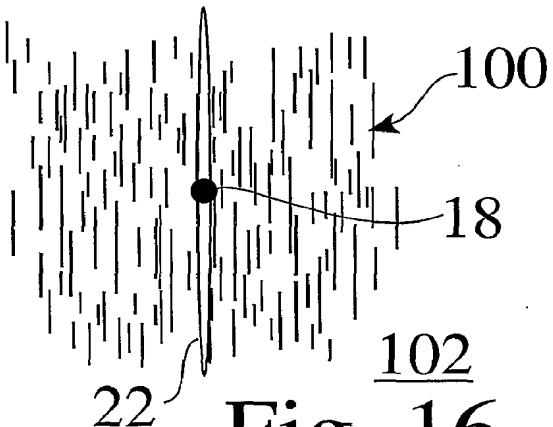


Fig. 16

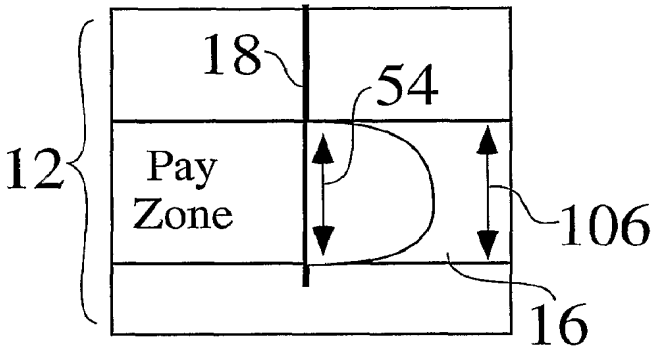
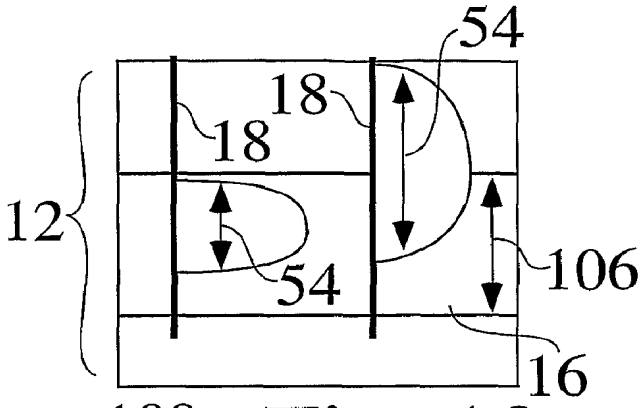


Fig. 17 104



108 Fig. 18

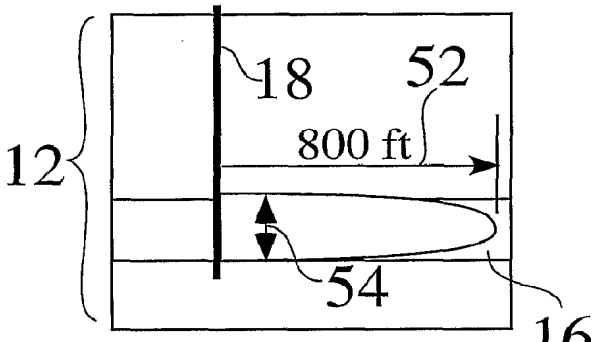
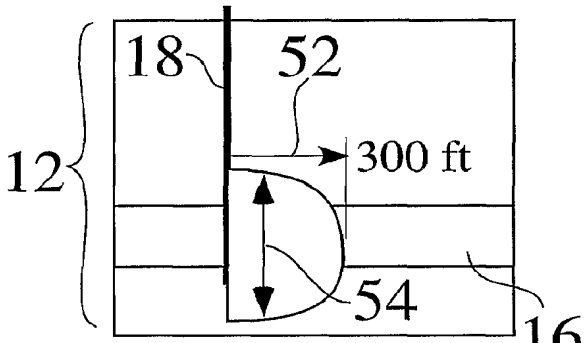


Fig. 19 110



112 Fig. 20

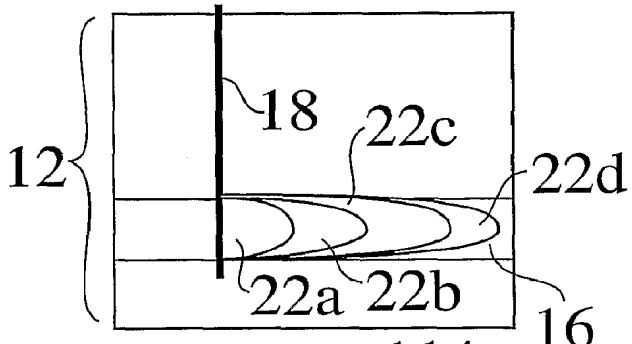
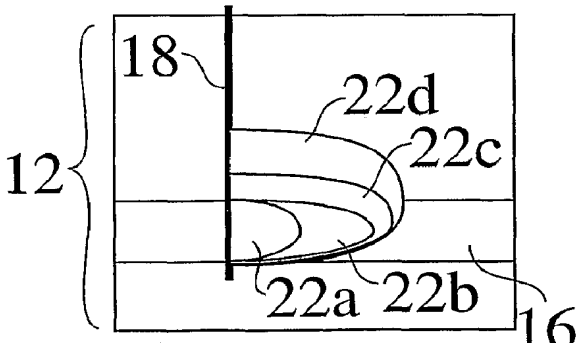


Fig. 21 114



116 Fig. 22

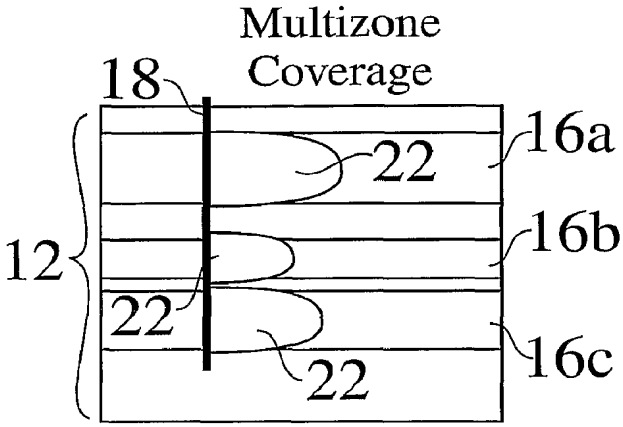
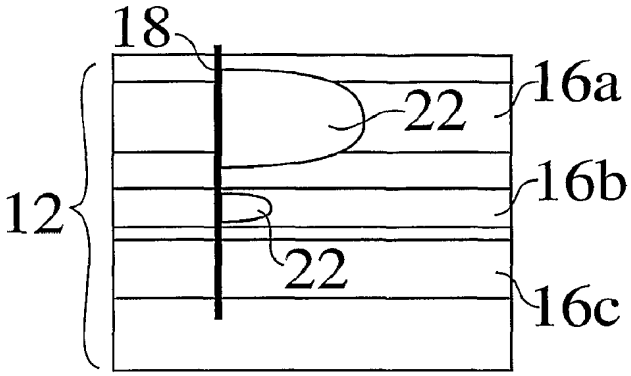


Fig. 23 118



120 Fig. 24

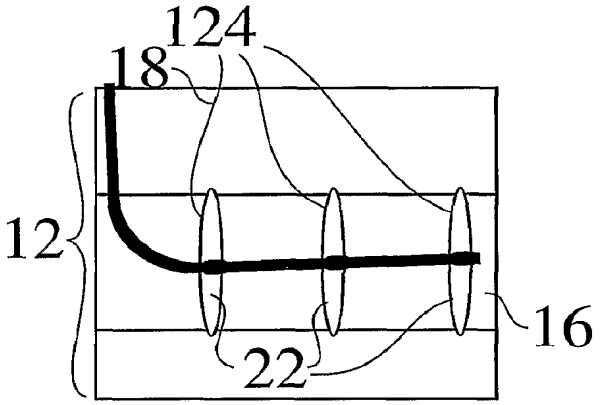
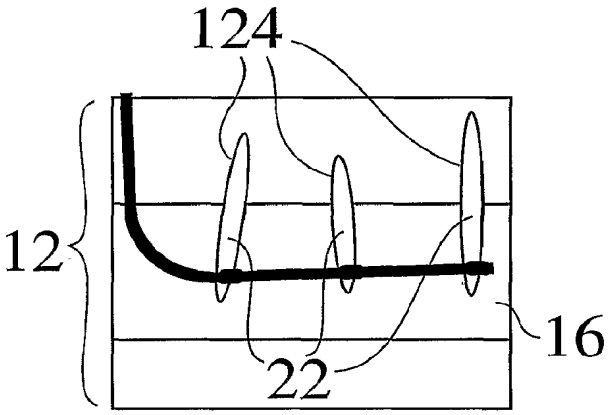


Fig. 25 122



126 Fig. 26

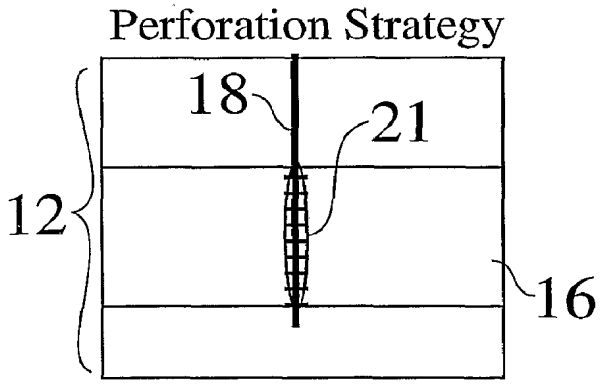
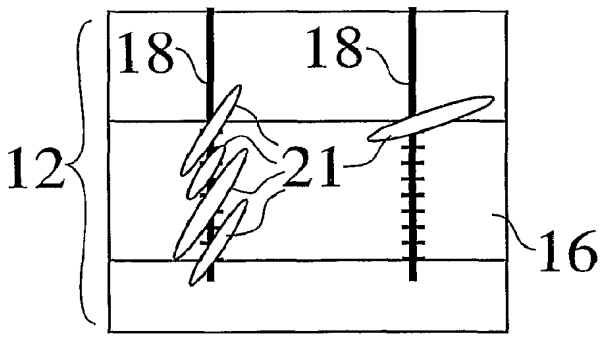


Fig. 27 128



130 Fig. 28

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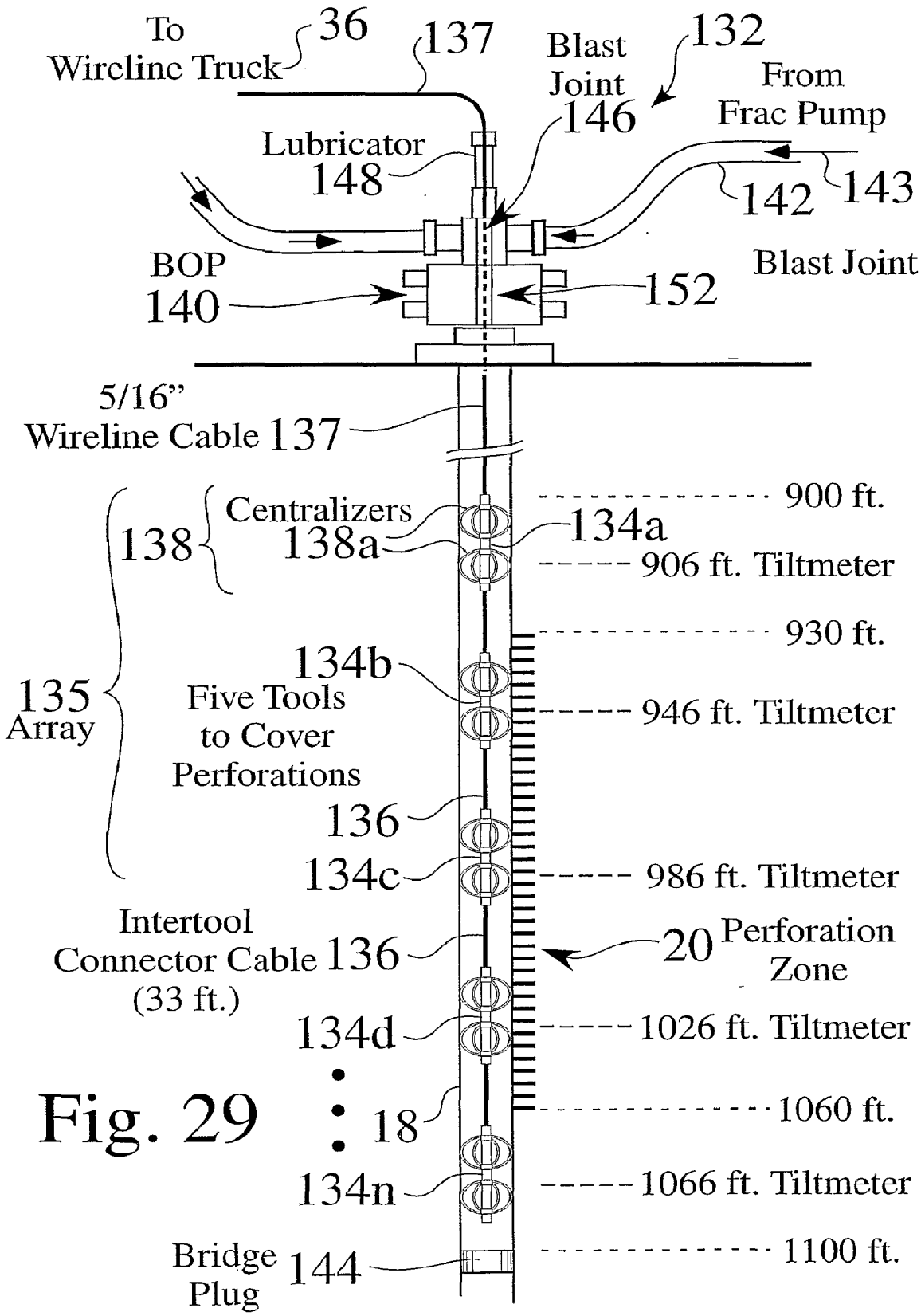

To Wireline Truck
36
137
Blast Joint
132
From Frac Pump
146
Lubricator
148
142
143
BOP
140
152
Blast Joint
5/16" Wireline Cable 137
138
Centralizers
138a
134a
900 ft.
906 ft. Tiltmeter
930 ft.
134b
135 Array
Five Tools to Cover Perforations
946 ft. Tiltmeter
136
134c
986 ft. Tiltmeter
Intertool Connector Cable 136 (33 ft.)
20 Perforation Zone
134d
1026 ft. Tiltmeter
18
1060 ft.
134n
1066 ft. Tiltmeter
Bridge Plug 144
1100 ft.

Fig. 29

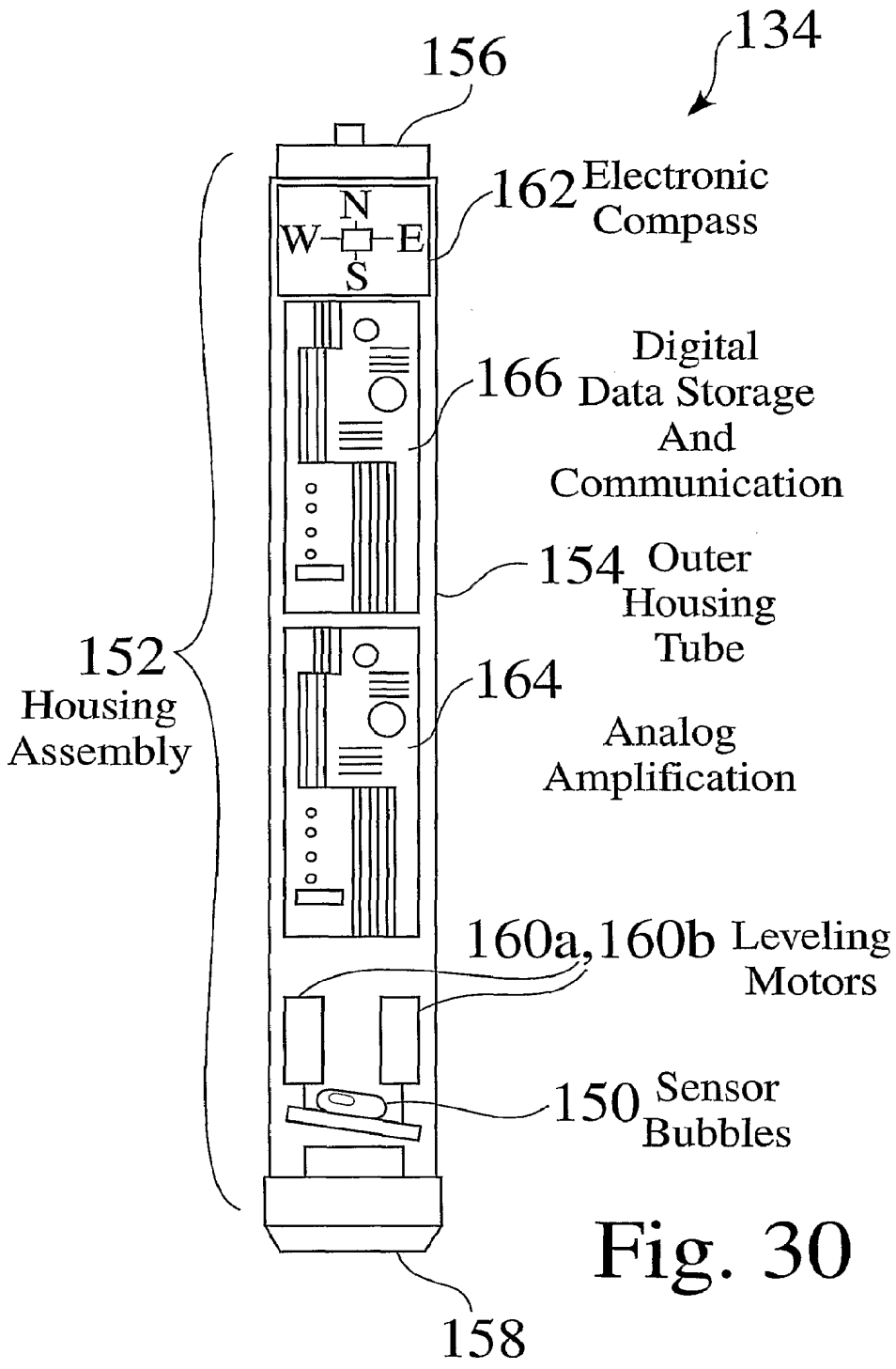

156
134
162 Electronic Compass
N
W
E
S
166 Digital Data Storage And Communication
154 Outer Housing Tube
152 Housing Assembly
164 Analog Amplification
160a, 160b Leveling Motors
150 Sensor Bubbles
158

Fig. 30

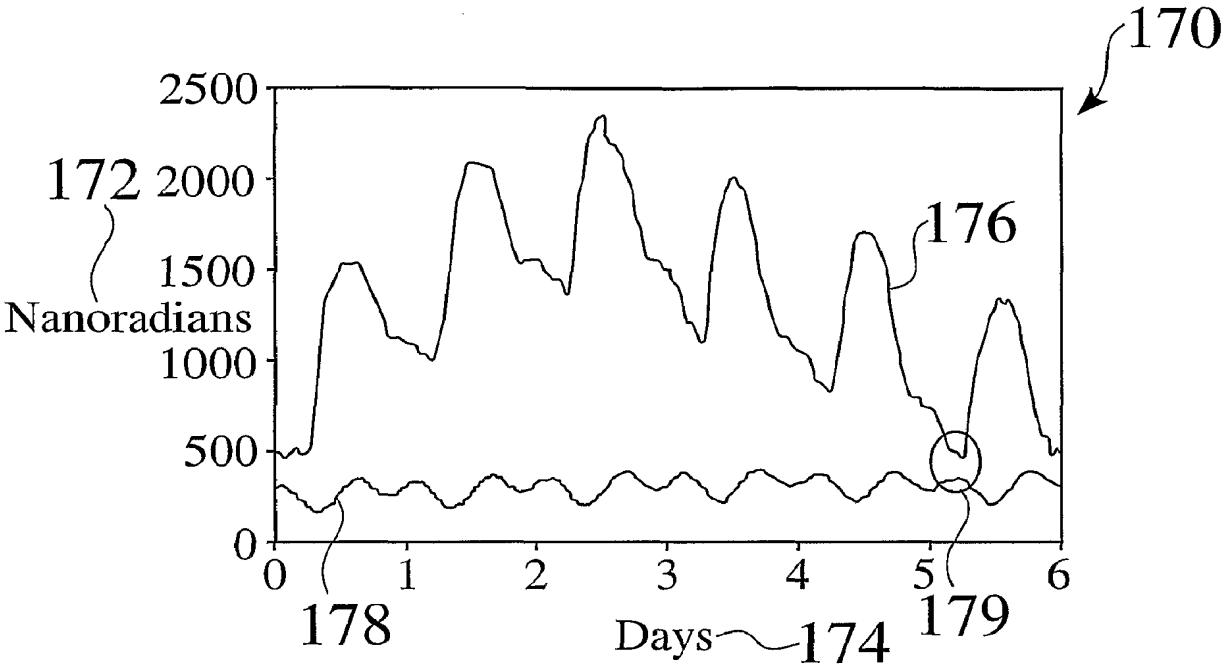

170
2500
172
2000
1500
Nanoradians
1000
500
0
176
0
1
2
3
4
5
6
178
179
Days
174

Fig. 31

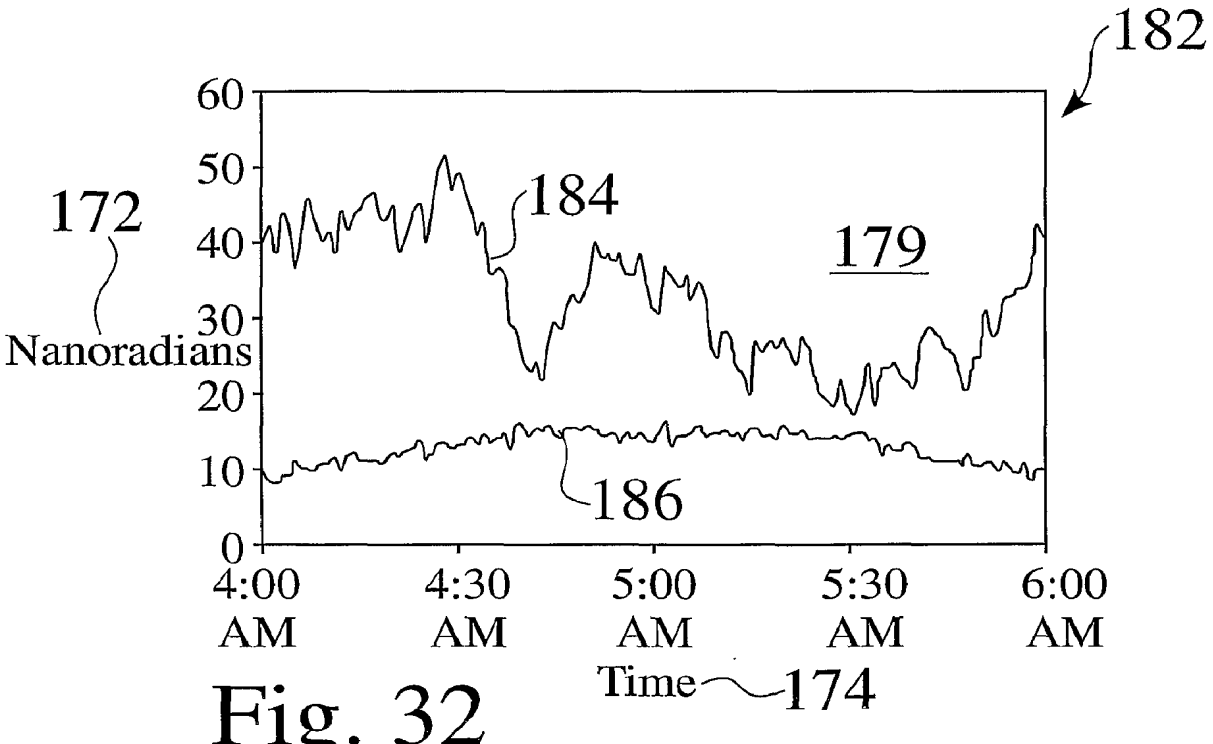

182
60
50
172
184
40
179
30
Nanoradians
20
10
186
0
4:00 AM
4:30 AM
5:00 AM
5:30 AM
6:00 AM
Time
174

Fig. 32

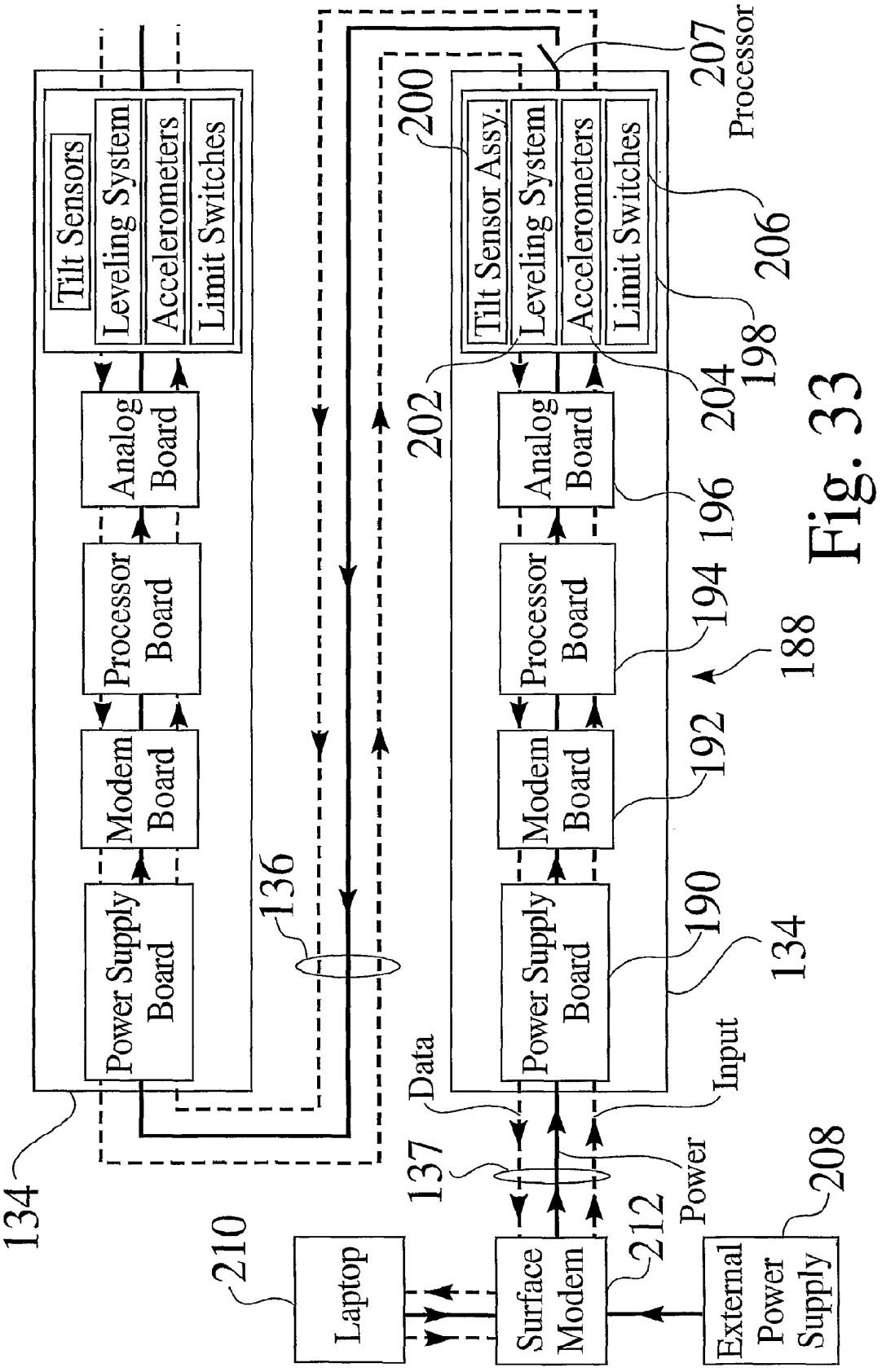

Tilt Sensors
Leveling System
Accelerometers
Limit Switches
Analog Board
Processor Board
Modem Board
Power Supply Board
136
134
200
Tilt Sensor Assy.
Leveling System
Accelerometers
Limit Switches
207
Processor
206
198
204
202
Analog Board
196
Processor Board
194
188
Modem Board
192
Power Supply Board
190
134
Data
Input
137
Power
212
208
210
Laptop
Surface Modem
External Power Supply

Fig. 33

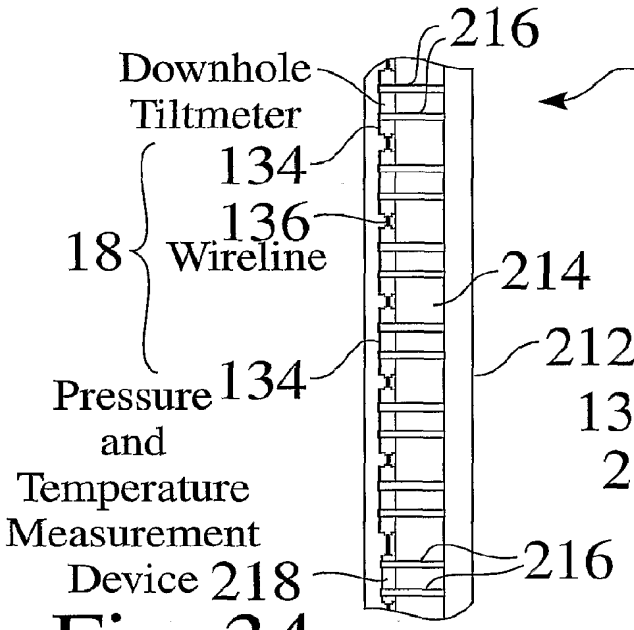


Fig. 34

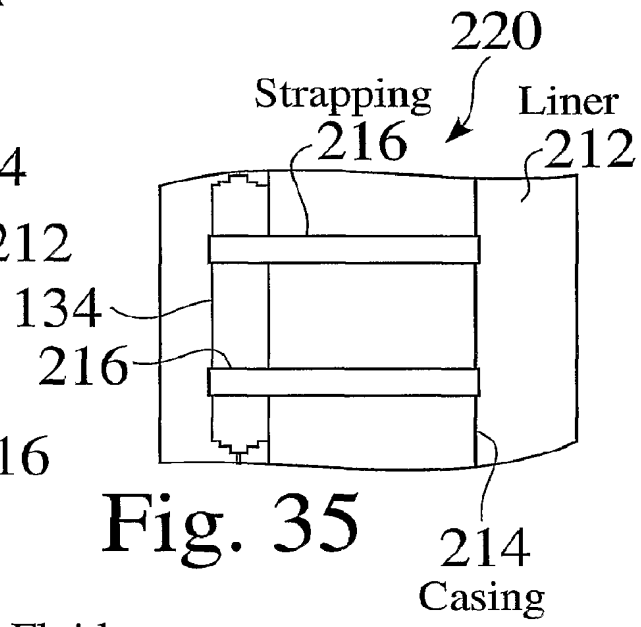


Fig. 35

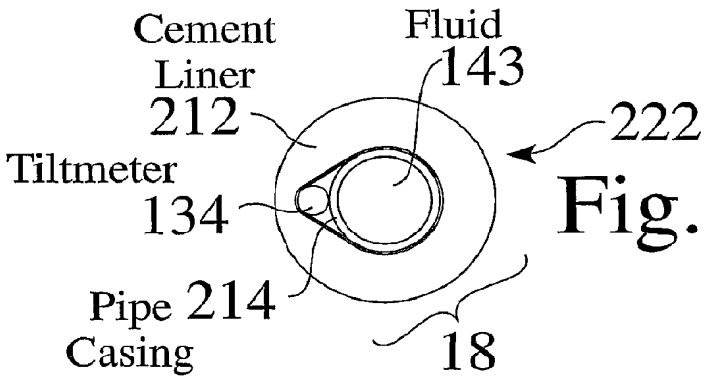


Fig. 36

Fig. 37

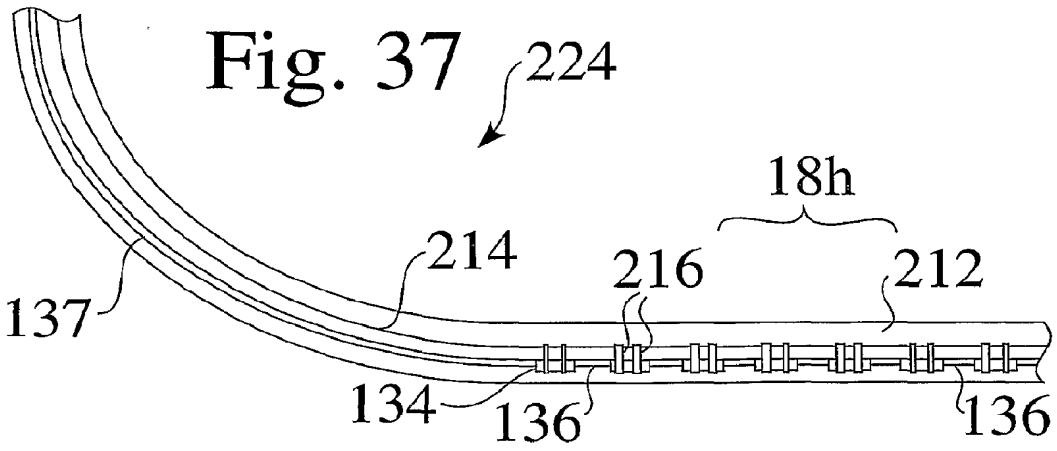
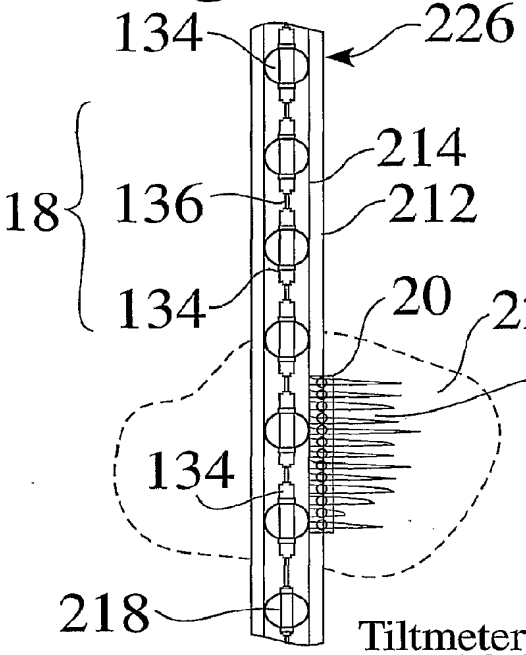


Fig. 38



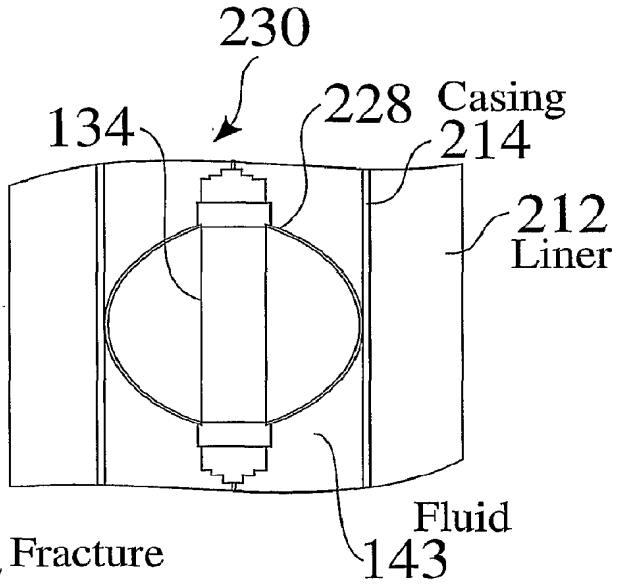


Fig. 39

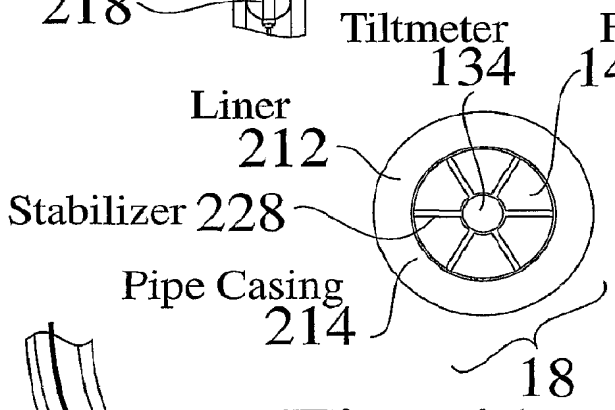
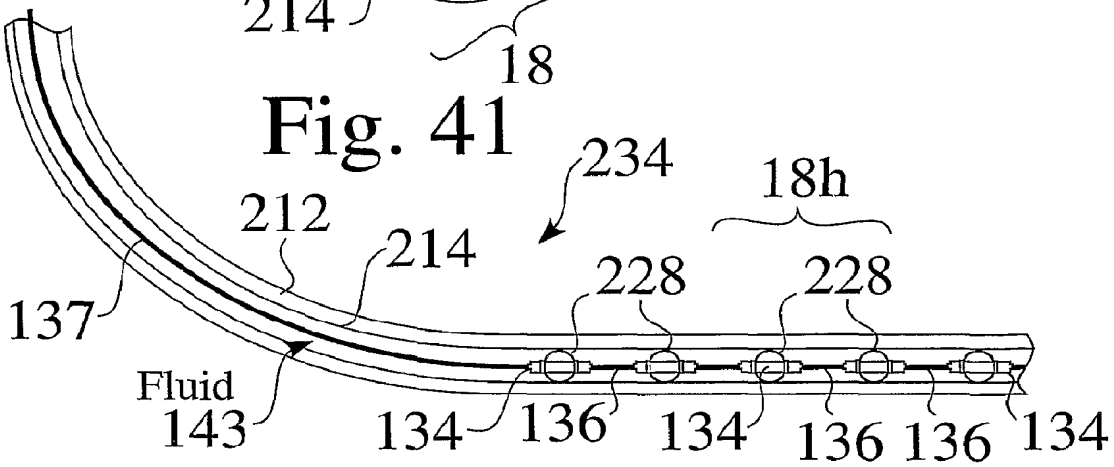


Fig. 40

Fig. 41



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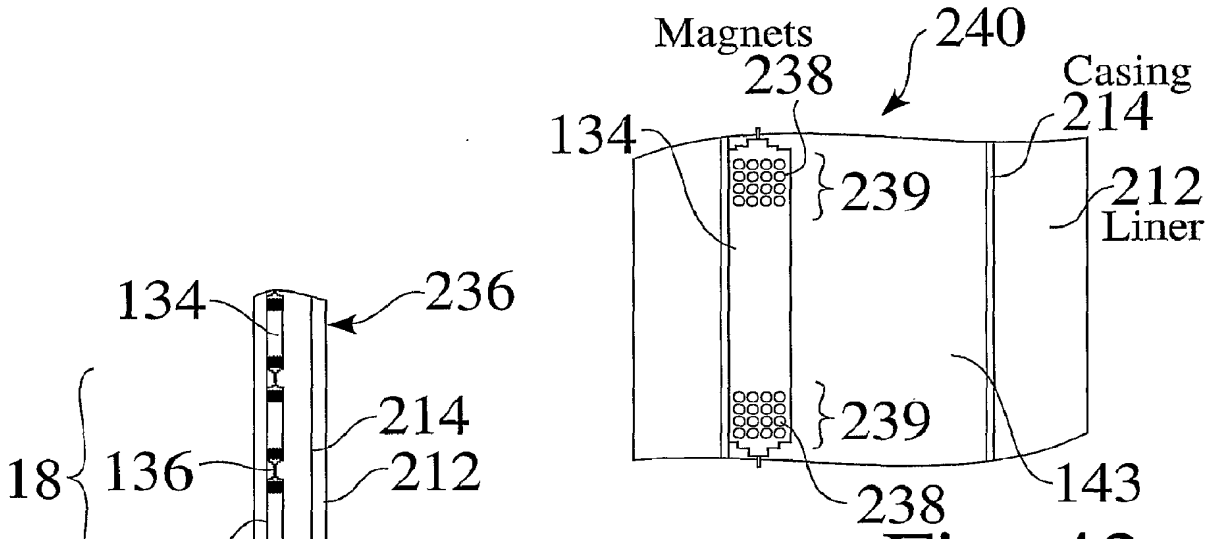


Fig. 43

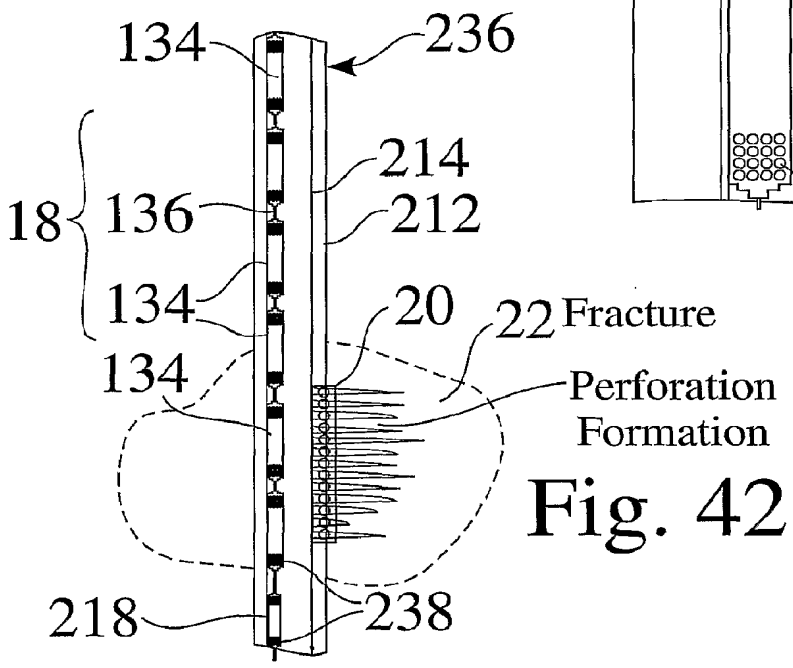


Fig. 42

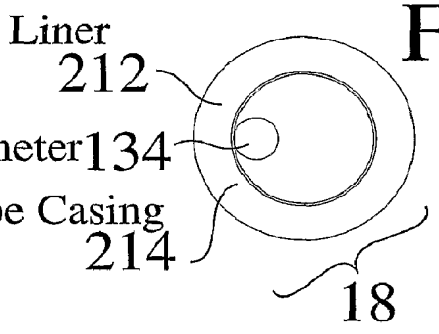
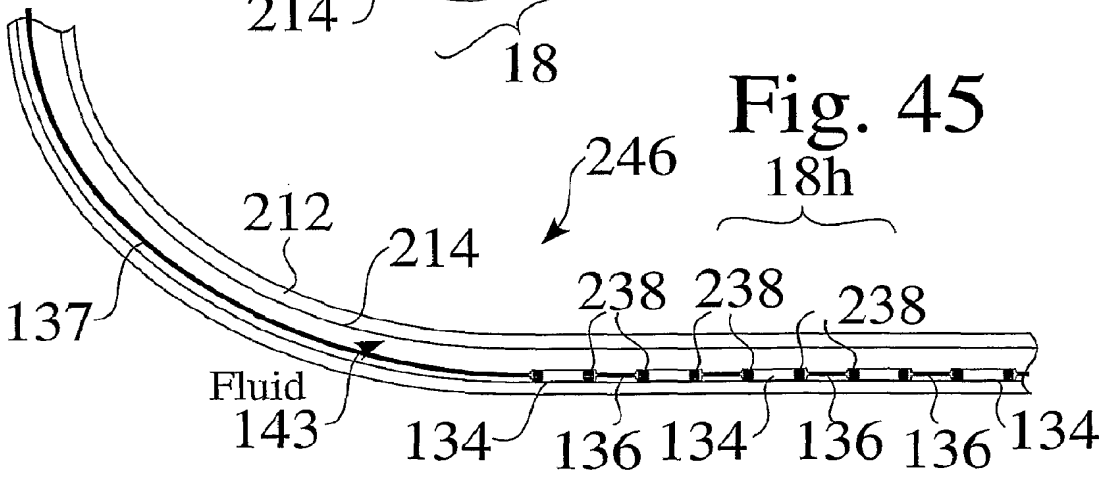


Fig. 44

Fig. 45



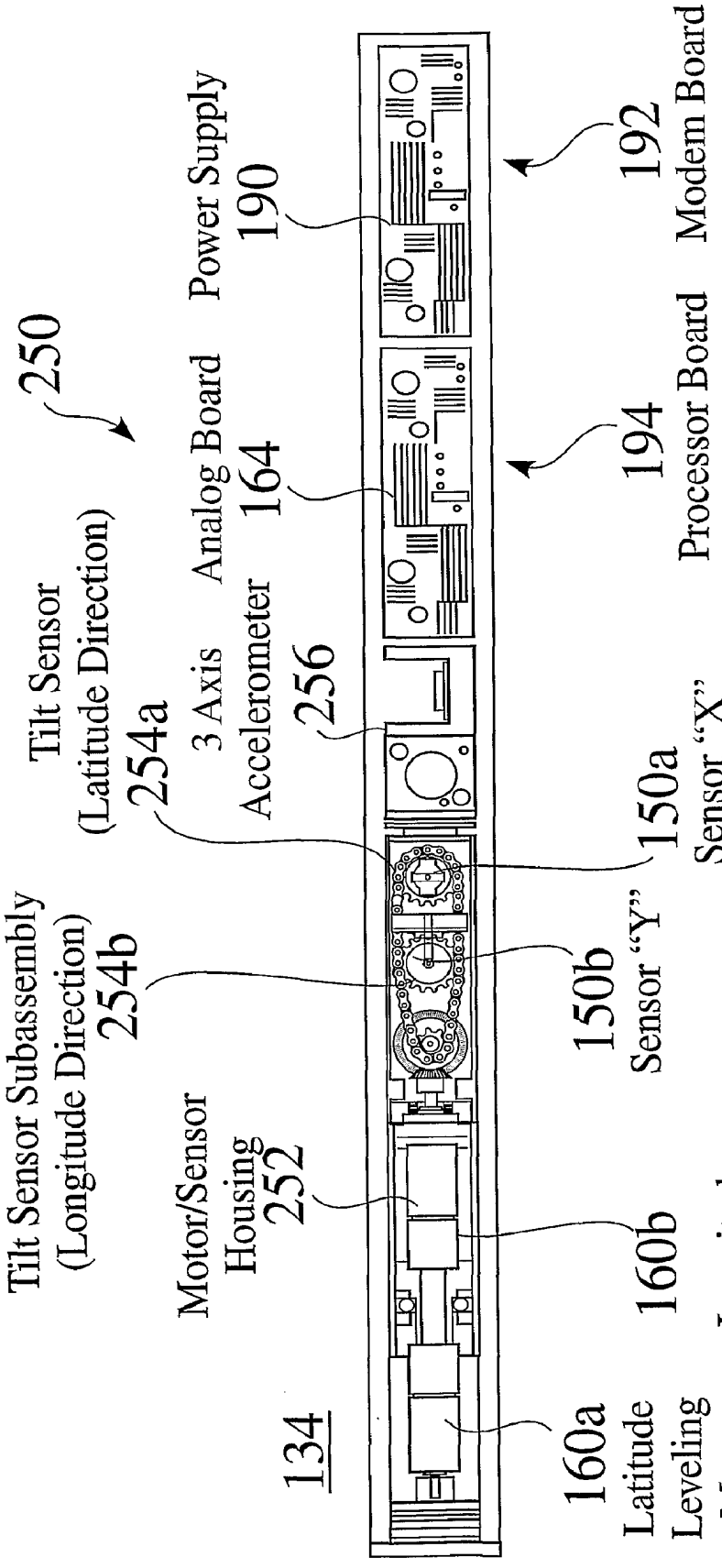

250
Tilt Sensor
(Latitude Direction)
254a
3 Axis
Accelerometer
256
Analog Board
164
Power Supply
190
192
Modem Board
(Back)
194
Processor Board
(Back)
Tilt Sensor Subassembly
(Longitude Direction)
254b
Motor/Sensor
Housing
252
150a
Sensor "X"
150b
Sensor "Y"
134
160a
Latitude
Leveling
Motor
160b
Longitude
Leveling
Motor

Fig. 46

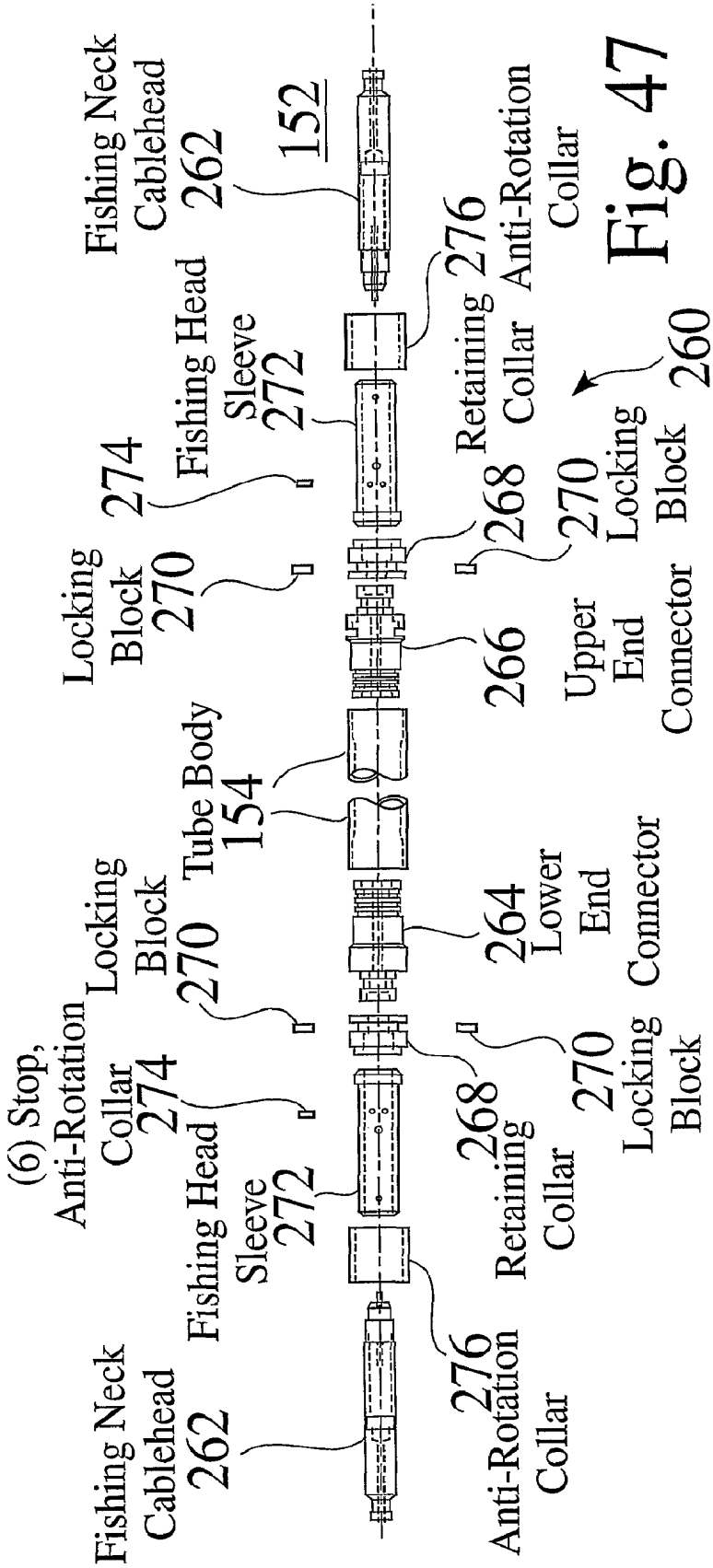

Fishing Neck Cablehead
262
Fishing Head Sleeve
272
(6) Stop, Anti-Rotation Collar
274
Locking Block
270
Tube Body
154
Anti-Rotation Collar
276
Retaining Collar
268
Lower End Connector
264
Upper End Connector
266
Locking Block
270
Locking Block
270
Retaining Collar
268
Anti-Rotation Collar
276
Fishing Head Sleeve
272
Fishing Neck Cablehead
262
152

Fig. 47

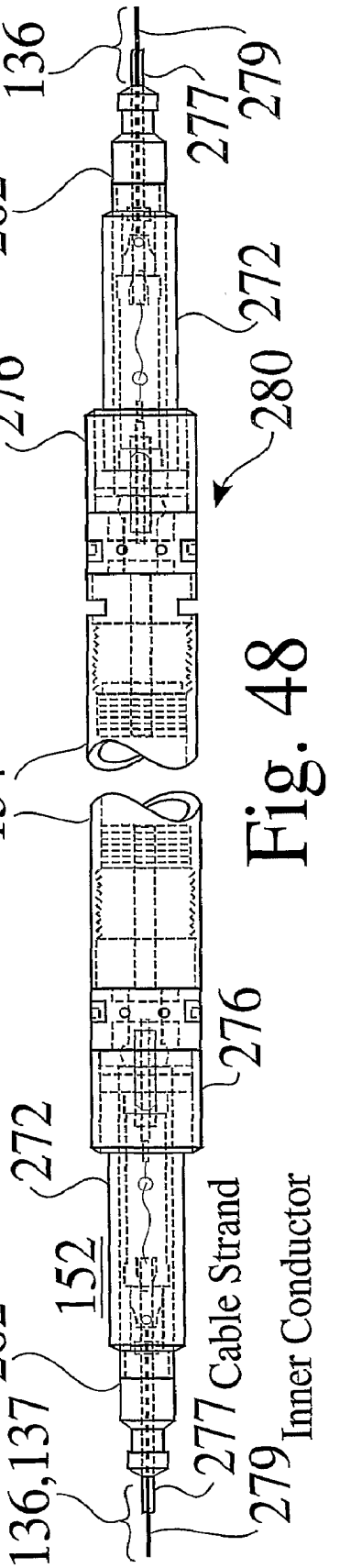

136
262
277
279
276
272
280
154
276
152
272
262
136,137
277 Cable Strand
279 Inner Conductor

Fig. 48

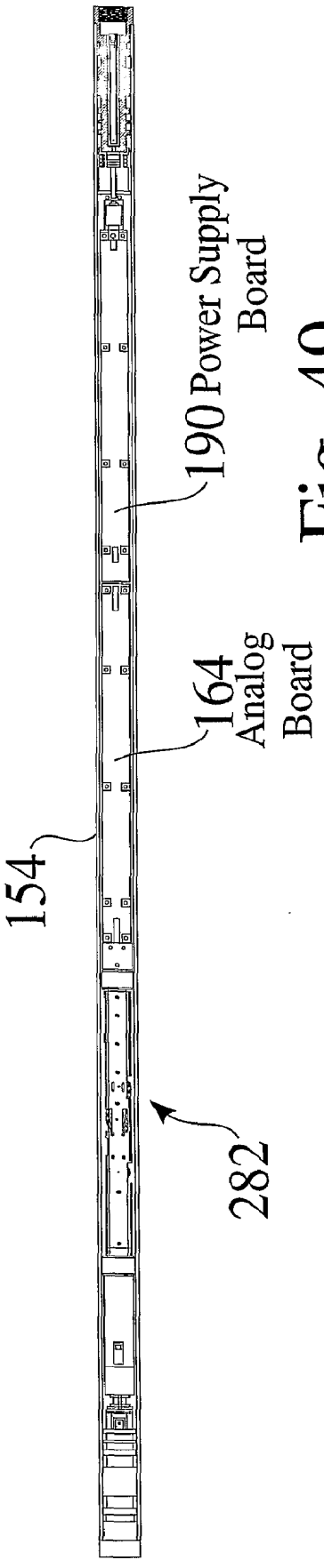

190 Power Supply Board
164 Analog Board
154
282

Fig. 49

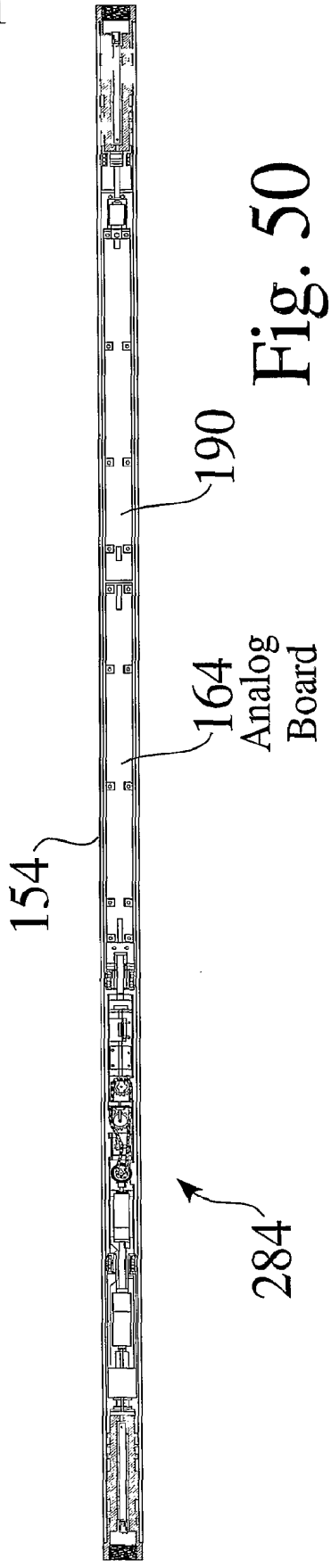

190
164 Analog Board
154
284

Fig. 50

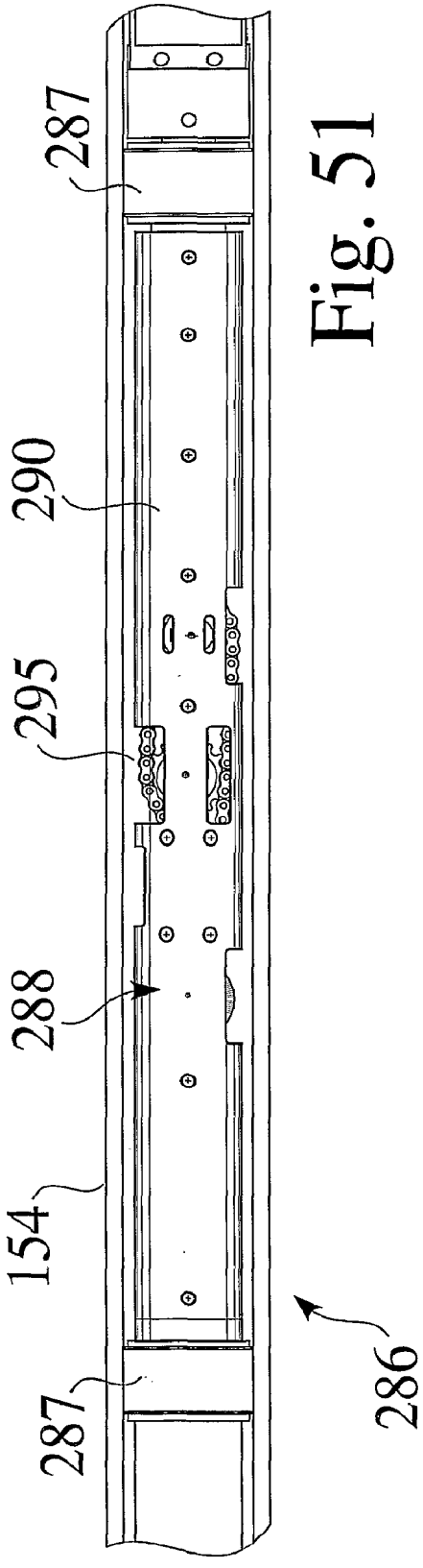

287
290
295
288
154
287
286

Fig. 51

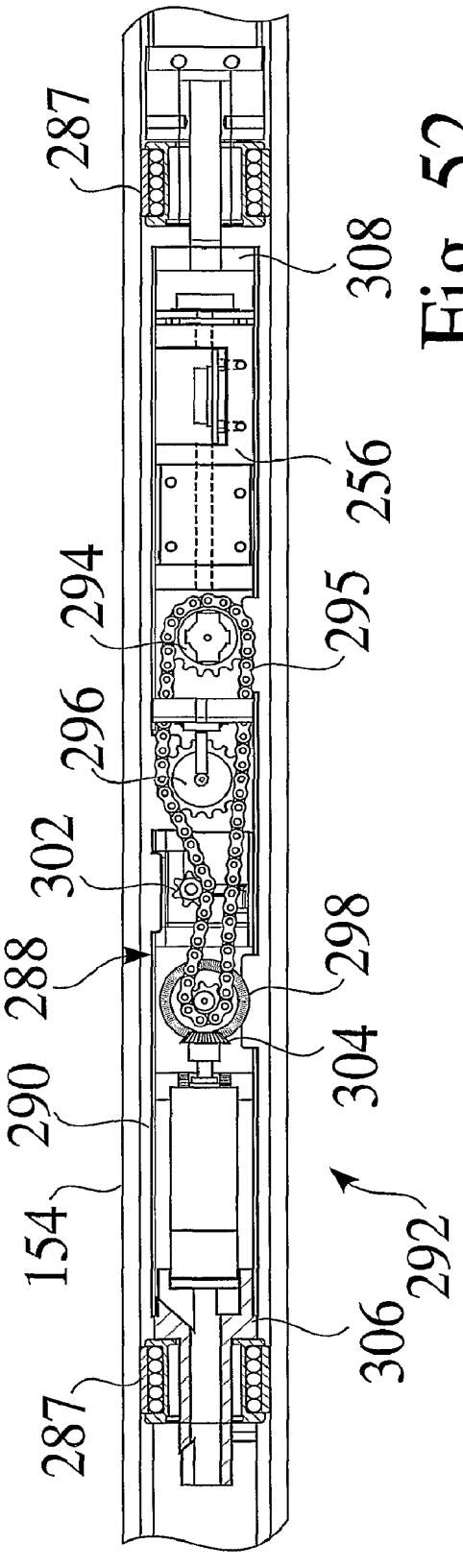

287
308
256
294
295
296
302
288
298
304
290
154
306
292
287

Fig. 52

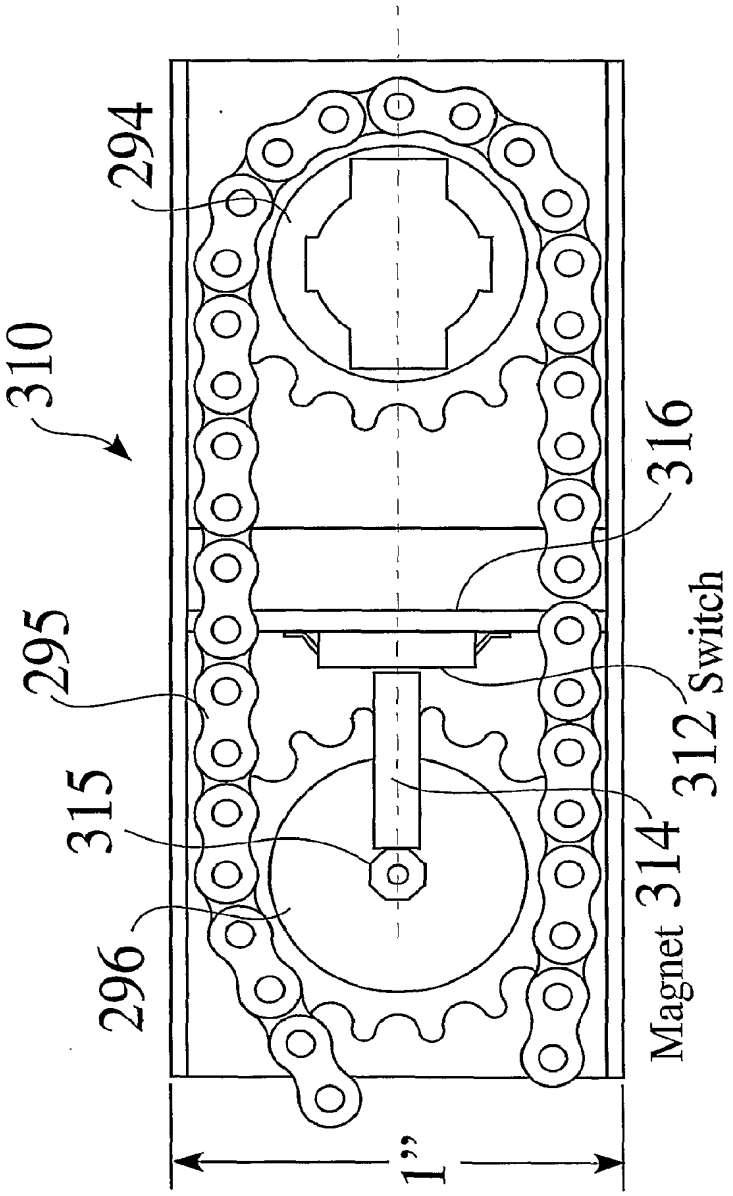


Fig. 53

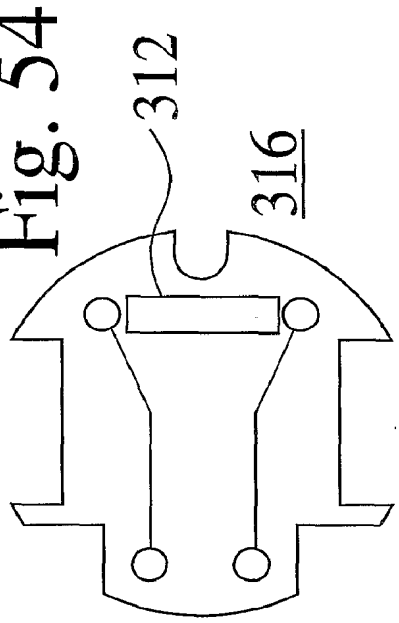
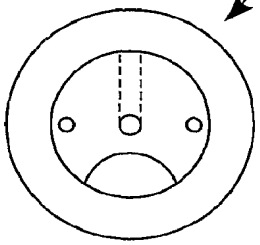


Fig. 54

Fig. 56



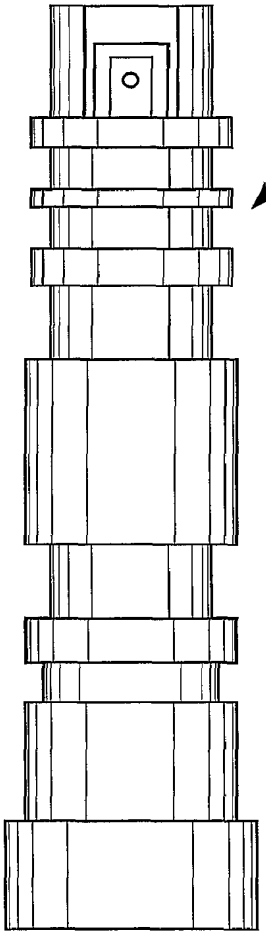


Fig. 55

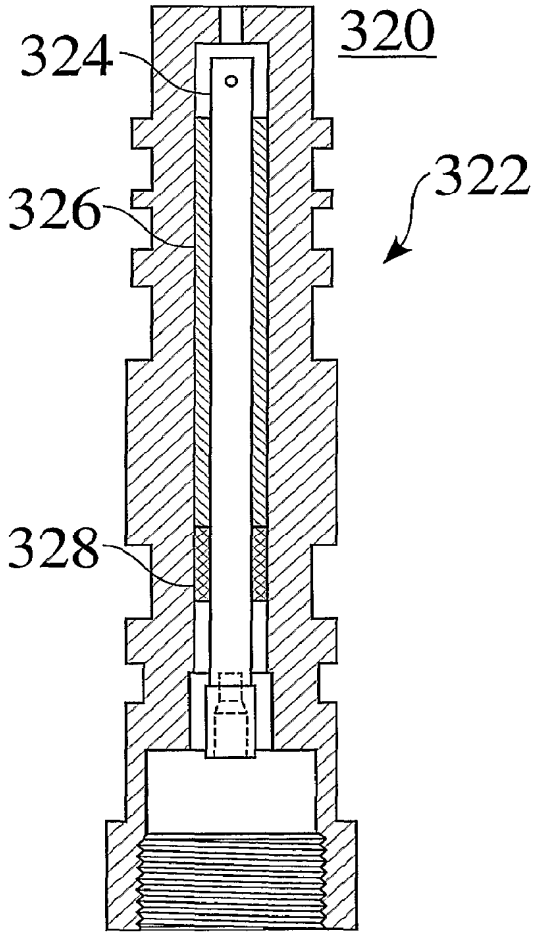


Fig. 57

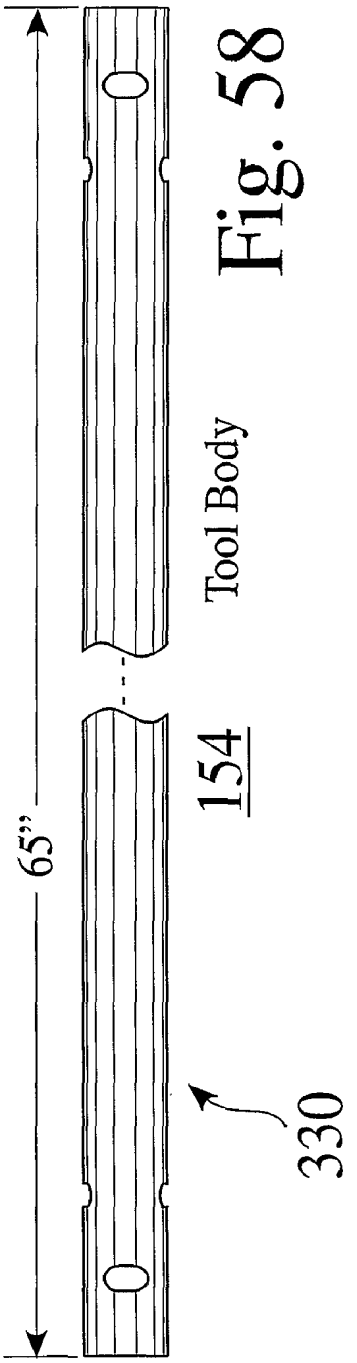


Fig. 58

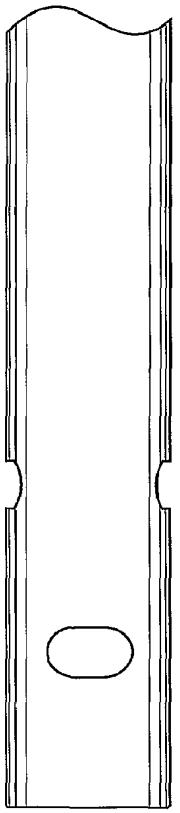


Fig. 59

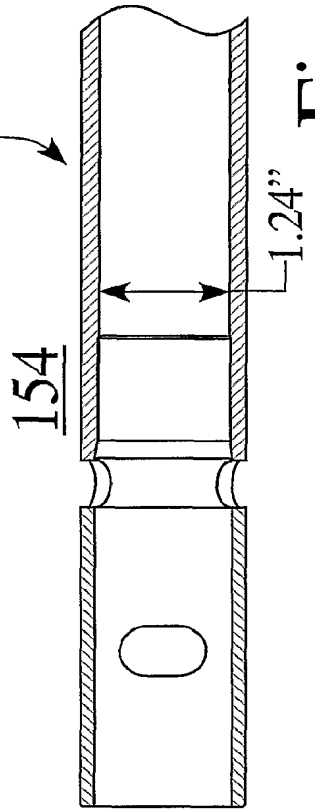


Fig. 60

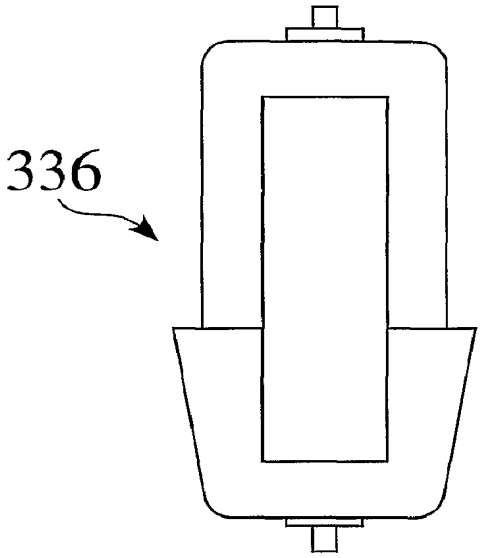


Fig. 61

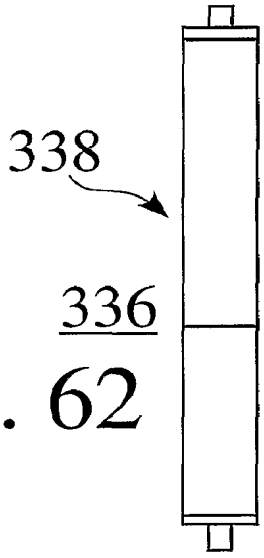


Fig. 62

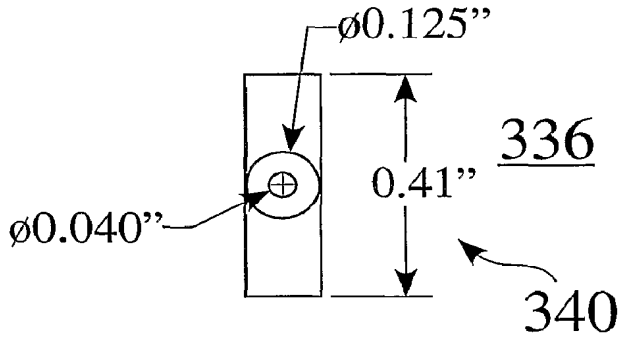


Fig. 63

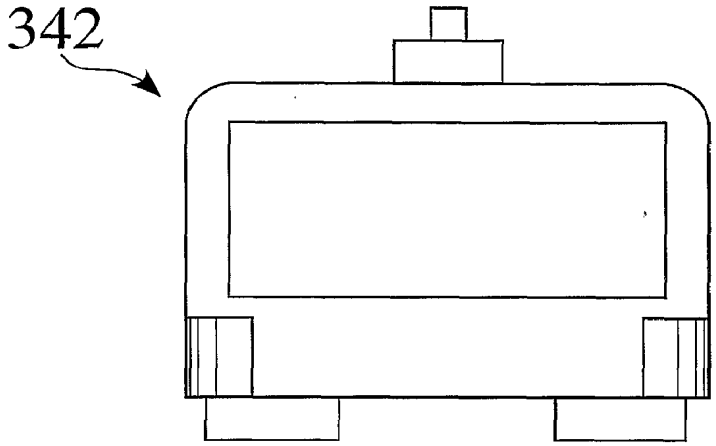


Fig. 64

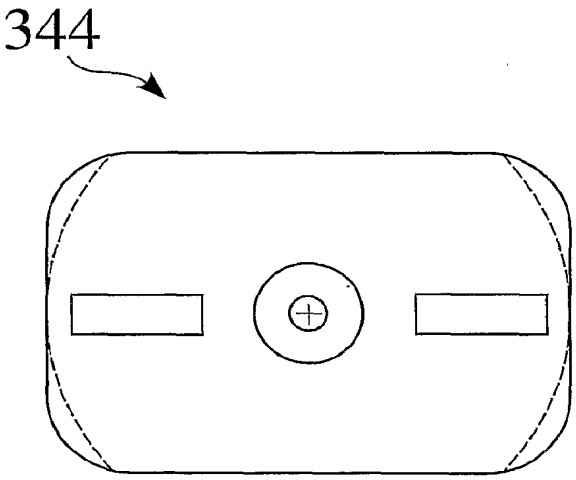


Fig. 65

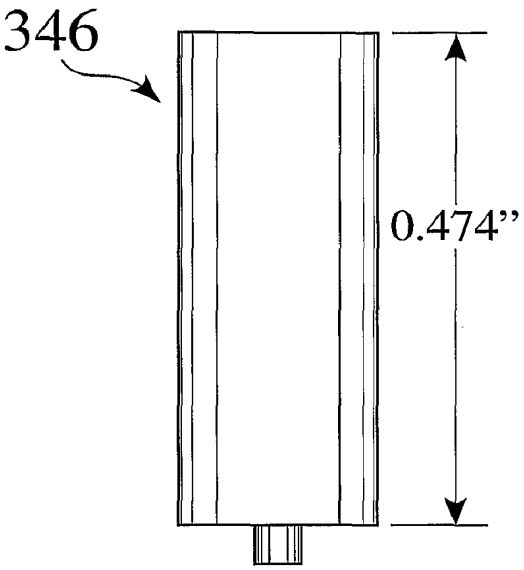


Fig. 66

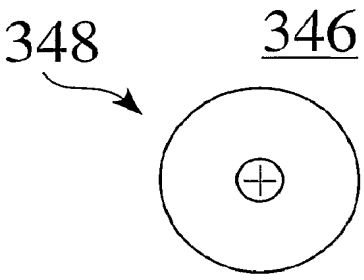


Fig. 67

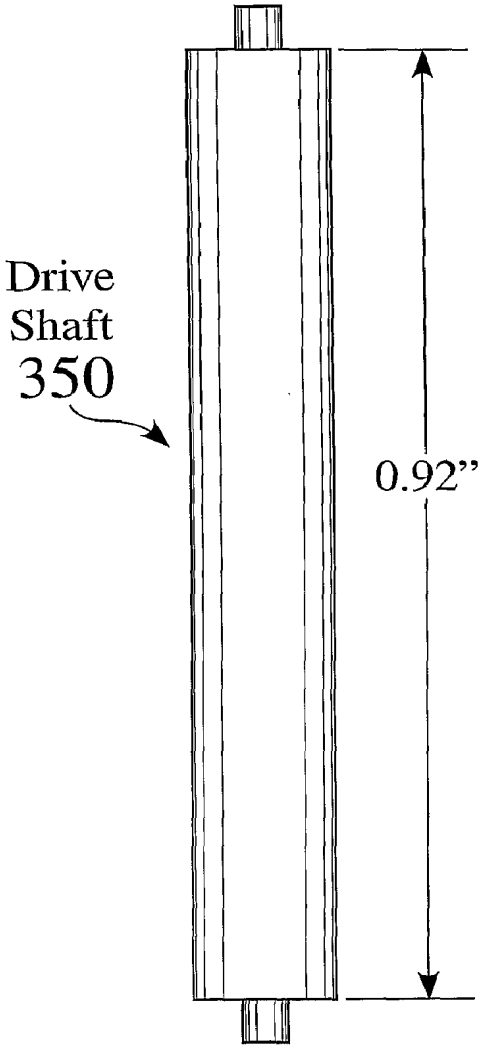


Fig. 68

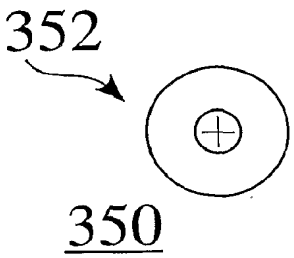


Fig. 69

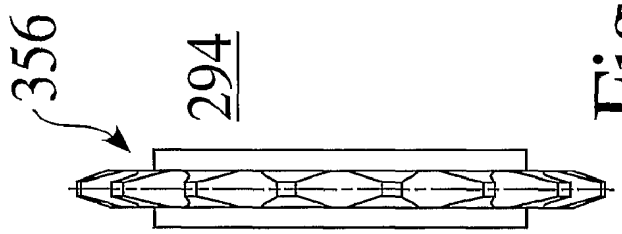


Fig. 71

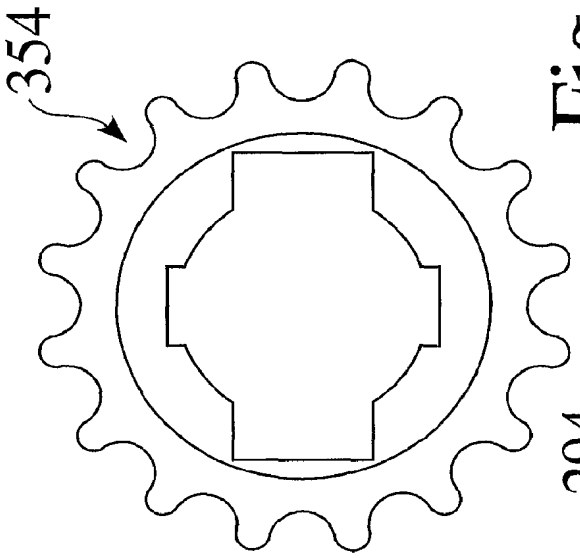


Fig. 70

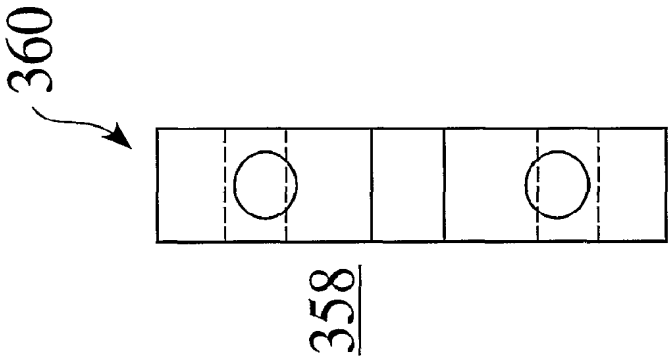


Fig. 73

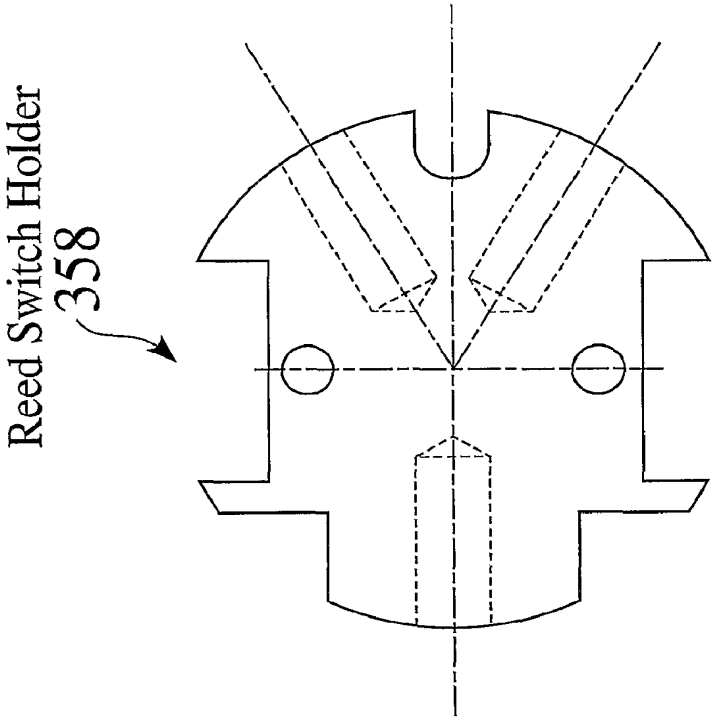


Fig. 72

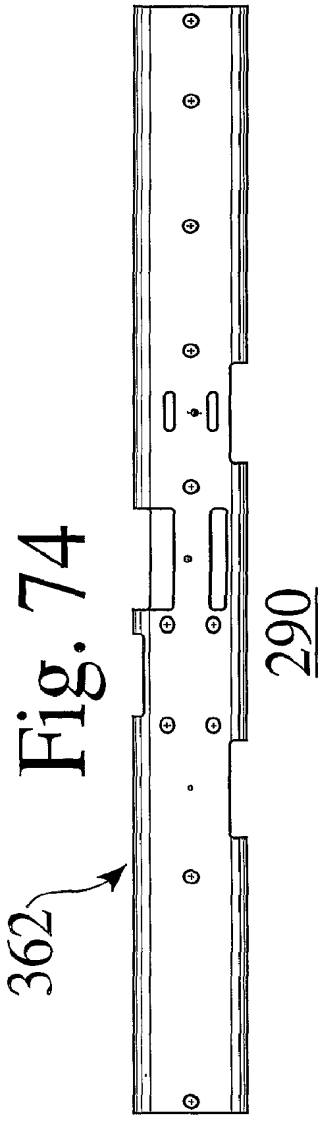


Fig. 74

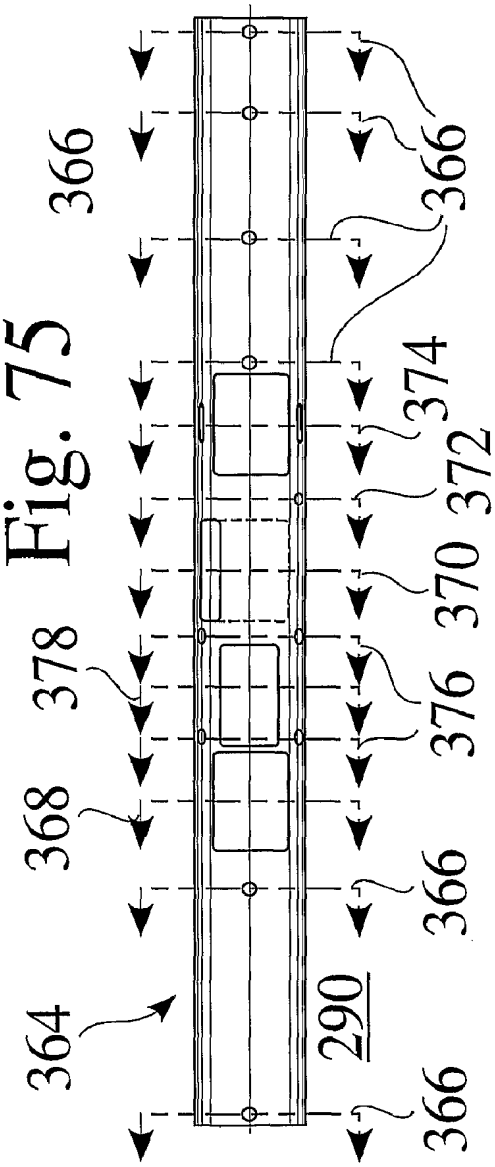


Fig. 75

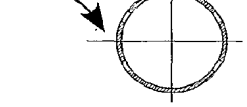


Fig. 79

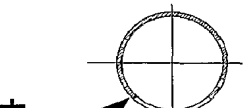


Fig. 80

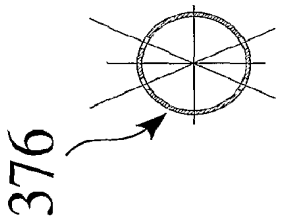


Fig. 81

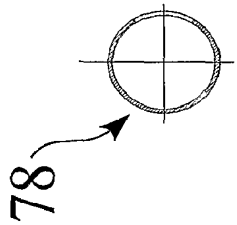


Fig. 82

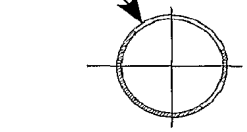


Fig. 78

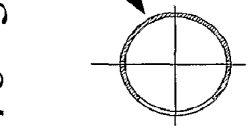


Fig. 77

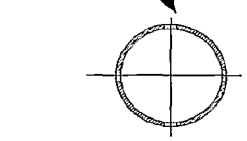


Fig. 76

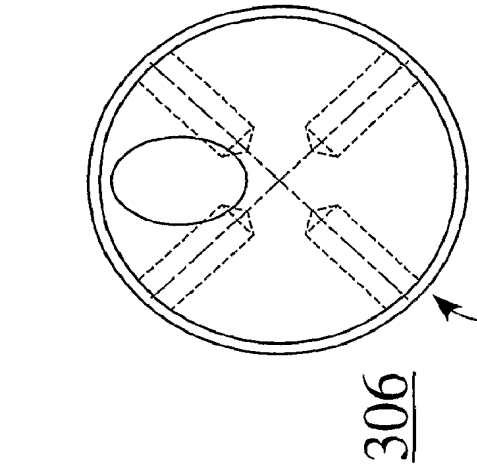


Fig. 85

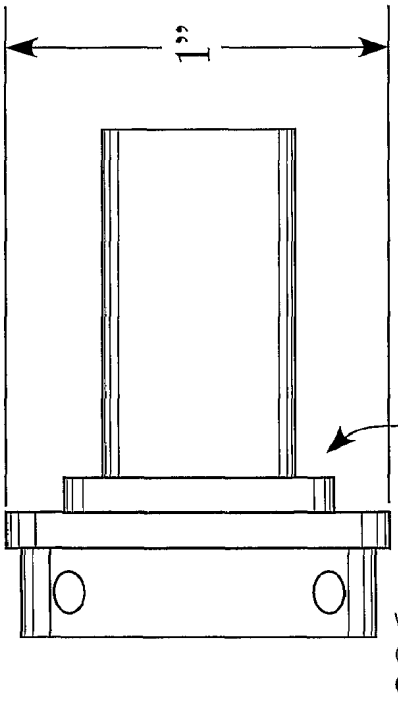


Fig. 83

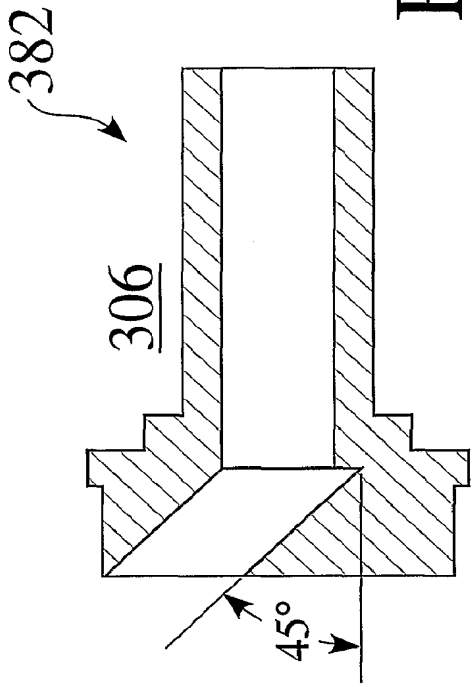


Fig. 84

Fig. 90

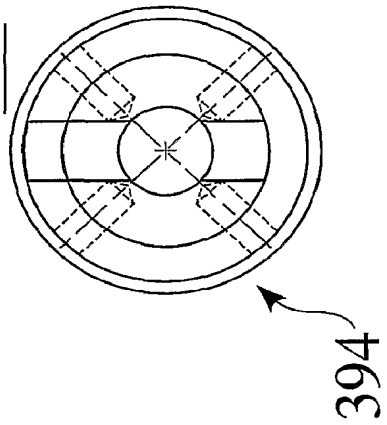


Fig. 91

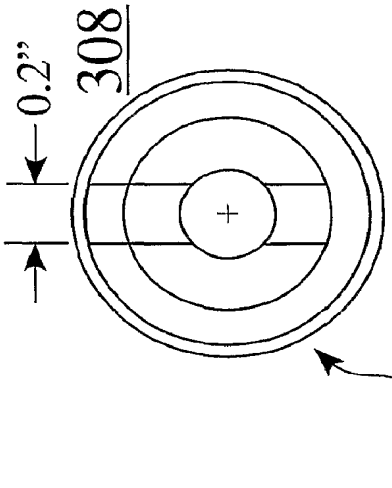


Fig. 86

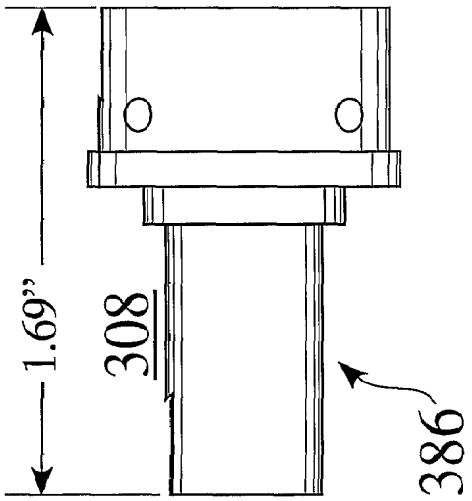


Fig. 87

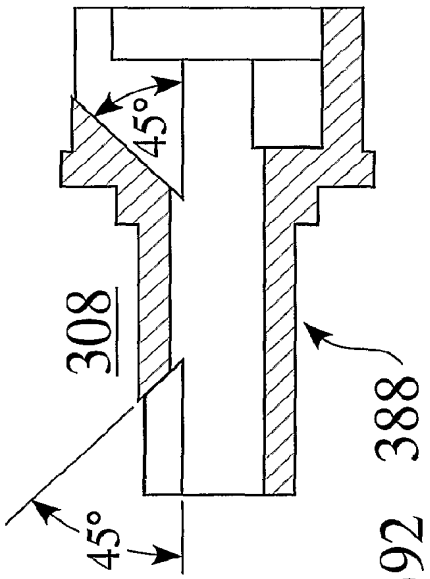


Fig. 88

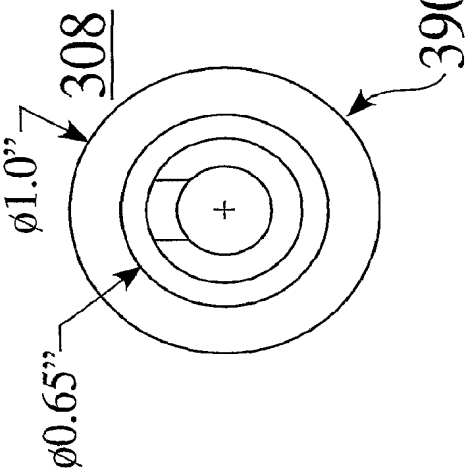
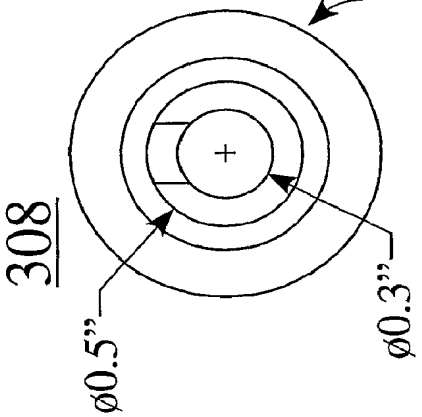


Fig. 89



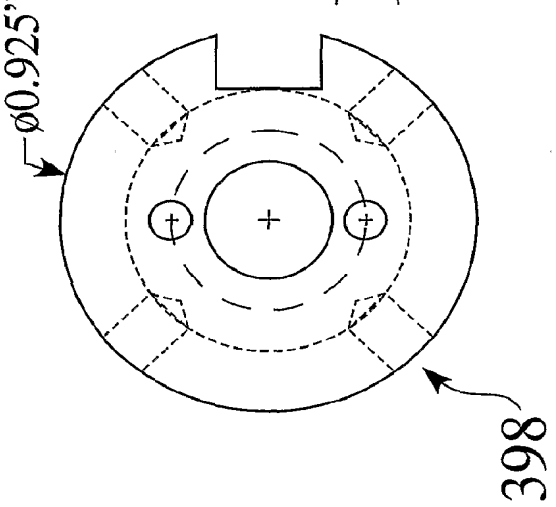


Fig. 92

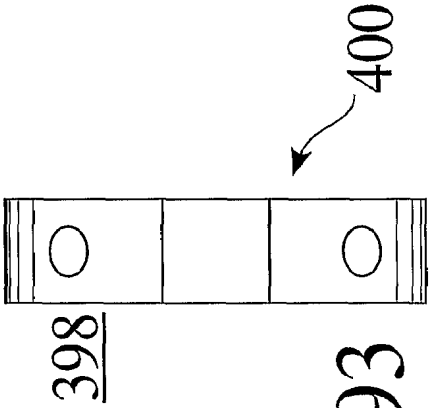


Fig. 93

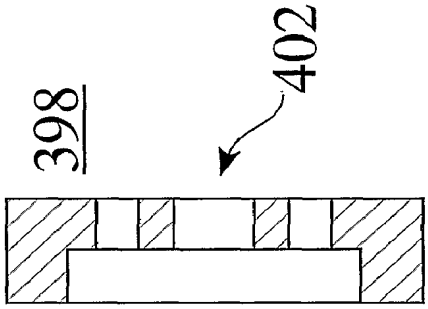


Fig. 94

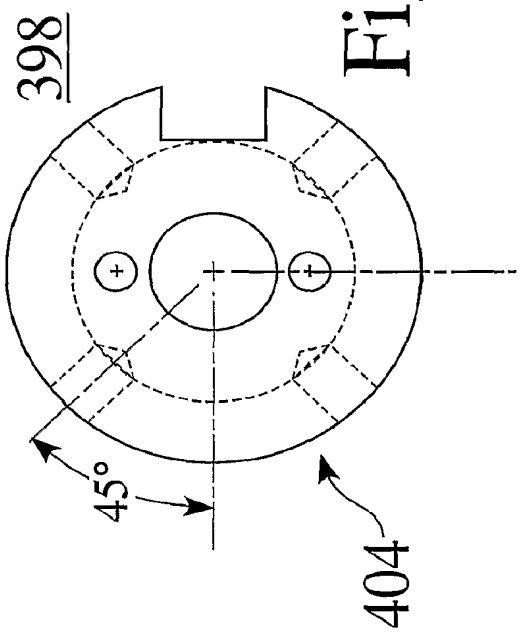


Fig. 95

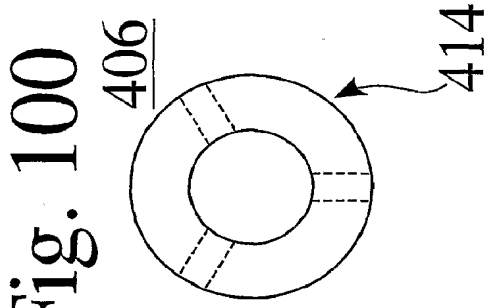


Fig. 100

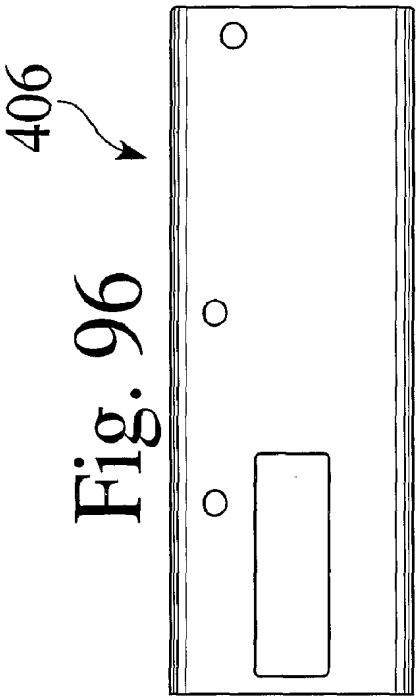


Fig. 96

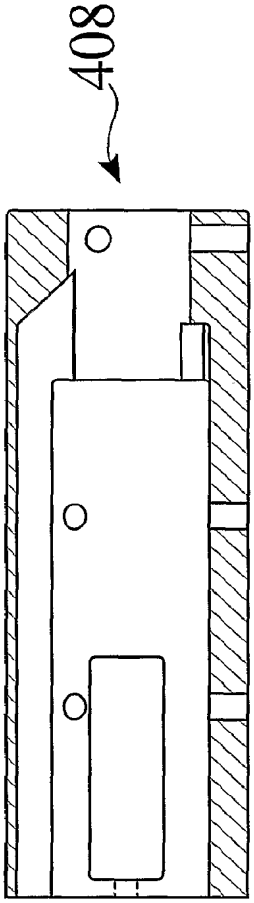


Fig. 97

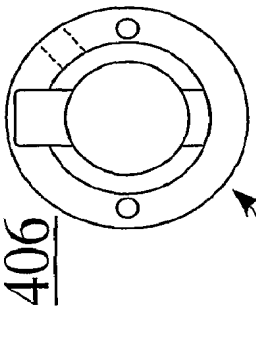


Fig. 98

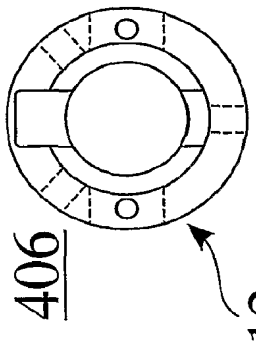


Fig. 99

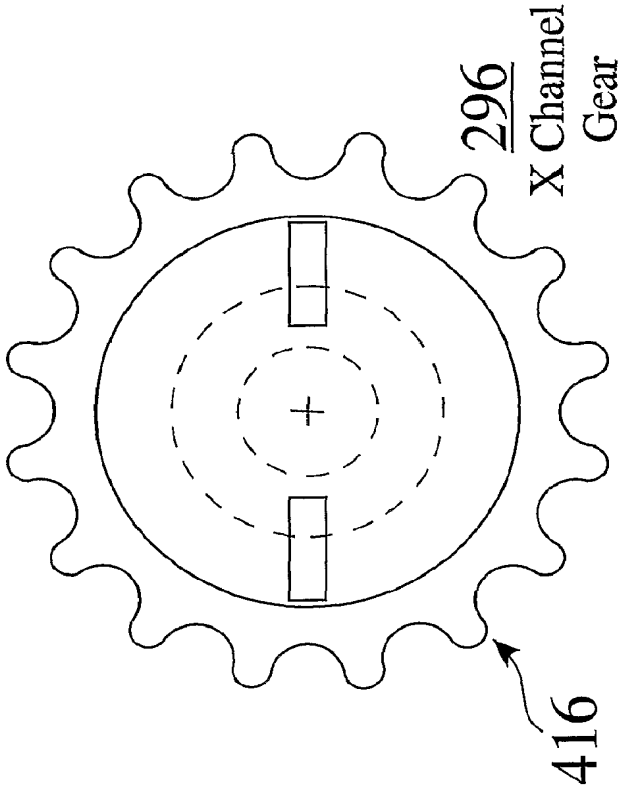


Fig. 101

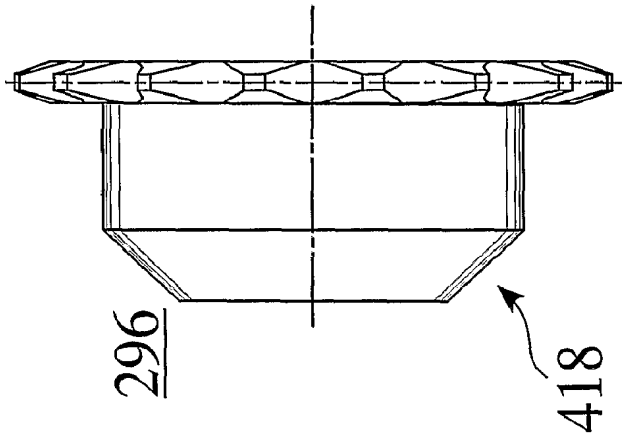


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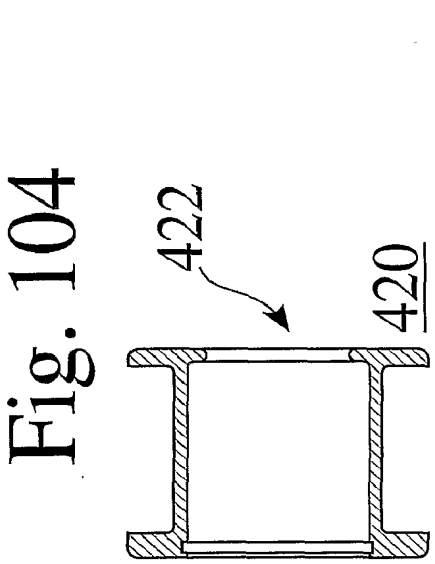


Fig. 104

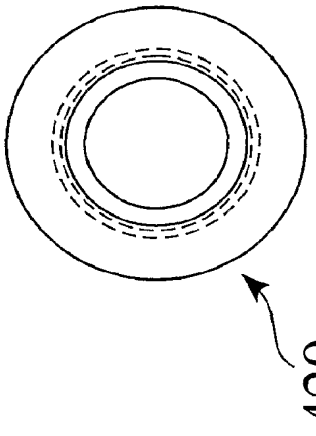


Fig. 103

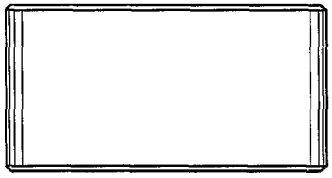


Fig. 106

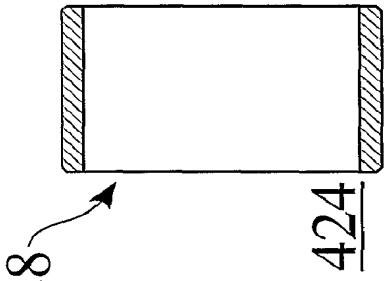


Fig. 107

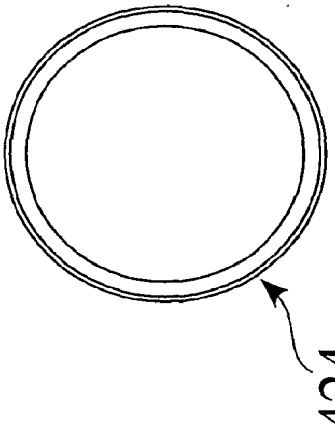


Fig. 105

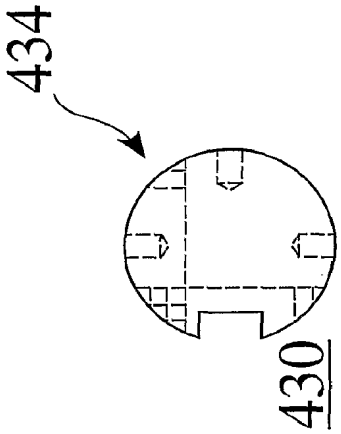


Fig. 110

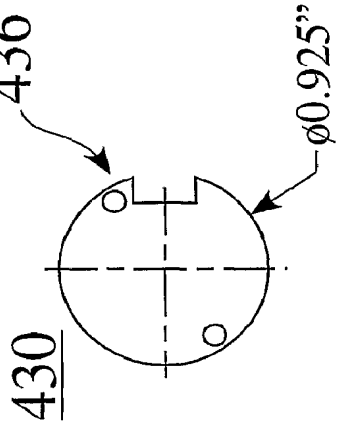


Fig. 111

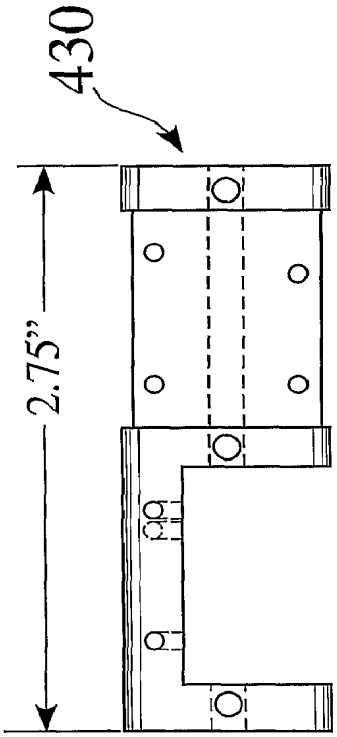


Fig. 108

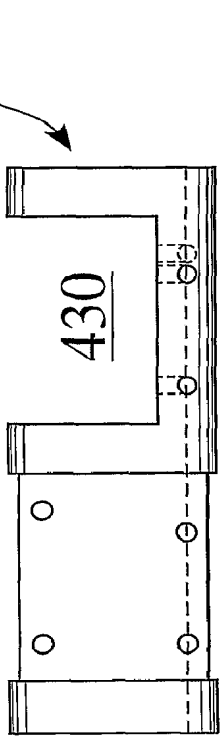


Fig. 109

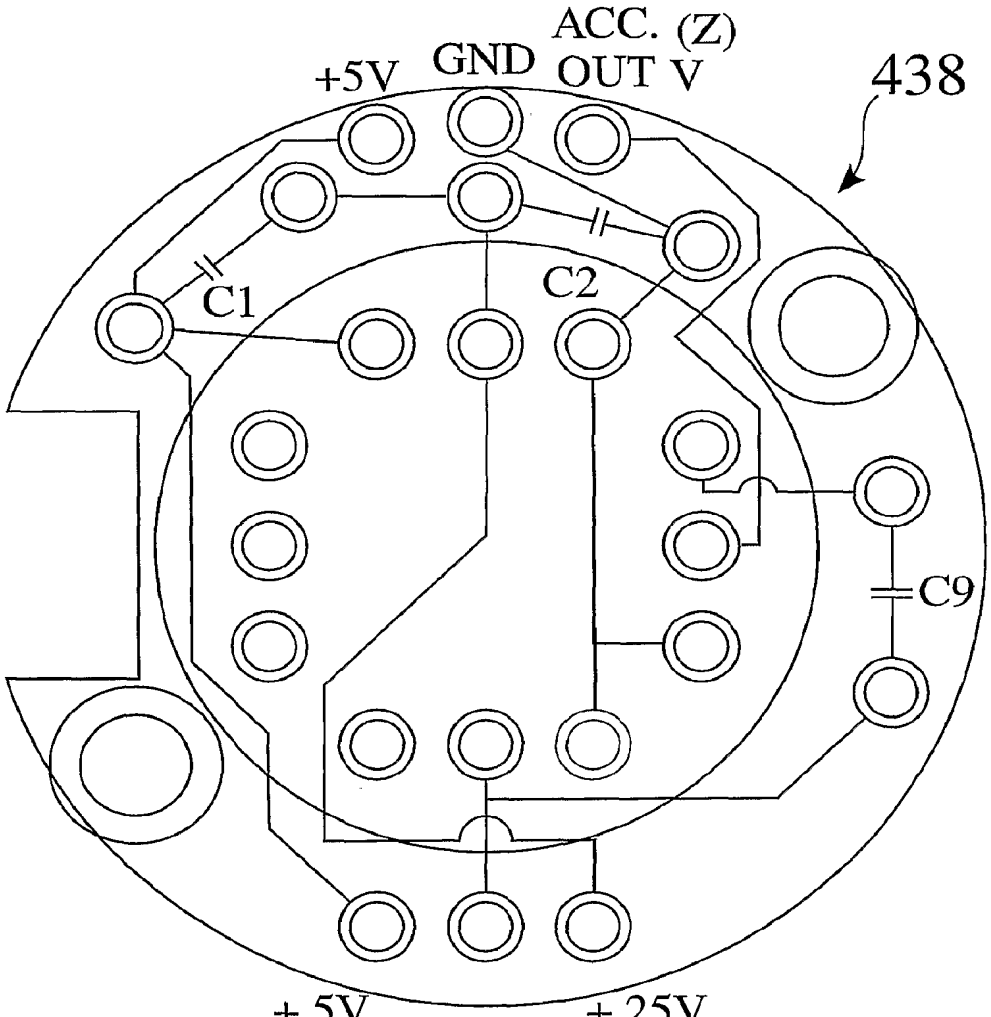
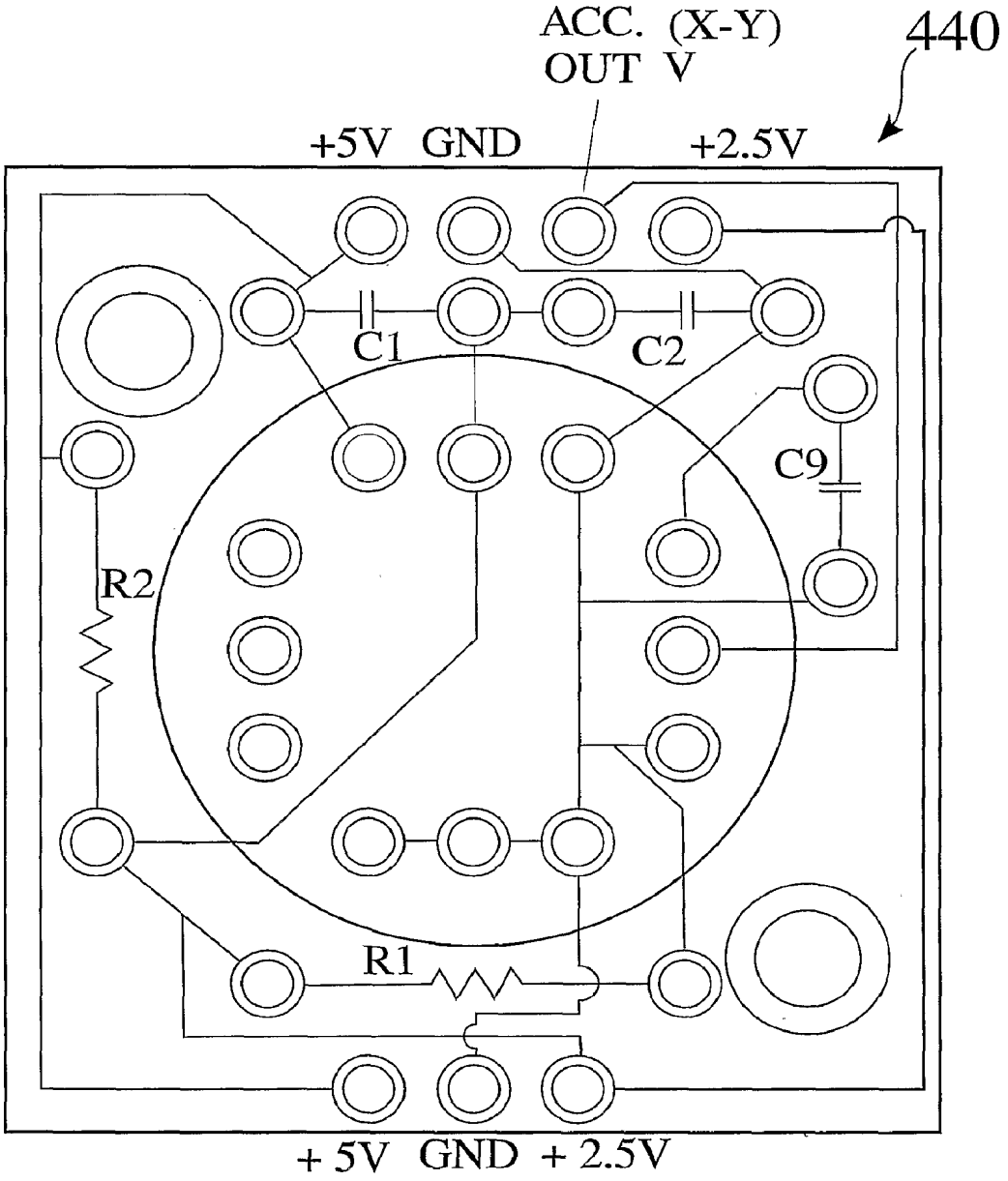


Fig. 112



Accelerometer Board
X and Y

Fig. 113

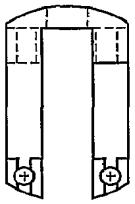


Fig. 114

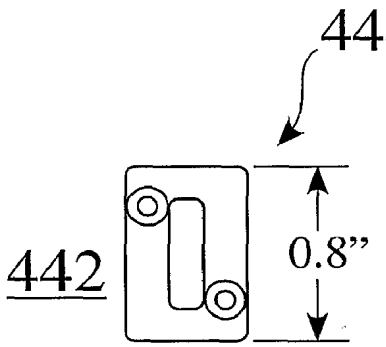


Fig. 115

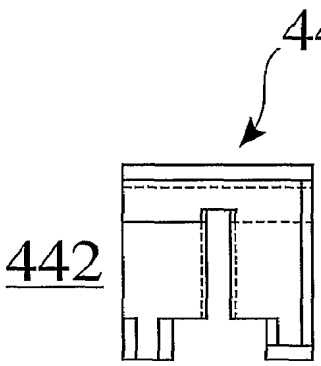


Fig. 116

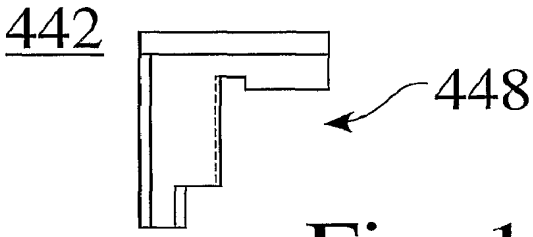


Fig. 117

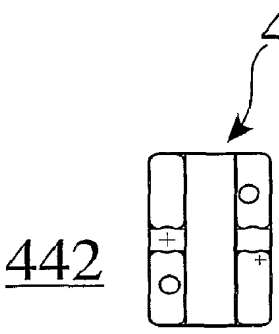


Fig. 118

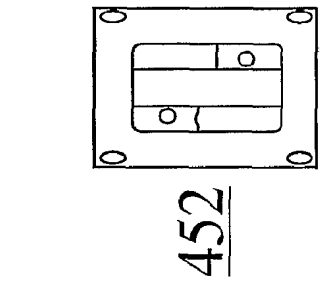


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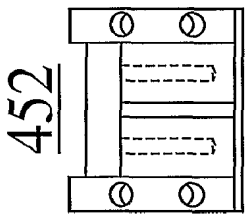


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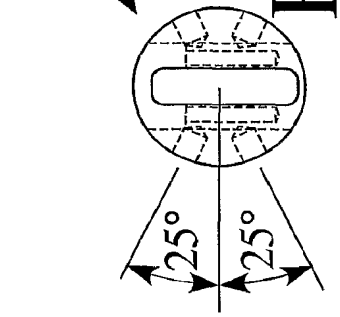


Fig. 123

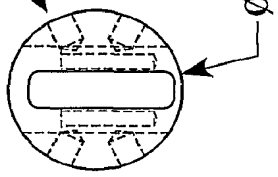


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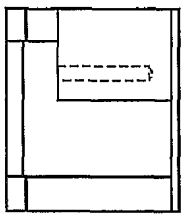


Fig. 121

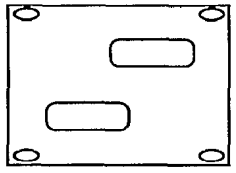


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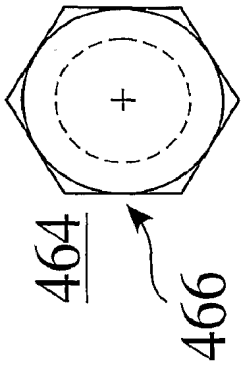


Fig. 126

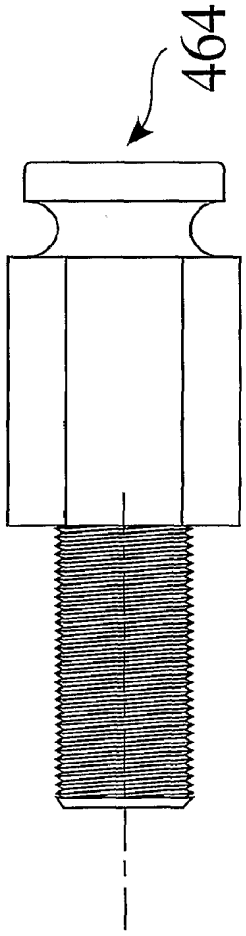


Fig. 125

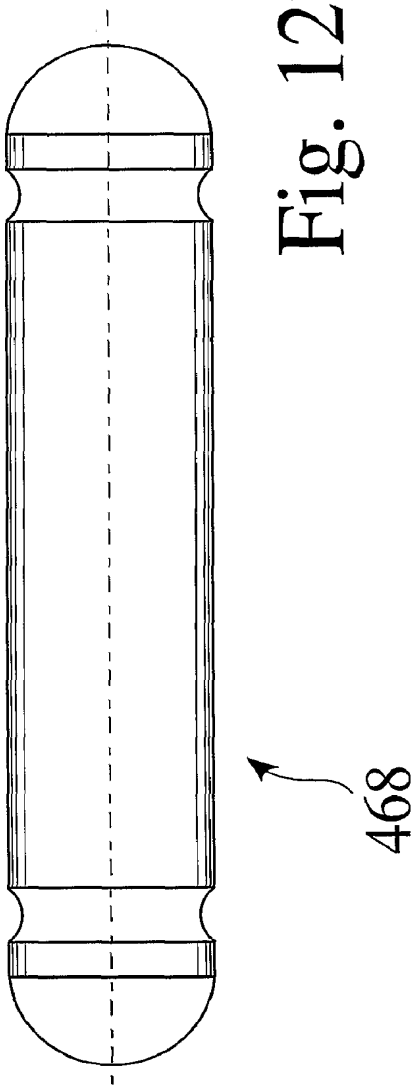


Fig. 127

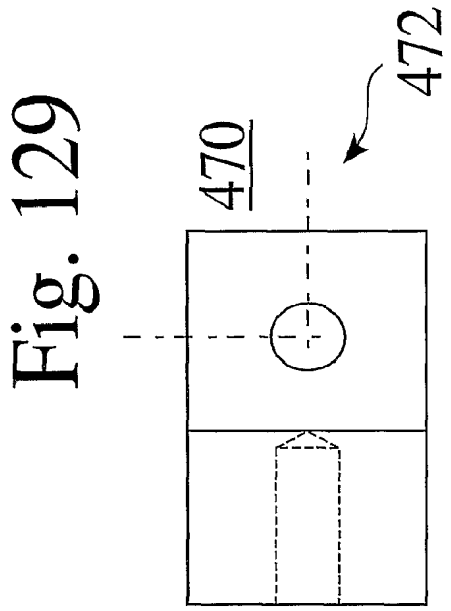


Fig. 129

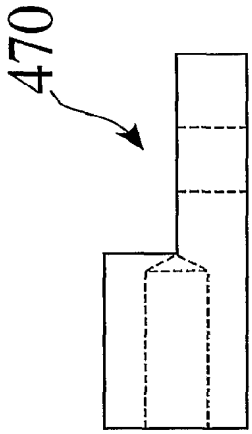


Fig. 128

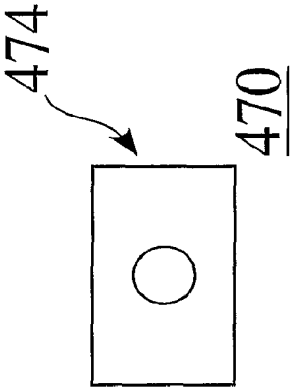


Fig. 130

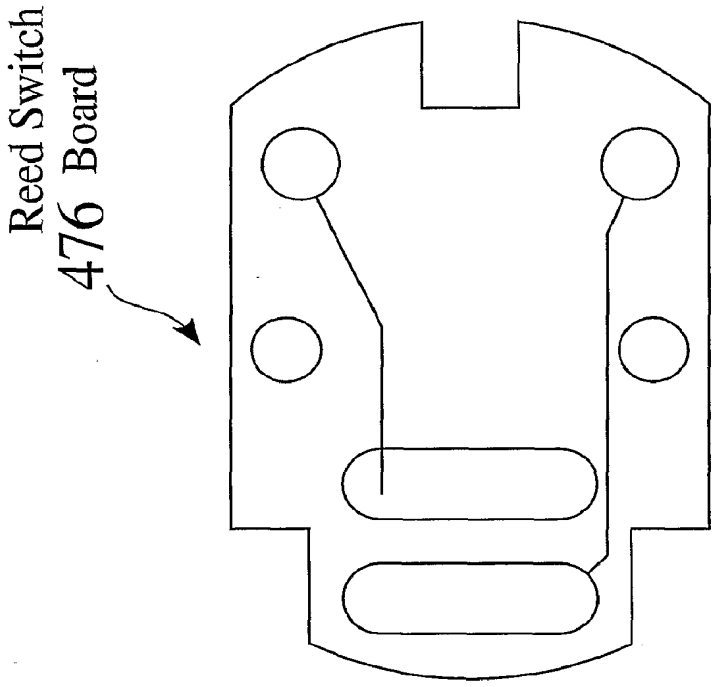
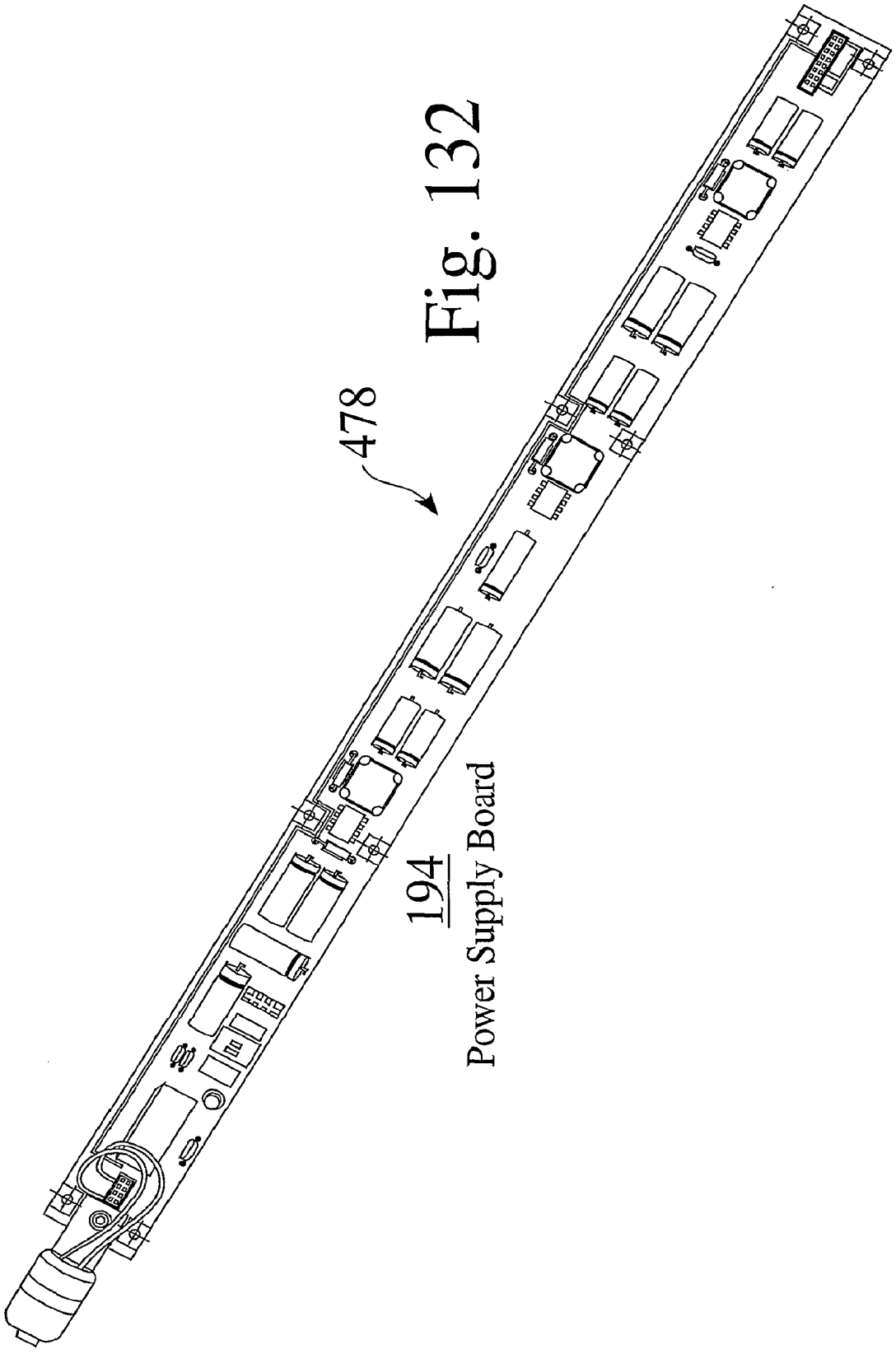


Fig. 131

Fig. 132



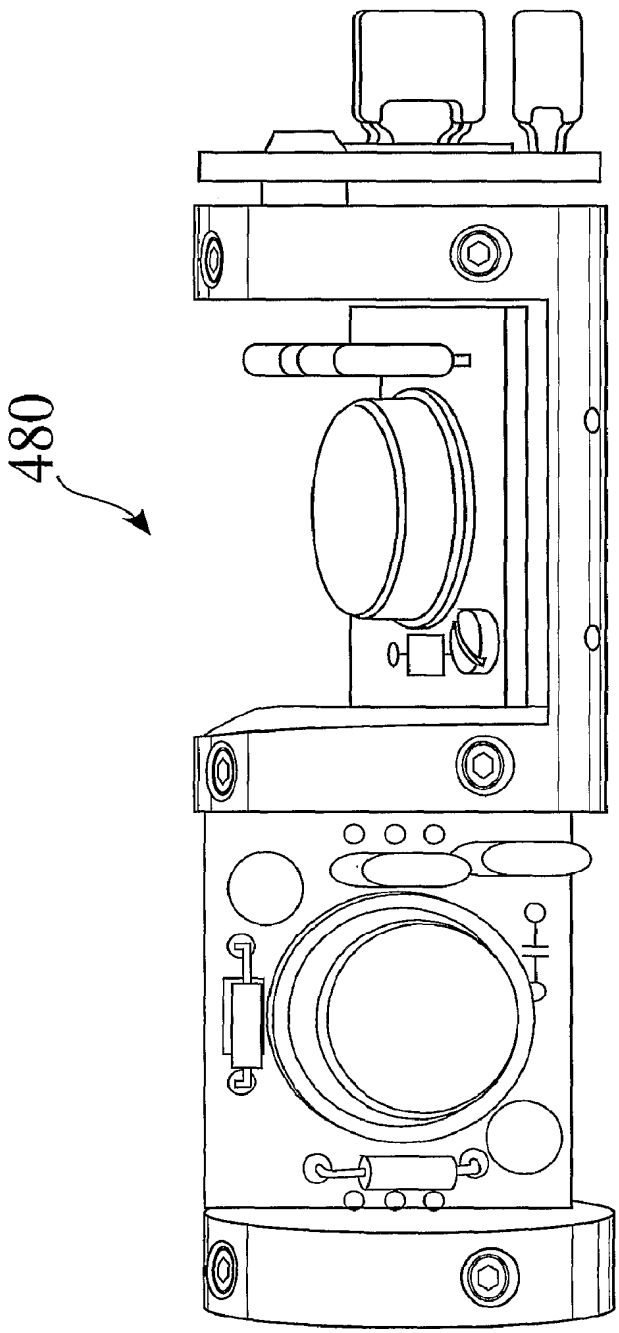
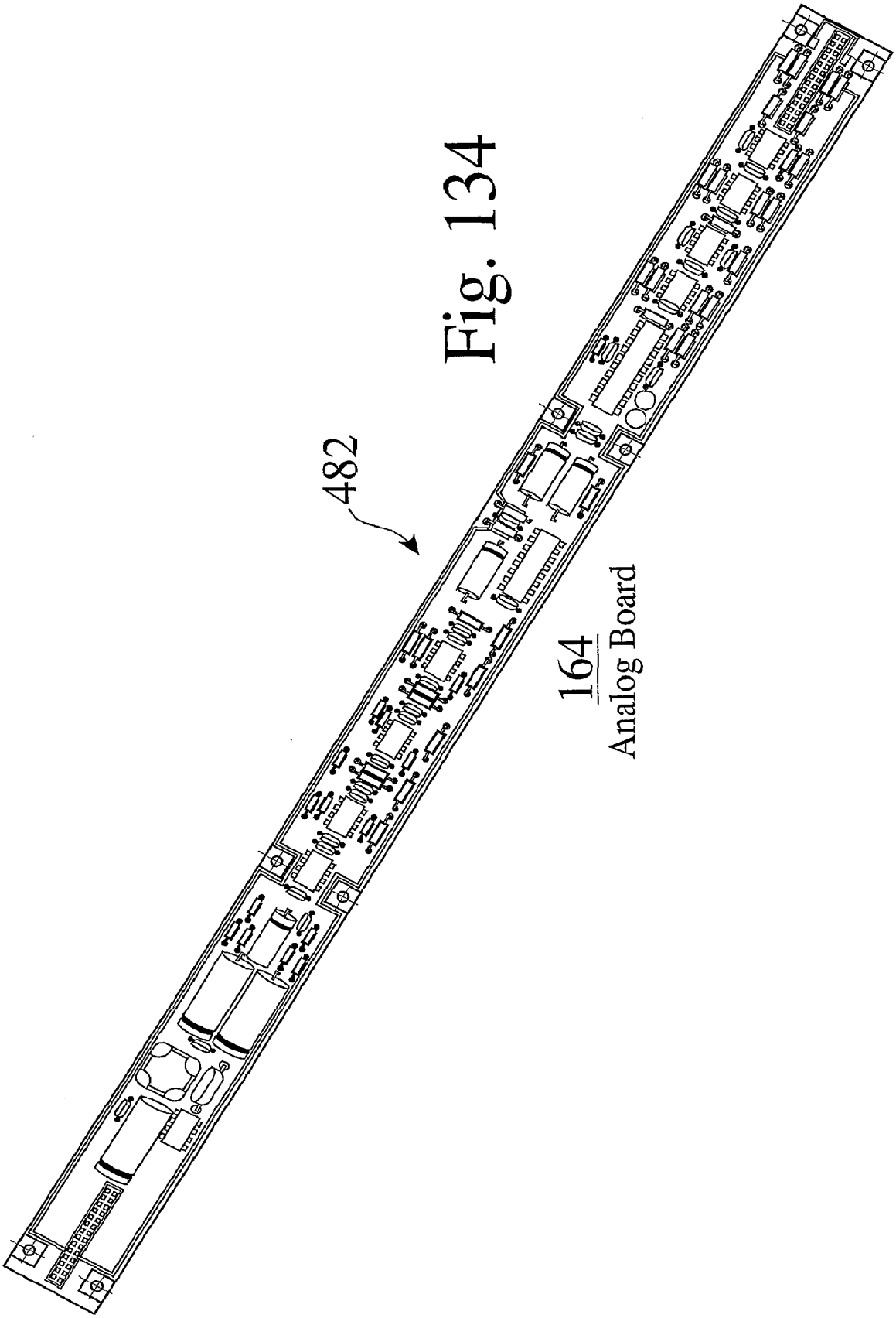


Fig. 133

Fig. 134



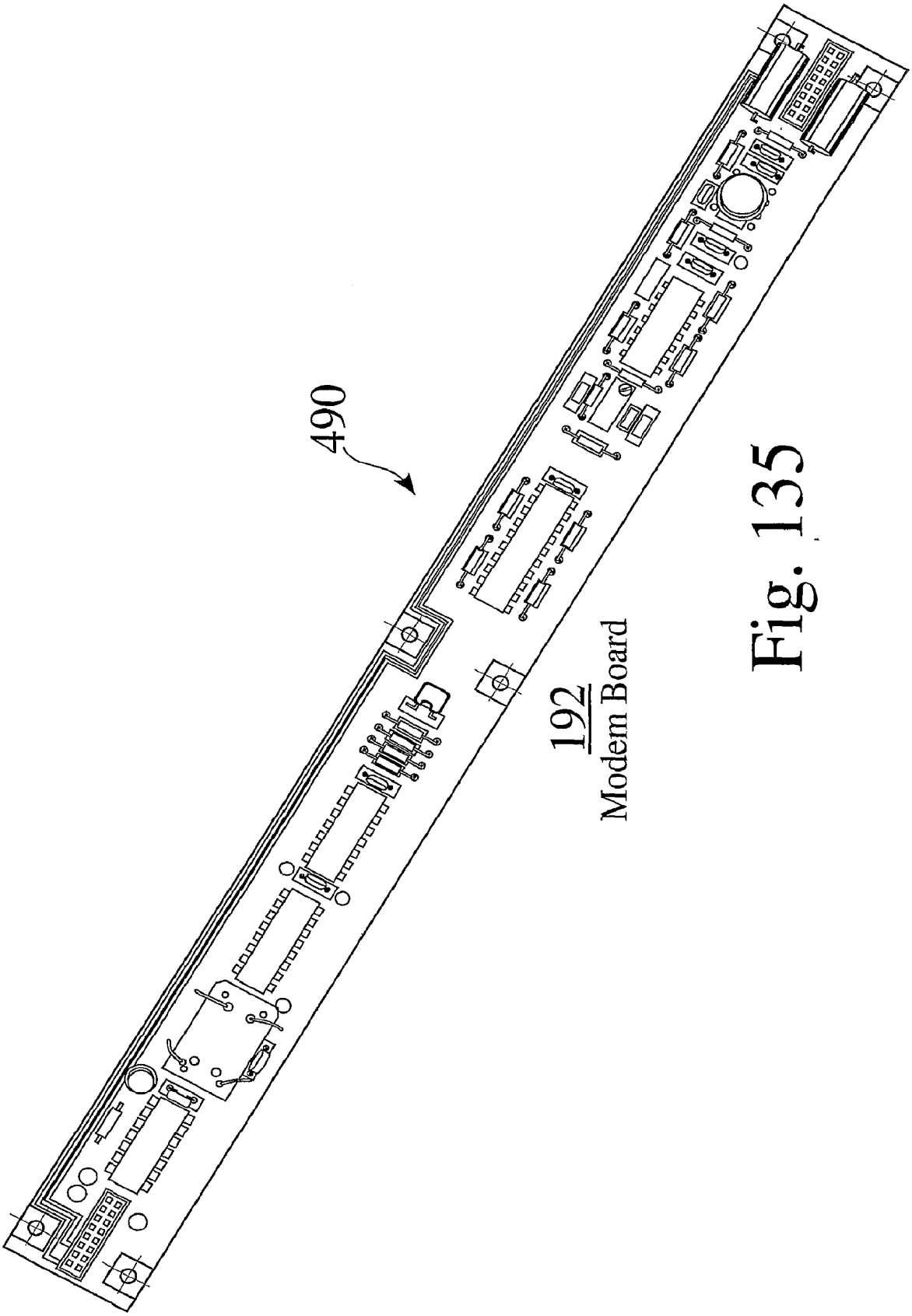


Fig. 135

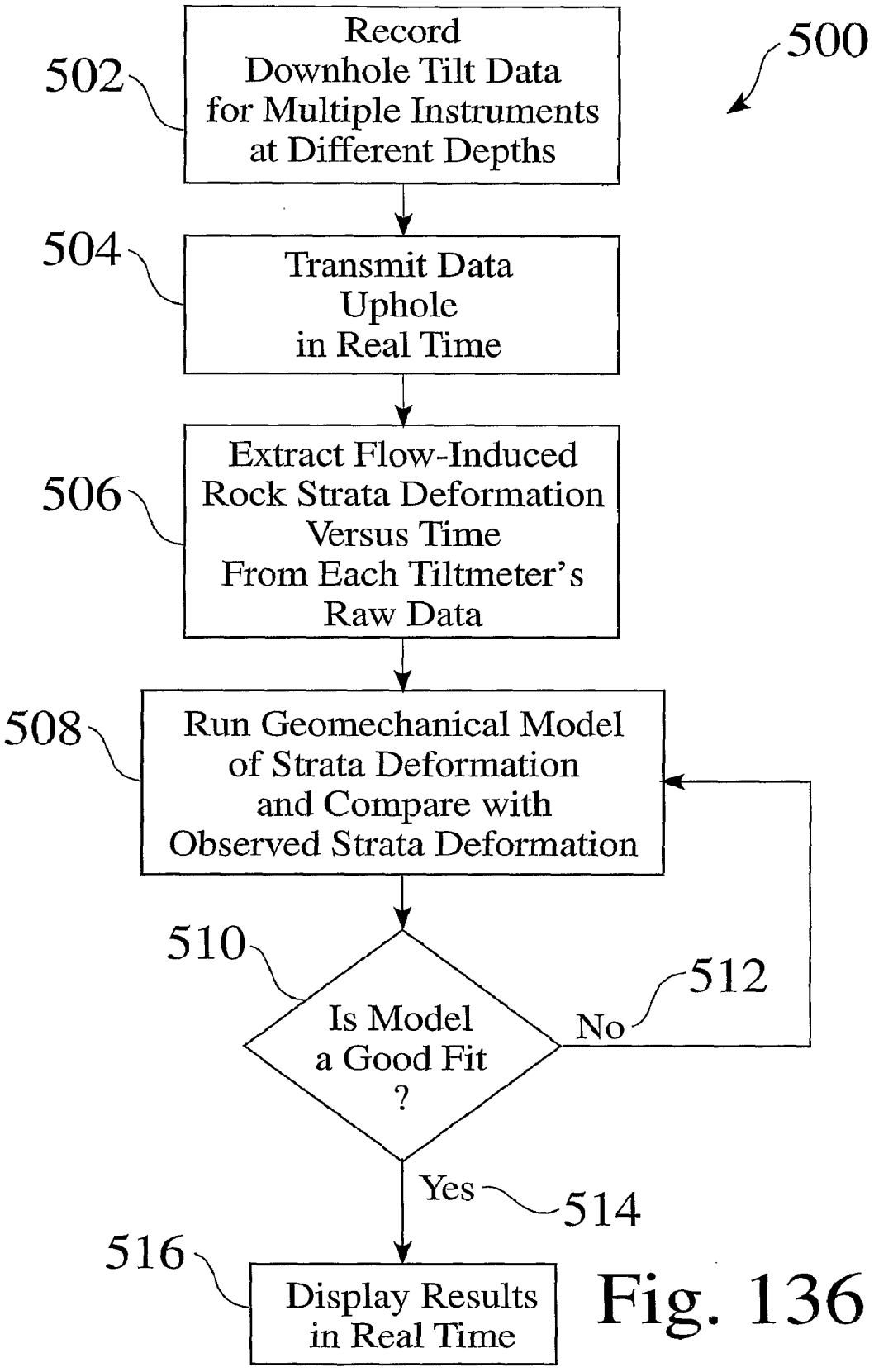

Record Downhole Tilt Data for Multiple Instruments at Different Depths
502
500
Transmit Data Uphole in Real Time
504
Extract Flow-Induced Rock Strata Deformation Versus Time From Each Tiltmeter's Raw Data
506
Run Geomechanical Model of Strata Deformation and Compare with Observed Strata Deformation
508
Is Model a Good Fit ?
510
No
512
Yes
514
Display Results in Real Time
516

Fig. 136

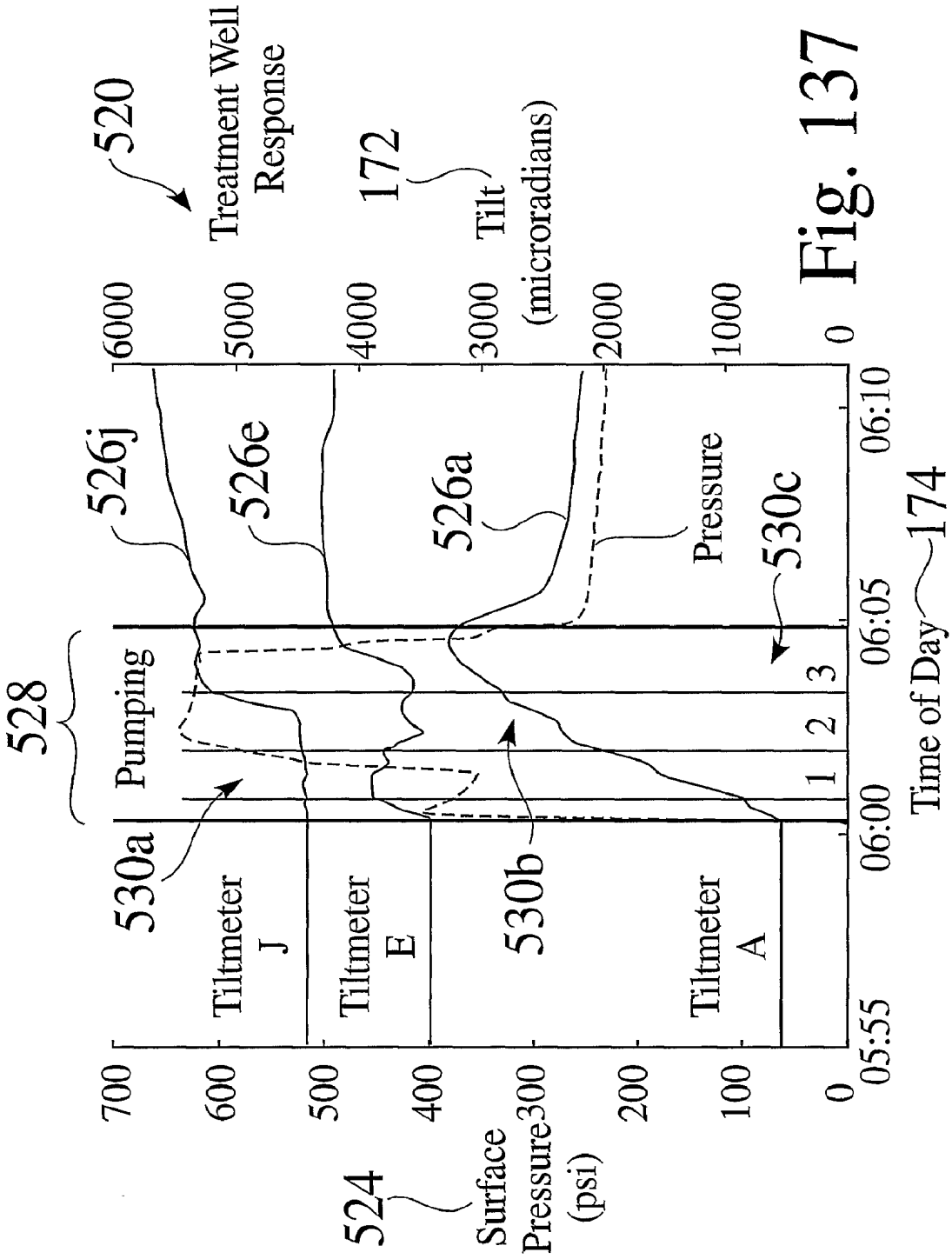

520
Treatment Well Response
172
Tilt (microradians)
526j
526e
526a
Pressure
530c
528
Pumping
530a
530b
Tiltmeter J
Tiltmeter E
Tiltmeter A
524
Surface Pressure (psi)
174
Time of Day
05:55
06:00
06:05
06:10
1
2
3
0
100
200
300
400
500
600
700
1000
2000
3000
4000
5000
6000

Fig. 137

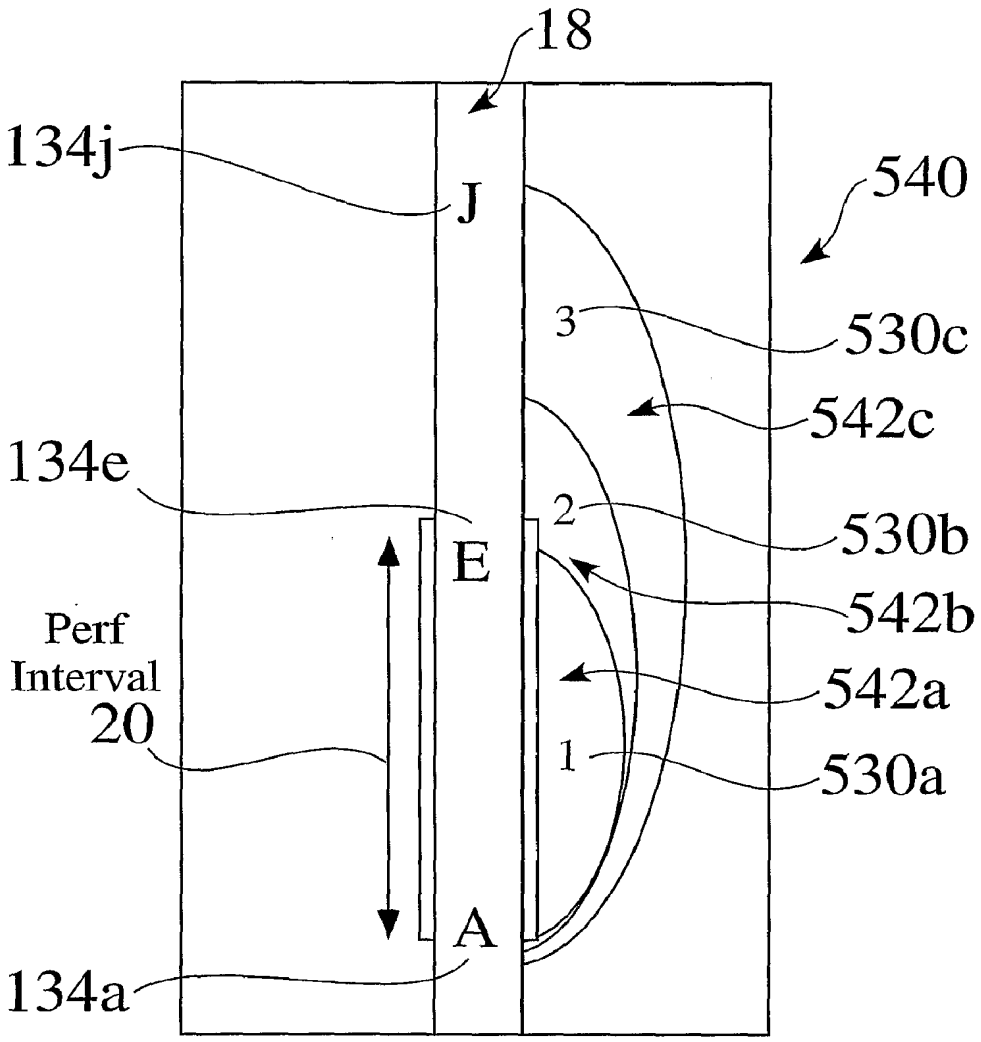

18
134j
J
540
3
530c
542c
134e
2
530b
E
542b
Perf
Interval
20
542a
1
530a
A
134a

Fig. 138

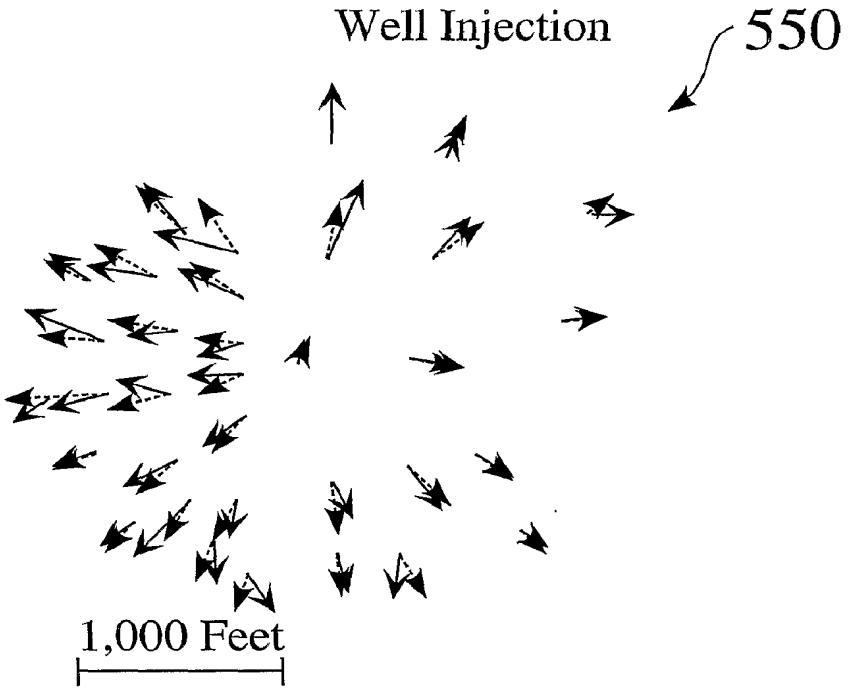

Well Injection
550
1,000 Feet
North
+ Tiltmeter Site
⊕ Wellhead
Measured Tilt
10 Microradians
Theoretical Tilt
10 Microradians

Fig. 139

51/51

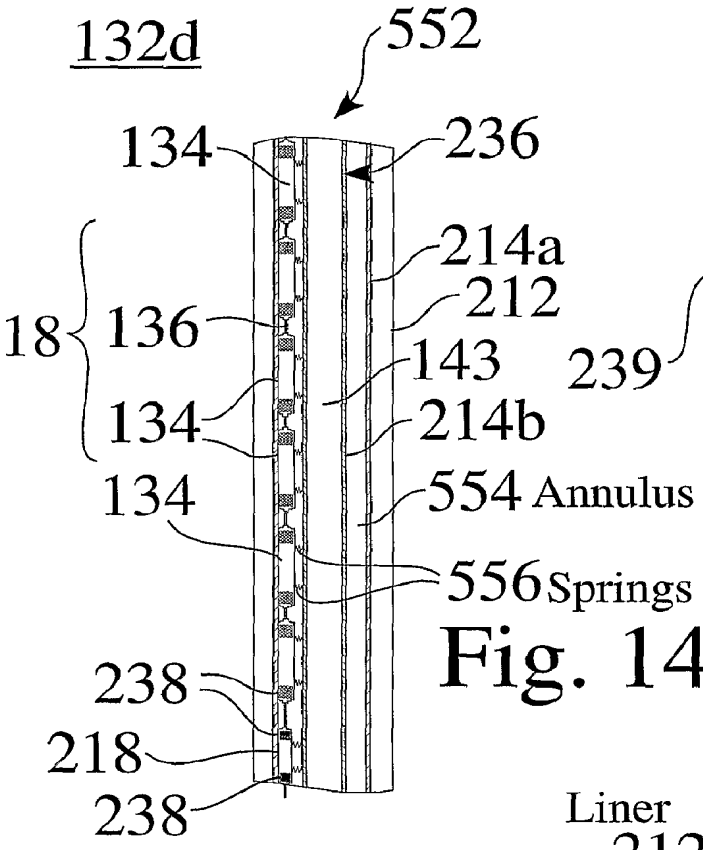


Fig. 140

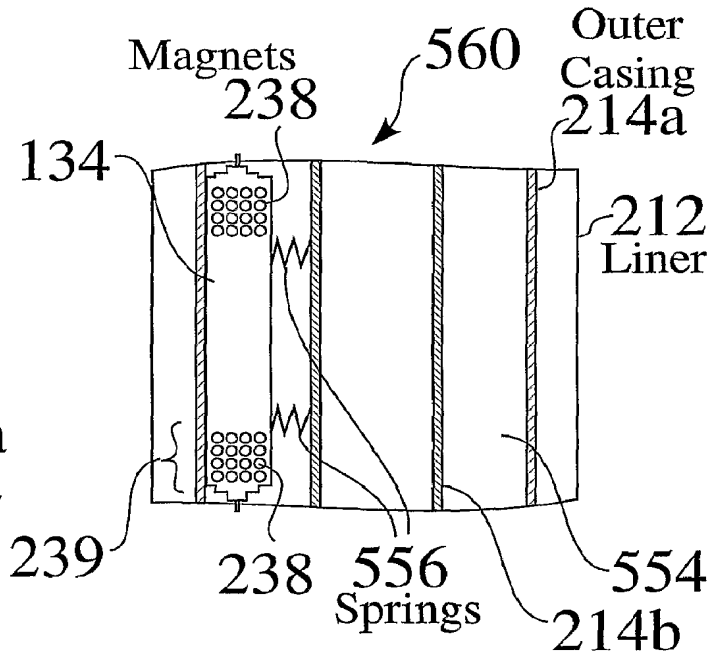


Fig. 141

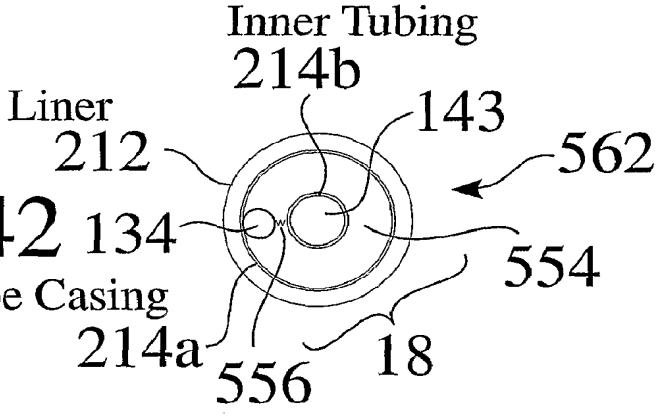


Fig. 142

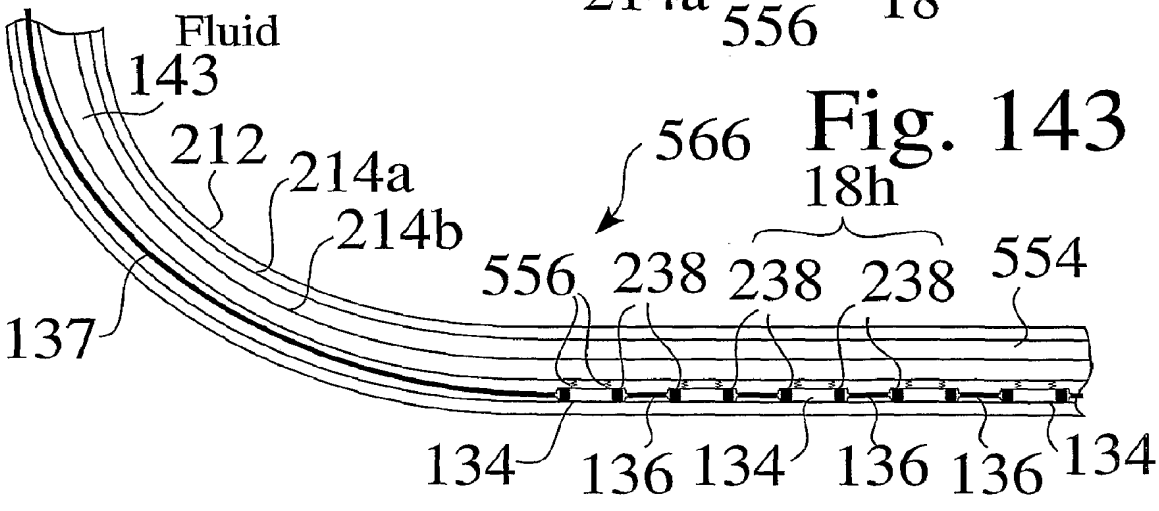


Fig. 143

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(11) **CA 2 482 943** (13) **A1**

(40) **30.10.2003**
(43) **30.10.2003**

(12)

(21) **2 482 943**

(22) **17.04.2003**

(51) Int. Cl.7: **E21B 43/26**, E21B 43/267

(85) **18.10.2004**

(86) **PCT/EP03/004066**

(87) **WO03/089757**

(30) **60/374,217 US 19.04.2002**

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(74)
SMART & BIGGAR

(54) MOYENS ET PROCEDES D'EVALUATION D'UNE FRACTURE SOUTERRAINE PENDANT OU APRES UN TRAITEMENT DE FRACTURATION HYDRAULIQUE

(54) MEANS AND METHOD FOR ASSESSING THE GEOMETRY OF A SUBTERRANEAN FRACTURE DURING OR AFTER A HYDRAULIC FRACTURING TREATMENT

(57)

The present invention relates to methods of fracturing a subterranean formation including the step of pumping at least one device actively transmitting data that provide information on the device position, and further comprising the step of assessing the fracture geometry based on the positions of said at least one device or pumping metallic elements, preferably as proppant agents, and further locating the position of said metallic elements with a tool selected from the group consisting of magnetometers, resistivity tools, electromagnetic devices and ultra-long arrays of electrodes. The invention allows monitoring of the fracture geometry and proppant placement.

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CA 2482943 A1 2003/10/30

(21) 2 482 943

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2003/04/17
(87) Date publication PCT/PCT Publication Date: 2003/10/30
(85) Entrée phase nationale/National Entry: 2004/10/18
(86) N° demande PCT/PCT Application No.: EP 2003/004066
(87) N° publication PCT/PCT Publication No.: 2003/089757
(30) Priorité/Priority: 2002/04/19 (60/374,217) US

(51) Cl.Int.^{7}/Int.Cl.^{7} E21B 43/26, E21B 43/267

(71) Demandeur/Applicant:
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(74) Agent: SMART & BIGGAR

(54) Titre : MOYENS ET PROCEDES D'EVALUATION D'UNE FRACTURE SOUTERRAINE PENDANT OU APRES UN TRAITEMENT DE FRACTURATION HYDRAULIQUE

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(57) Abrégé/Abstract:
The present invention relates to methods of fracturing a subterranean formation including the step of pumping at least one device actively transmitting data that provide information on the device position, and further comprising the step of assessing the fracture geometry based on the positions of said at least one device or pumping metallic elements, preferably as proppant agents, and further locating the position of said metallic elements with a tool selected from the group consisting of magnetometers, resistivity tools, electromagnetic devices and ultra-long arrays of electrodes. The invention allows monitoring of the fracture geometry and proppant placement.

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 October 2003 (30.10.2003)

PCT

(10) International Publication Number
WO 03/089757 A1

(51) International Patent Classification[7]: E21B 43/26, 43/267

(21) International Application Number: PCT/EP03/04066

(22) International Filing Date: 17 April 2003 (17.04.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/374,217 19 April 2002 (19.04.2002) US

(71) Applicant *(for AE, AG, AL, AU, BA, BB, BE, BF, BG, BJ, BR, BZ, CF, CG, CH, CI, CM, CN, CO, CR, CU, CY, CZ, DM, DZ, EC, EE, ES, FI, GA, GD, GE, GH, GM, GN, GQ, GR, GW, HU, ID, IE, IL, IN, IS, KE, KP, LC, LK, LR, LS, LT, LU, LV, MA, MC, MG, MK, ML, MN, MR, MW, MX, MZ, NE, NI, OM, PH, PT, SC, SD, SE, SG, SI, SK, SL, SN, SZ, TD, TG, TN, TR, TT, TZ, UG, UZ, VC, VN, YU, ZM, ZW only)*: **SOFITECH N.V.** [BE/BE]; 140 rue de Stalle, B-B-1180 Brussels (BE).

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 03/089757 A1

(54) Title: MEANS AND METHOD FOR ASSESSING THE GEOMETRY OF A SUBTERRANEAN FRACTURE DURING OR AFTER A HYDRAULIC FRACTURING TREATMENT

(57) Abstract: The present invention relates to methods of fracturing a subterranean formation including the step of pumping at least one device actively transmitting data that provide information on the device position, and further comprising the step of assessing the fracture geometry based on the positions of said at least one device or pumping metallic elements, preferably as proppant agents, and further locating the position of said metallic elements with a tool selected from the group consisting of magnetometers, resistivity tools, electromagnetic devices and ultra-long arrays of electrodes. The invention allows monitoring of the fracture geometry and proppant placement.

Means and Method for assessing the geometry of a subterranean fracture during or after a hydraulic fracturing treatment

Technical Field of the Invention

[0001] This invention relates generally to the art of hydraulic fracturing in subterranean formations and more particularly to a method and means for assessing the fracture geometry during or after the hydraulic fracturing.

Background of the Invention

[0002] Hydraulic fracturing is a primary tool for improving well productivity by placing or extending cracks or channels from the wellbore to the reservoir. This operation is essentially performed by hydraulically injecting a fracturing fluid into a wellbore penetrating a subterranean formation and forcing the fracturing fluid against the formation strata by pressure. The formation strata or rock is forced to crack, creating or enlarging one or more fractures. Proppant is placed in the fracture to prevent the fracture from closing and thus, provide improved flow of the recoverable fluid, i.e., oil, gas or water.

[0003] The proppant is thus used to hold the walls of the fracture apart to create a conductive path to the wellbore after pumping has stopped. Placing the appropriate proppant at the appropriate concentration to form a suitable proppant pack is thus critical to the success of a hydraulic fracture treatment.

[0004] The geometry of the hydraulic fracture placed affects directly the efficiency of the process and the success of the operation. This geometry is generally inferred using models and data interpretation, but to date, no direct measurements are available. The present invention is aimed at obtaining more direct measurements of the fracture geometry (e.g. length, height away from the wellbore).

[0005] The fracture geometry is often inferred through use of models and interpretation of pressure measurements. Occasionally, temperature logs and/or radioactive tracer logs are used to infer fracture height near the wellbore. Microseismic events generated in the vicinity of the created hydraulic fracture are recorded and interpreted to indicate the direction (azimuth) and length and height of the created fracture.

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[0006] However, these known methods are indirect measurement, and rely on interpretations that may be erroneous, and are difficult to use for real-time evaluation and optimization of the hydraulic fracture treatment.

[0007] It is therefore an object of the present invention to provide a new approach to evaluate the fracture geometry.

Summary of the Invention

[0008] According to the present invention, the fracture geometry is evaluated by placing inside the fracture small devices that, either actively or passively, give us measurements of the fracture geometry. Fracture materials (small objects with distinctive properties e.g. metal beads with very low resistivity) or devices (e.g. small electronic or acoustic transmitters) are introduced into the fracture during the fracture treatment with the fracturing fluid.

[0009] According to a first embodiment of the present invention, active devices are added into the fracturing fluid. These devices will actively transmit data that provide information on the device position and thereafter, can be associated with fracture geometry.

[0010] According to another embodiment of the present invention, passive devices are added into the fracturing fluid. In the preferred embodiment, these passive devices are also used as proppant.

Detailed description and preferred embodiments

[0011] Examples of "active" device include electronic microsensors , for example such as radio frequency transmitter, or acoustic transceivers. These "active" devices will be integrated with location tracking hardware to transmit their position as they flow with the fracture fluid/slurry inside the created fracture. The microsensors can be pumped with the hydraulic fracturing fluids throughout the treatment or during selected strategic stage of the fracturing treatment (pad, forward portion of the proppant-loaded fluid, tail portion of the proppant-loaded fluid) to provide direct indication of the fracture length and height. The microsensors would form a network using wireless links to neighboring microsensors and have location and positioning capability through for example local positioning algorithms.

[0012] Pressure and Temperature sensors could also be integrated with the above-mentioned active devices. The resulting pressure and temperature measurements

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would be used to better calibrate and advance the modeling techniques for hydraulic fracture propagation. They would also allow optimization of the fracturing fluids by indicating the actual conditions under which these fluids are expected to perform. In addition chemical sensors could also be integrated to allow monitoring of the fluid performance during the treatment.

[0013] Since the number of active devices required is small compared to the number of proppant grains, it is possible to use devices significantly bigger than the proppant pumped in the fracturing fluid. The active devices could be added after the blending unit and slurry pump, for instance through a lateral by-pass.

[0014] Examples of such device include small wireless sensor networks that combine microsensor technology, low power distributed signal processing, and low cost wireless networking capability in a compact system as disclosed for instance in International Patent Application WO0126334, preferably using a data-handling protocol such as TinyOS, so that the devices organize themselves in a network by listening to one another, therefore allowing communication from the tip of the fracture to the well and on to the surface even if the signals are weak so that the signals are relayed from the farthest devices towards the devices still closest to the recorder to allow uninterrupted transmission and capture of data.. The sensors may be designed using MEMS technology or the spherical shaped semiconductor integrated circuit as known form U.S. Patent 6,004,396.

[0015] A recorder placed at surface or, downhole in the wellbore, could capture and record/transmit the data sent by the devices to a computer for further processing and analysis. The data could also be transmitted to offices in any part of the world using the Internet to allow remote participation in decisions affecting the hydraulic fracturing treatment outcome.

[0016] Should the frequency range utilized by the electronic transmitters be such that the borehole metal casing would block its transmission from the formation behind the casing into the wellbore, antennas could be deployed across the perforation tunnels. These antennas could be mounted on non-conductive spherical or ovoid balls slightly larger than the perforation diameter and designed to be pumped and to seat in some of the perforations and relay the signals across the metallic casing wall. An alternative

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method of deployment would be for the transmitter to trail an antenna wire while being pumped.

[0017] A further variant would cover the case where the measuring devices are optical fibers with a physical link to a recorder at surface or in the borehole that would be deployed through the perforations when the well is cased perforated or directly into the fracture in an open hole situation. The optical fiber would allow length measurements as well as pressure and temperature.

[0018] An important alternative embodiment of this invention covers the use of materials with specific properties that would enable information on the fracture geometry to be obtained using an additional measurement device.

[0019] Specific examples of "passive" materials include the use of metallic fibers or beads as proppant. These would replace some or all of the conventional proppant and may have sufficient compressive strength to resist crushing at fracture closure. A tool to measure resistivity at varying depths of investigation would be deployed in the borehole of the fractured well. As the proppant is conductive with a significant contrast in resistivity compared to the surrounding formations, the resistance measurements would be interpreted to provide information on fracture geometry.

[0020] Another example is the use of ferrous/magnetic fibers or beads. These would replace some or all of the conventional proppant and may have sufficient compressive strength to resist crushing at fracture closure. A tool containing magnetometers would be deployed in the borehole of the fractured well. As the proppant generates a significant contrast in magnetic field compared to the surrounding formations, the magnetic field measurements would be interpreted to provide information on fracture geometry. According to a variant of this example, the measuring tools are deployed on the surface or in offset wells. More generally, tools such as resistivity tools, electromagnetic devices, and ultra long arrays of electrodes, can easily detect this proppant enabling fracture height, fracture width, and with processing, the propped fracture length to some extent can be determined.

[0021] A further step is covered whereby the information provided be the techniques described above would be used to calibrate parameters in a fracture propagation model to allow more accurate design and implementation of fractures in nearby wells

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in geological formations with similar properties and immediate action on the design of the fracture being placed to further the economic outcome.

[0022] For example, if the measurements indicate that the fracture treatment is confined to only a portion of the formation interval being treated, real time design tools would validate suggested actions, e.g. increase rate and viscosity of the fluid or use of ball sealer to divert the fluid and treat the remainder of the interval of interest.

[0023] If the measurements indicate that the sought after tip screenout did not occur yet in a typical Frac and Pack treatment and that the fracture created is still at a safe distance from a nearby water zone, the real time design tool would be re-calibrated and used to validate an extension of the pump schedule. This extension would incorporate injection of additional proppant laden slurry to achieve the tip screenout necessary for production performance, while not breaking through into the water zone.

[0024] The measurements would also indicate the success of special materials and pumping procedures that are utilized during a fracture treatment to keep the fracture confined away from a nearby water or gas zone. This knowledge would allow either proceeding with the treatment with confidence of its economic success, or taking additional actions, e.g. re-design or repeat the special pumping procedure and materials to ensure better success at staying away from the water zone.

[0025] Among the "passive" materials, metallic particles may be used. These particles may be added as a "filler" to the proppant or replaces part of the proppant, In a most preferred embodiment, metallic particles consisting of an elongated particulate metallic material, wherein individual particles of said particulate material have a shape with a length-basis aspect ration greater than 5 are used both as proppant and "passive" materials.

[0026] Advantageously, the use of metallic fibers as proppant contributes to enhance proppant conductivity and is further compatible with techniques known to enhance proppant conductivity such as the use of conductivity enhancing materials (in particular the use of breakers) and the use of non-damaging fracturing based fluids such as gelled oils, viscoelastic surfactant based fluids, foamed fluids and emulsified fluids.

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[0027] Where at least part of the proppant consists of metallic In all embodiments of the disclosed invention, at least part of the fracturing fluid comprises a proppant essentially consisting essentially of an elongated particulate metallic material, said individual particles of said particulate material have a shape with a length-basis aspect ration greater than 5. Though the elongated material is most commonly a wire segment, other shapes such as ribbon or fibers having a non-constant diameter may also be used, provided that the length to equivalent diameter is greater than 5, preferably greater than 8 and most preferably greater than 10. According to a preferred embodiment, the individual particles of said particulate material have a length ranging between about 1mm and 25mm, most preferably ranging between about 2mm and about 15mm, most preferably from about 5mm to about 10mm. Preferred diameters (or equivalent diameter where the base is not circular) typically range between about 0.1mm and about 1mm and most preferably between about 0.2mm and about 0.5mm. It must be understood that depending on the process of manufacturing, small variations of shapes, lengths and diameters are normally expected.

[0028] The elongated material is substantially metallic but can include an organic part for instance such as a resin-coating. Preferred metal includes iron, ferrite, low carbon steel, stainless steel and iron- alloys. Depending on the application, and more particularly of the closure stress expected to be encountered in the fracture, "soft" alloys may be used though metallic wires having a hardness between about 45 and about 55 Rockwell C are usually preferred.

[0029] The wire-proppant of the invention can be used during the whole propping stage or to only prop part of the fracture. In one embodiment, the method of propping a fracture in a subterranean formation comprises two non-simultaneous steps of placing a first proppant consisting of an essentially spherical particulate non-metallic material and placing a second proppant consisting essentially of an elongated material having a length to equivalent diameter greater than 5. By essentially spherical particulate non-metallic material it is meant hereby any conventional proppant, well known from those skilled in the art of fracturing, and consisting for instance of sand, silica, synthetic organic particles, glass microspheres, ceramics including alumino-silicates, sintered bauxite and mixtures thereof or deformable particulate material as described for instance in U.S. Patent No. 6,330,916. In another embodiment, the wire-

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proppant is only added to a portion of the fracturing fluid, preferably the tail portion. In both cases, the wire-proppant of the invention is not blended with the conventional material and the fracture proppant material or if blended with, the conventional material makes up to no more than about 25% by weight of the total fracture proppant mixture, preferably no more than about 15% by weight.

Experimental Methods

[0030] A test was made to compare proppant made of metallic balls, made of stainless steel SS 302, having an average diameter of about 1.6mm and wire proppant manufactured by cutting an uncoated iron wire of SS 302 stainless steel into segments approximately 7.6mm long. The wire was about 1.6mm diameter.

[0031] The proppant was deposited between two Ohio sandstone slabs in a fracture conductivity apparatus and subjected to a standard proppant pack conductivity test. The experiments were done at 100°F, 2lb/ft^2 proppant loading and 3 closure stresses, 3000, 6000 and 9000psi (corresponding to about 20.6, 41.4 and 62MPa). The permeability, fracture gap and conductivity results of steel balls and wires are shown in Table 1.

Table 1.

Closure Stress (psi)	Permeability (darcy)		Fracture Gap (inch)		Conductivity (md-ft)	
	Ball	Wire	Ball	Wire	Ball	Wire
3000	3,703	10,335	0.085	0.119	26,232	102,398
6000	1,077	4,126	0.061	0.095	5,472	33,090
9000	705	1,304	0.064	0.076	3,174	8,249

[0032] The conductivity is the product of the permeability (in milliDarcy) by the fracture gap (in feet).

CLAIMS:

1. A method of fracturing a subterranean formation comprising injecting a fracturing fluid, into a hydraulic fracture created into a subterranean formation, wherein at least a portion of the fracturing fluid comprises at least one device actively transmitting data that provide information on the device position, and further comprising the step of assessing the fracture geometry based on the positions of said devices.
2. The method of claim 1, wherein said devices are selected from the group including electronic devices and acoustic devices.
3. The method according to any of the preceding claims, wherein at least one device is pumped during the pad stage and at least one device is pumped during the tail portion.
4. The method according to any of the preceding claims wherein said devices also transmit information as to the temperature of the surrounding formation.
5. The method according to any of the preceding claims, wherein said devices also transmit information as to the pressure.
6. The method according to any of the preceding claims, wherein a plurality of devices is injected, said devices organized in a wireless network.
7. The method of claim 2, wherein the devices are electronic transmitters and the method further includes the deployment of at least an antenna.
8. The method of claim 7, wherein antennas are mounted on non-conductive balls that are pumped with the fluid and seat in some of the perforations relaying the signals from sensors behind the casing wall .
9. The method of claim 7, wherein the antenna is trailed by the transmitter within the fracture while the transmitter is pumped.
10. The method of claim 1, where the device is an optical fiber deployed through the perforation.
11. The method of claim 10, wherein the optical fiber is further deployed through the fracture

12. A method of fracturing a subterranean formation comprising injecting a fracturing fluid, into a hydraulic fracture created into a subterranean formation, wherein at least a portion of the fracturing fluid comprises metallic elements and further comprising the step of locating the position of said metallic elements with a tool selected from the group consisting of magnetometers, resistivity tools, electromagnetic devices and ultra-long arrays of electrodes, wherein said metallic elements comprise elongated particles having a length to equivalent diameter greater than 5.

13. The method of claim 12 wherein said metallic elements comprise elongated particles having a length to equivalent diameter greater than 8.

14. The method of claim 12 or 13, wherein said elongated particles are in a material selected from the group consisting of iron, ferrite, low carbon steel, stainless steel and iron- alloys.

15. The method of any of claims 12 to 14, wherein said elongated particles have a length of between 1 and 25mm.

16. The method according to any of the preceding claims, wherein the geometry of the fracture is monitored in real-time during the hydraulic fracturing treatment.

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An agency of Industry Canada

CA 2707269 A1 2010/12/09

(21) 2 707 269

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2010/06/08

(41) Mise à la disp. pub./Open to Public Insp.: 2010/12/09

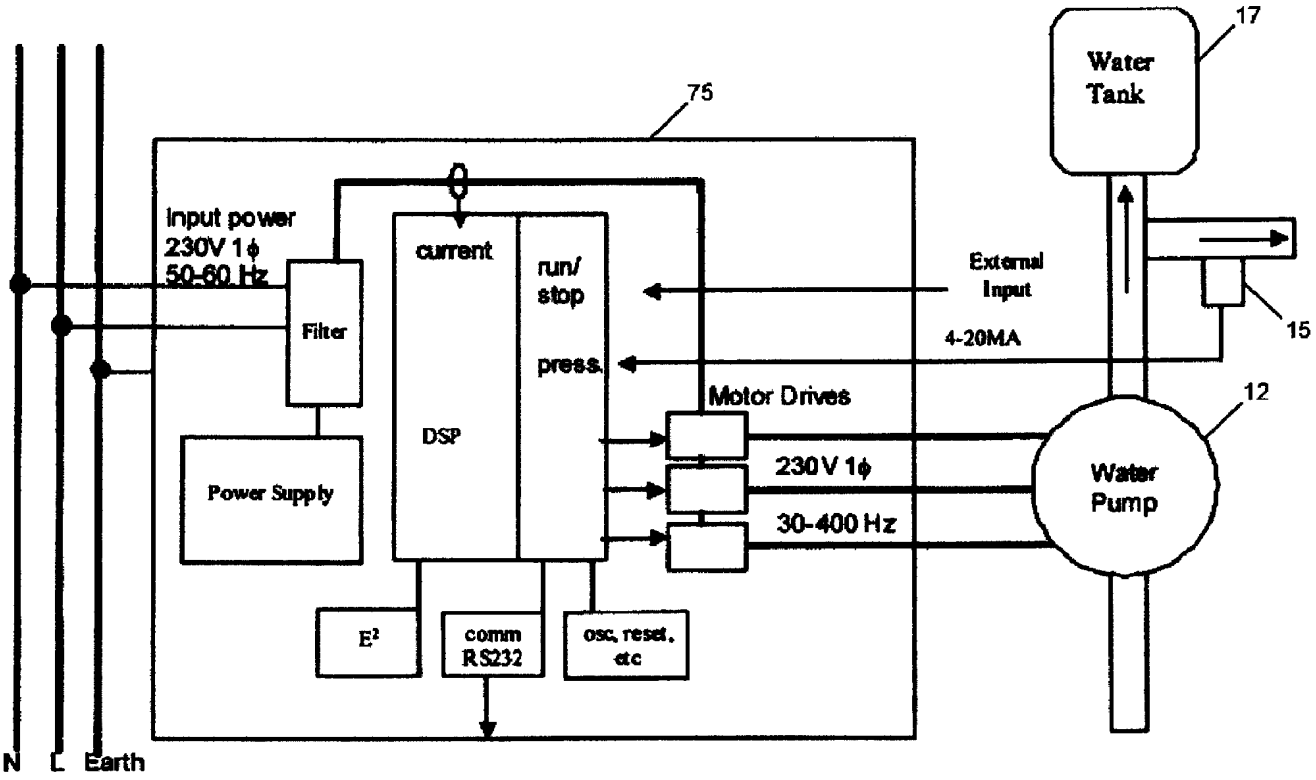
(30) Priorité/Priority: 2009/06/09 (US12/481,435)

(51) Cl.Int./Int.Cl. *F04B 49/06* (2006.01), *F04B 47/06* (2006.01), *F04D 13/08* (2006.01), *F04D 15/00* (2006.01), *H02K 7/14* (2006.01)

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(54) Titre : METHODE DE CONTROLE D'UNE POMPE ET DE SON MOTEUR
(54) Title: METHOD OF CONTROLLING A PUMP AND MOTOR



(57) Abrégé/Abstract:
Embodiments of the invention provide a variable frequency drive system and a method of controlling a pump driven by a motor with the pump in fluid communication with a fluid system. The drive system and method can provide one or more of the following: a sleep mode, pipe break detection, a line fill mode, an automatic start mode, dry run protection, an electromagnetic interference filter compatible with a ground fault circuit interrupter, two-wire and three-wire and three-phase motor compatibility, a simple start-up process, automatic password protection, a pump out mode, digital input/output terminals, and removable input and output power terminal blocks.

(21) 2 707 269

(13) A1

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Attorney Docket No. 105196.015200

ABSTRACT

Embodiments of the invention provide a variable frequency drive system and a method of controlling a pump driven by a motor with the pump in fluid communication with a fluid system. The drive system and method can provide one or more of the following: a sleep mode, pipe break detection, a line fill mode, an automatic start mode, dry run protection, an electromagnetic interference filter compatible with a ground fault circuit interrupter, two-wire and three-wire and three-phase motor compatibility, a simple start-up process, automatic password protection, a pump out mode, digital input/output terminals, and removable input and output power terminal blocks.

Attorney Docket No. 105196.015200

METHOD OF CONTROLLING A PUMP AND MOTOR

BACKGROUND

[0001] Submersible well pumps are connected to above-ground drive systems that control the operation of the pump. Some conventional pump controllers include only start capacitors and relays to turn the pump on and off based on system pressure. These pump controllers have limited capabilities with respect to pump control, safety, and customization. Variable frequency drives (VFDs) have also been used to control submersible well pumps but with limited capabilities regarding user-friendly control and customization. Conventional drives have also generally been designed for use with particular types of motors and often cannot be used to retrofit motors that are already installed in the well, especially two-wire, single-phase motors.

SUMMARY

[0002] Some embodiments of the invention provide a method of controlling a pump driven by a motor with the pump in fluid communication with a fluid system. The method can include determining whether the motor has reached a steady state operating frequency and causing the pump to temporarily boost a pressure in the fluid system once the motor has reached a steady state operating frequency. The method can also include determining whether the pressure in the fluid system drops after being temporarily boosted and causing the pump to enter a sleep mode if the pressure does not drop after being temporarily boosted.

[0003] In some embodiments, a method of controlling the pump can include determining whether the pump has entered the sleep mode during a predetermined time period and shutting down the pump due to a pipe break fault if the pump has not entered the sleep mode during the predetermined time period.

[0004] According to some embodiments, a method of controlling the pump can include determining a pressure in the fluid system when the pump starts and operating the motor in a line fill mode at a low frequency for a time period if the pressure in the fluid system is less than a minimum pressure set point in order to fill the fluid system. The method can also include operating the motor at a normal frequency after the minimum pressure set point is reached in order to increase the pressure to a normal pressure set point.

[0005] Some embodiments of the invention can provide a controller including a variable frequency drive circuit that controls operation of the pump and a control panel connected to the variable frequency drive circuit. The control panel can include an automatic start button and a stop button. The variable frequency drive circuit can automatically operate in a line fill mode when the pump starts when the automatic start button is engaged and the pump can be disabled when the stop button is engaged.

[0006] According to some embodiments, a method can include operating the motor at a normal operating frequency, determining an actual pressure in the fluid system, comparing the actual pressure to a pressure set point, and generating a dry run fault if the pressure set point cannot be achieved by operating the motor at the normal operating frequency.

DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a perspective view of a variable frequency drive according to one embodiment of the invention.

[0008] FIG. 2 is a perspective view of the variable frequency drive of FIG. 1 with a cover removed.

[0009] FIG. 3 is an interior view of the variable frequency drive of FIG. 1.

[0010] FIG. 4 is a front view of a control pad of the variable frequency drive of FIG. 1.

[0011] FIG. 5 is a schematic view of the variable frequency drive of FIG. 1 installed in a fluid system.

[0012] FIG. 6 is a schematic illustration of the variable frequency drive of FIG. 1.

[0013] FIG. 7 is a flow chart illustrating a pump out operation.

[0014] FIG. 8 is a flow chart illustrating an automatic line fill operation.

[0015] FIG. 9 is a flow chart illustrating a manual line fill operation.

[0016] FIG. 10 is a flow chart illustrating a stop operation.

[0017] FIG. 11 is a flow chart illustrating a proportional/integral/derivative (PID) mode control operation.

[0018] FIG. 12 is a flow chart illustrating a sleep mode operation.

[0019] FIG. 13 is a flow chart illustrating an alternate sleep mode operation.

[0020] FIG. 14 is a flow chart illustrating a digital input control operation.

[0021] FIG. 15 is a flow chart illustrating a relay output control operation.

[0022] FIG. 16 is a flow chart illustrating a main menu.

[0023] FIG. 17 is a flow chart illustrating a settings menu.

[0024] FIG. 18 is a flow chart illustrating a time parameter menu.

[0025] FIG. 19 is a flow chart illustrating a PID control parameter menu.

[0026] FIG. 20 is a flow chart illustrating a sleep parameter menu.

[0027] FIG. 21 is a flow chart illustrating a password parameter menu.

[0028] FIG. 22 is a flow chart illustrating an external set point parameter menu.

[0029] FIG. 23 is a flow chart illustrating a motor parameter menu.

[0030] FIG. 24 is a flow chart illustrating a sensor parameter menu.

[0031] FIG. 25 is a flow chart illustrating a pipe break parameter menu.

[0032] FIG. 26 is a flow chart illustrating a dry run parameter menu.

[0033] FIG. 27 is a flow chart illustrating an input/output parameter menu.

[0034] FIG. 28 is a flow chart illustrating a reset parameter menu.

[0035] FIG. 29 is a flow chart illustrating a backdoor parameter menu.

[0036] FIG. 30 is a flow chart illustrating an overheat prevention operation.

[0037] FIG. 31 is a flow chart illustrating an overcurrent prevention operation.

[0038] FIG. 32 is a flow chart illustrating a jam prevention operation.

[0039] FIG. 33 is a flow chart illustrating a pipe break prevention operation.

[0040] FIG. 34 is a flow chart illustrating a dry run detection operation.

[0041] FIG. 35 is a flow chart illustrating a dry run fault operation.

[0042] FIG. 36 is a flow chart illustrating a jam fault operation.

[0043] FIG. 37 is a flow chart illustrating an overtemperature fault operation.

[0044] FIG. 38 is a flow chart illustrating an overcurrent fault operation.

[0045] FIG. 39 is a flow chart illustrating an overvoltage fault operation.

[0046] FIG. 40 is a flow chart illustrating an internal fault operation.

[0047] FIG. 41 is a flow chart illustrating a ground fault operation.

[0048] FIG. 42 is a flow chart illustrating an open transducer fault operation.

[0049] FIG. 43 is a flow chart illustrating a shorted transducer fault operation.

[0050] FIGS. 44A-44B are flow charts illustrating a multiple faults operation.

[0051] FIG. 45 is a flow chart illustrating an undervoltage fault operation.

[0052] FIG. 46 is a flow chart illustrating a hardware fault operation.

[0053] FIG. 47 is a flow chart illustrating an external fault operation.

[0054] FIG. 48 is a flow chart illustrating a pump out button control operation.

[0055] FIG. 49 is a flow chart illustrating a pressure preset button control operation.

[0056] FIG. 50 is a flow chart illustrating a main menu button control operation.

[0057] FIG. 51 is a flow chart illustrating a fault log button control operation.

[0058] FIG. 52 is a flow chart illustrating an enter button control operation.

[0059] FIG. 53 is a flow chart illustrating a back button control operation.

[0060] FIG. 54 is a flow chart illustrating an up/down button control operation.

[0061] FIG. 55 is a flow chart illustrating a left/right button control operation.

[0062] FIG. 56 is a flow chart illustrating a password button control operation.

[0063] FIG. 57 is a flow chart illustrating a language button control operation.

[0064] FIG. 58 is a flow chart illustrating a status button control operation.

[0065] FIG. 59 is a flow chart illustrating a stop button control operation.

[0066] FIG. 60 is a flow chart illustrating an automatic start button control operation.

[0067] FIG. 61 is a flow chart illustrating a fault reset button control operation.

[0068] FIGS. 62A-62D are flow charts illustrating LED indicator control operations.

[0069] FIGS. 63A-63D are flow charts illustrating error display control operations.

DETAILED DESCRIPTION

[0070] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the

items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

[0071] The following discussion is presented to enable a person skilled in the art to make and use embodiments of the invention. Various modifications to the illustrated embodiments will be readily apparent to those skilled in the art, and the generic principles herein can be applied to other embodiments and applications without departing from embodiments of the invention. Thus, embodiments of the invention are not intended to be limited to embodiments shown, but are to be accorded the widest scope consistent with the principles and features disclosed herein. The following detailed description is to be read with reference to the figures, in which like elements in different figures have like reference numerals. The figures, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of embodiments of the invention. Skilled artisans will recognize the examples provided herein have many useful alternatives and fall within the scope of embodiments of the invention.

[0072] FIG. 1 illustrates a variable frequency drive (VFD, hereinafter "the drive") 10 according to one embodiment of the invention. In some embodiments, the drive 10 can be used to control the operation of an AC induction motor 11 that drives a water pump 12 (as shown in FIG. 5). The drive 10 can be used in a residential, commercial, or industrial pump system to maintain a substantially constant pressure. The motor 11 and pump 12 can be a submersible type or an above-ground type. The drive 10 can monitor certain operating parameters and control the operation of the motor 11 in response to the sensed conditions.

[0073] As shown in FIGS. 1 and 2, the drive 10 can include an enclosure 13 and a control pad 14. The enclosure 13 can be a NEMA 1 indoor enclosure or a NEMA 3R outdoor enclosure. In one embodiment, the enclosure 13 can have a width of about 9.25 inches, a height of about 17.5 inches, and a depth of about 6.0 inches. The enclosure 13 can include a keyhole mount 16 for fast and easy installation onto a wall, such as a basement wall. The enclosure 13 can include

slots 18 through which air that cools the drive 10 can pass out of the enclosure 13. The control pad 14 can be positioned within the enclosure 13 for access through a rectangular aperture 20.

[0074] As shown in FIG. 2, the enclosure 13 can include a removable cover 22 with attached side panels. Removing the cover 22 allows access to a wiring area 24, which is located adjacent to a bottom panel 25 of the enclosure 13 with several conduit holes 26. As shown in FIGS. 2 and 3, the wiring area 24 is free of any electrical components or printed circuit board material that may impede any wiring. The wiring area 24 can provide access to an input power terminal block 28, input/output (I/O) spring terminals 30, and an output power terminal block 32. Each one of the conduit holes 26 can be aligned with one of the input power terminal block 28, the I/O spring terminals 30, and the output power terminal block 32. In addition, in some embodiments, the I/O spring terminals 30 can include digital output terminals 30A, digital input terminals 30B, I/O power supply terminals 30C, and analog input terminals 30D.

[0075] The wiring area 24 can include a wiring space 34 between the bottom panel 25 and the input power terminal block 28, the I/O spring terminals 30, and the output power terminal block 32. The wiring space 34 can be between about three inches and about six inches in height in order to allow enough room for an installer to access the input power terminal block 28, the I/O spring terminals 30, and the output power terminal block 32.

[0076] The input power terminal block 28, I/O spring terminals 30, and the output power terminal block 32 can be used to control the motor 11 and to provide output information in any number of configurations and applications. Various types of inputs can be provided to the drive 10 to be processed and used to control the motor 11. The analog input terminals 30D can receive analog inputs and the digital input terminals 30B can receive digital inputs. For example, any suitable type of run/enable switch can be provided as an input to the drive 10 (e.g., via the digital input terminals 30B). The run/enable switch can be part of a lawn irrigation system, a spa pump controller, a pool pump controller, a float switch, or a clock/timer. In some embodiments, the digital input terminals 30B can accept a variety of input voltages, such as voltages ranging from about 12 volts to about 240 volts, direct current (DC) or alternating current (AC).

[0077] The digital output terminals 30A can connect to digital outputs, such as relay outputs. Any suitable type of indicator device, status output, or fault alarm output can serve as a digital,

or relay, output (e.g., be connected to the digital output terminals 30A). A status output can be used to control a second pump, for example, to run the second pump when the pump 12 is running. A fault alarm output can, for example, place a call using a pre-defined phone number, signal a residential alarm system, and/or shut down the pump 12 when a fault is determined. For example, when there is a pipe break fault (as described below with reference to FIG. 33), the digital output terminals 30A can energize a relay output, causing the pre-defined phone number to be automatically dialed. The input power terminal block 28, the I/O spring terminals 30, and the output power terminal block 32 can all be coupled to a drive circuit board (not shown), for connection to a controller 75 (as shown in FIG. 6) of the drive 10. Further, the input power terminal block 28 and/or the output power terminal block 32 can be removable and replaceable without replacing the drive circuit board or the entire drive 10.

[0078] As shown in FIGS. 1-4, a control pad 14 of the drive 10 can include a backlit liquid crystal display 36 and several control buttons 38. As shown in FIG. 4, the control buttons 38 can include a pump-out button 40, a pressure preset button 42, a main menu button 44, and a fault log button 46. The control buttons 38 can also include a keypad lockout button 48 and a language button 50. The control pad 14 can include several directional buttons 52, a back button 54, and an enter button 56. The control pad 14 can further include a status button 58, a stop button 60, an automatic start button 62, and a fault reset button 64. Finally, the control pad 14 can include light emitting diode (LED) indicators 66, to indicate a status of the drive 10, such as an ON LED 68, a Warning LED 70, and a Fault LED 72.

[0079] As shown in FIGS. 2 and 3, the drive 10 can include an electromagnetic interference (EMI) filter 74. The EMI filter 74 can reduce electrical noise generated by the motor 11, especially noise that interferes with AM radio stations. The drive 10 can reduce electrical noise while simultaneously being compatible with a Ground Fault Circuit Interrupter (GFCI). An unintentional electric path between a source of current and a grounded surface is generally referred to as a "ground fault." Ground faults occur when current is leaking somewhere, and in effect, electricity is escaping to the ground.

[0080] The drive 10 can be compatible with a number of different types of motors 11, including, but not limited to, AC induction motors that are two-wire permanent split capacitor

(PSC) single-phase motors; three-wire single-phase motors; or three-phase motors. The drive 10 can be connected to a previously-installed motor 11 in order to retrofit the controls for the motor 11. If the motor is a single-phase motor, the installer can use the control pad 14 to select either two-wire or three-wire. For a three-wire motor 11, the drive 10 can automatically generate a first waveform and a second waveform with the second waveform having a phase angle of about 90 degrees offset from the first waveform. In addition, the controller 75 (as shown in FIG. 6) can automatically set a minimum and maximum frequency allowance for the motor 11 depending on the selection.

[0081] The drive 10 can be programmed to operate after a simple start-up process by a user using the control pad 14. The start-up process can be a five-step process for a single-phase motor 11 and a four-step process for a three-phase motor 11. The start-up process for a single-phase motor 11 can include (1) entering a service factor current value, (2) selecting either a two-wire motor or a three-wire motor, (3) entering a current time, (4) entering a current date, and (5) engaging the pump-out button 40 or the automatic start button 62. The start-up process for a three-phase motor 11 can include (1) entering a service factor current value, (2) entering a current time, (3) entering a current date, and (4) engaging the pump-out button 40 or the automatic start button 62.

[0082] The pump-out button 40 can be used to enter the drive 10 in a pump out mode to clean out sand and dirt from a newly-dug well. The pump-out button 40 can be engaged once the pump 12 is installed in the new well and once the drive 10 is connected to the motor 11. The pump-out mode can provide an open discharge of sand and dirt from the well, for example, onto a lawn. In one embodiment, the drive 10 can operate the pump 12 in the pump out mode at about 45 Hertz (Hz). The pump out mode operation is further described below with respect to FIG. 7, and a pump-out button control operation is further described below with respect to FIG. 48.

[0083] The controller 75 can include software executed by a digital signal processor (DSP, as shown in FIG. 6) or a microprocessor and can perform real-time control including soft-start, speed regulation, and motor protection. The drive 10 can be controlled to maintain substantially constant water pressure in a water system that may or may not utilize a tank. To achieve this, the controller 75 can implement a classical Proportional/Integral/Derivative (PID) method using

pressure error as an input. Pressure error can be calculated by subtracting an actual water pressure from the desired water pressure (i.e., a pressure set point). An updated speed control command can then be generated by multiplying the pressure error by a proportional gain, multiplying the integral of the pressure error by an integral gain, multiplying the derivative of the pressure error by a derivative gain, and summing the results. Thus, the controller 75 can increase or decrease the speed of the motor 11 to maintain a constant pressure set point. The PID mode is further described below with respect to FIG. 11.

[0084] The controller 75 can determine the actual water pressure value from an electronic pressure transducer 15 (e.g., in communication with the controller 75 via the analog input terminals 30D). In some embodiments, as shown in FIG. 5, the pressure transducer 15 can be located near a pressure tank 17 fluidly coupled to the pump 12.

[0085] If motor 11 is off (i.e., not being driven), water pressure can still be monitored, but no actions are taken until the pressure falls below a certain value (e.g., a low band pressure value). If the water pressure falls below the low band pressure, the controller 75 can restart the motor 11. In some embodiments, the low band pressure can be set, or defaulted, to 1-10 pounds per square inch (PSI) lower than the pressure set point. Once the motor 11 is restarted, normal operation with PID control (i.e., PID mode) can commence. In one embodiment, one of two conditions can trigger the controller 75 to turn the motor 11 off. A first condition can be if a sleep mode (described with respect to FIG. 12) is triggered. A second condition can be if the pressure exceeds a certain safety value (i.e., about 20 PSI above the pressure set point). Other conditions that can stop the drive 10 are various faults (described further below), the user pressing the stop button 60, and lack of a digital input for an optional run enable mode.

[0086] For normal operation, with the motor 11 being driven, the controller 75 can regulate pump speed in a continuous fashion using PID control as long as the pressure remains below the safety pressure value, such as about 20 PSI above the pressure set point. The drive 10 can stop the motor 11 whenever the actual pressure exceeds the safety pressure value. During normal operation, as long as water usage does not exceed the motor/pump capabilities, the pressure can remain constant at approximately the pressure set point. Large instantaneous changes in flow requirements can result in variations from the desired pressure band. For example, if flow is

stopped, causing the pressure to quickly increase, the motor 11 can be stopped (i.e., set to 0 Hz). This can be considered an alternate sleep mode operation and is further described below with respect to FIG. 13.

[0087] FIGS. 7-15 are flow charts describing pump control according to some embodiments of the invention. The flow chart of FIG. 7 illustrates when the controller 75 receives a signal to run the pump in the pump out mode 76 (e.g., when the pump-out button 40 is pressed). The controller 75 first determines, at step 78, if the pump is already running in pump out mode. If so, the pump is being run at a correct, fixed frequency for pump out mode (step 80). If not, the controller 75, at step 82, ramps up the input frequency of power to the motor 11 to the correct frequency, then proceeds to step 80.

[0088] FIG. 8 illustrates an automatic line fill operation 84, according to some embodiments. This operation can automatically run at drive start-up (e.g., when the drive 10 is powered up, after a power interruption, when the motor 11 is restarted, or when the automatic start button 62 is pressed). Thus, the motor may be off (i.e., at 0 Hz) at the beginning of this operation. The controller 75 first can ramp up the frequency driving the motor from 0 Hz to about 45 Hz in less than a first time period, such as about two seconds (step 86). In a second time period, such as about two minutes, or about five minutes in some embodiments, the controller 75 can start to ramp up the frequency from, for example, about 45 Hz to about 55 Hz (step 88). During the second time period, the controller 75 determines the pressure via input from the pressure transducer 15 (step 90). If the sensed pressure has reached a minimum pressure, or pressure set point (e.g., about 10 PSI), indicating the line has been filled, the fill operation is completed and the controller 75 enters PID mode (step 92). However, if the sensed pressure is less than 10 PSI at step 90, the controller 75 determines if the second time period (e.g., about two minutes or about five minutes) has passed (step 94). If the second period has not passed, the controller 75 reverts back to step 88 and continues to ramp the motor frequency. If the second time period has passed, the controller 75 will hold the frequency at about 55 Hz for about one minute (step 96). The controller 75 then determines if the sensed pressure is about 10 PSI (step 98). If the sensed pressure is about 10 PSI, indicating the line has been filled, the fill operation is completed and the controller 75 enters PID mode (step 92). However, if the sensed pressure is still less than 10 PSI at step 90, the controller 75 determines if one minute has passed (step 100). If one minute

has not passed, the controller 75 reverts back to step 96. If one minute has passed, a dry run fault is recognized and a dry run fault operation is executed (step 102) (e.g., the system is stopped).

[0089] In one alternative embodiment, step 88 can include setting the frequency to about 45 Hz for the second time period, and if the sensed pressure is less than 10 PSI after the second time period, repeating step 88 with the frequency set to about 50 Hz for another second time period. If the sensed pressure is still less than 10 PSI after the second time period while at 50 Hz, step 88 can be repeated with the frequency set to about 55 Hz for yet another second time period. If the sensed pressure is still less than 10 PSI after the second time period while at 55 Hz, the controller 75 can continue to step 96.

[0090] FIG. 9 illustrates a manual line fill operation 104, according to some embodiments. The motor 11 is run at a manually-controlled frequency (e.g., entered by a user) at step 106. The motor 11 keeps running at this frequency until the sensed pressure reaches about 10 PSI (step 108). Once the sensed pressure has reached about 10 PSI, the controller 75 enters PID mode (step 110). In some embodiments, if the controller 75 does not enter PID mode within a time period (e.g., fifteen minutes), the drive 10 is stopped.

[0091] The manual fill line operation can be considered always enabled because it can be executed at any time during the auto line fill operation. For example, by using the up and down directional buttons 52 on the control pad 14, the user can interrupt the automatic line fill operation and adjust the frequency output to the motor 11, thus changing the motor speed. Once in manual line fill mode, the user can continue to change the speed as needed at any time. The motor 10 can continue at the new set frequency until the sensed pressure reaches about 10 PSI, and then it will proceed to PID mode, as described above. The manual fill line operation can be beneficial for both vertical or horizontal pipe fill applications. In addition, both the automatic fill line operation and the manual fill line operation can prevent common motor issues seen in conventional systems, such as motor overloading and the occurrence of water hammering.

[0092] FIG. 10 illustrates a stop operation 112, according to some embodiments. The controller 75 determines if the pump is running (step 114). If the pump is not running (e.g., if the drive 10 is in sleep mode or a run enable command is not triggered), the drive 10 is stopped

(step 116). If the pump is running, the motor is allowed to coast to a stop (i.e., 0 Hz) at step 118, then proceeds to step 116.

[0093] FIG. 11 illustrates a PID mode operation 120, according to some embodiments. The controller 75 continuously determines if the pressure is at a programmed set point (step 122). If the pressure is not at the programmed set point, PID feedback control is used to ramp the frequency until the pressure reaches the set point (step 124).

[0094] FIG. 12 illustrates the controller 75, running in PID mode (at step 126), checking if the pump should enter a sleep mode. First, at step 128, the controller 75 determines if the frequency of the motor 11 is stable within about +/- 3 Hz (e.g., at a steady-state frequency). If not (step 130), a boost delay timer is reset and the controller 75 reverts to step 126. If the frequency of the motor 11 is stable, the boost delay timer is incremented at step 132. If, at step 134 the boost delay timer is not expired after being incremented, the controller 75 reverts back to step 126. However, if, at step 134 the boost delay timer has expired, the controller 75 proceeds to step 136 and the pressure is boosted (e.g., about 3 PSI above the pressure set point) for a short period of time (e.g., about 15 seconds or about 30 seconds).

[0095] Until the short period of time has passed (step 138), the controller 75 determines if the pressure stays between the pressure set point (e.g., about 10 PSI) and the boosted pressure (step 140). If, in that short period of time, the pressure falls outside (i.e., below) the range between the pressure set point and the boosted pressure, the controller 75 reverts back to step 126. If, however, the pressure stays between the pressure set point and the boosted pressure, the controller 75 then decrements the pressure over another short period of time (step 142). Until the short period of time has passed (step 144), the controller 75 determines if the pressure stays between the pressure set point (e.g., the steady-state pressure) and the boosted pressure (step 146). If, in that short period of time, the pressure falls outside the range between the pressure set point and the boosted pressure, indicating that there is flow occurring, the controller 75 reverts back to step 126. If, however, the pressure stays between the pressure set point and the boosted pressure, indicating no flow, the controller 75 then determines if the pressure is above the pressure set point (step 148). If not, the controller 75 reverts back to step 126. If the pressure is above the pressure set point, the pump enters the sleep mode causing the motor frequency to

coast down to 0 Hz (step 150) and a "sleep mode active" message to be displayed on the liquid crystal display 36 (step 152). While in sleep mode, at step 154, the controller 75 continuously determines if the pressure stays above a wakeup differential pressure (e.g., about 5 PSI below the pressure set point). If the pressure drops below the wakeup differential pressure, the controller 75 reverts back to step 126.

[0096] In some embodiments, the controller 75 will only proceed from step 126 to step 128 if the pressure has been stable for at least a minimum time period (e.g., one or two minutes). Also, when the controller 75 cycles from step 128 to step 130 and back to step 126, the controller 75 can wait a time period (e.g., one or two minutes) before again proceeding to step 128. In some embodiments, the controller 75 can determine if the motor speed is stable at step 128. In addition, the controller 75 can perform some steps of FIGS. 11 and 12 simultaneously.

[0097] By using the sleep mode operation, a separate device does not need to be purchased for the drive 10 (e.g., a flow meter). Further, the sleep mode operation can self-adjust for changes in pump performance or changes in the pumping system. For example, well pump systems often have changes in the depth of the water in the well both due to drawdown as well as due to time of year or drought conditions. The sleep mode operation can be executed independent of such changes. In addition, the sleep mode operation does not require speed conditions specific to the pump being used.

[0098] FIG. 13 illustrates the controller 75, running in PID mode, checking if the pump should enter an alternate sleep mode 156. First, at step 158, the controller 75 determines if pressure is at a preset value above the pressure set point (e.g., 20 PSI above the pressure set point). If not (step 160), a timer is reset and the controller 75 reverts to step 156. If the pressure is 20 PSI above the pressure set point, the timer is incremented at step 162. If, at step 164 the timer is less than a value, such as 0.5 seconds, the controller 75 reverts back to step 156. However, if, at step 164 the timer has exceeded 0.5 seconds, the controller 75 proceeds to step 166 and the timer is reset. The controller 75 then sets the motor frequency to 0 Hz (step 168) and displays a "sleep mode active" message 170 on the liquid crystal display 36. The controller 75 then again increments the timer (step 172) until the time reaches another value, such as 1 minute (step 174), and then proceeds to step 176. At step 176, the controller 75 keeps the motor

frequency at 0 Hz and displays a "sleep mode active" message 178 on the liquid crystal display 36 as long as the pressure is above a wakeup differential pressure (step 180). If the pressure drops below the wakeup differential pressure (e.g., water is being used), the controller 75 reverts back to step 156.

[0099] FIG. 14 illustrates an example of controller operation using the digital input. The controller 75 first recognizes a digital input (step 182). If an external input parameter is unused (step 184), the controller 75 takes no action whether the input is high or low (steps 186 and 188, respectively). If the external input parameter is set to a run enabled mode (step 190) and the input is high (e.g., indicating allowing the drive 10 to be run), the controller 75 determines if the drive 10 is running (step 192). If the drive 10 is running, the controller 75 can take no action (step 196) and continue in its current mode of operation. If the drive 10 is not running, the controller 75 can start an auto line fill operation (step 194), as described with reference to FIG. 8 (e.g., similar to actions taken if the auto start button 62 is pressed). If the external input parameter is set to a run enabled mode (step 190) and the input is low (e.g., indicating to stop the drive 10), the controller 75 can check if the drive 10 is stopped (step 198). If the drive 10 is not stopped, the controller 75 can execute a stop operation (step 200), as described with reference to FIG. 10. If the drive 10 is stopped, the controller 75 can take no action (step 202). If the external input parameter is set to an external fault mode (step 204) and the input is high (e.g., indicating an external fault), the controller 75 can perform an external fault operation (step 206), as described with reference to FIG. 47. If the external input parameter is set to an external fault mode (step 204) and the input is low (e.g., indicating there is no external fault), the controller 75 can clear any external fault indications (step 208). If the external input parameter is set to an external set point mode (step 210) and the input is high, the controller 75 sets the PID set point to "external" (step 212), for example, so that the digital input controls the pressure set point for PID pressure control. If the external input parameter is set to an external set point mode (step 210) and the input is low, the controller 75 sets the PID set point to "normal" (step 214), for example, so that the digital input has no control over the pressure set point for PID pressure control.

[00100] FIG. 15 illustrates controller operation of a relay output. When the drive 10 is powered (step 216), the controller 75 determines if a relay output parameter is unused (step 218). If so, the controller 75 turns the relay off (step 220). If not, the controller 75 determines if the

relay output parameter is set to a run mode (step 222). If the relay output parameter is set to a run mode (at step 222), the controller 75 determines if the drive 10 is running (step 224). The controller 75 will then turn the relay off if the drive 10 is not running (step 226) or turn the relay on if the drive 10 is running (step 228). If the relay output parameter is not set to a run mode (at step 222), the controller 75 determines if the relay output parameter is set to a fault mode (step 230). If so, the controller 75 determines, at step 232, if the drive 10 is tripped (e.g., a fault has occurred and the drive 10 has been stopped). The controller 75 will then turn the relay off if the drive 10 has not been tripped (step 234) or turn the relay on if the drive 10 has been tripped (step 236). For example, if an alarm is the relay output, the alarm can be activated if the drive 10 has been tripped to indicate the fault condition to the user.

[00101] FIGS. 16-29 are flow charts describing menu operations according to some embodiments of the invention. FIG. 16 illustrates a main menu 238 of the controller 75. The main menu 238 can include the following parameters: settings menu 240, motor 242, sensor 244, pipe break 246, dry run 248, I/O (input/output) 250, and reset to defaults 252. The user can view the main menu 238 on the liquid crystal display 36 using the main menu button 44 on the control pad 14. The user can then toggle up and down through the parameters of the main menu 238 using the directional buttons 52. The user can select a parameter using the enter button 56.

[00102] From the main menu 238, the user can select the settings menu 240. The user can toggle up and down through the settings menu 240 to view the following parameters, as shown in FIG. 17: time 254, PID control 256, sleep 258, password 260, and external set point 262.

[00103] FIG. 18 illustrates the user's options after selecting the time parameter 254 from the settings menu 240. The user can toggle up and down between setting a current hour 264 or a date 266. If the user selects the hour parameter 264, the user can enter a current time 268, and a time value for the controller 75 will be changed according to the user's input 270. If the user selects the date parameter 266, the user can enter a current date 272 and a date value for the controller 75 will be changed according to the user's input 270.

[00104] FIG. 19 illustrates the user's options after selecting the PID control parameter 256 from the settings menu 240. The following parameters can be chosen after selecting PID control 256: proportional gain 274, integral time 276, derivative time 278, derivative limit 280, and

restore to defaults 282. The user can select any of the parameters 274-282 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270.

[00105] FIG. 20 illustrates the user's options after selecting the sleep parameter 258 from the settings menu 240. The following parameters can be chosen after selecting sleep 258: boost differential 284, boost delay 286, wakeup differential 288, and restore to defaults 290. The user can select any of the parameters 284-290 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270. The parameters can be set to modify or adjust the sleep mode operation described with reference to FIG. 12.

[00106] FIG. 21 illustrates the user's options after selecting the password parameter 260 from the settings menu 240. The following parameters can be chosen after selecting password 260: password timeout 292 and password 294. The user can select any of the parameters 292-294 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270. The password timeout parameter 292 can include a timeout period value. If the control pad 14 is not accessed within the set timeout period, the controller 75 175 can automatically lock the control pad 14 (i.e., enter a password protection mode). To unlock the keys, or leave the password protection mode, the user must enter the password that is set under the password parameter 294. This is further described below with reference to FIG. 56.

[00107] FIG. 22 illustrates the user's options after selecting the external set point parameter 262 from the settings menu 240. The user can select the external set point parameter 296 to modify one or more preferences associated with the parameter 296, and appropriate values for the controller 75 will be changed 270.

[00108] FIG. 23 illustrates the user's options after selecting the motor parameter 242 from the main menu 238. The following parameters can be chosen after selecting motor 242: service factor amps 298, connection type 300, minimum frequency 302, maximum frequency 304, and restore to defaults 306. The connection type parameter 300 may only be available if the drive 10 is being used to run a single-phase motor. If the drive 10 is being used to run a three-phase motor, the connection type parameter 300 may not be provided. The user can select any of the

parameters 298-306 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270.

[00109] FIG. 24 illustrates the user's options after selecting the sensor parameter 244 from the main menu 238. The following parameters can be chosen after selecting sensor 244: minimum pressure 308, maximum pressure 310, and restore to defaults 312. The user can select any of the parameters 308-312 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270.

[00110] FIG. 25 illustrates the user's options after selecting the pipe break parameter 246 from the main menu 238. The following parameters can be chosen after selecting pipe break 246: enable pipe break detection 314 and number of days without sleep 316. The user can select either of the parameters 314-316 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270. In some embodiments, the number of days without sleep parameter 316 can include values in the range of about four hours to about fourteen days. The enable pipe break detection parameter 314 can allow the user to enable or disable pipe break detection.

[00111] FIG. 26 illustrates the user's options after selecting the dry run parameter 248 from the main menu 238. The following parameters can be chosen after selecting dry run 248: auto reset delay 318, number of resets 320, and reset window 322. The user can select either of the parameters 318-320 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270. The user can select the reset window parameter 322 to view a value 324 indicating a reset window of the controller 75. The reset window value can be based from the values chosen for the auto reset delay 318 and the number of resets 320. Thus, the reset window parameter 322 can be a view-only (i.e., non-adjustable) parameter.

[00112] FIG. 27 illustrates the user's options after selecting the I/O parameter 250 from the main menu 238. The following parameters can be chosen after selecting I/O 250: external input 326 and relay output 328. The user can select either of the parameters 326-328 to modify one or more preferences associated with the parameters, and appropriate values for the controller 75 will be changed 270.

[00113] FIG. 28 illustrates the user's options after selecting the reset to defaults parameter 252 from the main menu 238. The user can select the parameter 330 to change all values to factory default values 270.

[00114] FIG. 29 illustrates a backdoor parameter 332, according to some embodiments. With the backdoor parameter 332, the user can choose a parameter 334 not normally accessible through other menus. The user can select the parameter 334 to modify one or more preferences associated with the parameter, and appropriate values for the controller 75 will be changed 270. The parameter 334 that the user selects can be from a list of parameters 336. The list of parameters 336 can include one or more of the parameters disclosed above as well as other parameters.

[00115] FIGS. 30-47 are flow charts describing drive warnings and faults according to some embodiments of the invention. FIG. 30 illustrates an overheat prevention operation of the controller 75. When the drive 10 is running (step 338), the controller 75 first determines, at step 340, if a power module temperature is greater than a first temperature (e.g., 115 degrees Celsius). If so, an overheat fault operation is executed (step 342). If not, the controller 75 then determines, at step 344, if the power module temperature is greater than a second temperature (e.g., about 113 degrees Celsius). If so, the controller 75, at step 346, decreases the speed of the motor by a first value (e.g., about 12 Hz per minute) and continues to step 348. If not, the controller 75 then determines, at step 350, if the power module temperature is greater than a third temperature (e.g., about 110 degrees Celsius). If so, the controller 75, at step 352, decreases the speed of the motor by a second value (e.g., about 6 Hz per minute) and continues to step 348. If not, the controller 75 then determines, at step 354, if the power module temperature is greater than a fourth temperature (e.g., about 105 degrees Celsius). If so, the controller 75, at step 356, decreases the speed of the motor by a third value (e.g., about 3 Hz per minute) and continues to step 348. If not, the controller 75 proceeds to step 348. At step 348, the controller 75 determines if the speed has been reduced (i.e., if the controller 75 performed steps 346, 352, or 356). If so, the controller 75, at step 358, determines if the power module temperature is less than a fifth value (e.g., about 95 degrees Celsius). If the power module temperature is less than the fifth value, then the controller 75 increases the speed of the motor by a fourth value (e.g., about 1.5 Hz per minute) until the motor's original speed is reached (step 360) and a warning message "TPM: Speed

Reduced" is displayed (step 362). If the power module temperature is greater than the fifth value, the controller 75 proceeds straight to step 362. From step 362, the controller 75 reverts back to step 338, and repeats the above process. If, at step 348, the controller 75 determines that the speed has not been reduced (i.e., the controller 75 did not performed steps 346, 352, or 356), then the "TPM: Speed Reduced" warning message is cleared (step 364), the controller 75 reverts back to step 338, and the above operation is repeated. In some embodiments, the power module being monitored can be the drive 10 itself or various components of the drive 10 (e.g., a heat sink of the controller 75, the motor 11, or the pump 12).

[00116] FIG. 31 illustrates an overcurrent prevention operation of the controller 75. When the drive 10 is running (step 366), the controller 75 determines, at step 368, if the drive current is being limited (e.g., because it is above the reference service factor amps parameter 298 in FIG. 23). If so, a warning message "TPM: Service Amps" is displayed (step 370) and the Warning LED 70 is illuminated (step 372). The controller 75 then reverts back to step 366 where the operation is repeated. If the drive current is not being limited, the "TPM: Service Amps" warning message and the Warning LED 70 are cleared (step 374).

[00117] FIG. 32 illustrates a jam prevention operation of the controller 75. When the motor is triggered to start (step 376), the controller 75 determines, at step 378, if a startup sequence is completed. If so, a timer and a counter are reset (step 380), any warning messages are cleared (step 382), and the motor is operating (step 384). If the startup sequence is not completed at step 378, then the controller 75 proceeds to step 386 to check if current limitation is active. If not, the timer and the counter can be reset (step 388), and the controller 75 can proceed back to step 376. If the controller 75 detects that current limitation is active at step 386, then the timer is incremented (step 390). If the timer has not reached five seconds, at step 392, the controller 75 reverts back to step 376. However, if the timer has reached five seconds, at step 392, the controller 75 proceeds to step 396. The controller 75 sets a jam warning (step 396) and increments the counter (step 398). If the counter is greater than five, at step 400, the controller 75 executes a jam fault operation (step 402). If the counter is not greater than five, the controller 75 determines if it is controlling a two-wire motor (step 404). If yes, the controller 75 pulses the motor about three times (step 406), then proceeds back to step 376. If the motor is not a two-

wire (e.g., if the motor is a three-wire motor), the controller 75 executes a series of three forward-reverse cycles (step 408), then proceeds back to step 376.

[00118] FIG. 33 illustrates a line or pipe break fault operation of the controller 75. During PID control (step 410), the controller 75 determines if a pipe break parameter (e.g., pipe break detection parameter 314 from FIG. 25) is enabled (step 412). The controller 75 continues back to step 410 until the parameter is enabled. If the controller 75 determines that the parameter is enabled at step 412, a timer is incremented (step 414), and the controller 75 determines if the pump is in sleep mode (step 416). If the pump is in sleep mode, the timer is reset (step 418) and the controller 75 reverts back to step 410. If the pump is not in sleep mode, the controller 75, at step 420, determines if the timer has been incremented above a certain number of days (e.g., as set by the number of days without sleep parameter 316). If the timer has not exceeded the set number of days, then the controller 75 proceeds back to step 410. If the timer has exceeded the set number of days, the motor is coasted to a stop and a "possible pipe break" fault message is displayed (step 422), causing the drive 10 to be stopped (step 424).

[00119] FIG. 34 illustrates a dry run detection operation of the controller 75. During PID control (step 426), the controller 75 determines, at step 428, if the frequency output to the motor is greater than a frequency preset value (e.g., about 30 Hz). If so, a timer is reset (step 430) and the controller 75 reverts back to step 426. If the frequency is under the frequency preset value, the controller 75 then determines, at step 432, if the pressure is greater than a pressure preset value (e.g., about 10 PSI). If so, the timer is reset (step 430) and the controller 75 reverts back to step 426. If the pressure is under 10 PSI, the timer is incremented (step 434) and the controller 75 determines if the timer has reached 15 seconds (step 436). If not, the controller 75 reverts back to step 426. However, if the timer has reached 15 seconds, the controller 75 determines that a dry run has occurred and executes a dry run fault operation (step 438). The preset value in step 428 can be checked to ensure the motor 11 is operating at a normal operating frequency (e.g., above 30 Hz).

[00120] FIG. 35 illustrates a dry run fault operation of the controller 75. The controller 75 can proceed to step 440 if step 438 of FIG. 34 was reached. From step 440, the controller 75 can check if a reset counter value is less than a set value (e.g., the value set under the number of

resets parameter 320 of FIG. 26) at step 442. If the reset counter is not less than the set value, the controller 75 can update a fault log (step 444), coast the motor to a stop and display a "Dry Run" fault message (step 446), so that the drive 10 is stopped (step 448). If, at step 442, the reset counter is less than the set value, the reset counter is incremented (step 450) and the fault log is updated (step 452). The controller 75 can then coast the motor to a stop and display a "Dry Run - Auto Restart Pending" fault message (step 454), then start a fault timer (step 456), and continuously check if the user has pressed the fault reset button 64 (step 458) or if a timer has exceeded a time value (step 460). The time value can be the auto reset delay parameter 318 (shown in FIG. 26) set by the user. If the user presses the fault reset button 64, the controller 75 will proceed from step 458 to step 462 and clear the fault message displayed, then stop the drive 10 (step 448). If the timer exceeds the time value, the controller 75 will proceed from step 460 to step 464 and clear the fault message displayed, then restart the drive 10 in PID mode (step 466).

[00121] FIG. 36 illustrates a jam fault operation of the controller 75. When a jam has been detected (step 468), the fault log is updated (step 470). After step 470, the motor is coasted to a stop and a "Foreign Object Jam" fault message is displayed (step 472), then the drive 10 is stopped (step 474).

[00122] FIG. 37 illustrates an overtemperature fault operation of the controller 75. When the drive 10 is powered (step 476), the controller 75 determines if the power module temperature is too high (step 478), for example, using the overheat prevention operation in FIG. 30. If the power module temperature is not too high, the fault is cleared (step 480) and the controller 75 reverts back to step 476. If the power module temperature is too high, the fault log is updated (step 482), the motor is coasted to a stop and a "Drive Temp - Auto Restart Pending" fault message is displayed (step 484), and a fault timer is incremented (step 486). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 488) until the timer has been incremented past a value (step 490). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 488 or step 490, respectively, to step 492 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 486. If the fault condition is not present, the controller 75 clears the fault (step 480) and reverts back to step 476.

[00123] The motor 11 and pump 12 combination can satisfy typical performance requirements as specified by the pump manufacturer while maintaining current under service factor amps as specified for the motor 11. Performance can match that of a typical capacitor start/capacitor run control box for each motor HP offering. If the motor 11 performs outside of such specifications, the controller 75 can generate a fault and stop the motor 11. For example, FIG. 38 illustrates an overcurrent fault operation of the controller 75. When the drive 10 is powered (step 494), the controller 75 determines if there is a high current spike (step 496), for example, using the overcurrent prevention operation of FIG. 31. If there is no high current spike, the fault is cleared (step 498) and the controller 75 reverts back to step 494. If there a high current spike, the fault log is updated (step 500), the motor is coasted to a stop and a "Motor High Amps - Auto Restart Pending" fault message is displayed (step 502), and a fault timer is incremented (step 504). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 506) until the timer has been incremented past a value (step 508). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 506 or step 508, respectively, to step 510 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 504. If the fault condition is not present, the controller 75 clears the fault (step 498) and reverts back to step 494.

[00124] FIG. 39 illustrates an overvoltage fault operation of the controller 75. When the drive 10 is powered (step 512), the controller 75 determines if a maximum bus voltage has been exceeded (step 514). If the bus voltage has not exceeded the maximum value, the fault is cleared (step 516) and the controller 75 reverts back to step 512. If the bus voltage has exceeded the maximum value, the fault log is updated (step 518), the motor is coasted to a stop and an "Over Voltage - Auto Restart Pending" fault message is displayed (step 520), and a fault timer is incremented (step 522). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 524) until the timer has been incremented past a value (step 526). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 524 or step 526, respectively, to step 528 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 522. If the fault condition is not present, the controller 75 clears the fault (step 516) and reverts back to step 512.

[00125] FIG. 40 illustrates an internal fault operation of the controller 75. When the drive 10 is powered (step 530), the controller 75 determines if any internal voltages are out of range (step 532). If the internal voltages are not out of range, the fault is cleared (step 534) and the controller 75 reverts back to step 530. If the internal voltages are out of range, the fault log is updated (step 536), the motor is coasted to a stop and an "Internal Fault - Auto Restart Pending" fault message is displayed (step 538), and a fault timer is incremented (step 540). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 542) until the timer has been incremented past a value (step 544). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 542 or step 544, respectively, to step 546 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 540. If the fault condition is not present, the controller 75 clears the fault (step 534) and reverts back to step 530.

[00126] FIG. 41 illustrates a ground fault operation of the controller 75. When the drive 10 is powered (step 548), the controller 75 continuously determines if there is current flow between an earth, or ground, lead and any motor lead (step 550). If so, the fault log is updated (step 552), the motor is coasted to a stop and a "Ground Fault" fault message is displayed (step 554), and the drive 10 is stopped (step 556).

[00127] FIG. 42 illustrates an open transducer fault operation of the controller 75. While in PID mode (step 558), the controller 75 determines if a current measured at the transducer input is less than a value, such as 2 milliamps (step 560). If the current is not less than the value, the controller 75 reverts back to step 558. If the current is less than the value, the fault log is updated (step 562), the motor is coasted to a stop and an "Open Transducer - Auto Restart Pending" fault message is displayed (step 564), and a fault timer is incremented (step 566). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 568) until the timer has been incremented past a value (step 570). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 568 or step 570, respectively, to step 572 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 566. If the fault condition is not present, the controller 75 reverts back to step 558.

[00128] FIG. 43 illustrates a shorted transducer fault operation of the controller 75. While in PID mode (step 574), the controller 75 determines if a current measured at the transducer input is greater than a value, such as 25 milliamps (step 576). If the current is not greater than the value, the controller 75 reverts back to step 574. If the current is greater than the value, the fault log is updated (step 578), the motor is coasted to a stop and a "Shorted Transducer - Auto Restart Pending" fault message is displayed (step 580), and a fault timer is incremented (step 582). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 586) until the timer has been incremented past a value (step 588). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 586 or step 588, respectively, to step 590 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 582. If the fault condition is not present, the controller 75 reverts back to step 574.

[00129] FIGS. 44A-44B illustrate a multiple faults operation of the controller 75. Referring to FIG. 44A, when the drive 10 is powered (step 592), the controller 75 continuously determines if a fault has occurred (step 594). If a fault has a occurred, a counter is incremented (step 596) and the controller 75 determines if the counter has reached a value, such as ten (step 598). If the counter has reached the value, the motor is coasted to a stop and a "Multiple Faults" fault message is displayed (step 600), and the drive 10 is stopped (step 602). The steps of FIG. 44B serve to provide a time frame for which the counter can reach the value. When the drive 10 is powered (step 592), the controller 75 continuously determines if the counter (i.e., the counter in step 596 of FIG. 44A) has been incremented (step 604). If so, a timer is incremented (step 606). The controller 75 continues to increment the timer as long as the counter is above zero until the timer reaches a value, such as thirty minutes (step 608). Once the timer has reached the value, the counter is decremented and the timer is reset (step 610).

[00130] FIG. 45 illustrates an undervoltage fault operation of the controller 75. When the drive 10 is powered (step 612), the controller 75 determines if the bus voltage is below a minimum value (step 614). If the bus voltage is not below the minimum value, the fault is cleared (step 616) and the controller 75 reverts back to step 612. If the bus voltage is below the minimum value, the fault log is updated (step 618), the motor is coasted to a stop and an "Under Voltage - Auto Restart Pending" fault message is displayed (step 620), the fault log is saved in

memory, such as the device's electrically erasable programmable read-only memory, or EEPROM (step 622) and a fault timer is incremented (step 624). The controller 75 then continuously determines if the user has pressed the fault reset button 64 (step 626) until the timer has been incremented past a value (step 628). If the user has pressed the fault reset button 64 or if the timer has incremented past the value, the controller 75 proceeds from step 626 or step 628, respectively, to step 630 to check if the fault condition is still present. If the fault condition is still present, the controller 75 reverts back to step 624. If the fault condition is not present, the controller 75 clears the fault (step 616) and reverts back to step 612.

[00131] FIG. 46 illustrates a hardware fault operation of the controller 75. When the controller 75 recognizes a hardware error (step 632), the fault log is updated (step 634). After step 634, the motor is coasted to a stop and a "Hardware Error" fault message is displayed (step 636), then the drive 10 is stopped (step 638).

[00132] FIG. 47 illustrates an external fault operation of the controller 75. When the drive 10 is powered (step 640), the controller 75 continuously determines if an external fault parameter is present, for example, from a relay input at the input power terminal block 28 or the digital input/output (I/O) spring terminals 30 (step 642). If so, the controller 75 determines if a digital input is high (step 644). If the digital input is not high, the controller 75 determines if the external fault is active (step 646). If the external fault is not active, the controller 75 reverts back to step 640. If the external fault is active, the controller 75 clears an "external fault" fault message (if it is being displayed) at step 648 and the device's previous state and operation are restored (step 650). If, at step 644, the digital input is high, the fault log is updated (step 652) and the device's current state and operation are saved (step 654). Following step 654, the motor is coasted to a stop and a "External Fault" fault message is displayed (step 656), then the drive 10 is stopped (step 658).

[00133] FIGS. 48-63 are flow charts describing control operations for the control pad 14 according to some embodiments of the invention. FIG. 48 illustrates a pump-out button control operation, according to some embodiments. When the pump-out button 40 is pressed (step 660), the controller 75 first determines if the control pad 14 is locked, or in the password protection mode (step 662). If so, the controller 75 executes a keys locked error operation (step 664). If

not, a valve screen 666 is displayed (step 668) asking the user if a valve is open. Once the user chooses if the valve is open or not and presses enter, a valve parameter value is changed (step 670). The controller 75 then determines, at step 672, if the valve parameter value is yes (i.e., if the valve is open). If the valve parameter is not yes (i.e., if the user selected that the valve was not open), a stopped screen is displayed (step 674), indicating that the pump 12 is stopped. If the valve parameter is yes, the controller 75 sets LED indicators 66 on or off accordingly (step 676), displays a status screen 678 (step 680), and runs the pump out operation to drive the motor 11 in the pump out mode (step 682). The status screen 678 can include information about the pump 12, such as motor frequency, pressure, and motor current during the pump out mode.

[00134] FIG. 49 illustrates a pressure preset button control operation, according to some embodiments. When the pressure preset button 42 is pressed (step 684), the controller 75 first determines if the control pad 14 is locked (step 686). If so, the controller 75 executes a keys locked error operation (step 688). If the control pad 14 is not locked, the controller 75 sets the LED indicators 66 on or off accordingly (step 690) and a preset pressure parameter is displayed (step 692). The user can adjust the displayed pressure parameter using the keypad and hit enter to change the value of the preset pressure parameter, changing the pressure set point for the controller 75 (step 694).

[00135] FIG. 50 illustrates a main menu button control operation, according to some embodiments. When the main menu button 44 is pressed (step 696), the controller 75 first determines if the control pad 14 is locked (step 698). If so, the controller 75 executes a keys locked error operation (step 700). If the control pad 14 is not locked, the controller 75 sets the LED indicators 66 on or off accordingly (step 702) and the main menu, as described with respect to FIG. 16, is displayed (step 704).

[00136] FIG. 51 illustrates a fault log button control operation, according to some embodiments. When the fault log button 46 is pressed (step 706), the controller 75 sets the LED indicators 66 on or off accordingly (step 708) and the fault log is displayed, detailing fault history information to the user (step 710).

[00137] FIG. 52 illustrates an enter button control operation, according to some embodiments. When the enter button 56 is pressed (step 712), the controller 75 first determines if the fault log

is active (e.g., being displayed) at step 714 or if the stopped status screen is being displayed (step 716). If either step 714 or step 716 is true, the controller 75 executes an invalid key error operation (step 718). If neither the fault log or stopped status screen are being displayed, the controller 75 determines if the control pad 14 is locked (step 720). If so, the controller 75 executes a keys locked error operation (step 722). If the control pad 14 is not locked, the controller 75 determines if the display currently selecting a menu option or a parameter (step 724). If the display is currently selecting a menu option, the controller 75 will enter the selected menu (step 726). If the display is currently selecting a parameter option, the controller 75 determines if the parameter is highlighted (step 728). If the parameter is highlighted, the controller 75 saves the value of the selected parameter and cancels the highlighting of the parameter (step 730). If, at step 728, the parameter is not highlighted, the controller 75 determines if the parameter can be changed with the motor is running and the drive 10 is stopped (step 732). If not, a running error operation is executed (step 734). If the parameter may be changed, then the selected parameter is highlighted (step 736).

[00138] FIG. 53 illustrates a back button control operation, according to some embodiments. When the back button 54 is pressed (step 738), the controller 75 determines if a status screen is being displayed (step 740). If so, an invalid key error operation is executed (step 742). If a status screen is not being displayed, the controller 75 determines if a line in the display is highlighted (step 744). If so, the new value on the highlighted line is cancelled and the highlighting is cancelled as well (step 746). If, at step 744, there is no highlighted line, the parent, or previous, menu is displayed (step 748).

[00139] FIG. 54 illustrates an up/down button control operation, according to some embodiments. When either the up or down directional button 52 is pressed (step 750), the controller 75 determines if a line in the display is highlighted (step 752). If so, the controller 75 then determines if the auto line fill operation is being executed (step 754). If so, the controller 75 proceeds to the manual line fill operation (step 756), as described with reference to FIG. 9, then scrolls to another value in the display (step 758). If the controller 75 determines that the auto line fill operation is not being executed at step 754, the controller 75 proceeds to step 758 and scrolls to another value in the display. If, at step 752, the controller 75 determines that no line is highlighted, the controller 75 then determines if a menu in the display can be scrolled (step 760).

If so, the menu is scrolled (step 762). If not, an invalid key error operation is executed (step 764).

[00140] FIG. 55 illustrates a left/right button control operation, according to some embodiments. When either the left or right directional button 52 is pressed (step 766), the controller 75 determines if a line in the display is highlighted (step 768). If not, an invalid key error operation is executed (step 770). If, at step 768, the controller 75 determines that the line is highlighted, the controller 75 then determines if a curser in the display can be moved (step 772). If so, the curser is moved (step 774). If not, an invalid key error operation is executed (step 776).

[00141] FIG. 56 illustrates a password button control operation, according to some embodiments. When the password button 48 is pressed (step 778), the controller 75 first determines if the control pad 14 is locked (step 780). If not, a status screen is displayed (step 782). If the control pad 14 is locked, the controller 75 sets the LED indicators 66 on or off accordingly (step 784) and executes a keys locked error operation (step 786). If a user then enters a password (step 788), the controller 75 determines if the password is correct (step 790). If the password is correct, any lockable keys are unlocked (step 792) and the status screen is displayed (step 794). If the password is incorrect, an invalid password error operation is executed (step 796), then the status screen is displayed (step 794). In some embodiments, the lockable keys can include the directional buttons 52, the language button 50, the pump-out button 40, the pressure preset button 42, and/or the main menu button 44.

[00142] FIG. 57 illustrates a language button control operation, according to some embodiments. When the language button 50 is pressed (step 796), the controller 75 first determines if the control pad 14 is locked (step 798). If so, the controller 75 executes a keys locked error operation (step 800). If the control pad 14 is not locked, the controller 75 sets the LED indicators 66 on or off accordingly (step 802) and a language parameter is displayed (step 804). The user can change the displayed language using the keypad and hit enter to update the language parameter (step 806).

[00143] FIG. 58 illustrates a status button control operation, according to some embodiments. When the status button 58 is pressed (step 808), the controller 75 sets the LED indicators 66 on or off accordingly (step 810) and determines if a current status screen is being displayed (step

812). If not, the current status screen 814 or 816 is displayed (step 818). If the controller 75, at step 812, determines that the current status screen is being displayed, the currents status screen is cleared and a power status screen 820 or 822 is displayed (step 824).

[00144] FIG. 59 illustrates a stop button control operation, according to some embodiments. When the stop button 60 is pressed (step 826), the controller 75 sets the LED indicators 66 on or off accordingly (step 828) and a stopped status screen 830 is displayed (step 832). The controller 75 then stops the drive 10 (step 834), as described with reference to FIG. 10.

[00145] FIG. 60 illustrates an automatic start button control operation, according to some embodiments. When the automatic start button 62 is pressed (step 836), the controller 75 sets the LED indicators 66 on or off accordingly (step 838) and a status screen 840 is displayed (step 842). The controller 75 then runs the automatic line fill operation (step 844), as described with reference to FIG. 8.

[00146] FIG. 61 illustrates a fault reset button control operation, according to some embodiments. When the fault reset button 64 is pressed (step 846), the controller 75 determines if there is an active fault (step 848). If not, the controller 75 executes an invalid key error operation (step 850). If there is an active fault, the controller 75 determines if the fault condition is still present (step 852). If so, the controller 75 stops the drive 10 (step 854), as described with reference to FIG. 10. If not, the controller 75 first clears the fault (step 856), then stops the drive 10 (step 854).

[00147] FIGS. 62A-62D illustrate LED indicator control operations, according to some embodiments. As shown in FIG. 62A, if a fault is active and a restart is pending (step 856), the Fault LED 72 blinks (step 858), and a "Restart Pending" message is displayed (step 860). As shown in FIG. 62B, if a fault is active and the drive 10 is stopped (step 862), the Fault LED 72 blinks (step 864), and a "Drive Stopped" message is displayed (step 866). As shown in FIG. 62C, if a TPM is active and the drive 10 is still running (step 868), the Warning LED 70 is lit (step 870), and a message is displayed describing the warning (step 872). As shown in FIG. 62D, when the drive 10 is powered up (step 874), the ON LED 68 is lit (step 876).

[00148] FIGS. 63A-63D illustrate error display control operations, according to some embodiments. As shown in FIG. 63A, for the invalid key error operation (step 878), a "Key Error! Invalid Key!" error screen can be displayed (step 880). The controller 75 can display the error screen for a time period, such as 0.9 seconds (step 882), then return the display to the previous screen (step 884). As shown in FIG. 63B, for the keys locked error operation (step 886), an "Error! Press Password Key" error screen can be displayed (step 888). The controller 75 can display the error screen for a time period, such as 0.9 seconds (step 890), then return the display to the previous screen (step 892). As shown in FIG. 63C, for the invalid password error operation (step 894), an "Error! Invalid Password!" error screen can be displayed (step 896). The controller 75 can display the error screen for a time period, such as 0.9 seconds (step 898), then return the display to the previous screen (step 900). As shown in FIG. 63D, for the running error operation (step 902), an "Error! Stop before editing" error screen can be displayed (step 904). The controller 75 can display the error screen for a time period, such as 0.9 seconds (step 906), then return the display to the previous screen (step 908).

[00149] It will be appreciated by those skilled in the art that while the invention has been described above in connection with particular embodiments and examples, the invention is not necessarily so limited, and that numerous other embodiments, examples, uses, modifications and departures from the embodiments, examples and uses are intended to be encompassed by the claims attached hereto. The entire disclosure of each patent and publication cited herein is incorporated by reference, as if each such patent or publication were individually incorporated by reference herein. Various features and advantages of the invention are set forth in the following claims.

CLAIMS

1. A method of controlling a pump driven by a motor, the pump in fluid communication with a fluid system, the method comprising:

determining whether the motor has reached a steady state operating frequency;

causing the pump to temporarily boost a pressure in the fluid system once the motor has reached a steady state operating frequency;

determining whether the pressure in the fluid system drops after being temporarily boosted; and

causing the pump to enter a sleep mode if the pressure does not drop after being temporarily boosted.

2. The method of claim 1 and further comprising causing the pump to continue normal operation if the pressure does drop after being temporarily boosted.

3. The method of claim 2 and further comprising periodically determining whether the motor has reached a steady state operating frequency again.

4. The method of claim 3 and further comprising determining whether the motor has reached a steady state operating frequency about every two minutes.

5. The method of claim 1 wherein determining whether the motor has reached a steady state operating frequency includes determining whether the speed of the motor is steady.

6. The method of claim 1 wherein entering the sleep mode is independent of well depth.

7. The method of claim 1 and further comprising boosting the pressure by about three pounds per square inch.

8. The method of claim 7 and further comprising determining whether the pressure drops below a pressure set point.

9. The method of claim 1 and further comprising disabling the sleep mode when the pressure drops to below a pressure set point minus about five pounds per square inch.

10. The method of claim 1 and further comprising determining whether the motor has reached a steady state operating frequency by determining whether a frequency of the motor has stayed constant for at least about one minute.

11. The method of claim 1 and further comprising determining whether the pressure in the fluid system drops within about 15 seconds after being temporarily boosted.

12. A method of controlling a pump driven by a motor, the pump in fluid communication with a fluid system, the method comprising:

causing the pump to enter a sleep mode if a pressure in the fluid system does not drop after being temporarily boosted;

determining whether the pump has entered the sleep mode during a predetermined time period; and

shutting down the pump due to a pipe break fault if the pump has not entered the sleep mode during the predetermined time period.

13. The method of claim 12 wherein the predetermined time period is at least about four hours.

14. The method of claim 12 wherein the predetermined time period is up to about fourteen days.

15. The method of claim 12 and further comprising determining whether the motor has reached a steady state operating frequency.

16. The method of claim 15 and further comprising causing the pump to temporarily boost the pressure in the fluid system once the motor has reached a steady state operating frequency.

17. The method of claim 12 and further comprising indicating on a display that there has been a pipe break fault.

18. The method of claim 12 and further comprising automatically causing a relay output to be energized when there is a pipe break fault.

19. The method of claim 12 and further comprising modifying the predetermined time period.

20. The method of claim 12 and further comprising temporarily disabling the pipe break fault.

21. A method of controlling a pump driven by a motor, the pump in fluid communication with a fluid system, the method comprising:

determining a pressure in the fluid system when the pump starts;

operating the motor in a line fill mode at a low frequency for a time period if the pressure in the fluid system is less than a minimum pressure set point in order to fill the fluid system; and

operating the motor at a normal frequency after the minimum pressure set point is reached in order to increase the pressure to a normal pressure set point.

22. The method of claim 21 and further comprising operating the motor at a low frequency until the pressure reaches a pressure set point of about 10 pounds per square inch.

23. The method of claim 21 and further comprising operating the motor at a low frequency for a time period of about five minutes.

24. The method of claim 21 and further comprising operating the motor at a low frequency of about 45 Hertz.

25. The method of claim 24 and further comprising operating the motor at about 45 Hertz for about one minute to about five minutes, then operating the motor at about 45 Hertz to about 50 Hertz for about three minutes to about five minutes, and then operating the motor at about 55 Hertz for about one minute, if the pressure has not reached the minimum pressure set point.

26. The method of claim 25 and further comprising operating the motor at about 55 Hertz for about five minutes if the pressure has not reached the minimum pressure set point.

27. The method of claim 21 and further comprising automatically operating the motor in the line fill mode unless a manual interrupt feature is enabled.

28. The method of claim 27 and further comprising enabling the manual interrupt feature by manually changing a speed of the motor.

29. The method of claim 21 and further comprising operating the motor in the line fill mode in order to help prevent water hammering.

30. The method of claim 21 and further comprising operating the motor in the line fill mode after the motor has been manually stopped and then started again.

31. The method of claim 21 and further comprising operating the motor at the normal frequency after the line fill mode and increasing the pressure up to a normal pressure set point of about 60 pounds per square inch.

32. A controller for a pump driven by a motor, the pump in fluid communication with a fluid system, the controller comprising:

a variable frequency drive circuit that controls operation of the pump; and

a control panel connected to the variable frequency drive circuit,

the control panel including an automatic start button and a stop button,

the variable frequency drive circuit automatically operating in a line fill mode when the pump starts when the automatic start button is engaged,

the variable frequency drive circuit disabling the pump when the stop button is engaged.

33. The controller of claim 32 wherein the variable frequency drive circuit operates in the line fill mode by determining a pressure in the fluid system when the pump starts.

34. The controller of claim 33 wherein the variable frequency drive circuit operates the motor at a low frequency for a time period if the pressure in the fluid system is less than a minimum pressure set point in order to fill the fluid system.

35. The controller of claim 34 wherein the variable frequency drive circuit operates the motor at a normal frequency after the timer period has expired in order to maintain a normal pressure set point.

36. The controller of claim 32 wherein the variable frequency drive circuit automatically starts and operates in the line fill mode after a power interruption if the automatic start button is engaged.

37. A method of controlling a pump driven by a motor, the pump in fluid communication with a fluid system, the method comprising:

operating the motor at a normal operating frequency;

determining an actual pressure in the fluid system;

comparing the actual pressure to a pressure set point; and

generating a dry run fault if the pressure set point cannot be achieved by operating the motor at the normal operating frequency.

38. The method of claim 37 and further comprising operating the motor at a normal operating frequency above about 30 Hertz.

39. The method of claim 37 and further comprising comparing the actual pressure to a pressure set point of about 10 pounds per square inch.

40. The method of claim 37 and further comprising determining an actual pressure adjacent to a pressure tank fluidly coupled to the pump.

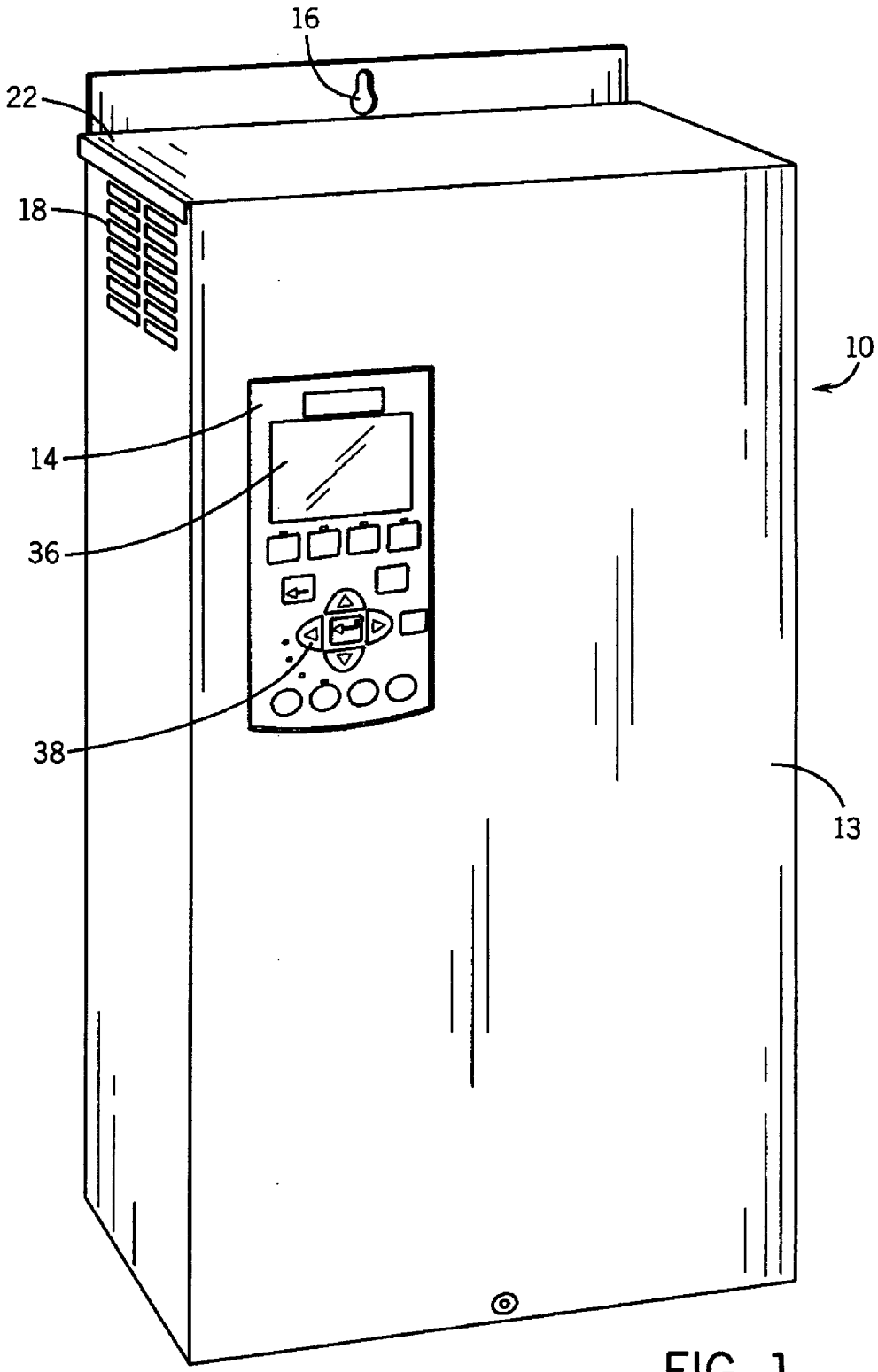


FIG. 1

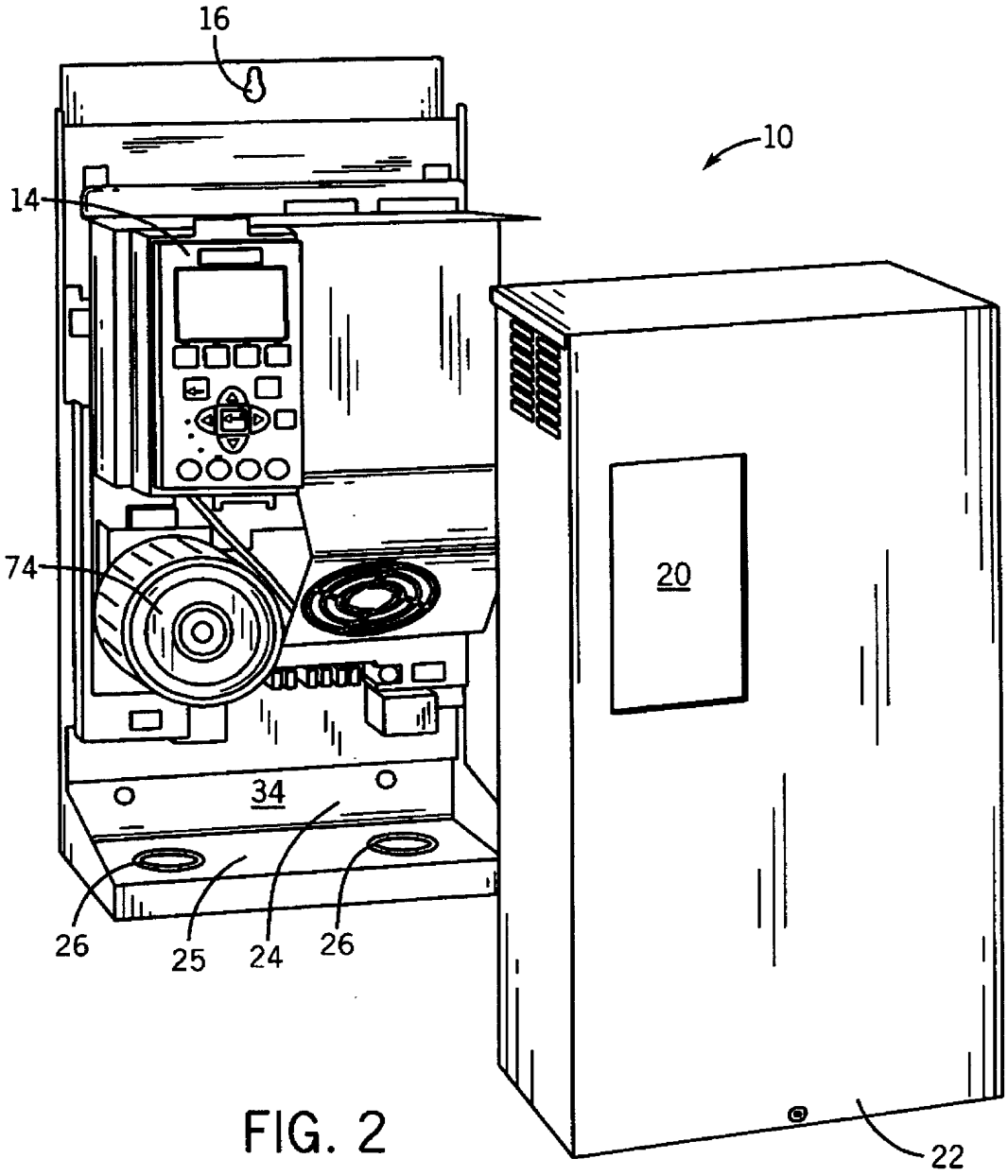


FIG. 2

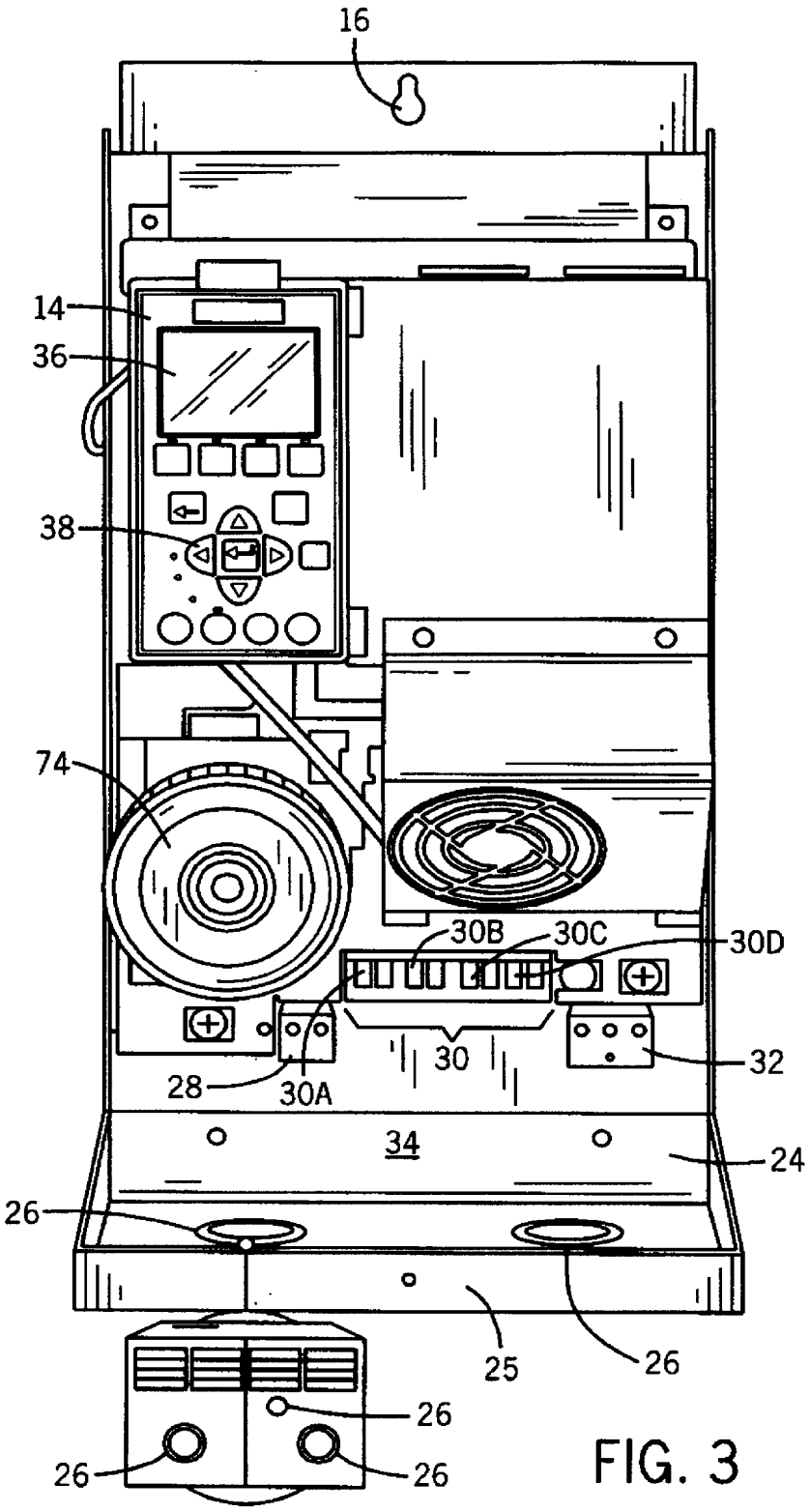


FIG. 3

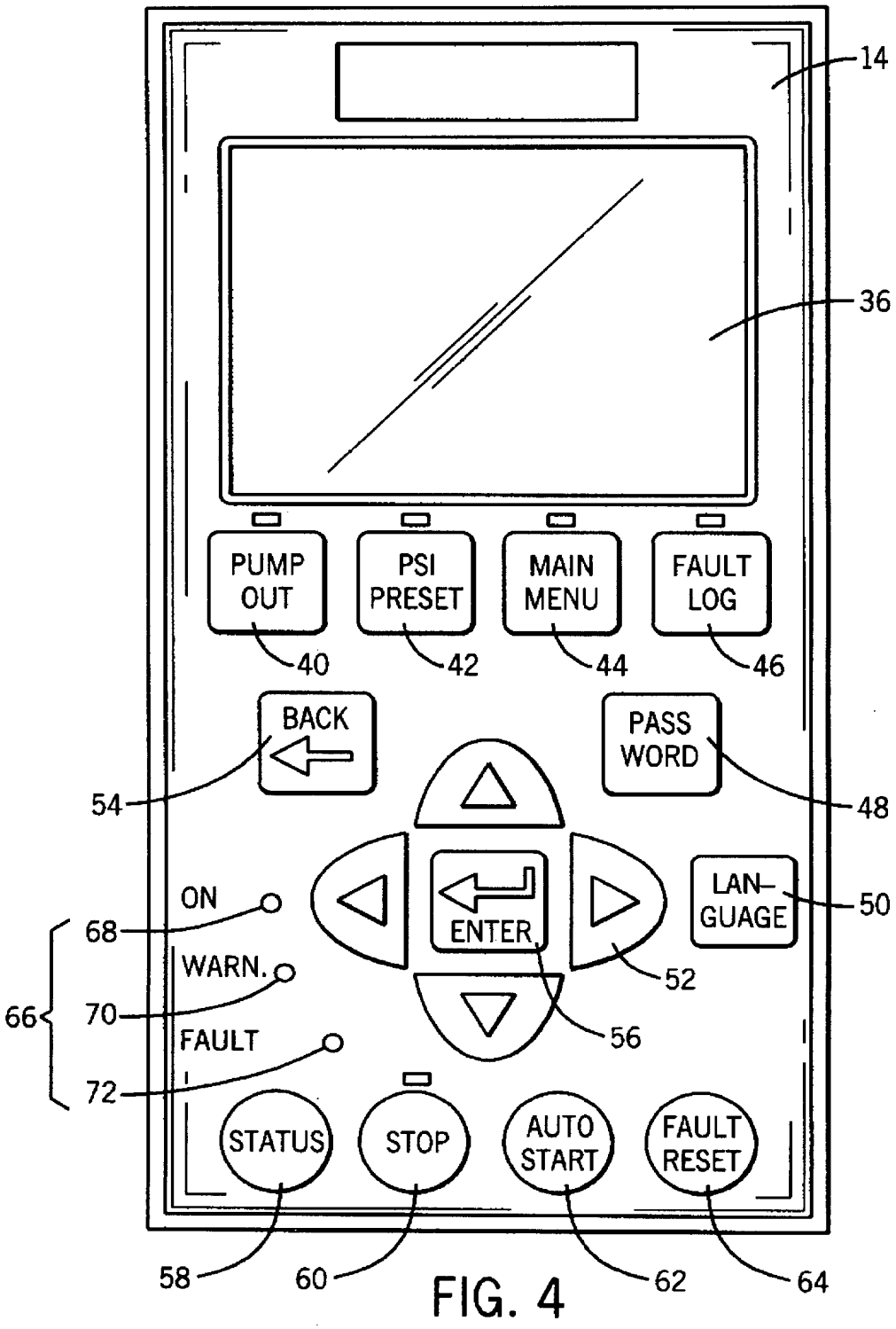

14
36
PUMP OUT
PSI PRESET
MAIN MENU
FAULT LOG
40
42
44
46
BACK
54
PASS WORD
48
ON
68
WARN.
70
FAULT
72
66
ENTER
52
56
LAN-GUAGE
50
STATUS
STOP
AUTO START
FAULT RESET
58
60
62
64

FIG. 4

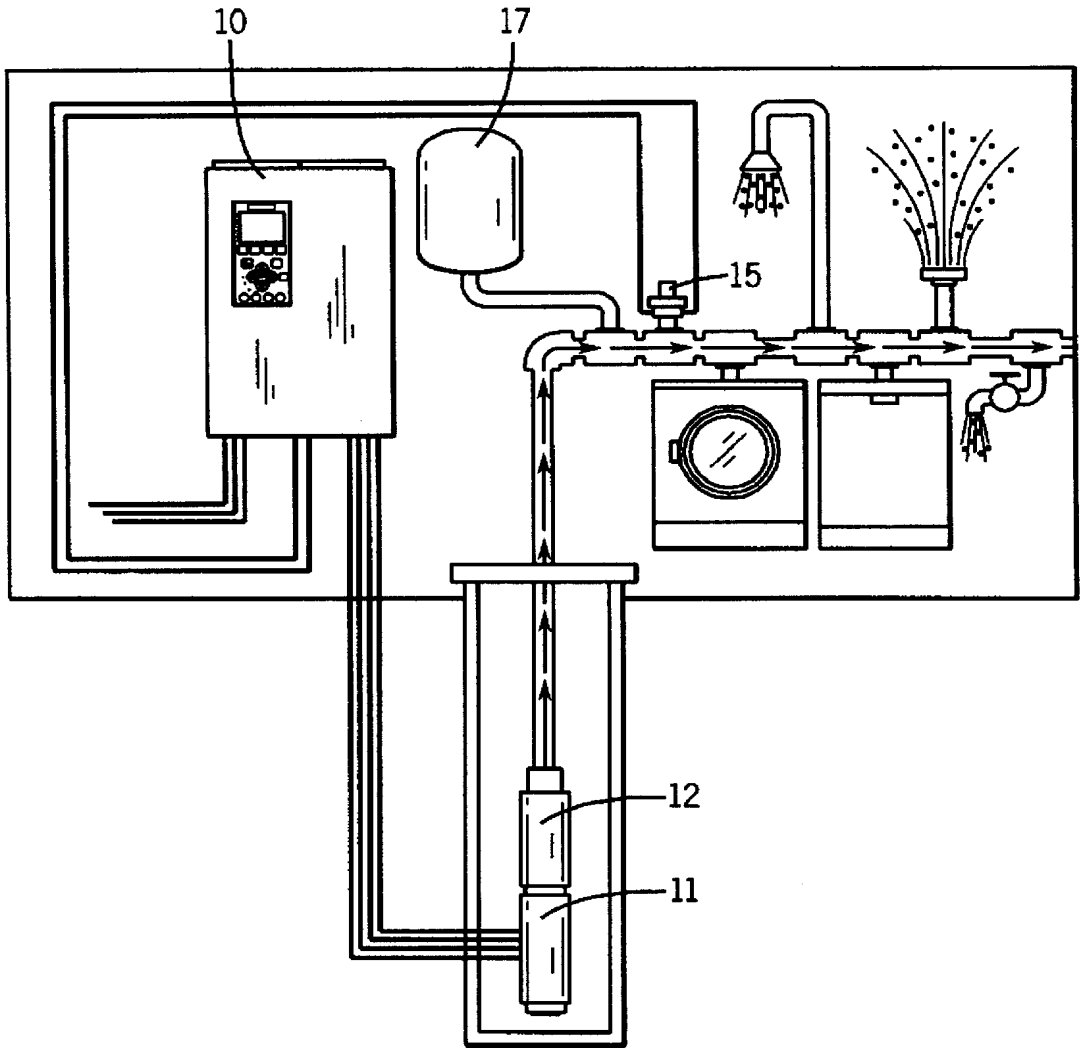


FIG. 5

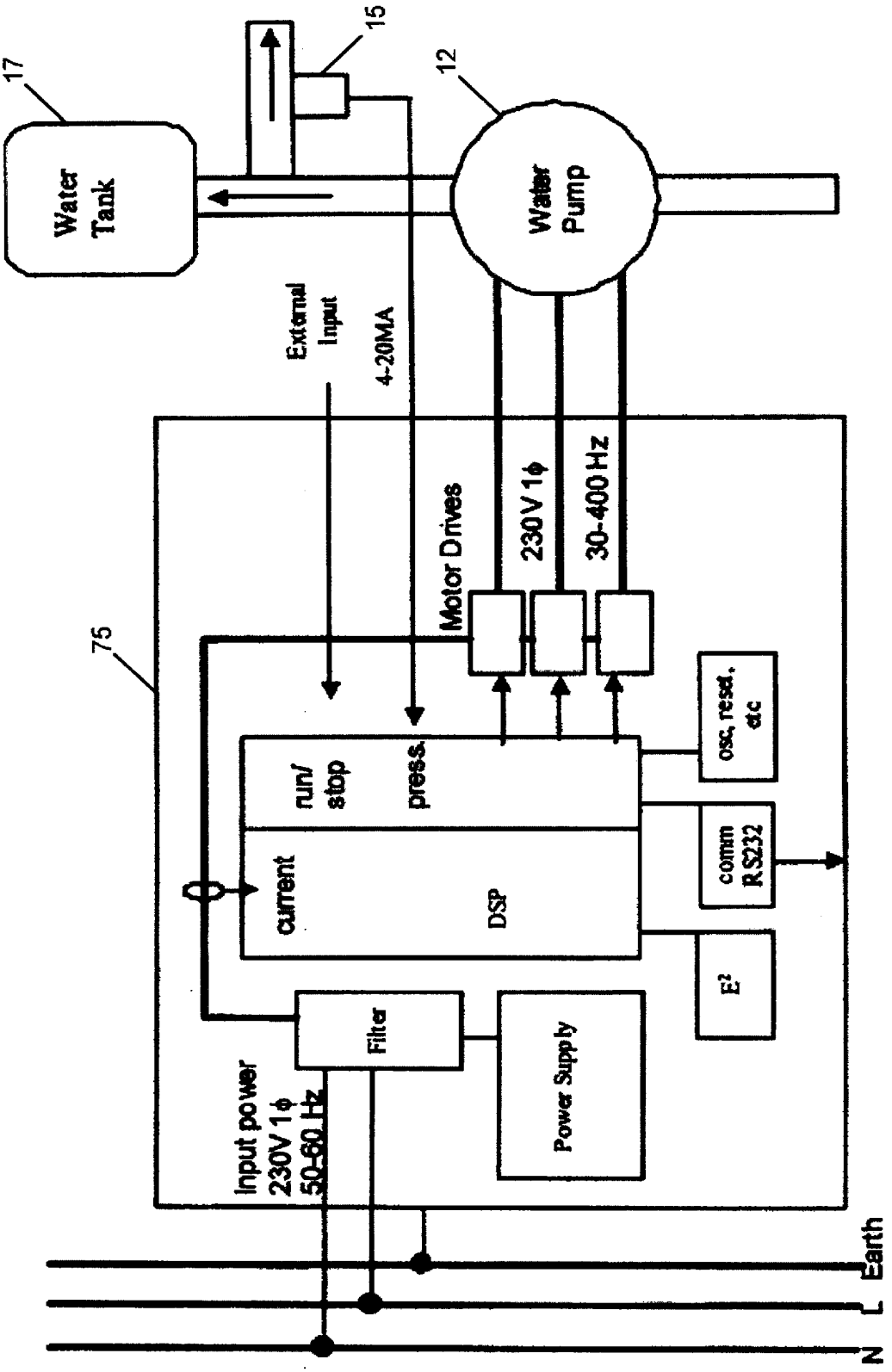

17
15
12
Water Tank
Water Pump
External Input
4-20MA
Motor Drives
230V 1ϕ
30-400 Hz
75
run/ stop
press.
current
DSP
osc, reset, etc
comm RS232
E²
Filter
Power Supply
Input power 230V 1ϕ 50-60 Hz
Earth
L
N

FIGURE 6

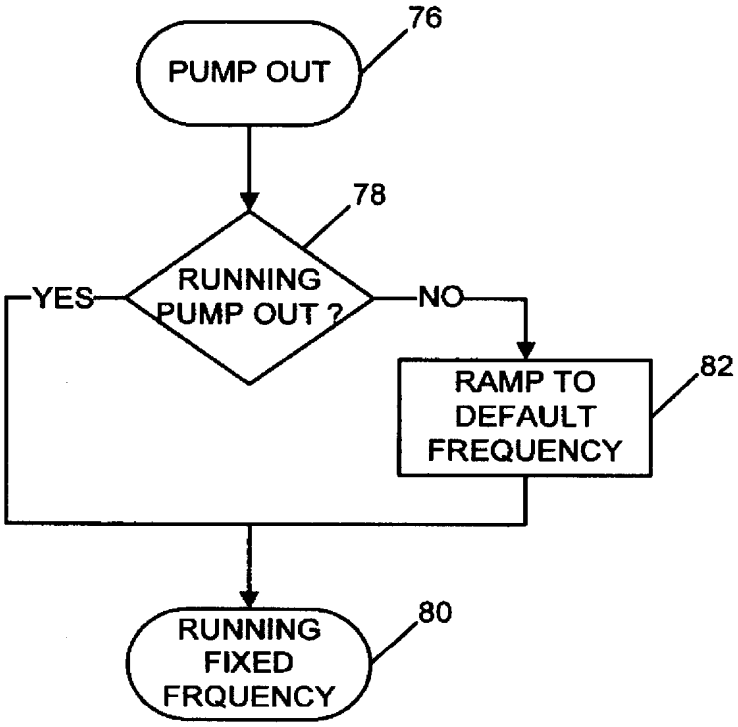

76
PUMP OUT
78
RUNNING
PUMP OUT ?
YES
NO
82
RAMP TO
DEFAULT
FREQUENCY
80
RUNNING
FIXED
FRQUENCY

FIGURE 7

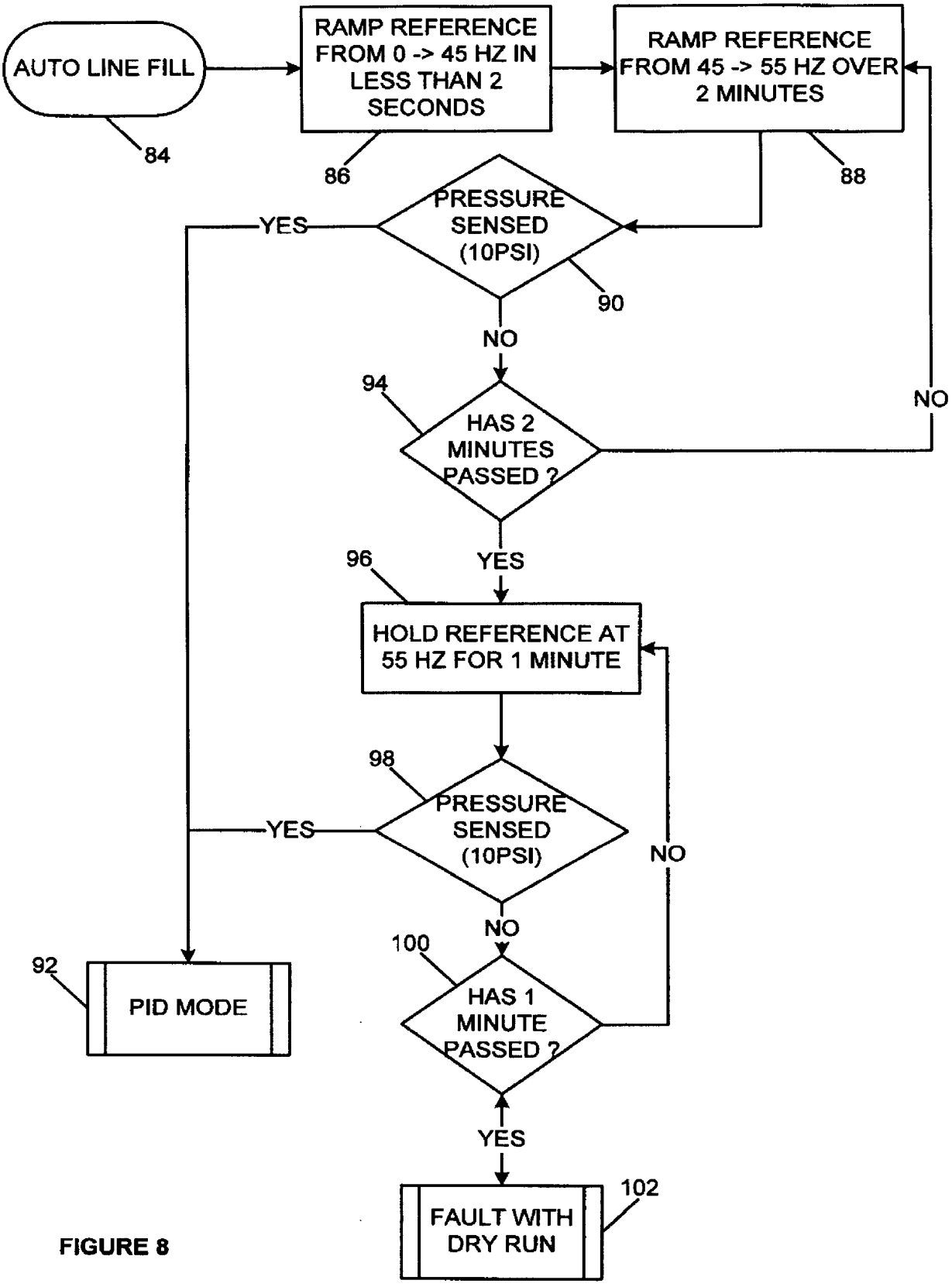

AUTO LINE FILL
84
RAMP REFERENCE FROM 0 -> 45 HZ IN LESS THAN 2 SECONDS
86
RAMP REFERENCE FROM 45 -> 55 HZ OVER 2 MINUTES
88
PRESSURE SENSED (10PSI)
90
YES
NO
94
HAS 2 MINUTES PASSED ?
NO
YES
96
HOLD REFERENCE AT 55 HZ FOR 1 MINUTE
98
PRESSURE SENSED (10PSI)
YES
NO
NO
100
HAS 1 MINUTE PASSED ?
YES
92
PID MODE
102
FAULT WITH DRY RUN

FIGURE 8

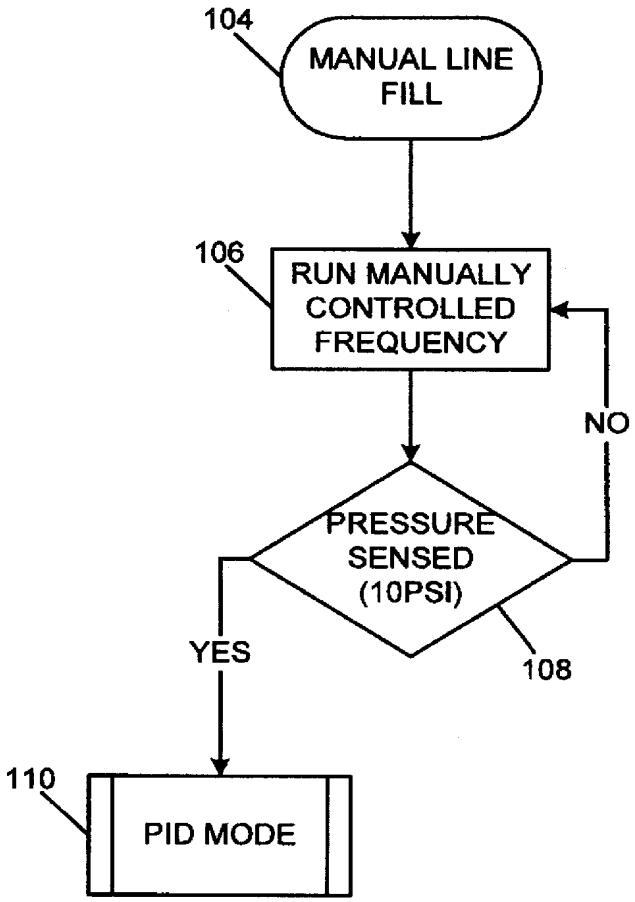

104
MANUAL LINE FILL
106
RUN MANUALLY CONTROLLED FREQUENCY
NO
PRESSURE SENSED (10PSI)
108
YES
110
PID MODE

FIGURE 9

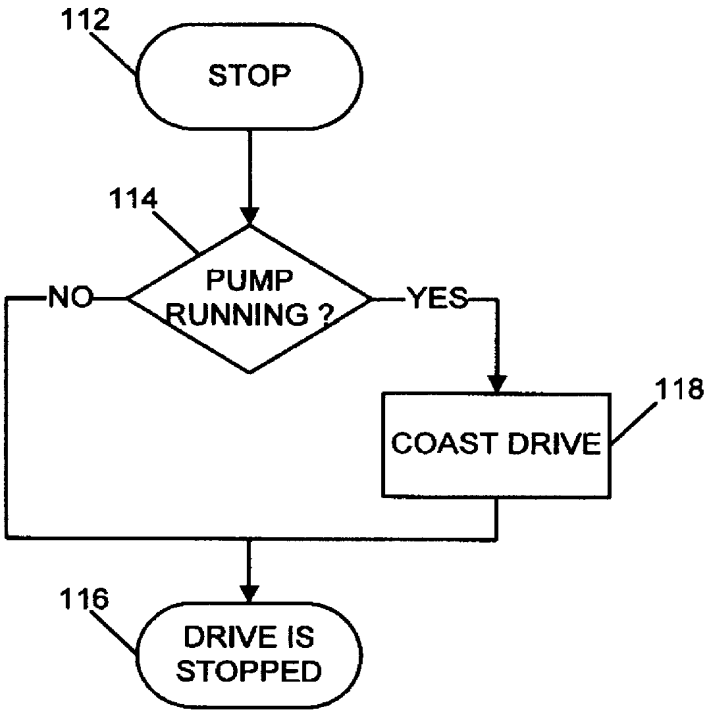

112
STOP
114
PUMP
RUNNING ?
NO
YES
118
COAST DRIVE
116
DRIVE IS
STOPPED

FIGURE 10

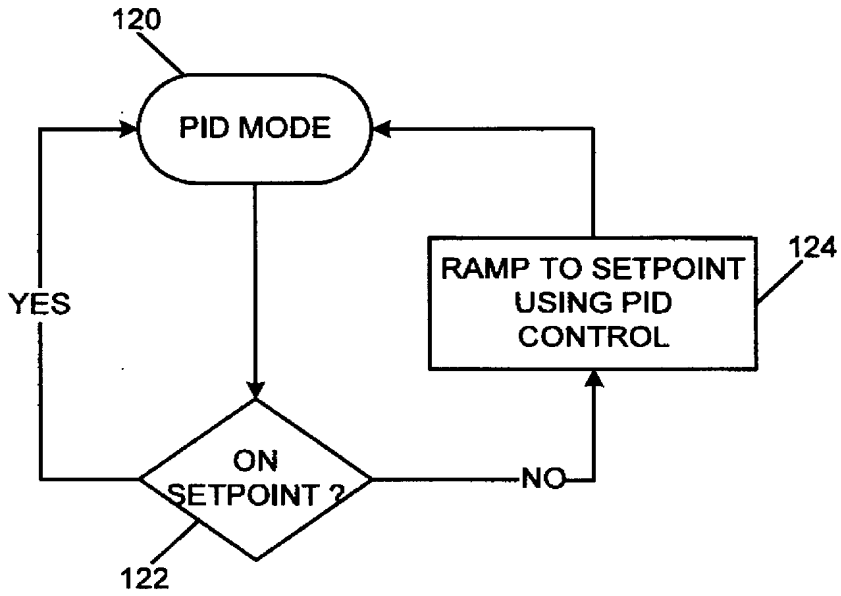

120
PID MODE
RAMP TO SETPOINT USING PID CONTROL
124
YES
ON SETPOINT ?
NO
122

FIGURE 11

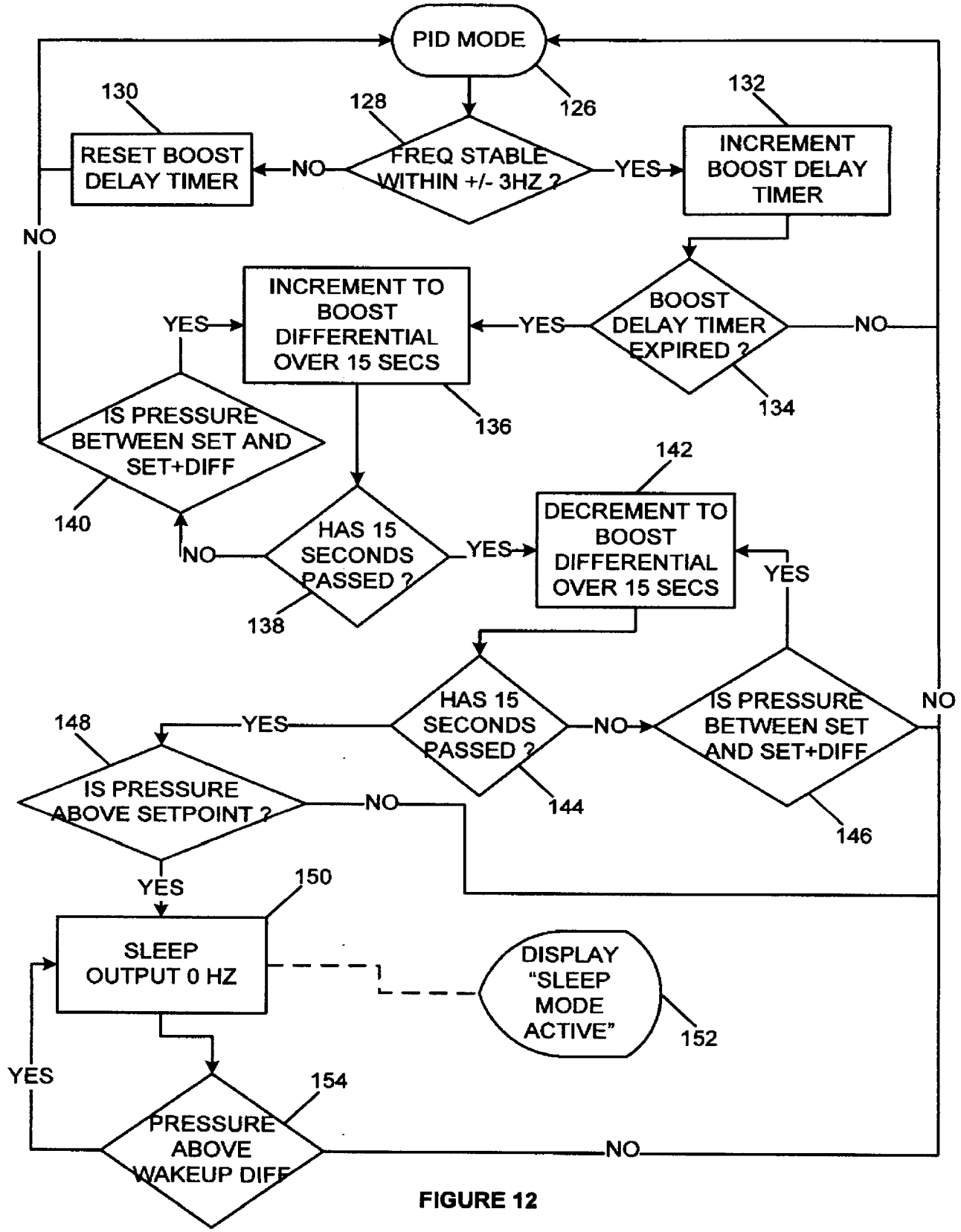

PID MODE
126
128
FREQ STABLE WITHIN +/- 3HZ ?
NO
130
RESET BOOST DELAY TIMER
YES
132
INCREMENT BOOST DELAY TIMER
NO
BOOST DELAY TIMER EXPIRED ?
134
YES
INCREMENT TO BOOST DIFFERENTIAL OVER 15 SECS
136
YES
IS PRESSURE BETWEEN SET AND SET+DIFF
140
NO
HAS 15 SECONDS PASSED ?
138
YES
142
DECREMENT TO BOOST DIFFERENTIAL OVER 15 SECS
YES
HAS 15 SECONDS PASSED ?
144
NO
IS PRESSURE BETWEEN SET AND SET+DIFF
146
NO
148
YES
IS PRESSURE ABOVE SETPOINT ?
NO
YES
150
SLEEP OUTPUT 0 HZ
DISPLAY "SLEEP MODE ACTIVE"
152
YES
154
PRESSURE ABOVE WAKEUP DIFF
NO

FIGURE 12

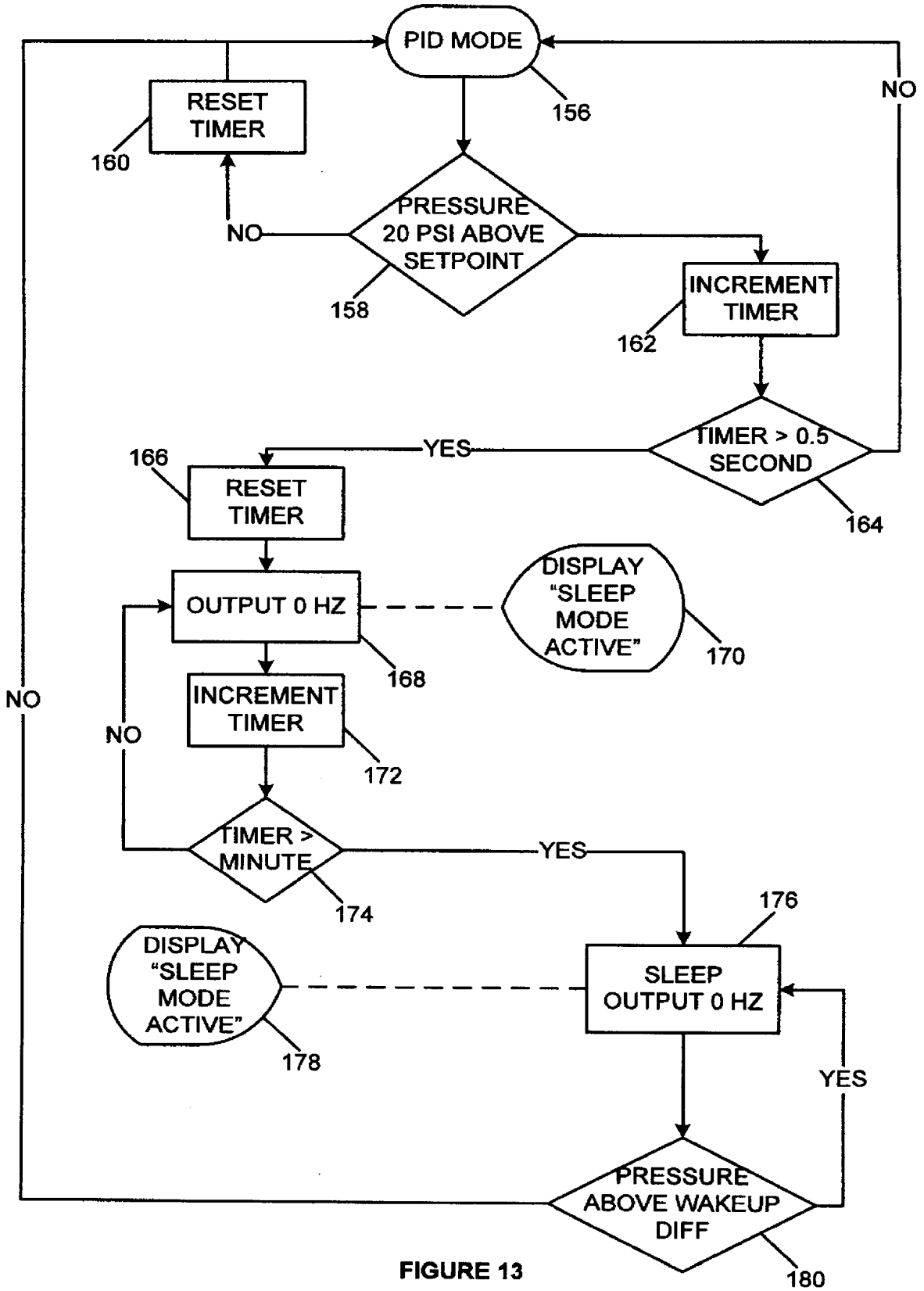

PID MODE
156
NO
RESET TIMER
160
PRESSURE 20 PSI ABOVE SETPOINT
158
NO
INCREMENT TIMER
162
TIMER > 0.5 SECOND
164
YES
166
RESET TIMER
OUTPUT 0 HZ
168
DISPLAY "SLEEP MODE ACTIVE"
170
INCREMENT TIMER
172
NO
NO
TIMER > MINUTE
174
YES
176
DISPLAY "SLEEP MODE ACTIVE"
178
SLEEP OUTPUT 0 HZ
YES
PRESSURE ABOVE WAKEUP DIFF
180

FIGURE 13

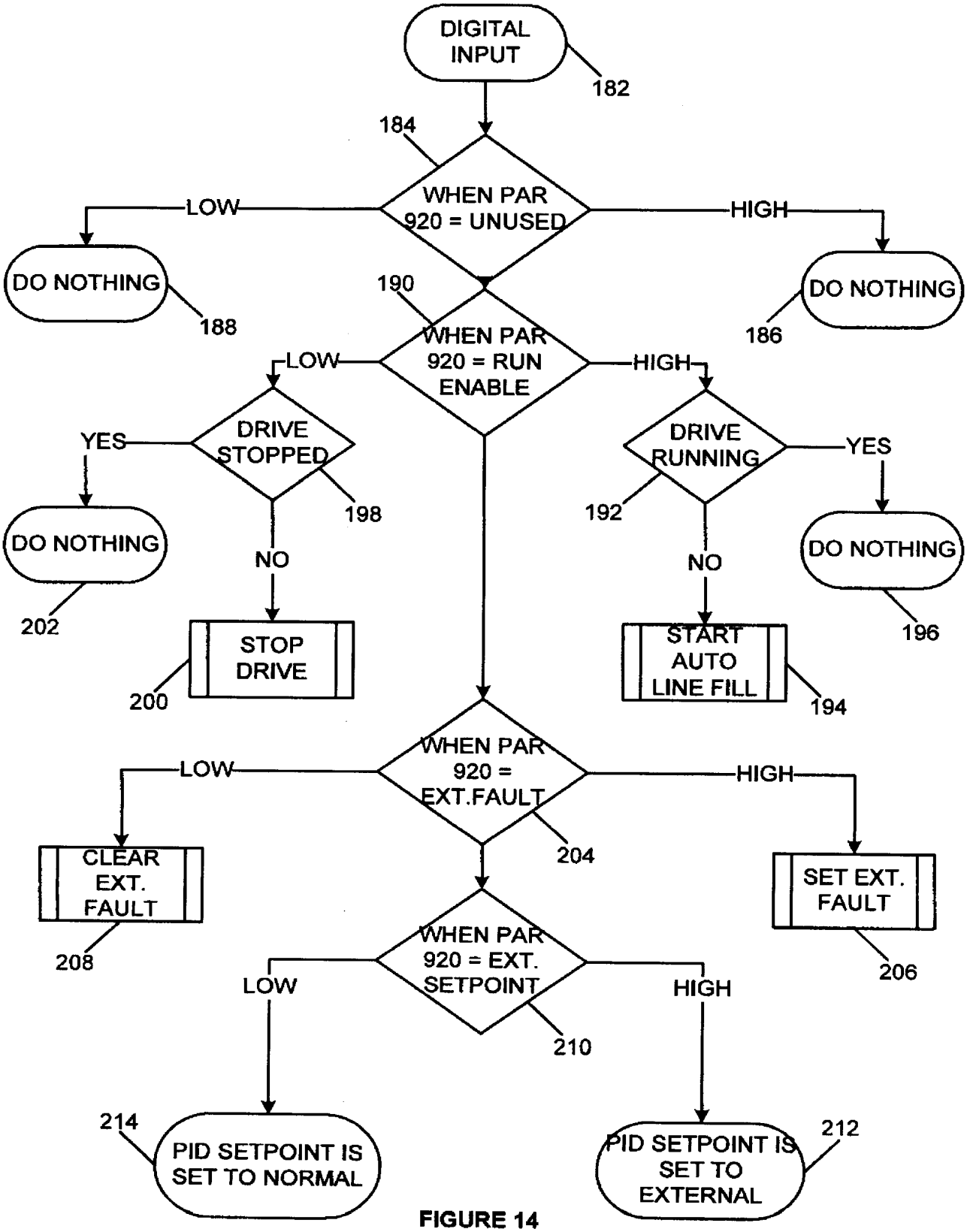

DIGITAL INPUT
182
184
WHEN PAR 920 = UNUSED
LOW
HIGH
DO NOTHING
188
DO NOTHING
186
190
WHEN PAR 920 = RUN ENABLE
LOW
HIGH
DRIVE STOPPED
198
YES
NO
DO NOTHING
202
STOP DRIVE
200
DRIVE RUNNING
192
YES
NO
DO NOTHING
196
START AUTO LINE FILL
194
WHEN PAR 920 = EXT.FAULT
204
LOW
HIGH
CLEAR EXT. FAULT
208
SET EXT. FAULT
206
WHEN PAR 920 = EXT. SETPOINT
210
LOW
HIGH
214
PID SETPOINT IS SET TO NORMAL
212
PID SETPOINT IS SET TO EXTERNAL

FIGURE 14

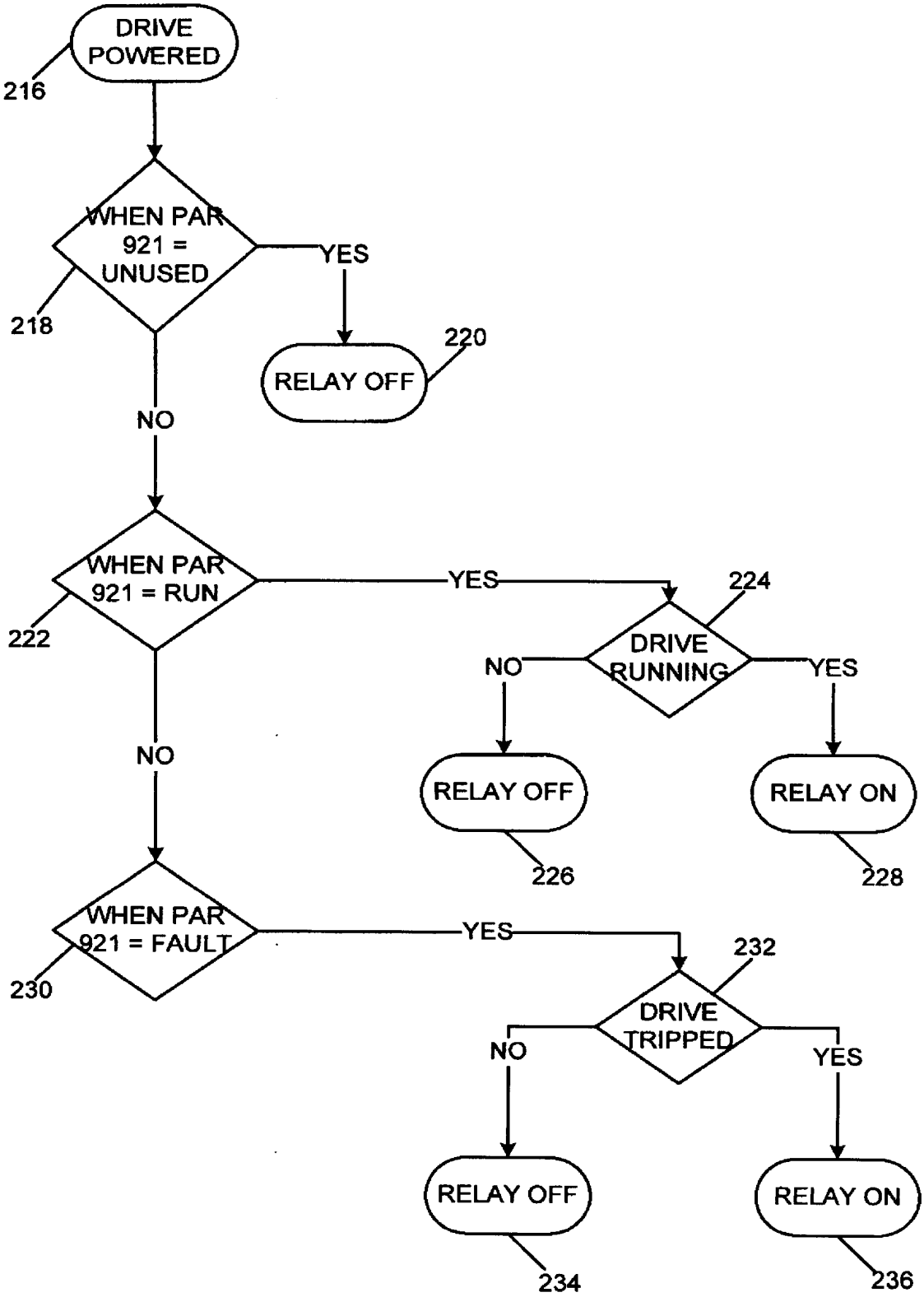

DRIVE POWERED
216
WHEN PAR 921 = UNUSED
218
YES
220
RELAY OFF
NO
WHEN PAR 921 = RUN
222
YES
224
DRIVE RUNNING
NO
YES
RELAY OFF
226
RELAY ON
228
NO
WHEN PAR 921 = FAULT
230
YES
232
DRIVE TRIPPED
NO
YES
RELAY OFF
234
RELAY ON
236

FIGURE 15

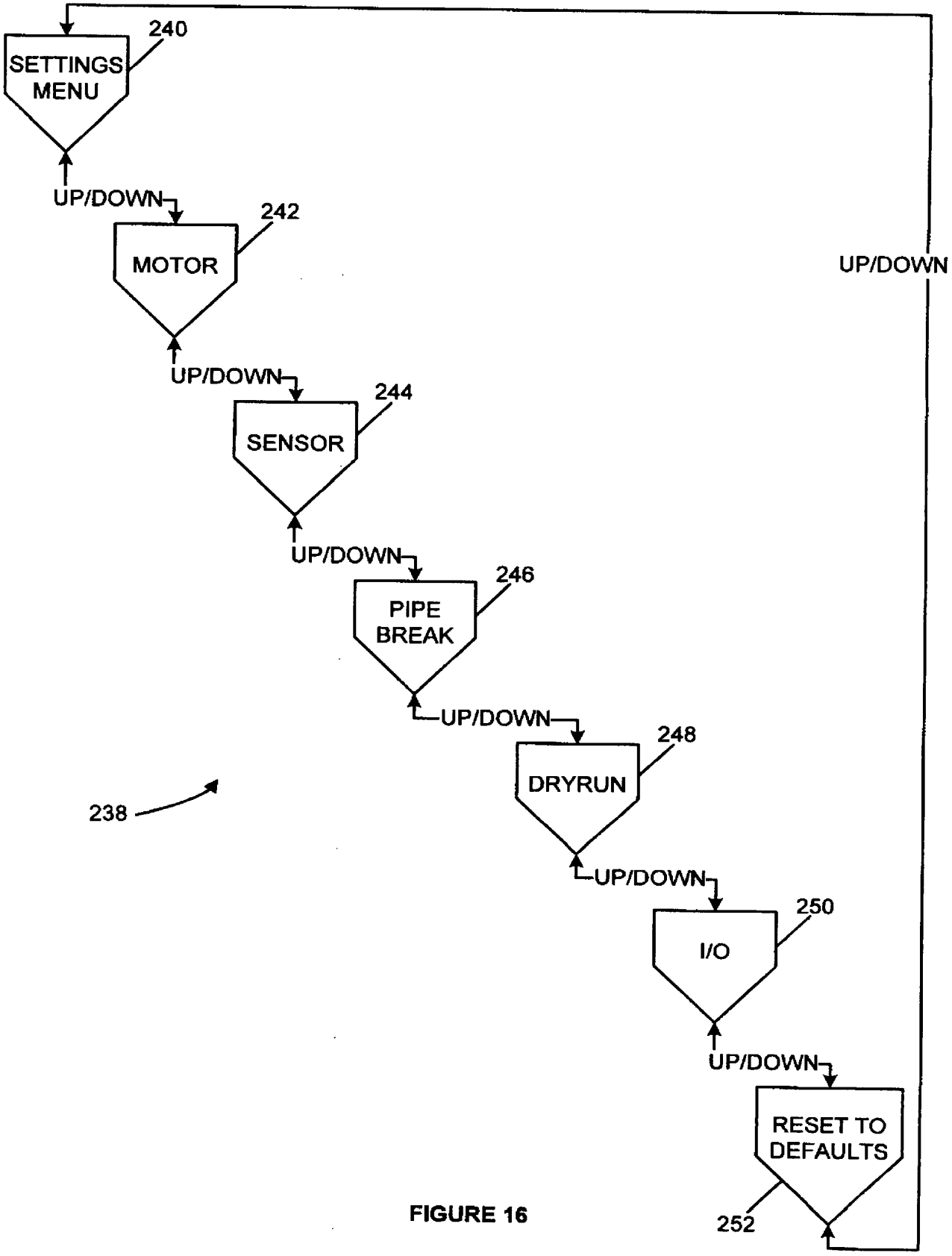

SETTINGS MENU
240
UP/DOWN
MOTOR
242
UP/DOWN
SENSOR
244
UP/DOWN
PIPE BREAK
246
UP/DOWN
DRYRUN
248
UP/DOWN
I/O
250
UP/DOWN
RESET TO DEFAULTS
252
UP/DOWN
238

FIGURE 16

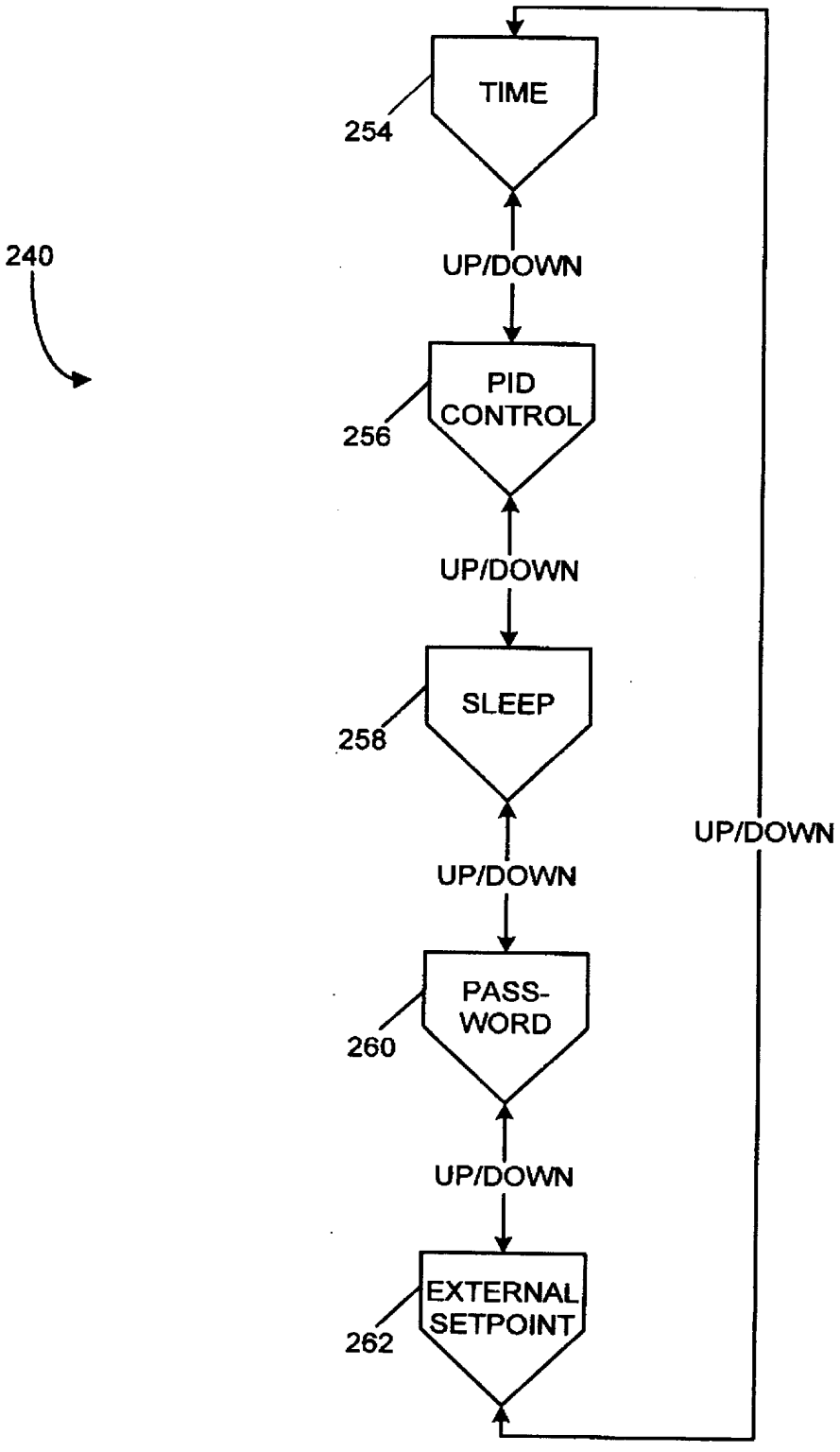

240
TIME
254
UP/DOWN
PID CONTROL
256
UP/DOWN
SLEEP
258
UP/DOWN
PASS-WORD
260
UP/DOWN
EXTERNAL SETPOINT
262
UP/DOWN

FIGURE 17

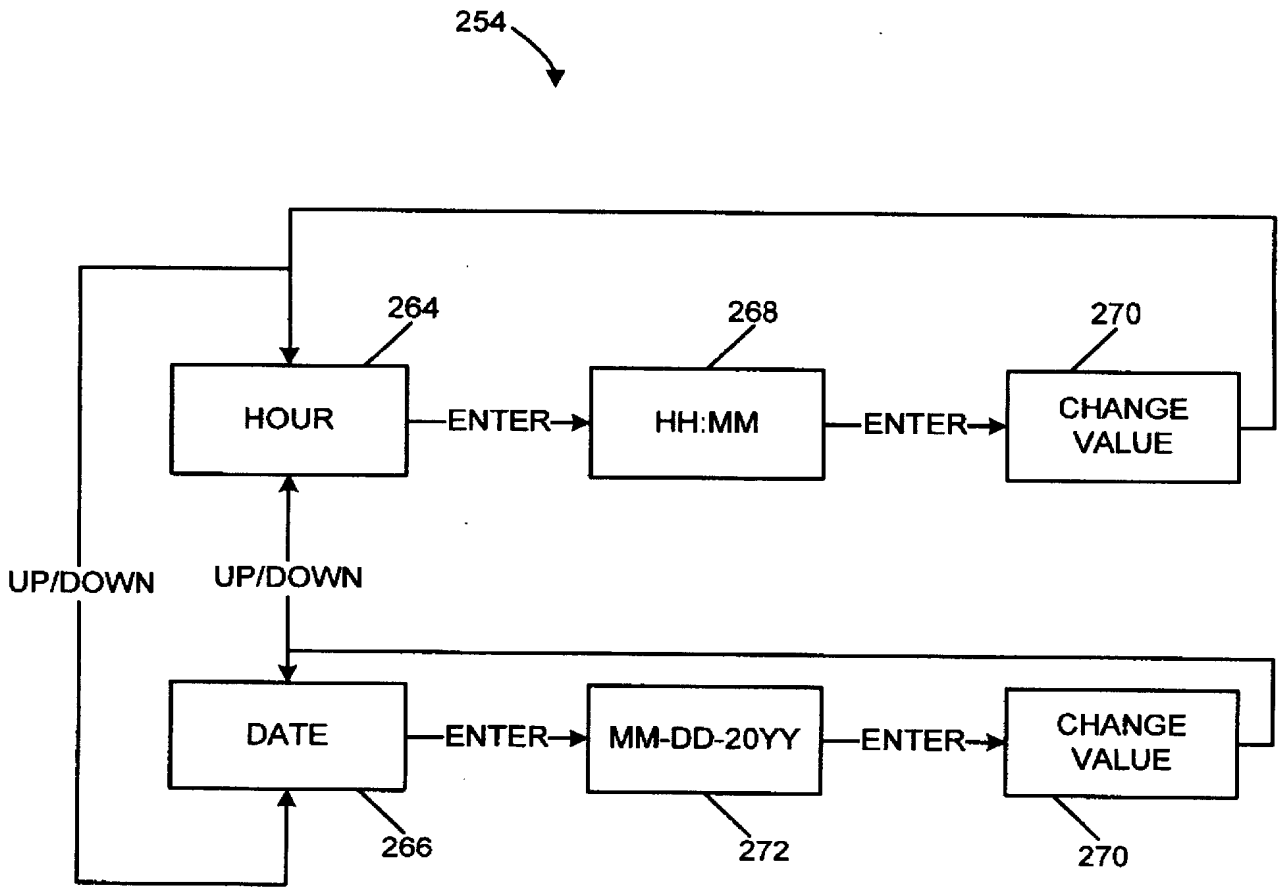

254
264
268
270
HOUR
ENTER
HH:MM
ENTER
CHANGE VALUE
UP/DOWN
UP/DOWN
DATE
ENTER
MM-DD-20YY
ENTER
CHANGE VALUE
266
272
270

FIGURE 18

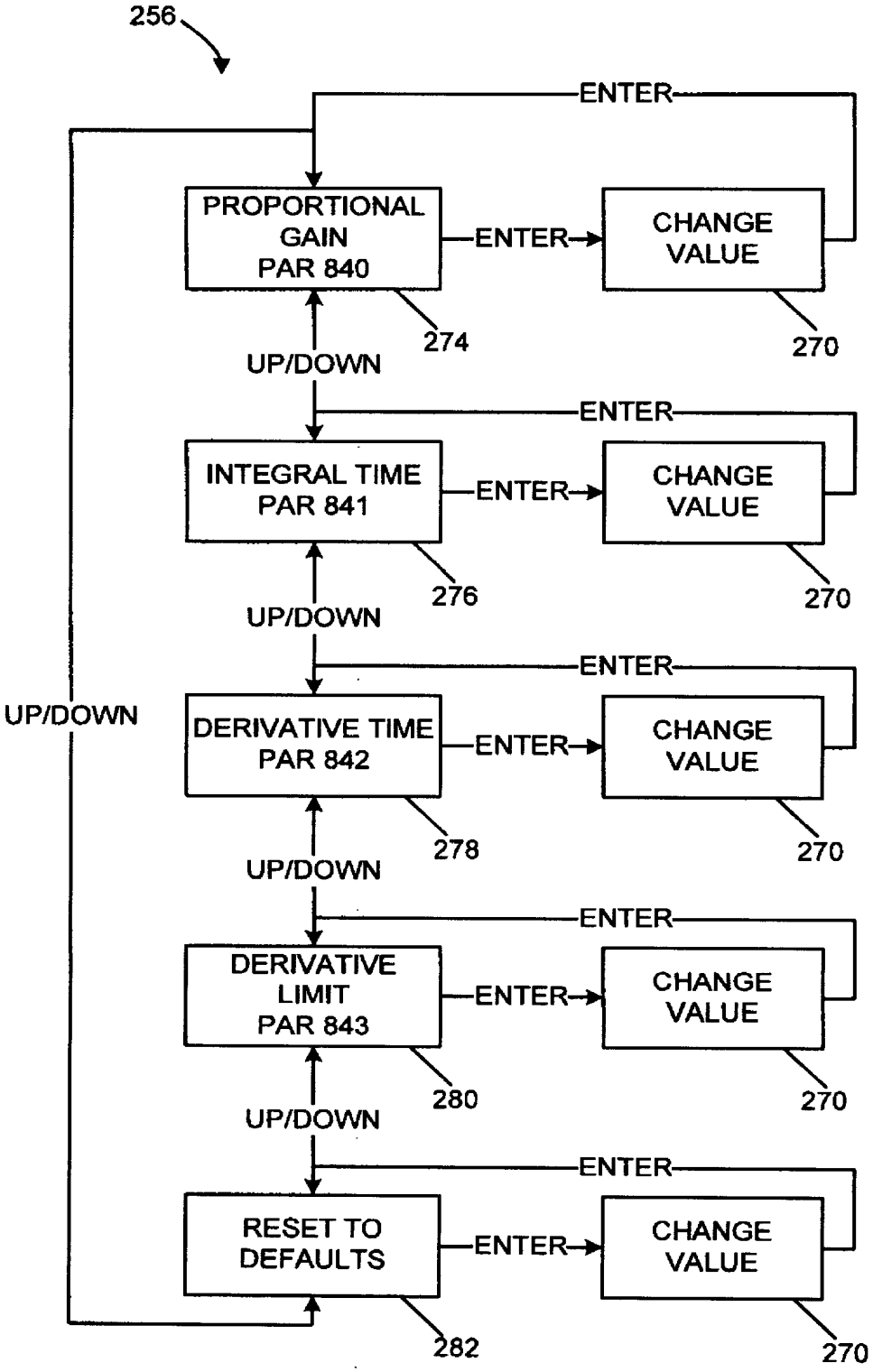

256
ENTER
PROPORTIONAL GAIN PAR 840
ENTER
CHANGE VALUE
274
270
UP/DOWN
ENTER
INTEGRAL TIME PAR 841
ENTER
CHANGE VALUE
276
270
UP/DOWN
ENTER
UP/DOWN
DERIVATIVE TIME PAR 842
ENTER
CHANGE VALUE
278
270
UP/DOWN
ENTER
DERIVATIVE LIMIT PAR 843
ENTER
CHANGE VALUE
280
270
UP/DOWN
ENTER
RESET TO DEFAULTS
ENTER
CHANGE VALUE
282
270

FIGURE 19

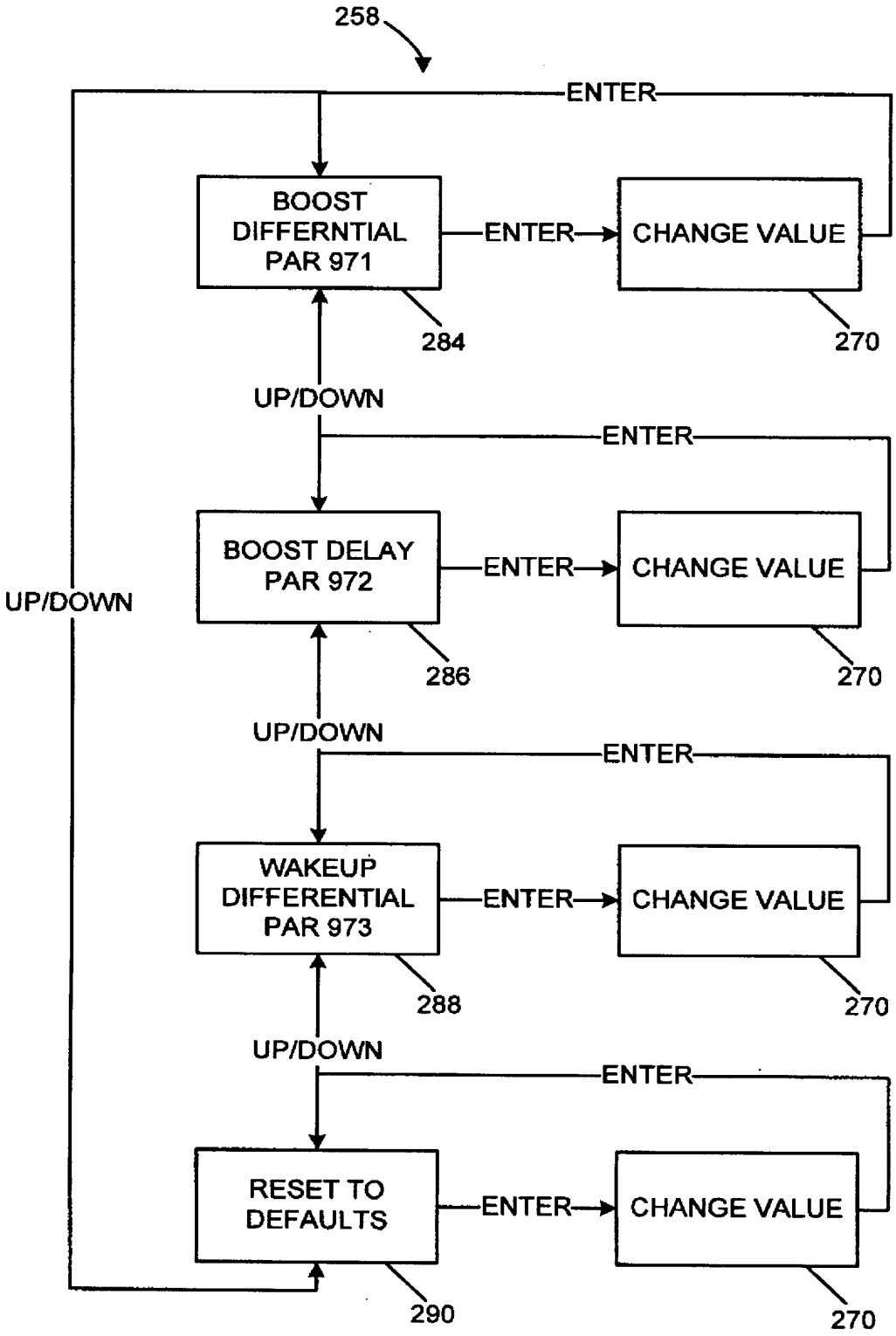

258
ENTER
BOOST DIFFERNTIAL PAR 971
ENTER
CHANGE VALUE
284
270
UP/DOWN
ENTER
BOOST DELAY PAR 972
ENTER
CHANGE VALUE
UP/DOWN
286
270
UP/DOWN
ENTER
WAKEUP DIFFERENTIAL PAR 973
ENTER
CHANGE VALUE
288
270
UP/DOWN
ENTER
RESET TO DEFAULTS
ENTER
CHANGE VALUE
290
270

FIGURE 20

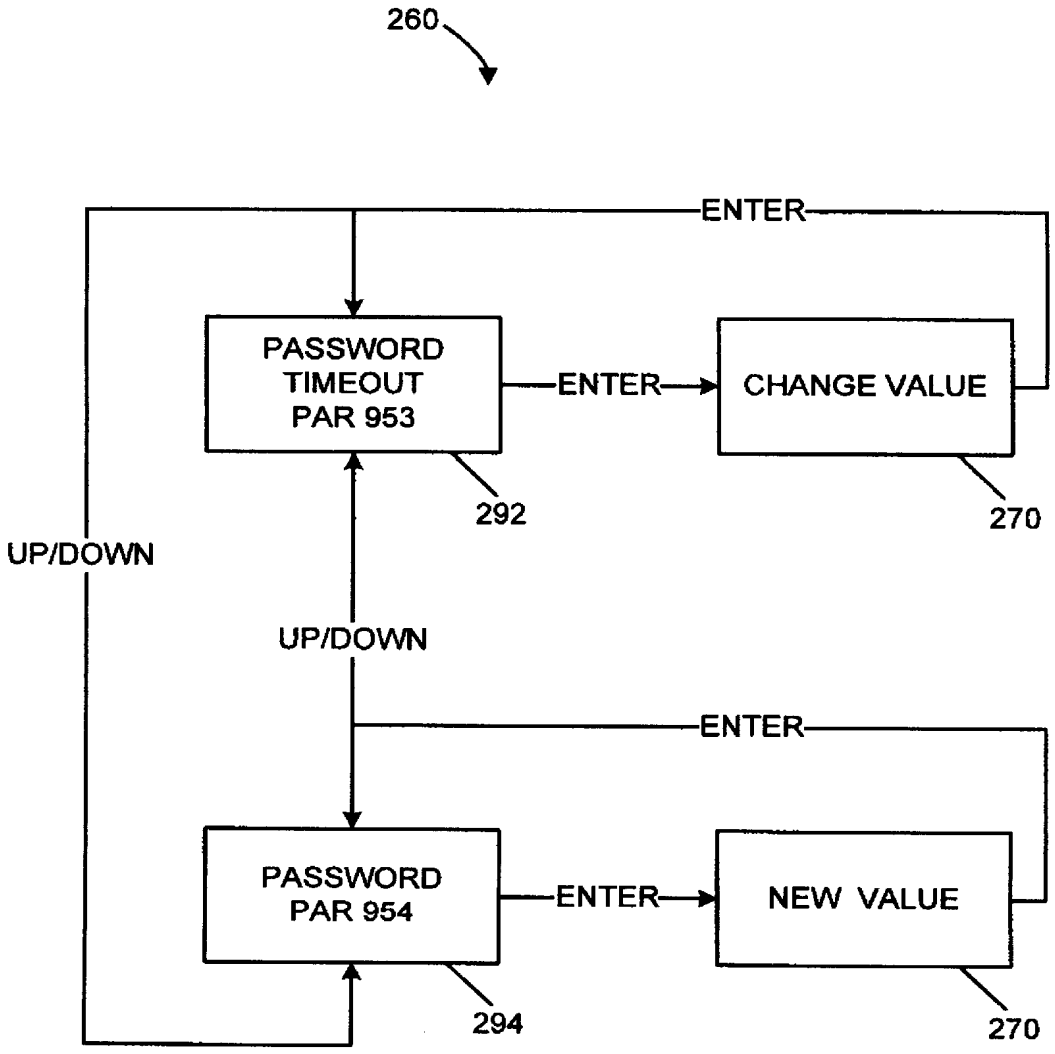

260
ENTER
PASSWORD
TIMEOUT
PAR 953
ENTER
CHANGE VALUE
292
270
UP/DOWN
UP/DOWN
ENTER
PASSWORD
PAR 954
ENTER
NEW VALUE
294
270

FIGURE 21

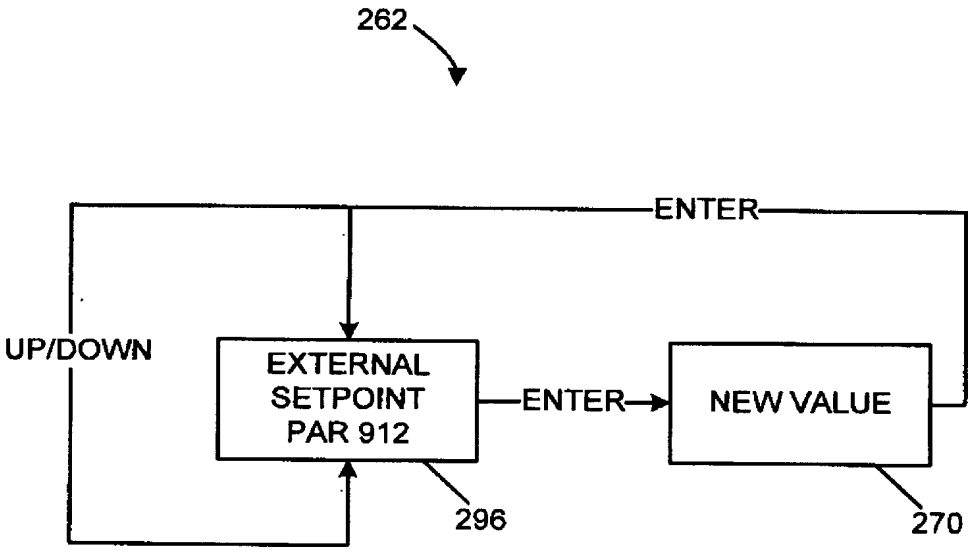

262
ENTER
UP/DOWN
EXTERNAL SETPOINT PAR 912
ENTER
NEW VALUE
296
270

FIGURE 22

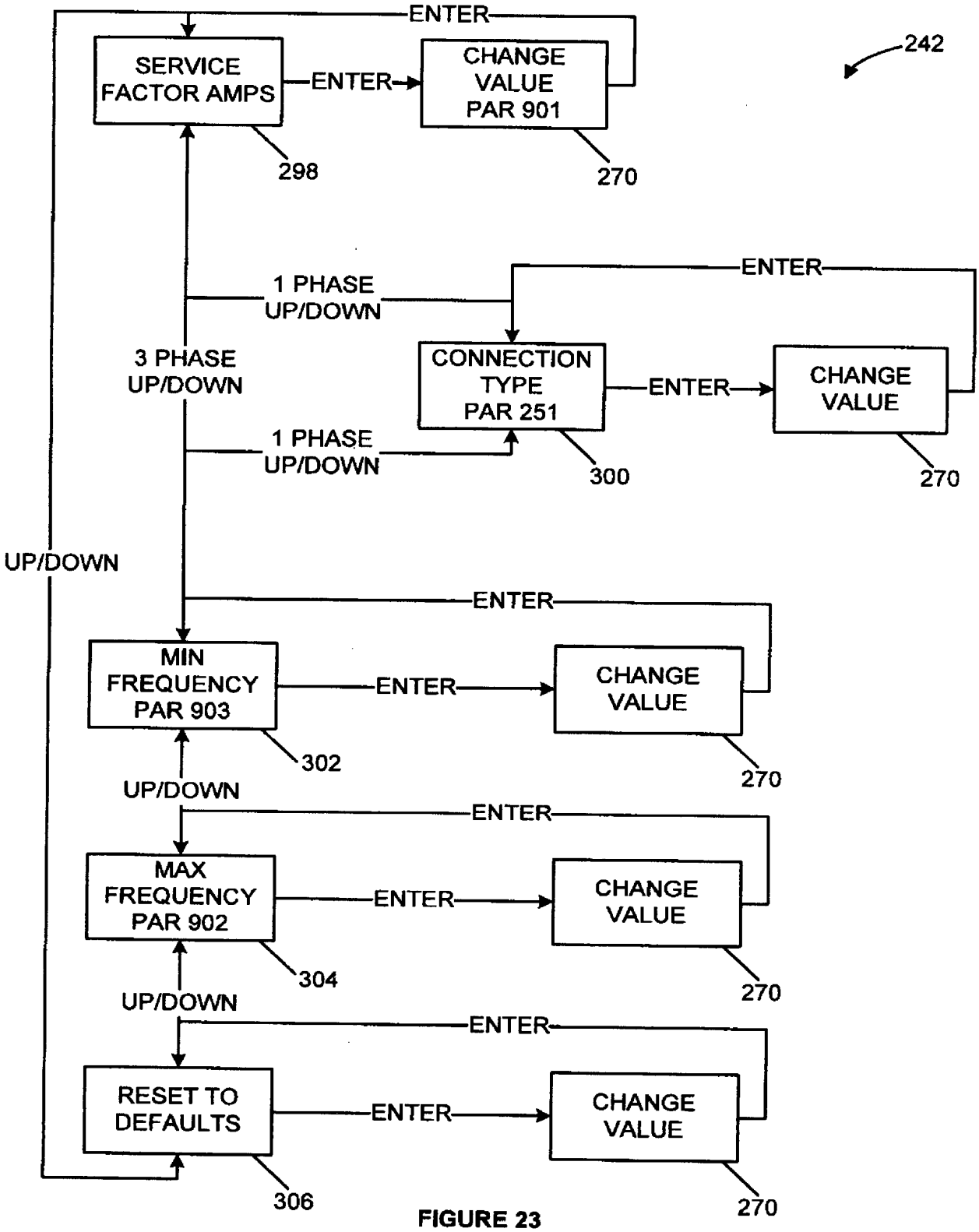

ENTER
SERVICE FACTOR AMPS
ENTER
CHANGE VALUE PAR 901
242
298
270
1 PHASE UP/DOWN
ENTER
3 PHASE UP/DOWN
CONNECTION TYPE PAR 251
ENTER
CHANGE VALUE
1 PHASE UP/DOWN
300
270
UP/DOWN
ENTER
MIN FREQUENCY PAR 903
ENTER
CHANGE VALUE
302
270
UP/DOWN
ENTER
MAX FREQUENCY PAR 902
ENTER
CHANGE VALUE
304
270
UP/DOWN
ENTER
RESET TO DEFAULTS
ENTER
CHANGE VALUE
306
270

FIGURE 23

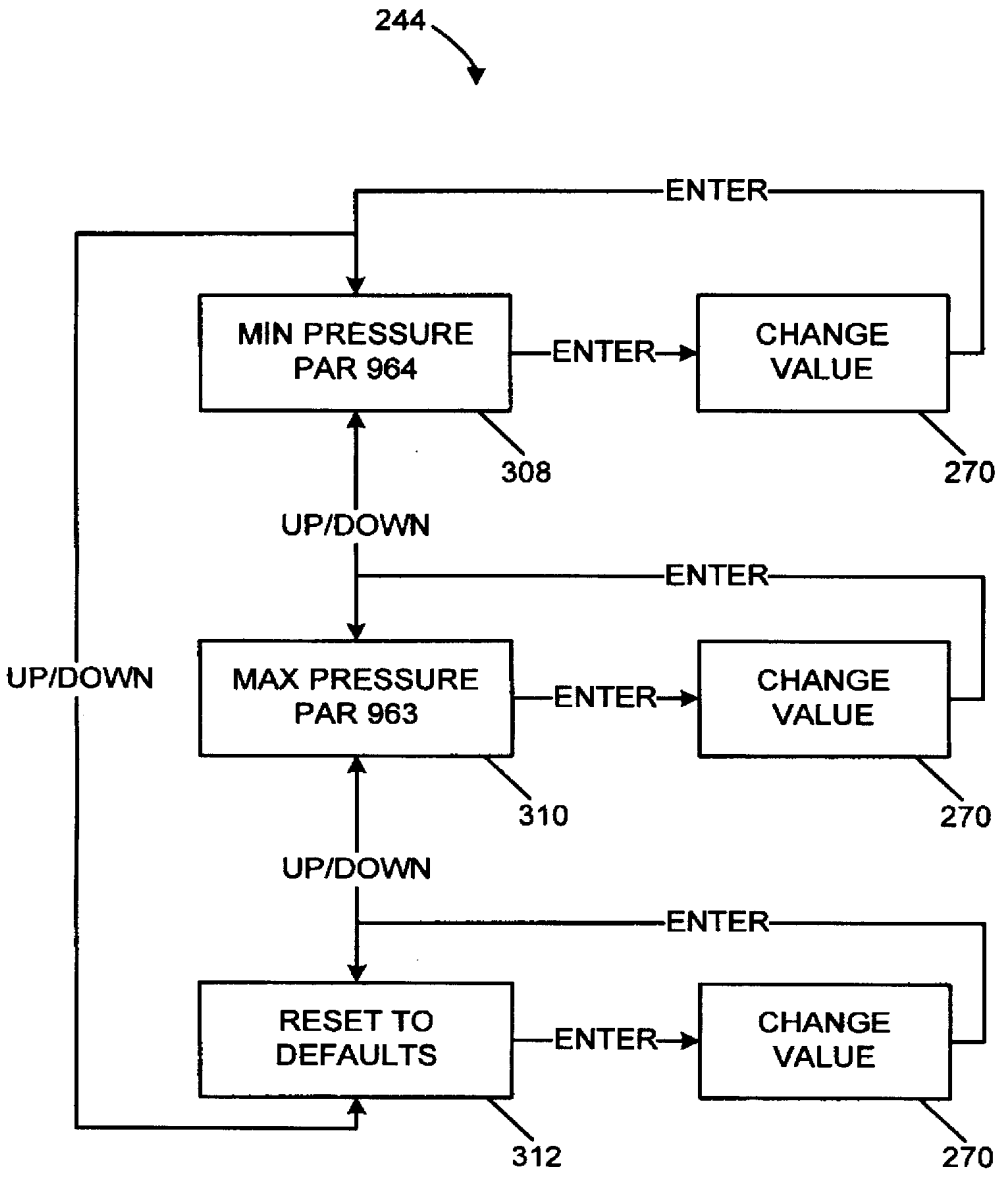

244
ENTER
MIN PRESSURE
PAR 964
ENTER
CHANGE
VALUE
308
270
UP/DOWN
ENTER
UP/DOWN
MAX PRESSURE
PAR 963
ENTER
CHANGE
VALUE
310
270
UP/DOWN
ENTER
RESET TO
DEFAULTS
ENTER
CHANGE
VALUE
312
270

FIGURE 24

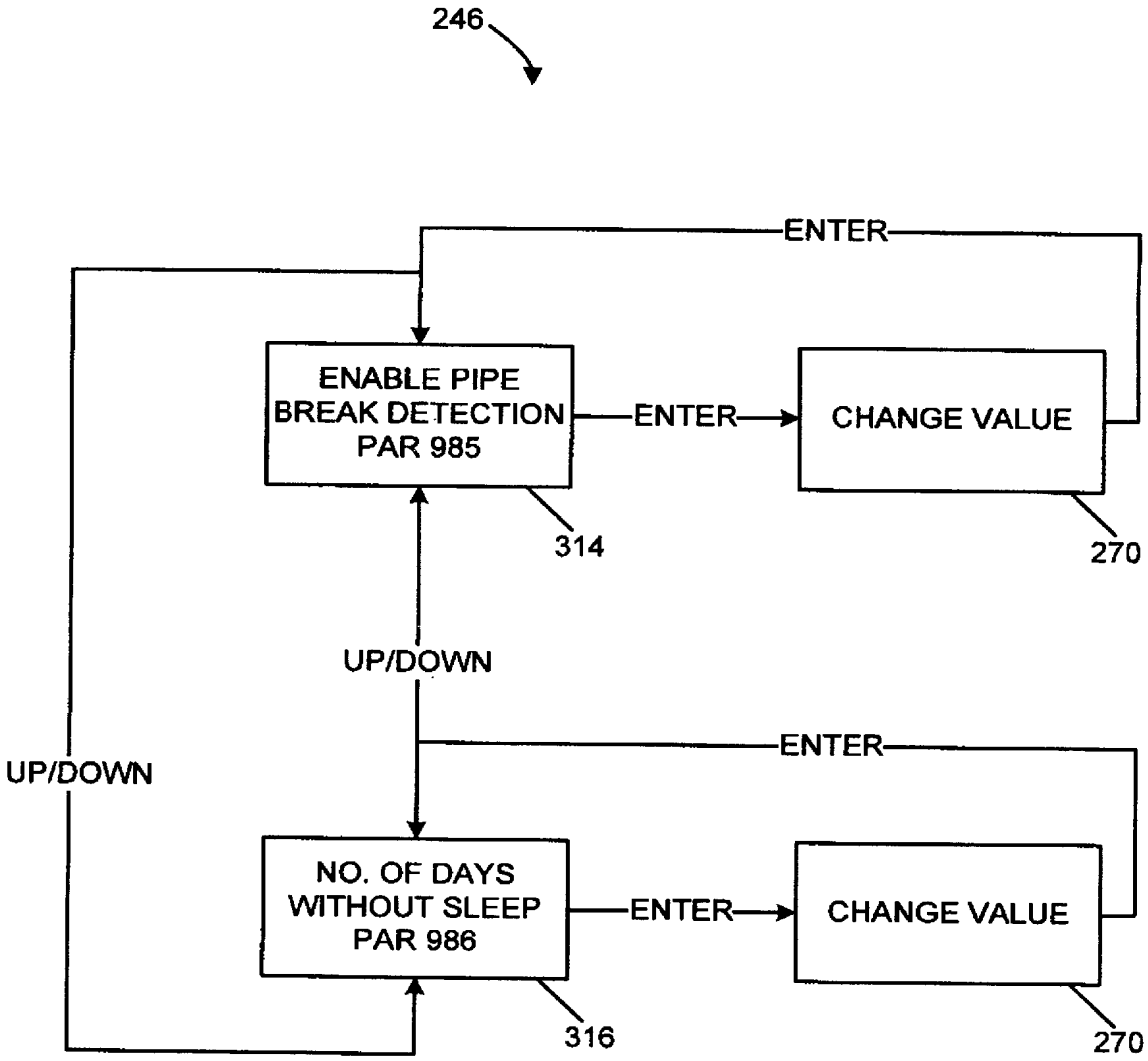

246
ENTER
ENABLE PIPE BREAK DETECTION PAR 985
ENTER
CHANGE VALUE
314
270
UP/DOWN
ENTER
UP/DOWN
NO. OF DAYS WITHOUT SLEEP PAR 986
ENTER
CHANGE VALUE
316
270

FIGURE 25

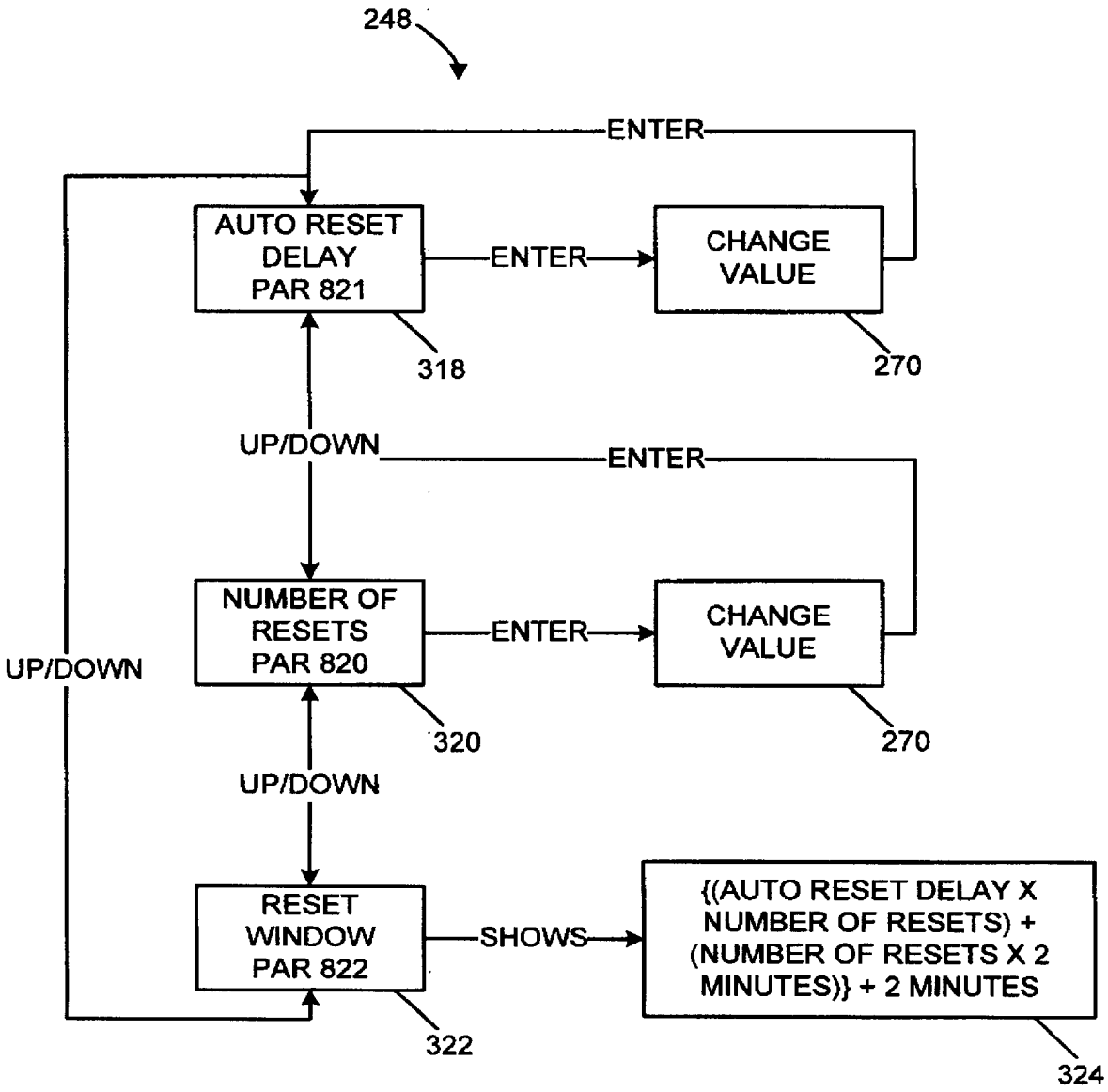

248
ENTER
AUTO RESET DELAY PAR 821
ENTER
CHANGE VALUE
318
270
UP/DOWN
ENTER
NUMBER OF RESETS PAR 820
ENTER
CHANGE VALUE
UP/DOWN
320
270
UP/DOWN
RESET WINDOW PAR 822
SHOWS
{(AUTO RESET DELAY X NUMBER OF RESETS) + (NUMBER OF RESETS X 2 MINUTES)} + 2 MINUTES
322
324

FIGURE 26

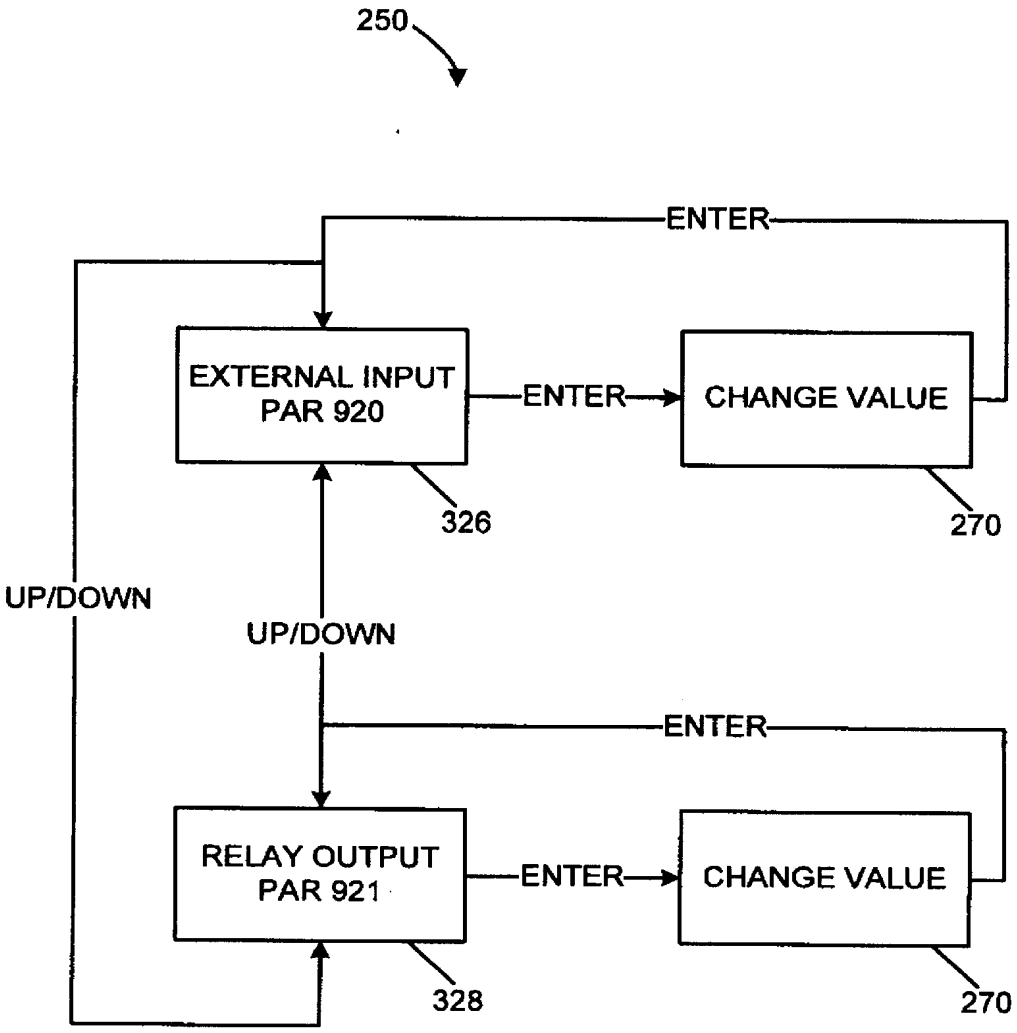

250
ENTER
EXTERNAL INPUT
PAR 920
ENTER
CHANGE VALUE
326
270
UP/DOWN
UP/DOWN
ENTER
RELAY OUTPUT
PAR 921
ENTER
CHANGE VALUE
328
270

FIGURE 27

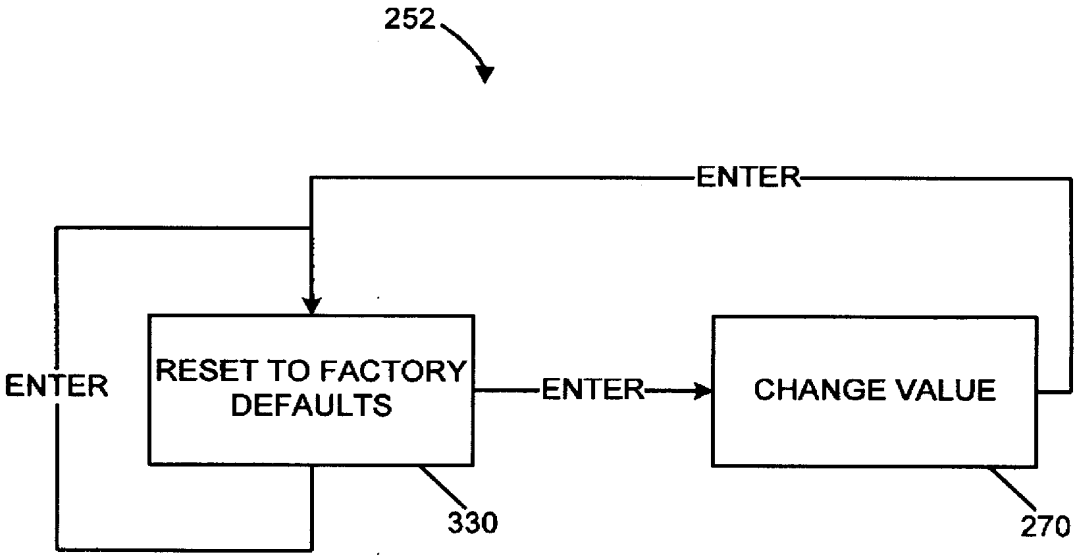

252
ENTER
ENTER
RESET TO FACTORY DEFAULTS
ENTER
CHANGE VALUE
330
270

FIGURE 28

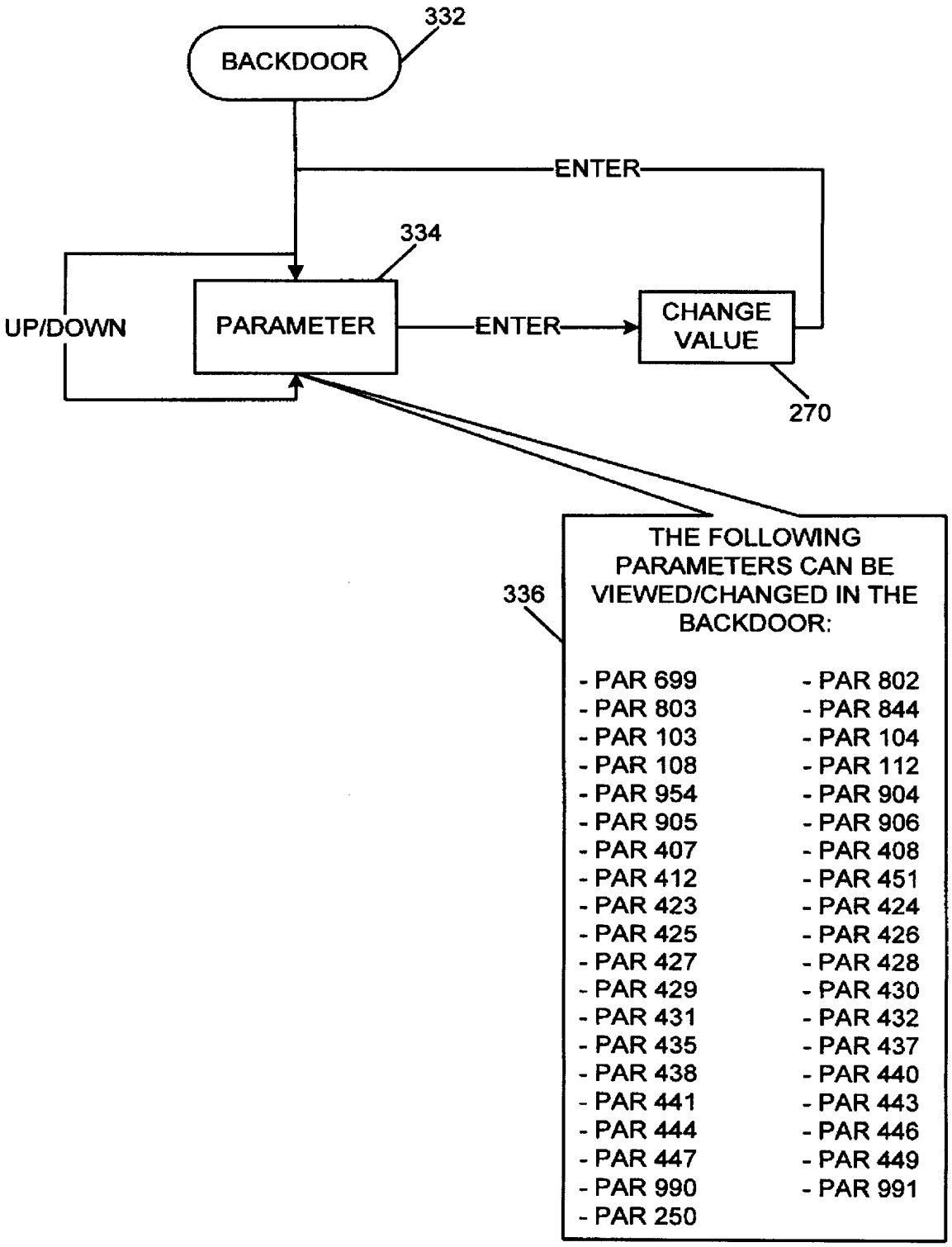

332
BACKDOOR
ENTER
334
UP/DOWN
PARAMETER
ENTER
CHANGE VALUE
270
336
THE FOLLOWING PARAMETERS CAN BE VIEWED/CHANGED IN THE BACKDOOR:
- PAR 699
- PAR 802
- PAR 803
- PAR 844
- PAR 103
- PAR 104
- PAR 108
- PAR 112
- PAR 954
- PAR 904
- PAR 905
- PAR 906
- PAR 407
- PAR 408
- PAR 412
- PAR 451
- PAR 423
- PAR 424
- PAR 425
- PAR 426
- PAR 427
- PAR 428
- PAR 429
- PAR 430
- PAR 431
- PAR 432
- PAR 435
- PAR 437
- PAR 438
- PAR 440
- PAR 441
- PAR 443
- PAR 444
- PAR 446
- PAR 447
- PAR 449
- PAR 990
- PAR 991
- PAR 250

FIGURE 29

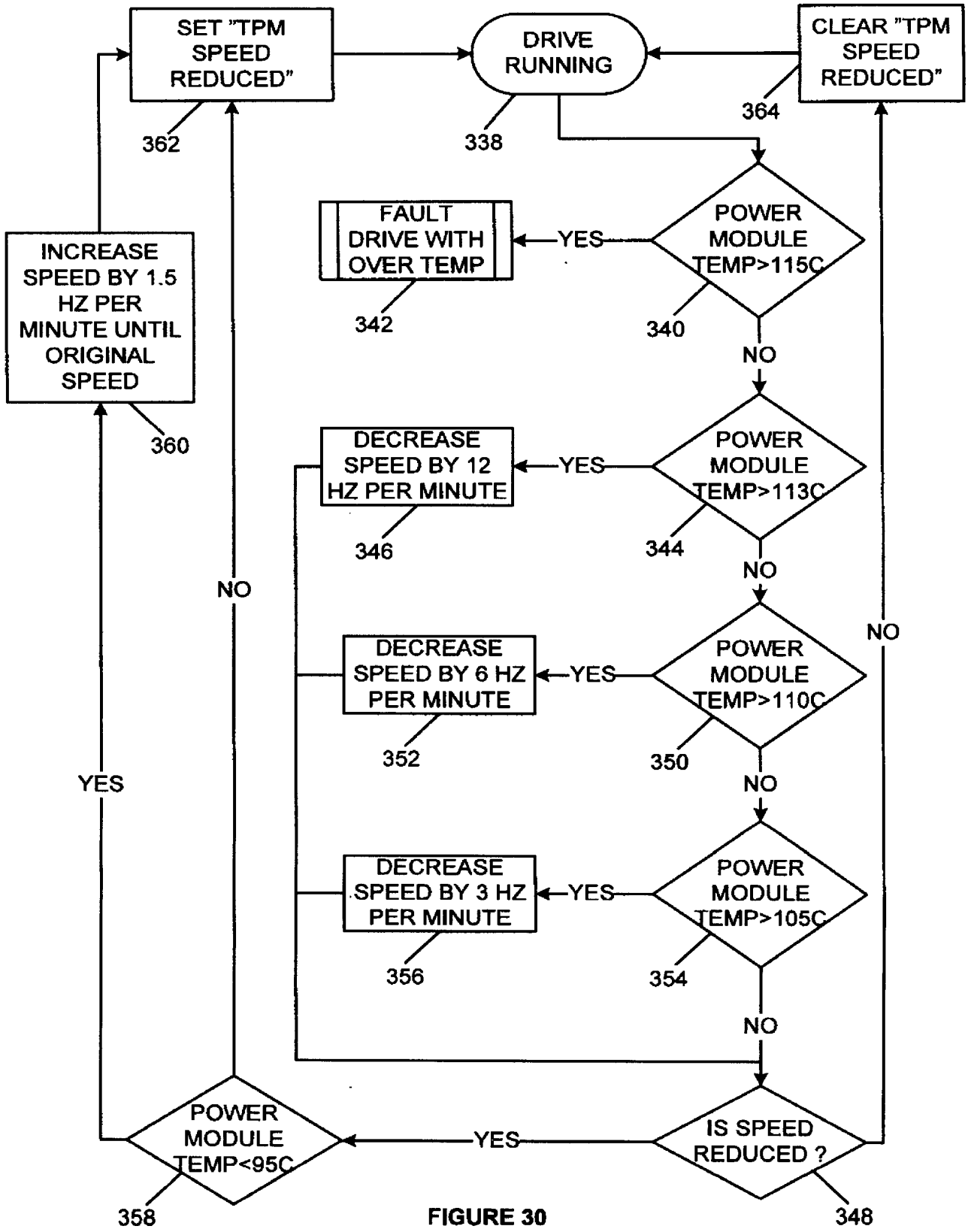

SET "TPM SPEED REDUCED"
362
DRIVE RUNNING
338
CLEAR "TPM SPEED REDUCED"
364
POWER MODULE TEMP>115C
340
YES
FAULT DRIVE WITH OVER TEMP
342
NO
POWER MODULE TEMP>113C
344
YES
DECREASE SPEED BY 12 HZ PER MINUTE
346
NO
POWER MODULE TEMP>110C
350
YES
DECREASE SPEED BY 6 HZ PER MINUTE
352
NO
POWER MODULE TEMP>105C
354
YES
DECREASE SPEED BY 3 HZ PER MINUTE
356
NO
IS SPEED REDUCED ?
348
YES
POWER MODULE TEMP<95C
358
NO
YES
INCREASE SPEED BY 1.5 HZ PER MINUTE UNTIL ORIGINAL SPEED
360
NO

FIGURE 30

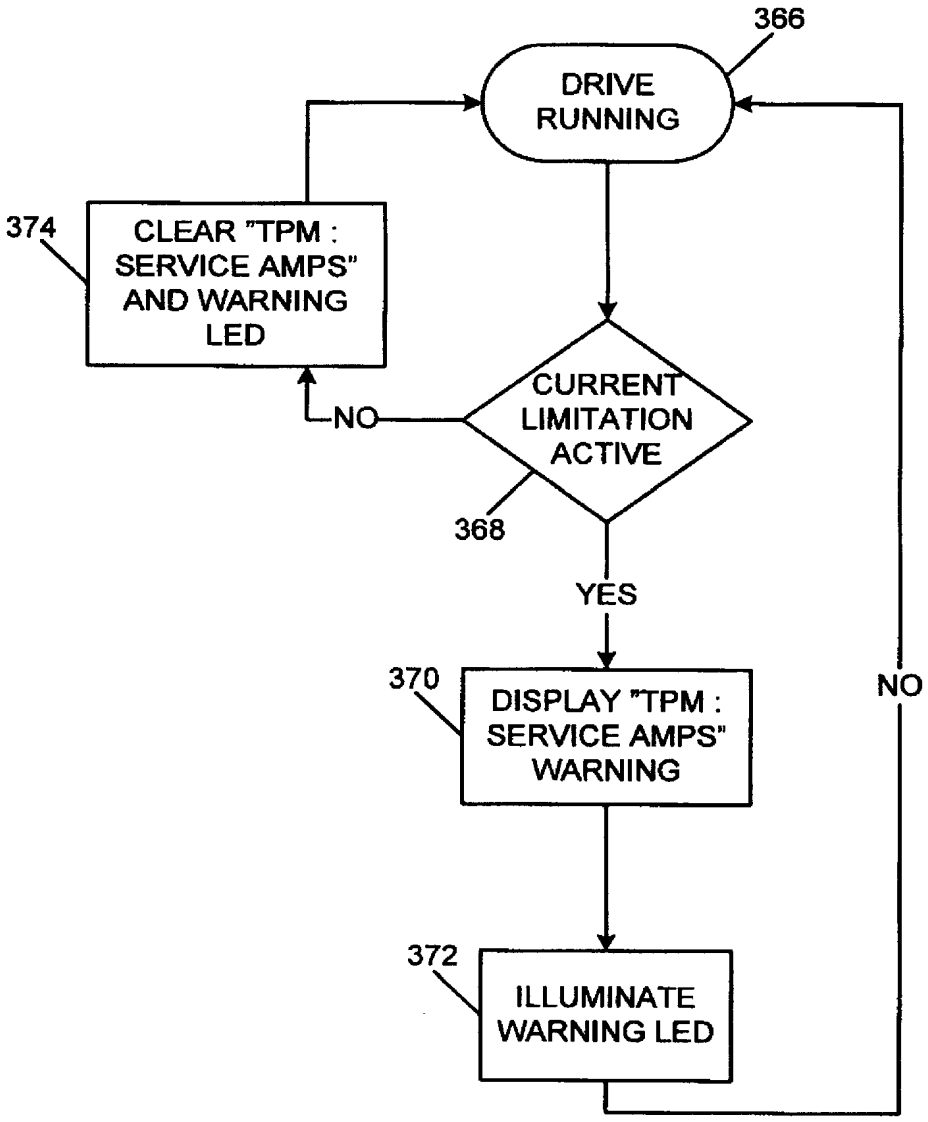

366
DRIVE RUNNING
374
CLEAR "TPM : SERVICE AMPS" AND WARNING LED
NO
CURRENT LIMITATION ACTIVE
368
YES
370
DISPLAY "TPM : SERVICE AMPS" WARNING
372
ILLUMINATE WARNING LED
NO

FIGURE 31

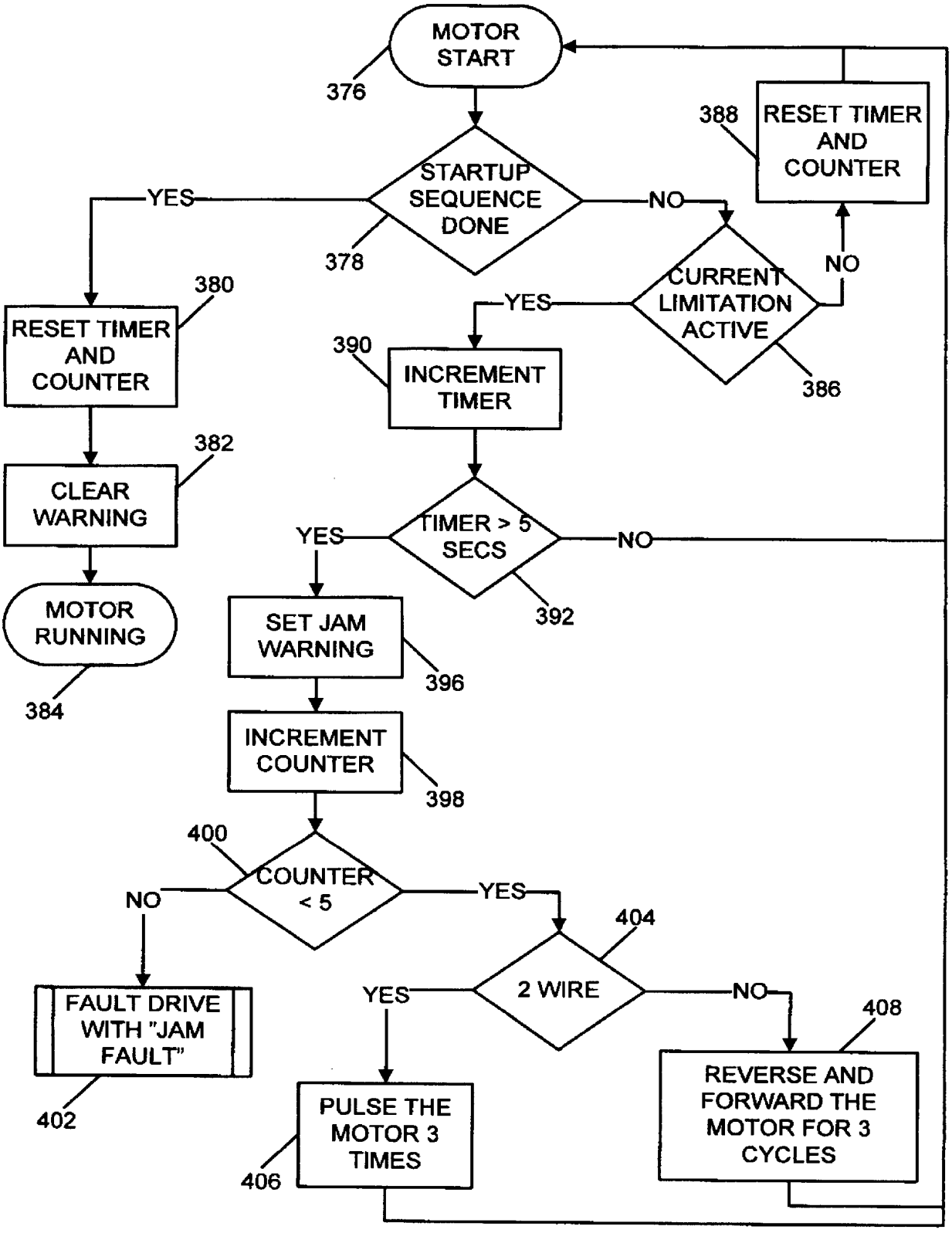

MOTOR START
376
STARTUP SEQUENCE DONE
378
YES
NO
RESET TIMER AND COUNTER
380
CLEAR WARNING
382
MOTOR RUNNING
384
388
RESET TIMER AND COUNTER
CURRENT LIMITATION ACTIVE
386
YES
NO
390
INCREMENT TIMER
TIMER > 5 SECS
392
YES
NO
SET JAM WARNING
396
INCREMENT COUNTER
398
400
COUNTER < 5
NO
YES
FAULT DRIVE WITH "JAM FAULT"
402
404
2 WIRE
YES
NO
PULSE THE MOTOR 3 TIMES
406
408
REVERSE AND FORWARD THE MOTOR FOR 3 CYCLES

FIGURE 32

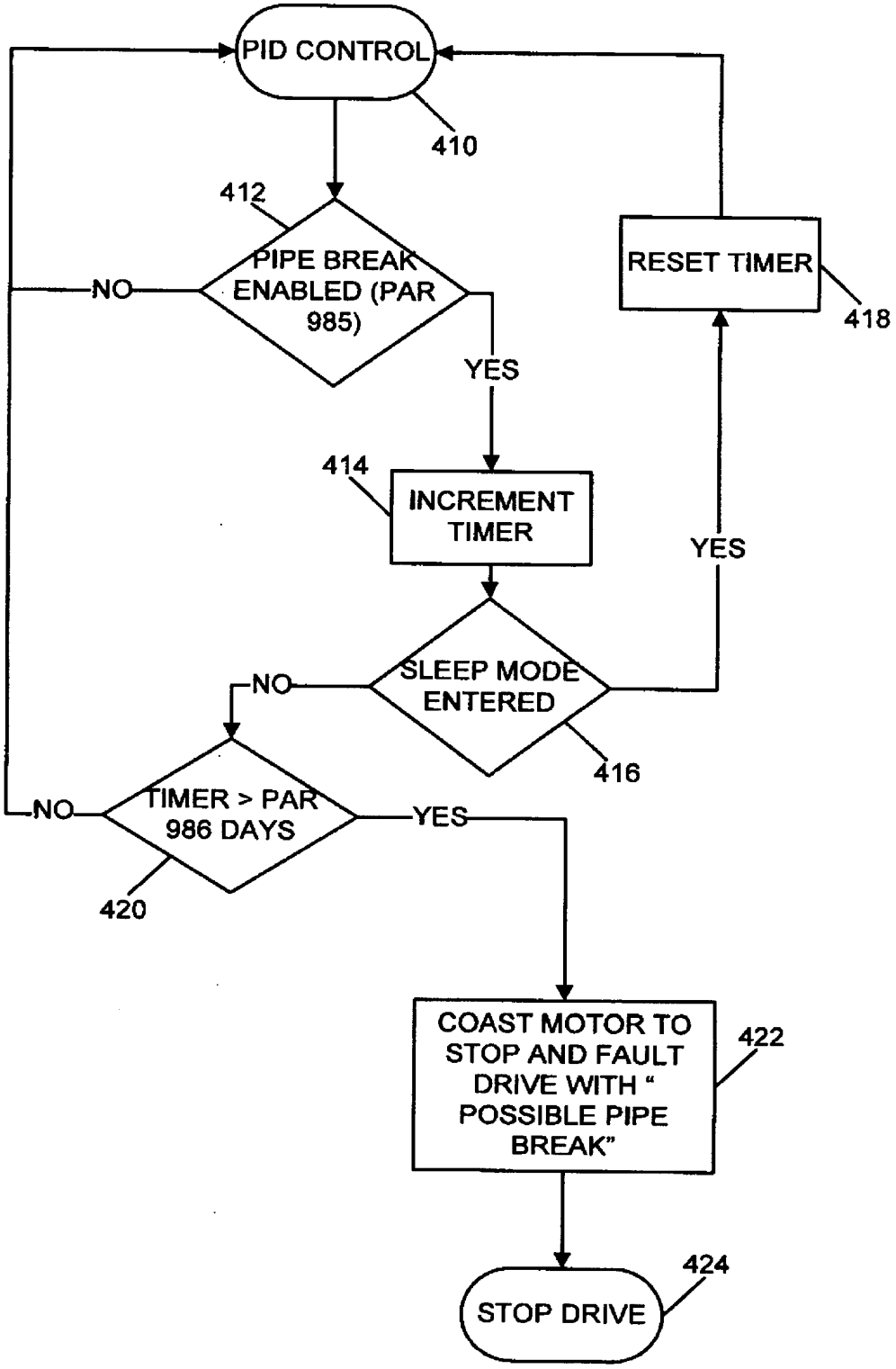

PID CONTROL
410
412
PIPE BREAK ENABLED (PAR 985)
NO
YES
414
INCREMENT TIMER
SLEEP MODE ENTERED
NO
YES
416
TIMER > PAR 986 DAYS
NO
YES
420
RESET TIMER
418
COAST MOTOR TO STOP AND FAULT DRIVE WITH " POSSIBLE PIPE BREAK"
422
STOP DRIVE
424

FIGURE 33

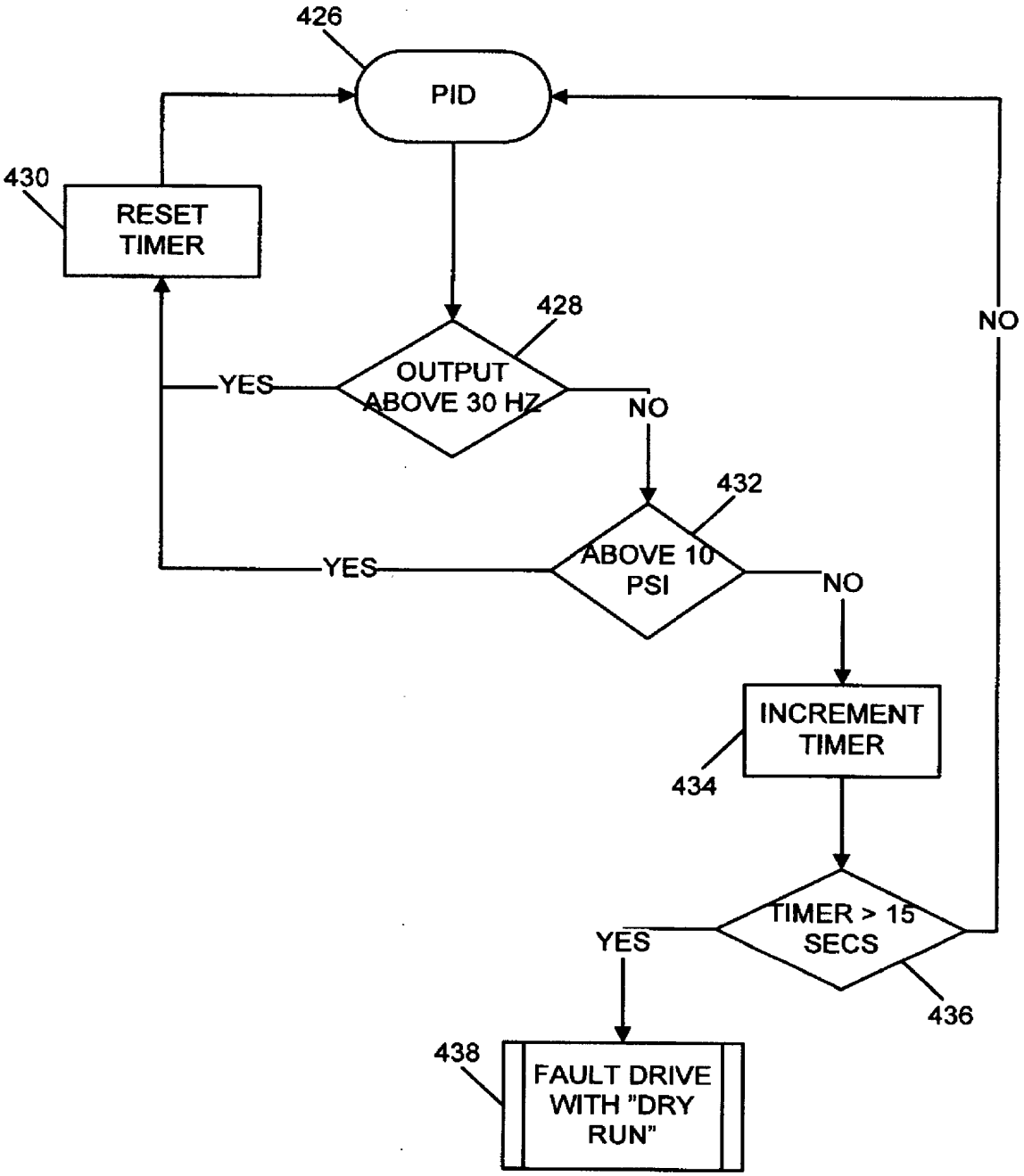

426
PID
430
RESET TIMER
428
OUTPUT ABOVE 30 HZ
YES
NO
NO
432
ABOVE 10 PSI
YES
NO
INCREMENT TIMER
434
TIMER > 15 SECS
YES
436
438
FAULT DRIVE WITH "DRY RUN"

FIGURE 34

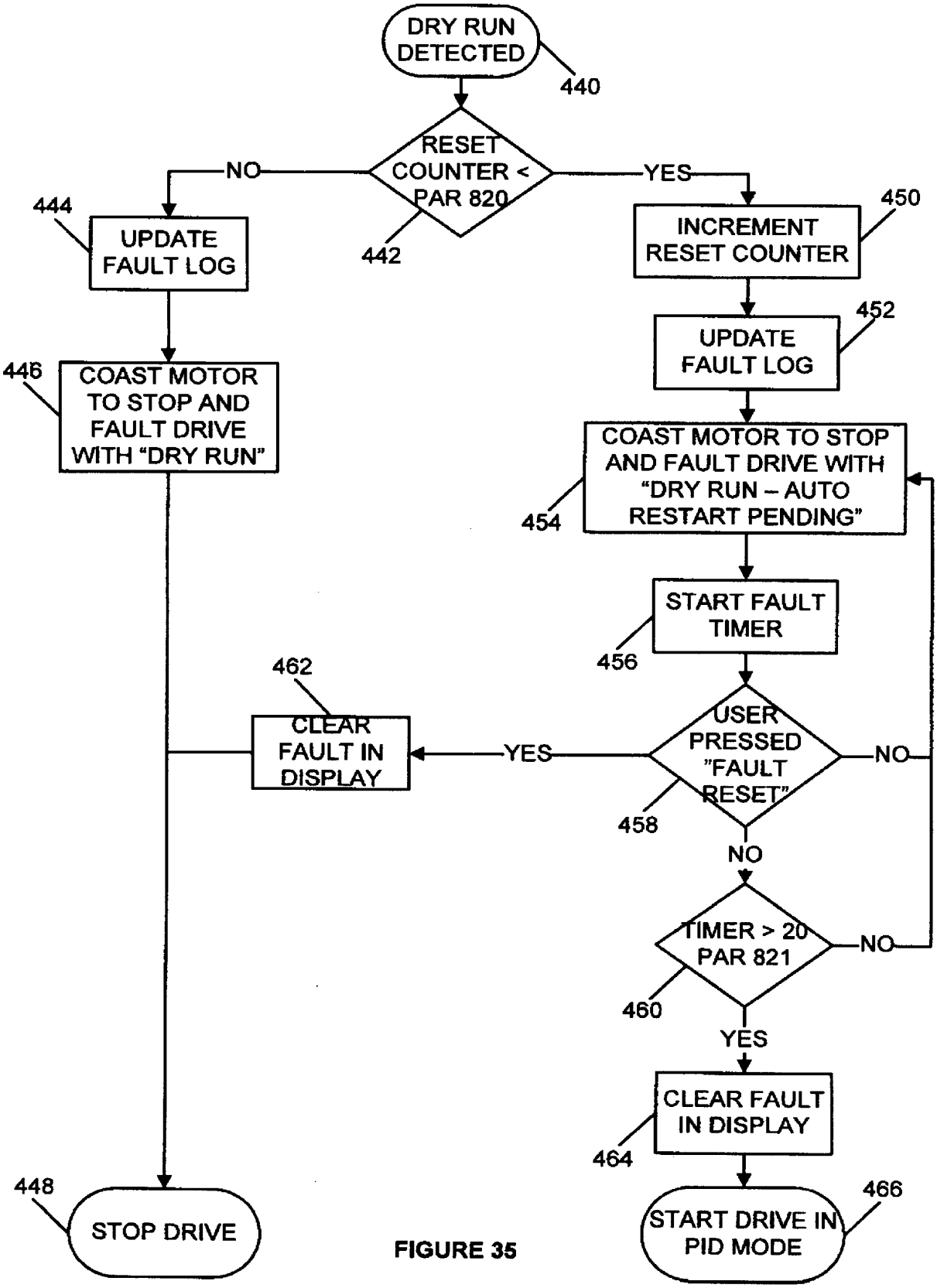

DRY RUN DETECTED
440
RESET COUNTER < PAR 820
442
NO
YES
444
UPDATE FAULT LOG
446
COAST MOTOR TO STOP AND FAULT DRIVE WITH "DRY RUN"
450
INCREMENT RESET COUNTER
452
UPDATE FAULT LOG
454
COAST MOTOR TO STOP AND FAULT DRIVE WITH "DRY RUN – AUTO RESTART PENDING"
456
START FAULT TIMER
458
USER PRESSED "FAULT RESET"
YES
NO
462
CLEAR FAULT IN DISPLAY
NO
460
TIMER > 20 PAR 821
NO
YES
464
CLEAR FAULT IN DISPLAY
466
START DRIVE IN PID MODE
448
STOP DRIVE

FIGURE 35

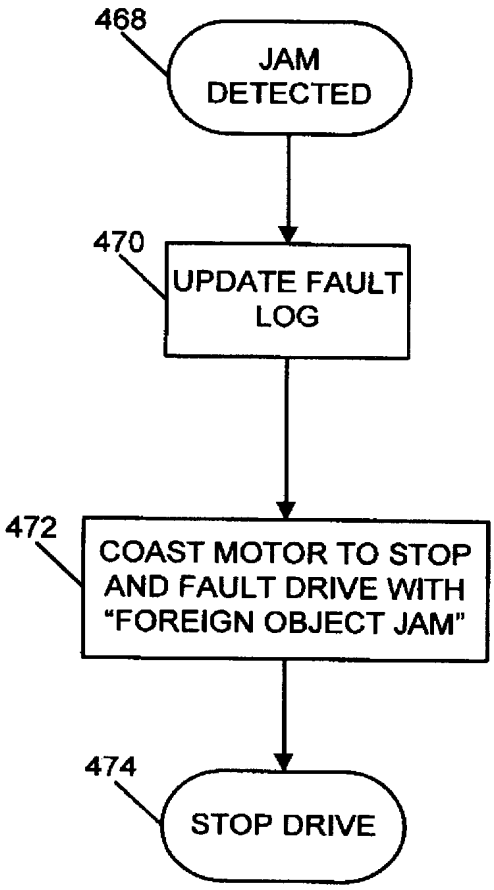

468
JAM DETECTED
470
UPDATE FAULT LOG
472
COAST MOTOR TO STOP AND FAULT DRIVE WITH "FOREIGN OBJECT JAM"
474
STOP DRIVE

FIGURE 36

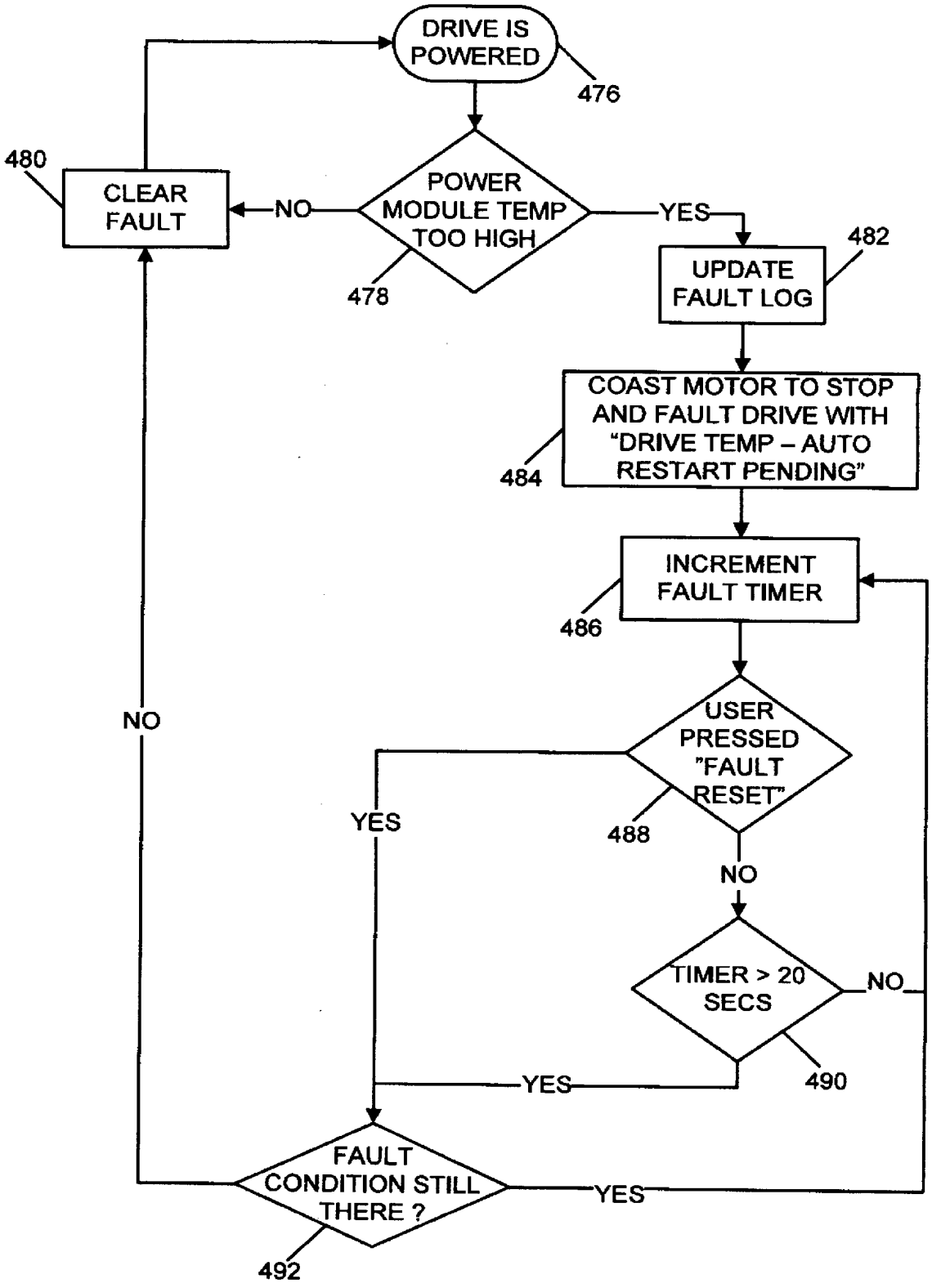

DRIVE IS POWERED
476
POWER MODULE TEMP TOO HIGH
478
NO
YES
480
CLEAR FAULT
482
UPDATE FAULT LOG
COAST MOTOR TO STOP AND FAULT DRIVE WITH "DRIVE TEMP – AUTO RESTART PENDING"
484
INCREMENT FAULT TIMER
486
USER PRESSED "FAULT RESET"
488
YES
NO
TIMER > 20 SECS
490
NO
YES
FAULT CONDITION STILL THERE ?
492
YES
NO

FIGURE 37

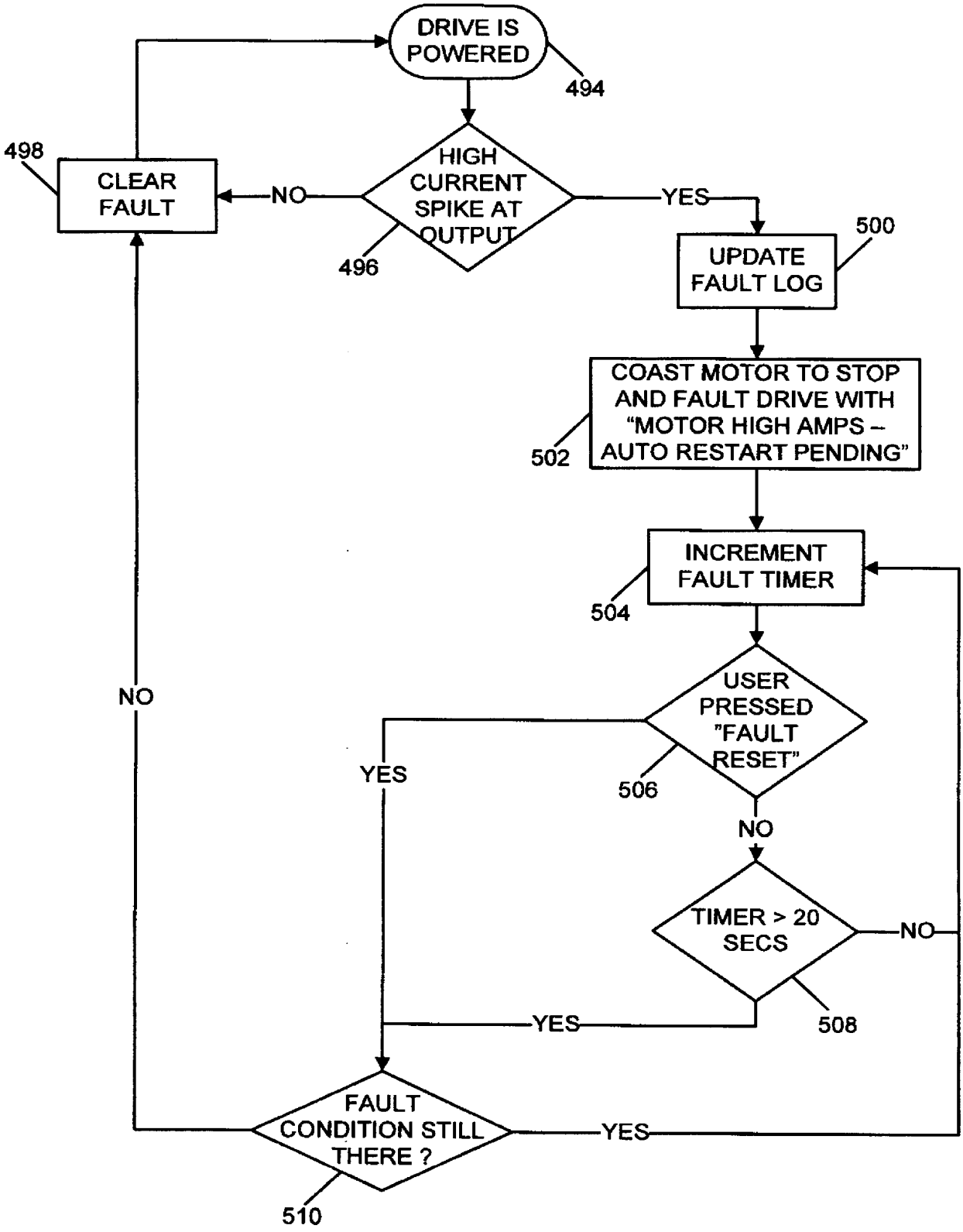

DRIVE IS POWERED
494
HIGH CURRENT SPIKE AT OUTPUT
496
NO
CLEAR FAULT
498
YES
UPDATE FAULT LOG
500
COAST MOTOR TO STOP AND FAULT DRIVE WITH "MOTOR HIGH AMPS – AUTO RESTART PENDING"
502
INCREMENT FAULT TIMER
504
USER PRESSED "FAULT RESET"
506
YES
NO
TIMER > 20 SECS
508
NO
YES
FAULT CONDITION STILL THERE ?
510
YES
NO

FIGURE 38

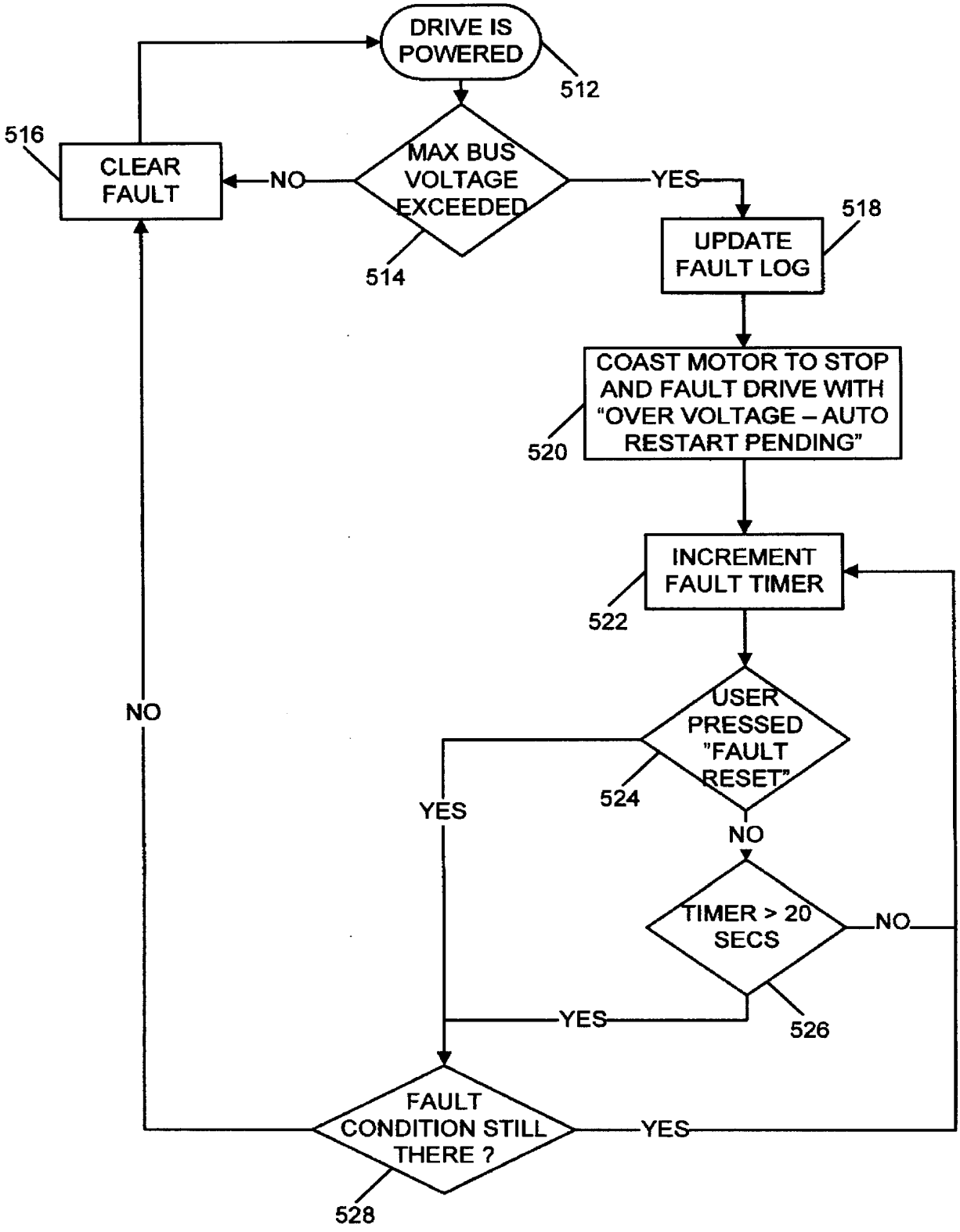

DRIVE IS POWERED
512
MAX BUS VOLTAGE EXCEEDED
514
NO
YES
516
CLEAR FAULT
518
UPDATE FAULT LOG
520
COAST MOTOR TO STOP AND FAULT DRIVE WITH "OVER VOLTAGE – AUTO RESTART PENDING"
522
INCREMENT FAULT TIMER
524
USER PRESSED "FAULT RESET"
YES
NO
TIMER > 20 SECS
NO
YES
526
FAULT CONDITION STILL THERE ?
YES
NO
528

FIGURE 39

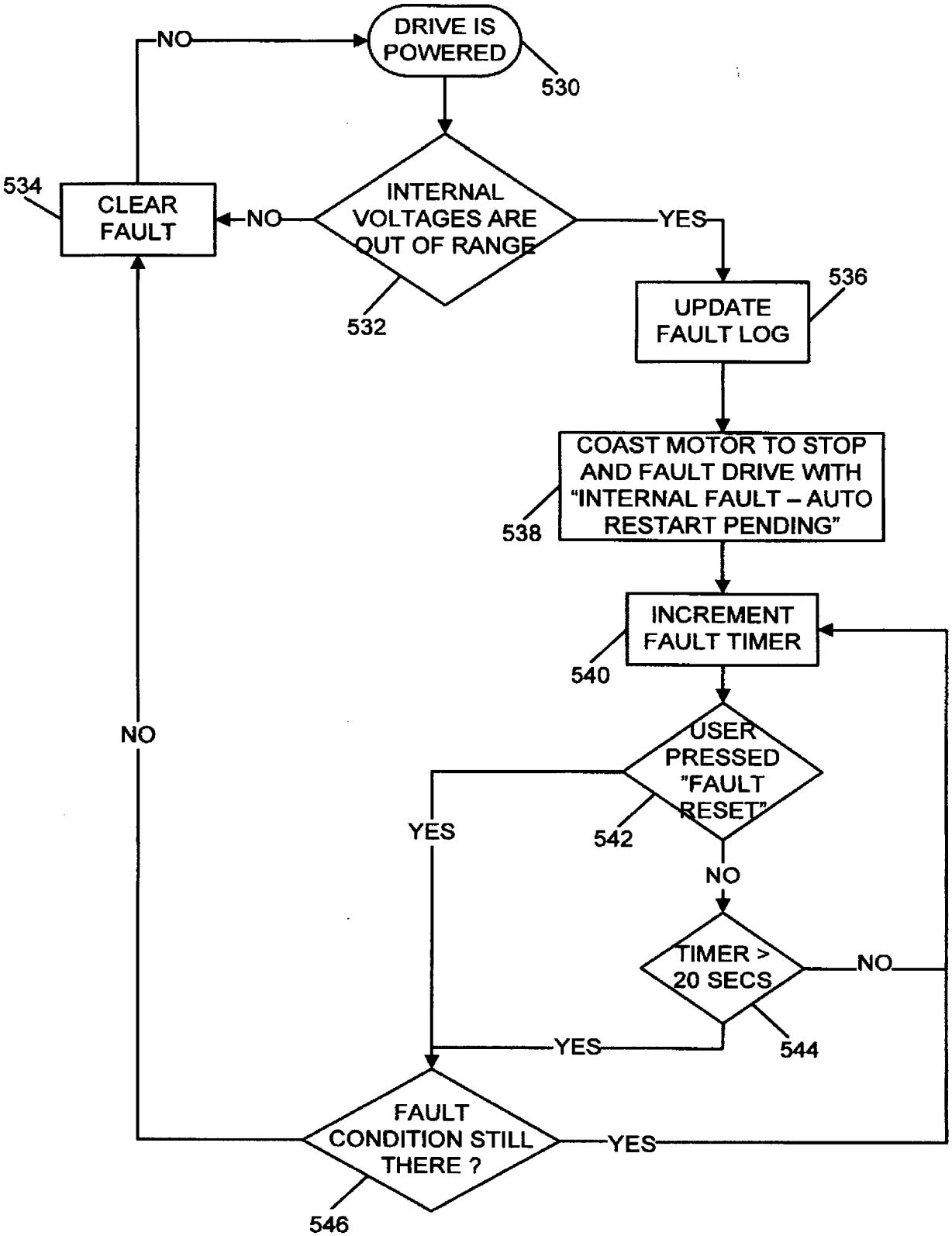

DRIVE IS POWERED
530
NO
INTERNAL VOLTAGES ARE OUT OF RANGE
532
NO
CLEAR FAULT
534
YES
UPDATE FAULT LOG
536
COAST MOTOR TO STOP AND FAULT DRIVE WITH "INTERNAL FAULT – AUTO RESTART PENDING"
538
INCREMENT FAULT TIMER
540
USER PRESSED "FAULT RESET"
542
YES
NO
TIMER > 20 SECS
544
NO
YES
FAULT CONDITION STILL THERE ?
546
YES
NO

FIGURE 40

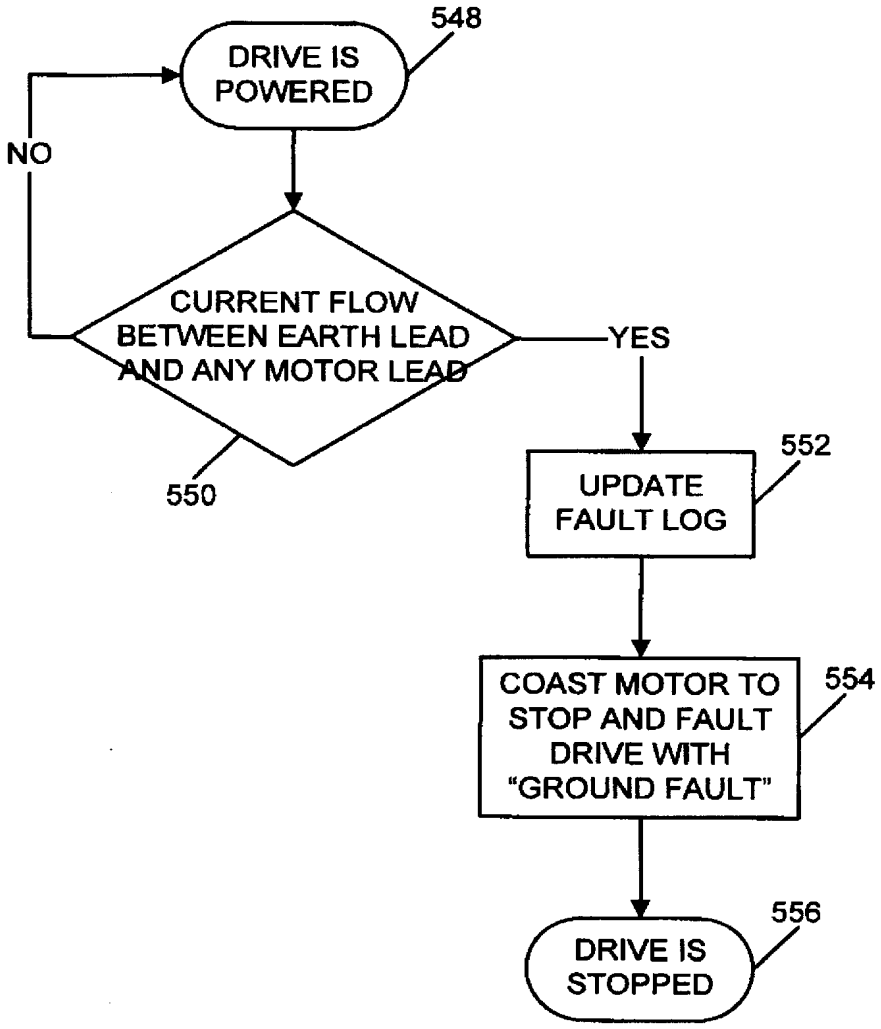

548
DRIVE IS POWERED
NO
CURRENT FLOW BETWEEN EARTH LEAD AND ANY MOTOR LEAD
YES
550
552
UPDATE FAULT LOG
554
COAST MOTOR TO STOP AND FAULT DRIVE WITH "GROUND FAULT"
556
DRIVE IS STOPPED

FIGURE 41

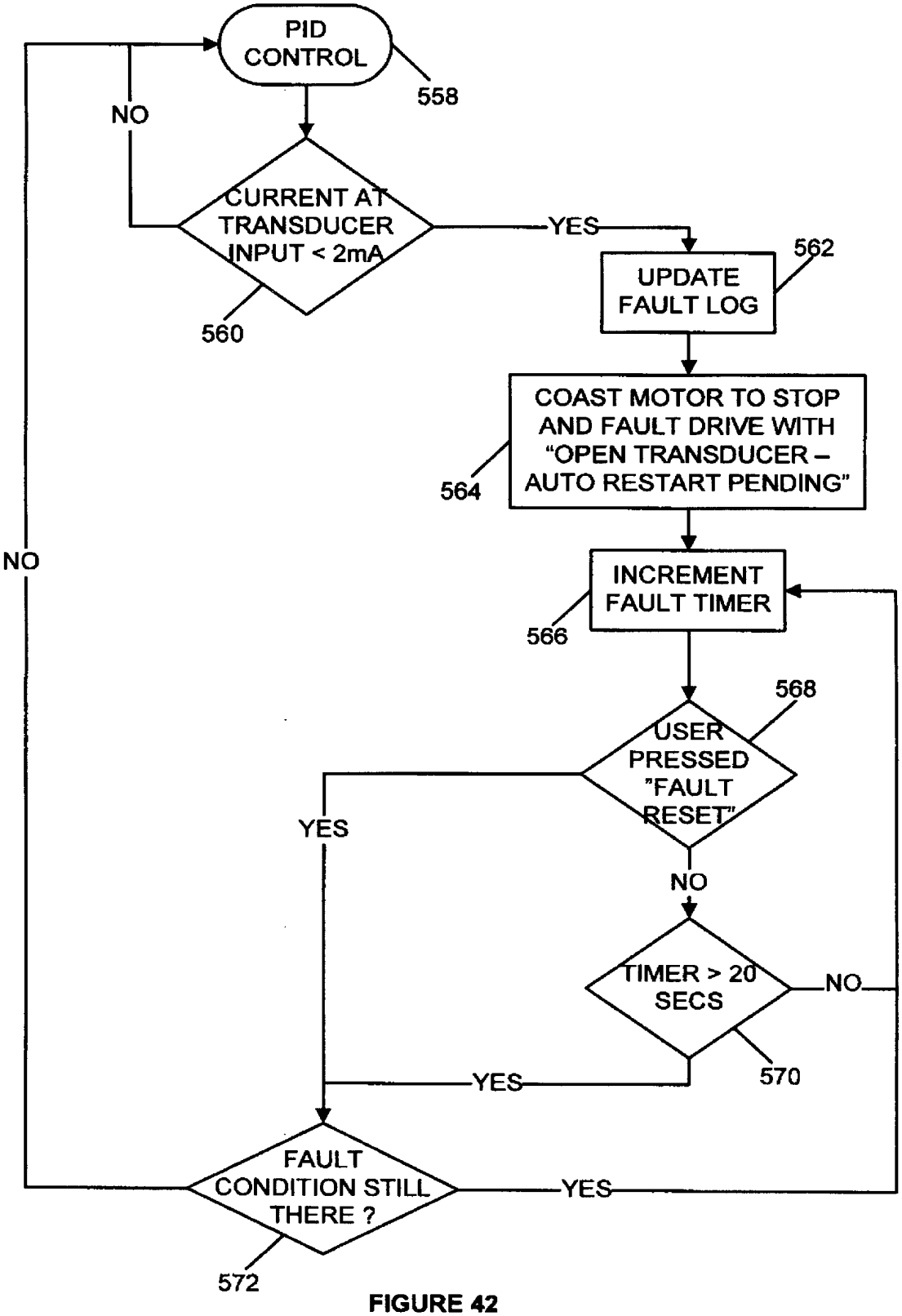

PID CONTROL
558
NO
CURRENT AT TRANSDUCER INPUT < 2mA
YES
560
562
UPDATE FAULT LOG
COAST MOTOR TO STOP AND FAULT DRIVE WITH "OPEN TRANSDUCER – AUTO RESTART PENDING"
564
NO
INCREMENT FAULT TIMER
566
568
USER PRESSED "FAULT RESET"
YES
NO
TIMER > 20 SECS
NO
570
YES
FAULT CONDITION STILL THERE ?
YES
572

FIGURE 42

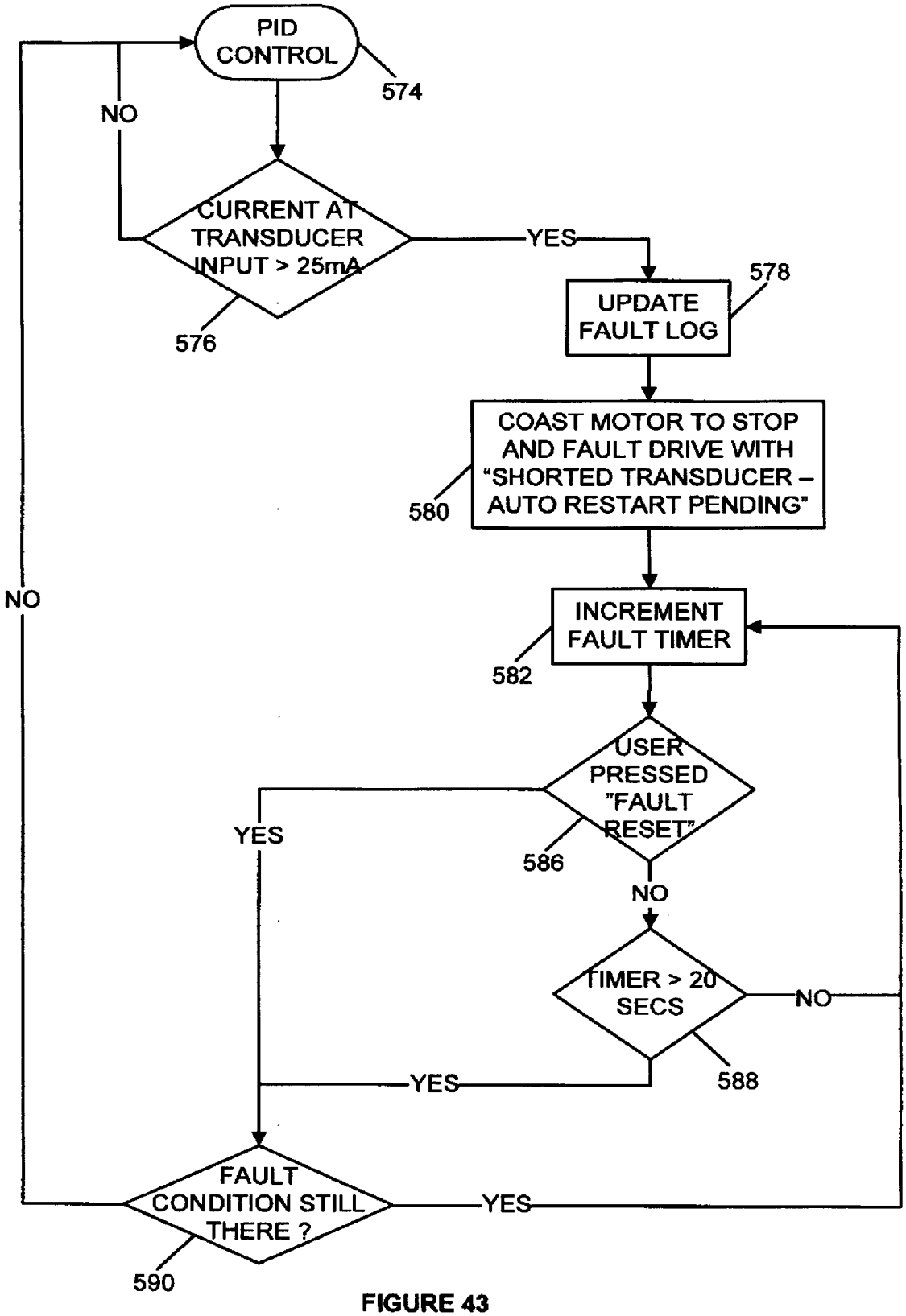

PID CONTROL
574
NO
CURRENT AT TRANSDUCER INPUT > 25mA
YES
576
578
UPDATE FAULT LOG
COAST MOTOR TO STOP AND FAULT DRIVE WITH "SHORTED TRANSDUCER – AUTO RESTART PENDING"
580
NO
INCREMENT FAULT TIMER
582
USER PRESSED "FAULT RESET"
YES
586
NO
TIMER > 20 SECS
NO
588
YES
FAULT CONDITION STILL THERE ?
YES
590

FIGURE 43

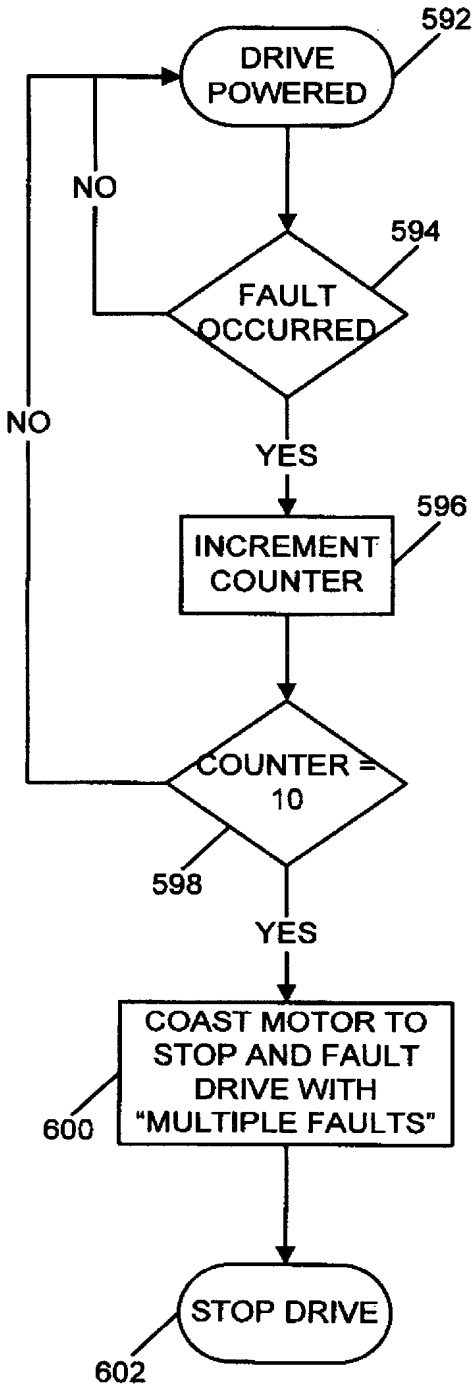


FIGURE 44A

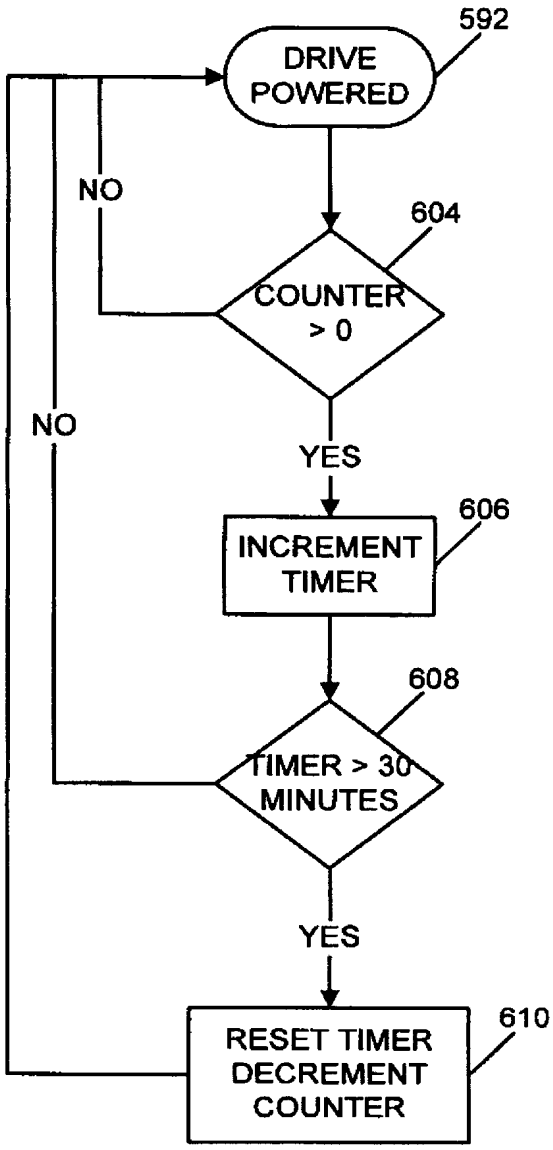


FIGURE 44B

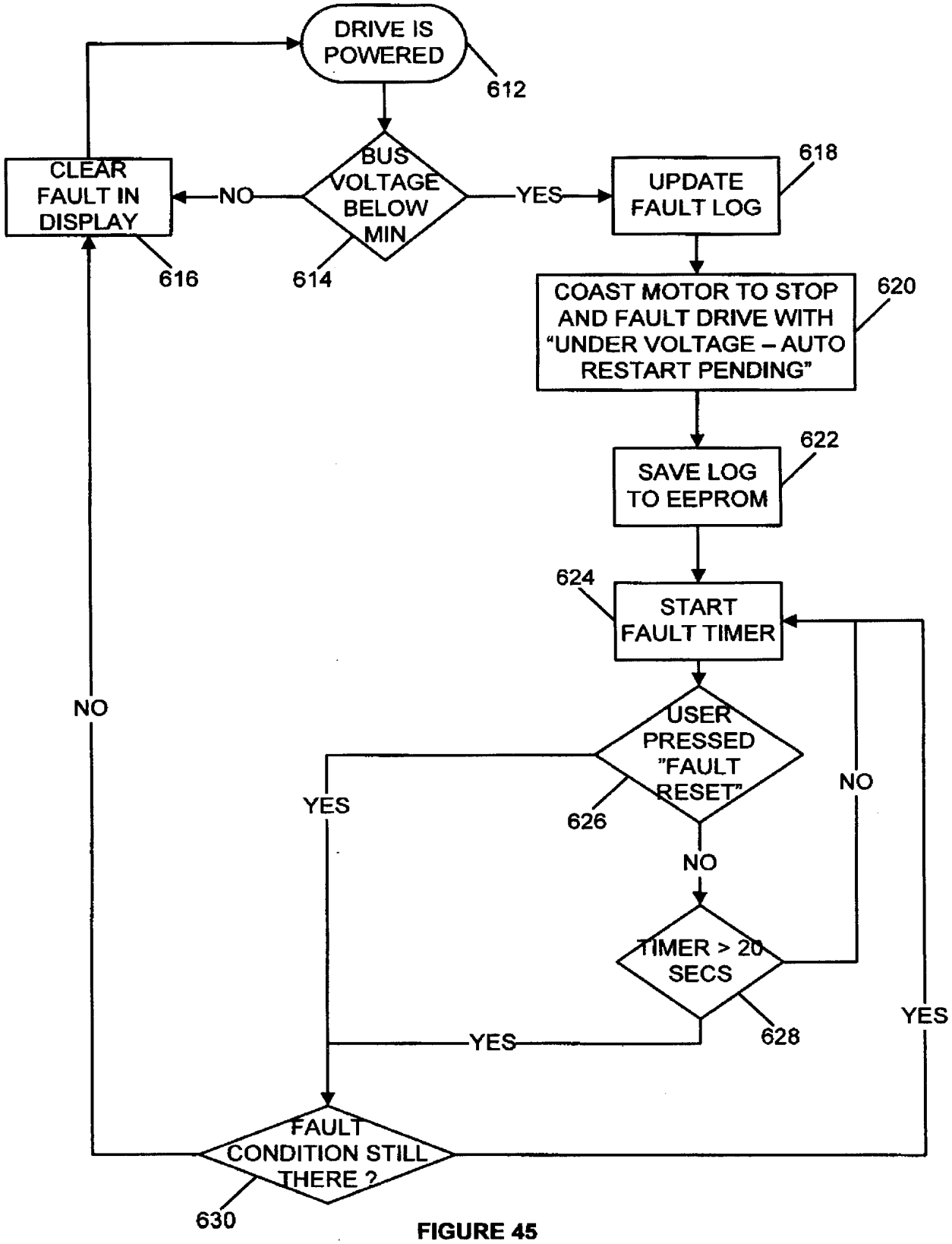

DRIVE IS POWERED
612
BUS VOLTAGE BELOW MIN
614
NO
CLEAR FAULT IN DISPLAY
616
YES
UPDATE FAULT LOG
618
COAST MOTOR TO STOP AND FAULT DRIVE WITH "UNDER VOLTAGE – AUTO RESTART PENDING"
620
SAVE LOG TO EEPROM
622
START FAULT TIMER
624
USER PRESSED "FAULT RESET"
626
YES
NO
TIMER > 20 SECS
628
YES
NO
YES
FAULT CONDITION STILL THERE ?
630
NO

FIGURE 45

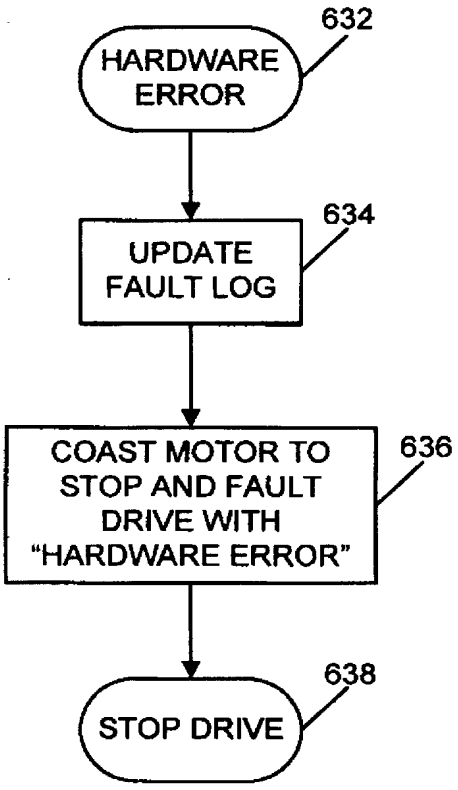

632
HARDWARE ERROR
634
UPDATE FAULT LOG
636
COAST MOTOR TO STOP AND FAULT DRIVE WITH "HARDWARE ERROR"
638
STOP DRIVE

FIGURE 46

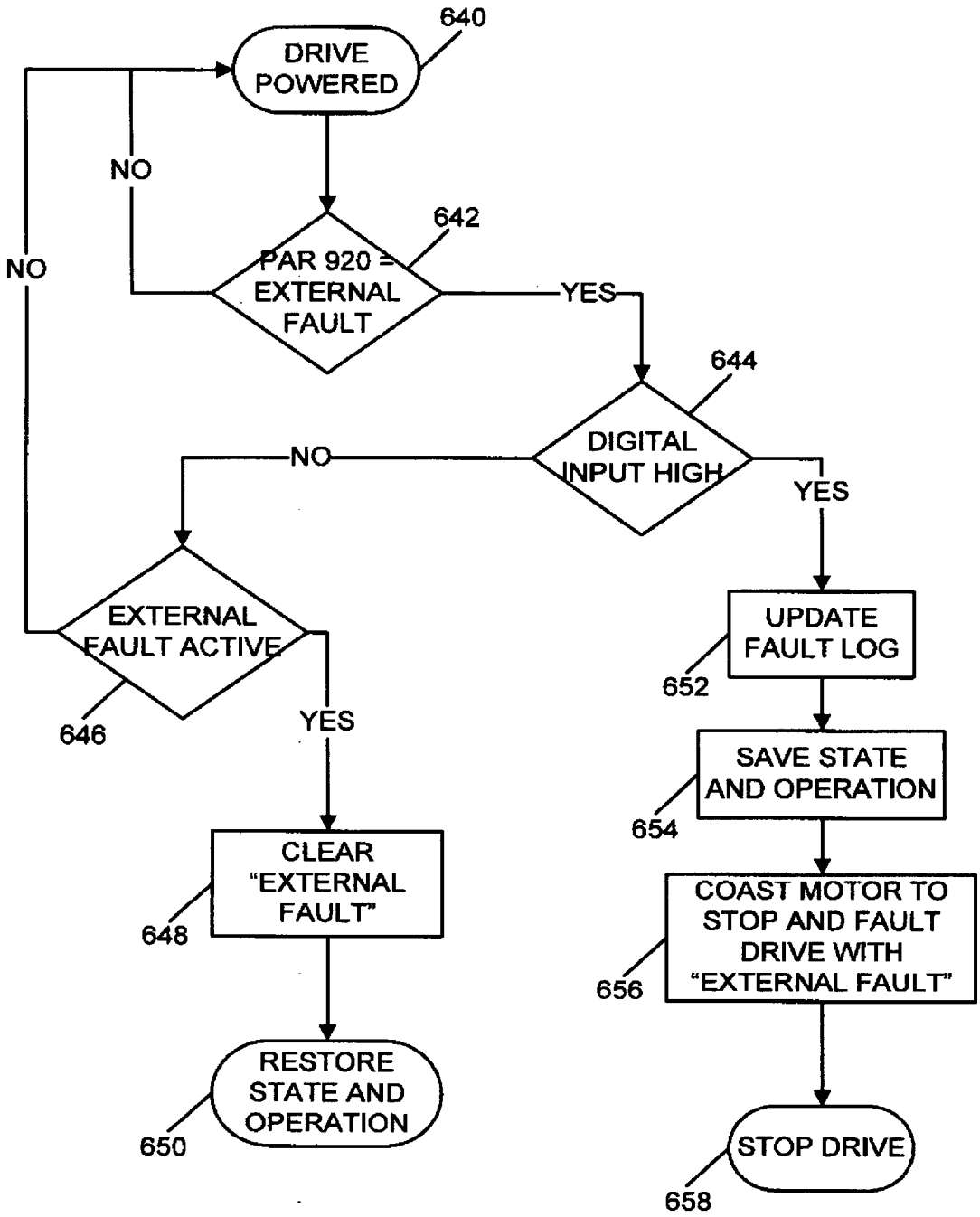

640
DRIVE POWERED
NO
642
PAR 920 = EXTERNAL FAULT
NO
YES
644
DIGITAL INPUT HIGH
NO
YES
EXTERNAL FAULT ACTIVE
646
YES
UPDATE FAULT LOG
652
SAVE STATE AND OPERATION
654
CLEAR "EXTERNAL FAULT"
648
COAST MOTOR TO STOP AND FAULT DRIVE WITH "EXTERNAL FAULT"
656
RESTORE STATE AND OPERATION
650
STOP DRIVE
658

FIGURE 47

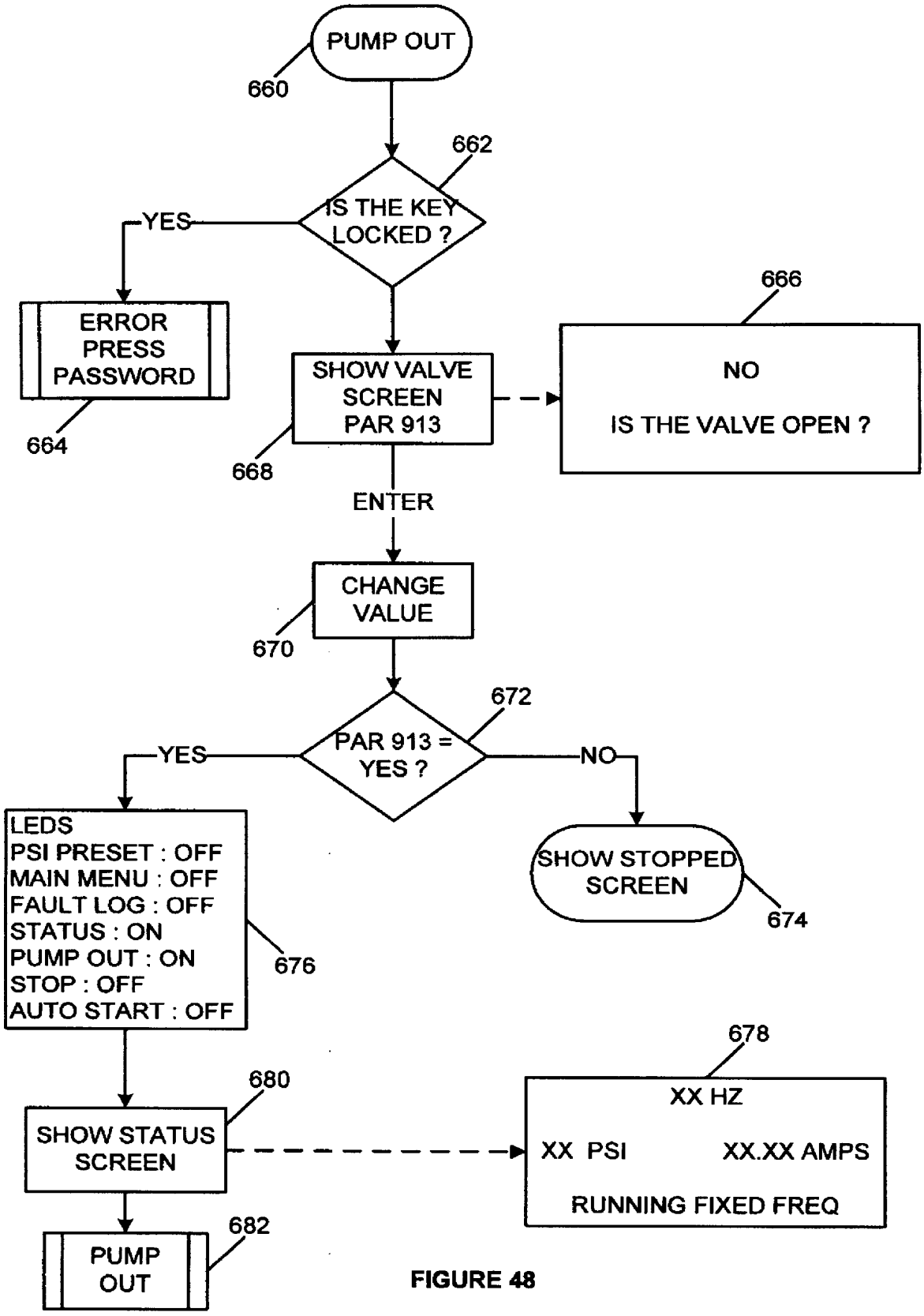

PUMP OUT
660
662
IS THE KEY LOCKED ?
YES
ERROR PRESS PASSWORD
664
SHOW VALVE SCREEN PAR 913
668
666
NO
IS THE VALVE OPEN ?
ENTER
CHANGE VALUE
670
672
PAR 913 = YES ?
YES
NO
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : ON
PUMP OUT : ON
STOP : OFF
AUTO START : OFF
676
SHOW STOPPED SCREEN
674
678
XX HZ
XX PSI
XX.XX AMPS
RUNNING FIXED FREQ
680
SHOW STATUS SCREEN
682
PUMP OUT

FIGURE 48

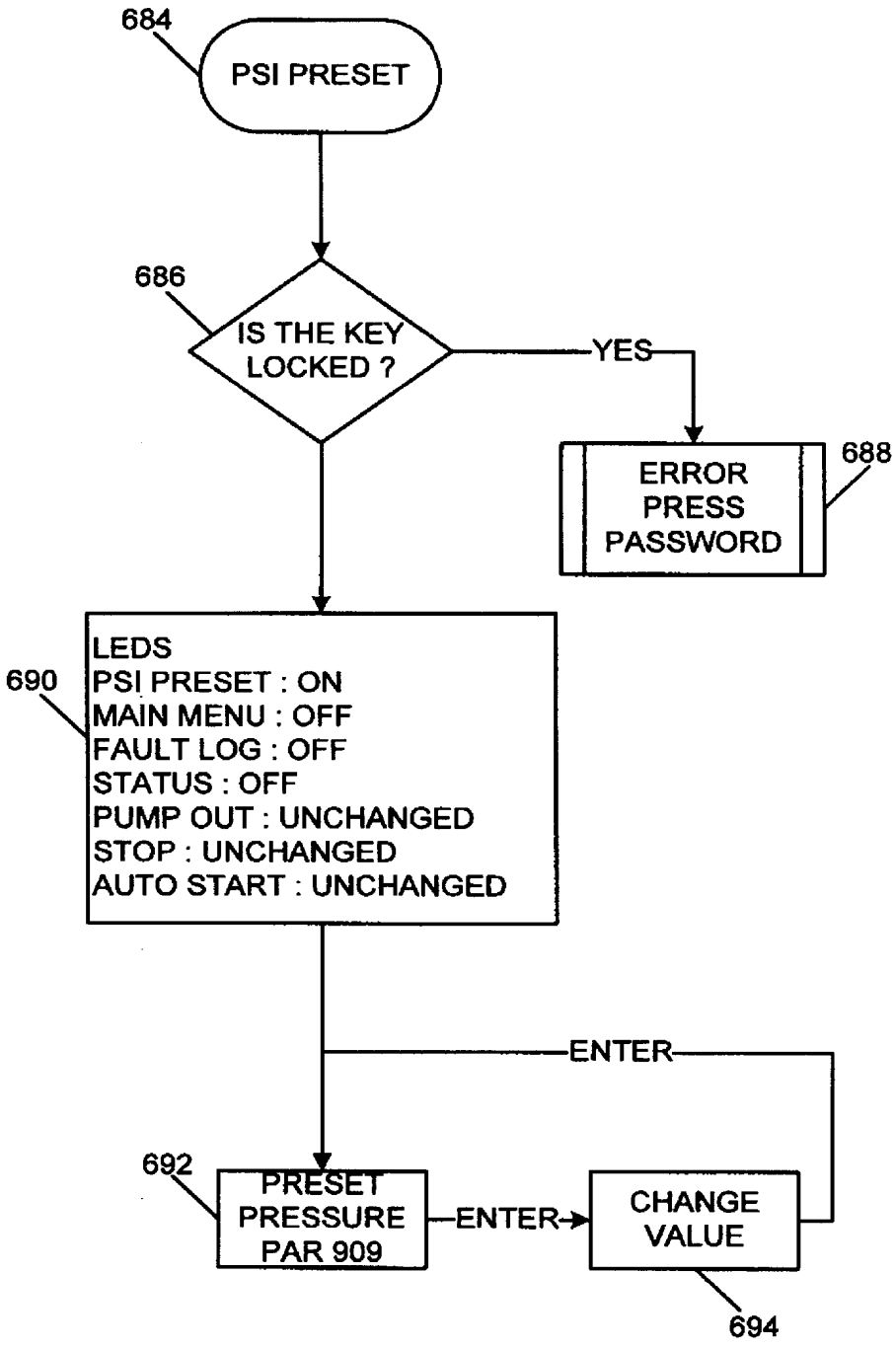

684
PSI PRESET
686
IS THE KEY LOCKED ?
YES
688
ERROR
PRESS
PASSWORD
690
LEDS
PSI PRESET : ON
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
ENTER
692
PRESET
PRESSURE
PAR 909
ENTER
CHANGE
VALUE
694

FIGURE 49

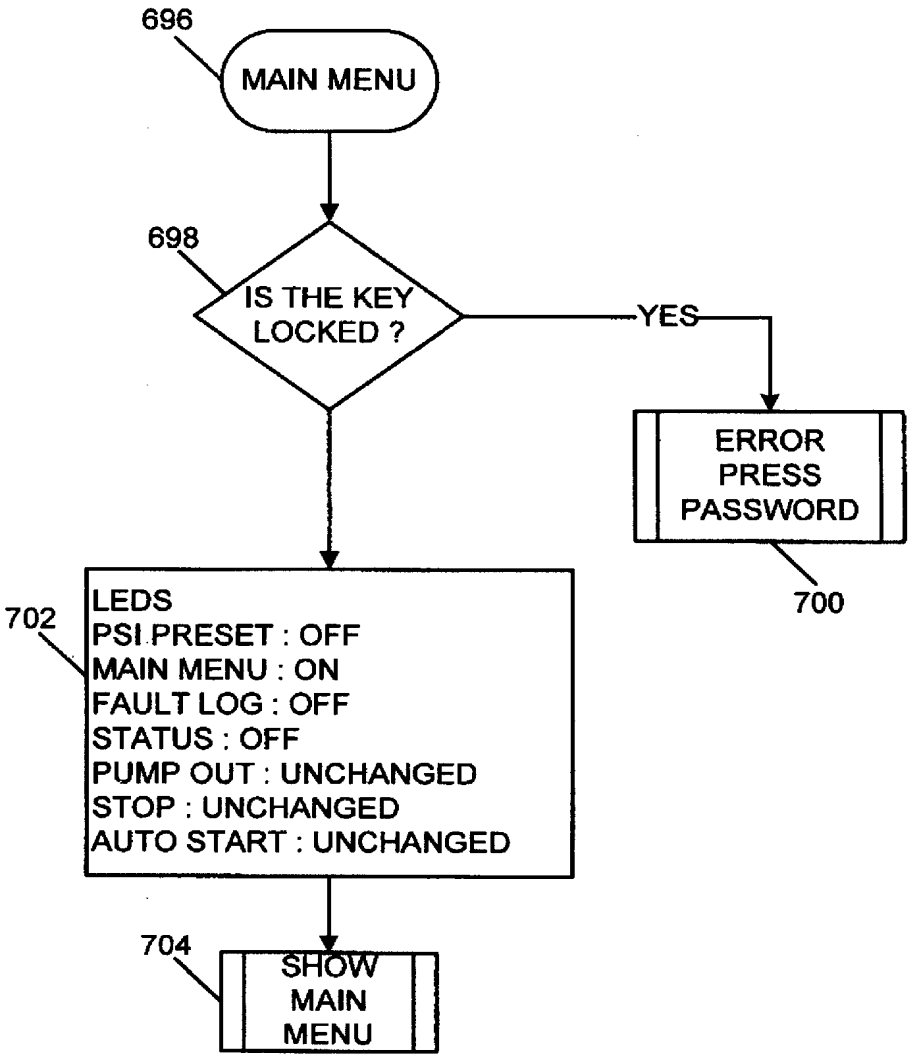

696
MAIN MENU
698
IS THE KEY LOCKED ?
YES
ERROR PRESS PASSWORD
700
702
LEDS
PSI PRESET : OFF
MAIN MENU : ON
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
704
SHOW MAIN MENU

FIGURE 50

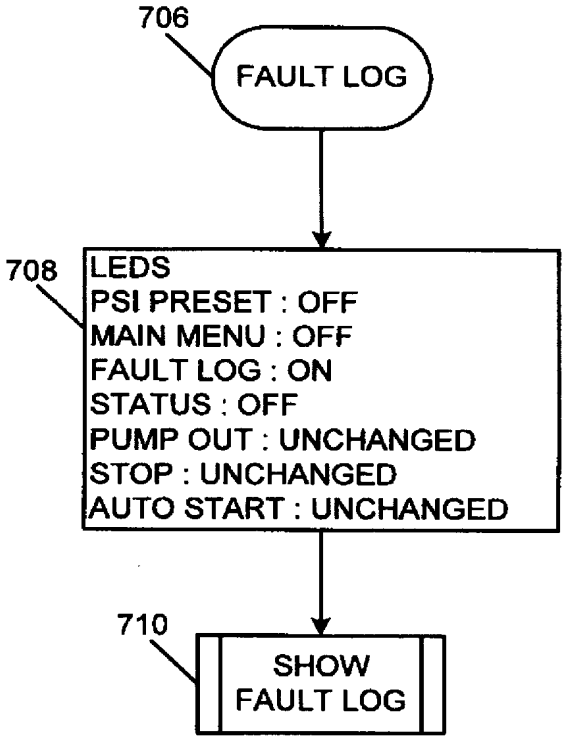

706
FAULT LOG
708
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : ON
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
710
SHOW
FAULT LOG

FIGURE 51

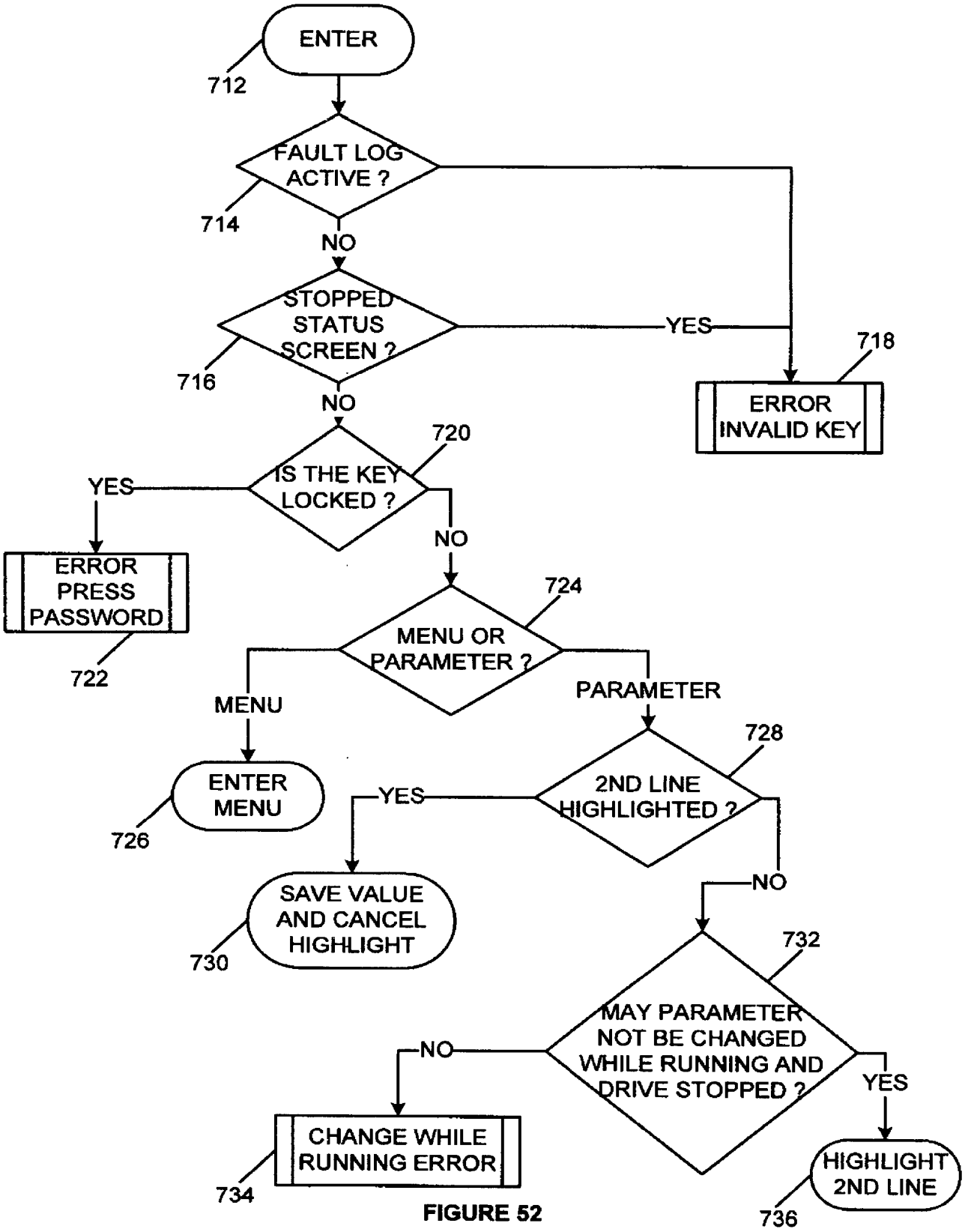

ENTER
712
FAULT LOG ACTIVE ?
714
NO
STOPPED STATUS SCREEN ?
716
YES
718
ERROR INVALID KEY
NO
720
IS THE KEY LOCKED ?
YES
ERROR PRESS PASSWORD
722
NO
724
MENU OR PARAMETER ?
MENU
ENTER MENU
726
PARAMETER
728
2ND LINE HIGHLIGHTED ?
YES
SAVE VALUE AND CANCEL HIGHLIGHT
730
NO
732
MAY PARAMETER NOT BE CHANGED WHILE RUNNING AND DRIVE STOPPED ?
NO
CHANGE WHILE RUNNING ERROR
734
YES
HIGHLIGHT 2ND LINE
736

FIGURE 52

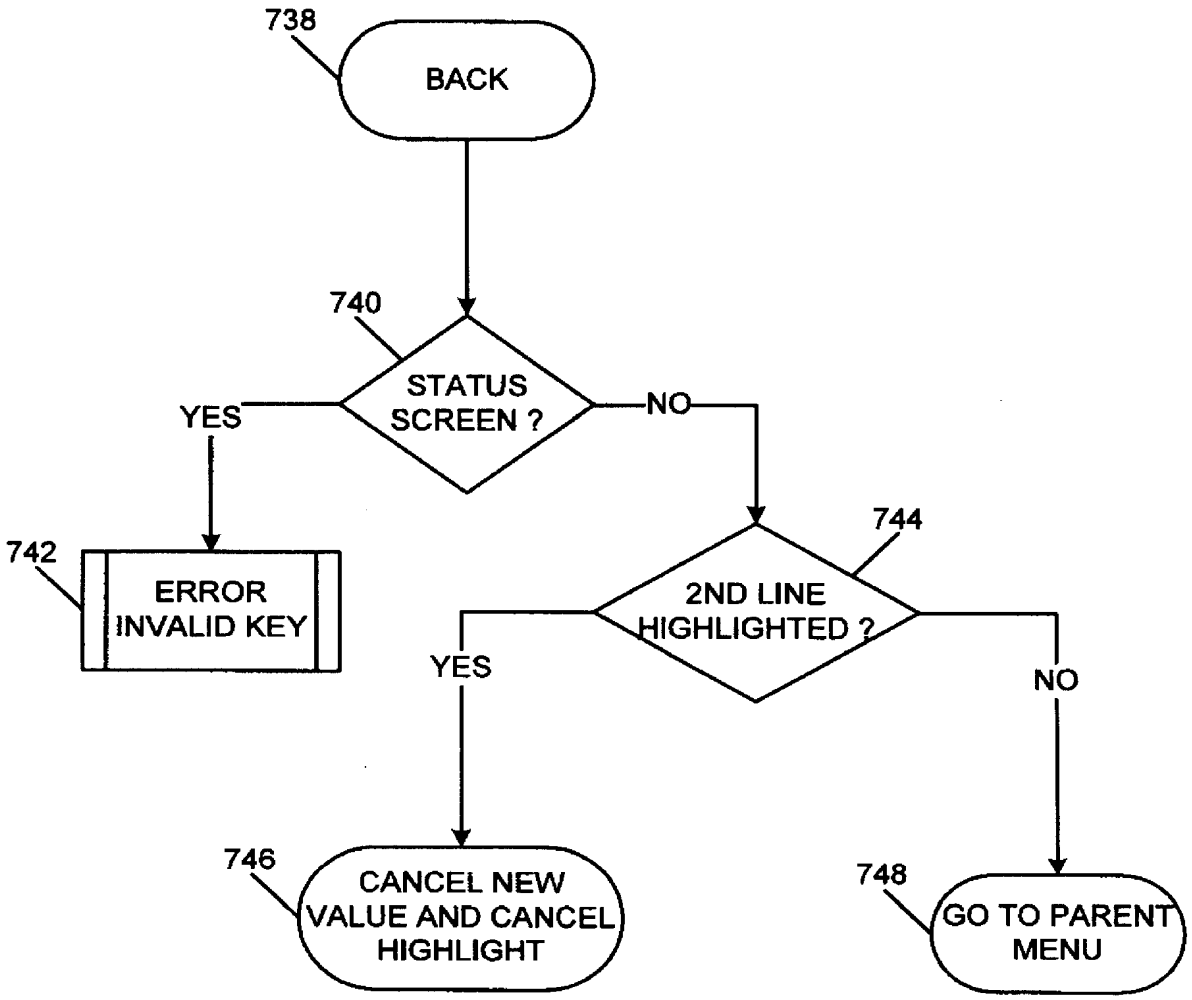

738
BACK
740
STATUS SCREEN ?
YES
NO
742
ERROR INVALID KEY
744
2ND LINE HIGHLIGHTED ?
YES
NO
746
CANCEL NEW VALUE AND CANCEL HIGHLIGHT
748
GO TO PARENT MENU

FIGURE 53

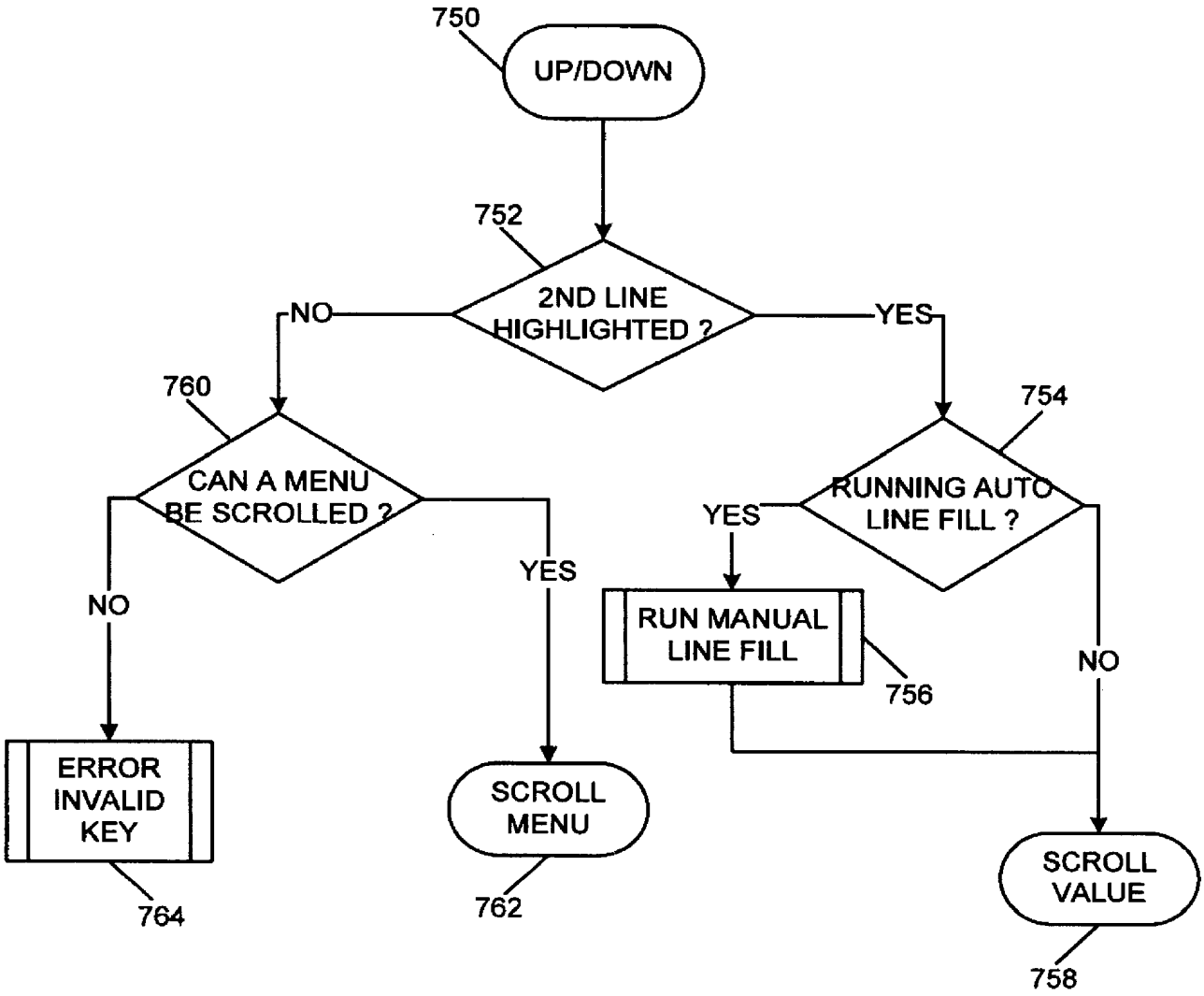

750
UP/DOWN
752
2ND LINE HIGHLIGHTED ?
NO
YES
760
CAN A MENU BE SCROLLED ?
754
RUNNING AUTO LINE FILL ?
YES
NO
YES
NO
RUN MANUAL LINE FILL
756
ERROR INVALID KEY
764
SCROLL MENU
762
SCROLL VALUE
758

FIGURE 54

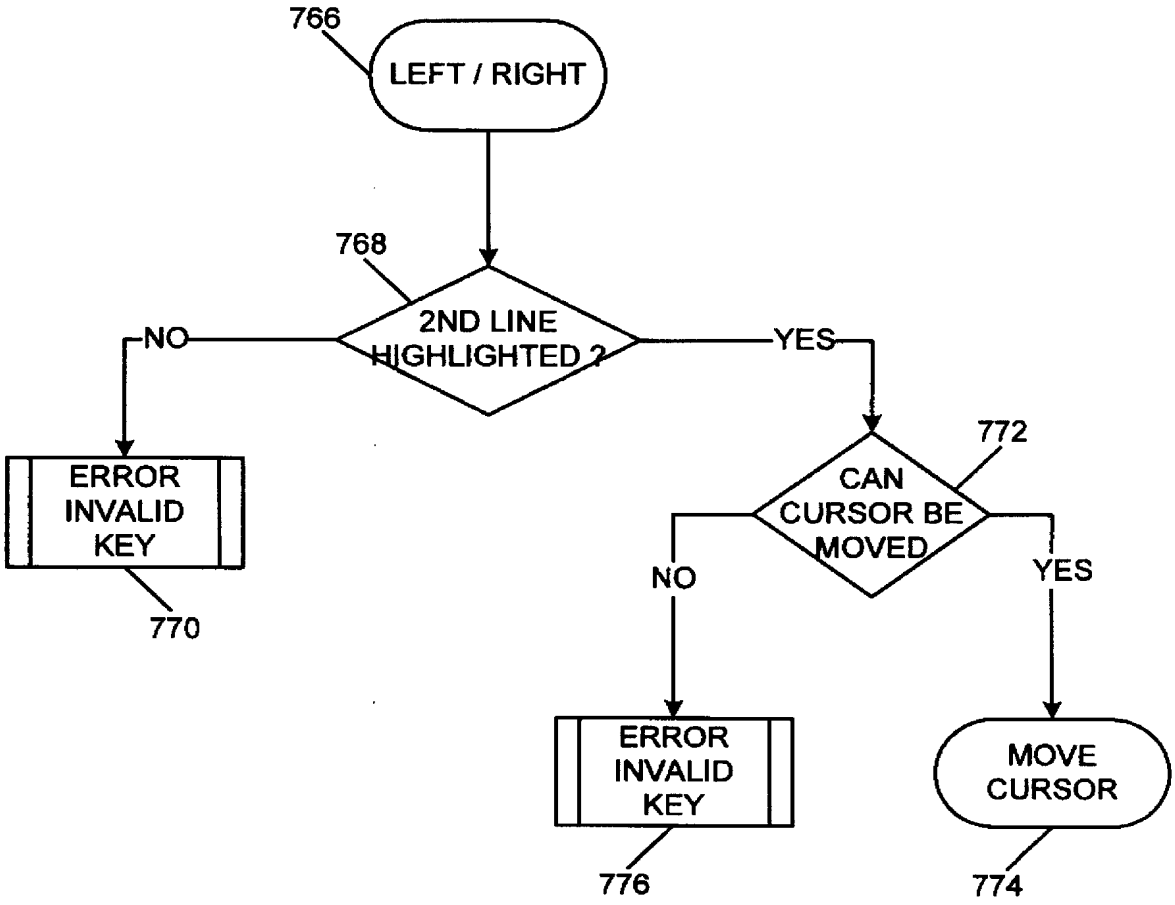

766
LEFT / RIGHT
768
2ND LINE HIGHLIGHTED ?
NO
YES
ERROR INVALID KEY
770
772
CAN CURSOR BE MOVED
NO
YES
ERROR INVALID KEY
776
MOVE CURSOR
774

FIGURE 55

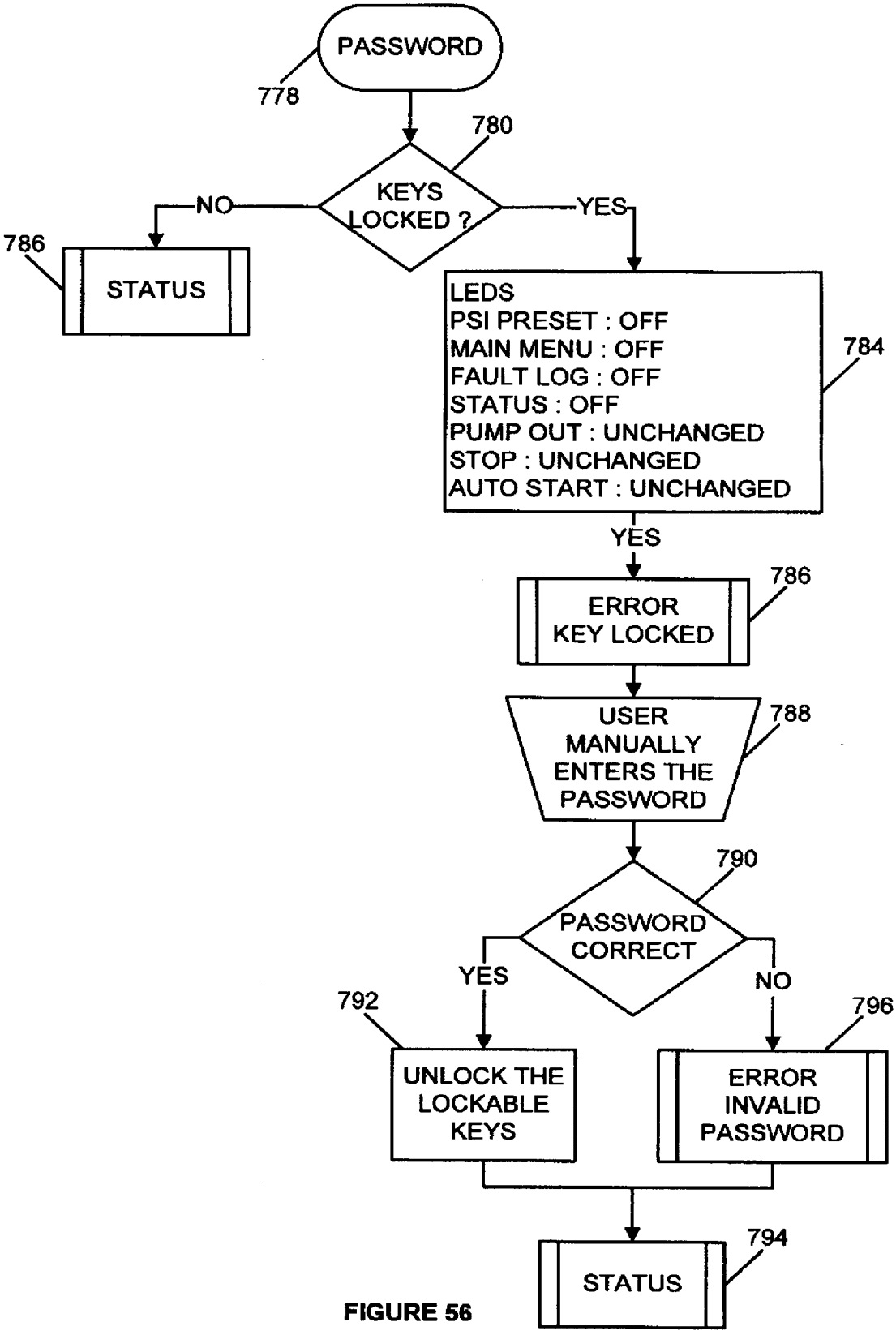

PASSWORD
778
780
KEYS LOCKED ?
NO
YES
786
STATUS
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
784
YES
786
ERROR KEY LOCKED
788
USER MANUALLY ENTERS THE PASSWORD
790
PASSWORD CORRECT
YES
NO
792
UNLOCK THE LOCKABLE KEYS
796
ERROR INVALID PASSWORD
794
STATUS

FIGURE 56

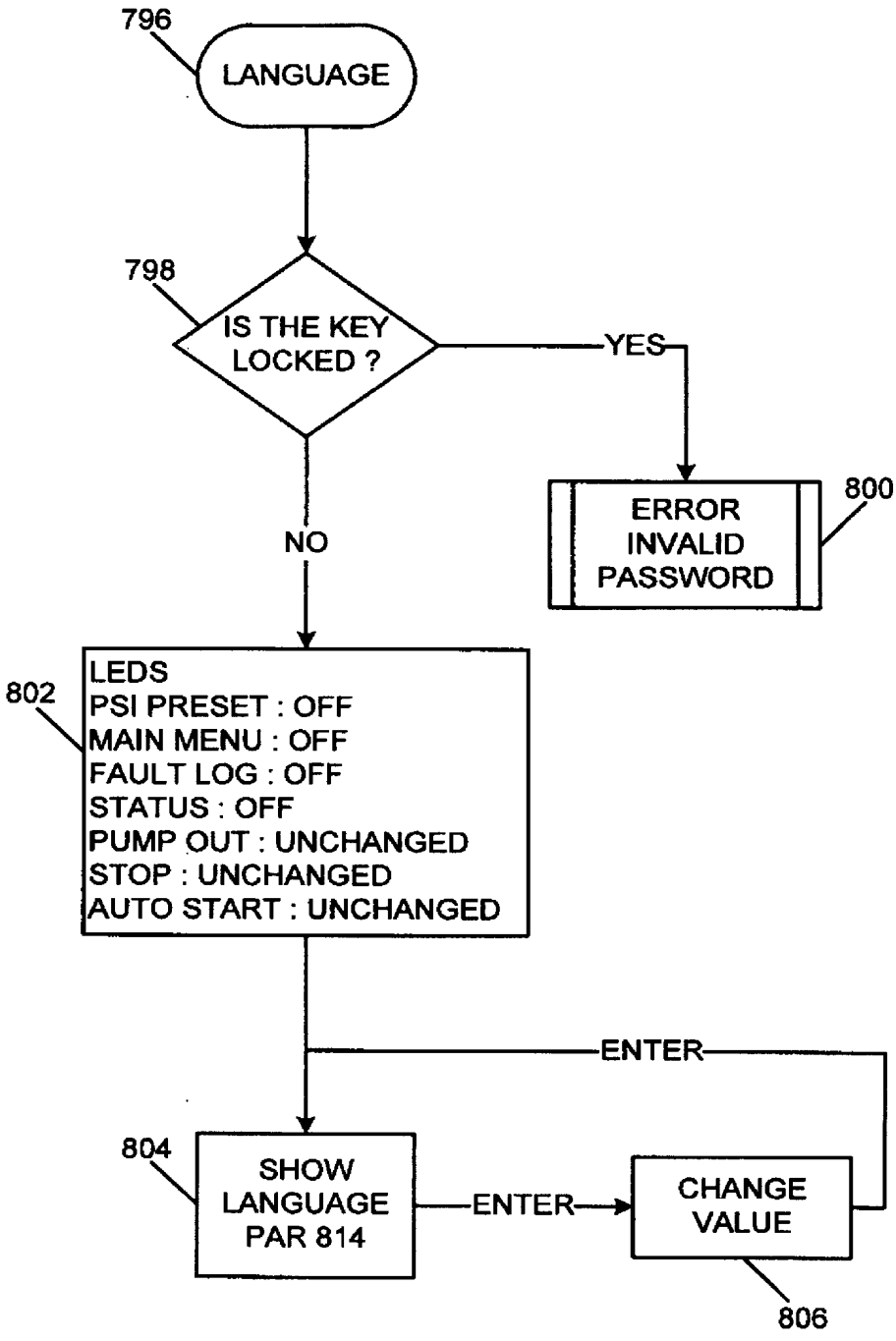

796
LANGUAGE
798
IS THE KEY LOCKED ?
YES
NO
800
ERROR
INVALID
PASSWORD
802
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
ENTER
804
SHOW
LANGUAGE
PAR 814
ENTER
CHANGE
VALUE
806

FIGURE 57

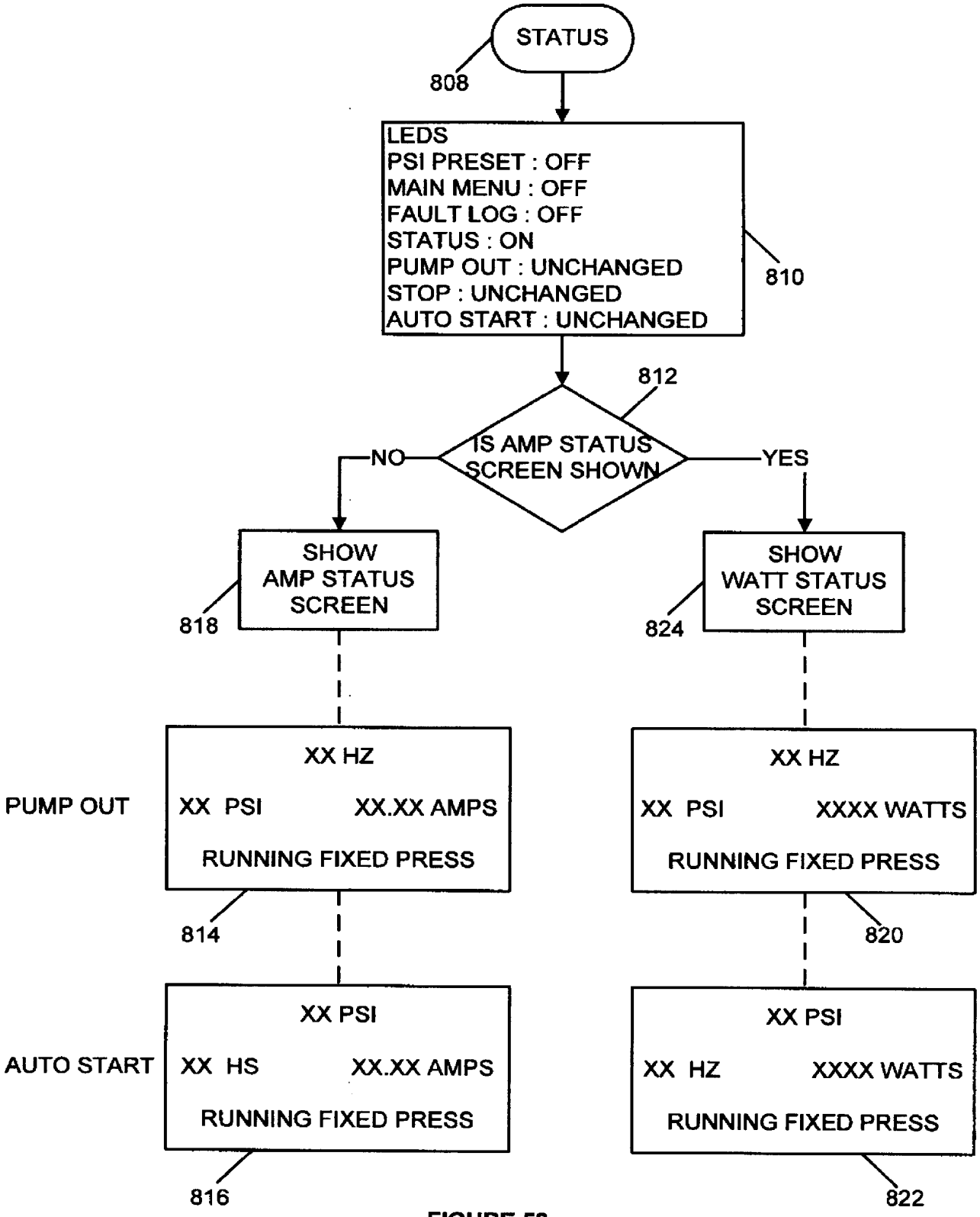

STATUS
808
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : ON
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
810
812
IS AMP STATUS SCREEN SHOWN
NO
YES
SHOW AMP STATUS SCREEN
818
SHOW WATT STATUS SCREEN
824
XX HZ
PUMP OUT
XX PSI
XX.XX AMPS
RUNNING FIXED PRESS
814
XX HZ
XX PSI
XXXX WATTS
RUNNING FIXED PRESS
820
XX PSI
AUTO START
XX HS
XX.XX AMPS
RUNNING FIXED PRESS
816
XX PSI
XX HZ
XXXX WATTS
RUNNING FIXED PRESS
822

FIGURE 58

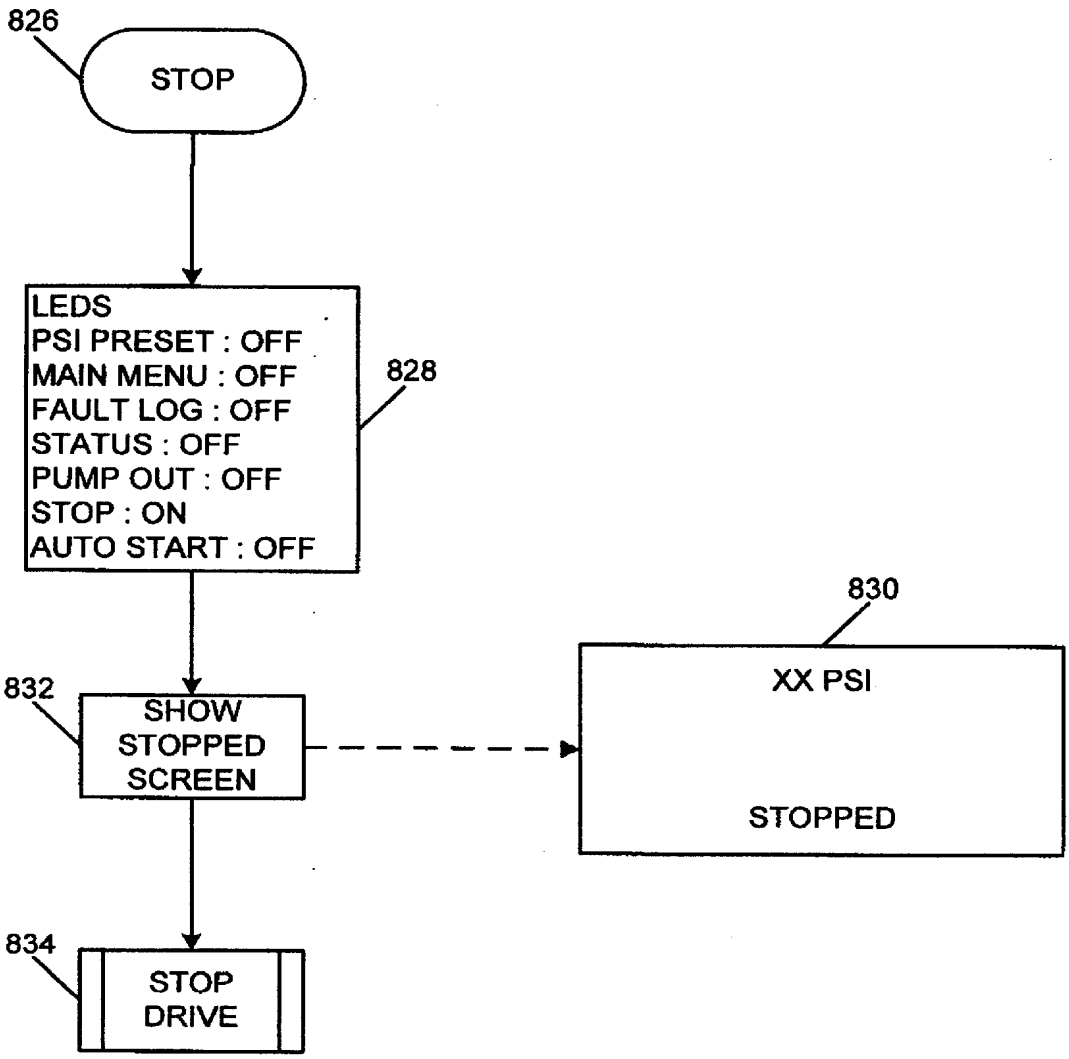

826
STOP
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : OFF
STOP : ON
AUTO START : OFF
828
830
XX PSI
STOPPED
832
SHOW
STOPPED
SCREEN
834
STOP
DRIVE

FIGURE 59

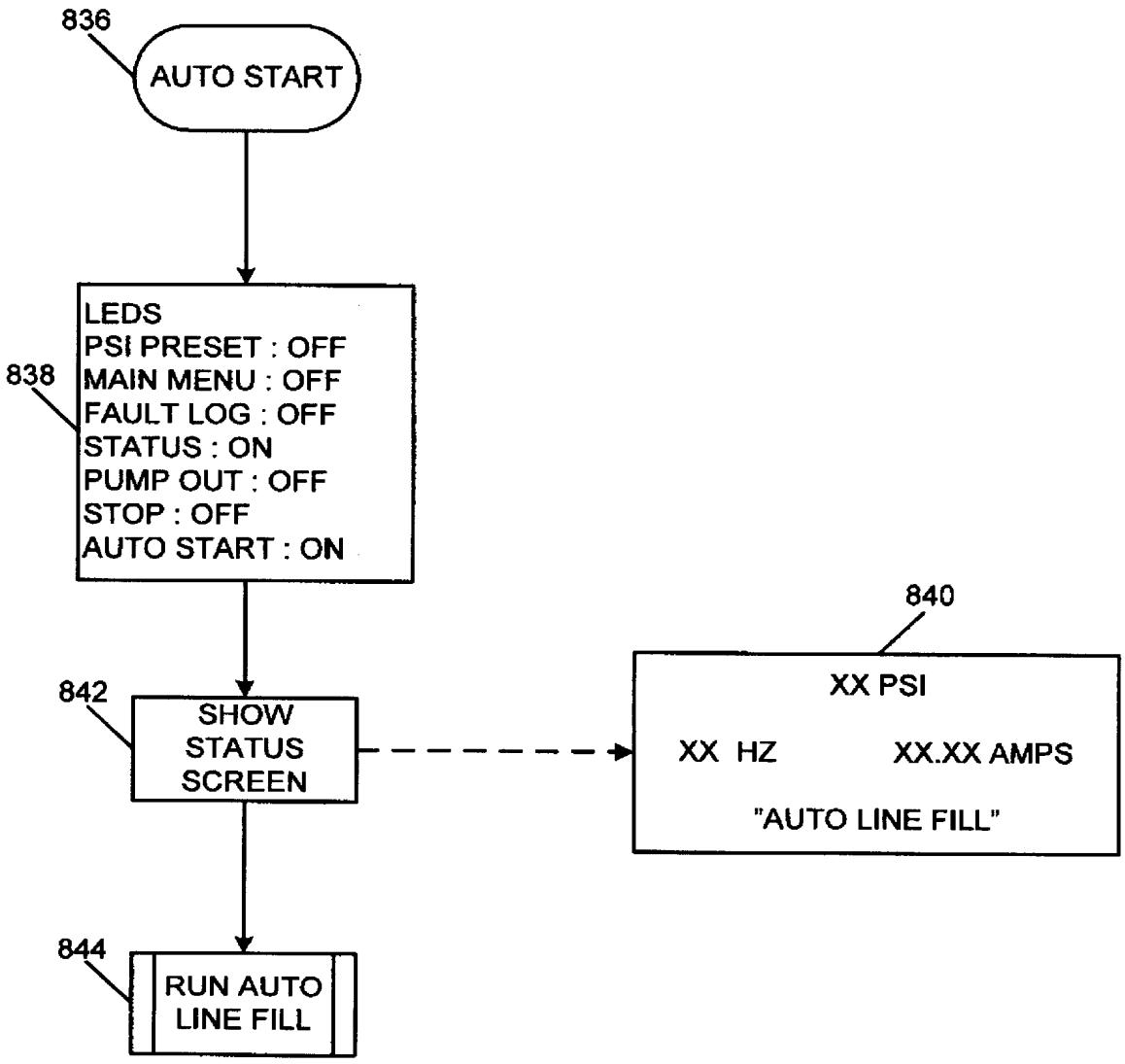

836
AUTO START
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : ON
PUMP OUT : OFF
STOP : OFF
AUTO START : ON
838
840
842
SHOW
STATUS
SCREEN
XX PSI
XX HZ
XX.XX AMPS
"AUTO LINE FILL"
844
RUN AUTO
LINE FILL

FIGURE 60

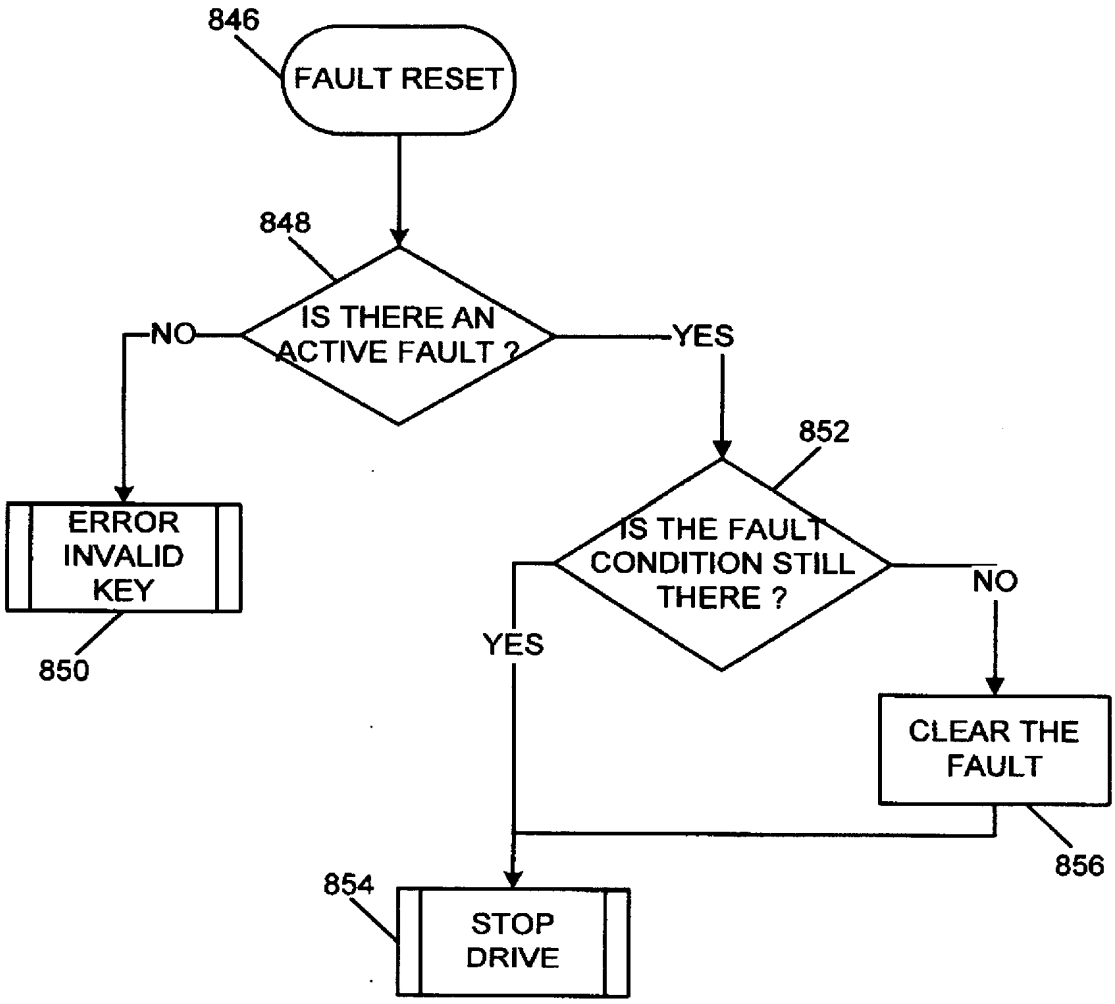

846
FAULT RESET
848
IS THERE AN ACTIVE FAULT ?
NO
YES
ERROR INVALID KEY
850
852
IS THE FAULT CONDITION STILL THERE ?
NO
YES
CLEAR THE FAULT
856
854
STOP DRIVE

FIGURE 61

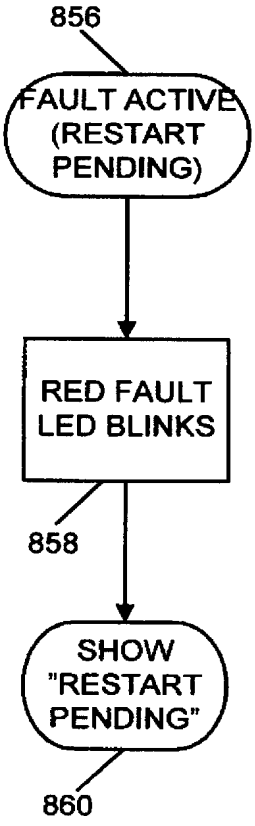


FIGURE 62A

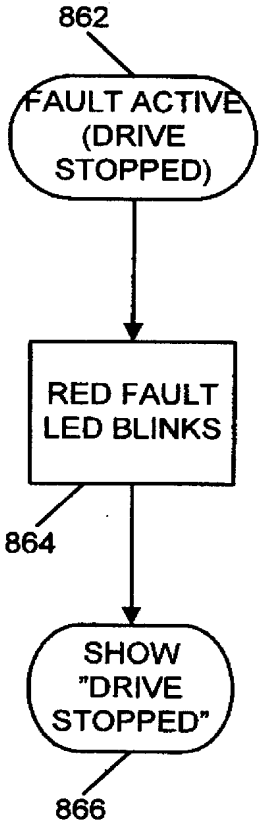


FIGURE 62B

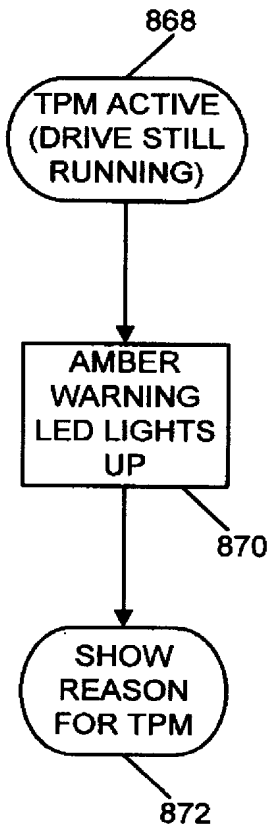


FIGURE 62C

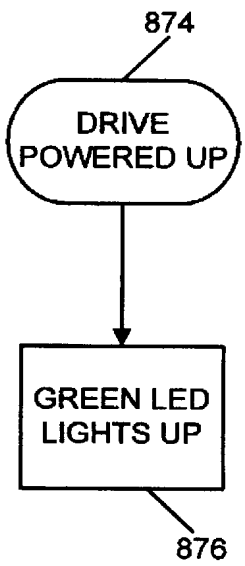


FIGURE 62D

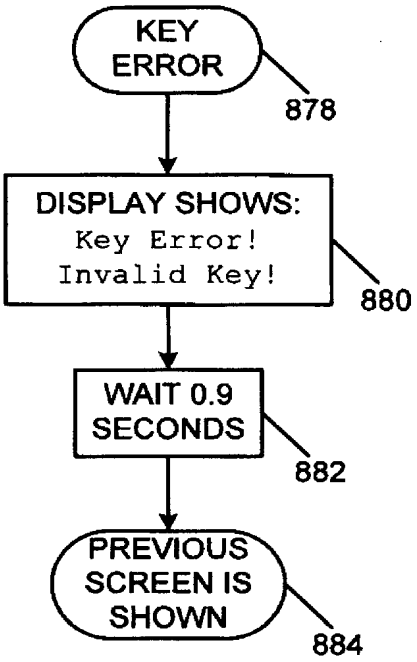


FIGURE 63A

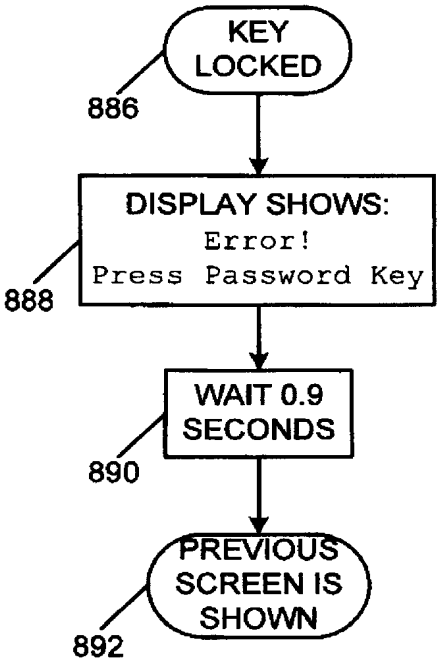


FIGURE 63B

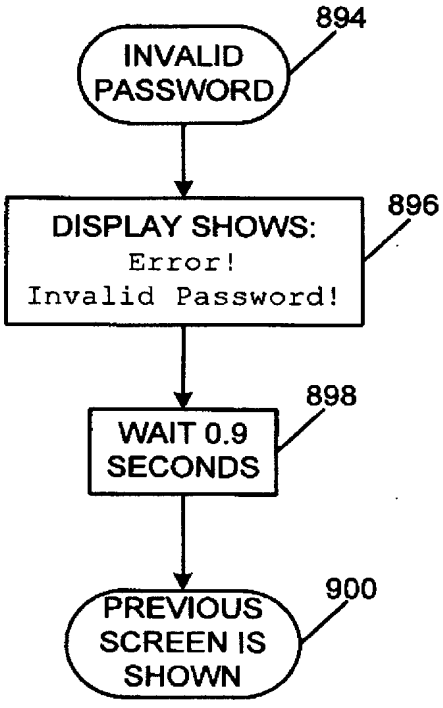


FIGURE 63C

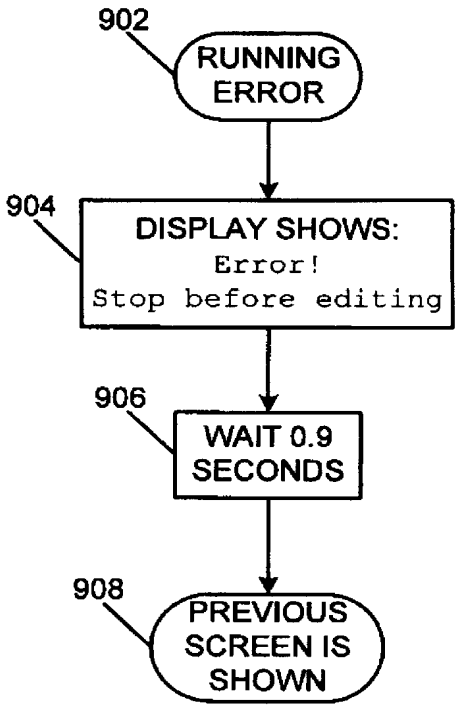
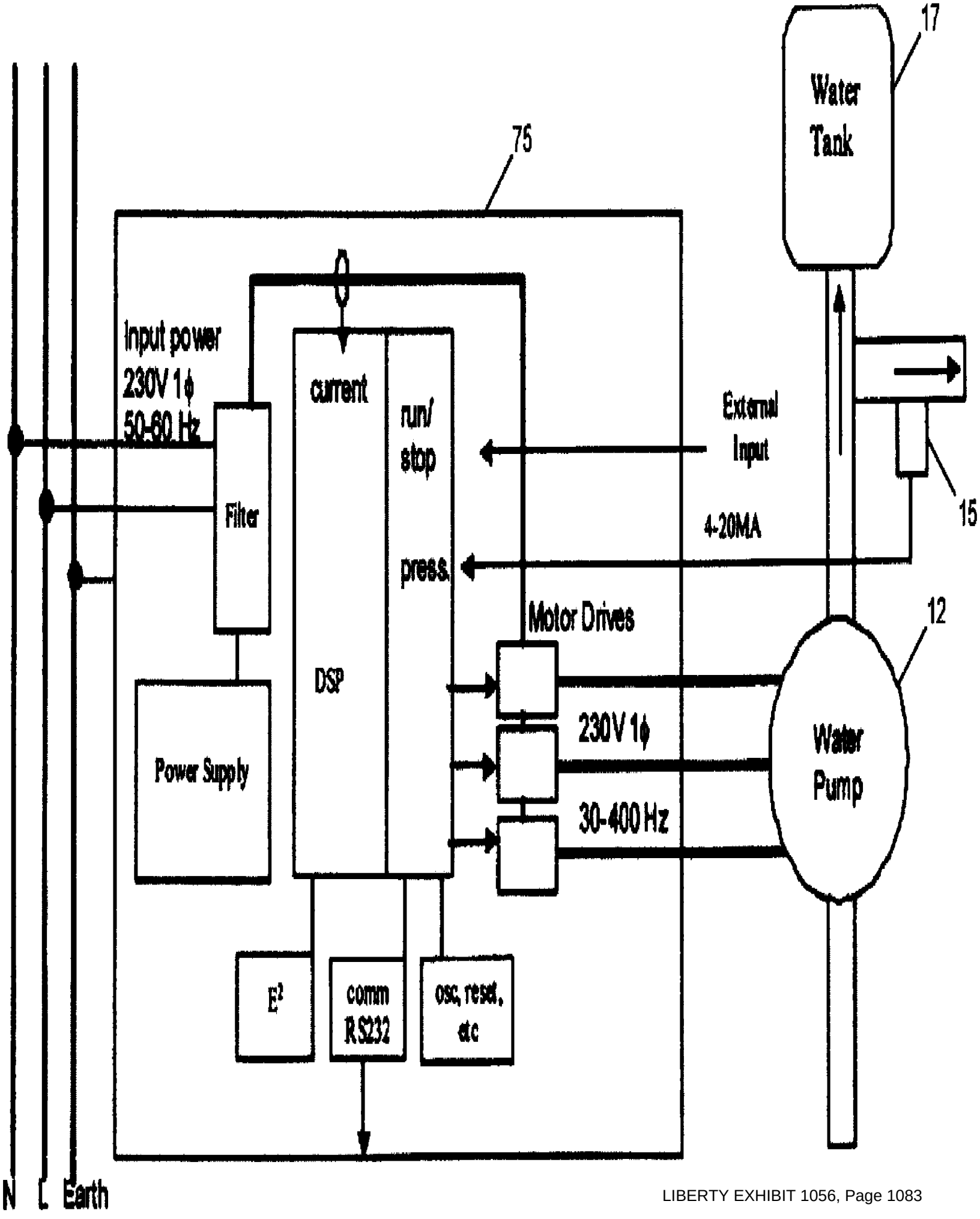


FIGURE 63D


17
Water Tank
75
Input power
230V 1ϕ
50-60 Hz
current
run/ stop
press.
External Input
4-20MA
15
Filter
Motor Drives
12
DSP
230V 1ϕ
Water Pump
Power Supply
30-400 Hz
E²
comm RS232
osc, reset, etc
N
L
Earth