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

(Not for submission under 37 CFR 1.99)

Application Number	16597014
Filing Date	2019-10-09
First Named Inventor	Jared Oehring
Art Unit	3674
Examiner Name	Christopher S. Bobish
Attorney Docket Number	047158.100048

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	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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	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	

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	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)		
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	Filing Date	2019-10-09
	First Named Inventor	Jared Oehring
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	Attorney Docket Number	047158.100048

	5	20140219824		2014-08-07	Burnette	
	6	20160281484		2016-09-29	Lestz	
	7	20190010793		2019-01-10	Hinderliter	
	8	20150211512		2015-07-30	Wiegman	
	9	20170234250		2017-08-17	Janik	
	10	20120049625		2012-03-01	Hopwood	
	11	20190120024		2019-04-25	Oehring	
	12	20190010793		2019-01-10	Hinderliter	
	13	20180028992		2018-02-01	Stegemoeller	
	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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	Attorney Docket Number	047158.100048

	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	
	21	20140060658		2014-03-06	Hains	
	22	20150027712		2015-01-29	Vicknair	
	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)		
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	Art Unit	3674
	Examiner Name	Christopher S. Bobish
	Attorney Docket Number	047158.100048

	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	

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	2707269	CA		2010-12-09	Kidd		X

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	16597014
	Filing Date	2019-10-09
	First Named Inventor	Jared Oehring
	Art Unit	3674
	Examiner Name	Christopher S. Bobish
	Attorney Docket Number	047158.100048

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	☒
	9	Office Action mailed August 19, 2019 in related U.S. Patent Application No. 15/356,436	☒
	10	Office Action mailed October 2, 2019 in related U.S. Patent Application No. 16/152,732	☒

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Art Unit	3674
	Examiner Name	Christopher S. Bobish
	Attorney Docket Number	047158.100048

	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	☒
	17	Office Action mailed December 6, 2019 in related U.S. Patent Application No. 16/564,186	☒

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

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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16597014
Filing Date	2019-10-09
First Named Inventor	Jared Oehring
Art Unit	3674
Examiner Name	Christopher S. Bobish
Attorney Docket Number	047158.100048

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)* 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 --- Y	US 2016/0105022 A1 (US WELL SERVICES LLC) 14 April 2016 (14.04.2016) entire document	1, 2, 4, 5, 9-11, 13, 14 --- 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 047168.500040	FOR FURTHER ACTION 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 10, 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]).

Form PCT/ISA/237 (Box No. V) (January 2015)

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. [0026]) 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 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/US2019/037483

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
---		---
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:

- [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	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 1002, Page 881

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	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
047158.500047		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2019/055323	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 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.

LIBERTY EXHIBIT 1002, Page 897

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

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-*-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.

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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.

LIBERTY EXHIBIT 1002, Page 916

Electronic Acknowledgement Receipt

EFS ID:	39742771
Application Number:	16597014
International Application Number:	
Confirmation Number:	4687
Title of Invention:	MODULAR SWITCHGEAR SYSTEM AND POWER DISTRIBUTION FOR ELECTRIC OILFIELD EQUIPMENT
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:	047158.100048
Receipt Date:	17-JUN-2020
Filing Date:	09-OCT-2019
Time Stamp:	11:22:37
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)	100048_IDS_2.pdf	1036192 9fe082827d5144472097c2007e0aa3b3629eb413	no	9

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Information:					
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New International Application Filed with the USPTO as a Receiving Office

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16597014
Filing Date	2019-10-09
First Named Inventor	Jared Oehring
Art Unit	3746
Examiner Name	Christopher S. Bobish
Attorney Docket Number	047158.100048

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3764233		1973-10-09	Strickland	
	2	5879137		1999-03-09	Yie	
	3	7563076		2009-07-21	Brunet	
	4	7683499		2010-03-23	Saucier	
	5	8083504		2011-12-27	Williams	
	6	3334495		1967-08-08	Jensen	
	7	1671436		1928-05-29	Melott	
	8	2004077		1935-06-04	McCartney	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16597014
	Filing Date	2019-10-09
	First Named Inventor	Jared Oehring
	Art Unit	3746
	Examiner Name	Christopher S. Bobish
	Attorney Docket Number	047158.100048

	9	2220622		1940-11-05	Aitken	
	10	3066503		1962-12-04	Fleming	
	11	3837179		1974-09-24	Barth	
	12	4037431		1977-07-26	Sugimoto	
	13	5907970		1999-06-01	Havlovick et al.	
	14	6142878		2000-11-07	Barin	
	15	8789601		2014-07-29	Broussard	
	16	6271637		2001-08-07	Kushion	
	17	6529135		2003-03-04	Bowers et al.	
	18	6931310		2005-08-16	Shimizu et al.	
	19	7755310		2010-07-13	West et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16597014
	Filing Date	2019-10-09
	First Named Inventor	Jared Oehring
	Art Unit	3746
	Examiner Name	Christopher S. Bobish
	Attorney Docket Number	047158.100048

	20	8054084		2011-11-08	Schulz et al.	
	21	8310272		2012-11-13	Quarto	
	22	8354817		2013-01-15	Yeh et al.	
	23	8838341		2014-09-16	Kumano	
	24	9018881		2015-04-28	Mao et al.	
	25	2248051		1941-07-08	Armstrong	
	26	3722595		1973-03-27	Kiel	
	27	7312593		2007-12-25	Streicher et al.	
	28	4226299		1980-10-07	Hansen	
	29	4456092		1984-06-26	Kubozuka	
	30	5655361		1997-08-12	Kishi	

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	31	6254462		2001-07-03	Kelton	
	32	3061039		1962-10-30	Peters	
	33	3773140		1973-11-20	Mahajan	
	34	5548093		1996-08-20	Sato	
	35	6202702		2001-03-20	Ohira	
	36	6802690		2004-10-12	Han	
	37	8534235		2013-09-17	Chandler	
	38	8727068		2014-05-20	Bruin	
	39	9103193		2015-08-11	Coli	
	40	6164910		2000-12-26	Mayleben	
	41	7500642		2009-03-10	Cunningham	

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	42	8899940		2014-12-02	Laugemors	
	43	8905056		2004-12-09	Kendrick	
	44	4151575		1979-04-24	Hogue	
	45	5130628		1992-07-14	Owen	
	46	6315523		2001-11-13	Mills	
	47	7336514		2008-02-26	Amarillas	
	48	7525264		1999-04-28	Dodge	
	49	8096891		2012-01-17	Lochtefeld	
	50	9160168		2015-10-13	Chapel	
	51	8146665		2012-04-03	Neal	
	52	8474521		2013-07-02	Kajaria	

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	53	9067182		2015-06-30	Nichols	
	54	8807960		2014-08-19	Stephenson	
	55	5025861		1991-06-25	Huber et al.	
	56	7170262		2007-01-30	Pettigrew	
	57	8997904		2015-04-07	Cryer	
	58	9051822		2015-06-09	Ayan	
	59	9366114		2016-06-14	Coli et al.	
	60	9140110		2015-09-22	Coli et al.	
	61	5422550		1995-06-06	McClanahan	
	62	5865247		1999-02-02	Paterson	
	63	7845413		2010-12-07	Shampine et al.	

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	64	8596056		2013-12-03	Woodmansee	
	65	8774972		2014-07-08	Rusnak et al.	
	66	8905138		2014-12-09	Lundstedt et al.	
	67	9410410		2016-08-09	Broussard et al.	
	68	3881551		1975-05-06	Terry	
	69	4512387		1985-04-23	Rodriguez	
	70	4845981		1989-07-11	Pearson	
	71	6776227		2004-08-17	Beida	
	72	8037936		2011-10-18	Neuroth	
	73	8760657		2014-06-24	Pope	
	74	8857506		2014-10-14	Stone, Jr.	

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	75	5131472		1992-07-21	Dees et al.	
	76	5894888		1999-04-20	Wiemers	
	77	6491098		2002-12-10	Dallas	
	78	7173399		2007-02-06	Sihler	
	79	7445041		2008-11-04	O'Brien	
	80	7807048		2010-10-05	Collette	
	81	8272439		2012-09-25	Strickland	
	82	8573303		2013-11-05	Kerfoot	
	83	9322239		2016-04-26	Angeles Boza et al.	
	84	4506982		1985-03-26	Smithers et al.	
	85	4538916		1985-09-03	Zimmerman, Harold M.	

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	86	4922463		1990-05-01	Del Zotto et al.	
	87	5590976		1997-01-07	Kilheffer et al.	
	88	6808303		2004-10-26	Fisher, Gene	
	89	9587649		2017-03-07	Oehring, Jared	
	90	4793386		1988-12-27	Sloan, Albert H.	
	91	2220622		1940-11-05	Homer, P.A.	
	92	5736838		1998-04-07	Dove et al.	
	93	8692408		2014-04-08	Zhang et al.	
	94	5790972		1998-08-04	Kohlenberger	
	95	6477852		2002-11-12	Dodo	
	96	7845413		2010-12-07	Shampine	

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	97	8261528		2012-09-11	Chillar	
	98	3849662		1974-11-19	Blaskowski	
	99	4442665		1984-04-17	Fick et al.	
	100	4676063		1987-06-30	Goebel et al.	
	101	7977824		2011-07-12	Halen et al.	
	102	9450385		2016-09-20	Kristensen	
	103	7717193		2010-05-18	Egilsson et al.	
	104	8154419		2012-04-10	Daussin et al.	
	105	8232892		2012-07-31	Overholt et al.	
	106	8616274		2013-12-31	Belcher et al.	
	107	9611728		2017-04-04	Oehring	

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	108	9650879		2017-05-16	Broussard et al.	
	109	9745840		2017-08-29	Oehring et al.	
	110	9650871		2017-05-16	Oehring et al.	
	111	9840901		2017-12-12	Oehring et al.	
	112	4529887		1985-07-16	Johnson	
	113	2183364		1939-12-12	Bailey	
	114	7675189		2010-03-09	Grenier	
	115	2753940		1956-07-10	Bonner	
	116	9562420		2017-02-07	Morris et al.	
	117	9534473		2017-01-03	Morris et al.	
	118	9475021		2016-10-25	Coli et al.	

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	119	9475020		2016-10-25	Coli et al.	
	120	9121257		2015-09-01	Coli et al.	
	121	9738461		2017-08-22	DeGaray	
	122	8139383		2012-03-20	Efraimsson	
	123	7104233		2006-09-12	Ryczek et al.	
	124	9863228		2018-01-09	Shampine et al.	
	125	4265266		1981-05-05	Kierbow et al.	
	126	7494263		2009-02-24	Dykstra et al.	
	127	9893500		2018-02-13	Oehring	
	128	9970278		2018-05-15	Broussard	
	129	9995218		2018-06-12	Oehring	

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	130	10020711		2018-07-10	Oehring	
	131	10036238		2018-07-31	Oehring	
	132	10119381		2018-11-06	Oehring	
	133	10107086		2018-10-23	Oehring	
	134	6138764		2000-10-13	Scarsdale et al.	
	135	4432064		1984-02-14	Barker	
	136	5006044		1991-04-09	Walker, Sr.	
	137	4100822		1978-07-18	Rosman	
	138	8851860		2014-10-07	Mail	
	139	6208098		2001-03-27	Kume	
	140	5189388		1993-02-23	Mosley	

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	1	20100303655		2010-12-02	Scekic	
	2	20110085924		2011-04-14	Shampine	
	3	20120085541		2012-04-12	Love et al.	
	4	20120205301		2012-08-16	McGuire et al.	
	5	20120255734		2012-10-11	Coli et al.	
	6	20070201305		2007-08-30	Heilman et al.	
	7	20100132949		2010-06-03	DeFosse et al.	
	8	20110272158		2011-11-10	Neal	
	9	20140251623		2014-09-11	Lestz et al.	

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	10	20140010671		2014-01-09	Cryer et al.	
	11	20070187163		2007-08-16	Cone	
	12	20080112802		2008-05-15	Orlando	
	13	20090065299		2009-03-12	Vito	
	14	20090188181		2009-07-30	Forbis	
	15	20100000508		2010-01-07	Chandler	
	16	20140000899		2014-01-02	Nevison	
	17	20140096974		2014-04-10	Coli	
	18	20150083426		2015-03-26	Lesko	
	19	20150114652		2015-04-30	Lestz	
	20	20150225113		2015-08-13	Lungu	

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	21	20160177678		2016-06-23	Morris	
	22	20130233542		2013-09-12	Shampine	
	23	20150211524		2015-07-30	Broussard	
	24	20120127635		2012-05-24	Grindeland	
	25	20080264649		2008-10-30	Crawford	
	26	20120018016		2012-01-26	Gibson	
	27	20150252661		2015-09-10	Glass	
	28	20080137266		2008-06-12	Jensen	
	29	20090260826		2009-10-22	Sherwood	
	30	20150175013		2015-06-25	Cryer et al.	
	31	20160105022		2016-04-14	Oehring	

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	32	20160208592		2016-04-14	Oehring	
	33	20160273328		2016-09-22	Oehring	
	34	20160319650		2016-11-03	Oehring	
	35	20160290114		2016-10-06	Oehring	
	36	20160349728		2016-12-01	Oehring	
	37	20160348479		2016-12-01	Oehring	
	38	20160326854		2016-11-10	Broussard	
	39	20100322802		2010-12-23	Kugelev	
	40	20130306322		2013-11-21	Sanborn et al.	
	41	20140124162		2014-05-08	Leavitt	
	42	20160032703		2016-02-04	Broussard et al.	

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	43	20160258267		2016-09-08	Payne et al.	
	44	20110005757		2011-01-13	Hebert	
	45	20150159911		2015-06-11	Holt	
	46	20080217024		2008-09-11	Moore	
	47	20110017468		2011-01-27	Birch et al.	
	48	20130341029		2013-12-26	Roberts et al.	
	49	20150176386		2015-06-25	Castillo et al.	
	50	20070278140		2007-12-06	Mallet et al.	
	51	20090308602		2009-12-17	Bruins et al.	
	52	20100250139		2010-09-30	Hobbs et al.	
	53	20090153354		2009-06-18	Daussin et al.	

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	54	20070226089		2007-09-27	DeGaray et al.	
	55	20120205400		2012-08-16	DeGaray et al.	
	56	20130025706		2013-01-31	DeGaray et al.	
	57	20130199617		2013-08-08	DeGaray et al.	
	58	20160221220		2016-08-04	Paige, Daniel	
	59	20170022788		2017-01-26	Oehring et al.	
	60	20170028368		2017-02-02	Oehring et al.	
	61	20030138327		2003-07-24	Jones et al.	
	62	20170030178		2017-02-02	Oehring et al.	
	63	20170030177		2017-02-02	Oehring et al.	
	64	20090200035		2009-08-13	Bjerkreim et al.	

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	65	20100146981		2010-06-17	Motakef	
	66	20100293973		2010-11-25	Erickson	
	67	20050116541		2005-06-02	Seiver	
	68	20080208478		2008-08-28	Ella et al.	
	69	20090095482		2009-04-16	Surjaatmadja	
	70	20100051272		2010-03-04	Loree et al.	
	71	20120255734		2012-10-11	Coli et al.	
	72	20140138079		2014-05-22	Broussard et al.	
	73	20140174717		2014-06-26	Broussard et al.	
	74	20150144336		2015-05-28	Hardin et al.	
	75	20170037717		2017-02-09	Oehring	

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	76	20170222409		2017-08-03	Oehring	
	77	20170218843		2017-08-03	Oehring	
	78	20120232728		2012-09-13	Karimi et al.	
	79	20020169523		2002-11-14	Ross et al.	
	80	20100019574		2010-01-28	Baldassarre et al.	
	81	20130009469		2013-01-10	Gillett	
	82	20140054965		2014-02-27	Jain	
	83	20040102109		2004-05-27	Cratty et al.	
	84	20160230525		2016-08-11	Lestz et al.	
	85	20130175038		2013-07-11	Conrad	
	86	20130175039		2013-07-11	Guidry	

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	87	20140246211		2014-09-04	Guidry et al.	
	88	20170259227		2017-09-14	Morris et al.	
	89	20170104389		2017-04-13	Morris et al.	
	90	20170037718		2017-02-09	Coli et al.	
	91	20170036178		2017-02-09	Coli et al.	
	92	20160369609		2016-12-22	Morris et al.	
	93	20160326855		2016-11-10	Coli et al.	
	94	20160208594		2016-07-21	Coli et al.	
	95	20160208593		2016-07-21	Coli et al.	
	96	20160177675		2016-06-23	Morris et al.	
	97	20150314225		2015-11-05	Coli et al.	

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	98	20150300145		2015-10-22	Coli et al.	
	99	20150068754		2015-03-12	Coli et al.	
	100	20150068724		2015-03-12	Coli et al.	
	101	20170369258		2017-12-28	DeGaray	
	102	20170314380		2017-11-02	Oehring	
	103	20090078410		2009-03-26	Krenek et al.	
	104	20100172202		2010-07-08	Borgstadt	
	105	20110061855		2011-03-17	Case et al.	
	106	20160160889		2016-06-09	Hoffman et al.	
	107	20170021318		2017-01-26	McIver et al.	
	108	20170226842		2017-08-10	Omont et al.	

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	109	20090093317		2009-04-09	Kajiwara et al.	
	110	20170313499		2017-11-02	Hughes et al.	
	111	20160312108		2016-10-27	Lestz et al.	
	112	20130343858		2013-12-26	Flusche	
	113	20160186531		2016-06-30	Harkless et al.	
	114	20170145918		2017-05-25	Oehring	
	115	20180156210		2018-06-07	Oehring	
	116	20170226839		2017-08-10	Broussard	
	117	20180183219		2018-06-28	Oehring	
	118	20180258746		2018-09-13	Broussard	
	119	20180274446		2018-09-27	Oehring	

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	120	20170292513		2017-10-12	Haddad	
	121	20140095114		2014-04-03	Thomeer	
	122	20150217672		2015-08-06	Shampine	
	123	20170328179		2017-11-16	Dykstra	
	124	20040040746		2004-03-04	Niedermayr et al.	
	125	20140379300		2014-12-25	Devine	
	126	20060052903		2006-03-09	Bassett	
	127	20170037717		2017-02-09	Oehring	
	128	20110247878		2011-10-13	Rasheed	
	129	20160230524		2016-08-11	Dumoit	
	130	20170114625		2017-04-27	Norris	

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	131	20170022807		2017-01-26	Dursun	
	132	20160208595		2016-07-21	Tang	
	133	20150075778		2015-03-19	Walters	
	134	20180320483		2018-11-08	Zhang	
	135	20180038216		2018-02-08	Zhang	
	136	20160102537		2016-04-14	Lopez	
	137	20140290768		2014-10-02	Randle	
	138	20140277772		2014-09-18	Lopez	
	139	20170096885		2017-04-06	Oehring	
	140	20070277982		2007-12-06	Shampine	
	141	20170051732		2017-02-23	Baker Hughes Incorporated	

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	142	20160341281		2016-11-24	Onesubsea IP UK Limited	
	143	20050274508		2005-12-15	Folk	
	144	20070131410		2007-06-14	Hill	
	145	20190003329		2019-01-03	Morris	
	146	20090045782		2009-02-19	Datta	
	147	20150097504		2015-04-09	Lamascus	
	148	20170241221		2017-08-24	Seshadri	
	149	20150330172		2015-11-19	Allmaras	
	150	20110166046		2011-07-07	Weaver	
	151	20160265457		2016-09-15	Stephenson	
	152	20190120024		2019-04-25	Oehring	

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	153	20190112910		2019-04-18	Oehring	
	154	20140219824		2014-08-07	Burnette	
	155	20160281484		2016-09-29	Lestz	
	156	20190010793		2019-01-10	Hinderliter	
	157	20150211512		2015-07-30	Wiegman	
	158	20170234250		2017-08-17	Janik	
	159	20120049625		2012-03-01	Hopwood	
	160	20180028992		2018-02-01	Stegemoeller	

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	1	2004264589	JP		2004-09-24	Toshiba KK [TOKE]		X

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	2	101977016	CN		2011-02-16	Univ Tianjin Technology		☒
	3	2966672	CA		2012-10-07	Evolution Well Services LLC		☒
	4	2016/144939	WO		2016-09-15	Schlumberger Technologies Corporation		☒
	5	2016/160458	WO		2016-10-06	Schlumberger Technologies Corporation		☒
	6	2833711	CA		2014-05-16	Broussard		☒
	7	2955706	CA		2012-10-07	Coli		☒
	8	2964593	CA		2017-10-15	Oehring		☒

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	1	UK Power Networks - Transformers to Supply Heat to Tate Modern - from Press Releases May 16, 2013.	☓
	2	Non-Final Office Action issued in corresponding Application No. 15/293,681 dated February 16, 2017.	☒

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	3	Non-Final Office Action issued in corresponding Application No. 15/294,349 dated March 14, 2017.	☒
	4	Final Office Action issued in corresponding Application No. 15/145,491 dated January 20, 2017.	☒
	5	Non-Final Office Action issued in corresponding Application No. 15/145,443 dated February 7, 2017.	☒
	6	Notice of Allowance issued in corresponding Application No. 15/217,040 dated March 28, 2017.	☒
	7	Notice of Allowance issued in corresponding Application No. 14/622,532 dated March 27, 2017.	☒
	8	Non-Final Office Action issued in corresponding Application No. 15/291,842 dated January 6, 2017.	☒
	9	Final Office Action issued in corresponding Application No. 14/622,532 dated December 7, 2016.	☒
	10	Non-Final Office Action issued in corresponding Application No. 14/622,532 dated May 17, 2016.	☒
	11	Final Office Action issued in corresponding Application No. 14/622,532 dated December 21, 2015.	☒
	12	Non-Final Office Action issued in corresponding Application No. 14/622,532 dated August 5, 2015.	☒
	13	Non-Final Office Action issued in corresponding Application No. 15/145,491 on September 12, 2016.	☒

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	14	Non-Final Office Action issued in corresponding Application No. 15/217,040 dated November 29, 2016.	☒
	15	Non-Final Office Action issued in corresponding Application No. 15/235,788 dated December 14, 2016.	☒
	16	Non-Final Office Action issued in corresponding Application No. 15/145,491 dated May 15, 2017.	☒
	17	Non-Final Office Action issued in corresponding Application No. 15/486,970 dated June 22, 2017	☒
	18	Non-Final Office Action issued in corresponding Application No. 15/487,656 dated June 23, 2017	☒
	19	Non-Final Office Action issued in corresponding Application No. 15/487,694 dated June 26, 2017	☒
	20	Final Office Action issued in corresponding Application No. 15/294,349 dated July 6, 2017	☒
	21	Non-Final Office Action issued in corresponding Application No. 14/884,363 dated September 5, 2017	☒
	22	Final Office Action issued in corresponding Application No. 15/145,491 dated September 6, 2017	☒
	23	Non-Final Office Action issued in corresponding Application No. 14/881,535 dated October 6, 2017	☒
	24	Non-Final Office Action issued in corresponding Application No. 15/145,414 dated November 29, 2017	☒

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	25	Non-Final Office Action issued in corresponding Application No. 15/644,487 dated November 13, 2017	☒
	26	Canadian Office Action dated March 2, 2018 in related Canadian Patent Application No. 2,833,711	☒
	27	Office Action dated April 10, 2018 in related U.S. Patent Application No. 15/294,349	☒
	28	Office Action dated April 2, 2018 in related U.S. Patent Application No. 15/183,387	☒
	29	Office Action dated May 29, 2018 in related U.S. Patent Application No. 15/235,716	☒
	30	Candian Office Action dated April 18, 2018 in related Canadian Patent Application No. 2,928,711	☒
	31	Canadian Office Action dated June 22, 2018 in related Canadian Patent Application No. 2,886,697	☒
	32	Office Action dated July 25, 2018 in related U.S. Patent Application No. 15/644,487	☒
	33	Office Action dated October 4, 2018 in related U.S. Patent Application No. 15/217,081	☒
	34	International Search Report and Written Opinion dated September 19, 2018 in related PCT Patent Application No. PCT/US2018/040683	☒
	35	Canadian Office Action dated September 28, 2018 in related Canadian Patent Application No. 2,945,281	☒

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	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	☒
	39	International Search Report and Written Opinion dated December 31, 2018 in related PCT Patent Application No. PCT/US18/55913	☒
	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	☒

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	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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Examiner Name	Christopher S. Bobish
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Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

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Signature	/Taylor P. Evans/	Date (YYYY-MM-DD)	2020-06-17
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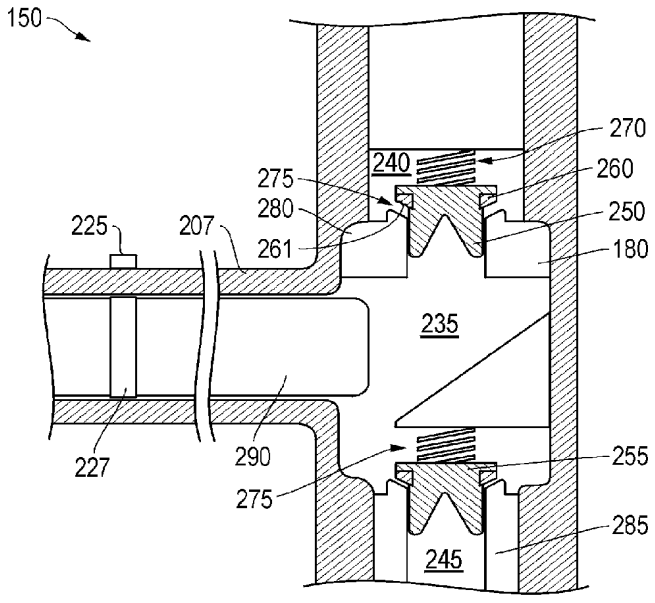
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[Continued on next page]

(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.

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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

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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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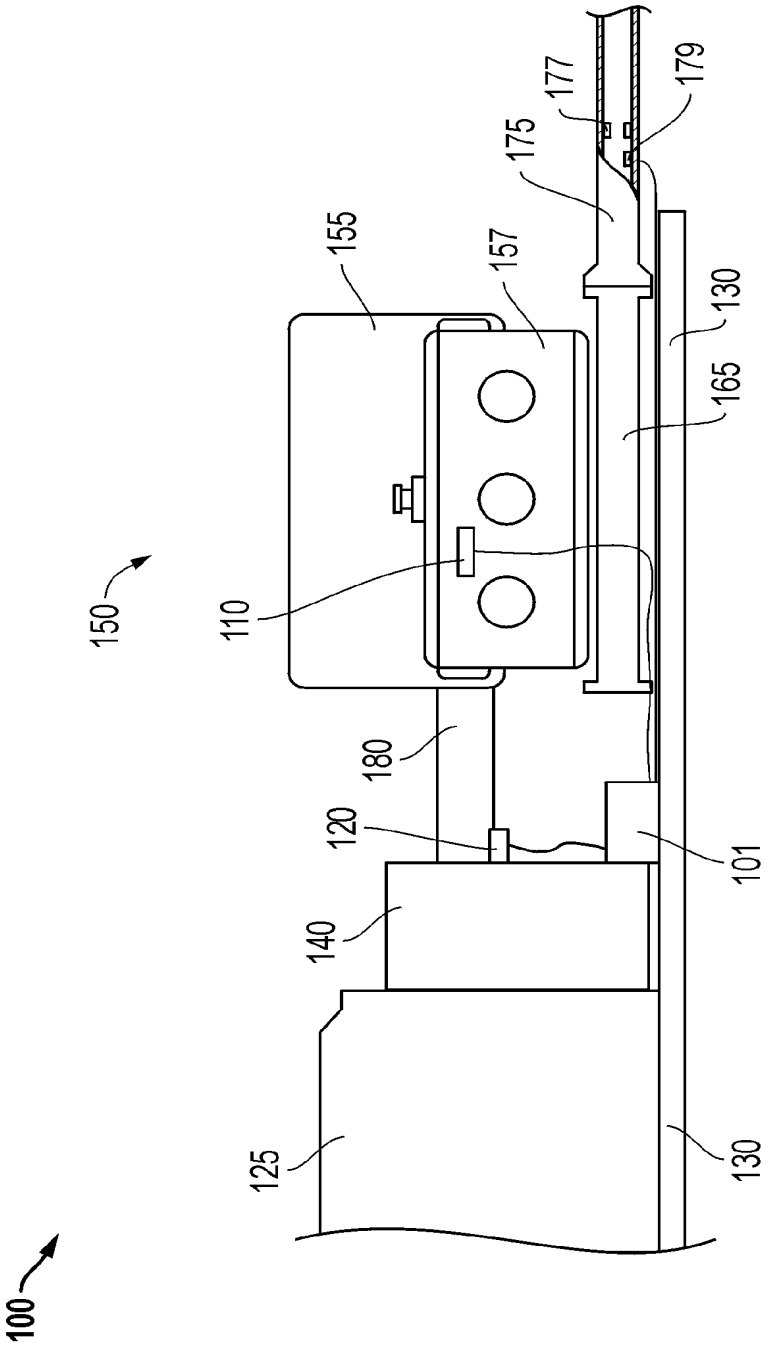


FIG. 1

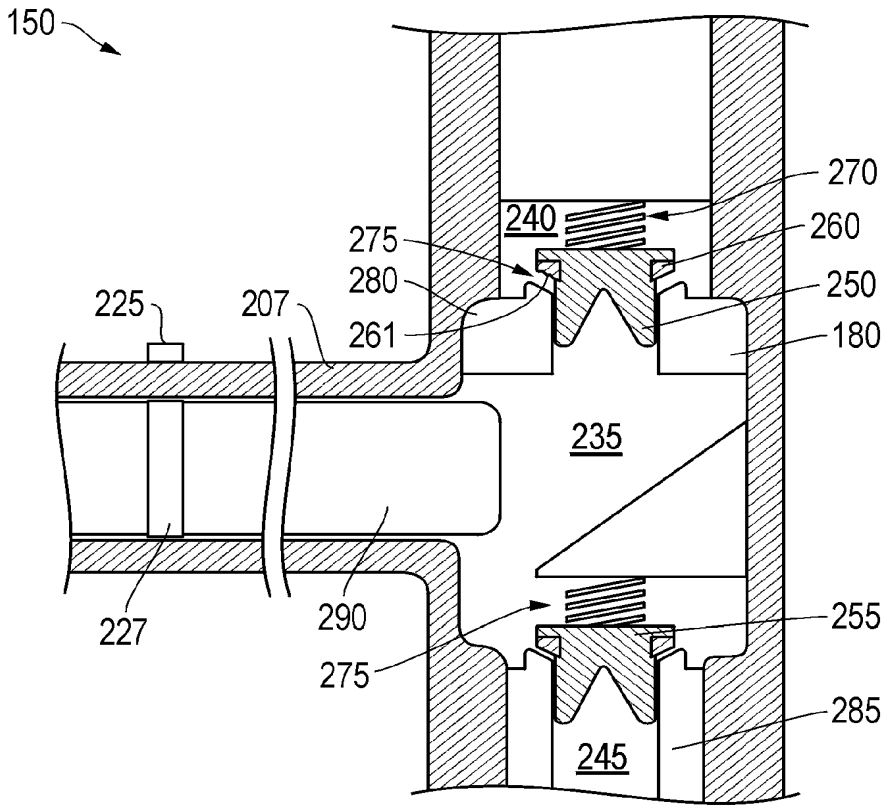

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FIG. 2

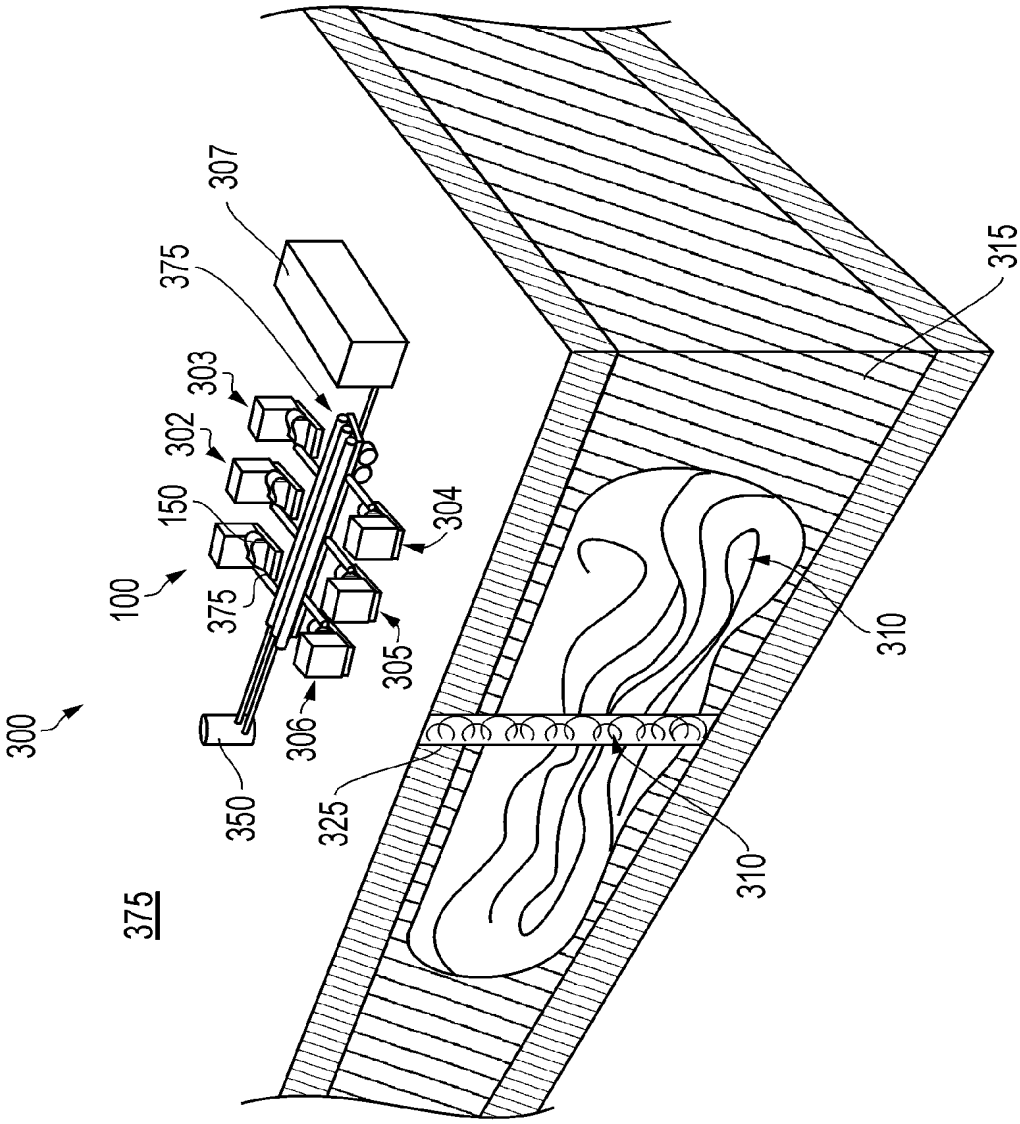


FIG. 3

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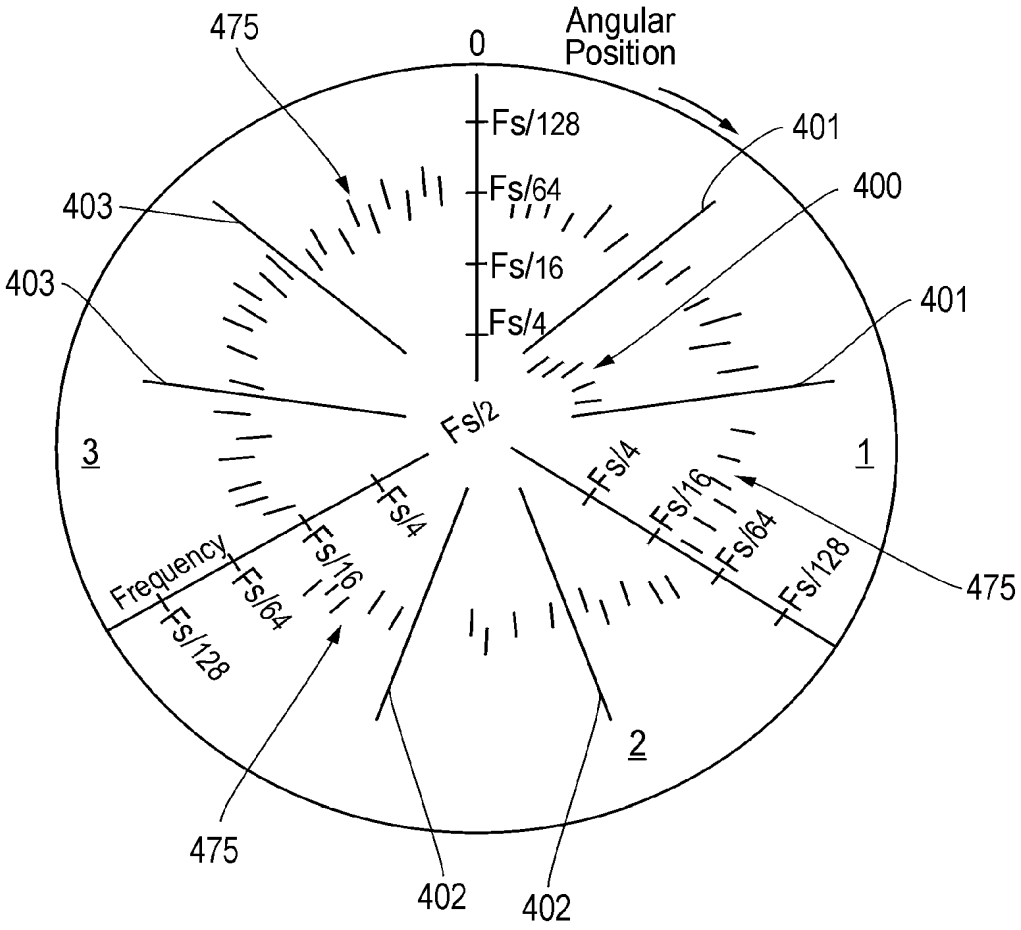

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Fs/4
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FIG. 4

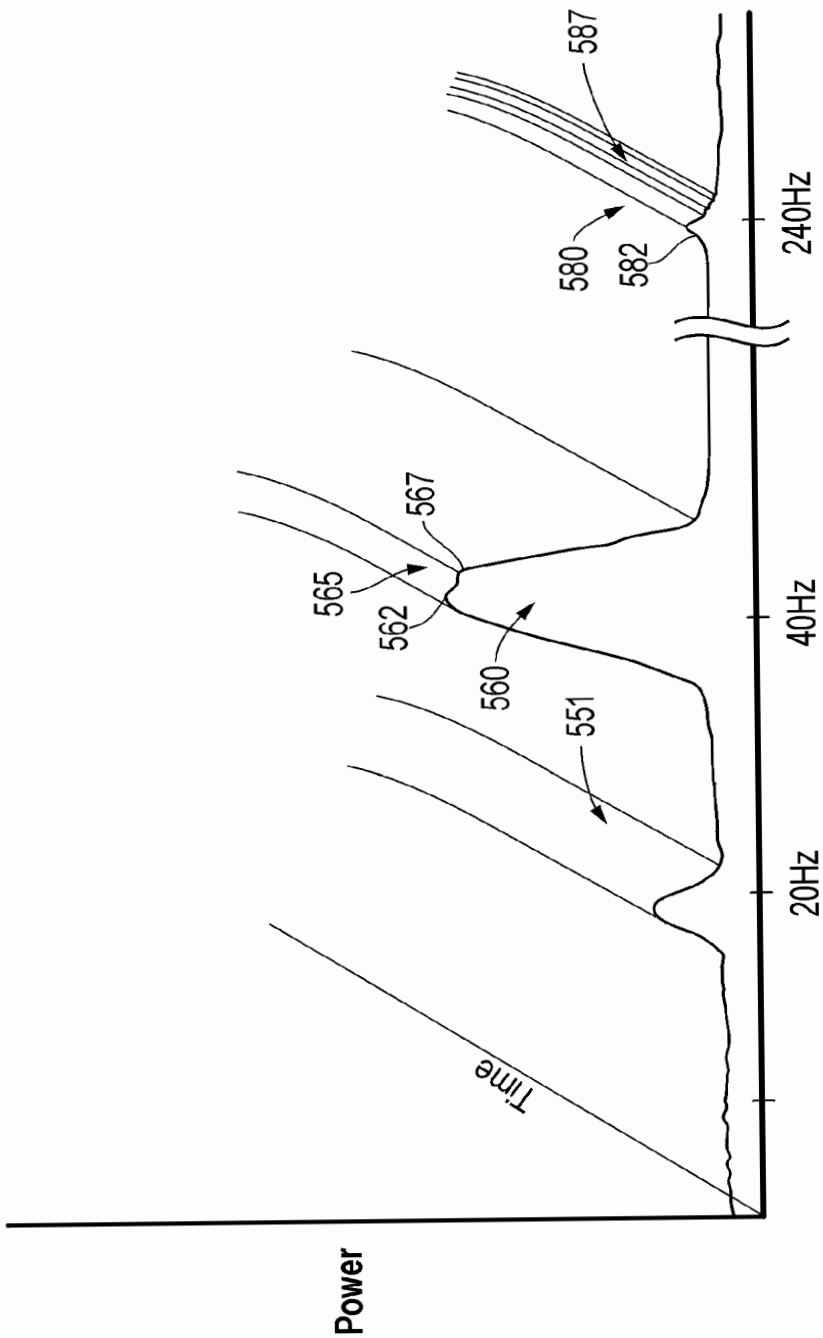


FIG. 5A

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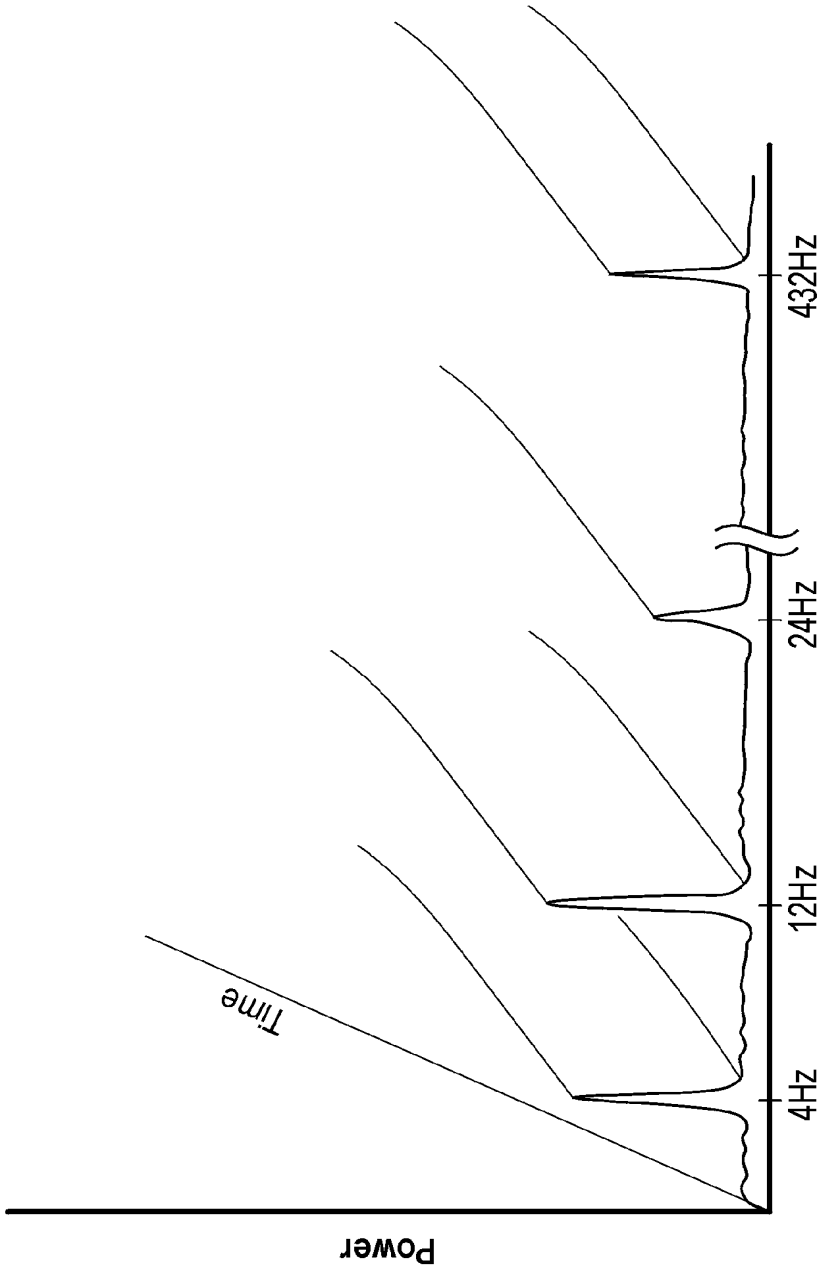


FIG. 5B

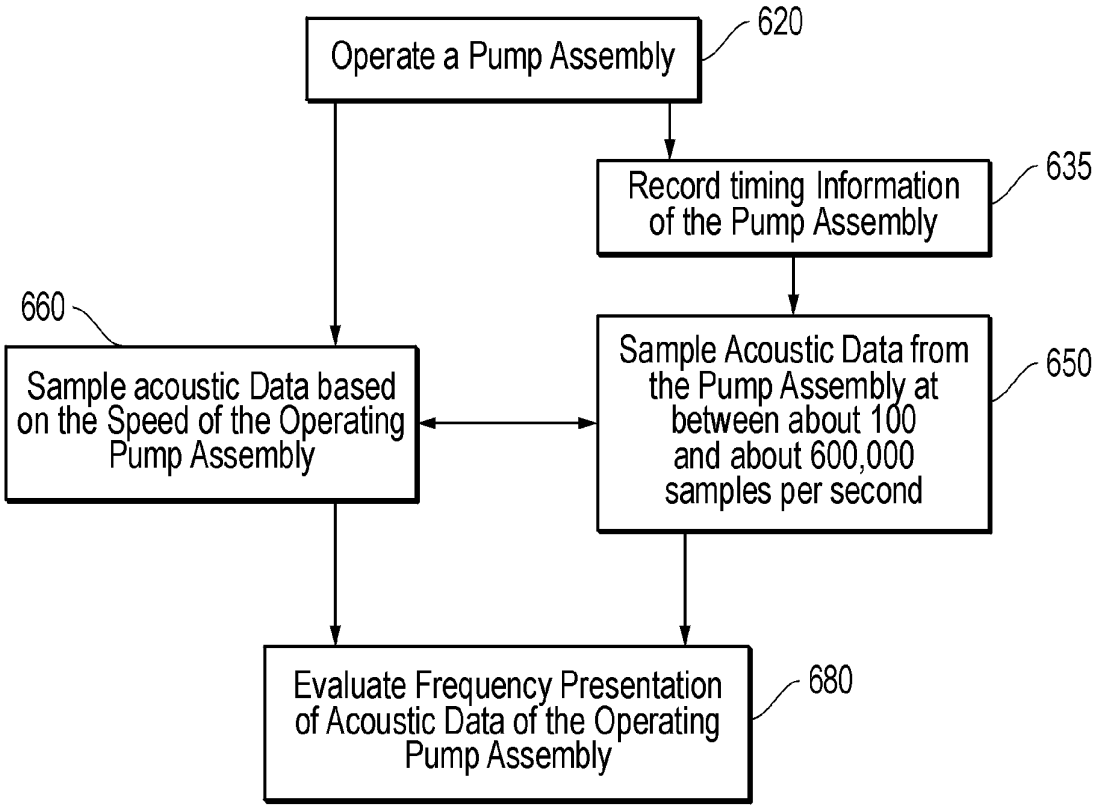

Operate a Pump Assembly
620
Record timing Information of the Pump Assembly
635
660
Sample acoustic Data based on the Speed of the Operating Pump Assembly
Sample Acoustic Data from the Pump Assembly at between about 100 and about 600,000 samples per second
650
Evaluate Frequency Presentation of Acoustic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

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
A	US 5 825 657 A (HERNANDEZ WALTER C [US]) 20 October 1998 (1998-10-20) the whole document	1-25

☐ 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 document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

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"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

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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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2007/054995

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 6351714	B1	26-02-2002	NONE		
US 2004230384	A1	18-11-2004	NONE		
US 5825657	A	20-10-1998	AT	262167 T	15-04-2004
			CA	2278701 A1	28-08-1997
			CN	1219234 A	09-06-1999
			DE	69631913 D1	22-04-2004
			DE	69631913 T2	10-03-2005
			EP	1021698 A1	26-07-2000
			JP	2000505196 T	25-04-2000
			WO	9731253 A1	28-08-1997

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(85) **21.10.2002**

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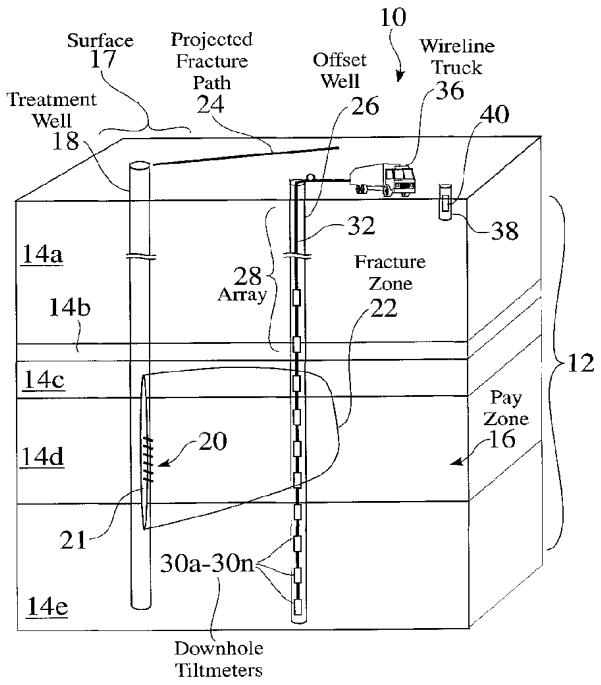
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SMITH, PAUL RAYMOND

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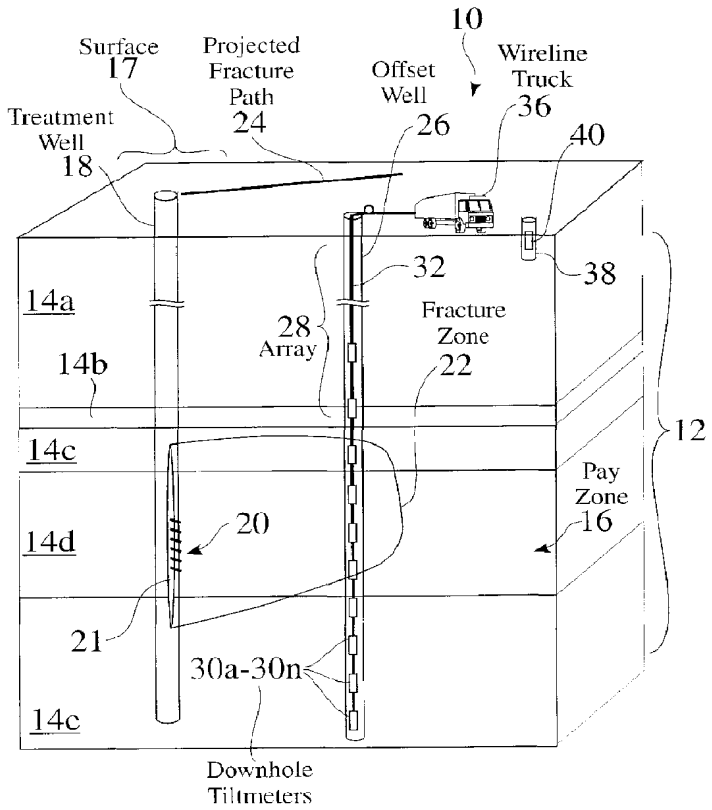
(51) Cl.Int.^{7}/Int.Cl.^{7} E21B 43/26, E21B 47/02, E21B 49/00

(71) Demandeur/Applicant:
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(74) Agent: SMITH, PAUL RAYMOND

(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.

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(71) Applicant *(for all designated States except US)*: **PINNACLE TECHNOLOGIES, INC.** [US/US]; 600 Townsend Street, Suite 160W, San Francisco, CA 94103 (US).

(72) Inventors; and

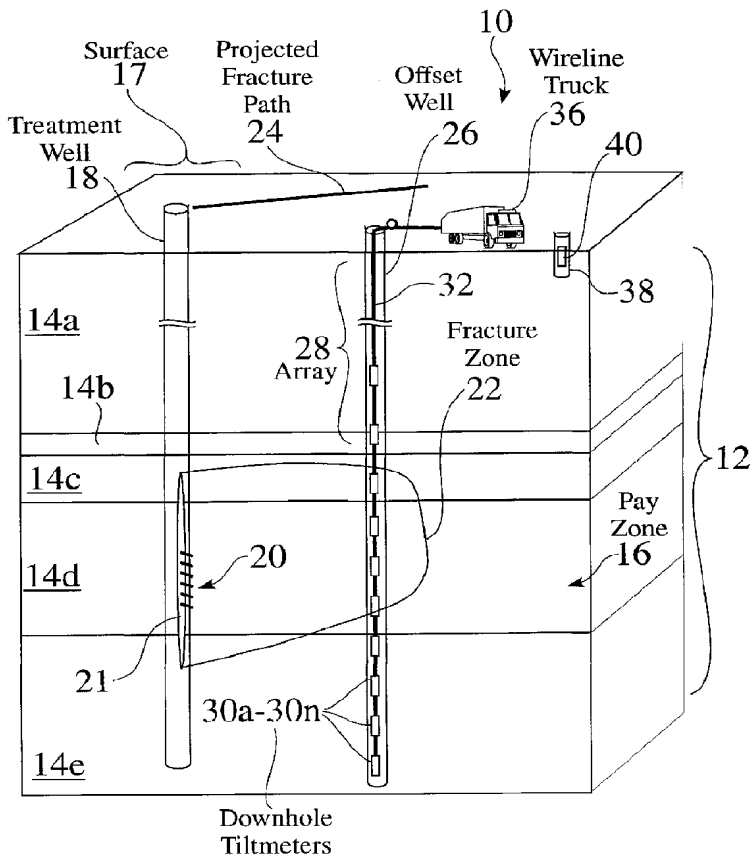
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(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK,

[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.

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Published:

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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

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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.

LIBERTY EXHIBIT 1002, Page 1007

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;

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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;

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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;

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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;

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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;

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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;

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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.

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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

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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

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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.

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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

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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.

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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

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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

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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.

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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.

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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.

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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

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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

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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

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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.

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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.

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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.

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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.

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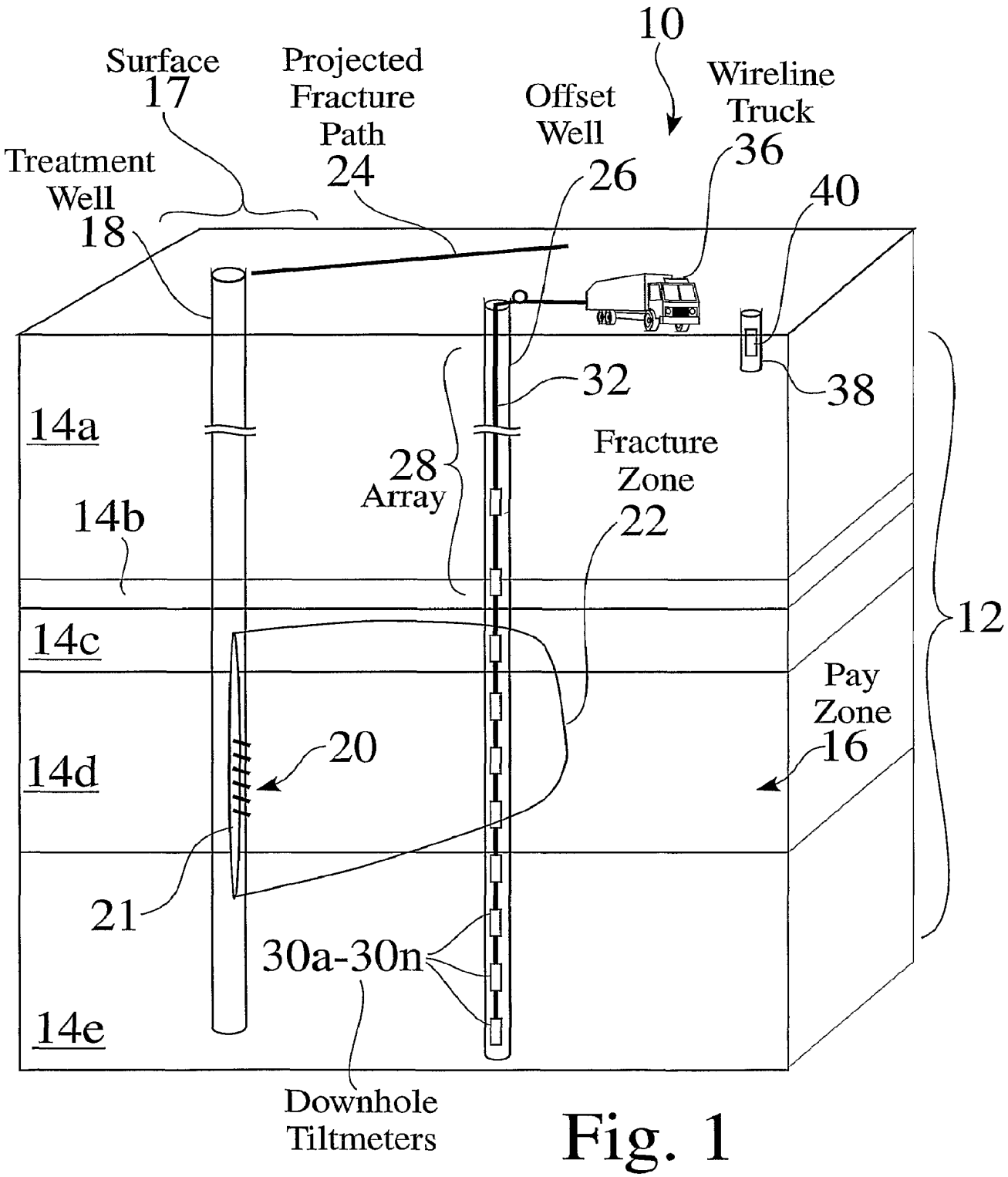

10
Surface
17
Projected
Fracture
Path
24
Offset
Well
26
Wireline
Truck
36
40
Treatment
Well
18
32
38
14a
28
Array
Fracture
Zone
22
14b
12
14c
Pay
Zone
16
20
14d
21
30a-30n
14e
Downhole
Tiltmeters

Fig. 1

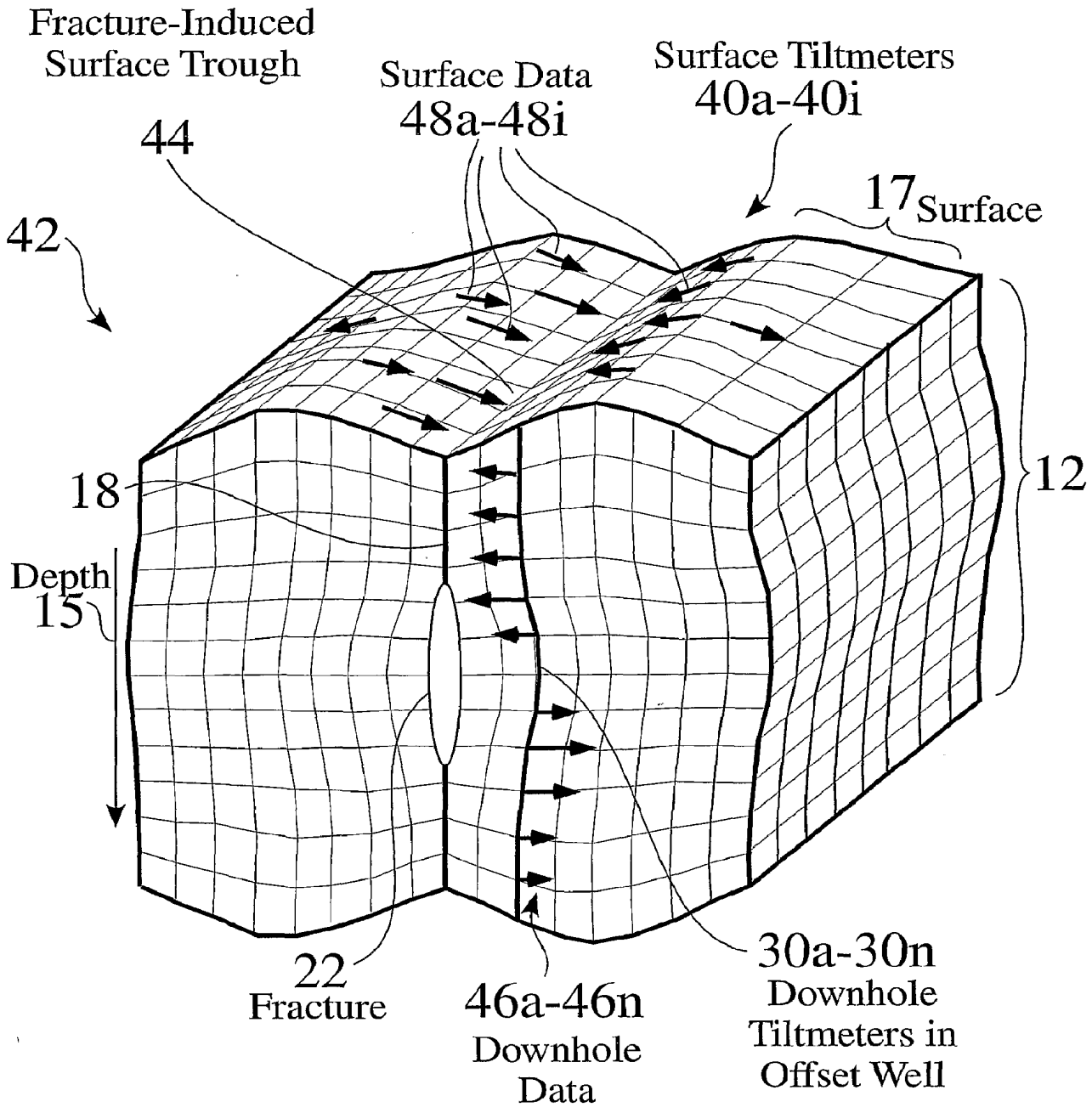

Fracture-Induced
Surface Trough
44
Surface Data
48a-48i
Surface Tiltmeters
40a-40i
17 Surface
42
18
12
Depth
15
22
Fracture
46a-46n
Downhole
Data
30a-30n
Downhole
Tiltmeters in
Offset Well

Fig. 2

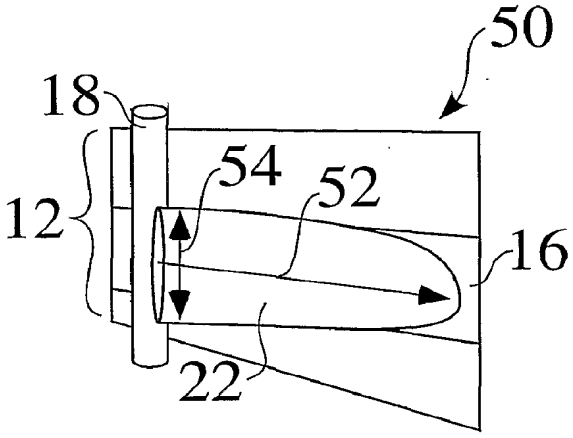


Fig. 3

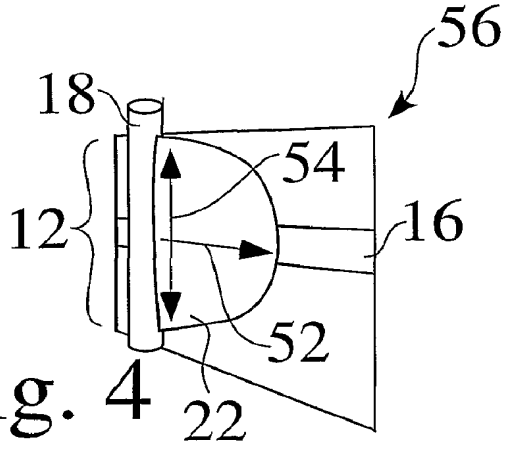


Fig. 4

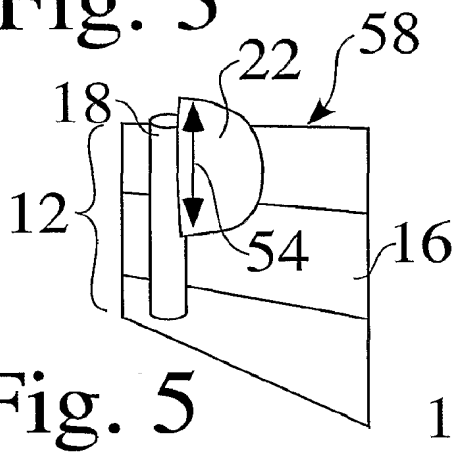


Fig. 5

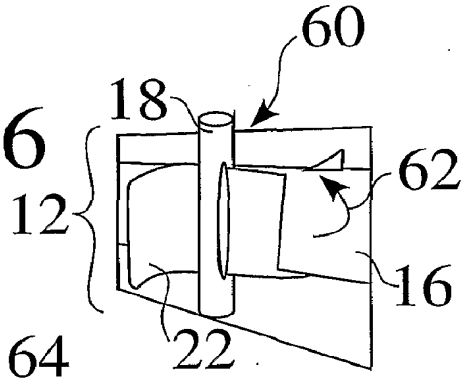


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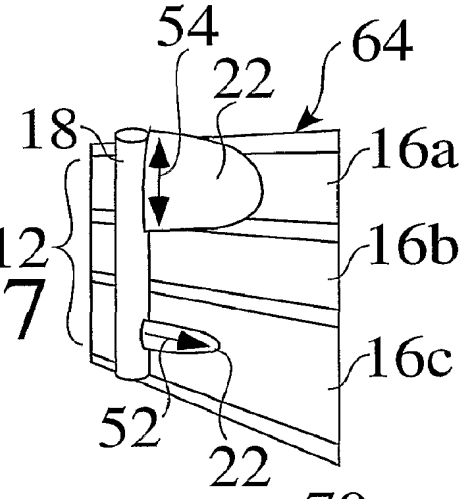
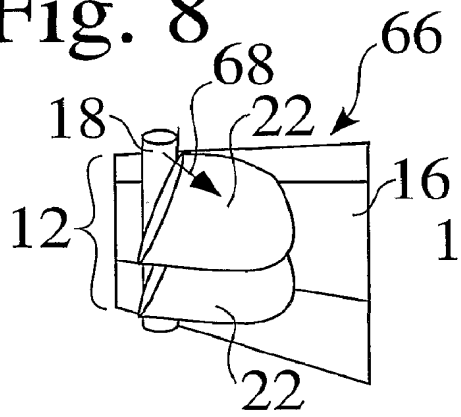


Fig. 7

Fig. 8



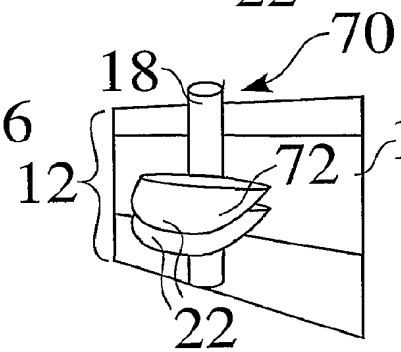


Fig. 9

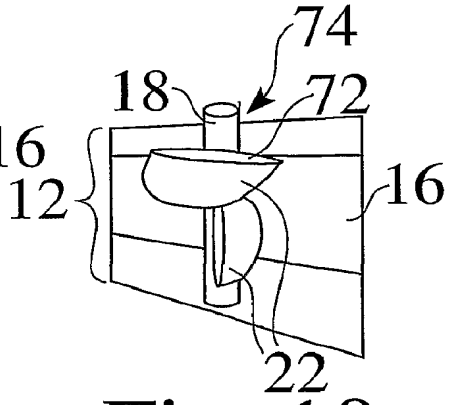


Fig. 10

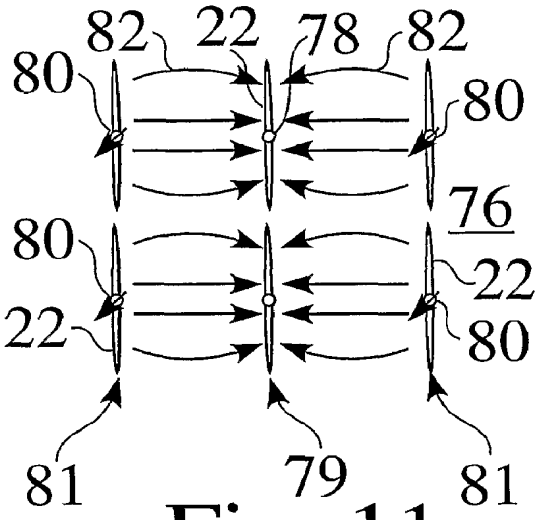


Fig. 11

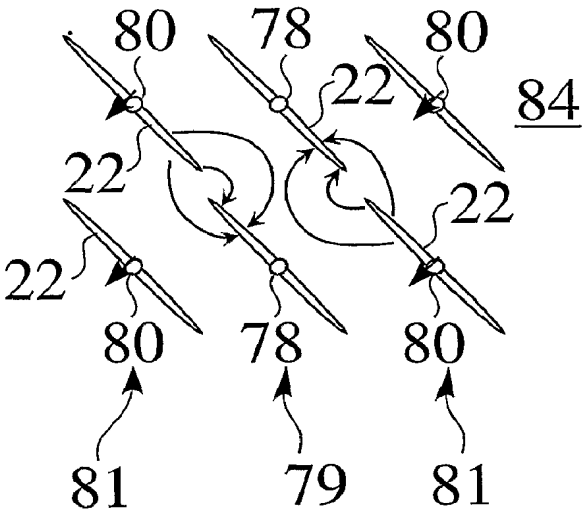


Fig. 12

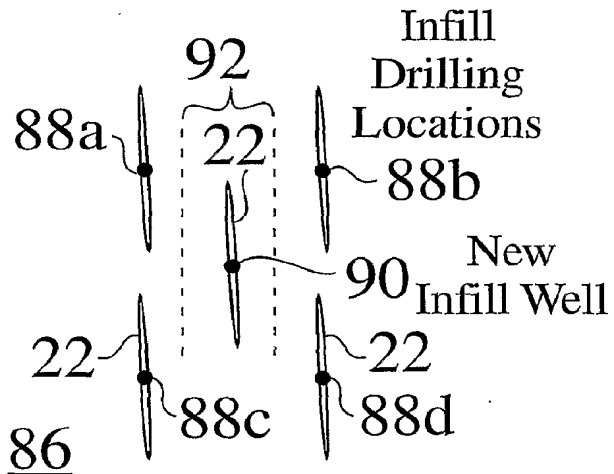


Fig. 13

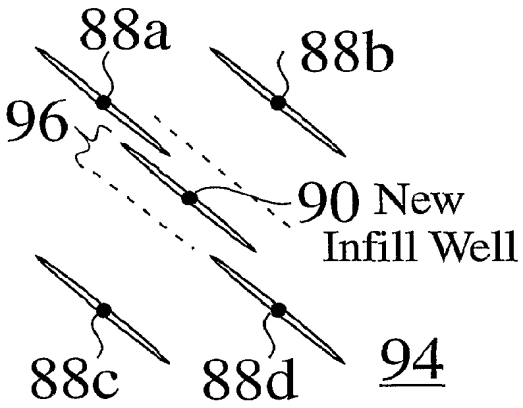


Fig. 14

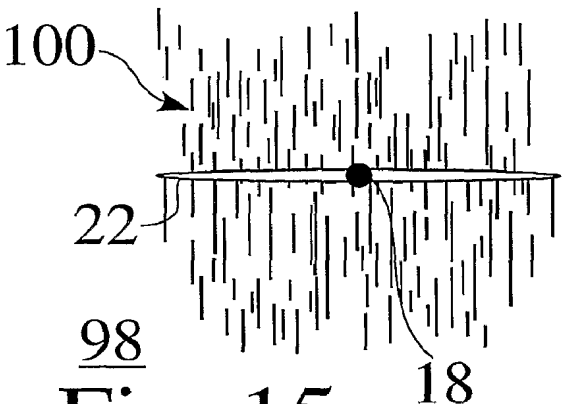


Fig. 15

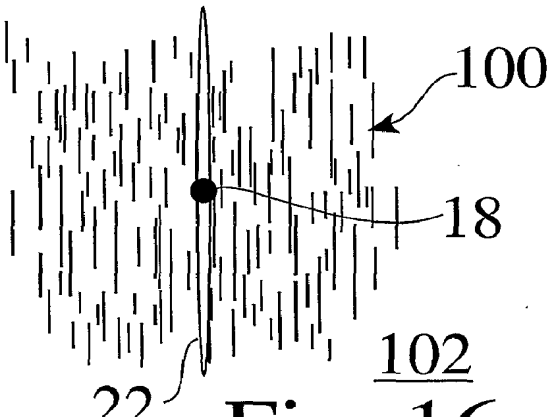


Fig. 16

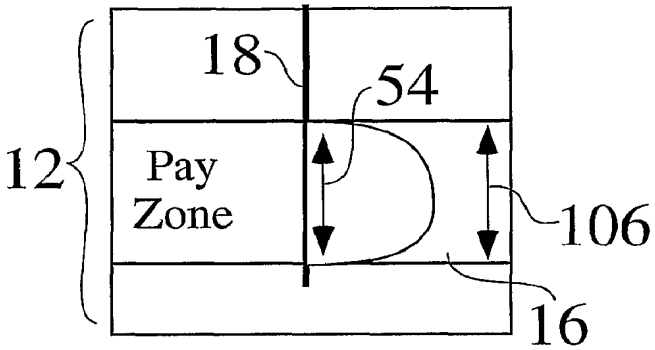
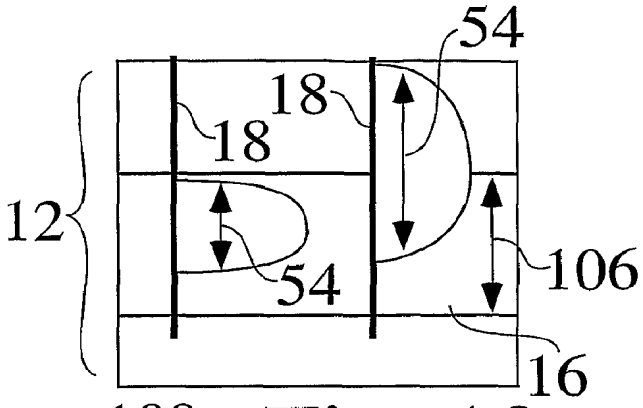


Fig. 17 104



108 Fig. 18

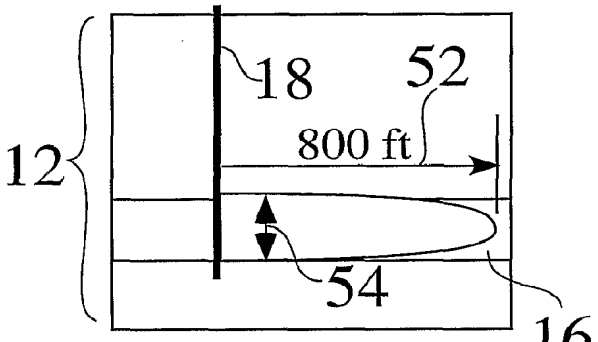
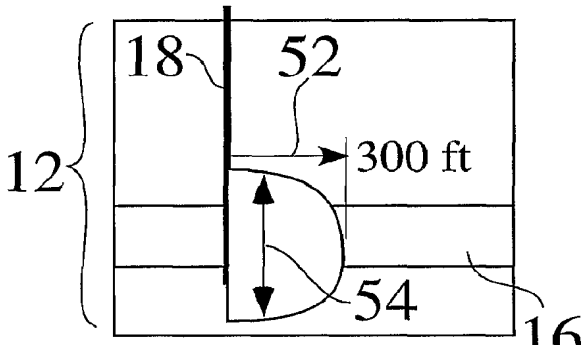


Fig. 19 110



112 Fig. 20

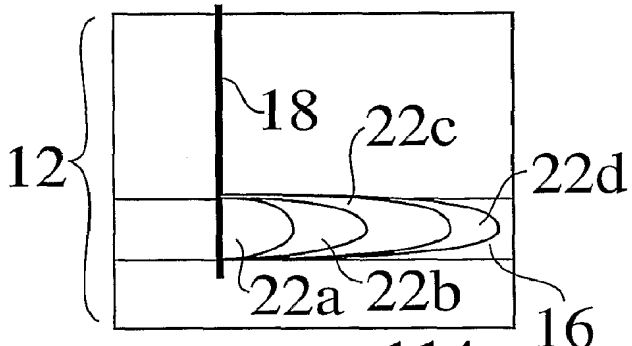
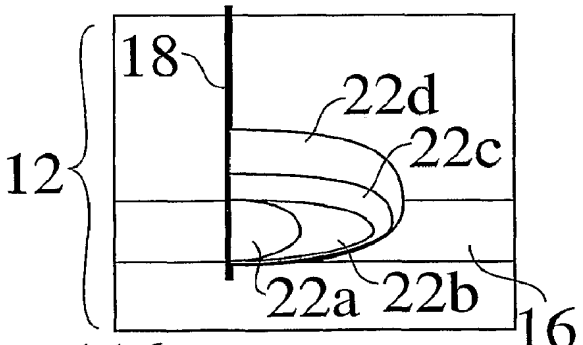


Fig. 21 114



116 Fig. 22

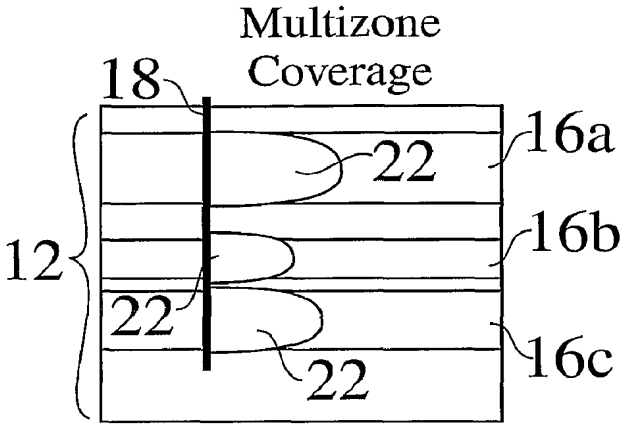
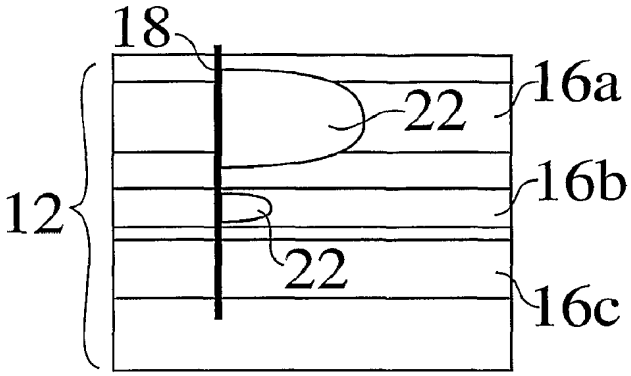


Fig. 23 118



120 Fig. 24

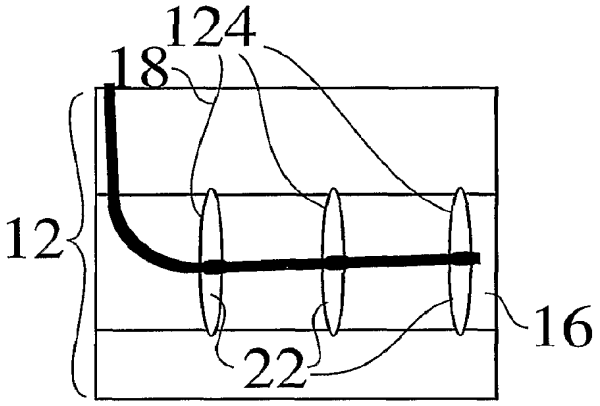
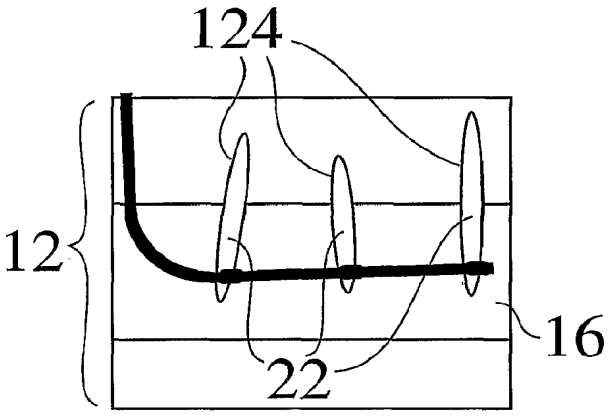


Fig. 25 122



126 Fig. 26

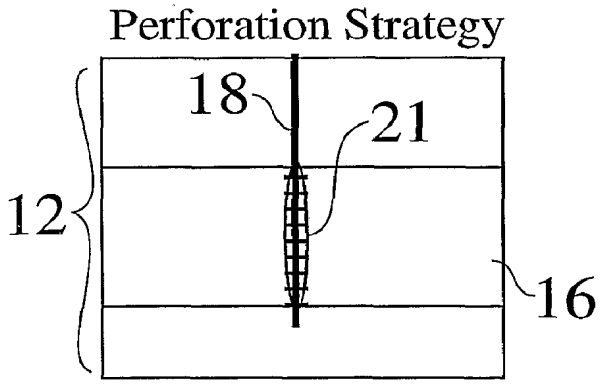
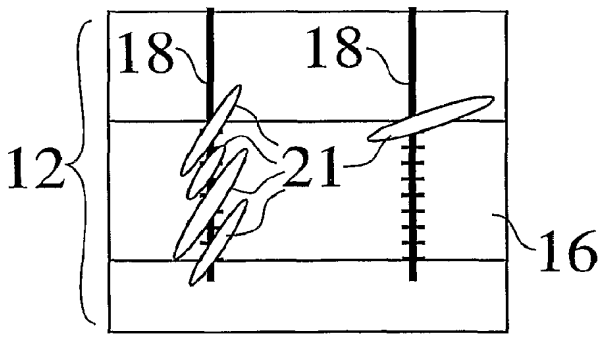


Fig. 27 128



130 Fig. 28

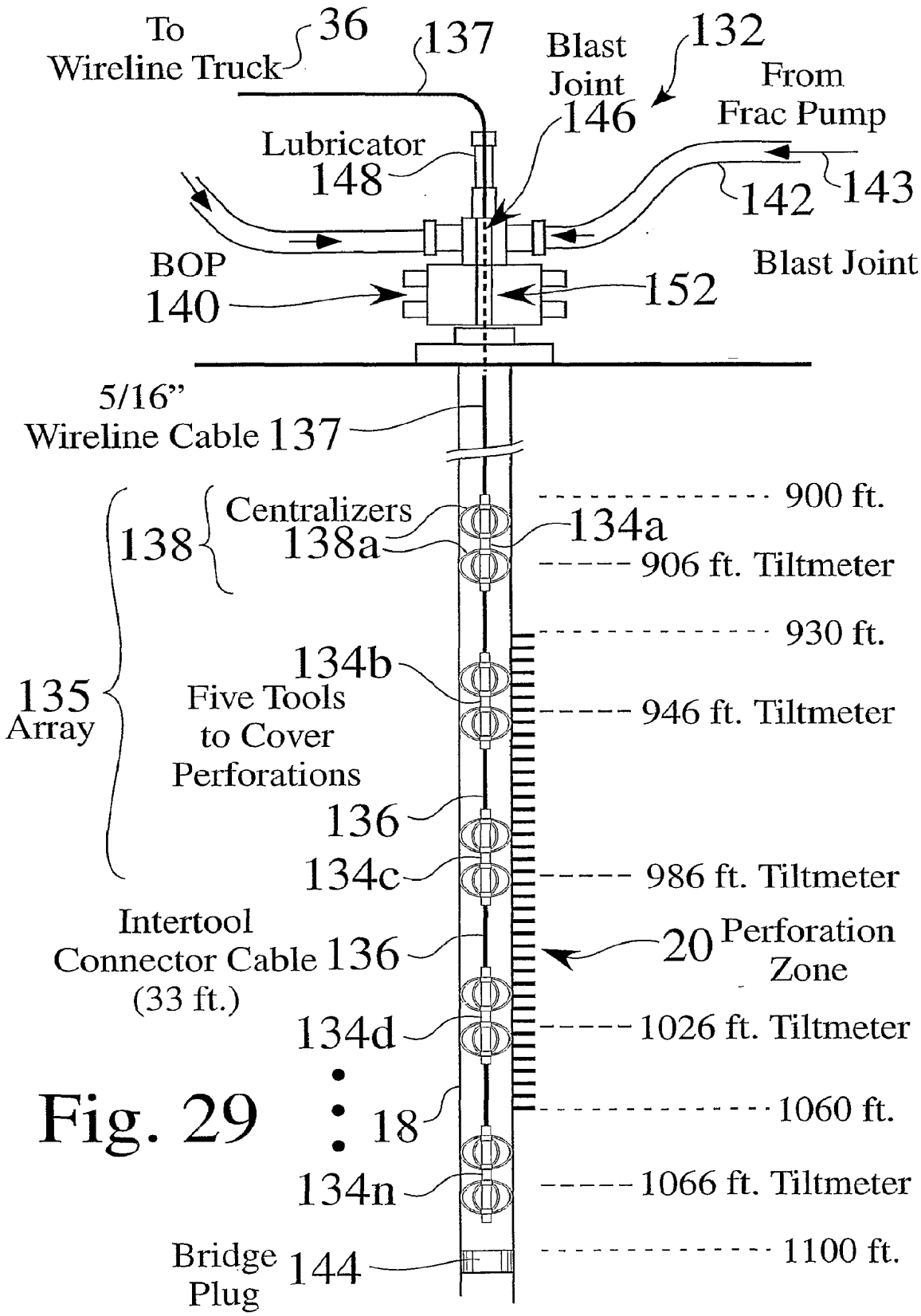

To Wireline Truck
36
137
Blast Joint
132
From Frac Pump
146
Lubricator
148
142
143
BOP
140
152
Blast Joint
5/16" Wireline Cable 137
138
Centralizers
138a
134a
900 ft.
906 ft. Tiltmeter
930 ft.
134b
135 Array
Five Tools to Cover Perforations
946 ft. Tiltmeter
136
134c
986 ft. Tiltmeter
Intertool Connector 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

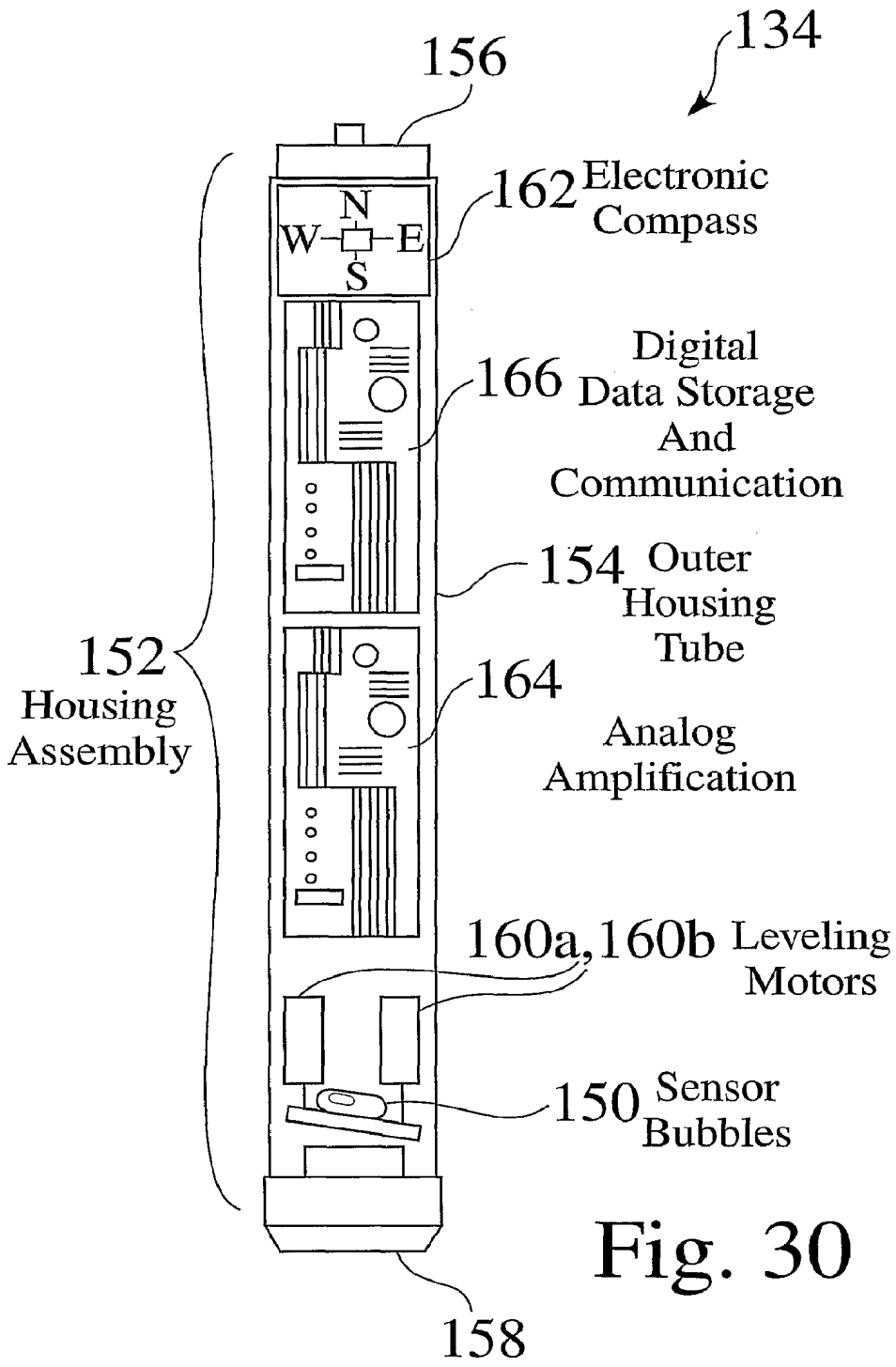

156
134
162 Electronic Compass
N
W
E
S
166 Digital Data Storage And Communication
154 Outer Housing Tube
152 Housing Assembly
164 Analog Amplification
160a, 160b Leveling Motors
150 Sensor Bubbles
158

Fig. 30

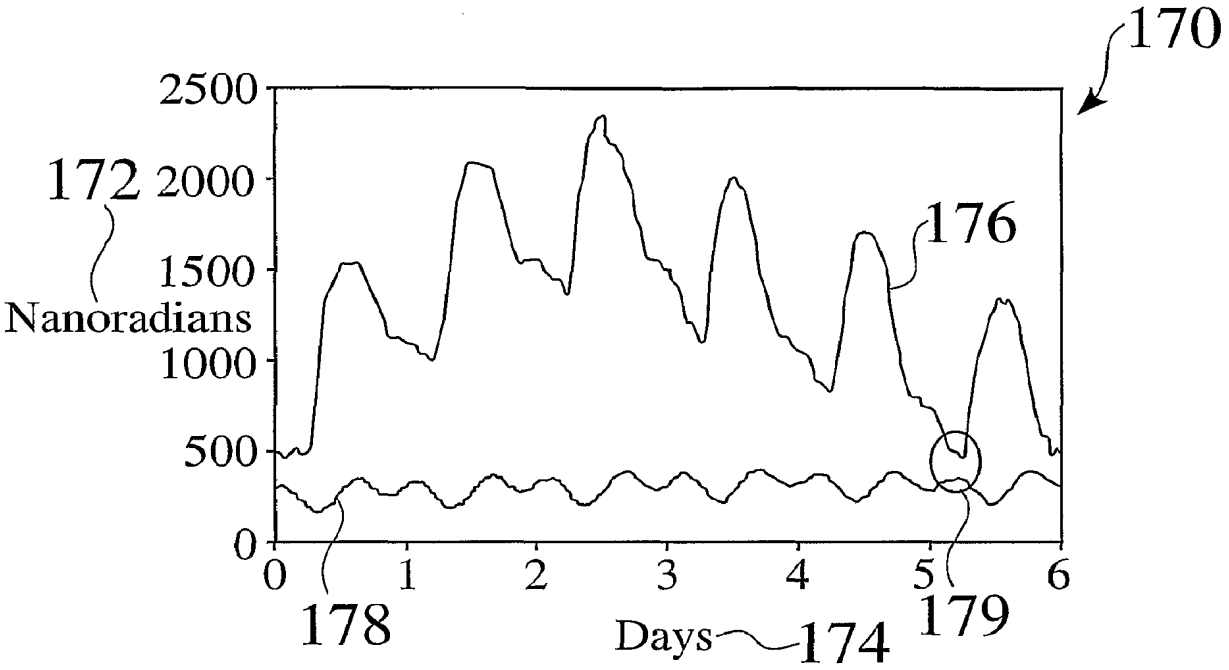

170
2500
172
2000
1500
Nanoradians
1000
500
0
176
0
1
2
3
4
5
6
178
179
Days
174

Fig. 31

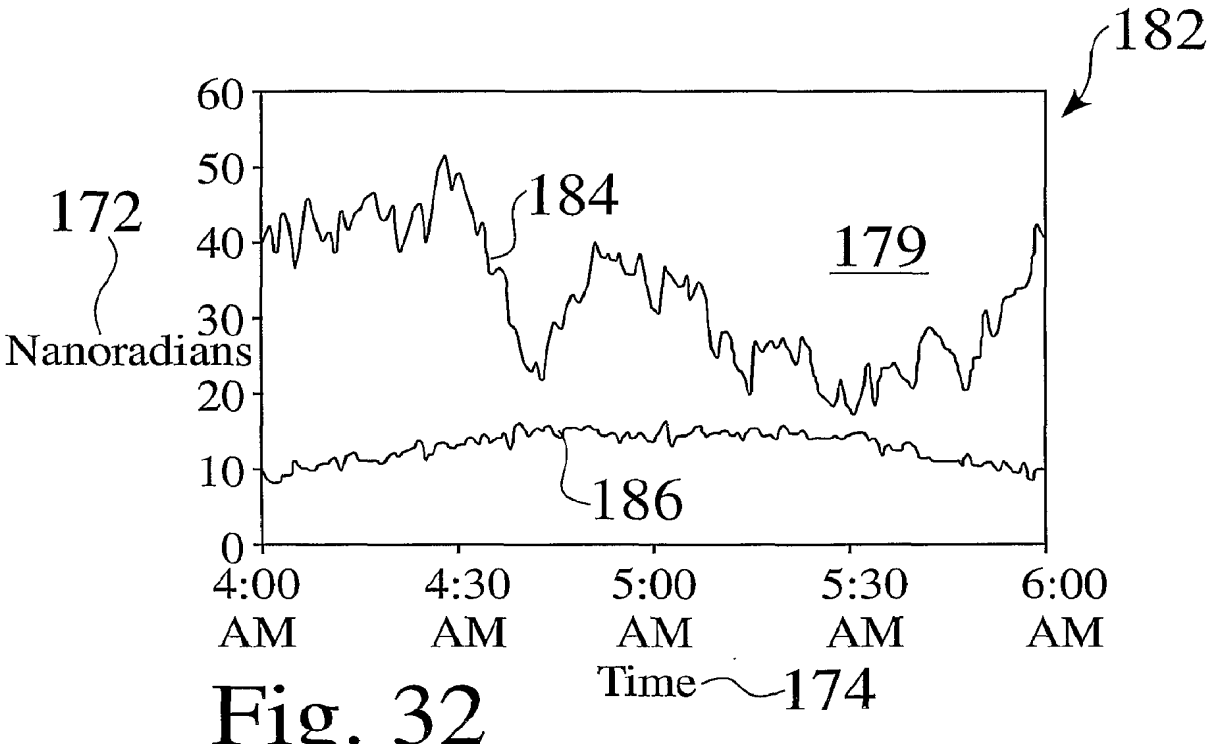

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172
184
40
179
30
Nanoradians
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10
186
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4:30 AM
5:00 AM
5:30 AM
6:00 AM
Time
174

Fig. 32

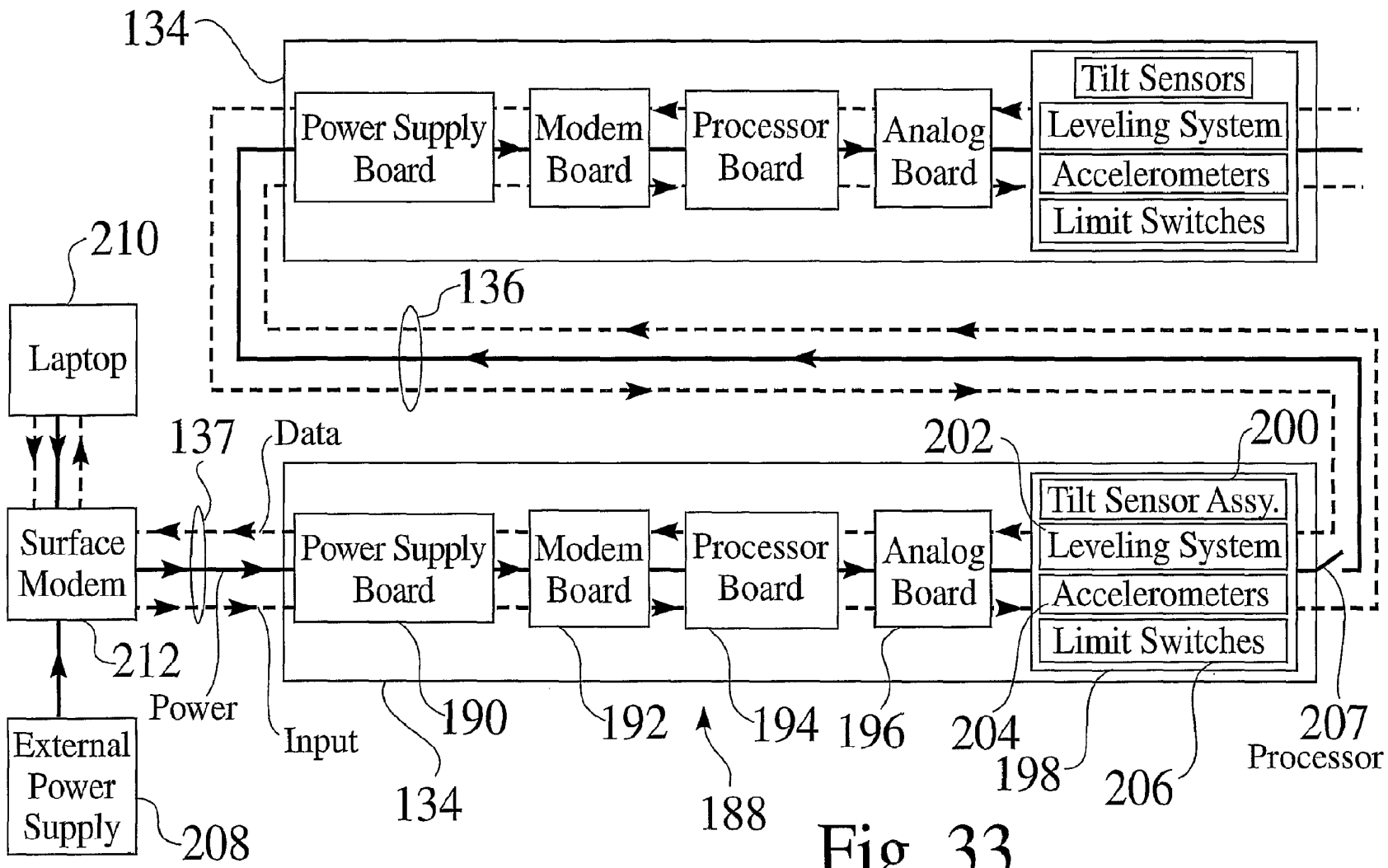

134
Power Supply Board
Modem Board
Processor Board
Analog Board
Tilt Sensors
Leveling System
Accelerometers
Limit Switches
210
136
Laptop
137
Data
202
200
Surface Modem
Power Supply Board
Modem Board
Processor Board
Analog Board
Tilt Sensor Assy.
Leveling System
Accelerometers
Limit Switches
212
Power
Input
190
192
194
196
204
198
206
207
Processor
External Power Supply
208
134
188

Fig. 33

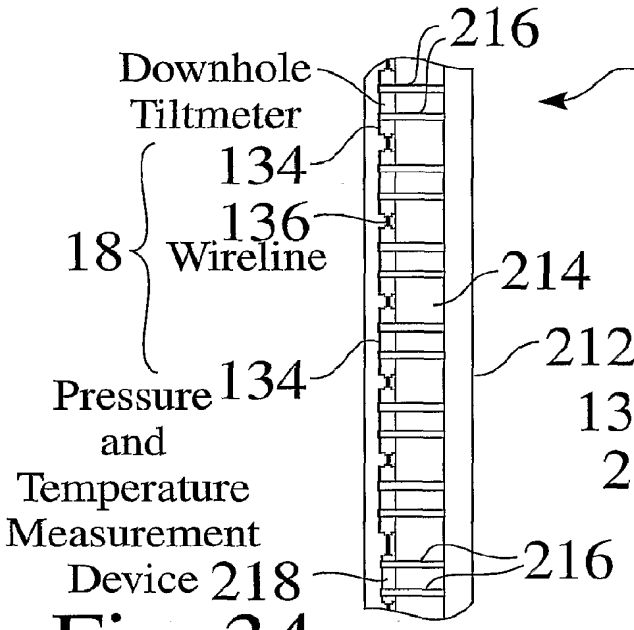


Fig. 34

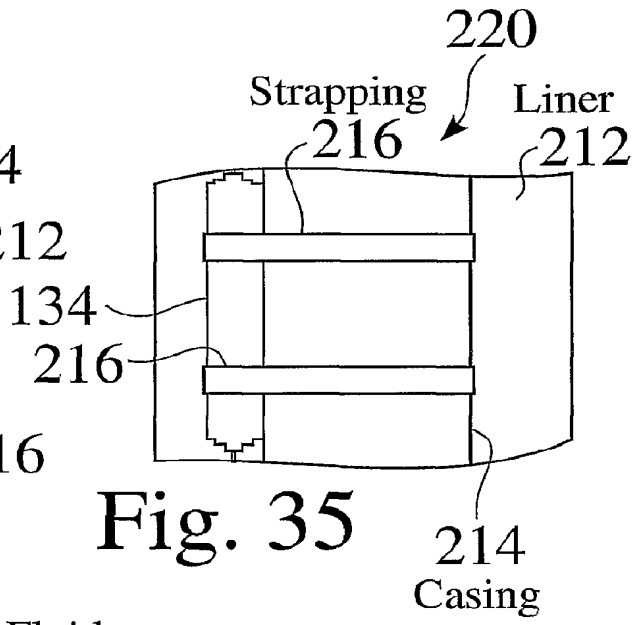


Fig. 35

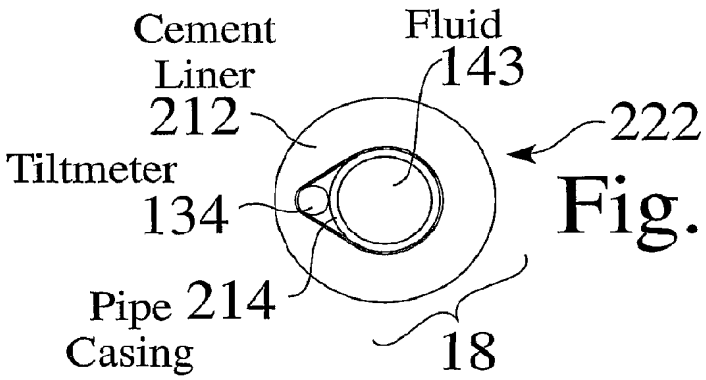


Fig. 36

Fig. 37

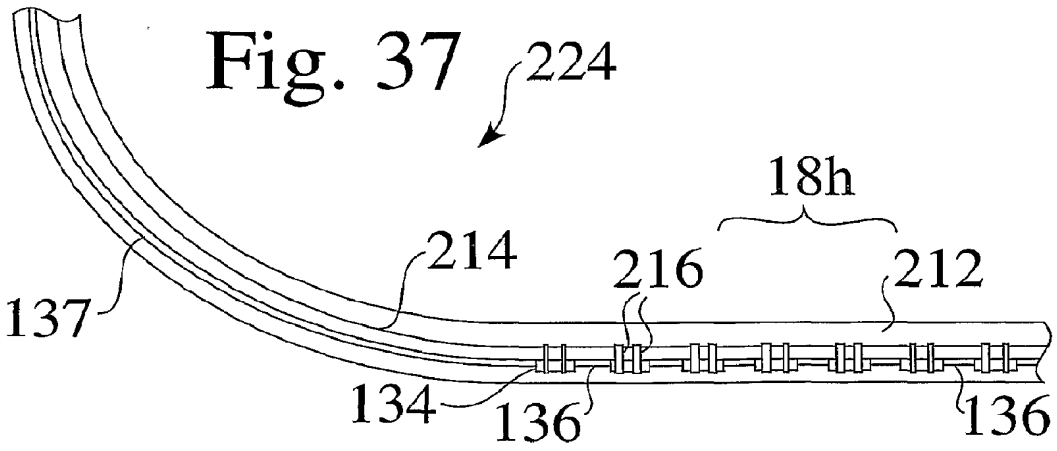
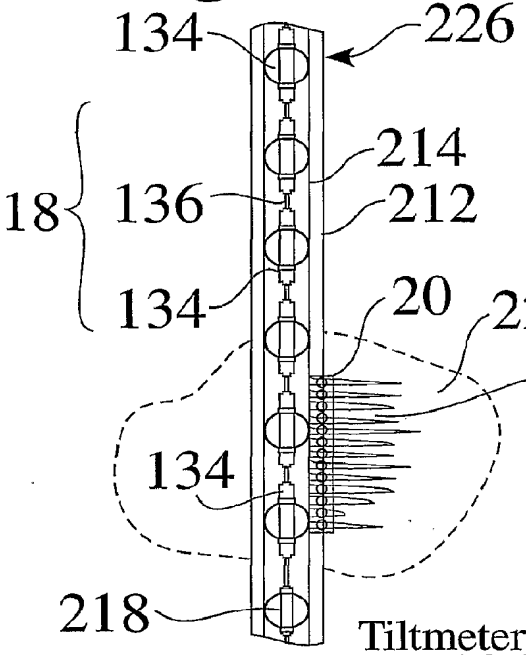


Fig. 38



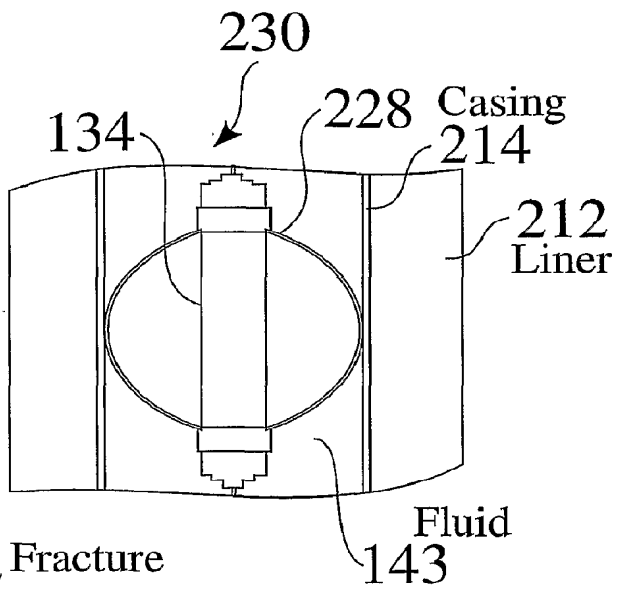


Fig. 39

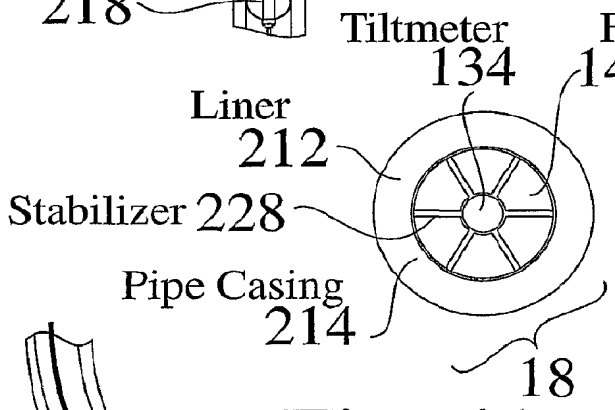
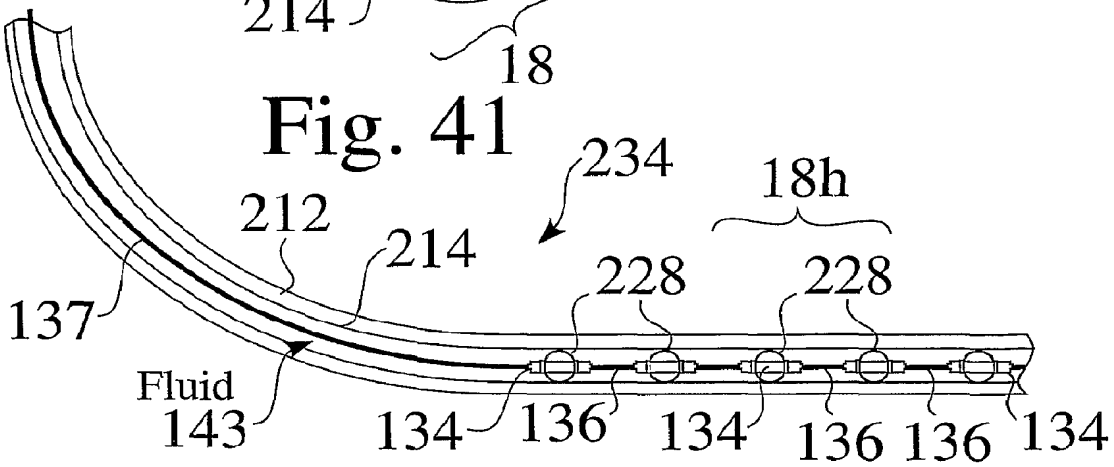


Fig. 40

Fig. 41



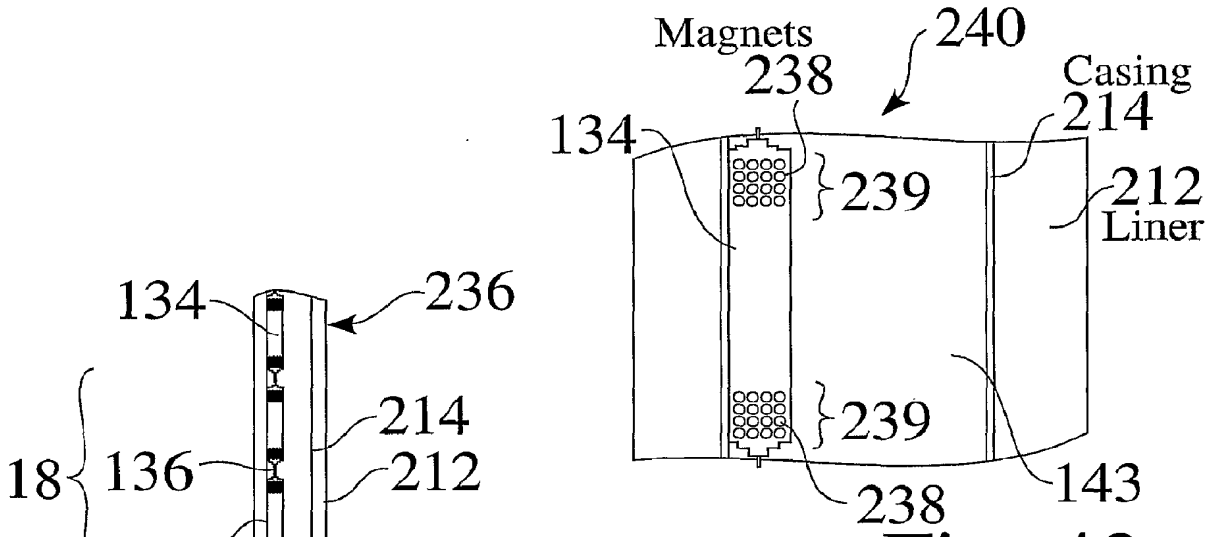


Fig. 43

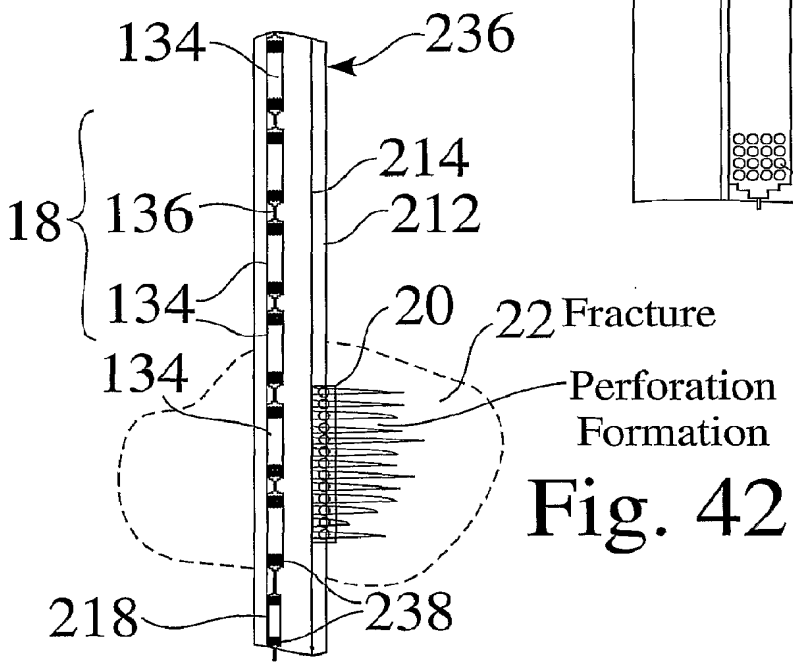


Fig. 42

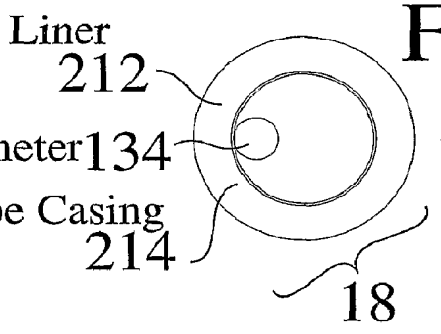


Fig. 44

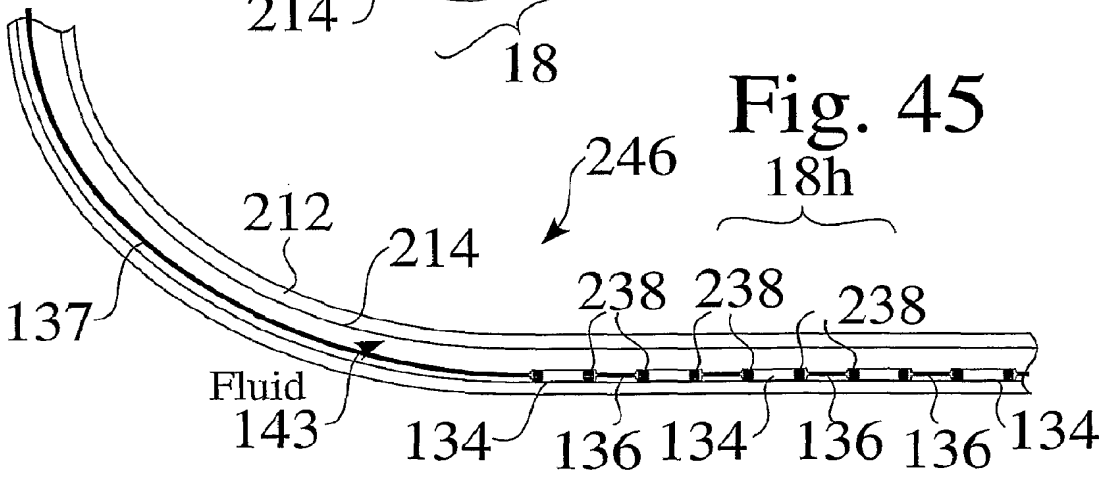


Fig. 45

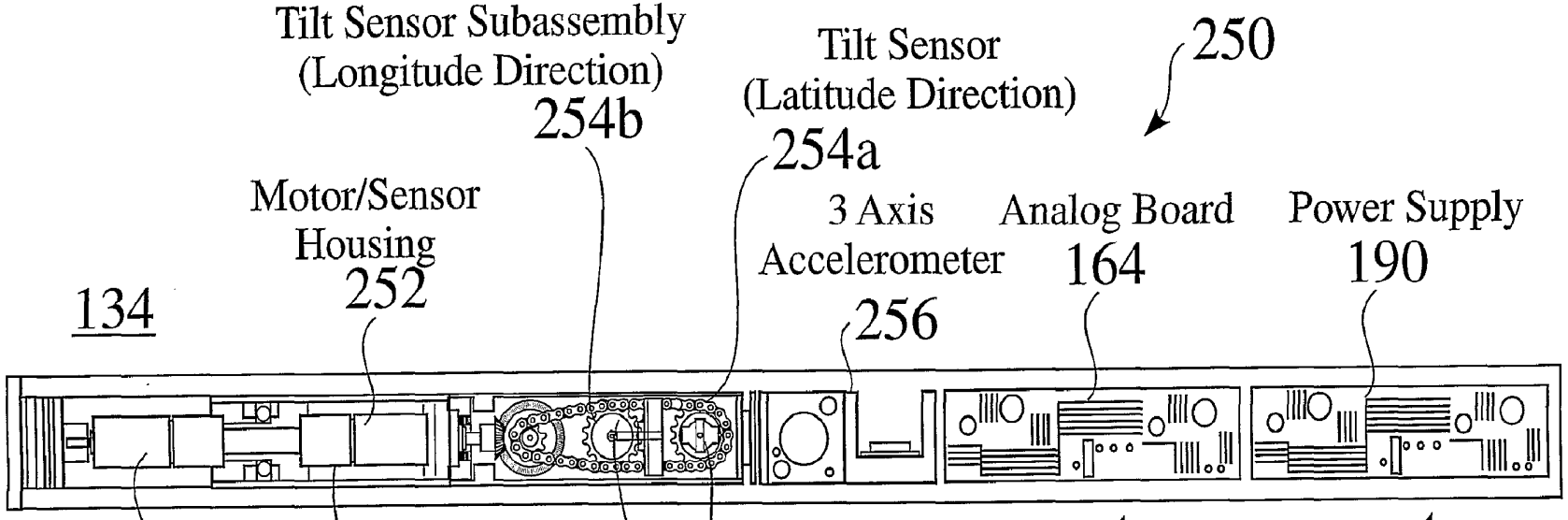

Tilt Sensor Subassembly
(Longitude Direction)
254b
Tilt Sensor
(Latitude Direction)
250
254a
Motor/Sensor
Housing
252
3 Axis
Accelerometer
256
Analog Board
164
Power Supply
190
134
160a
Latitude
Leveling
Motor
160b
Longitude
Leveling
Motor
150b
Sensor "Y"
150a
Sensor "X"
194
Processor Board
(Back)
192
Modem Board
(Back)

Fig. 46

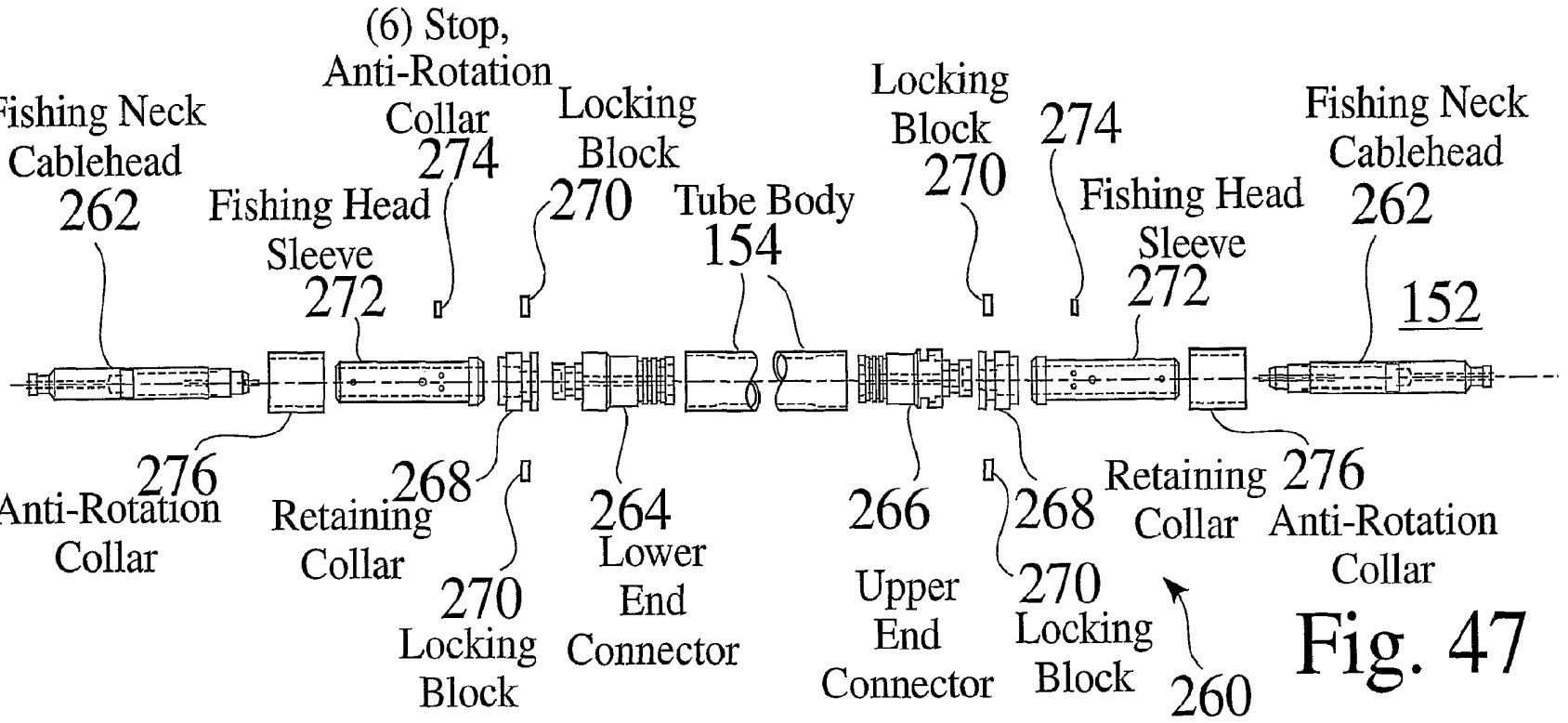


Fig. 47

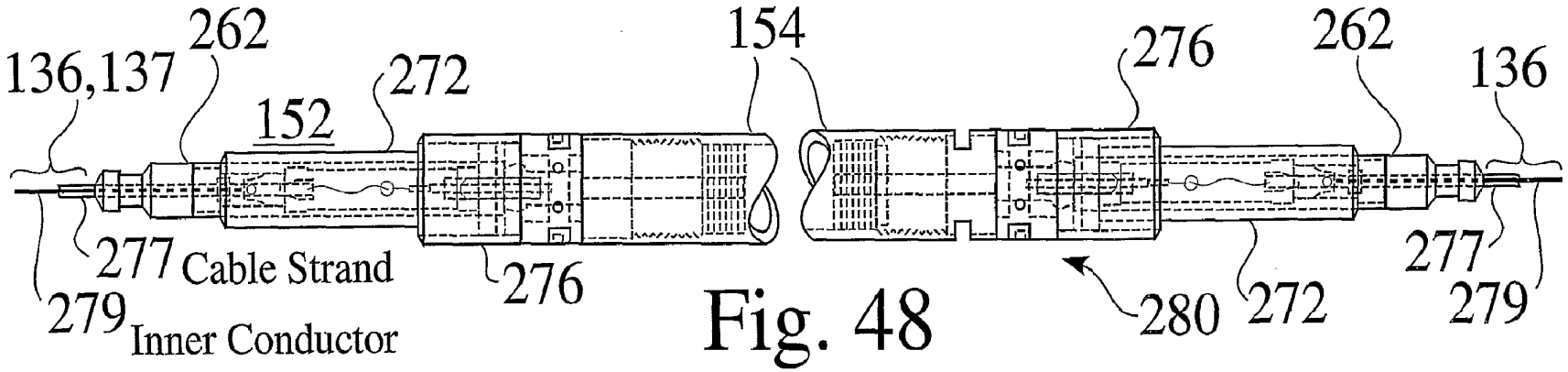


Fig. 48

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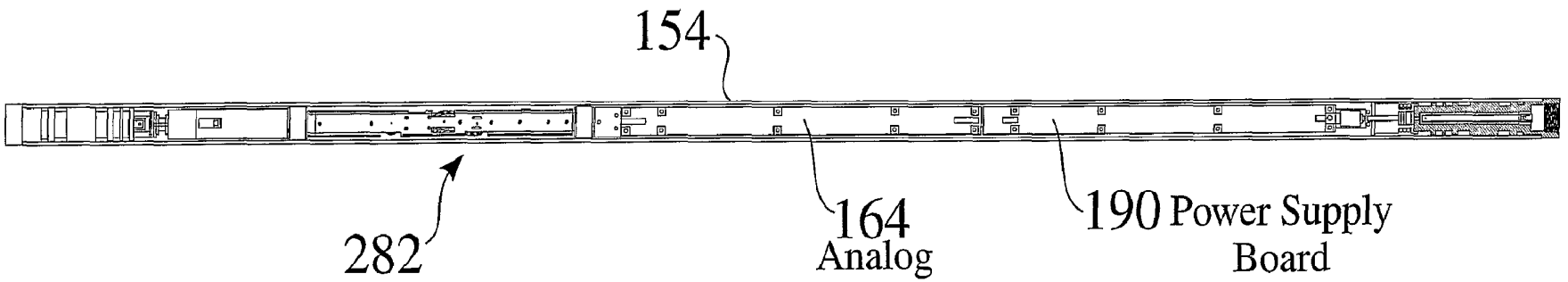

154
282
164
Analog
Board
190 Power Supply
Board

Fig. 49

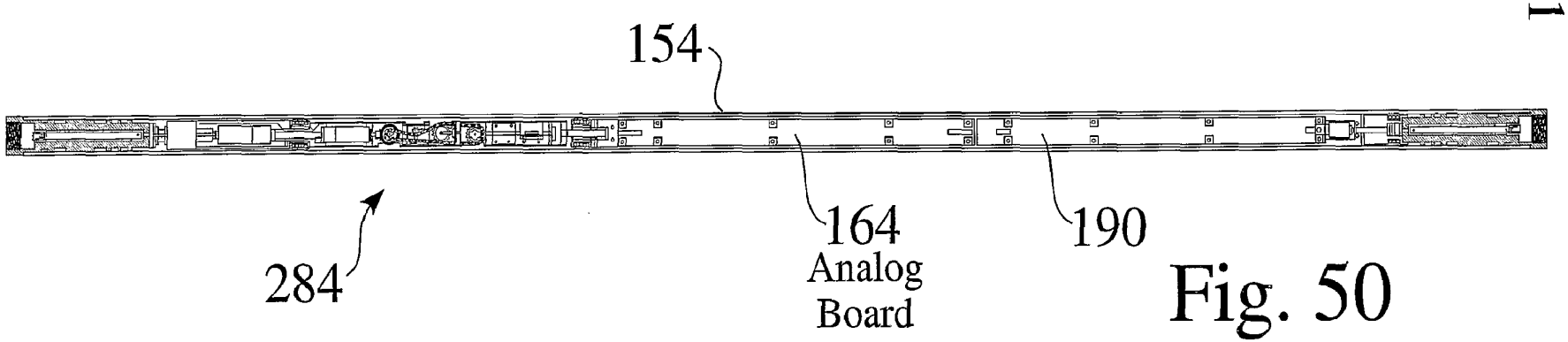

154
284
164
Analog
Board
190

Fig. 50

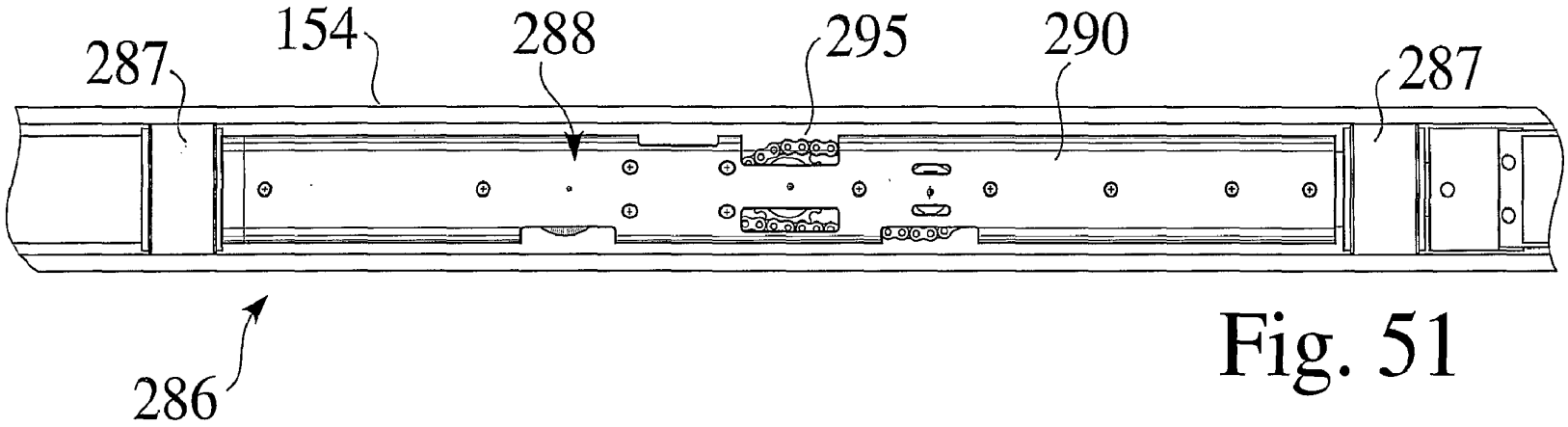

287
154
288
295
290
287
286

Fig. 51

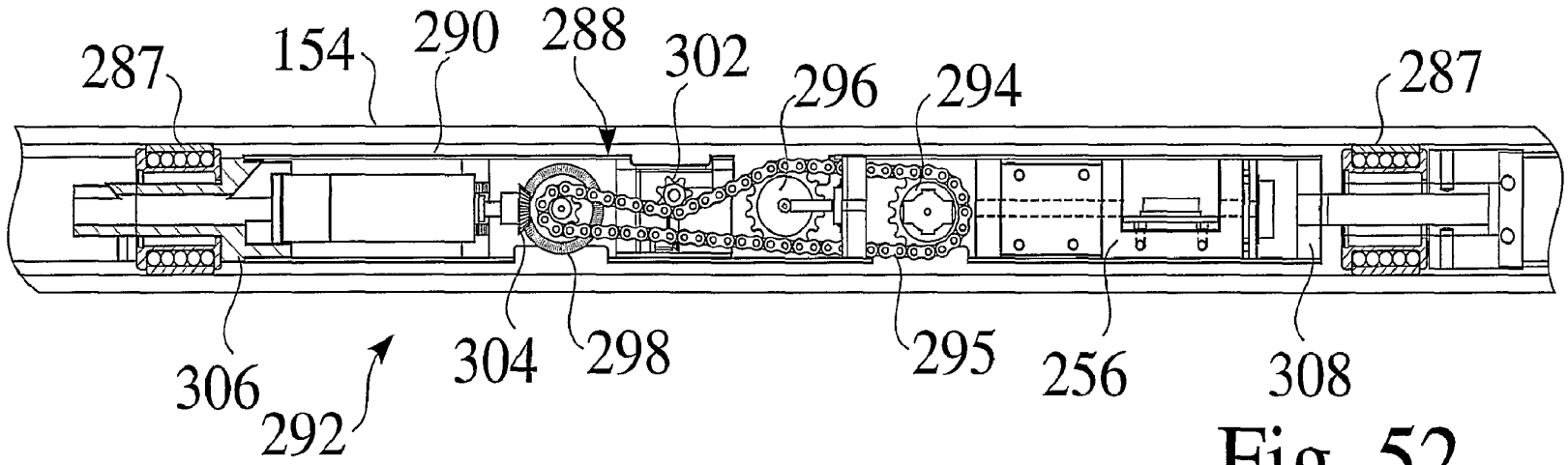

287
154
290
288
302
296
294
287
306
292
304
298
295
256
308

Fig. 52

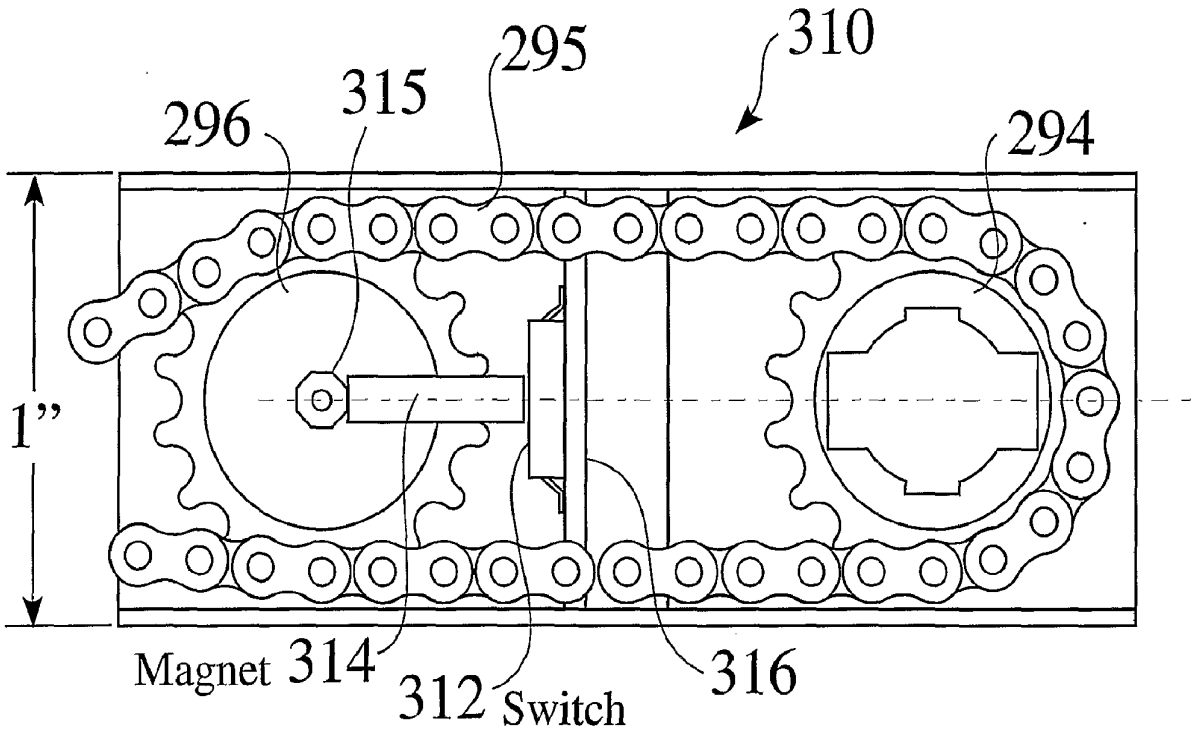


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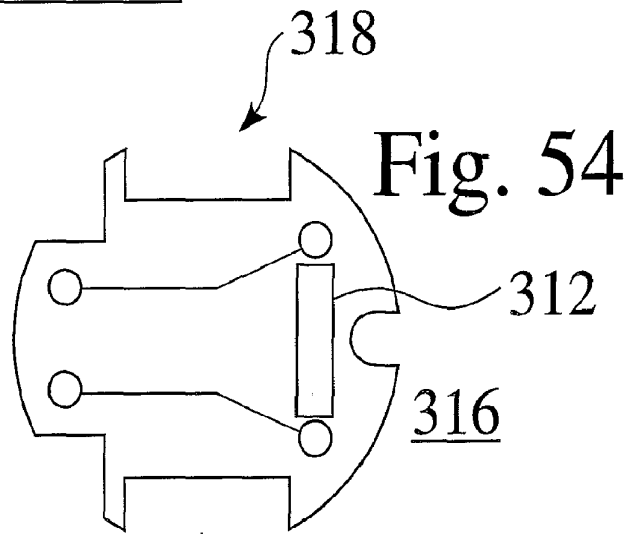
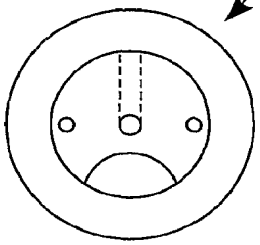


Fig. 54

Fig. 56



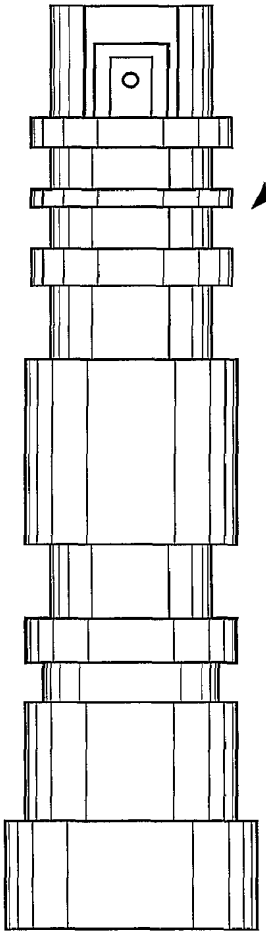


Fig. 55

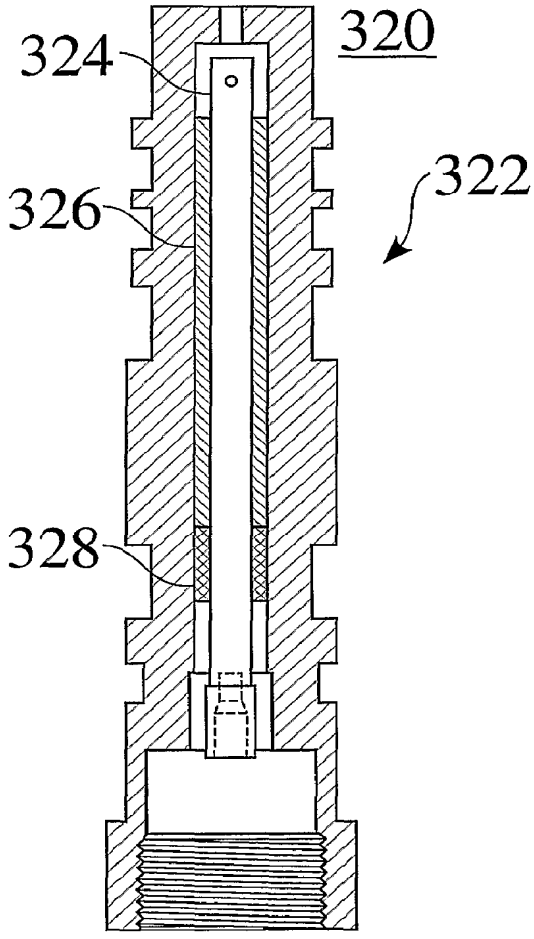


Fig. 57

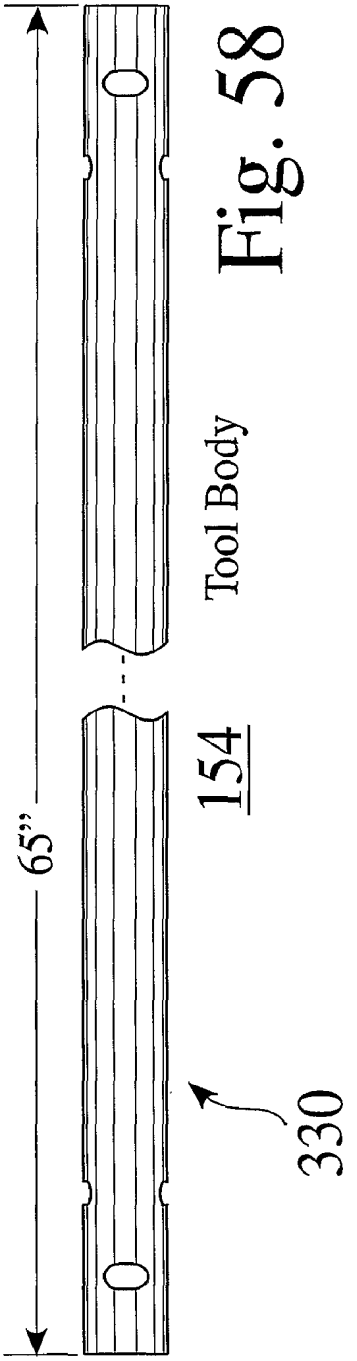


Fig. 58

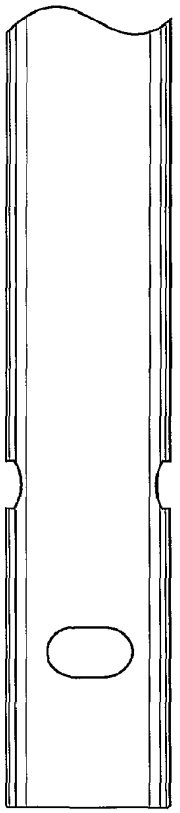


Fig. 59

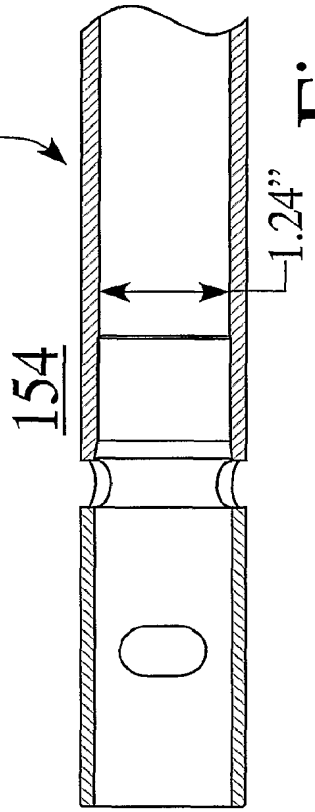


Fig. 60

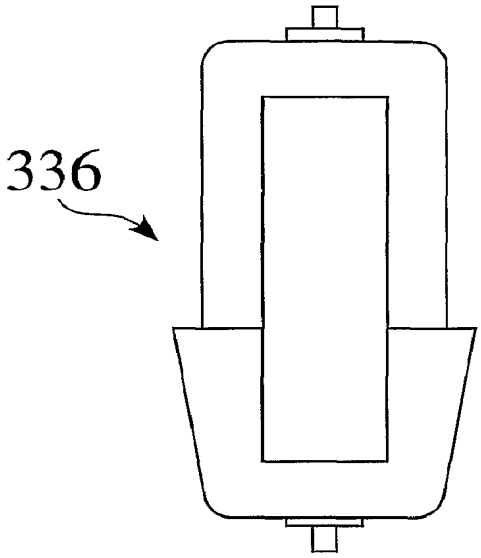


Fig. 61

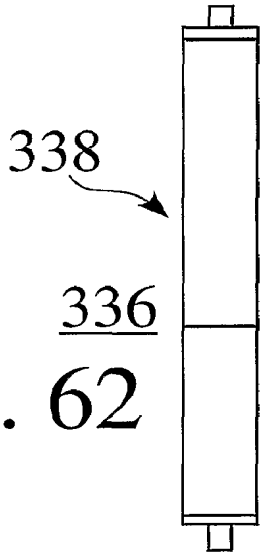


Fig. 62

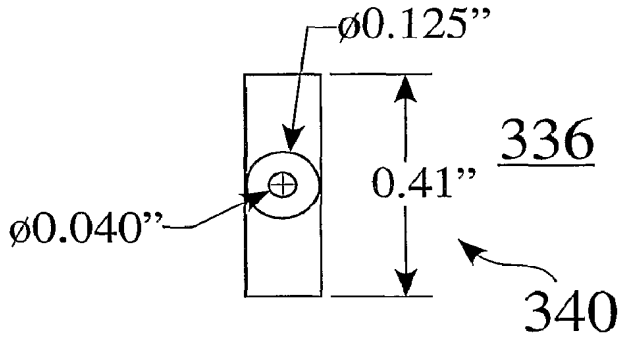


Fig. 63

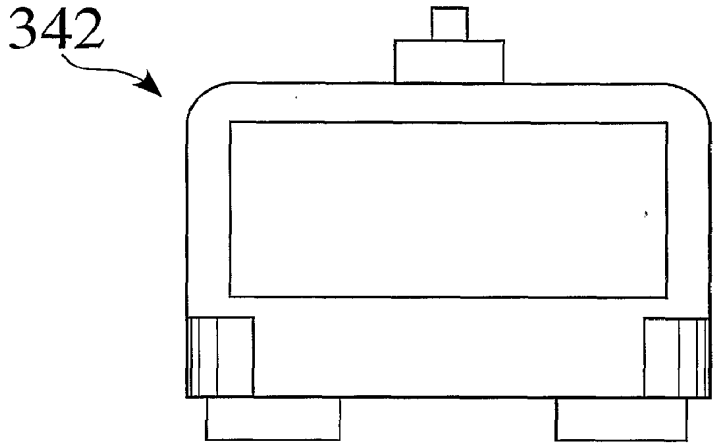


Fig. 64

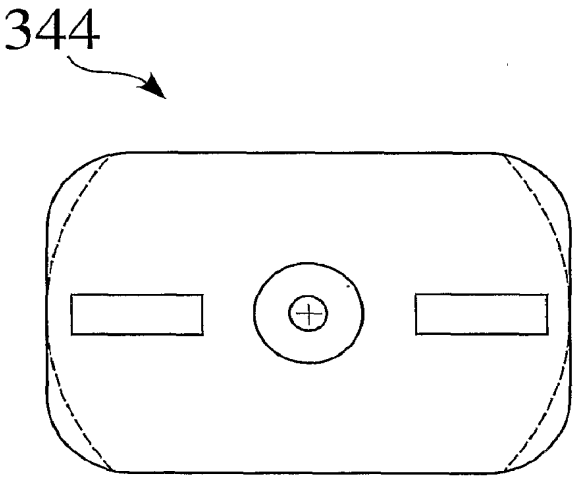


Fig. 65

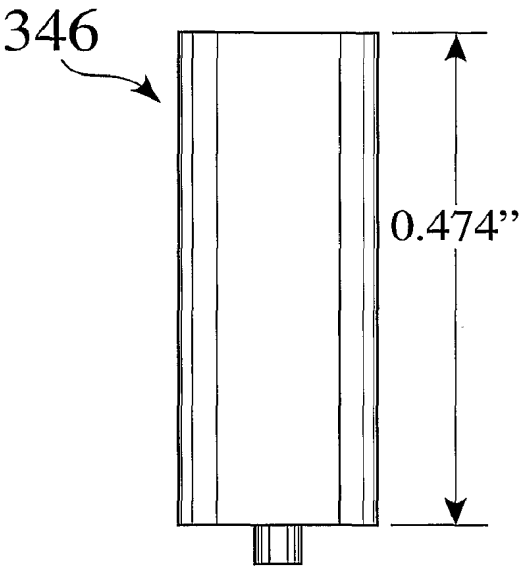


Fig. 66

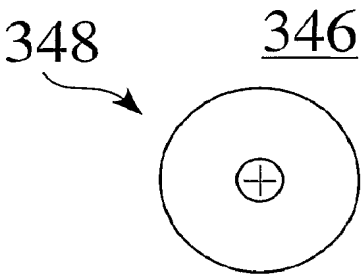


Fig. 67

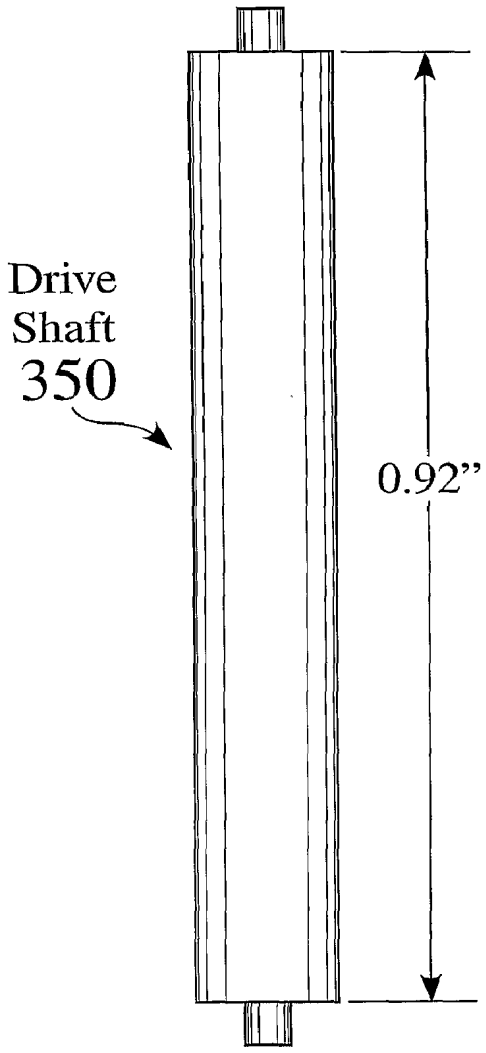


Fig. 68

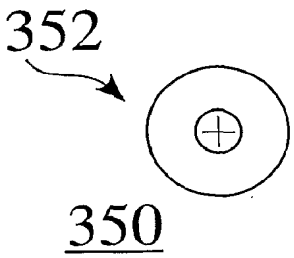


Fig. 69

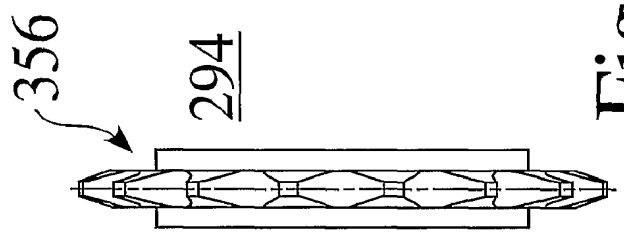


Fig. 71

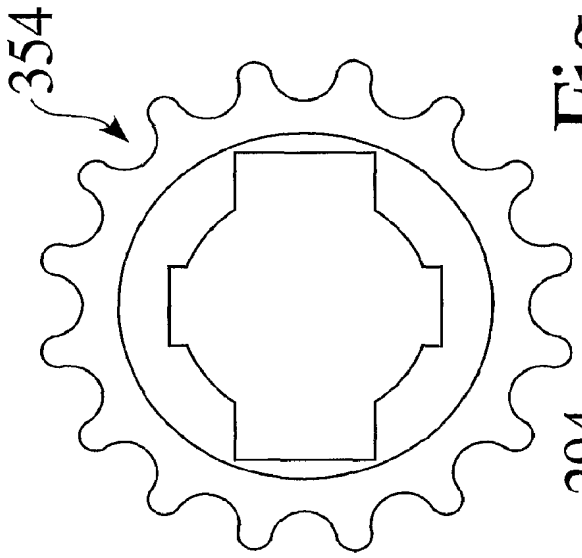


Fig. 70

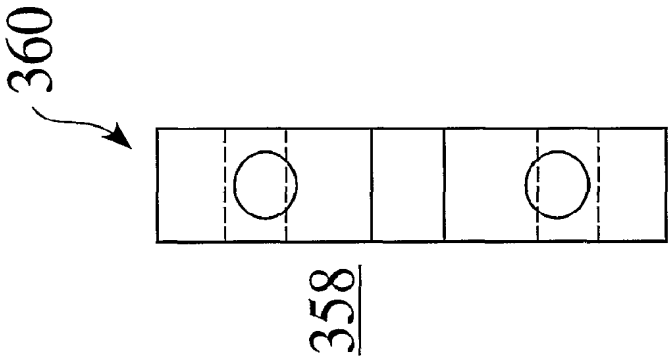


Fig. 73

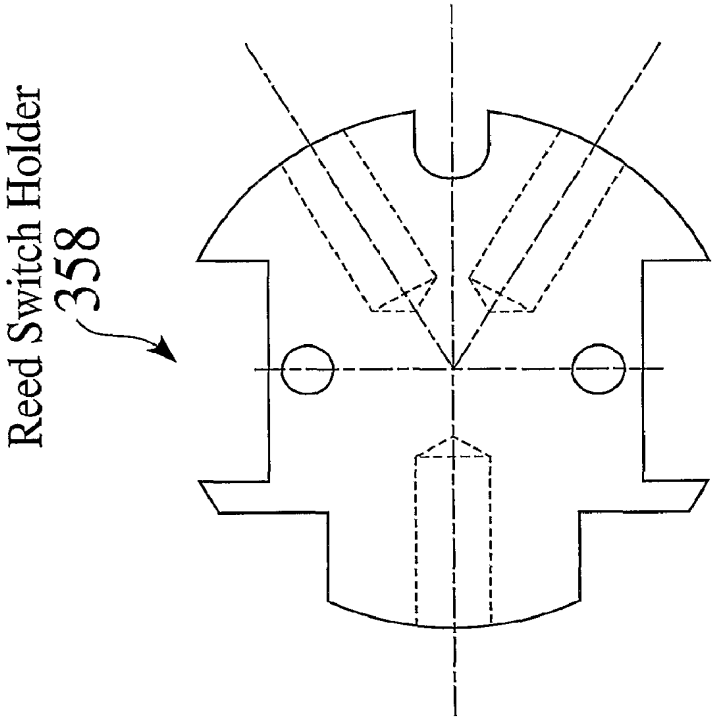
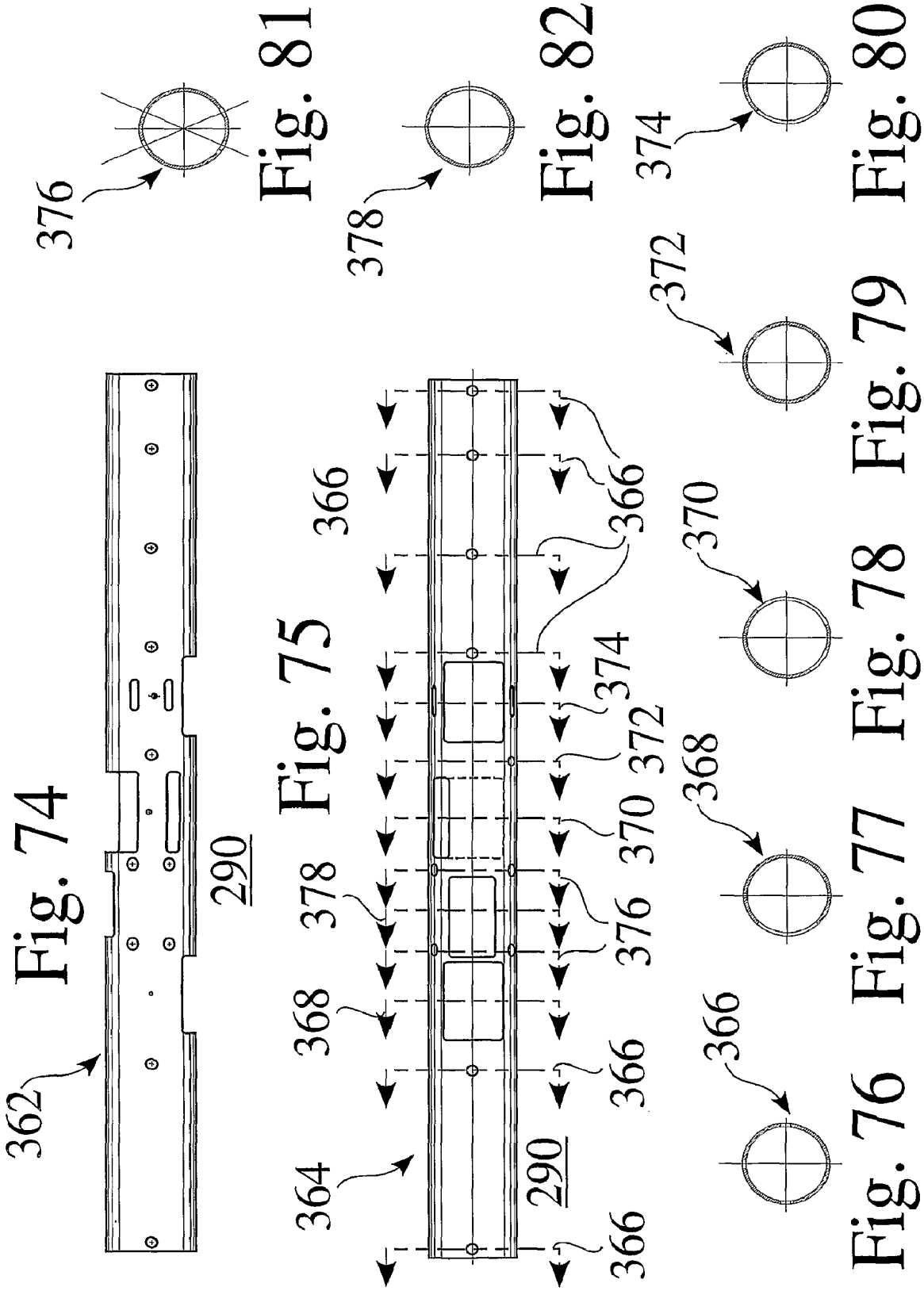


Fig. 72



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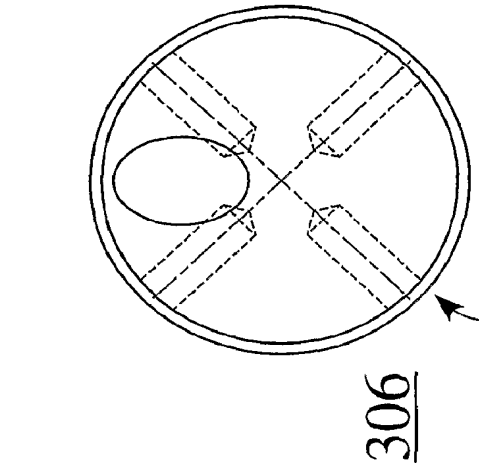


Fig. 85

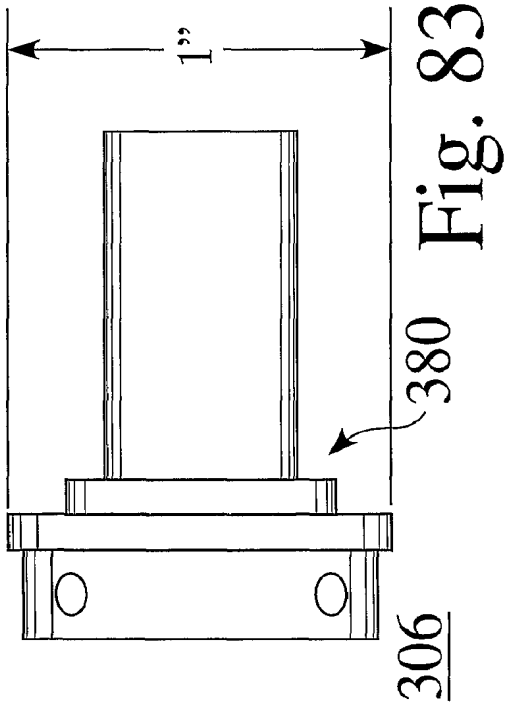


Fig. 83

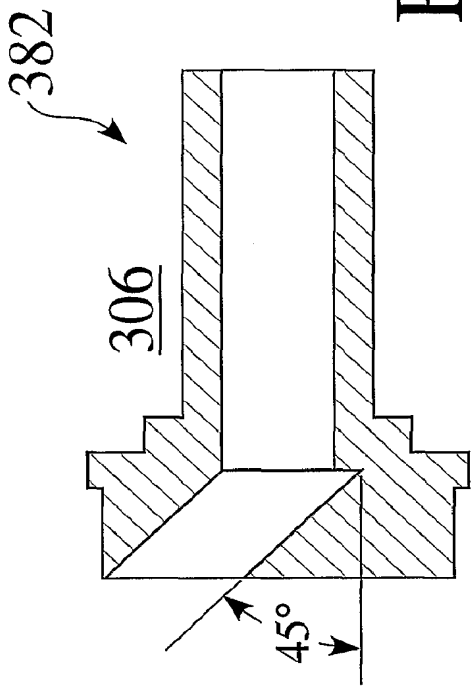


Fig. 84

Fig. 88

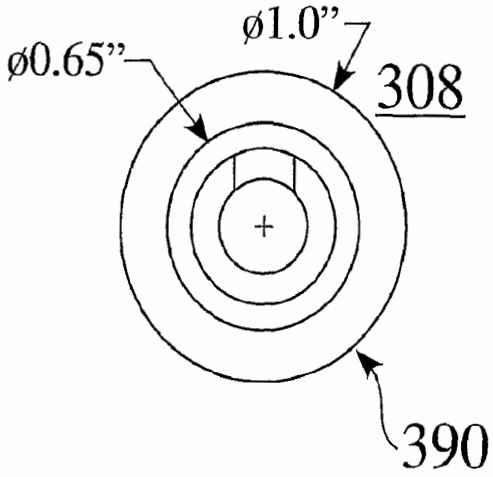


Fig. 86

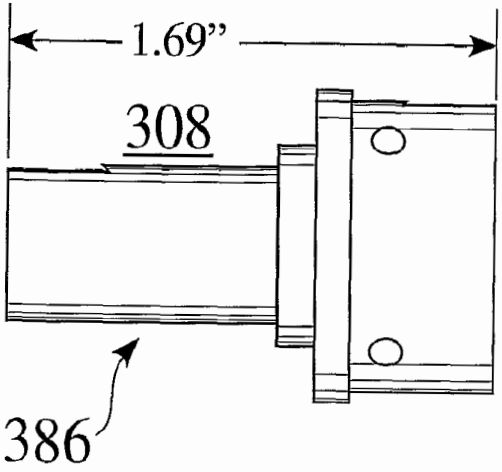
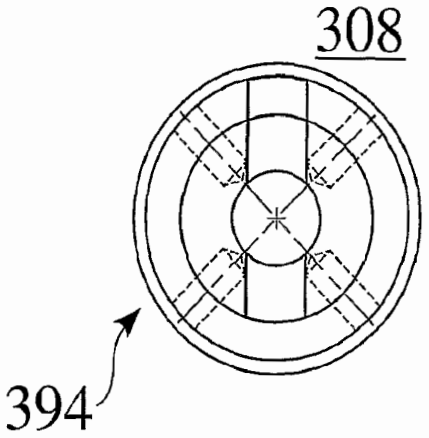


Fig. 90



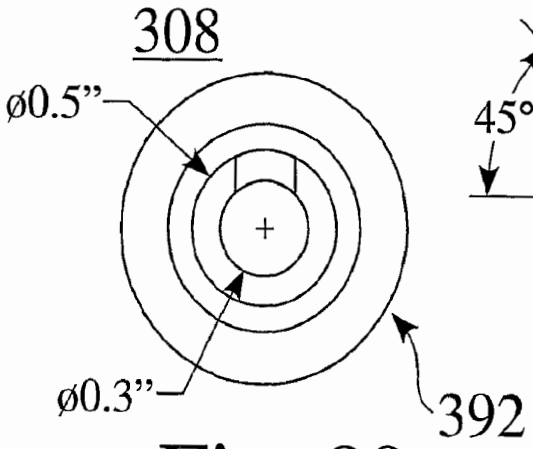


Fig. 89

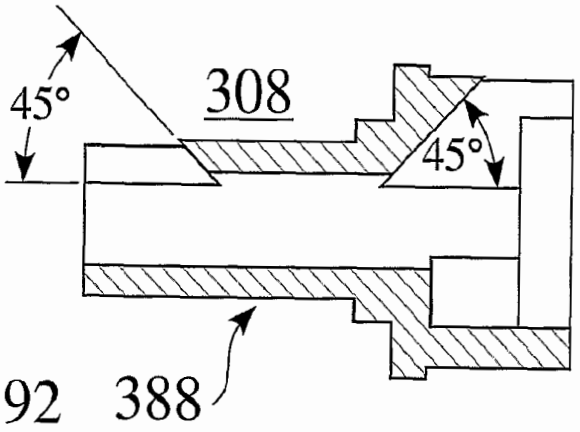


Fig. 87

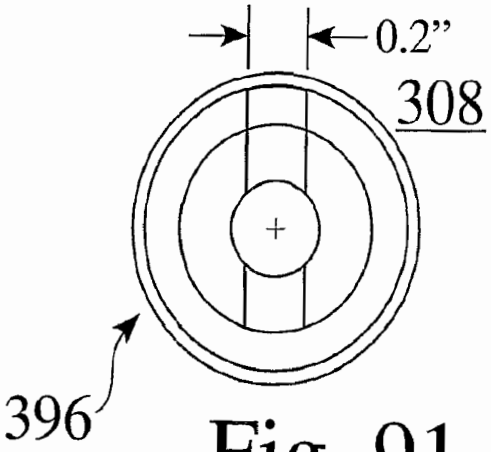


Fig. 91

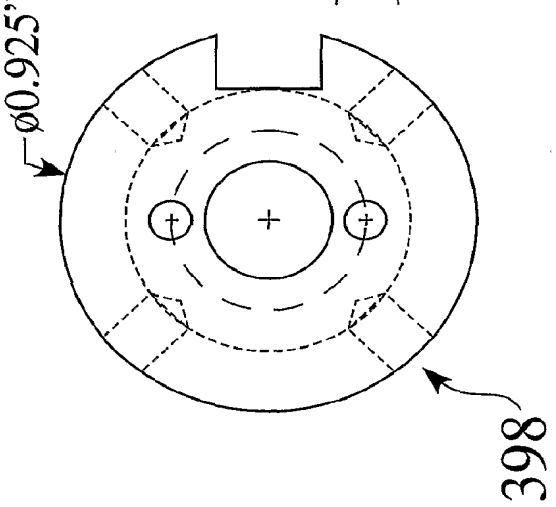


Fig. 92

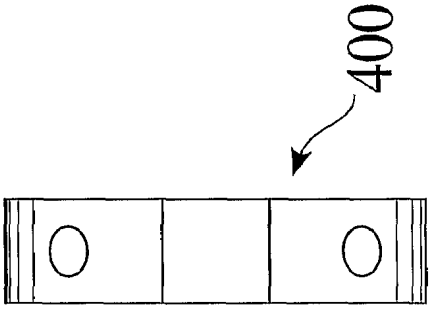


Fig. 93

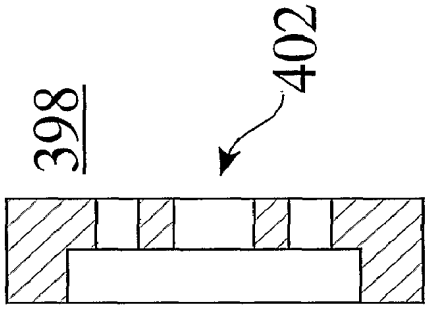


Fig. 94

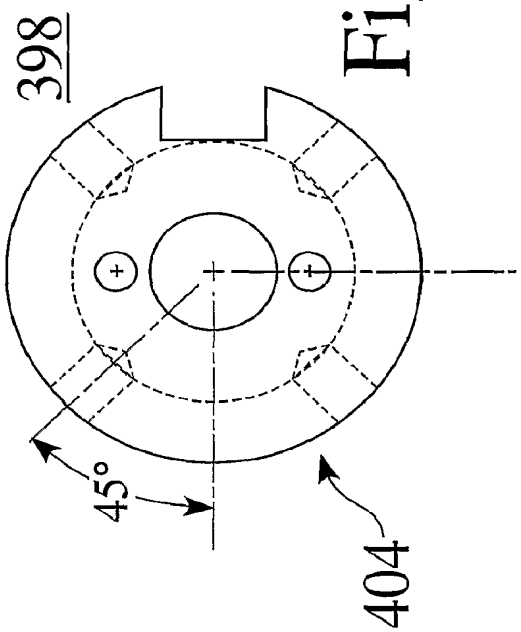


Fig. 95

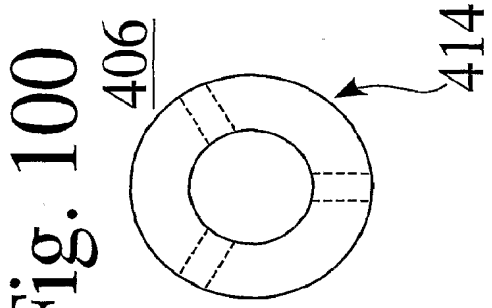


Fig. 100

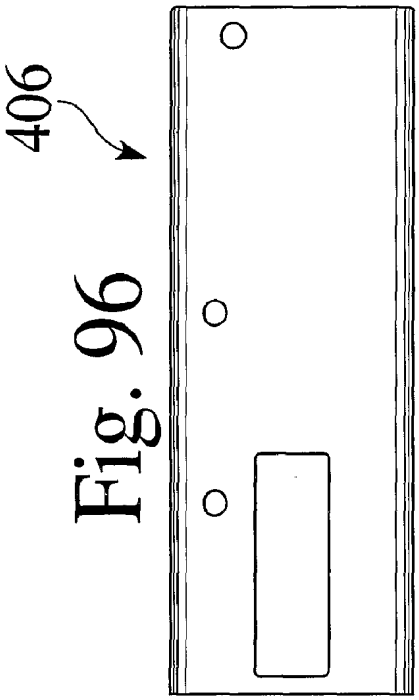


Fig. 96

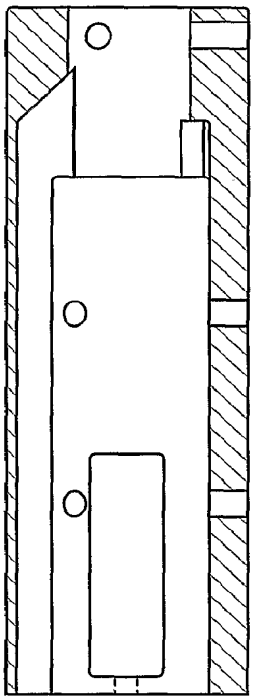


Fig. 97

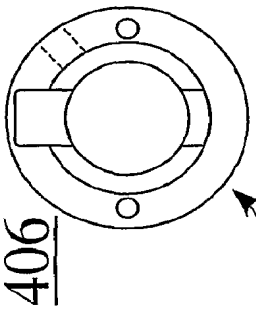


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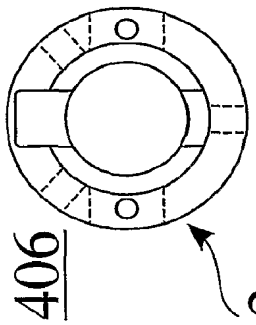


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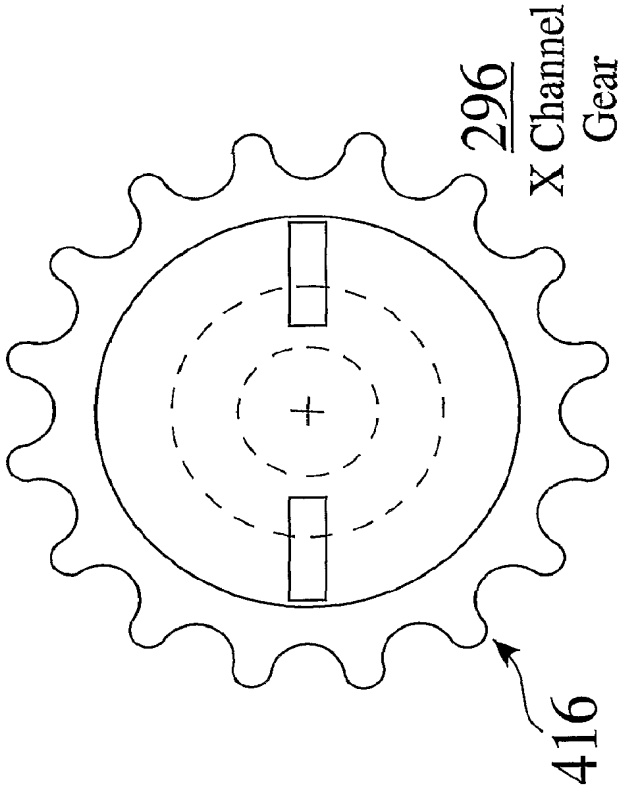


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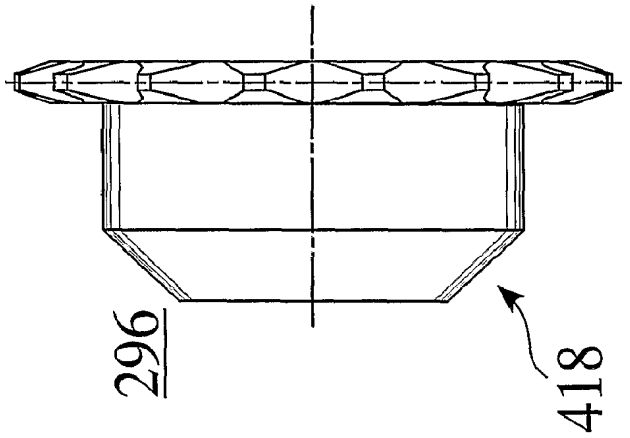


Fig. 102

Fig. 103

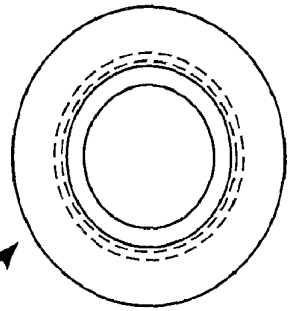
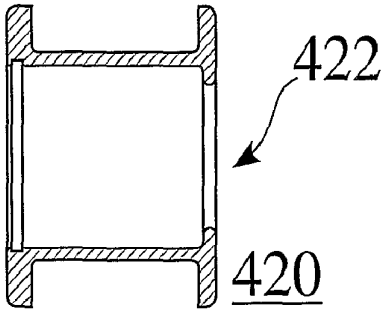


Fig. 104



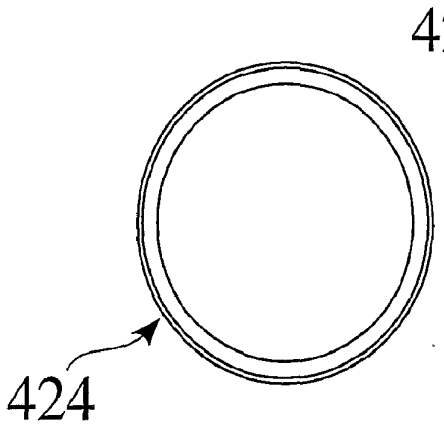


Fig. 105

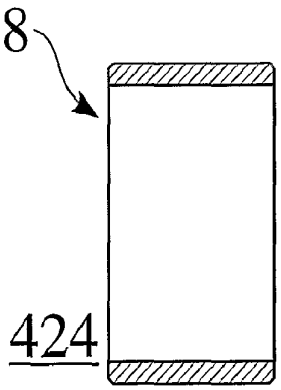


Fig. 107

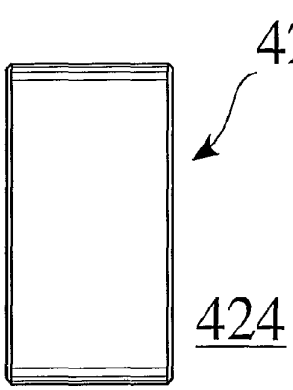


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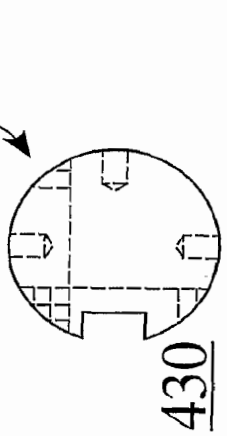


Fig. 110

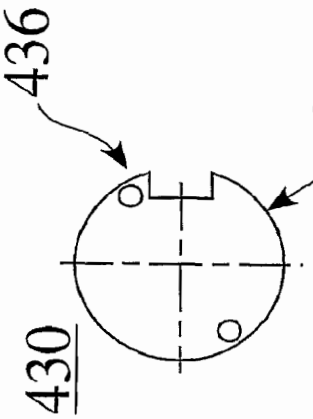


Fig. 111

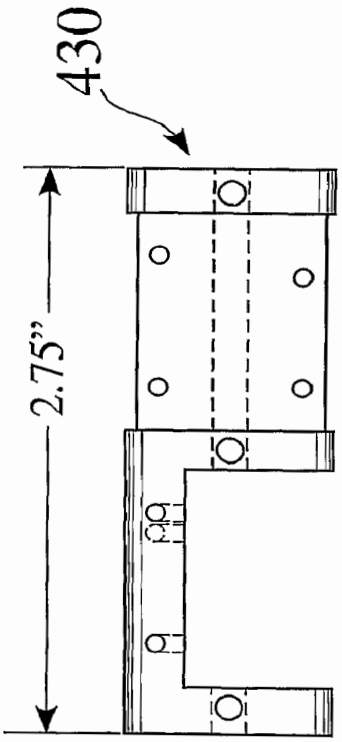


Fig. 108

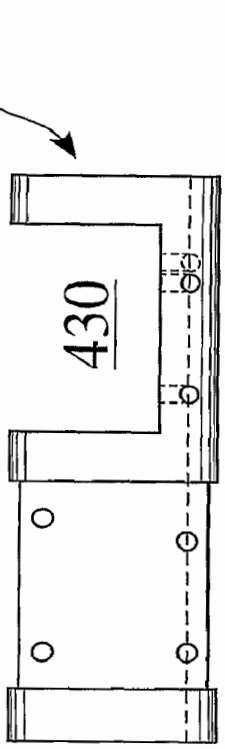


Fig. 109

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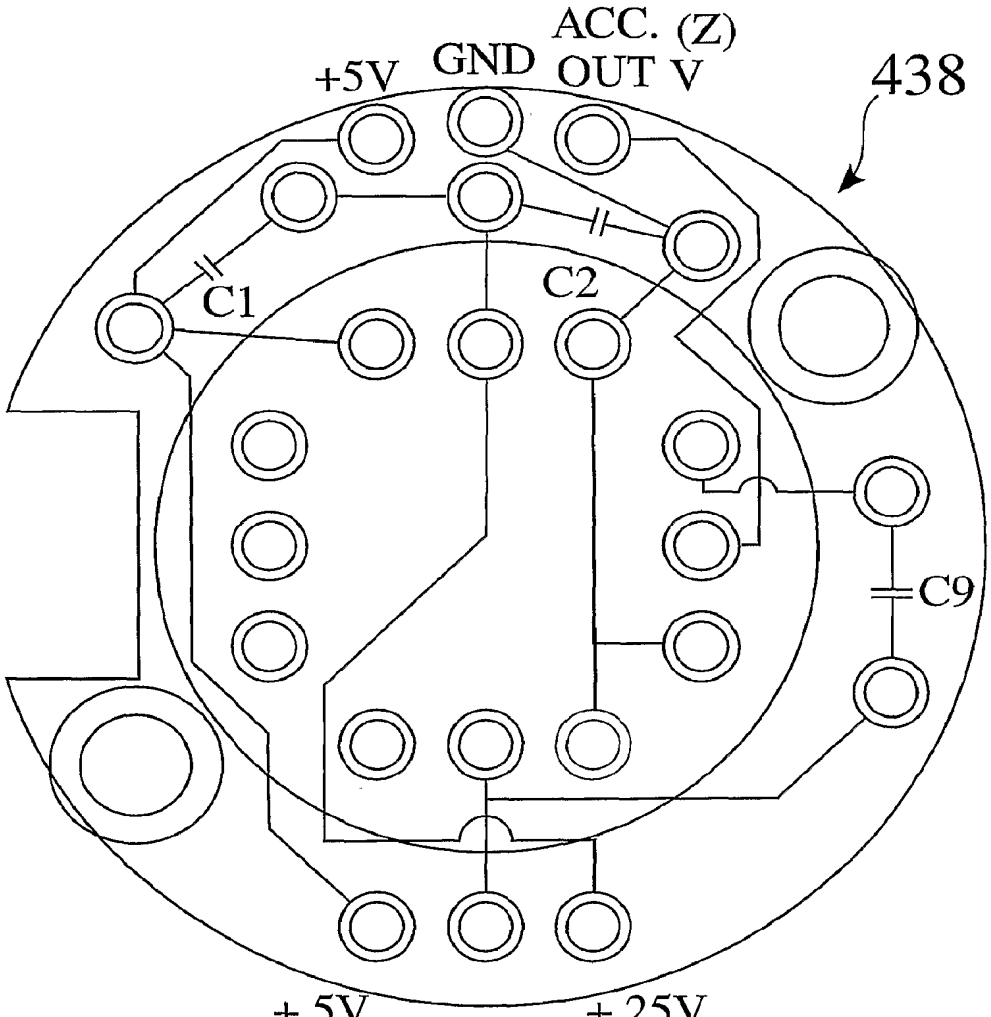
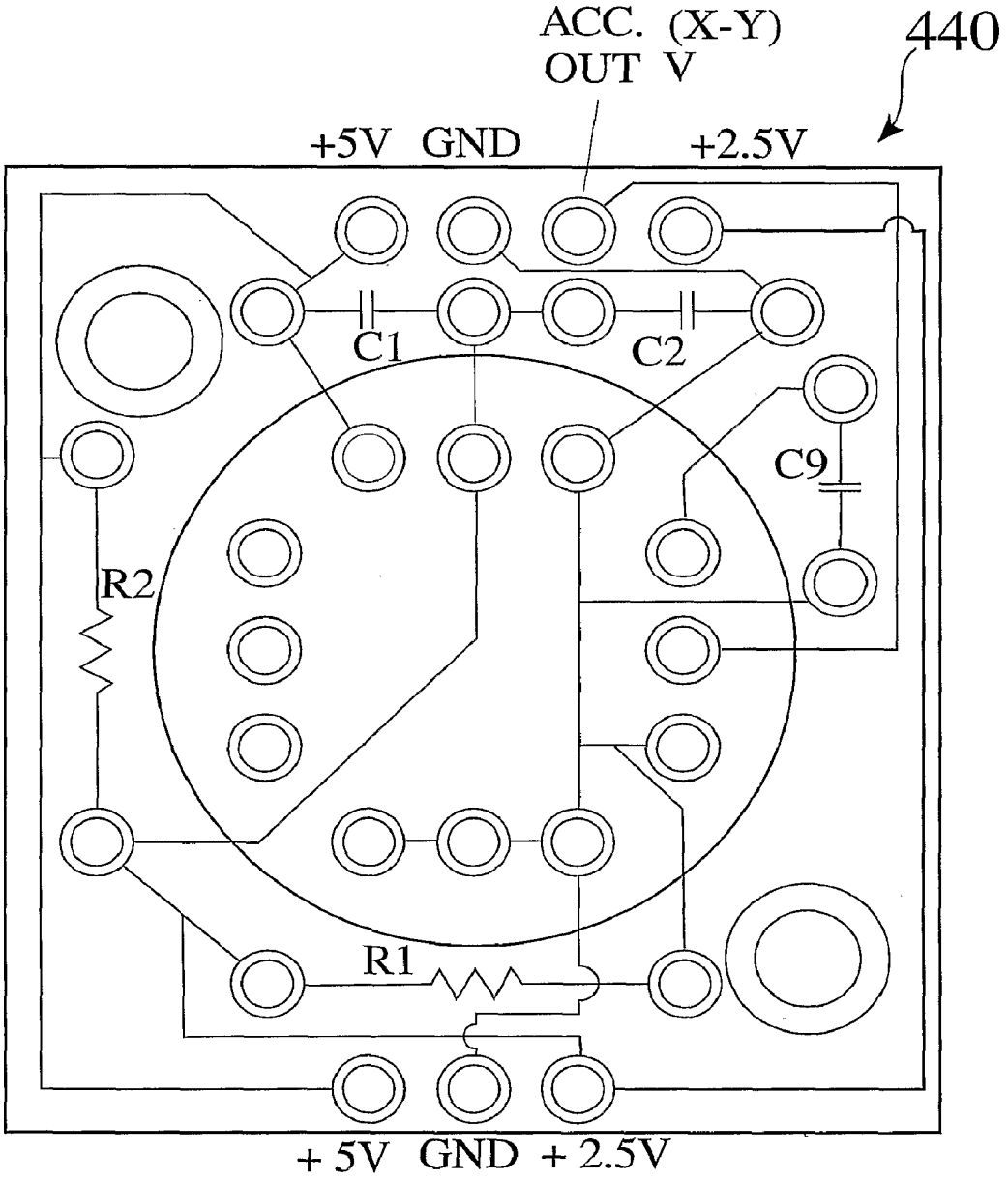


Fig. 112



Accelerometer Board
X and Y

Fig. 113

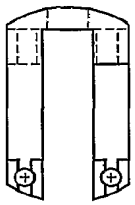


Fig. 114

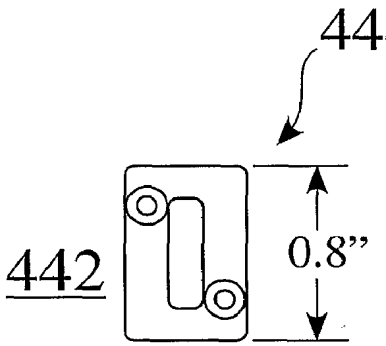


Fig. 115

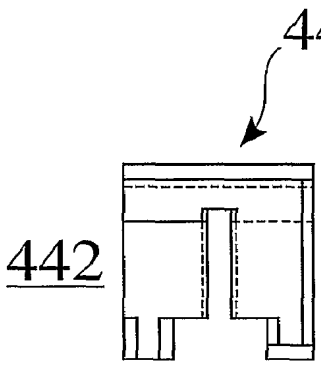


Fig. 116

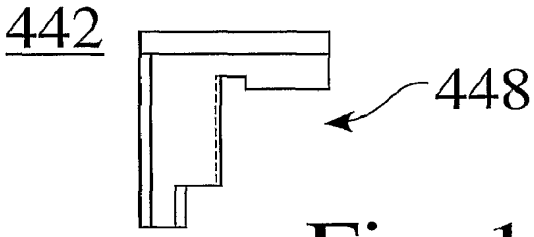


Fig. 117

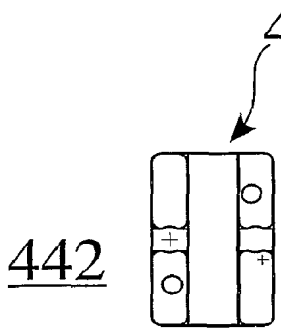


Fig. 118

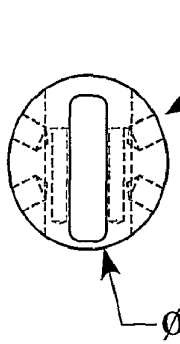


Fig. 119

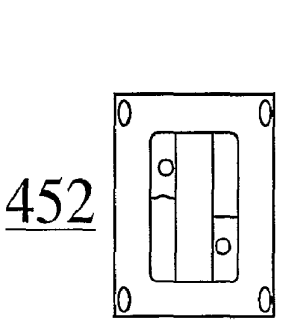


Fig. 120

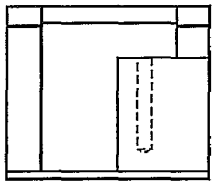


Fig. 121

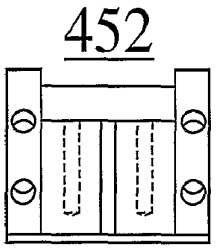


Fig. 122

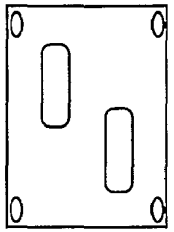


Fig. 124

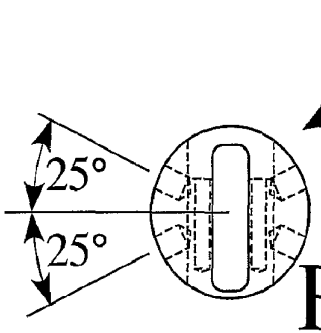


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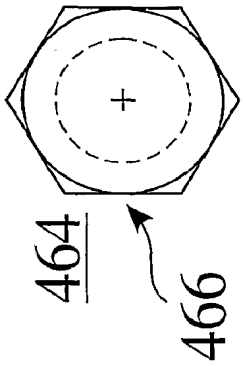


Fig. 126

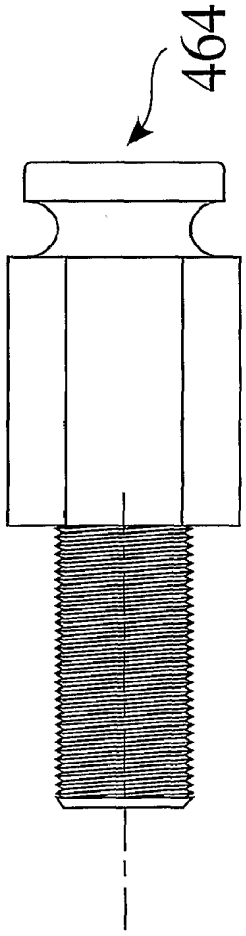


Fig. 125

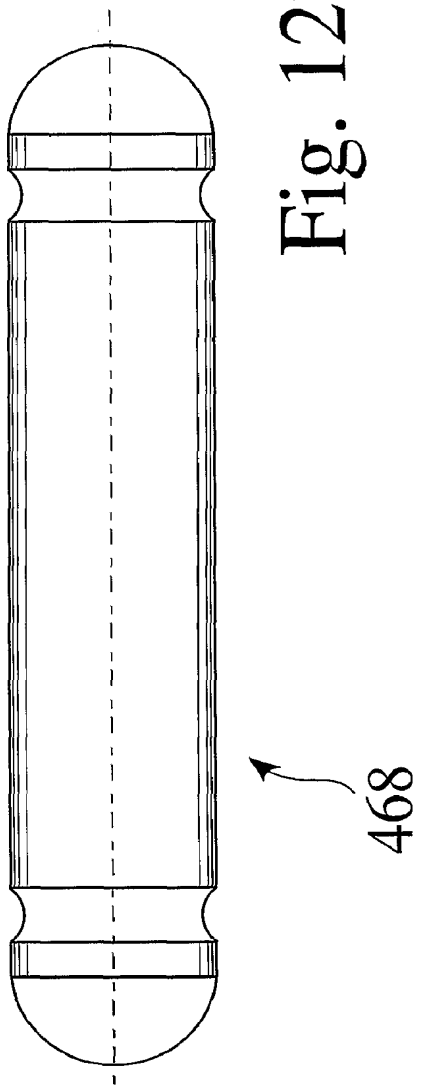


Fig. 127

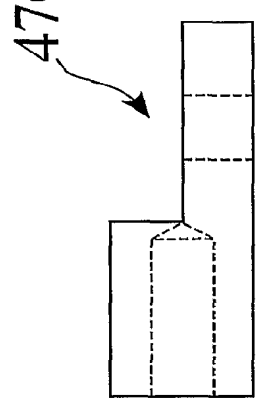


Fig. 128

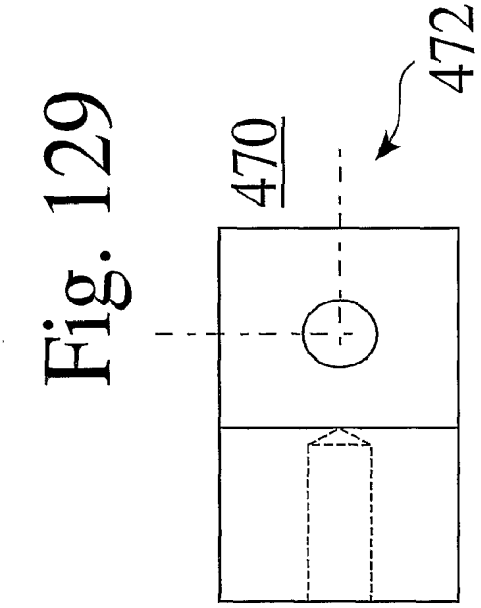


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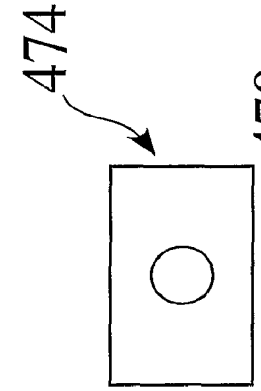


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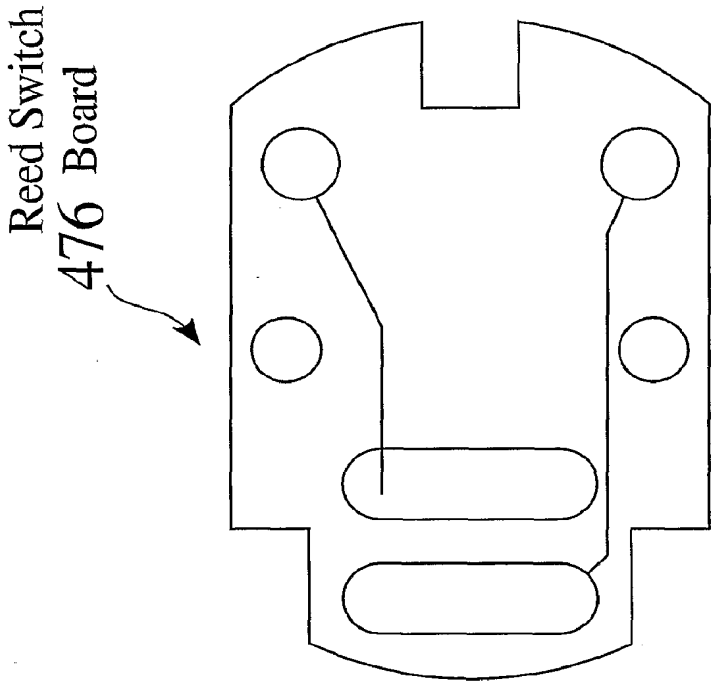
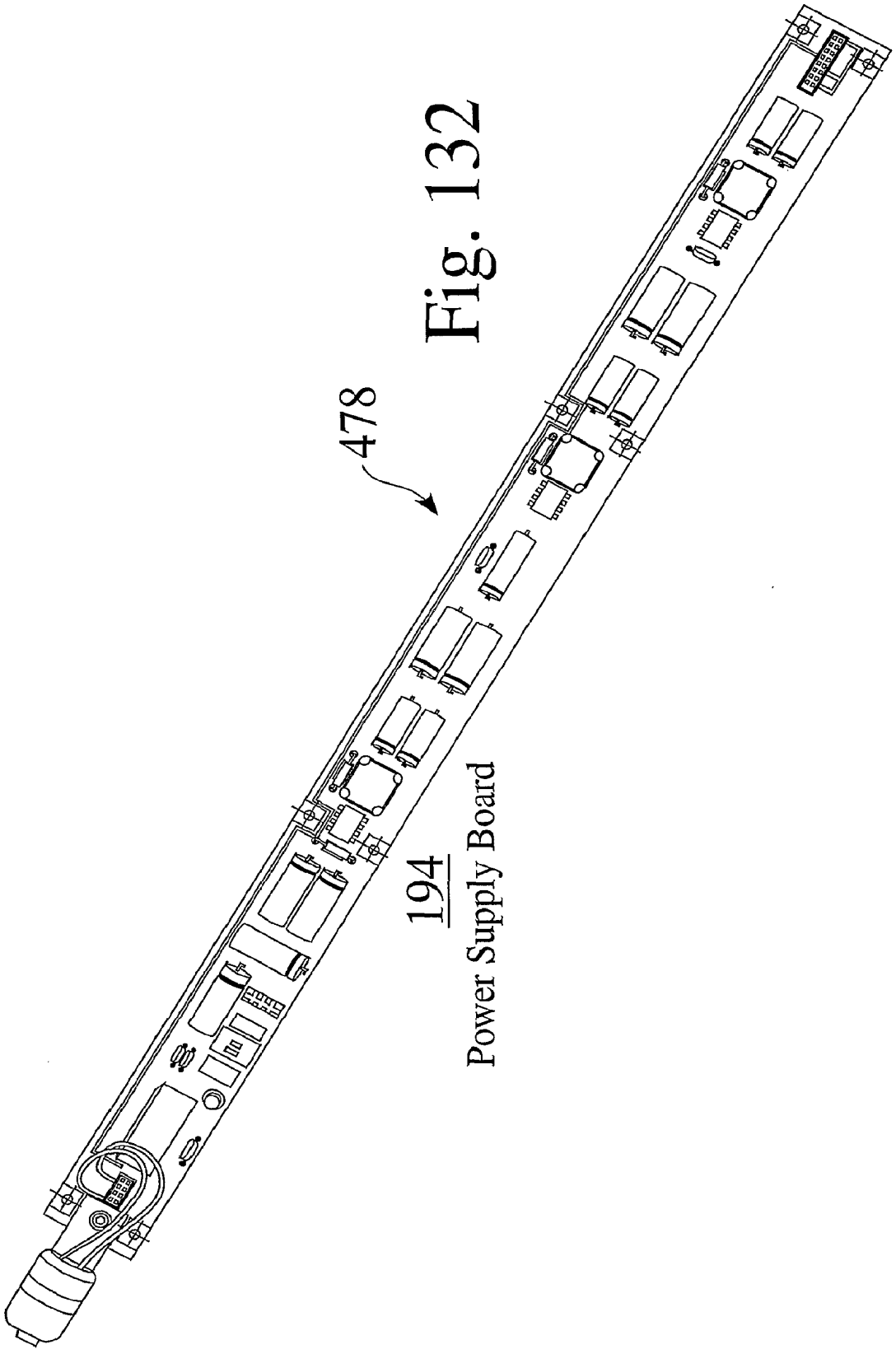


Fig. 131

Fig. 132



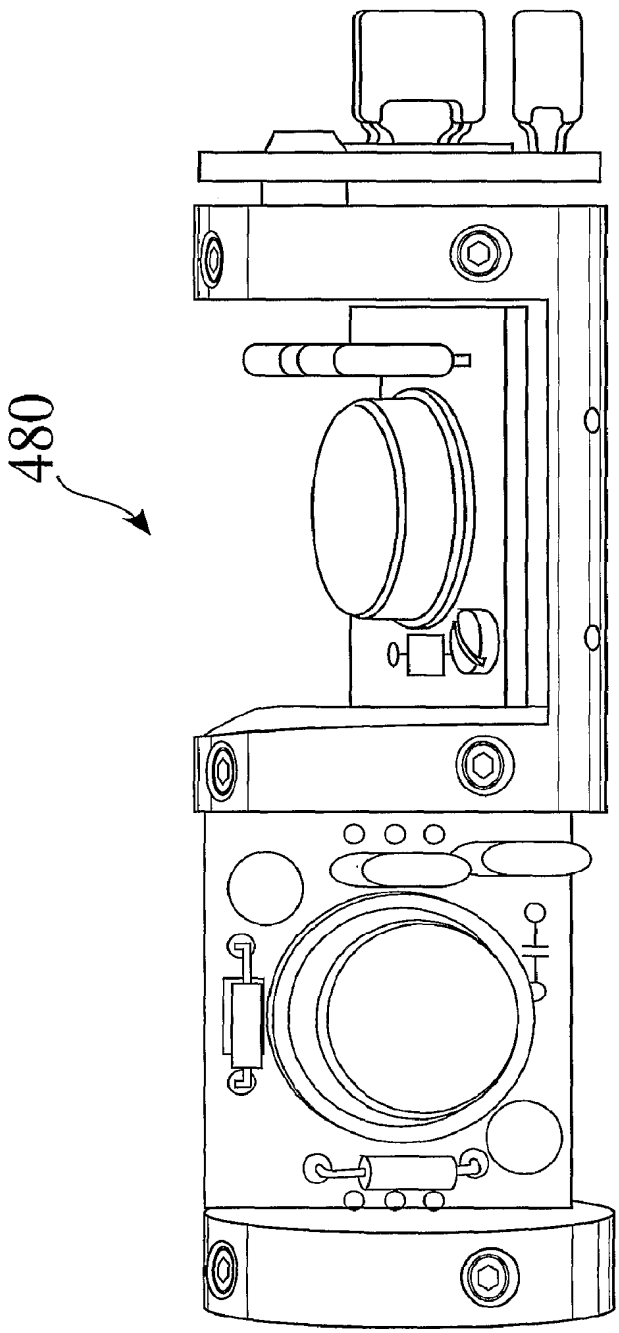
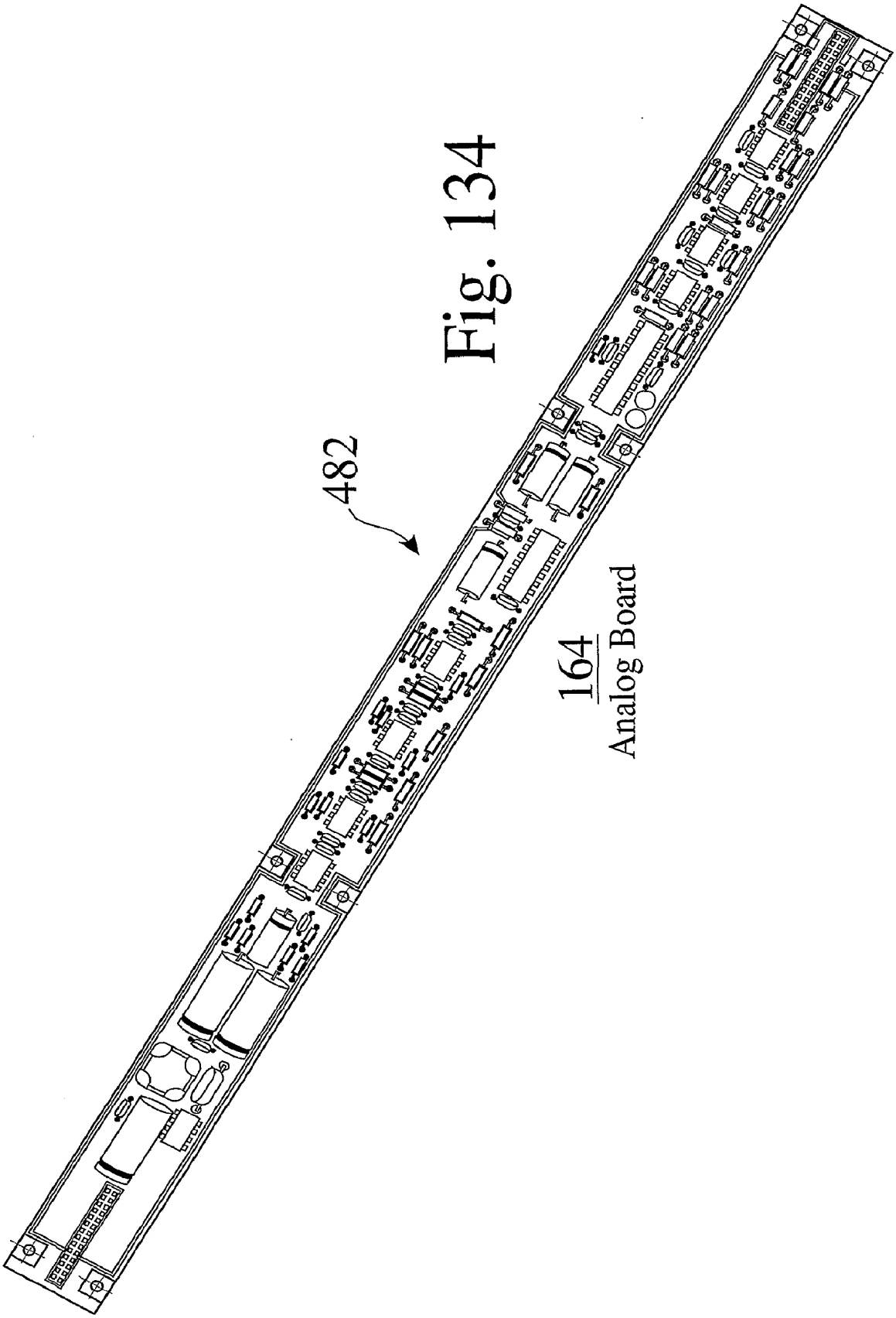


Fig. 133

Fig. 134



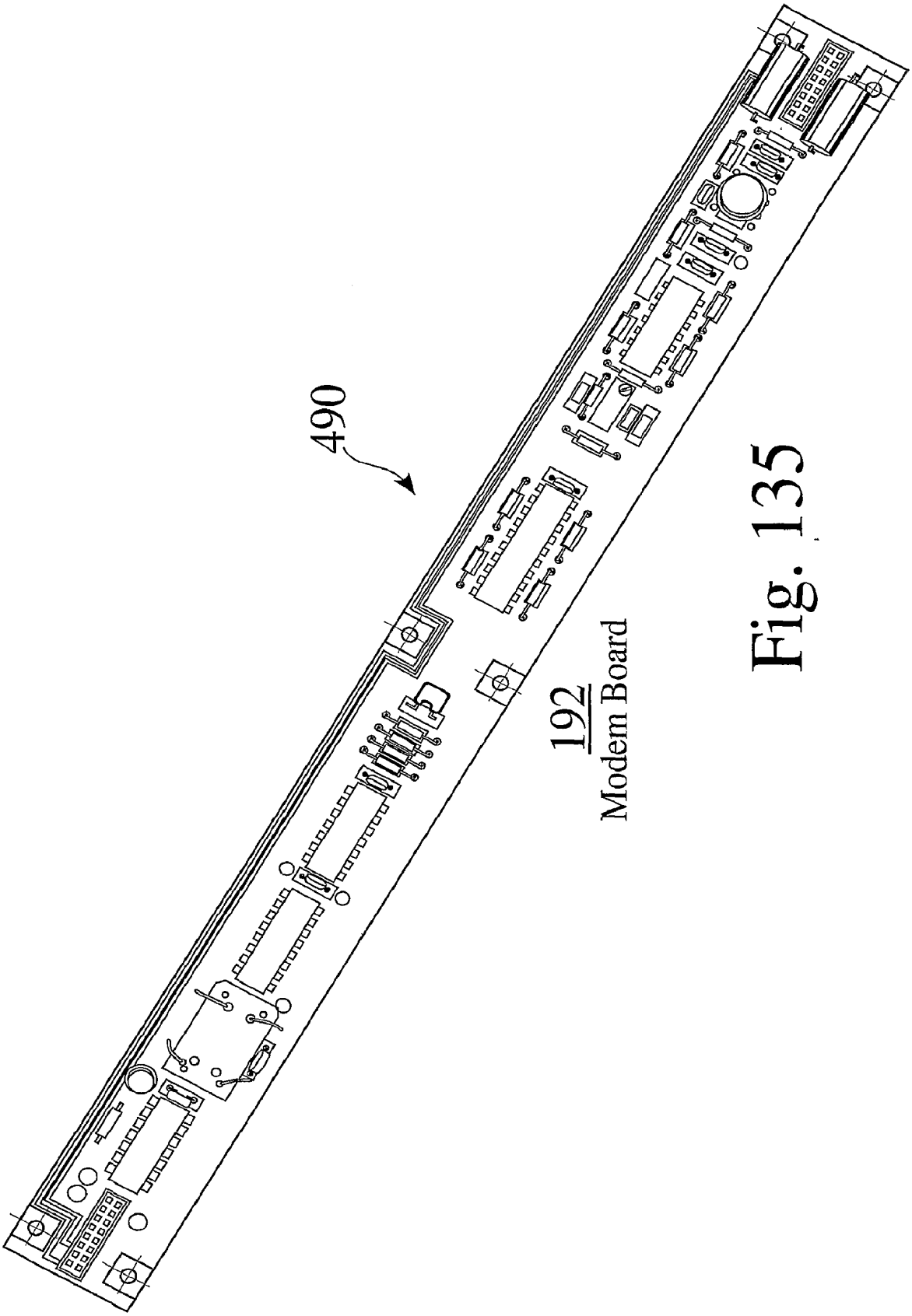


Fig. 135

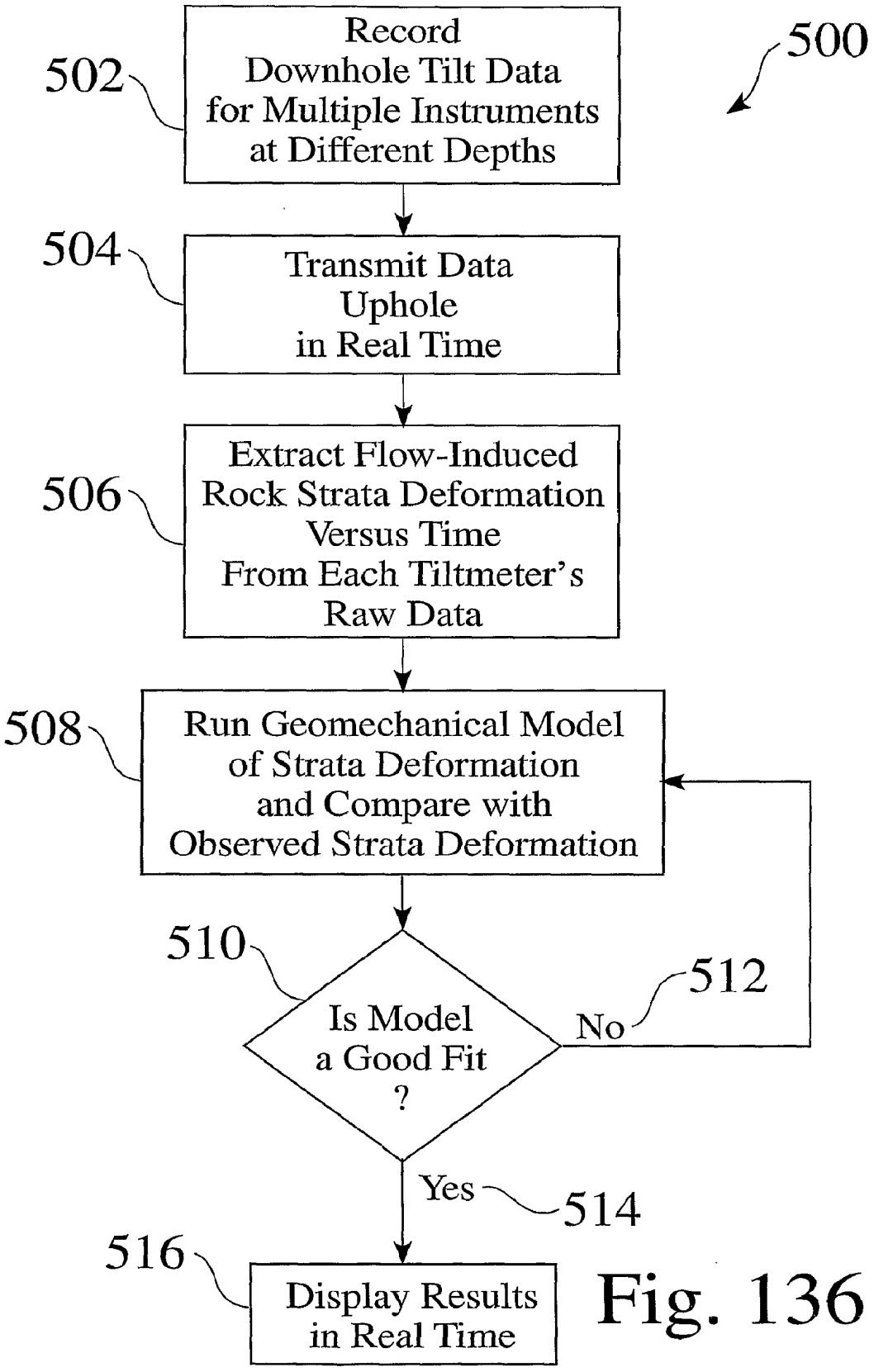

500
502
Record Downhole Tilt Data for Multiple Instruments at Different Depths
504
Transmit Data Uphole in Real Time
506
Extract Flow-Induced Rock Strata Deformation Versus Time From Each Tiltmeter's Raw Data
508
Run Geomechanical Model of Strata Deformation and Compare with Observed Strata Deformation
510
Is Model a Good Fit ?
512
No
Yes
514
516
Display Results in Real Time

Fig. 136

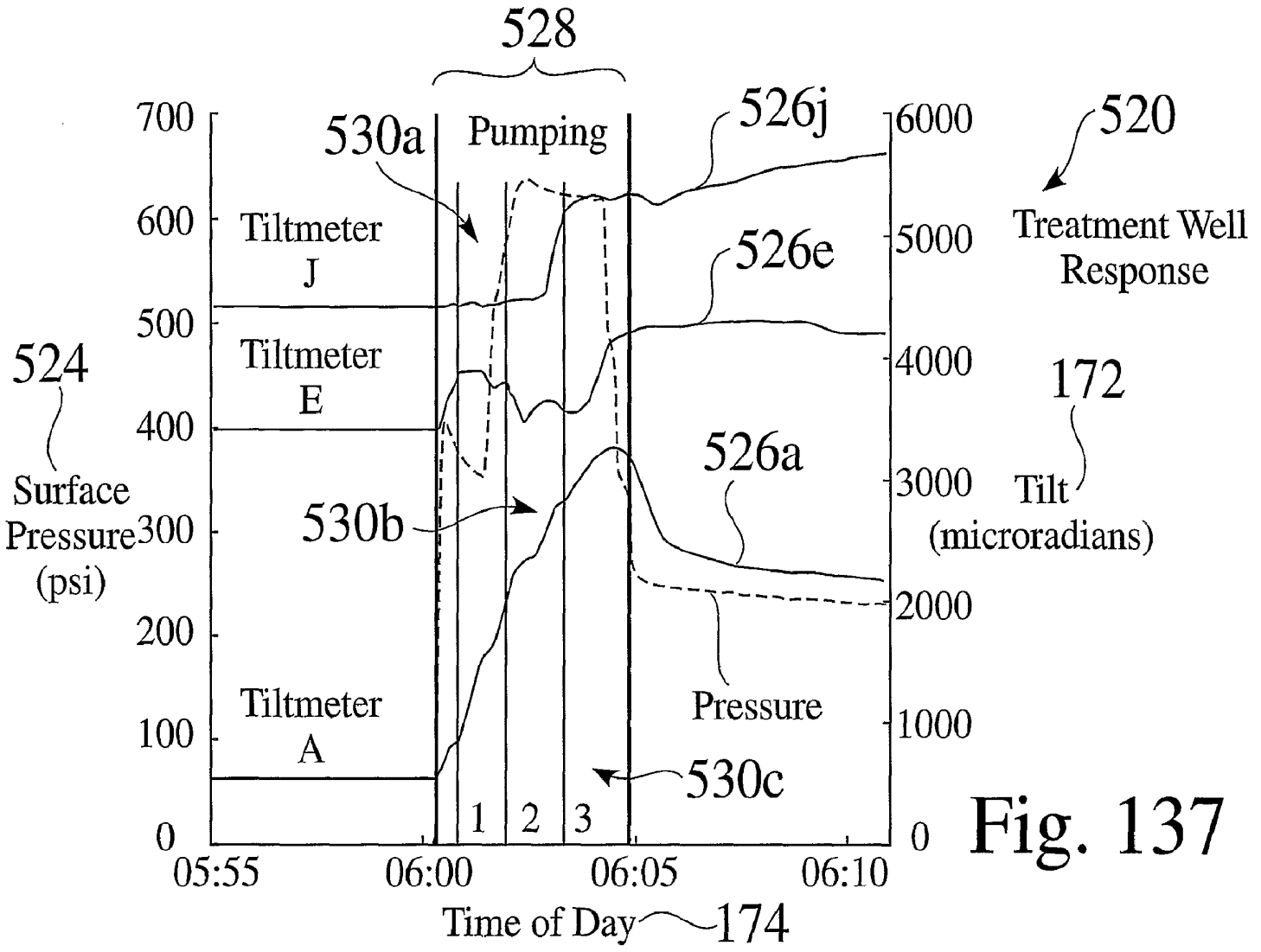

528
530a
Pumping
526j
520
Treatment Well Response
Tiltmeter J
526e
Tiltmeter E
524
Surface Pressure (psi)
172
Tilt (microradians)
526a
530b
Tiltmeter A
Pressure
530c
1
2
3
700
600
500
400
300
200
100
0
6000
5000
4000
3000
2000
1000
0
05:55
06:00
06:05
06:10
Time of Day
174

Fig. 137

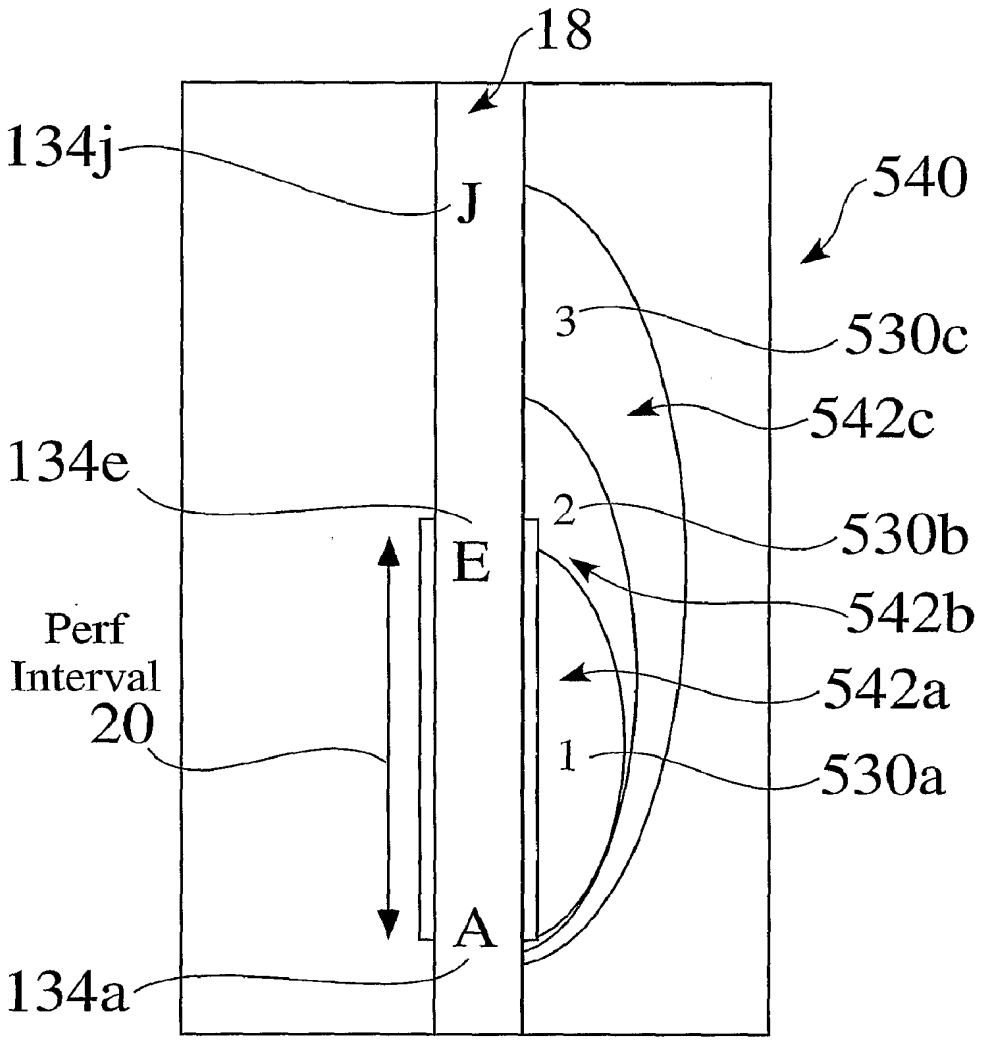
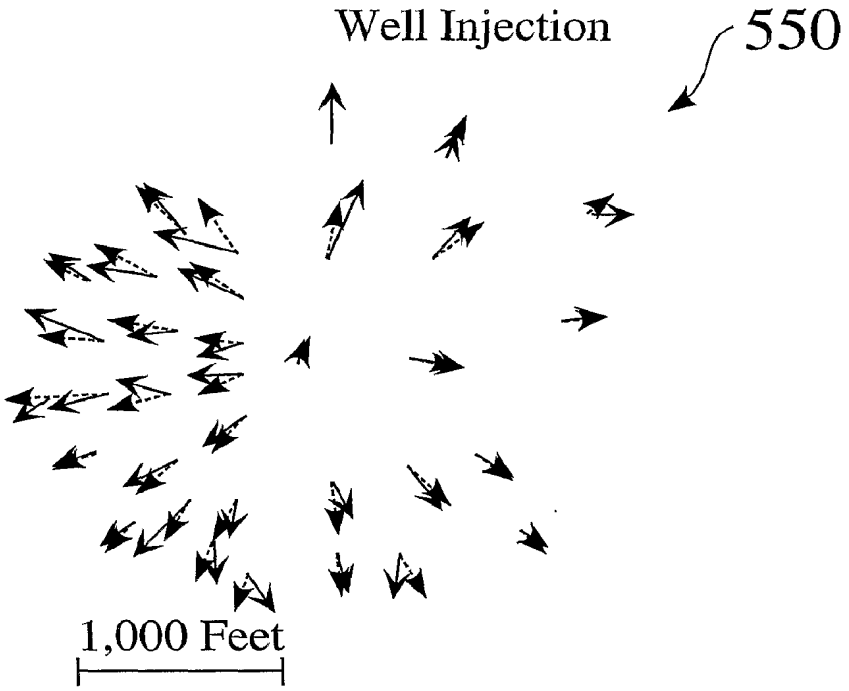

18
134j
J
540
3
530c
542c
134e
E
2
530b
542b
Perf
Interval
20
542a
1
530a
A
134a

Fig. 138



North

+ Tiltmeter Site

⊕ Wellhead

Measured Tilt
10 Microradians

Theoretical Tilt
10 Microradians

Fig. 139

51/51

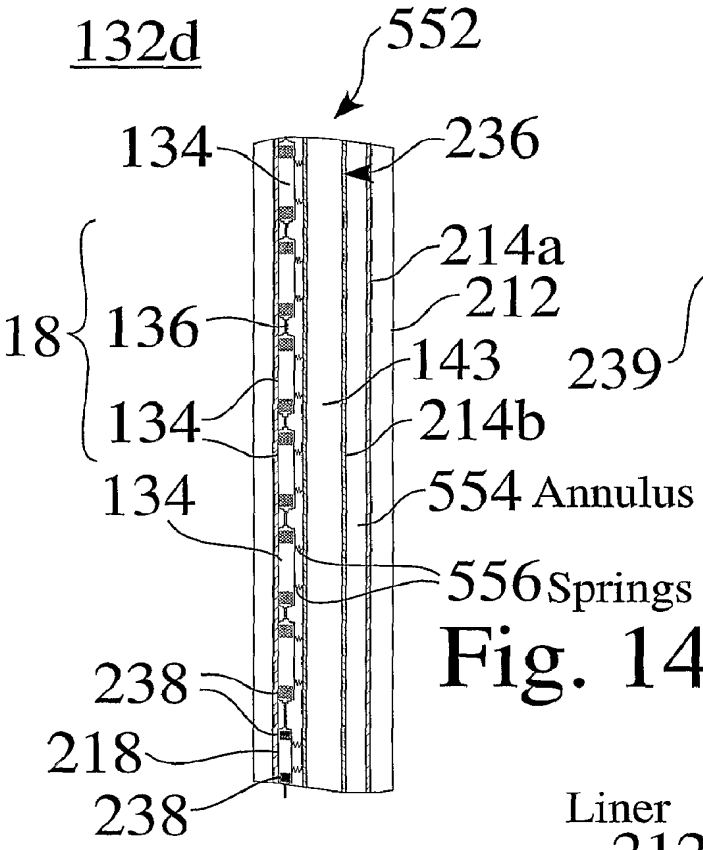


Fig. 140

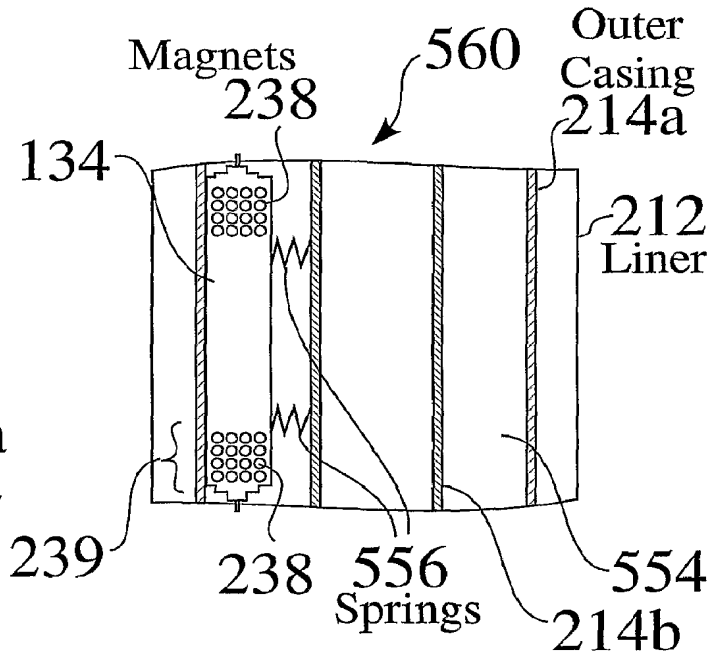


Fig. 141

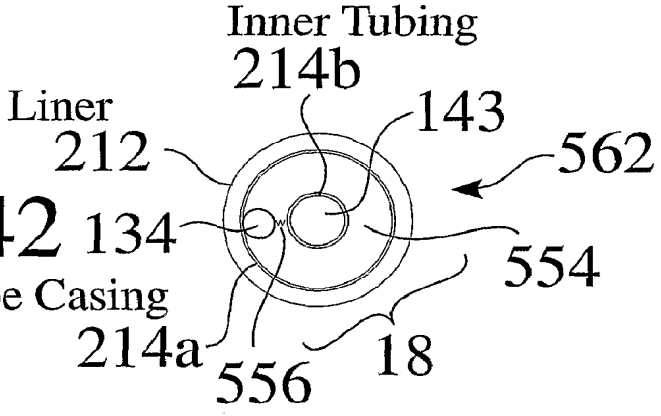


Fig. 142

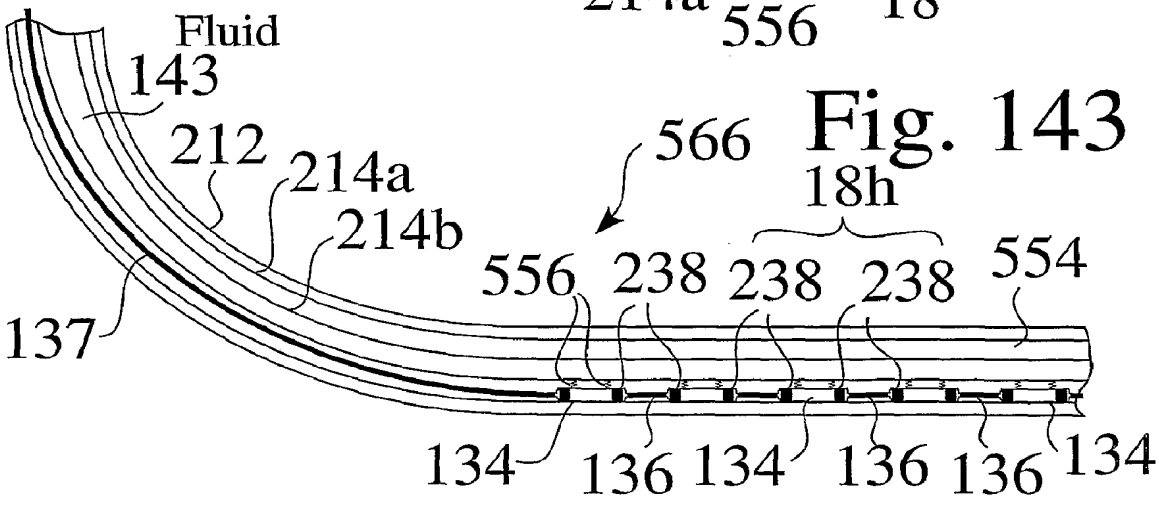


Fig. 143

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(43) 30.10.2003

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(85) 18.10.2004

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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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(71) Demandeur/Applicant:
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(54) Titre : MOYENS ET PROCEDES D'EVALUATION D'UNE FRACTURE SOUTERRAINE PENDANT OU APRES UN TRAITEMENT DE FRACTURATION HYDRAULIQUE

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(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).

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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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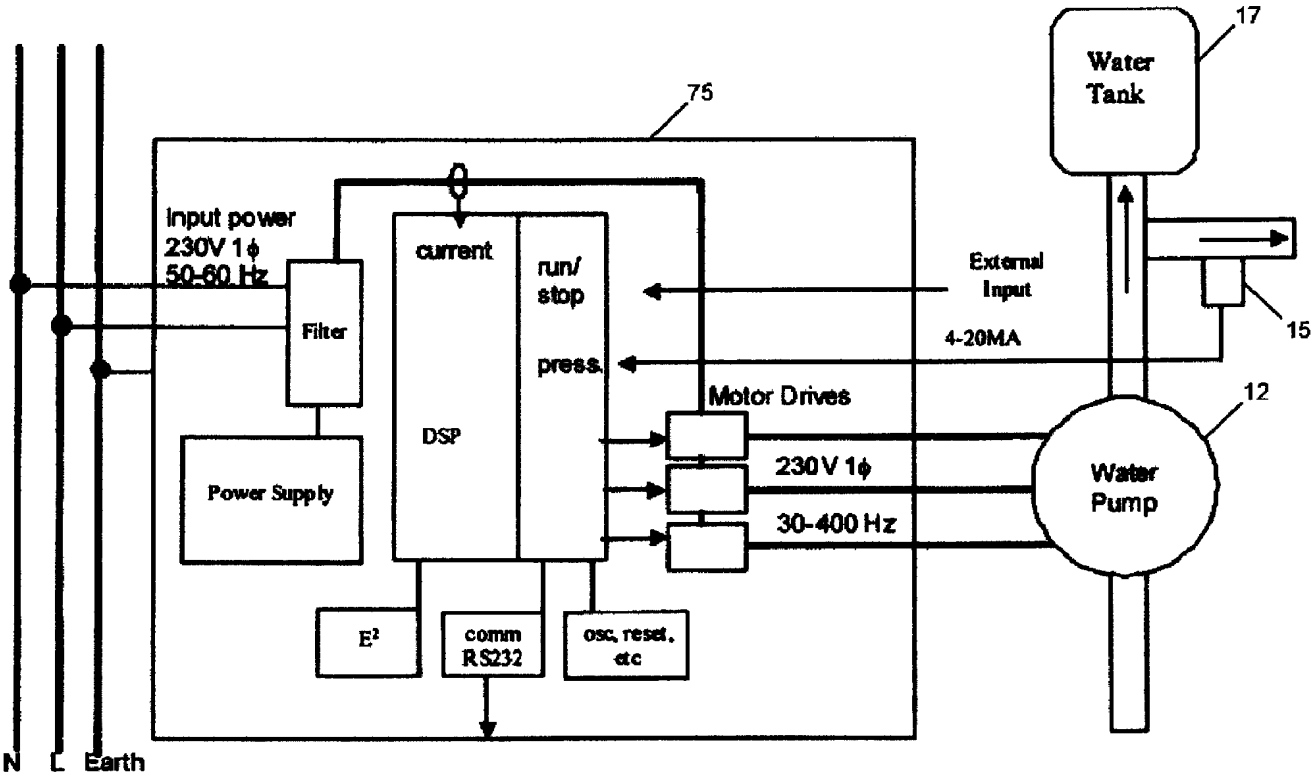
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(54) Titre : METHODE DE CONTROLE D'UNE POMPE ET DE SON MOTEUR
(54) Title: METHOD OF CONTROLLING A PUMP AND MOTOR



(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.

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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.

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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.

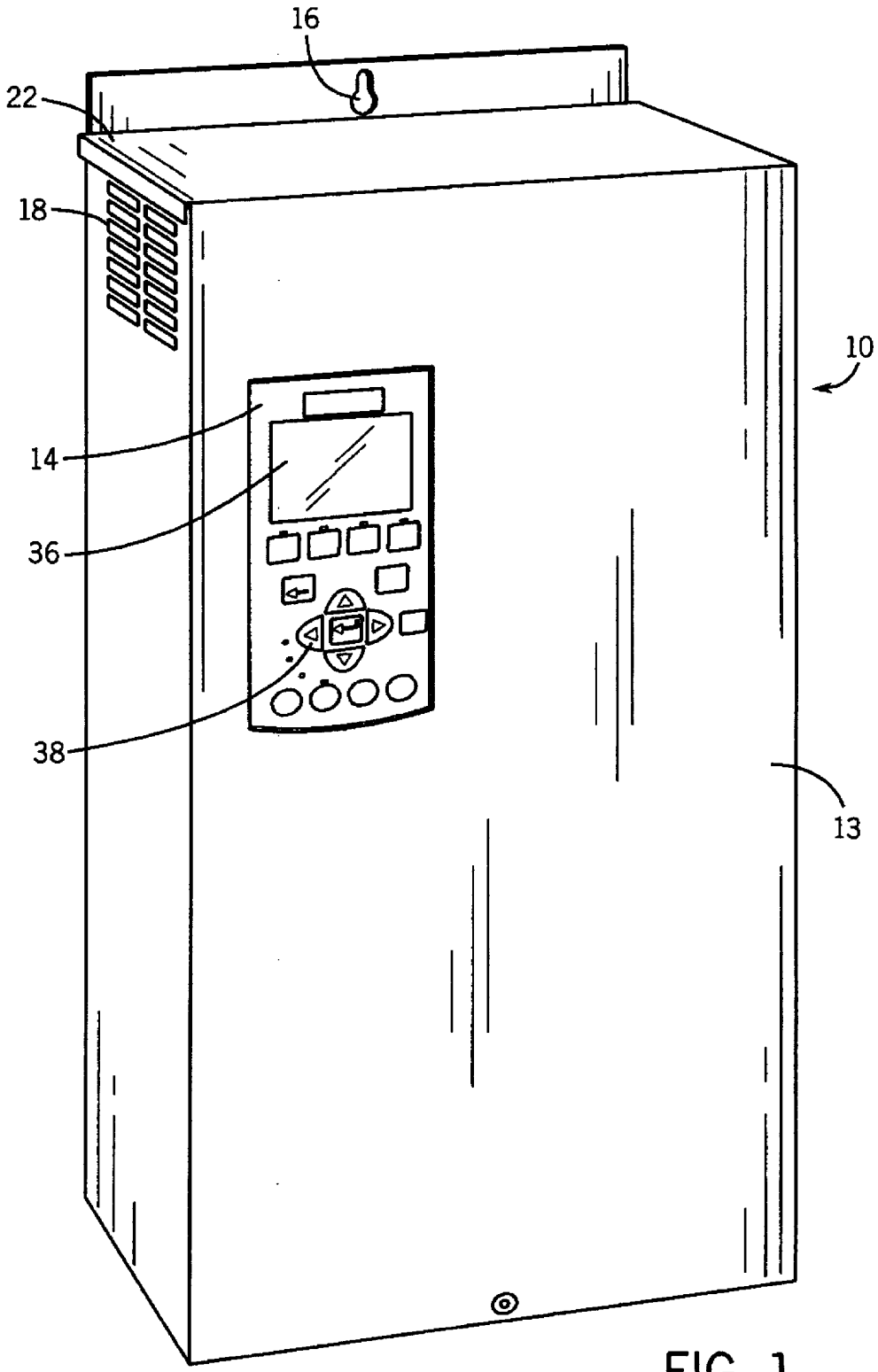


FIG. 1

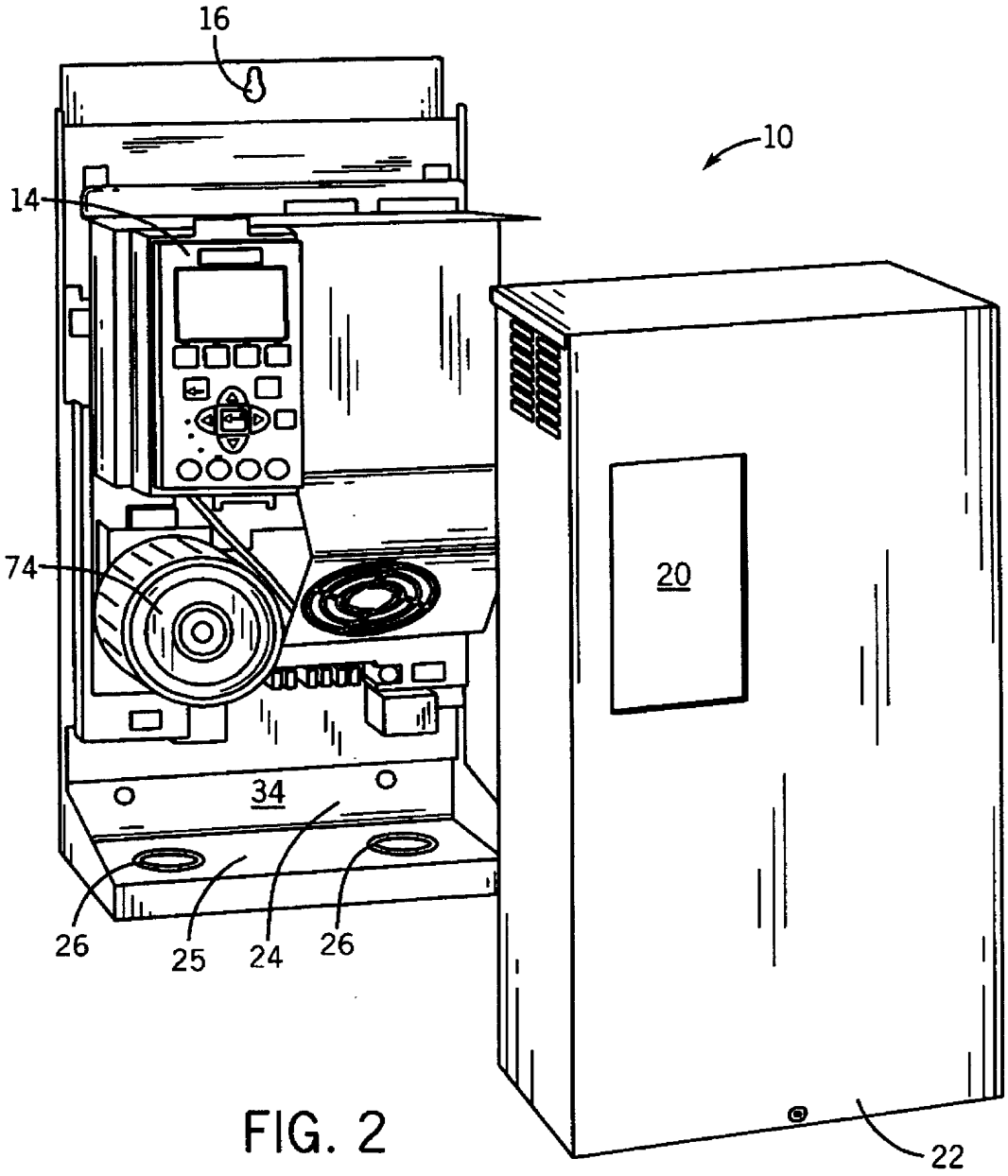


FIG. 2

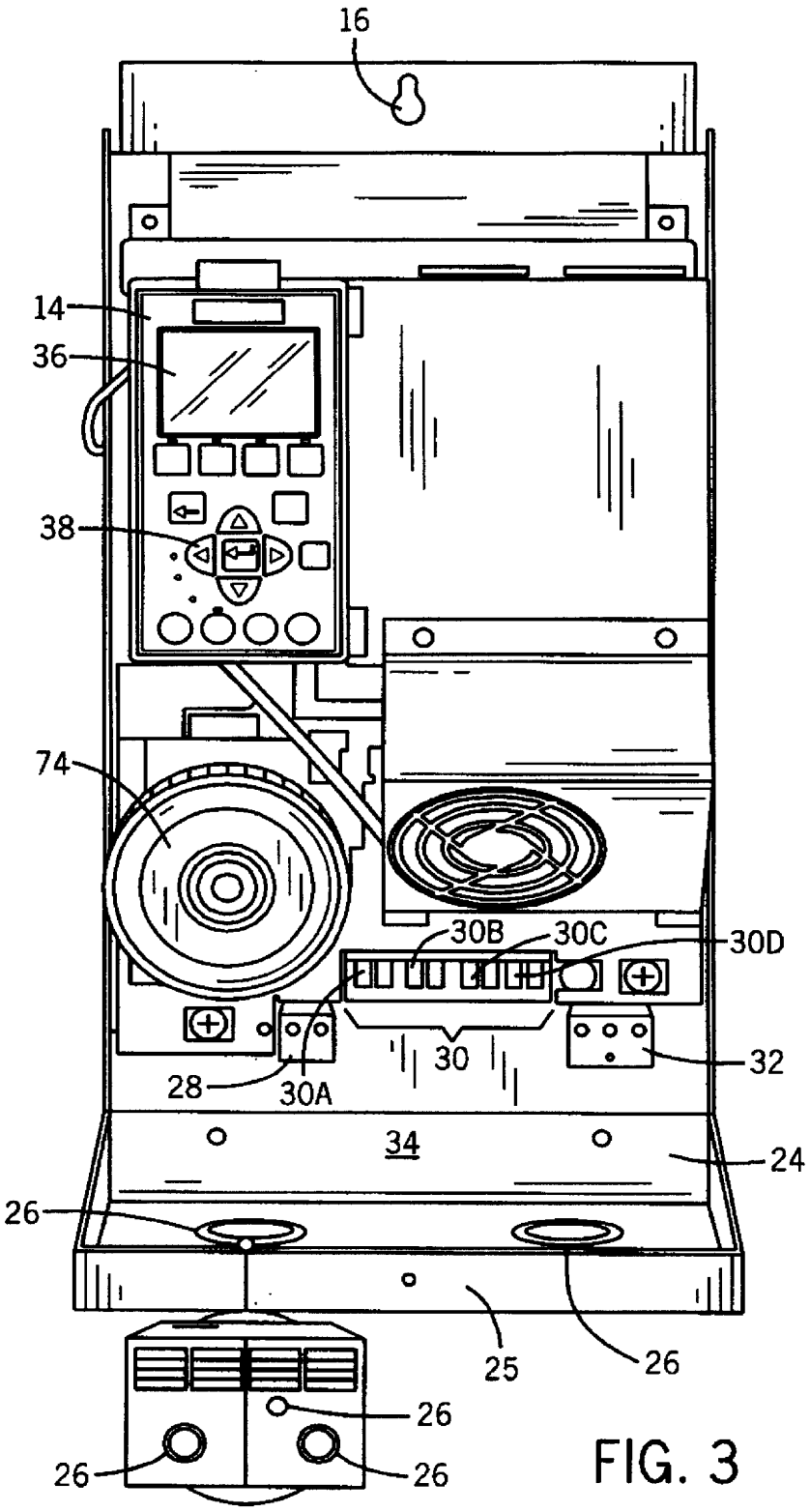


FIG. 3

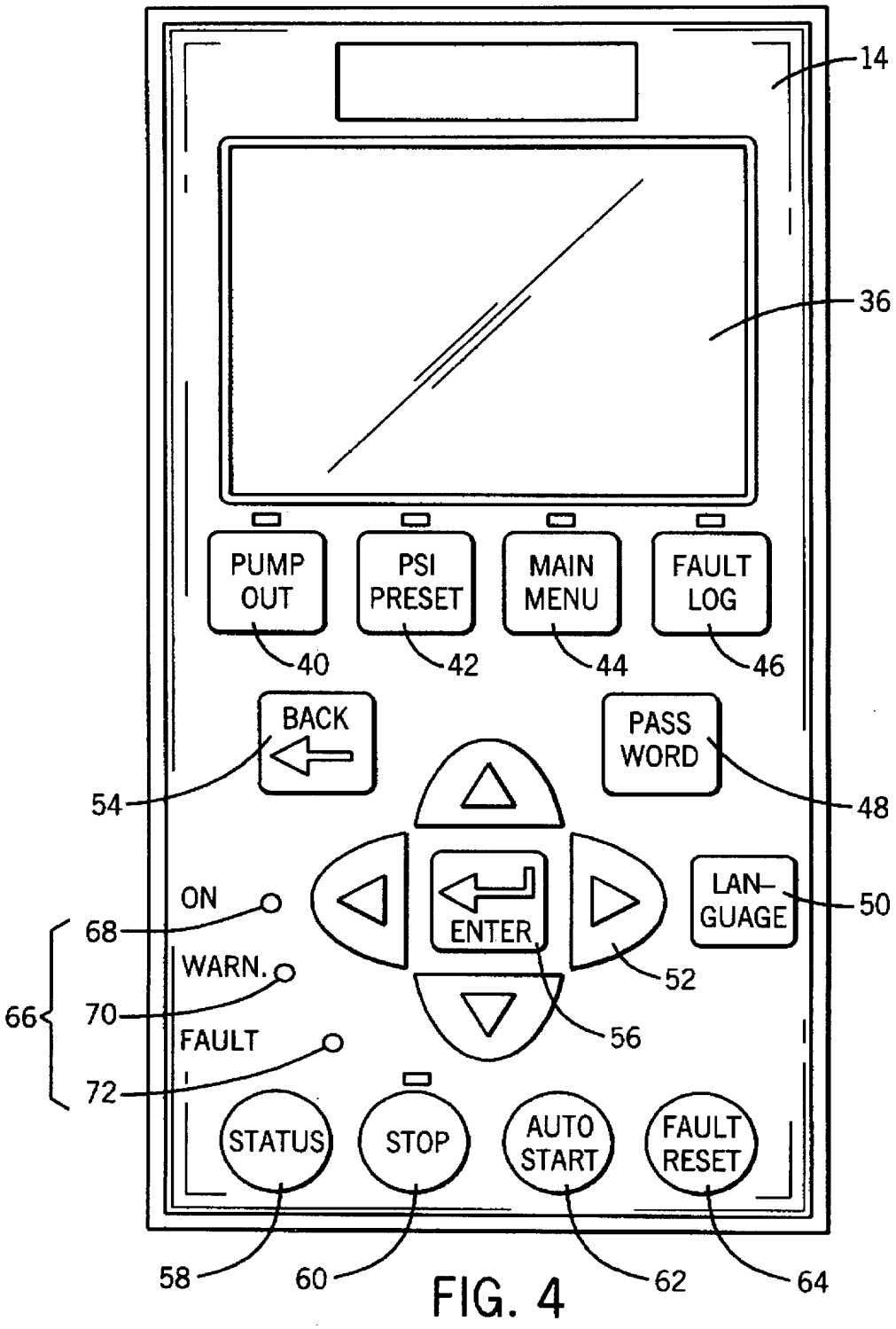

14
36
PUMP OUT
PSI PRESET
MAIN MENU
FAULT LOG
40
42
44
46
BACK
54
PASS WORD
48
ON
68
WARN.
70
FAULT
72
66
ENTER
52
56
LAN-GUAGE
50
STATUS
STOP
AUTO START
FAULT RESET
58
60
62
64

FIG. 4

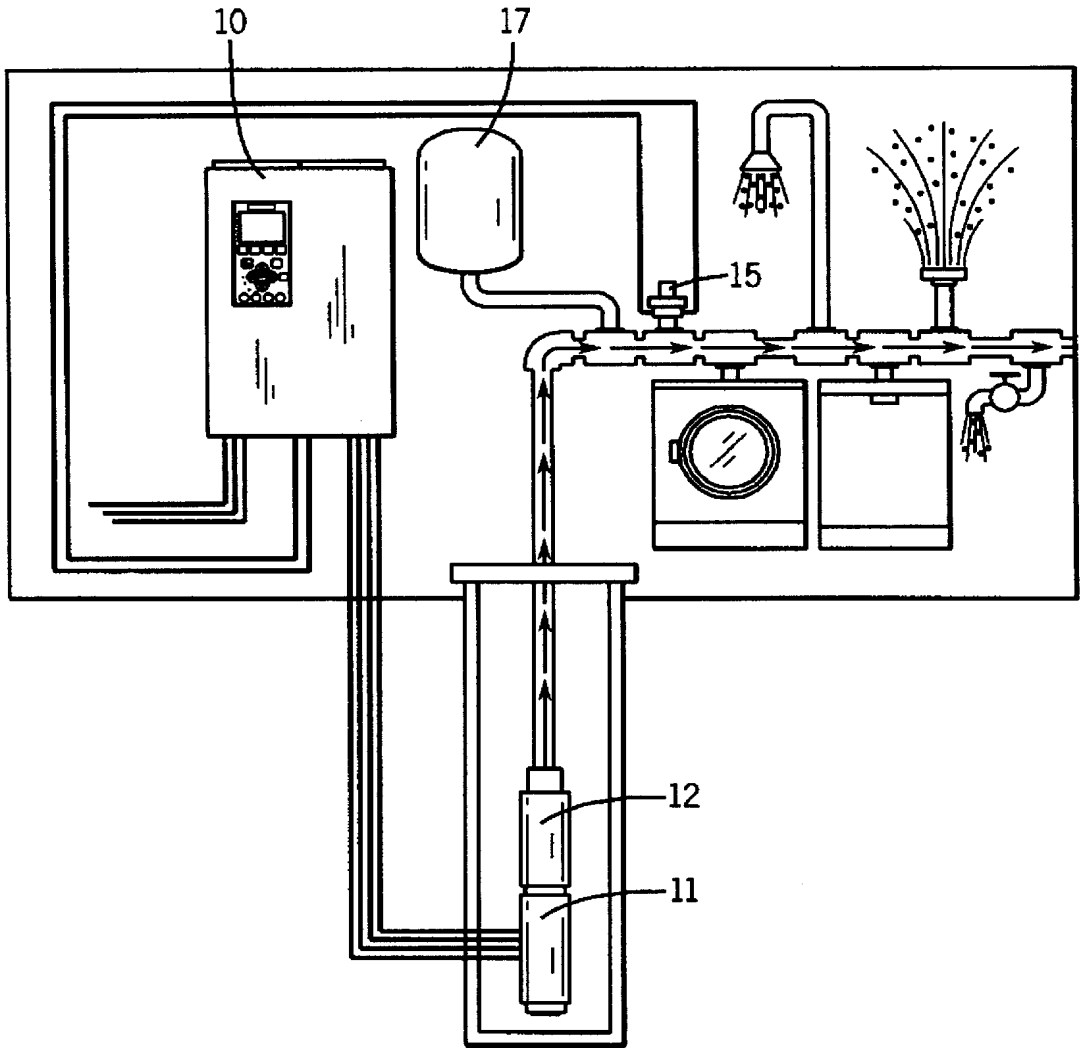


FIG. 5

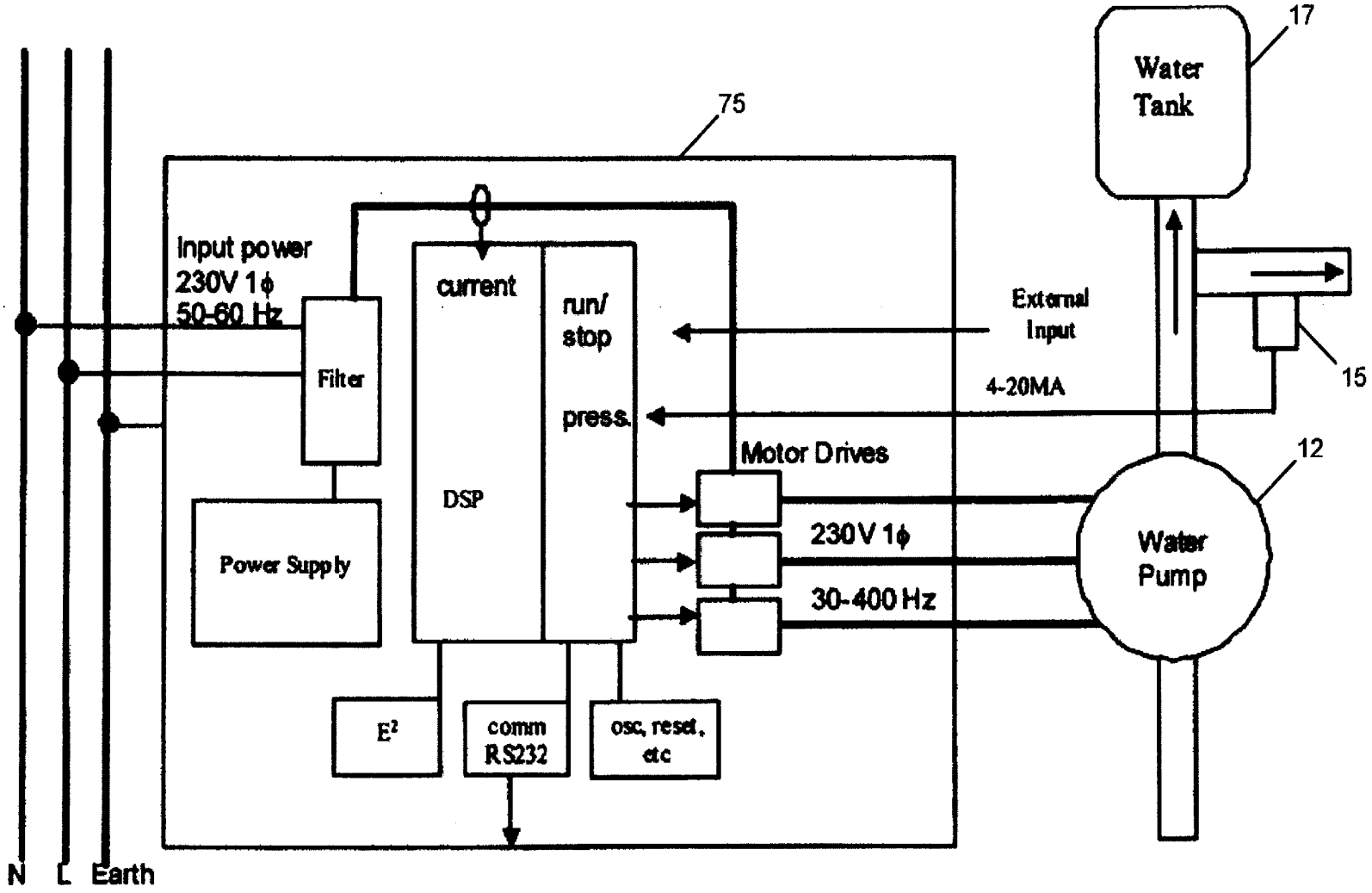


FIGURE 6

CA 02707269 2010-06-08

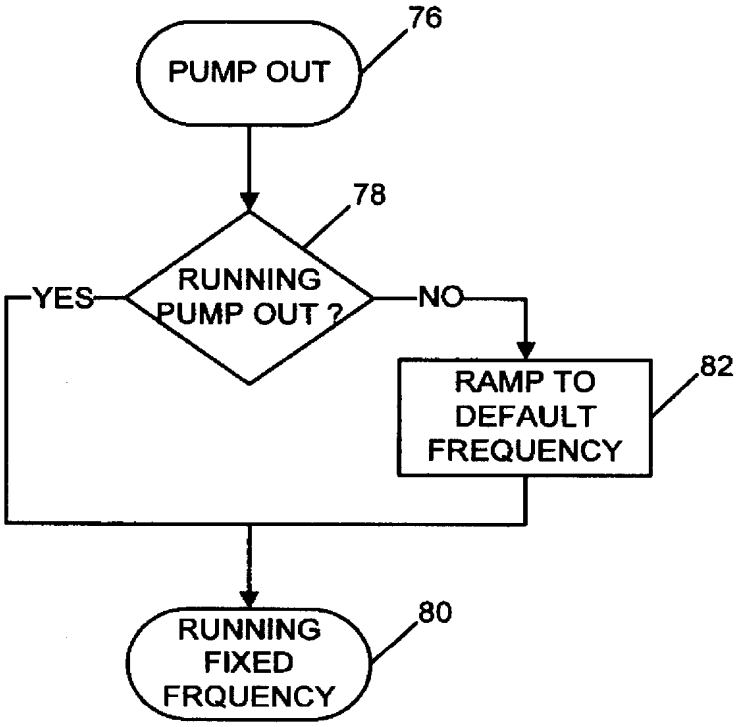

76
PUMP OUT
78
RUNNING
PUMP OUT ?
YES
NO
82
RAMP TO
DEFAULT
FREQUENCY
80
RUNNING
FIXED
FRQUENCY

FIGURE 7

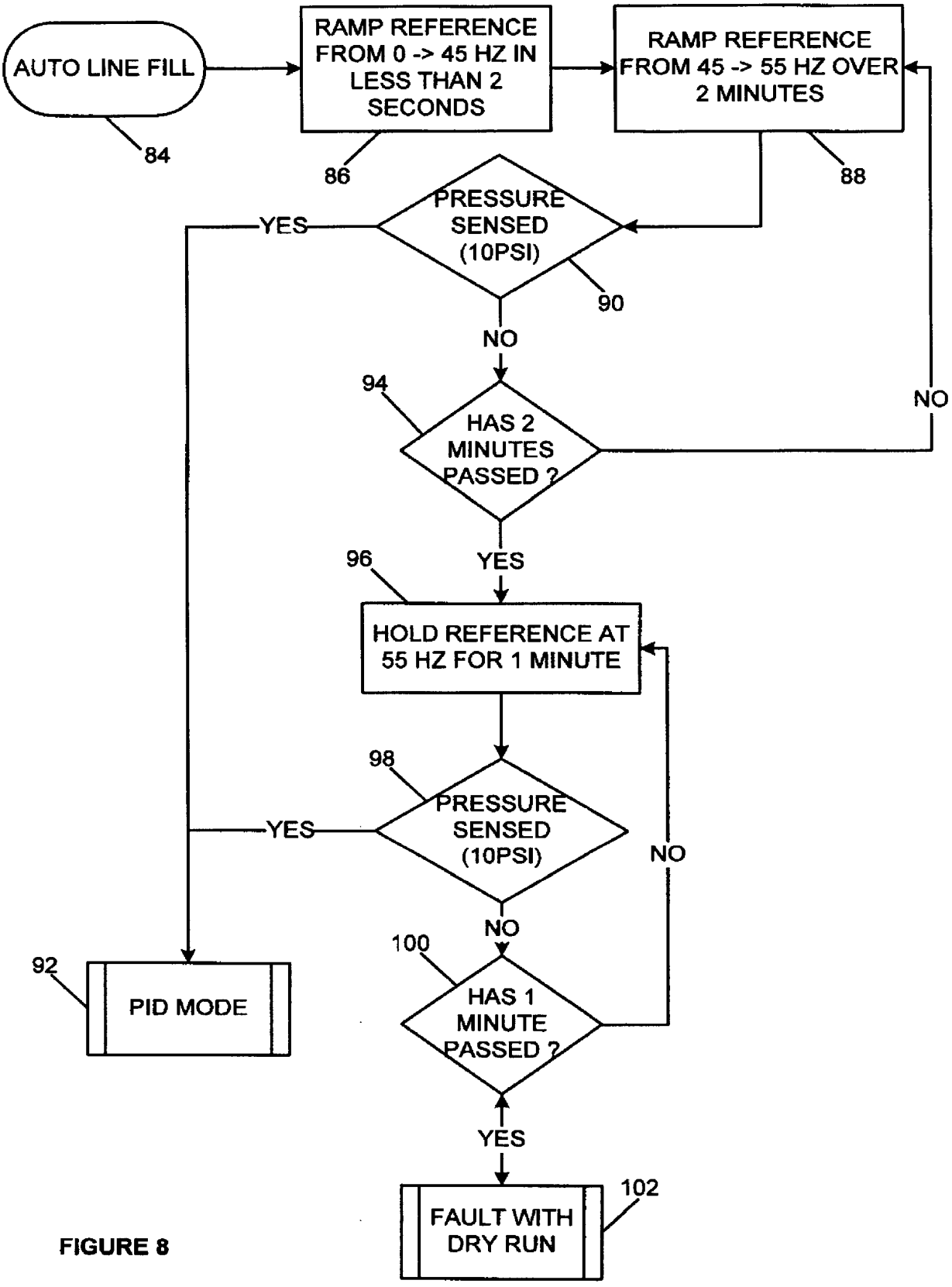

AUTO LINE FILL
84
RAMP REFERENCE FROM 0 -> 45 HZ IN LESS THAN 2 SECONDS
86
RAMP REFERENCE FROM 45 -> 55 HZ OVER 2 MINUTES
88
PRESSURE SENSED (10PSI)
90
YES
NO
94
HAS 2 MINUTES PASSED ?
NO
YES
96
HOLD REFERENCE AT 55 HZ FOR 1 MINUTE
98
PRESSURE SENSED (10PSI)
YES
NO
NO
100
HAS 1 MINUTE PASSED ?
YES
92
PID MODE
102
FAULT WITH DRY RUN

FIGURE 8

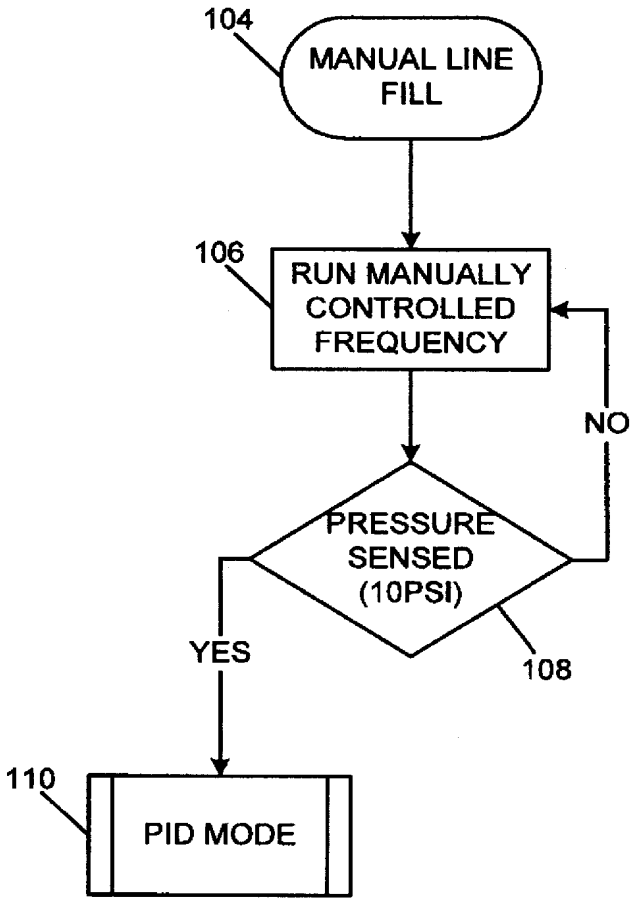

104
MANUAL LINE FILL
106
RUN MANUALLY CONTROLLED FREQUENCY
NO
PRESSURE SENSED (10PSI)
108
YES
110
PID MODE

FIGURE 9

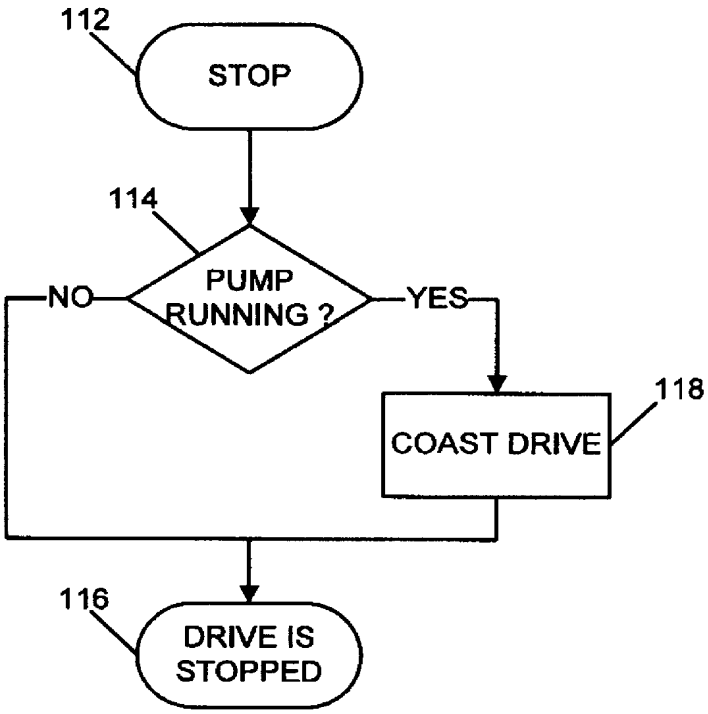

112
STOP
114
PUMP RUNNING ?
NO
YES
118
COAST DRIVE
116
DRIVE IS STOPPED

FIGURE 10

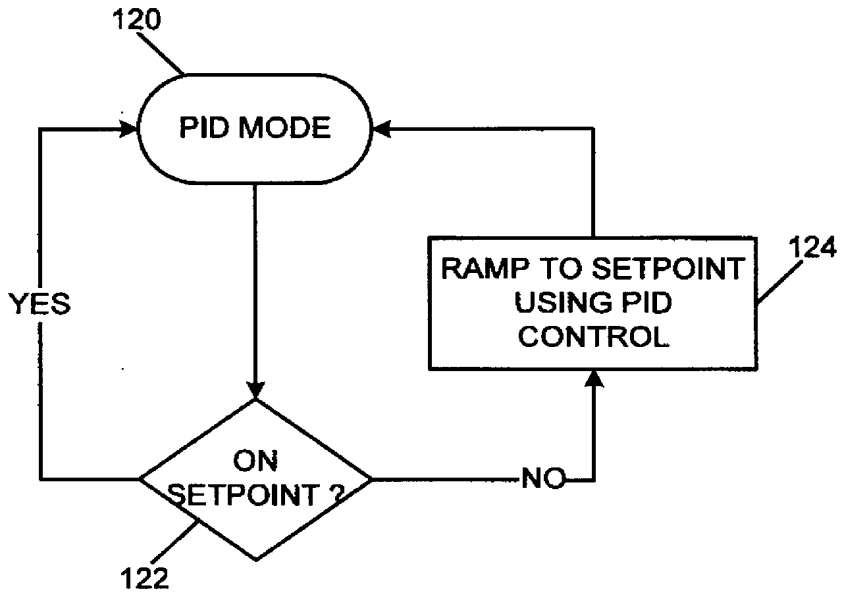

120
PID MODE
RAMP TO SETPOINT USING PID CONTROL
124
YES
ON SETPOINT ?
NO
122

FIGURE 11

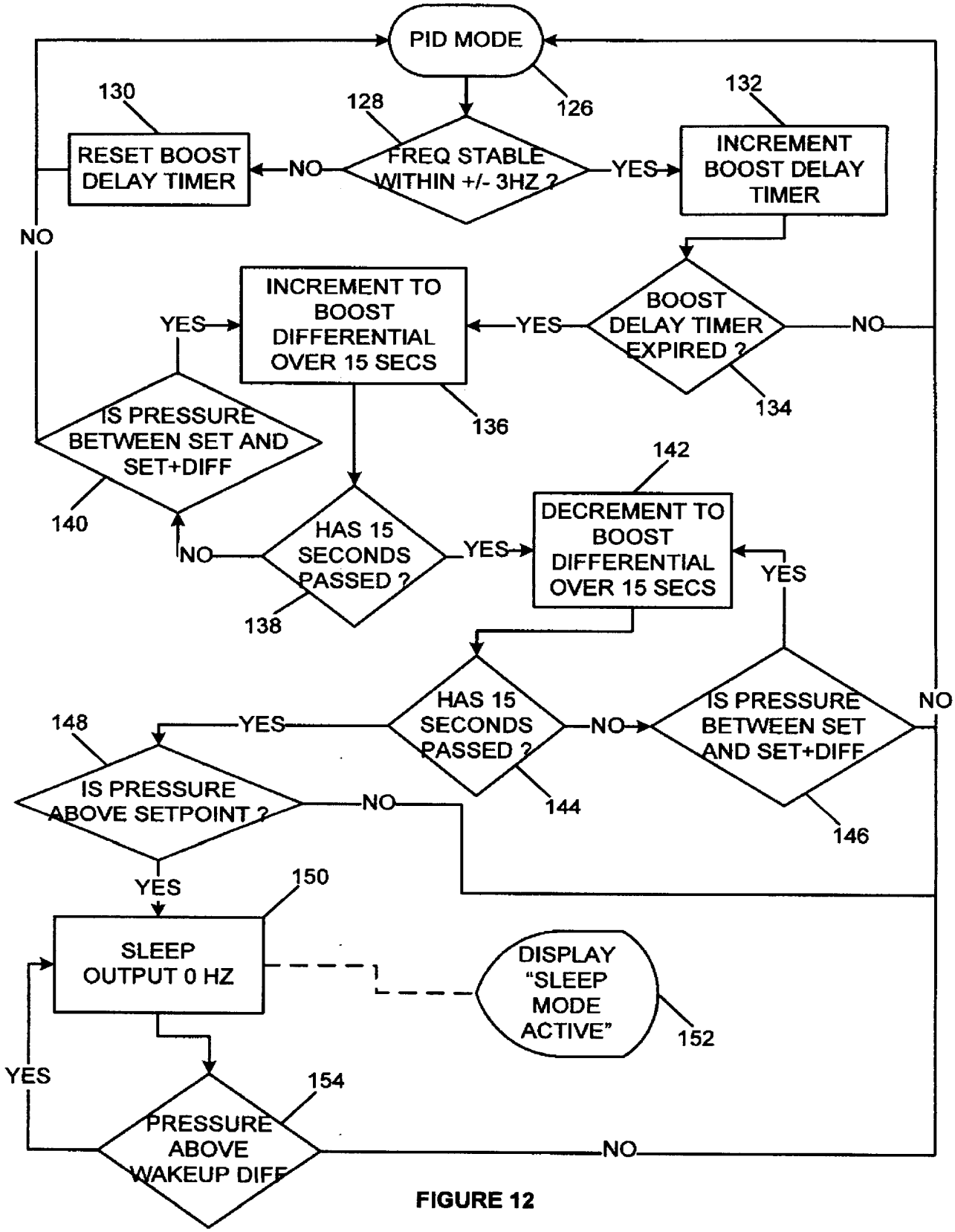

PID MODE
126
128
FREQ STABLE WITHIN +/- 3HZ ?
NO
YES
130
RESET BOOST DELAY TIMER
132
INCREMENT BOOST DELAY TIMER
NO
BOOST DELAY TIMER EXPIRED ?
YES
NO
134
INCREMENT TO BOOST DIFFERENTIAL OVER 15 SECS
YES
136
IS PRESSURE BETWEEN SET AND SET+DIFF
140
NO
HAS 15 SECONDS PASSED ?
YES
138
142
DECREMENT TO BOOST DIFFERENTIAL OVER 15 SECS
YES
NO
HAS 15 SECONDS PASSED ?
YES
NO
144
IS PRESSURE BETWEEN SET AND SET+DIFF
146
148
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

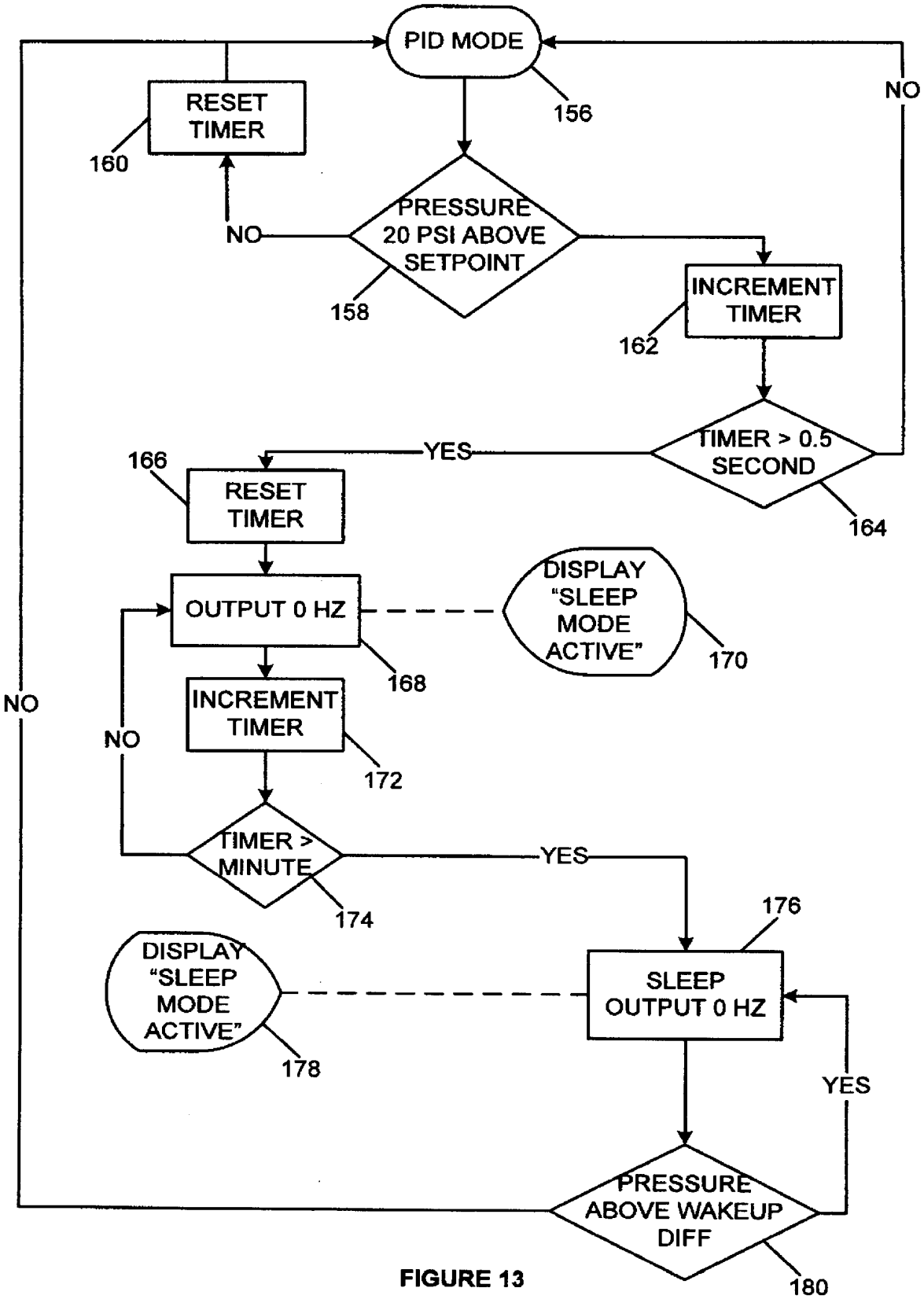

PID MODE
156
NO
RESET TIMER
160
PRESSURE 20 PSI ABOVE SETPOINT
158
NO
INCREMENT TIMER
162
TIMER > 0.5 SECOND
164
YES
166
RESET TIMER
OUTPUT 0 HZ
168
DISPLAY "SLEEP MODE ACTIVE"
170
INCREMENT TIMER
172
NO
NO
TIMER > MINUTE
174
YES
176
DISPLAY "SLEEP MODE ACTIVE"
178
SLEEP OUTPUT 0 HZ
YES
PRESSURE ABOVE WAKEUP DIFF
180

FIGURE 13

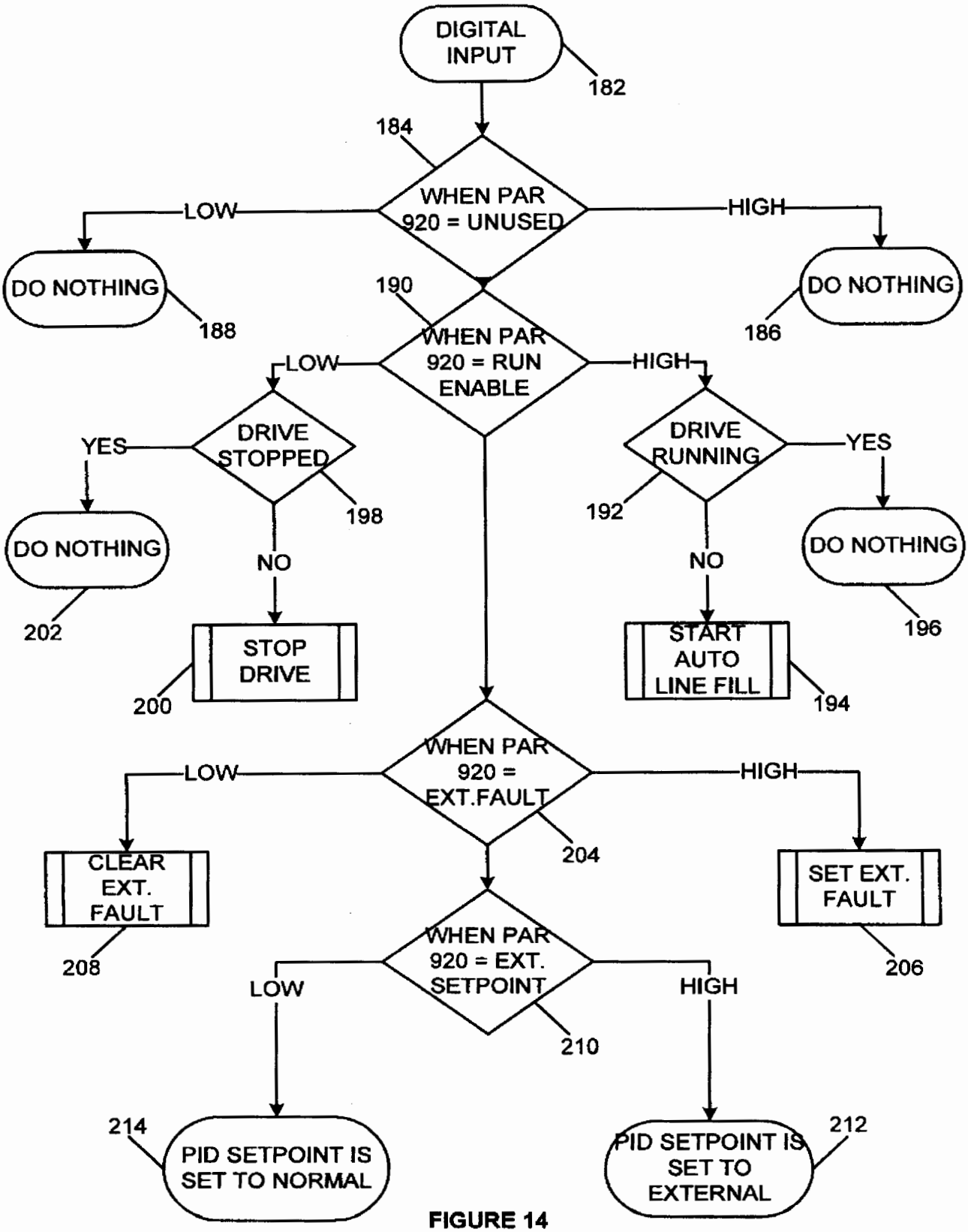

DIGITAL INPUT
182
184
WHEN PAR 920 = UNUSED
LOW
HIGH
DO NOTHING
188
DO NOTHING
186
190
WHEN PAR 920 = RUN ENABLE
LOW
HIGH
DRIVE STOPPED
198
YES
NO
DO NOTHING
202
STOP DRIVE
200
DRIVE RUNNING
192
YES
NO
DO NOTHING
196
START AUTO LINE FILL
194
WHEN PAR 920 = EXT.FAULT
204
LOW
HIGH
CLEAR EXT. FAULT
208
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

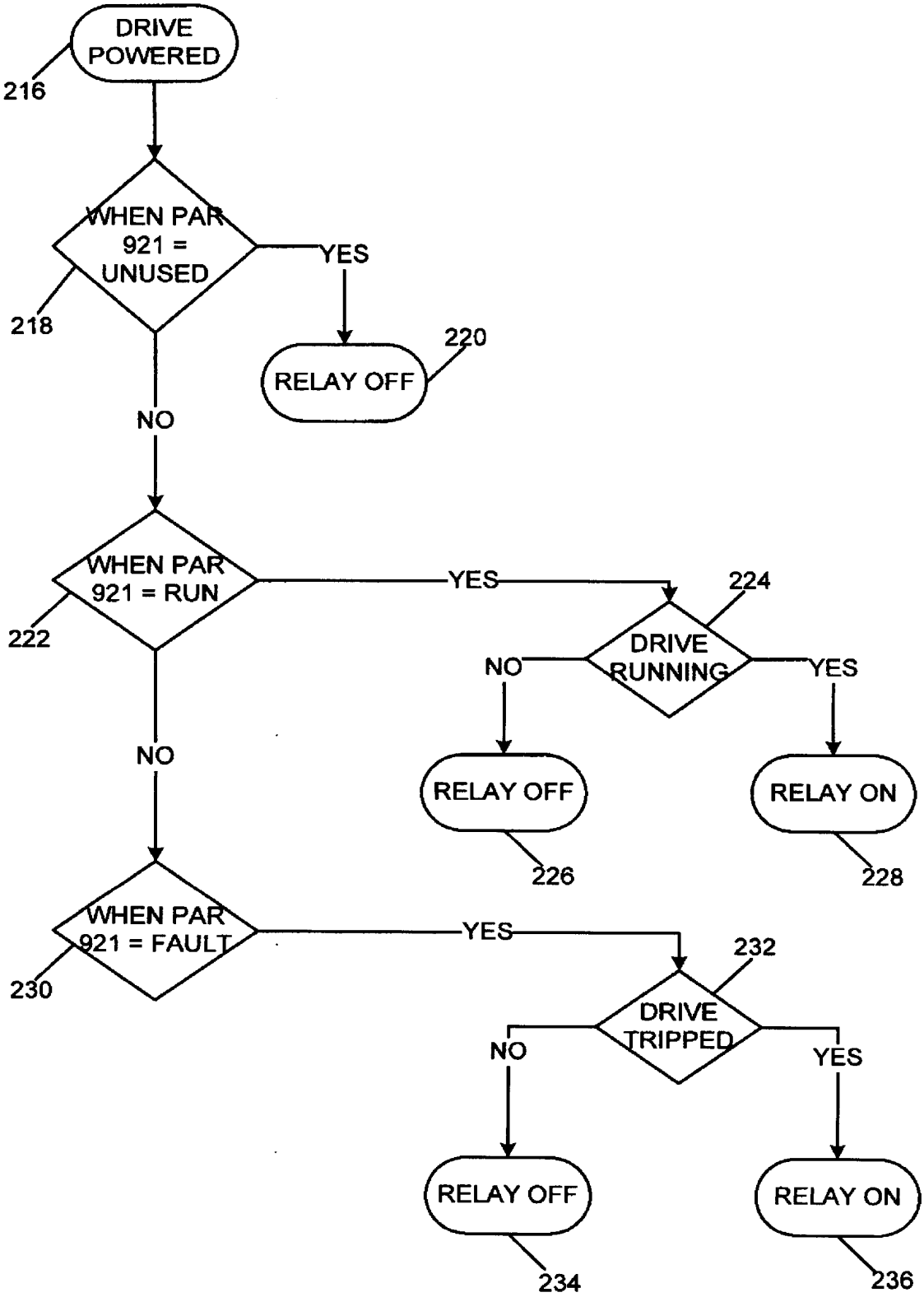

DRIVE POWERED
216
WHEN PAR 921 = UNUSED
218
YES
220
RELAY OFF
NO
WHEN PAR 921 = RUN
222
YES
224
DRIVE RUNNING
NO
YES
RELAY OFF
226
RELAY ON
228
NO
WHEN PAR 921 = FAULT
230
YES
232
DRIVE TRIPPED
NO
YES
RELAY OFF
234
RELAY ON
236

FIGURE 15

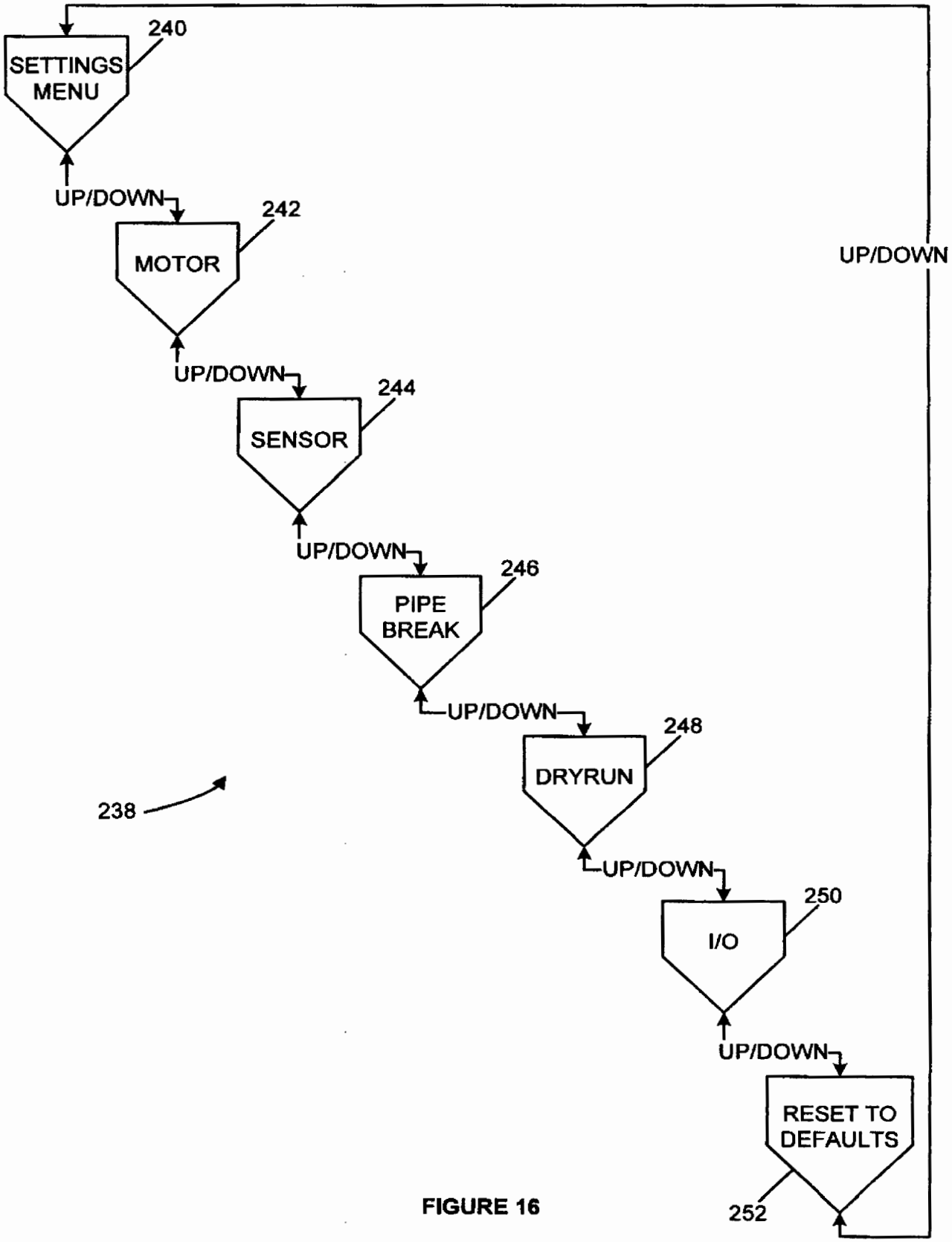

240
SETTINGS MENU
UP/DOWN
242
MOTOR
UP/DOWN
244
SENSOR
UP/DOWN
246
PIPE BREAK
UP/DOWN
248
DRYRUN
UP/DOWN
250
I/O
UP/DOWN
RESET TO DEFAULTS
252
UP/DOWN
238

FIGURE 16

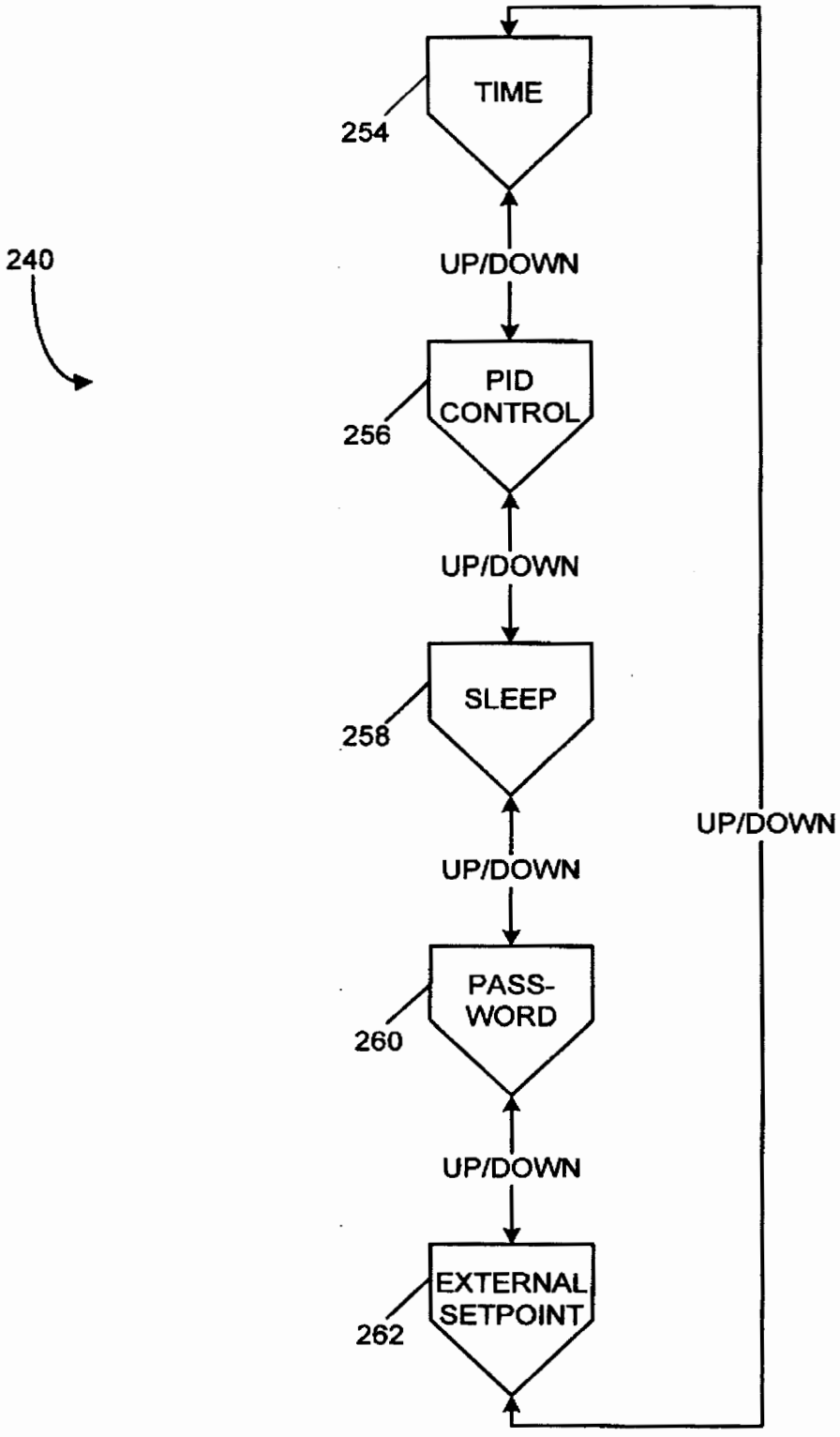

240
TIME
254
UP/DOWN
PID CONTROL
256
UP/DOWN
SLEEP
258
UP/DOWN
PASS-WORD
260
UP/DOWN
EXTERNAL SETPOINT
262
UP/DOWN

FIGURE 17

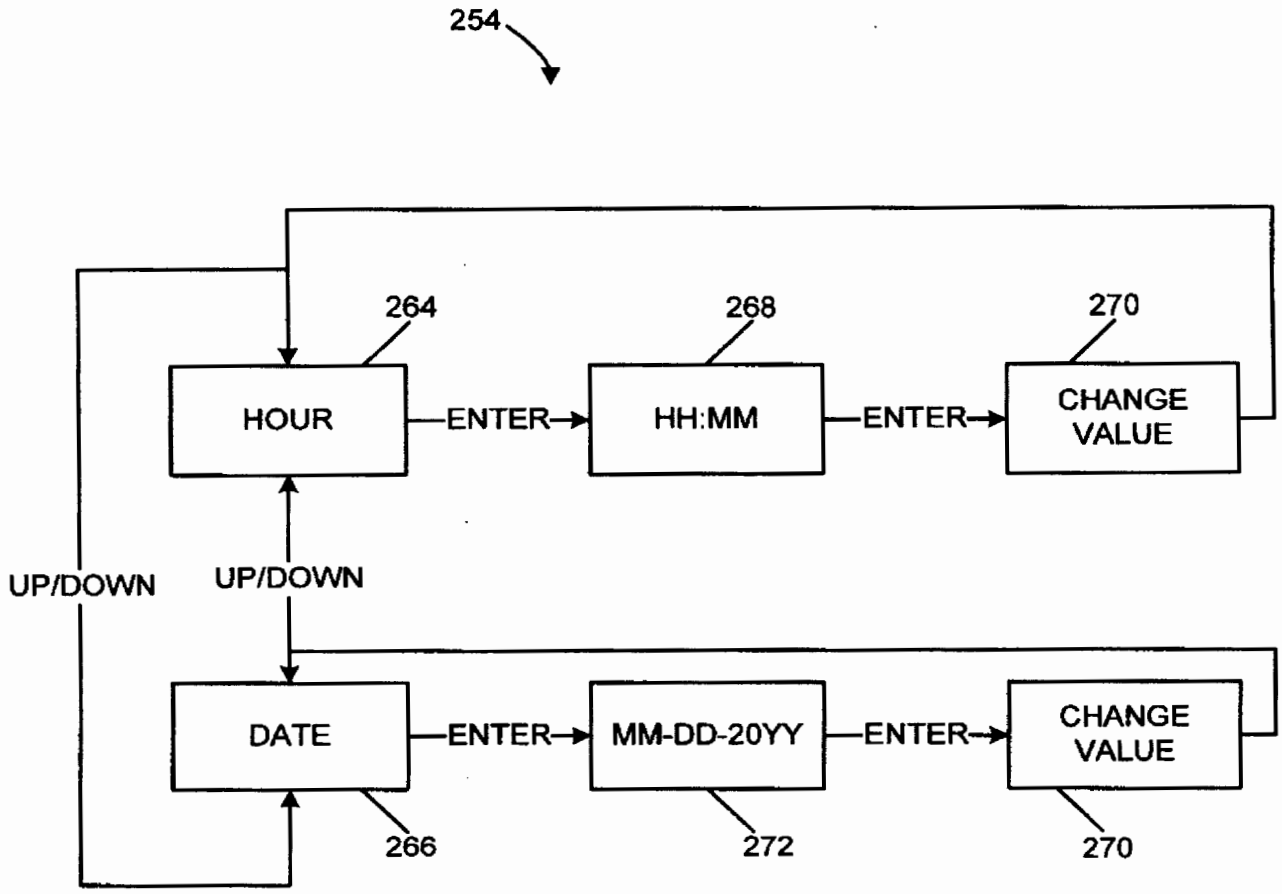

254
264
268
270
HOUR
ENTER
HH:MM
ENTER
CHANGE VALUE
UP/DOWN
UP/DOWN
DATE
ENTER
MM-DD-20YY
ENTER
CHANGE VALUE
266
272
270

FIGURE 18

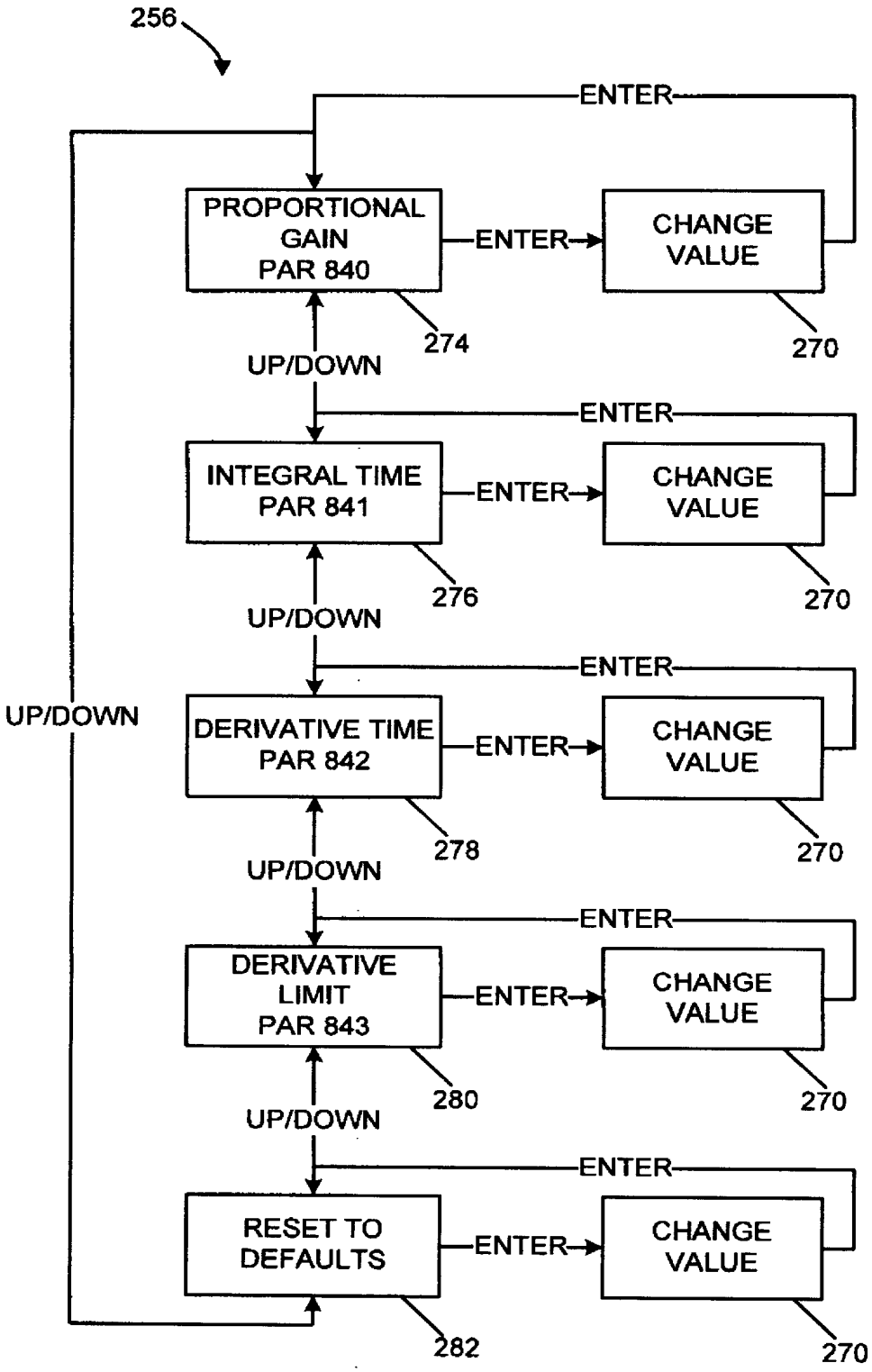

256
ENTER
PROPORTIONAL GAIN PAR 840
ENTER
CHANGE VALUE
274
270
UP/DOWN
ENTER
INTEGRAL TIME PAR 841
ENTER
CHANGE VALUE
276
270
UP/DOWN
ENTER
UP/DOWN
DERIVATIVE TIME PAR 842
ENTER
CHANGE VALUE
278
270
UP/DOWN
ENTER
DERIVATIVE LIMIT PAR 843
ENTER
CHANGE VALUE
280
270
UP/DOWN
ENTER
RESET TO DEFAULTS
ENTER
CHANGE VALUE
282
270

FIGURE 19

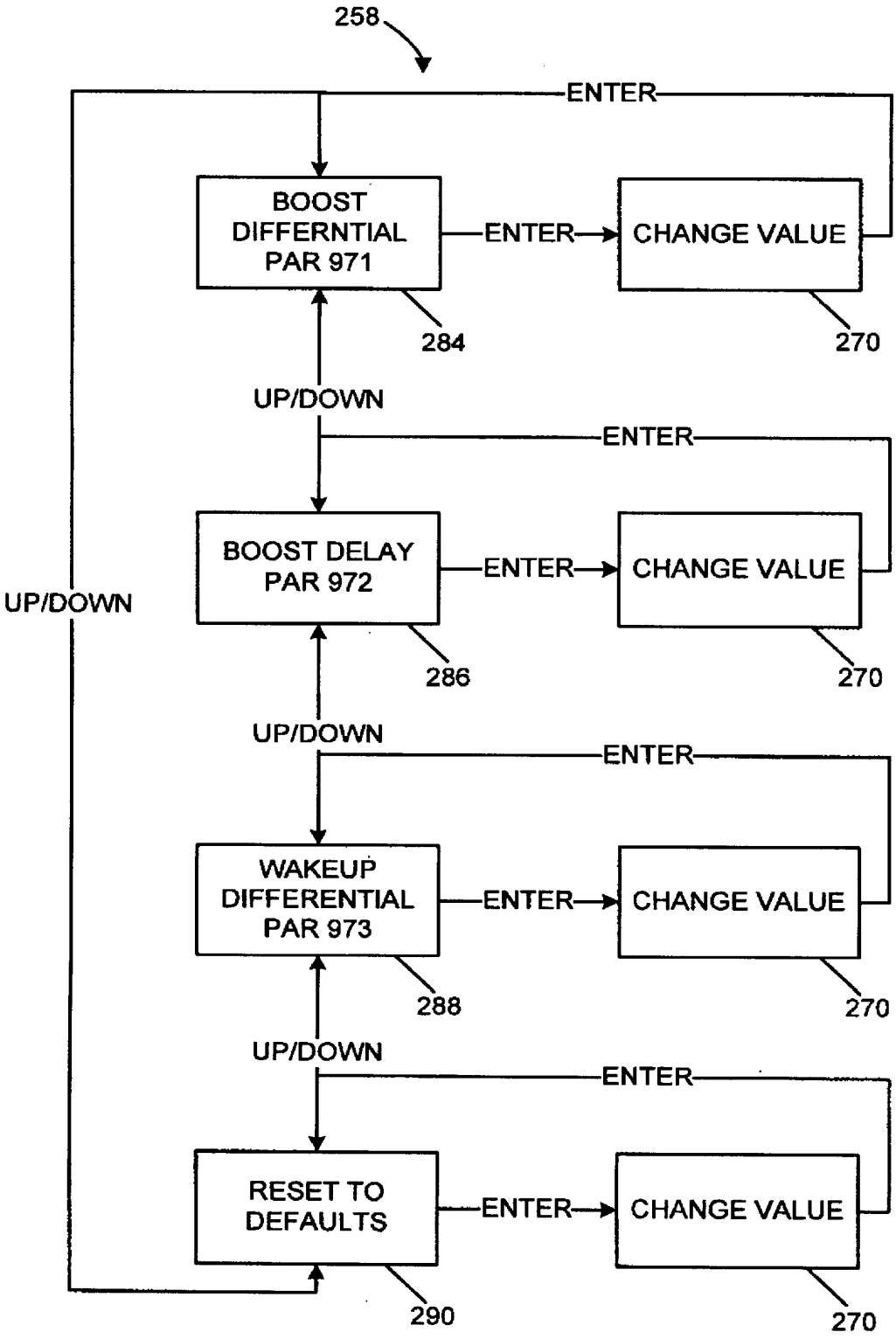

258
ENTER
BOOST DIFFERNTIAL PAR 971
ENTER
CHANGE VALUE
284
270
UP/DOWN
ENTER
BOOST DELAY PAR 972
ENTER
CHANGE VALUE
UP/DOWN
286
270
UP/DOWN
ENTER
WAKEUP DIFFERENTIAL PAR 973
ENTER
CHANGE VALUE
288
270
UP/DOWN
ENTER
RESET TO DEFAULTS
ENTER
CHANGE VALUE
290
270

FIGURE 20

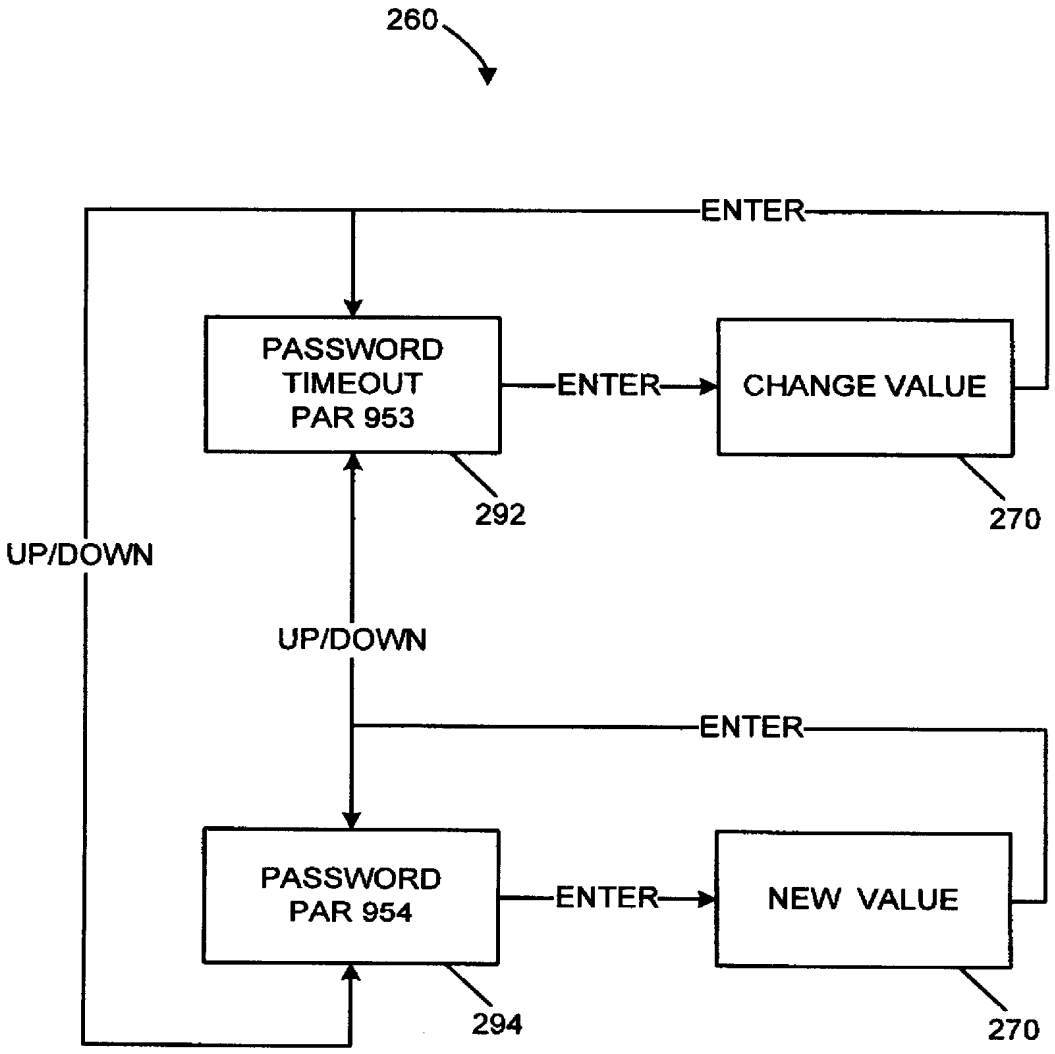

260
ENTER
PASSWORD
TIMEOUT
PAR 953
ENTER
CHANGE VALUE
292
270
UP/DOWN
UP/DOWN
ENTER
PASSWORD
PAR 954
ENTER
NEW VALUE
294
270

FIGURE 21

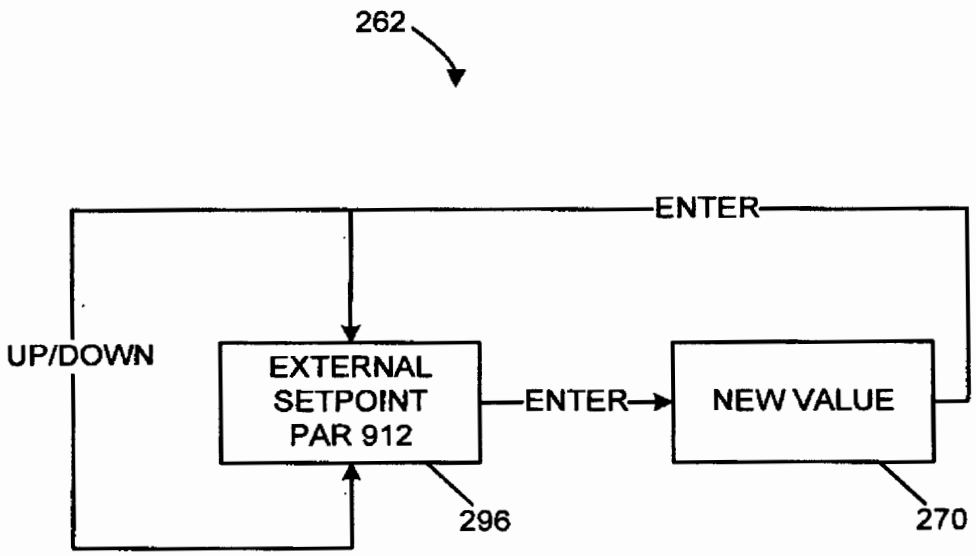

262
ENTER
UP/DOWN
EXTERNAL SETPOINT PAR 912
ENTER
NEW VALUE
296
270

FIGURE 22

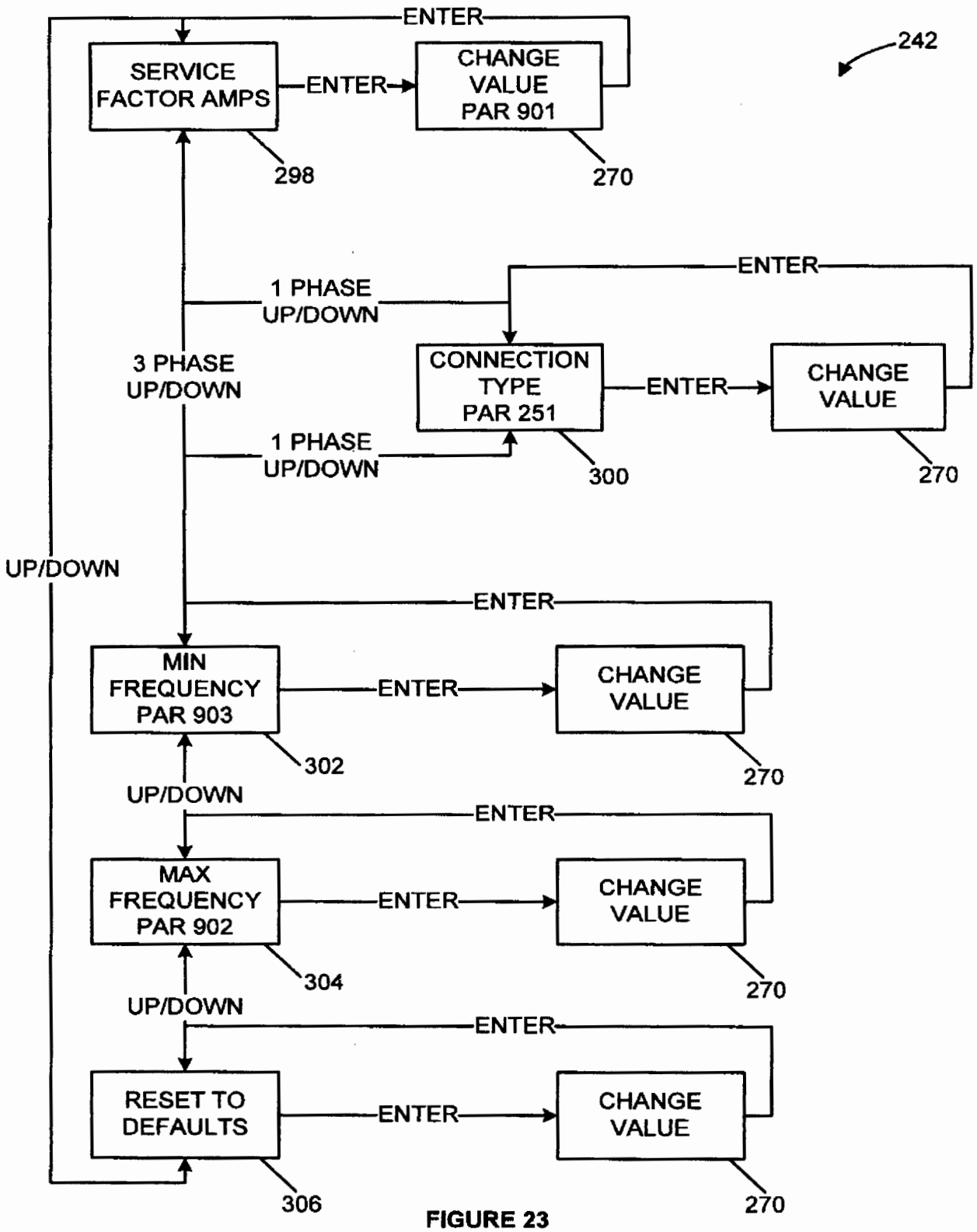

ENTER
242
SERVICE FACTOR AMPS
ENTER
CHANGE VALUE PAR 901
298
270
1 PHASE UP/DOWN
ENTER
3 PHASE UP/DOWN
CONNECTION TYPE PAR 251
ENTER
CHANGE VALUE
1 PHASE UP/DOWN
300
270
UP/DOWN
ENTER
MIN FREQUENCY PAR 903
ENTER
CHANGE VALUE
302
270
UP/DOWN
ENTER
MAX FREQUENCY PAR 902
ENTER
CHANGE VALUE
304
270
UP/DOWN
ENTER
RESET TO DEFAULTS
ENTER
CHANGE VALUE
306
270

FIGURE 23

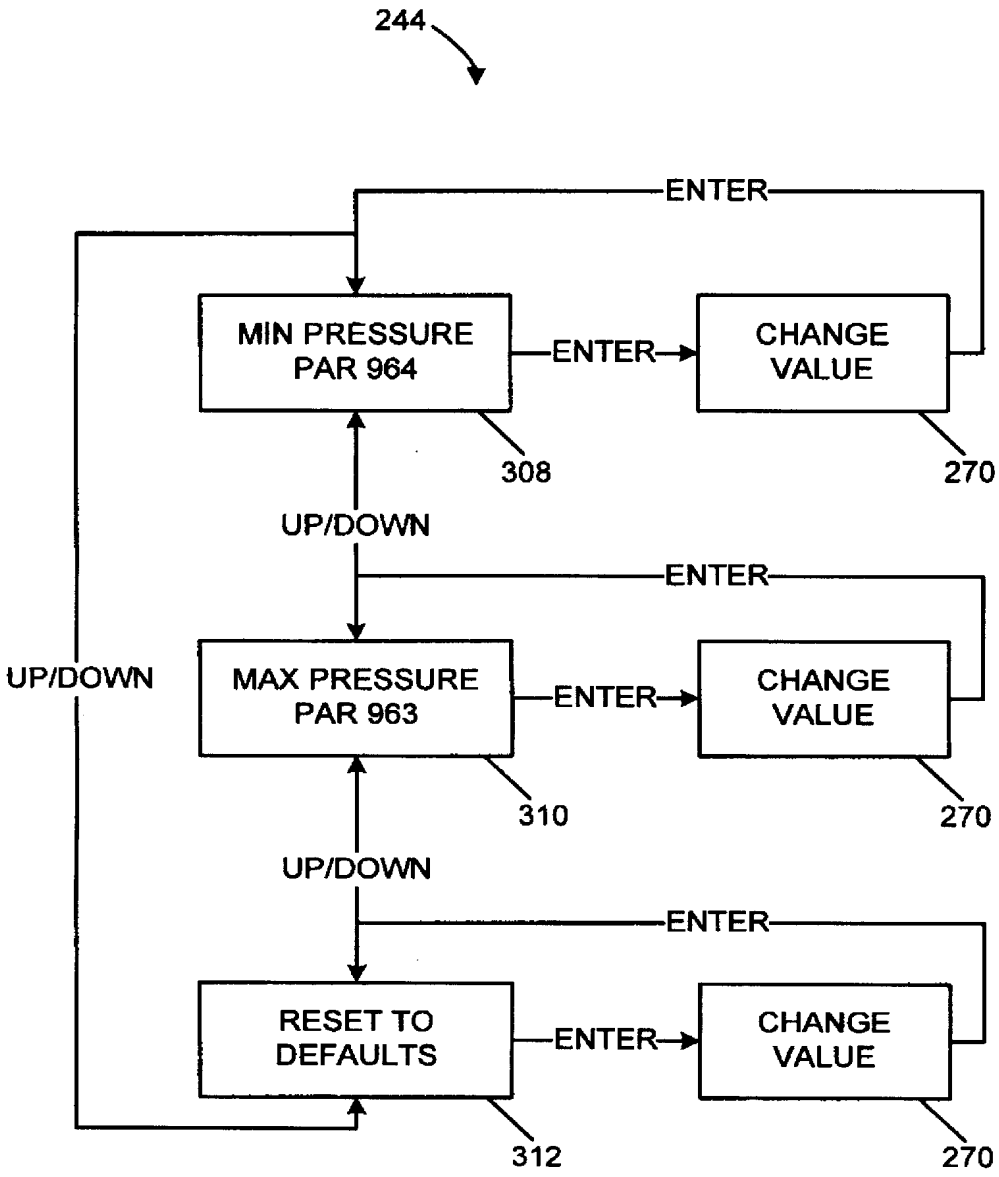

244
ENTER
MIN PRESSURE
PAR 964
ENTER
CHANGE
VALUE
308
270
UP/DOWN
ENTER
UP/DOWN
MAX PRESSURE
PAR 963
ENTER
CHANGE
VALUE
310
270
UP/DOWN
ENTER
RESET TO
DEFAULTS
ENTER
CHANGE
VALUE
312
270

FIGURE 24

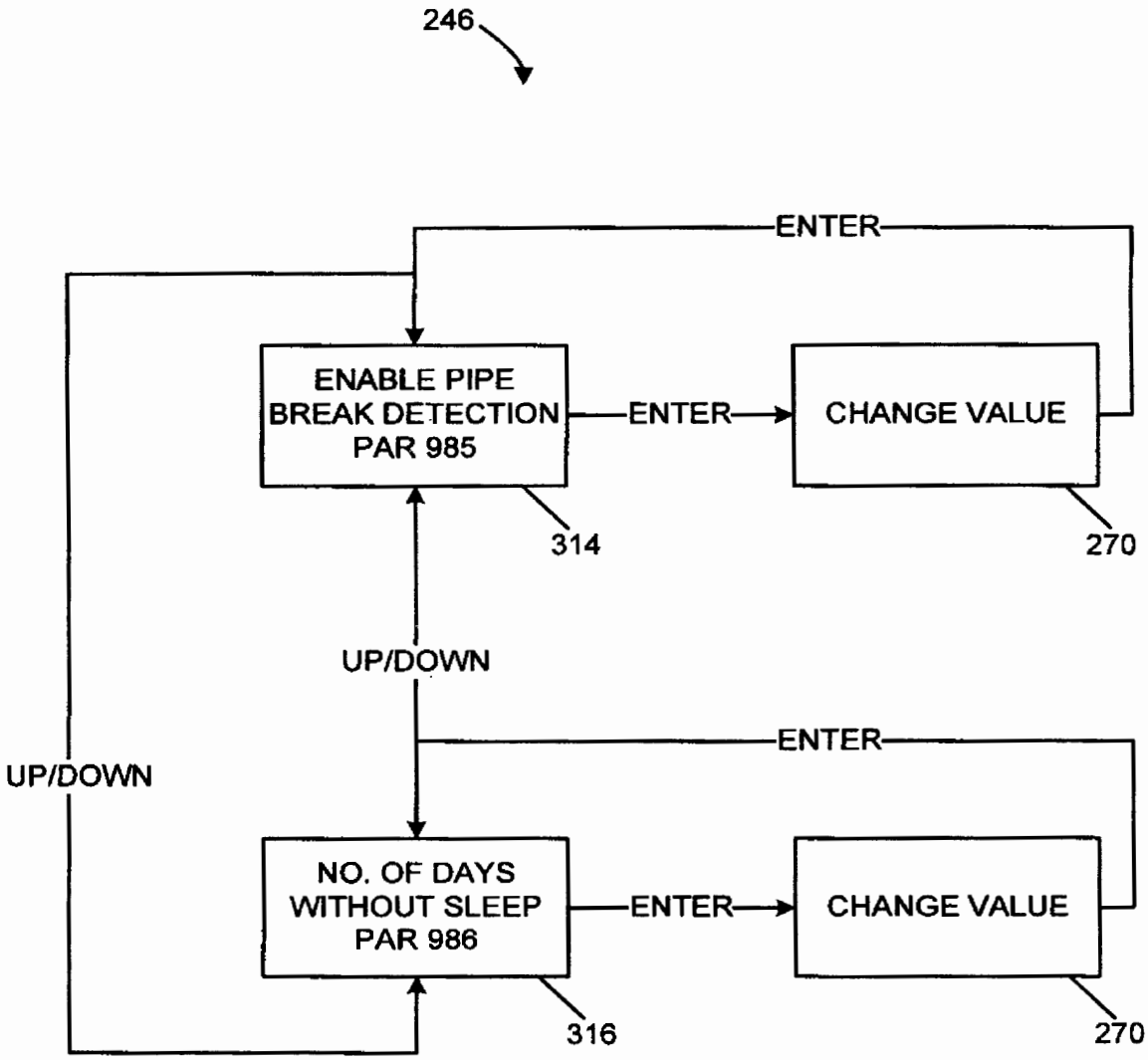

246
ENTER
ENABLE PIPE BREAK DETECTION PAR 985
ENTER
CHANGE VALUE
314
270
UP/DOWN
ENTER
UP/DOWN
NO. OF DAYS WITHOUT SLEEP PAR 986
ENTER
CHANGE VALUE
316
270

FIGURE 25

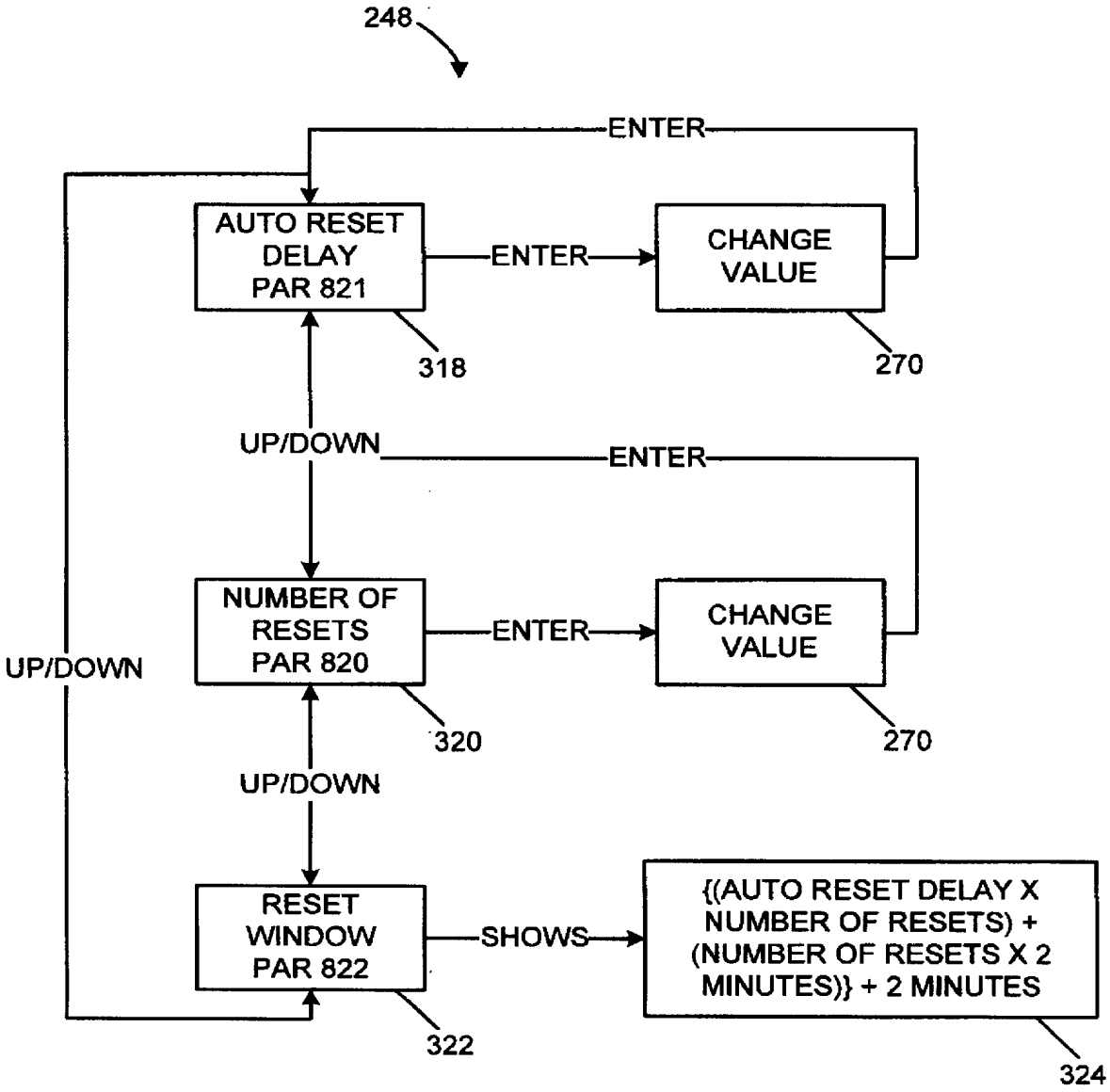

248
ENTER
AUTO RESET DELAY PAR 821
ENTER
CHANGE VALUE
318
270
UP/DOWN
ENTER
NUMBER OF RESETS PAR 820
ENTER
CHANGE VALUE
UP/DOWN
320
270
UP/DOWN
RESET WINDOW PAR 822
SHOWS
{(AUTO RESET DELAY X NUMBER OF RESETS) + (NUMBER OF RESETS X 2 MINUTES)} + 2 MINUTES
322
324

FIGURE 26

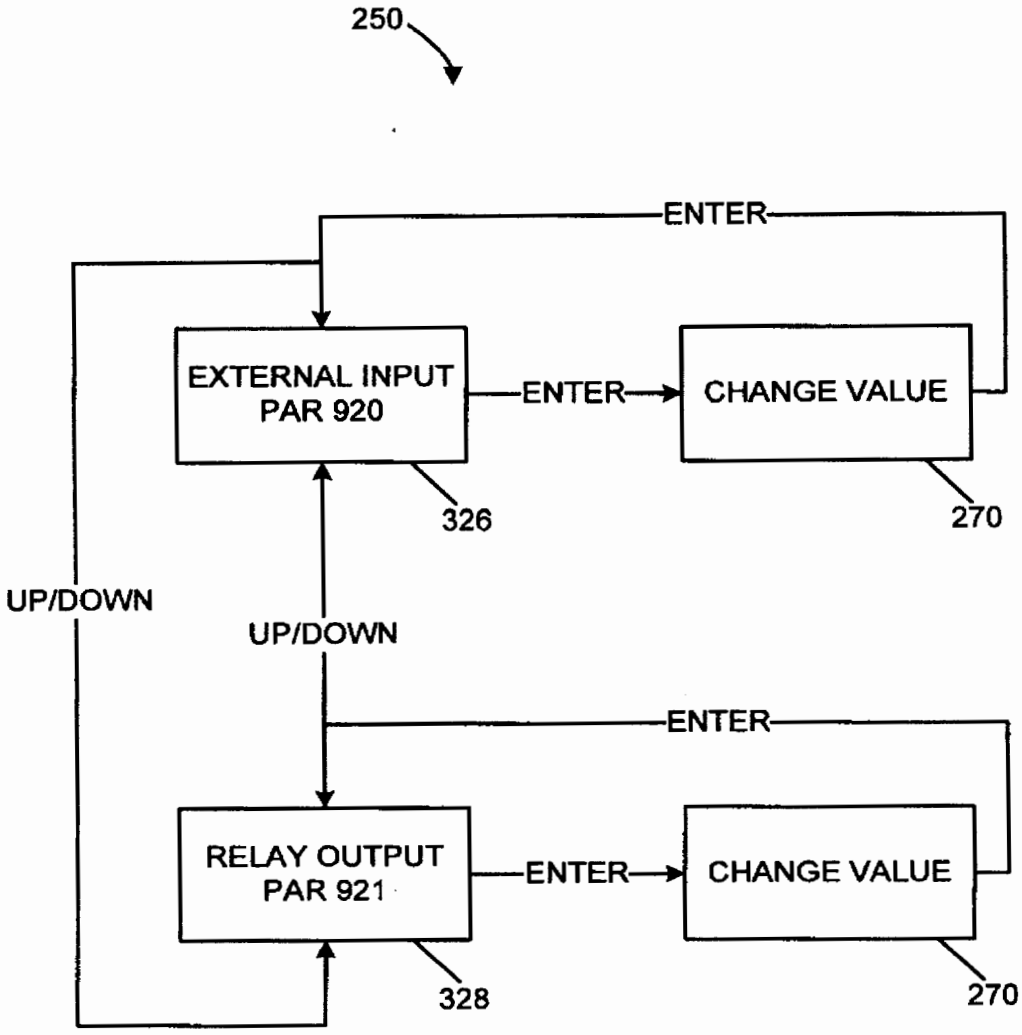

250
ENTER
EXTERNAL INPUT
PAR 920
ENTER
CHANGE VALUE
326
270
UP/DOWN
UP/DOWN
ENTER
RELAY OUTPUT
PAR 921
ENTER
CHANGE VALUE
328
270

FIGURE 27

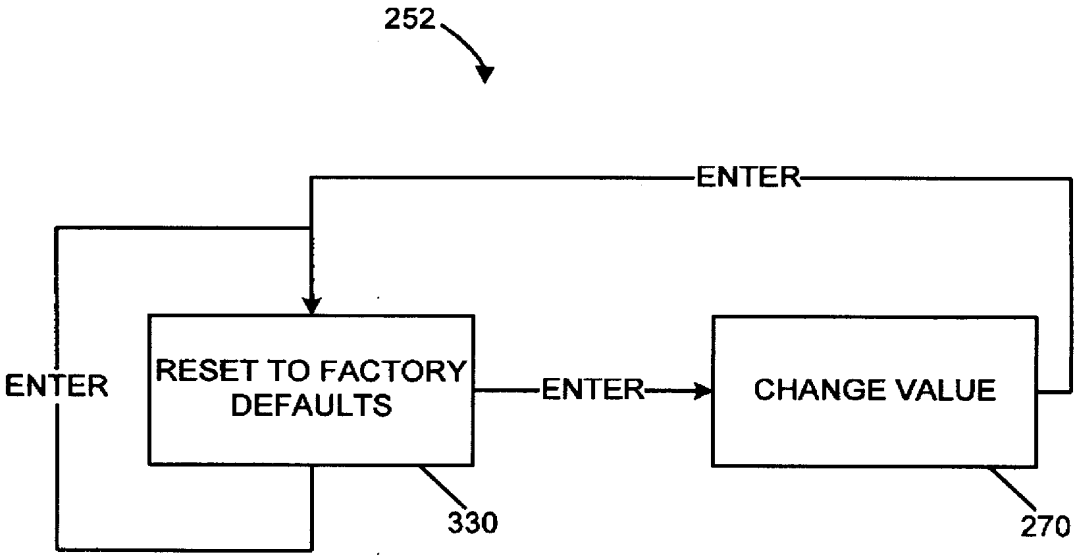

252
ENTER
ENTER
RESET TO FACTORY DEFAULTS
ENTER
CHANGE VALUE
330
270

FIGURE 28

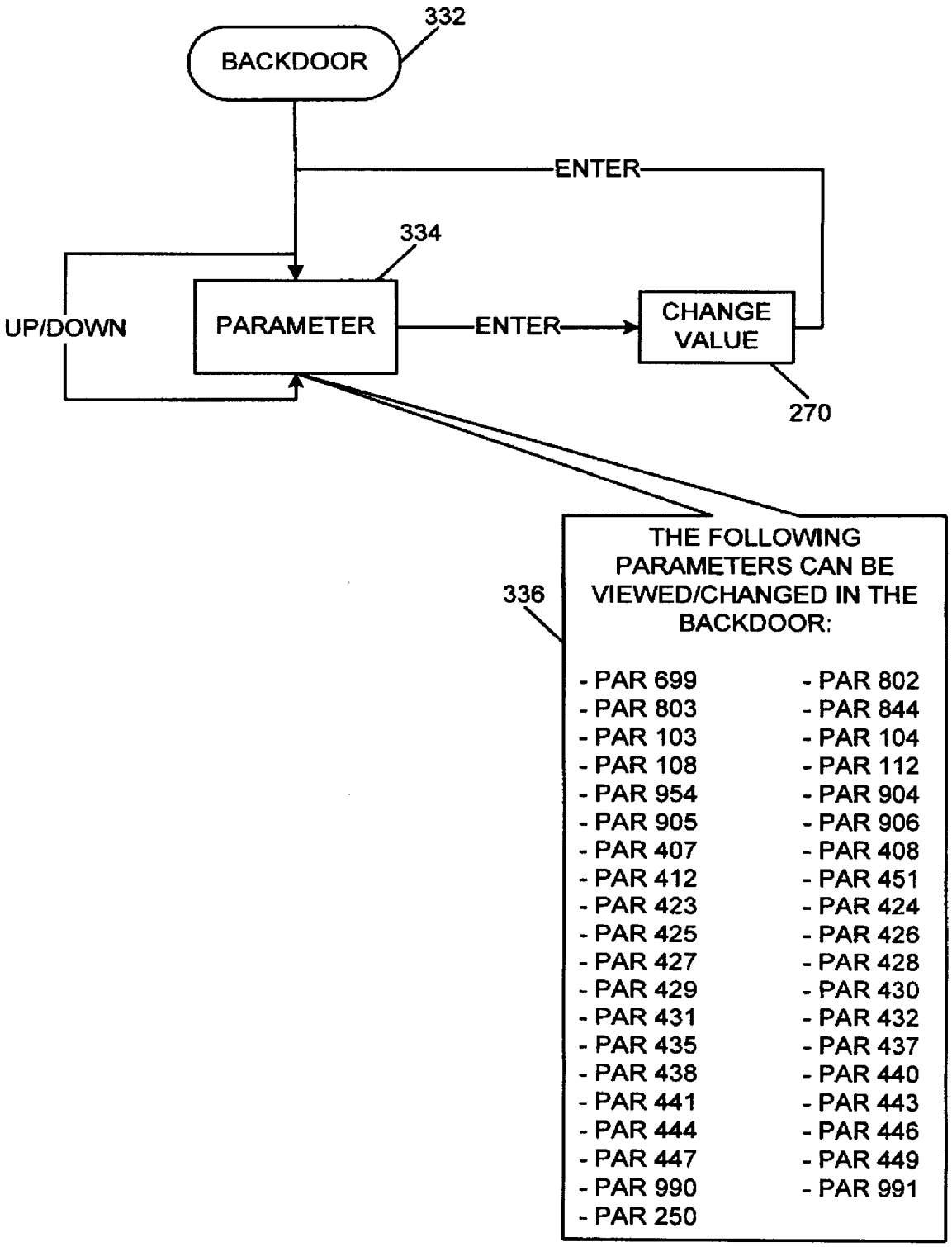

332
BACKDOOR
ENTER
334
UP/DOWN
PARAMETER
ENTER
CHANGE VALUE
270
336
THE FOLLOWING PARAMETERS CAN BE VIEWED/CHANGED IN THE BACKDOOR:
- PAR 699
- PAR 802
- PAR 803
- PAR 844
- PAR 103
- PAR 104
- PAR 108
- PAR 112
- PAR 954
- PAR 904
- PAR 905
- PAR 906
- PAR 407
- PAR 408
- PAR 412
- PAR 451
- PAR 423
- 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

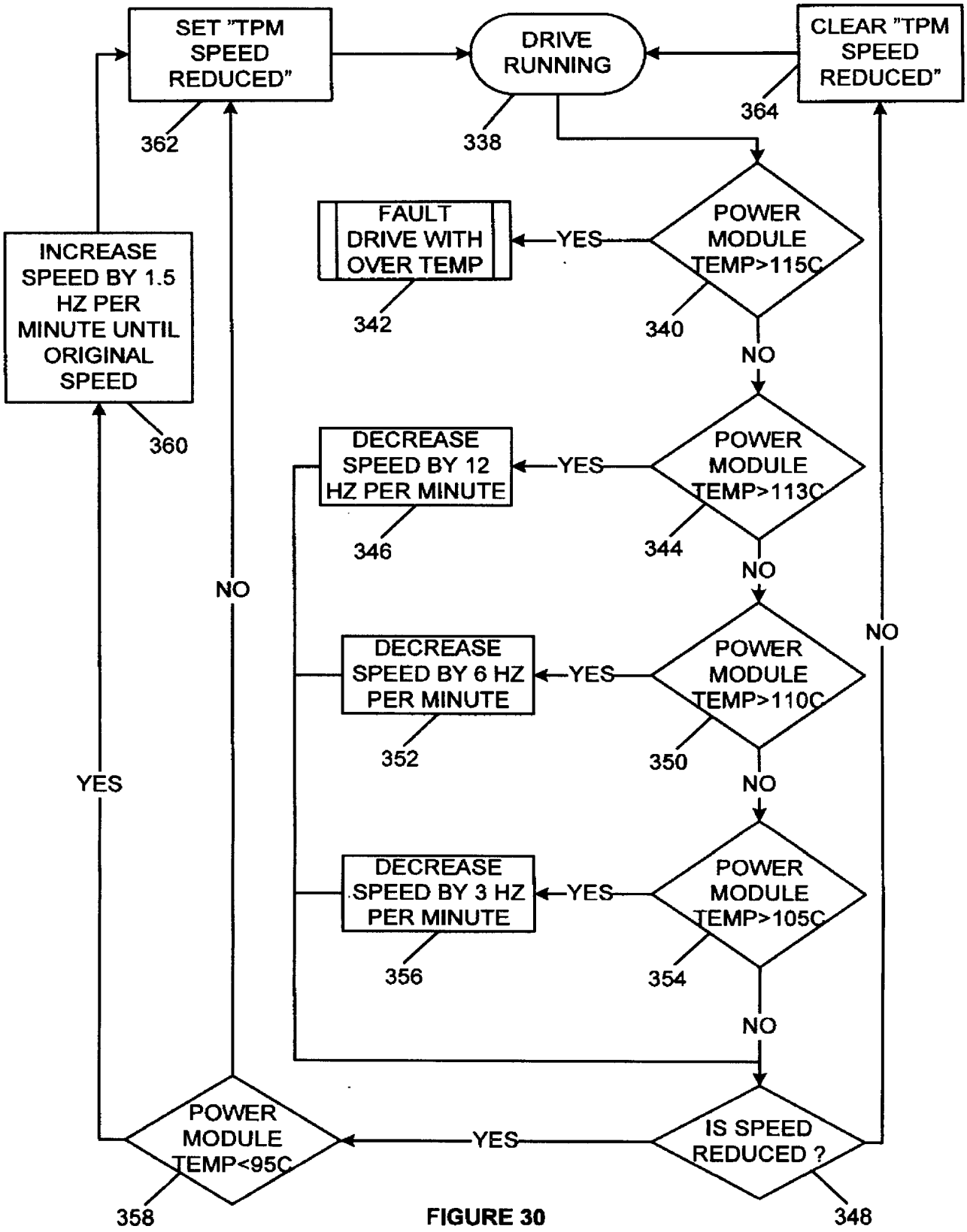

SET "TPM SPEED REDUCED"
362
DRIVE RUNNING
338
CLEAR "TPM SPEED REDUCED"
364
POWER MODULE TEMP>115C
340
YES
FAULT DRIVE WITH OVER TEMP
342
NO
POWER MODULE TEMP>113C
344
YES
DECREASE SPEED BY 12 HZ PER MINUTE
346
NO
POWER MODULE TEMP>110C
350
YES
DECREASE SPEED BY 6 HZ PER MINUTE
352
NO
POWER MODULE TEMP>105C
354
YES
DECREASE SPEED BY 3 HZ PER MINUTE
356
NO
IS SPEED REDUCED ?
348
YES
POWER MODULE TEMP<95C
358
YES
INCREASE SPEED BY 1.5 HZ PER MINUTE UNTIL ORIGINAL SPEED
360
NO
NO

FIGURE 30

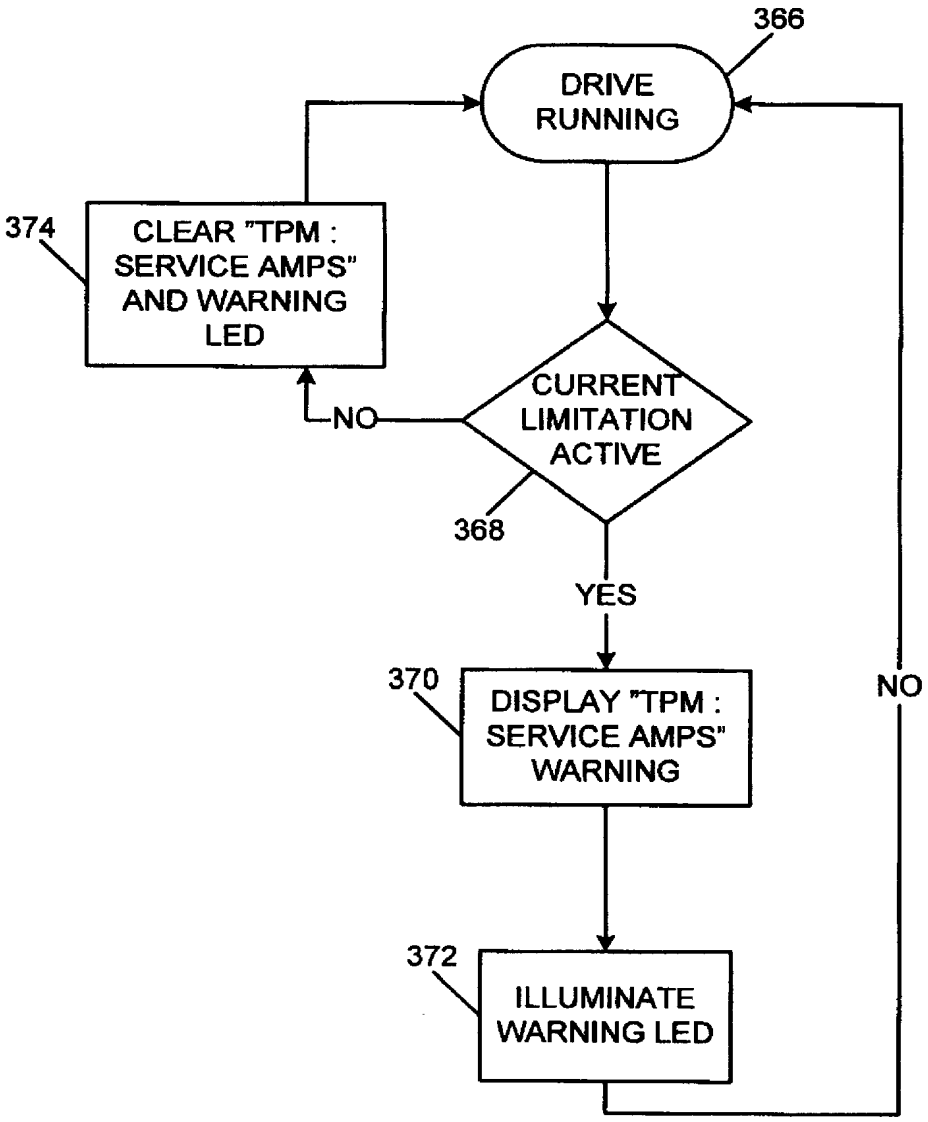

366
DRIVE RUNNING
374
CLEAR "TPM : SERVICE AMPS" AND WARNING LED
CURRENT LIMITATION ACTIVE
NO
368
YES
370
DISPLAY "TPM : SERVICE AMPS" WARNING
372
ILLUMINATE WARNING LED
NO

FIGURE 31

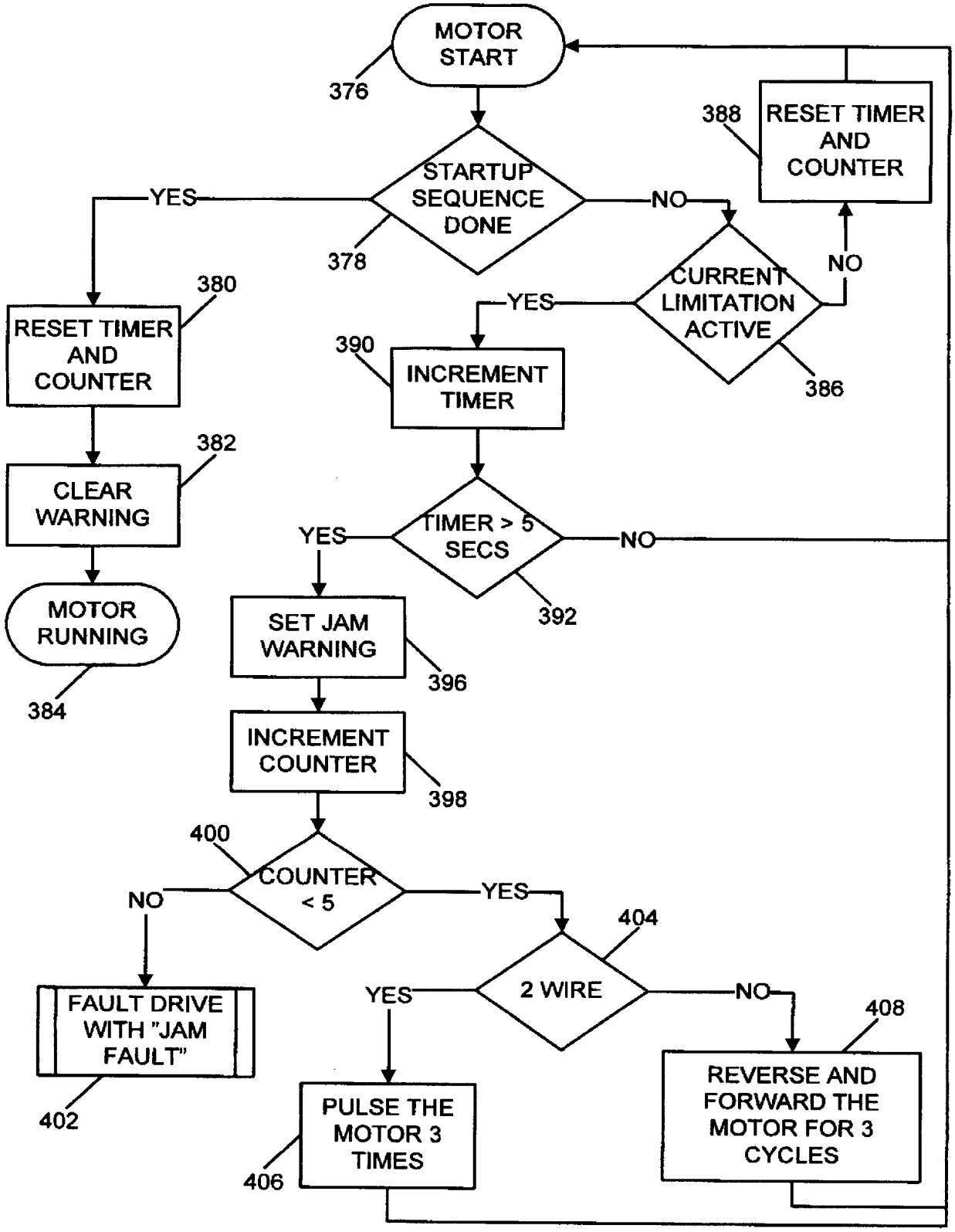

MOTOR START
376
STARTUP SEQUENCE DONE
378
YES
NO
RESET TIMER AND COUNTER
388
CURRENT LIMITATION ACTIVE
386
NO
YES
RESET TIMER AND COUNTER
380
INCREMENT TIMER
390
CLEAR WARNING
382
TIMER > 5 SECS
392
YES
NO
MOTOR RUNNING
384
SET JAM WARNING
396
INCREMENT COUNTER
398
COUNTER < 5
400
NO
YES
2 WIRE
404
YES
NO
FAULT DRIVE WITH "JAM FAULT"
402
PULSE THE MOTOR 3 TIMES
406
REVERSE AND FORWARD THE MOTOR FOR 3 CYCLES
408

FIGURE 32

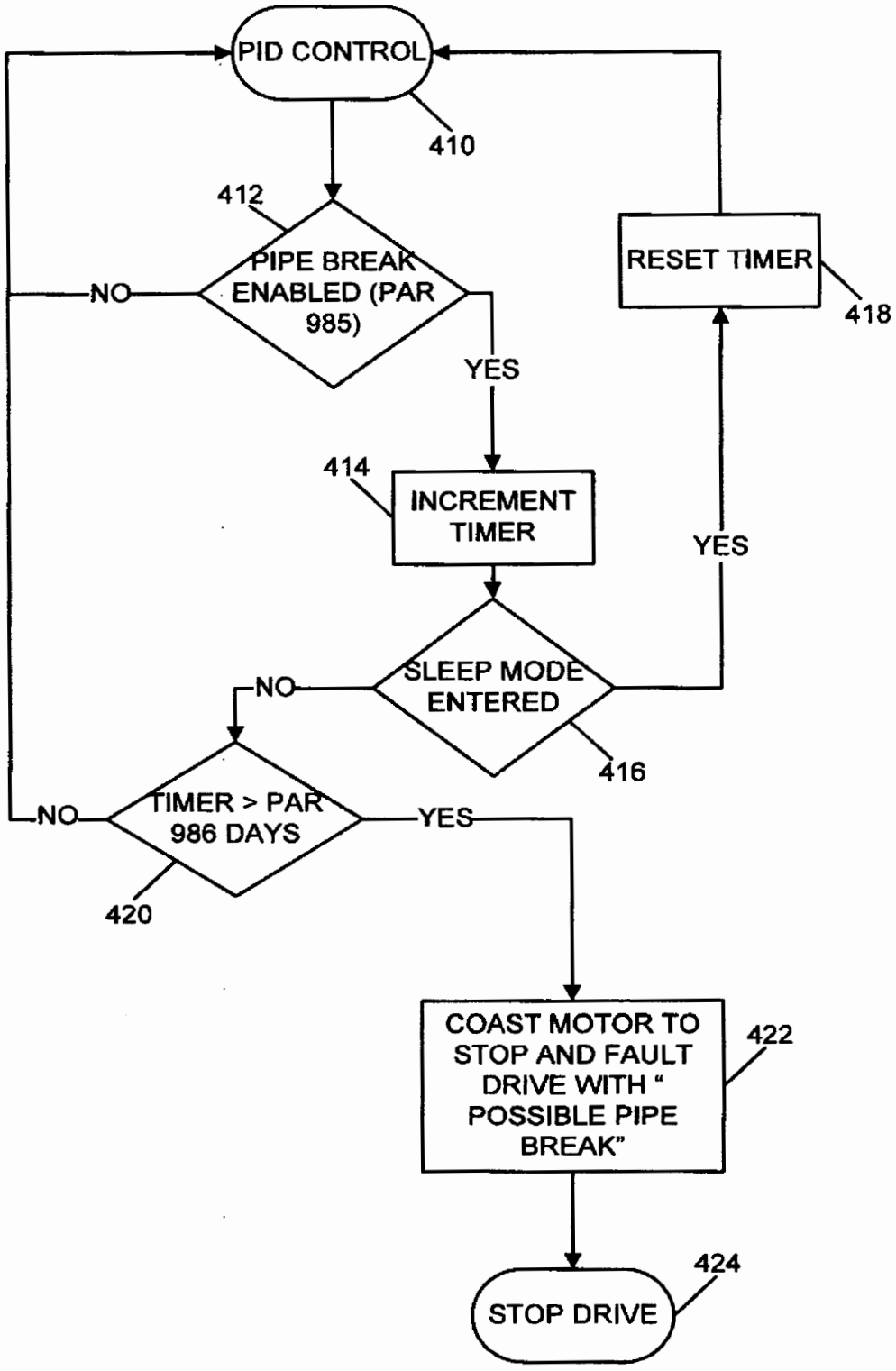

PID CONTROL
410
412
PIPE BREAK ENABLED (PAR 985)
NO
YES
414
INCREMENT TIMER
SLEEP MODE ENTERED
NO
416
TIMER > PAR 986 DAYS
NO
YES
420
RESET TIMER
418
YES
COAST MOTOR TO STOP AND FAULT DRIVE WITH " POSSIBLE PIPE BREAK"
422
STOP DRIVE
424

FIGURE 33

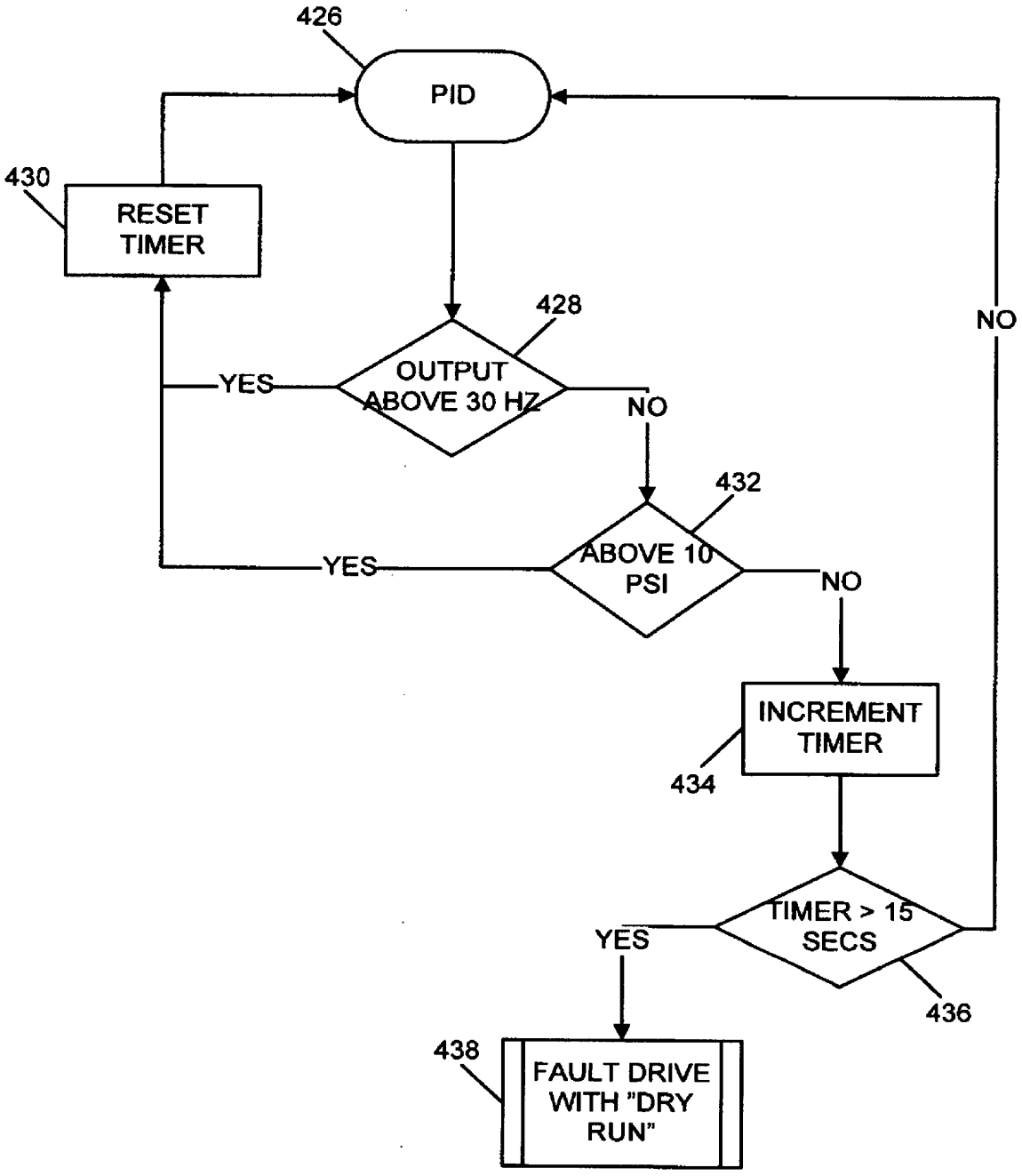

426
PID
430
RESET TIMER
428
OUTPUT ABOVE 30 HZ
YES
NO
NO
432
ABOVE 10 PSI
YES
NO
INCREMENT TIMER
434
TIMER > 15 SECS
YES
436
438
FAULT DRIVE WITH "DRY RUN"

FIGURE 34

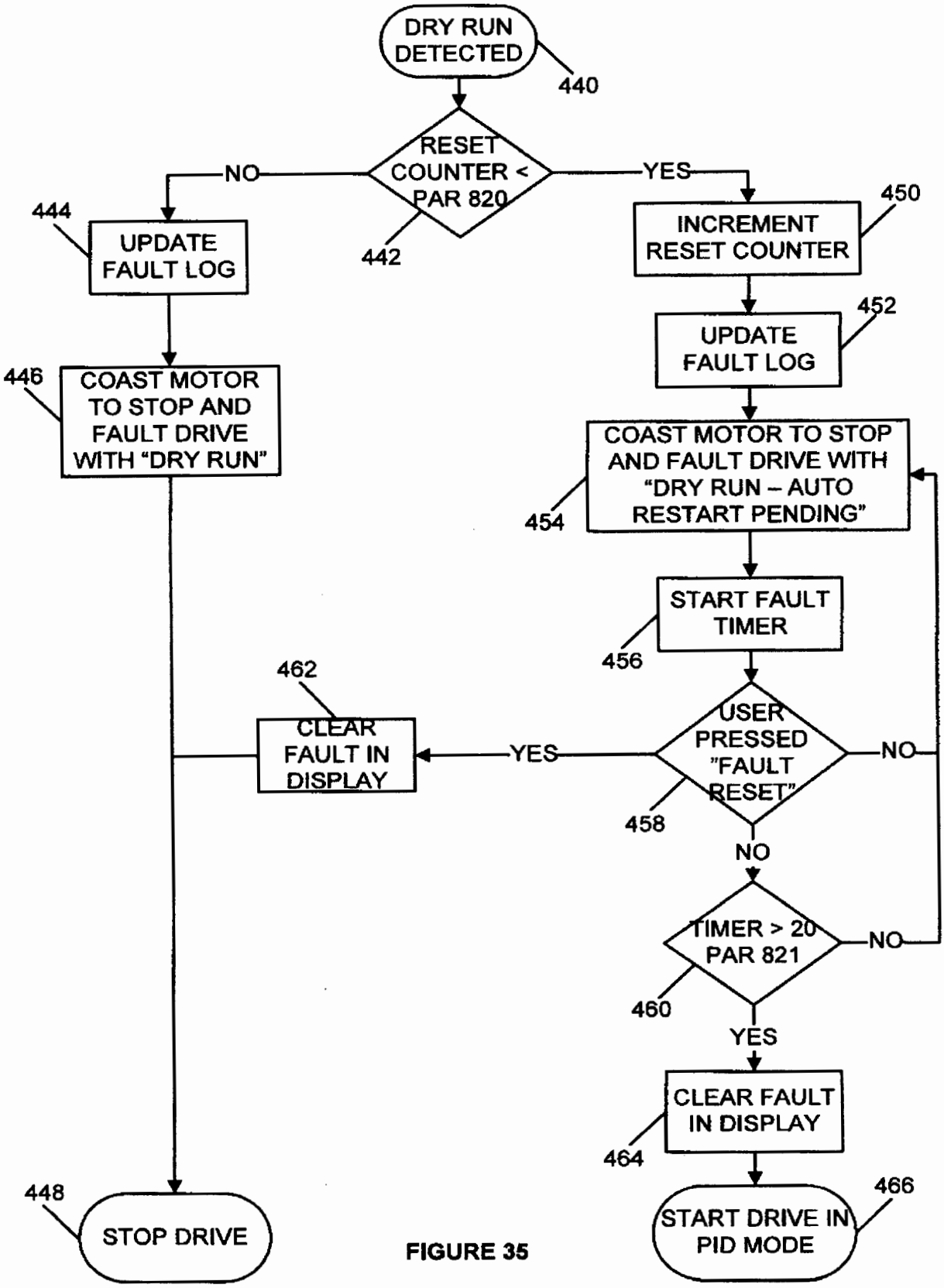

DRY RUN DETECTED
440
RESET COUNTER < PAR 820
442
NO
YES
444
UPDATE FAULT LOG
446
COAST MOTOR TO STOP AND FAULT DRIVE WITH "DRY RUN"
448
STOP DRIVE
450
INCREMENT RESET COUNTER
452
UPDATE FAULT LOG
454
COAST MOTOR TO STOP AND FAULT DRIVE WITH "DRY RUN – AUTO RESTART PENDING"
456
START FAULT TIMER
458
USER 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

FIGURE 35

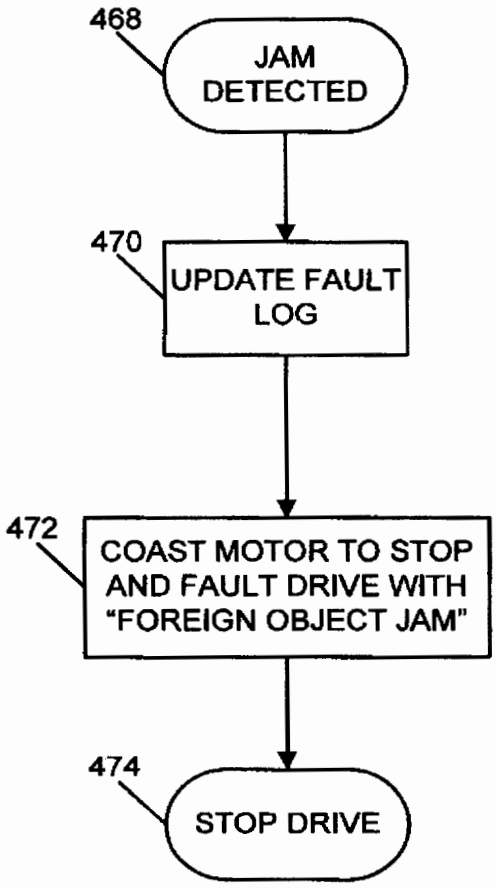

468
JAM DETECTED
470
UPDATE FAULT LOG
472
COAST MOTOR TO STOP AND FAULT DRIVE WITH "FOREIGN OBJECT JAM"
474
STOP DRIVE

FIGURE 36

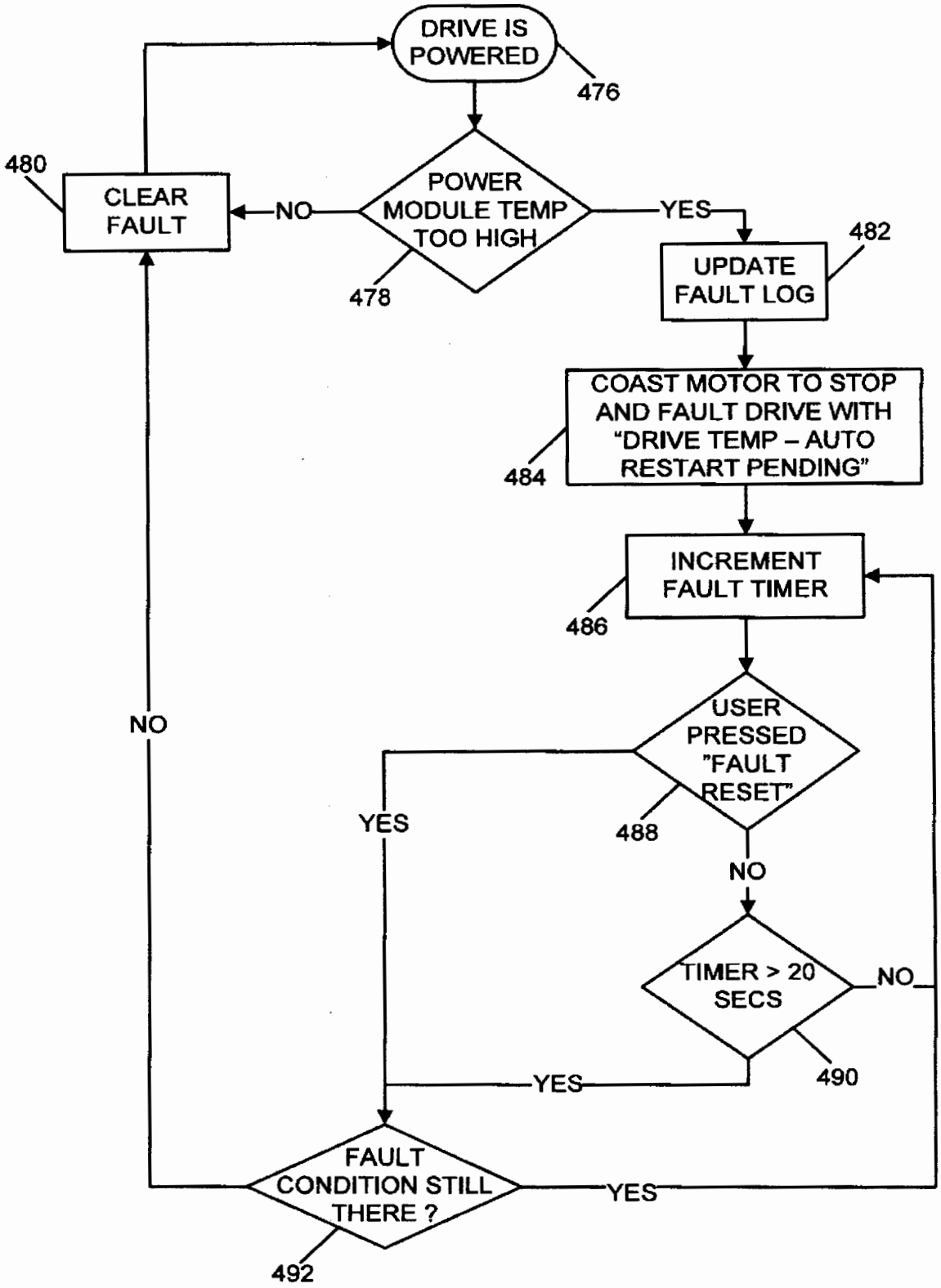

DRIVE IS POWERED
476
POWER MODULE TEMP TOO HIGH
478
NO
YES
480
CLEAR FAULT
482
UPDATE FAULT LOG
COAST MOTOR TO STOP AND FAULT DRIVE WITH "DRIVE TEMP – AUTO RESTART PENDING"
484
INCREMENT FAULT TIMER
486
USER PRESSED "FAULT RESET"
488
YES
NO
TIMER > 20 SECS
490
NO
YES
FAULT CONDITION STILL THERE ?
492
YES
NO

FIGURE 37

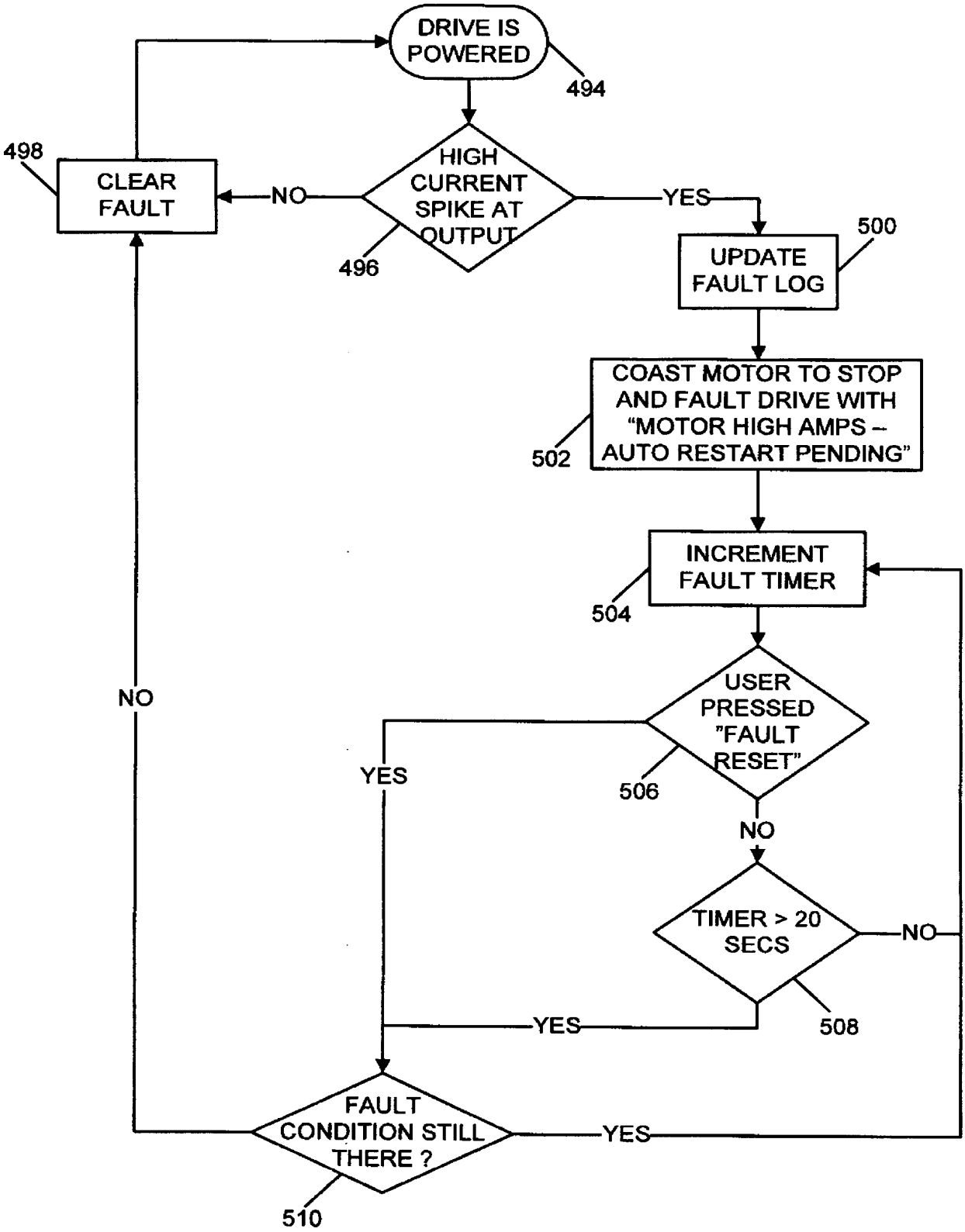

DRIVE IS POWERED
494
HIGH CURRENT SPIKE AT OUTPUT
496
NO
CLEAR FAULT
498
YES
UPDATE FAULT LOG
500
COAST MOTOR TO STOP AND FAULT DRIVE WITH "MOTOR HIGH AMPS – AUTO RESTART PENDING"
502
INCREMENT FAULT TIMER
504
USER PRESSED "FAULT RESET"
506
YES
NO
TIMER > 20 SECS
508
NO
YES
FAULT CONDITION STILL THERE ?
510
YES
NO

FIGURE 38

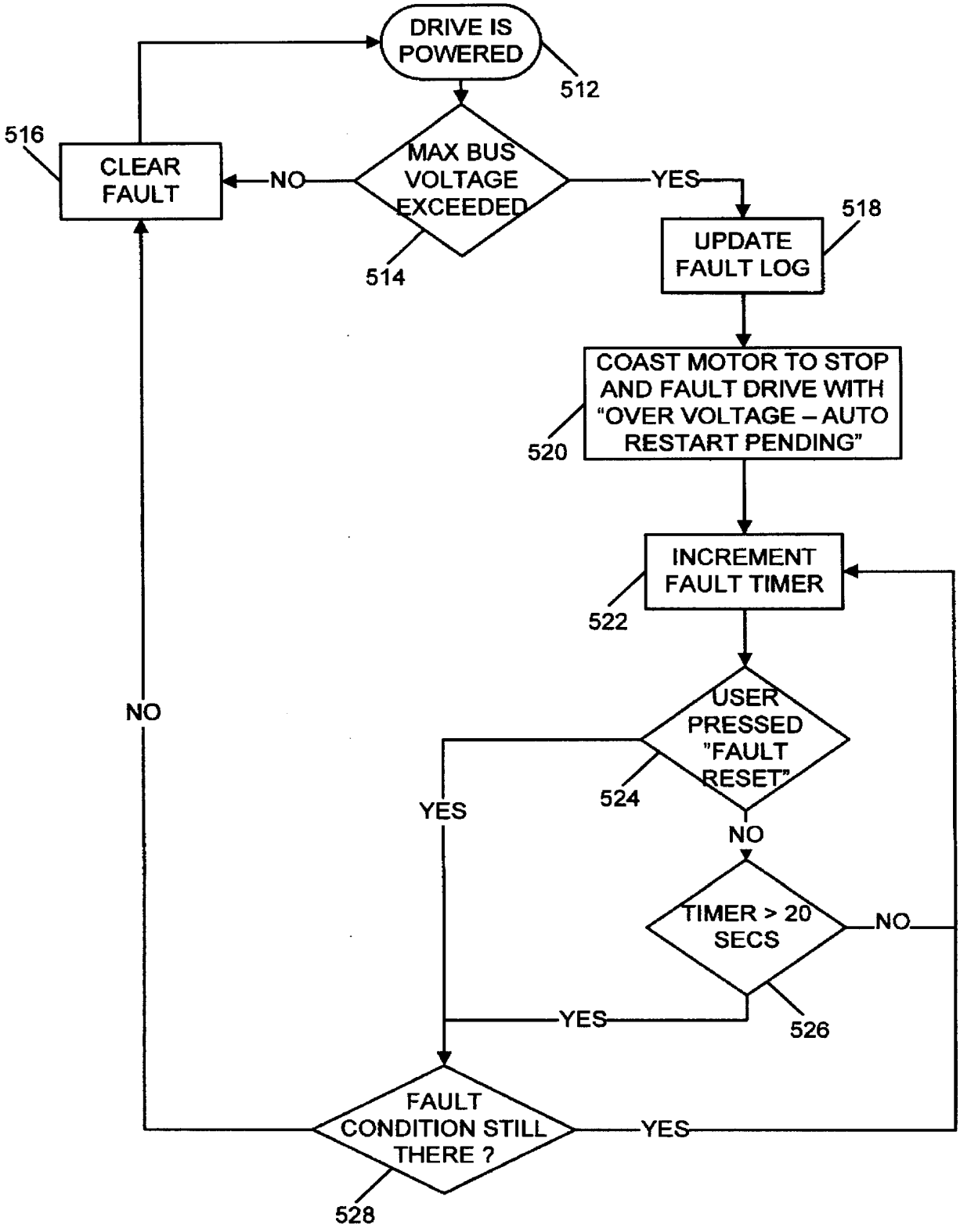

DRIVE IS POWERED
512
MAX BUS VOLTAGE EXCEEDED
514
NO
CLEAR FAULT
516
YES
UPDATE FAULT LOG
518
COAST MOTOR TO STOP AND FAULT DRIVE WITH "OVER VOLTAGE – AUTO RESTART PENDING"
520
INCREMENT FAULT TIMER
522
USER PRESSED "FAULT RESET"
524
YES
NO
TIMER > 20 SECS
NO
YES
526
FAULT CONDITION STILL THERE ?
YES
NO
528

FIGURE 39

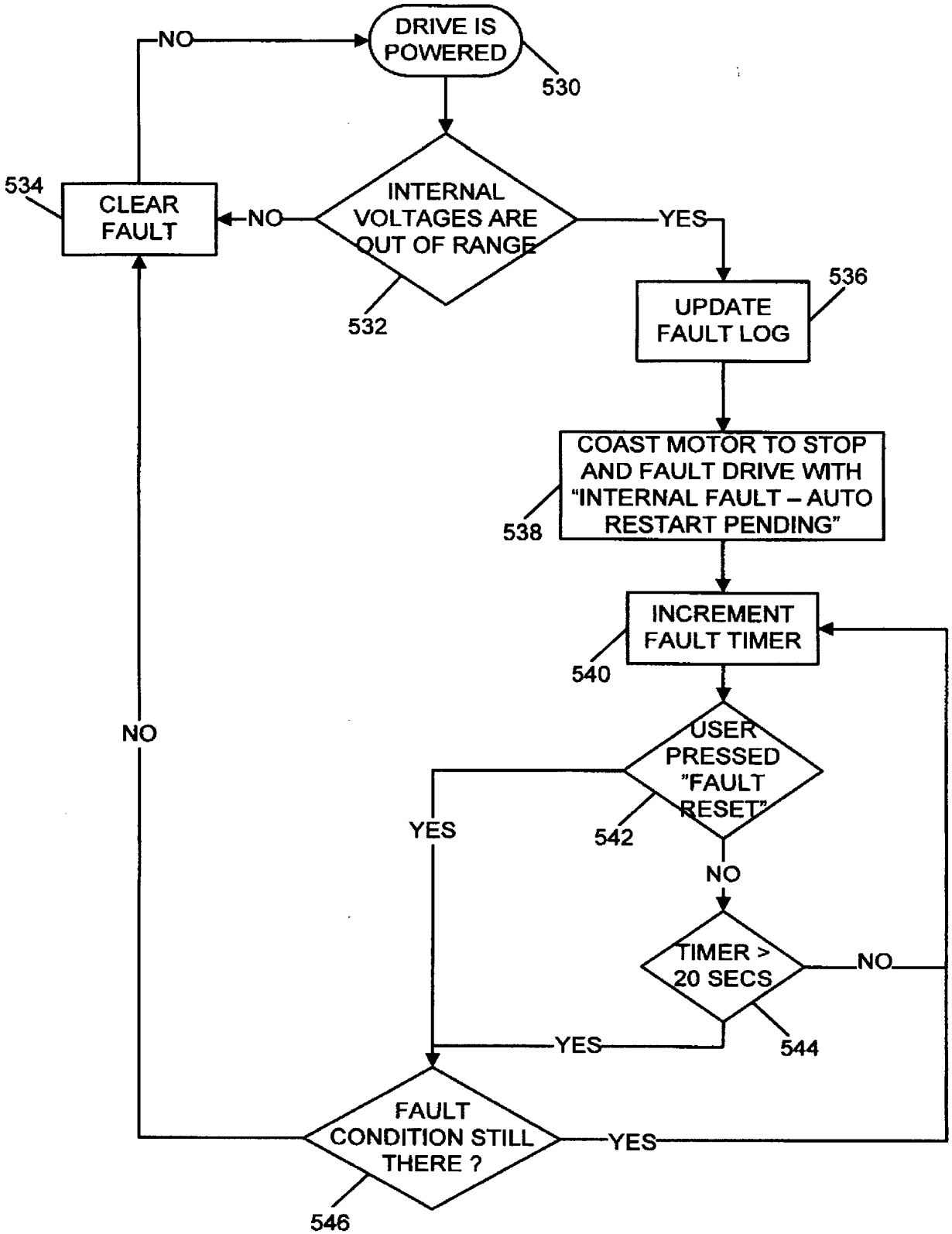

DRIVE IS POWERED
530
NO
INTERNAL VOLTAGES ARE OUT OF RANGE
532
NO
CLEAR FAULT
534
YES
UPDATE FAULT LOG
536
COAST MOTOR TO STOP AND FAULT DRIVE WITH "INTERNAL FAULT – AUTO RESTART PENDING"
538
INCREMENT FAULT TIMER
540
USER PRESSED "FAULT RESET"
542
YES
NO
TIMER > 20 SECS
544
NO
YES
FAULT CONDITION STILL THERE ?
546
YES
NO

FIGURE 40

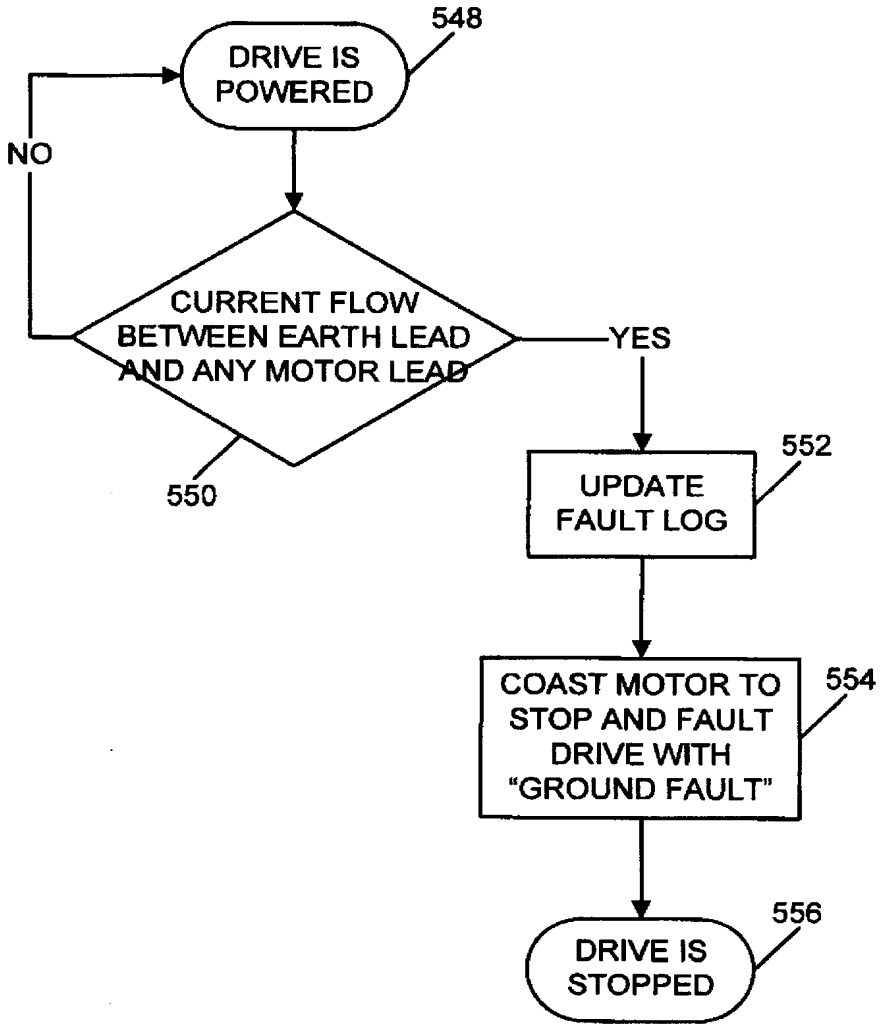

548
DRIVE IS POWERED
NO
CURRENT FLOW BETWEEN EARTH LEAD AND ANY MOTOR LEAD
YES
550
552
UPDATE FAULT LOG
554
COAST MOTOR TO STOP AND FAULT DRIVE WITH "GROUND FAULT"
556
DRIVE IS STOPPED

FIGURE 41

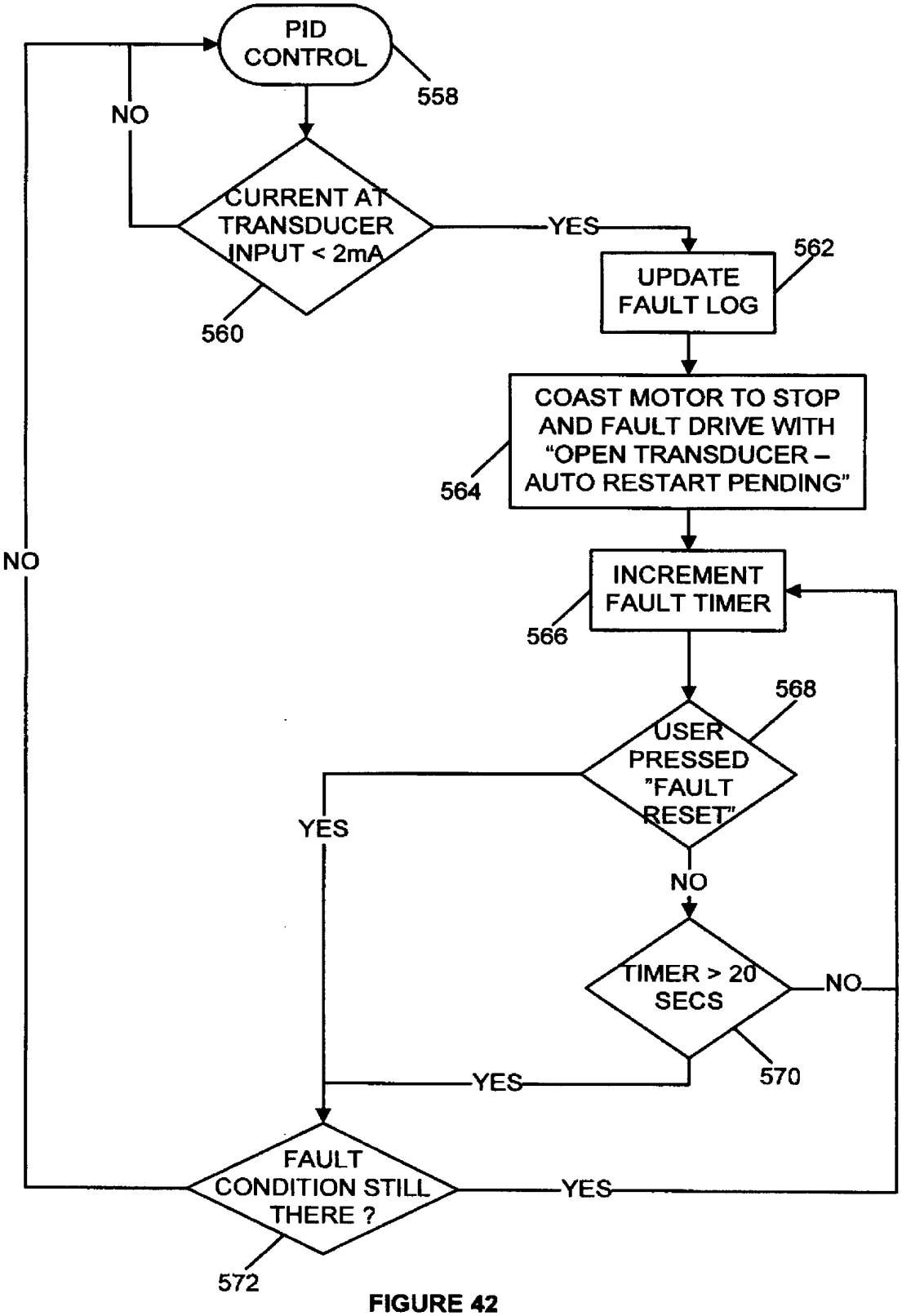

PID CONTROL
558
NO
CURRENT AT TRANSDUCER INPUT < 2mA
YES
560
562
UPDATE FAULT LOG
COAST MOTOR TO STOP AND FAULT DRIVE WITH "OPEN TRANSDUCER – AUTO RESTART PENDING"
564
NO
INCREMENT FAULT TIMER
566
568
USER PRESSED "FAULT RESET"
YES
NO
TIMER > 20 SECS
NO
570
YES
FAULT CONDITION STILL THERE ?
YES
572

FIGURE 42

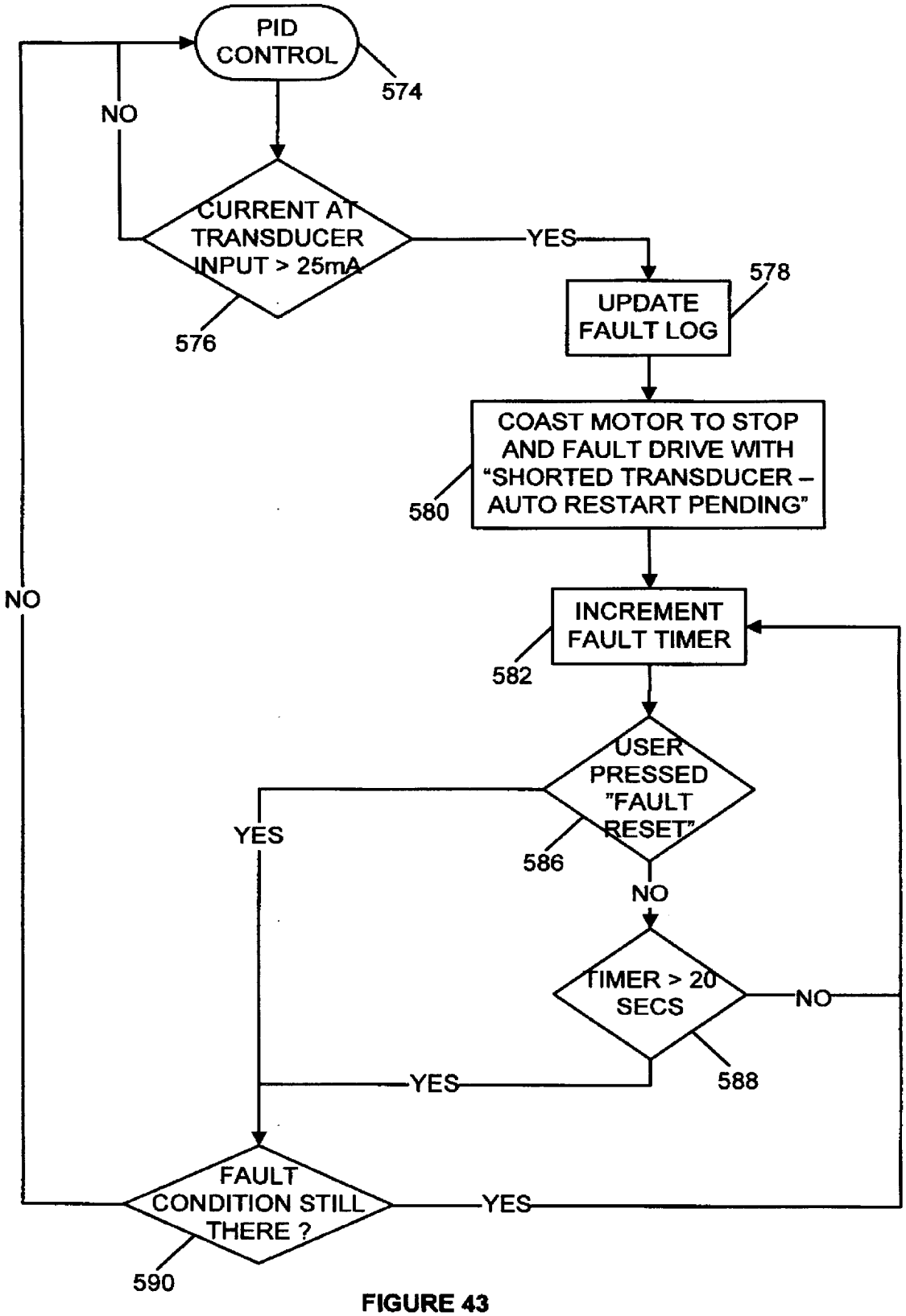

PID CONTROL
574
NO
CURRENT AT TRANSDUCER INPUT > 25mA
YES
576
578
UPDATE FAULT LOG
COAST MOTOR TO STOP AND FAULT DRIVE WITH "SHORTED TRANSDUCER – AUTO RESTART PENDING"
580
NO
INCREMENT FAULT TIMER
582
USER PRESSED "FAULT RESET"
YES
586
NO
TIMER > 20 SECS
NO
588
YES
FAULT CONDITION STILL THERE ?
YES
590

FIGURE 43

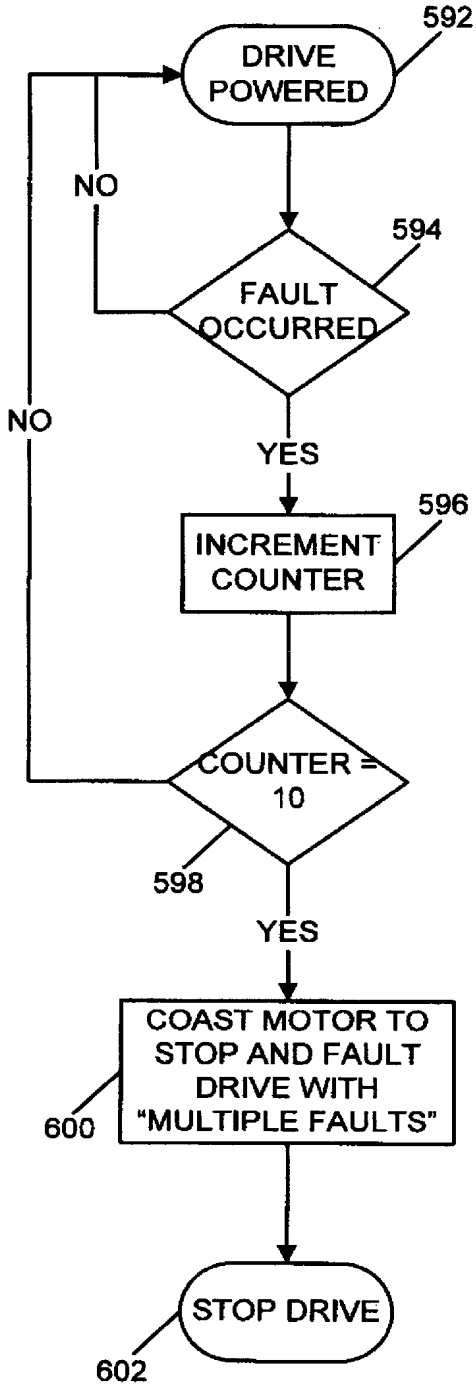


FIGURE 44A

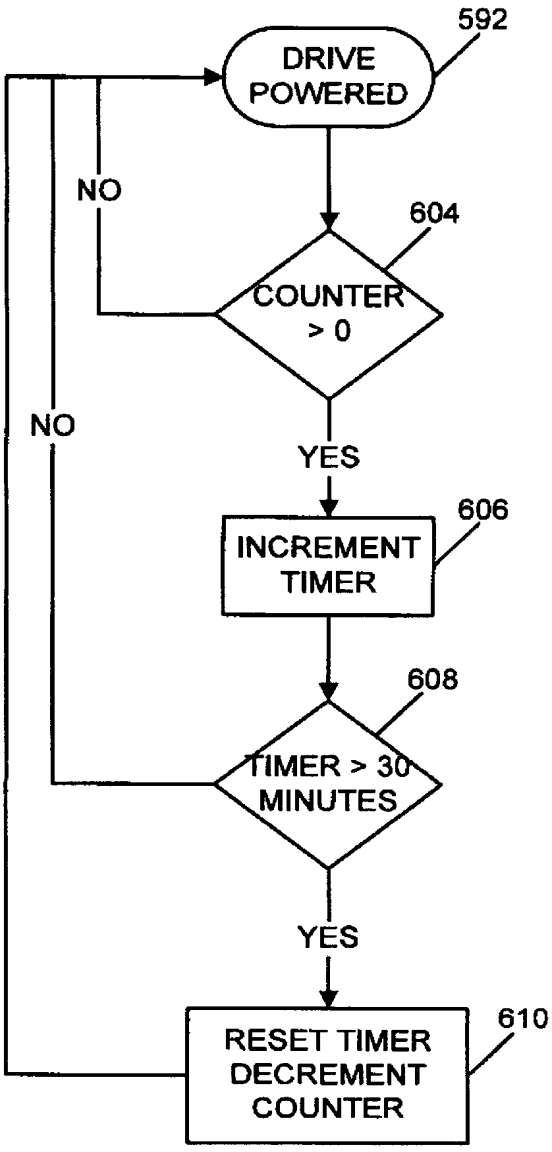


FIGURE 44B

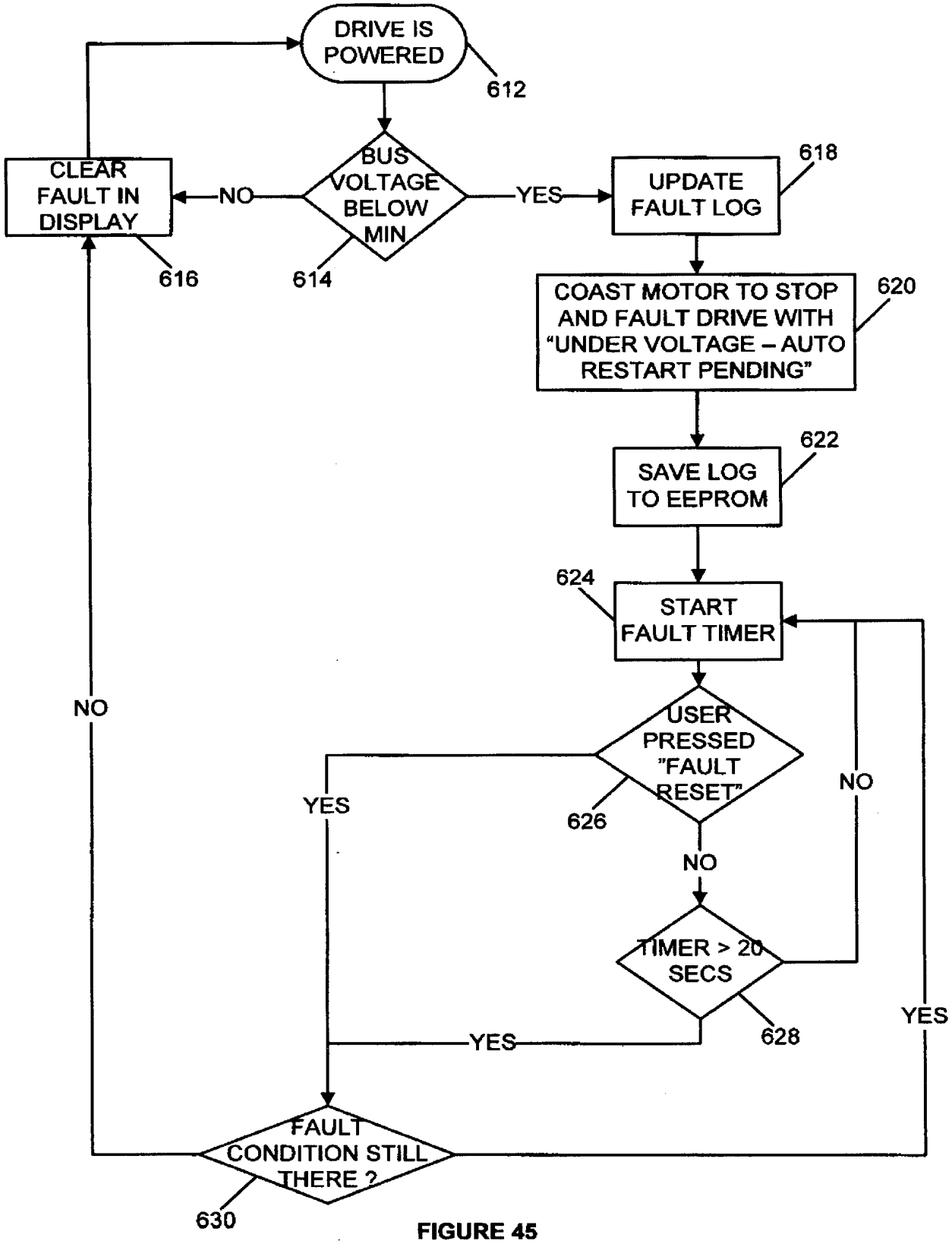

DRIVE IS POWERED
612
BUS VOLTAGE BELOW MIN
614
NO
YES
CLEAR FAULT IN DISPLAY
616
UPDATE FAULT LOG
618
COAST MOTOR TO STOP AND FAULT DRIVE WITH "UNDER VOLTAGE – AUTO RESTART PENDING"
620
SAVE LOG TO EEPROM
622
START FAULT TIMER
624
USER PRESSED "FAULT RESET"
626
YES
NO
TIMER > 20 SECS
628
YES
NO
YES
FAULT CONDITION STILL THERE ?
630
NO

FIGURE 45

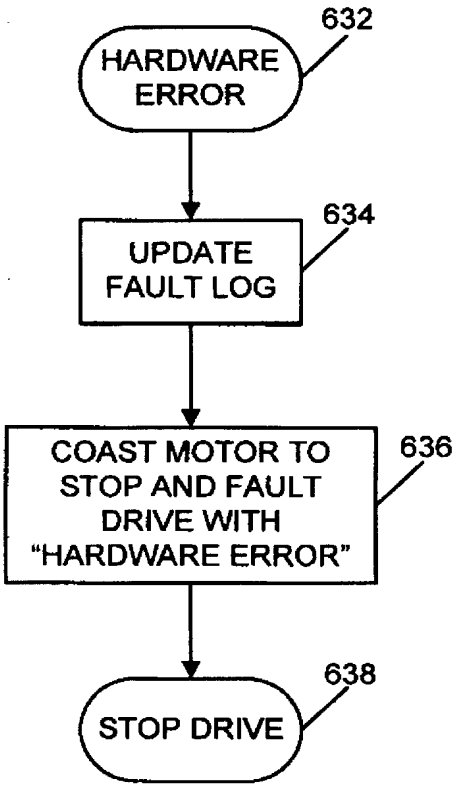

632
HARDWARE ERROR
634
UPDATE FAULT LOG
636
COAST MOTOR TO STOP AND FAULT DRIVE WITH "HARDWARE ERROR"
638
STOP DRIVE

FIGURE 46

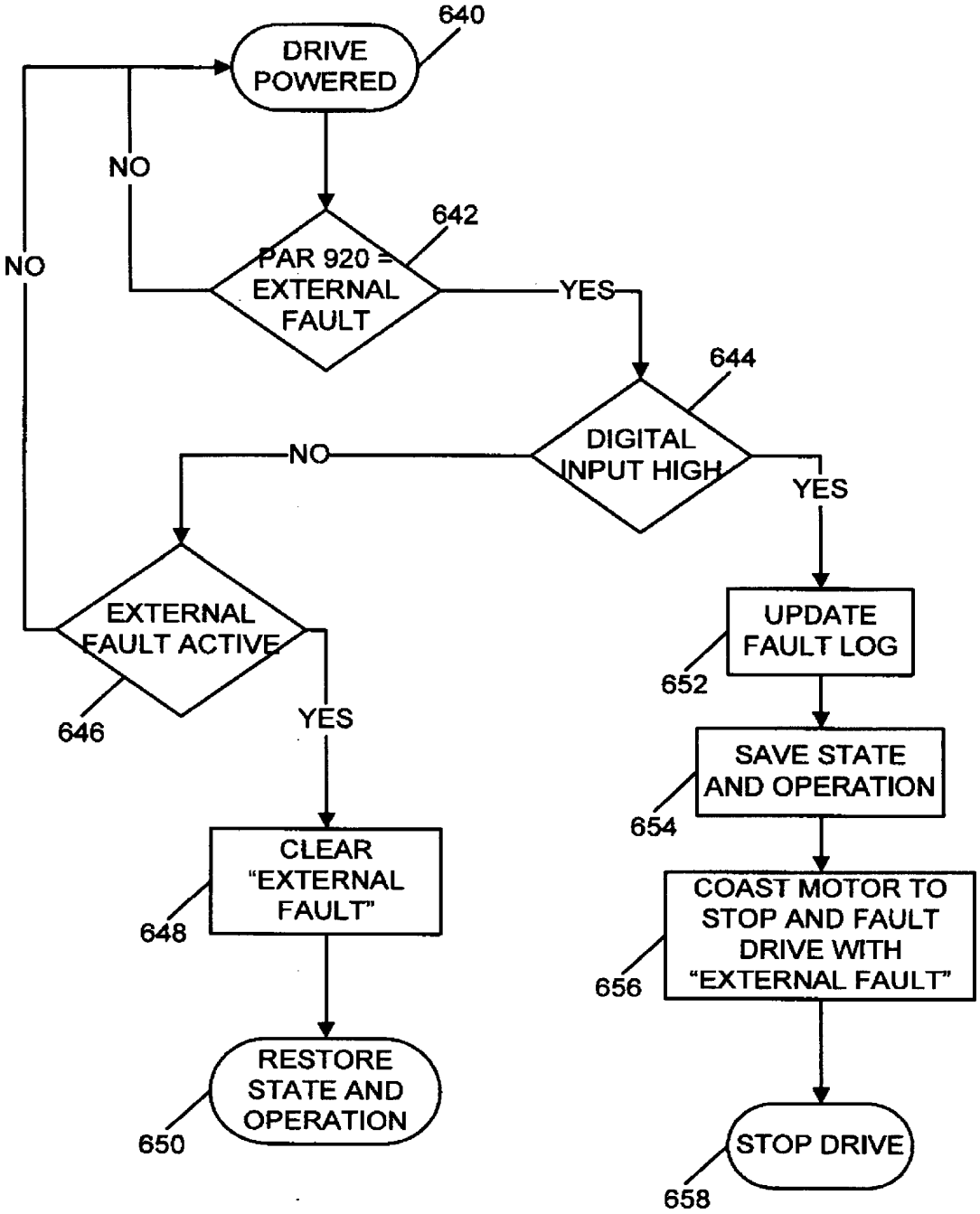

640
DRIVE POWERED
NO
642
PAR 920 = EXTERNAL FAULT
NO
YES
644
DIGITAL INPUT HIGH
NO
YES
EXTERNAL FAULT ACTIVE
646
YES
UPDATE FAULT LOG
652
SAVE STATE AND OPERATION
654
CLEAR "EXTERNAL FAULT"
648
COAST MOTOR TO STOP AND FAULT DRIVE WITH "EXTERNAL FAULT"
656
RESTORE STATE AND OPERATION
650
STOP DRIVE
658

FIGURE 47

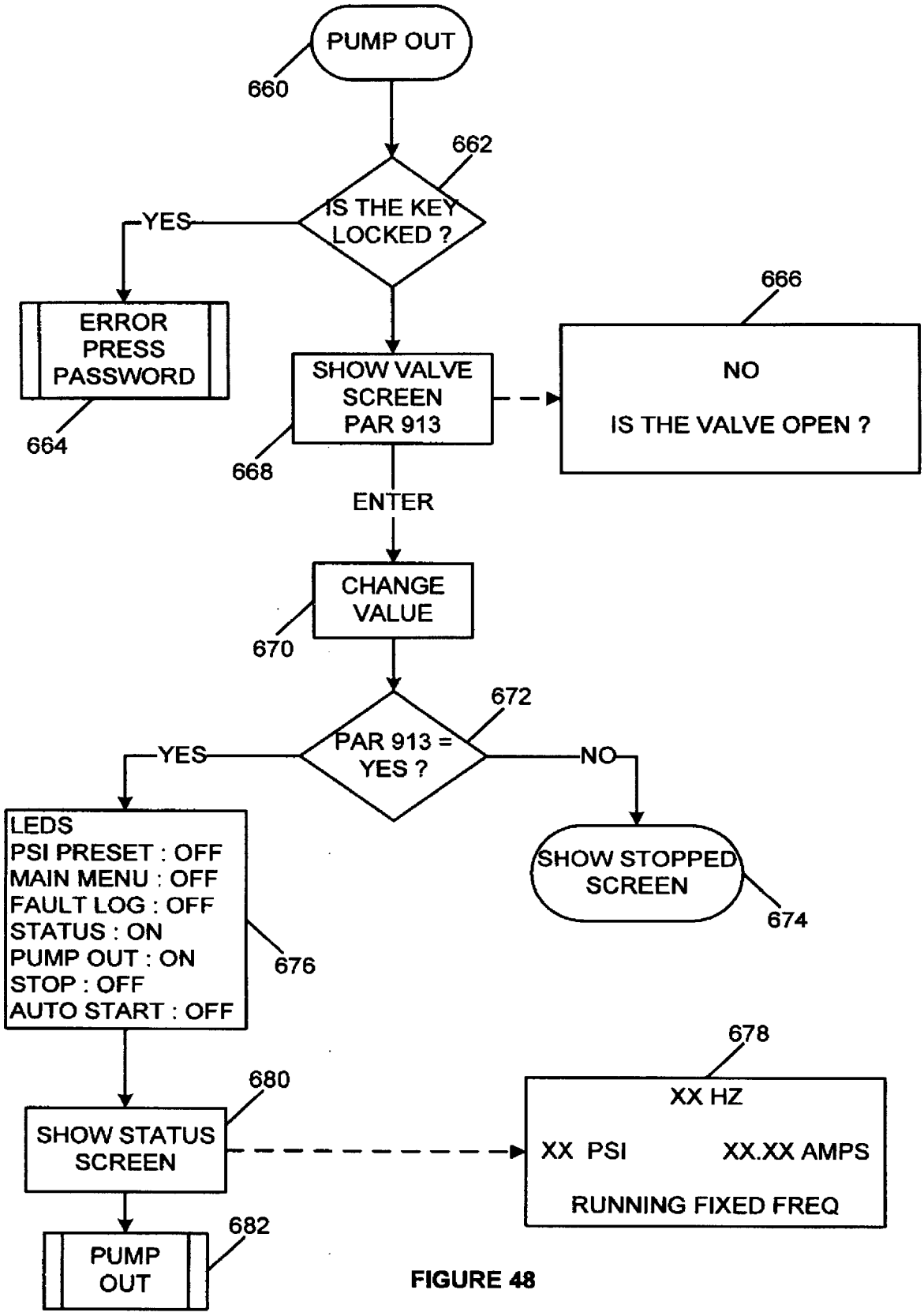

PUMP OUT
660
662
IS THE KEY LOCKED ?
YES
ERROR PRESS PASSWORD
664
SHOW VALVE SCREEN PAR 913
668
666
NO
IS THE VALVE OPEN ?
ENTER
CHANGE VALUE
670
672
PAR 913 = YES ?
YES
NO
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : ON
PUMP OUT : ON
STOP : OFF
AUTO START : OFF
676
SHOW STOPPED SCREEN
674
678
XX HZ
XX PSI
XX.XX AMPS
RUNNING FIXED FREQ
680
SHOW STATUS SCREEN
682
PUMP OUT

FIGURE 48

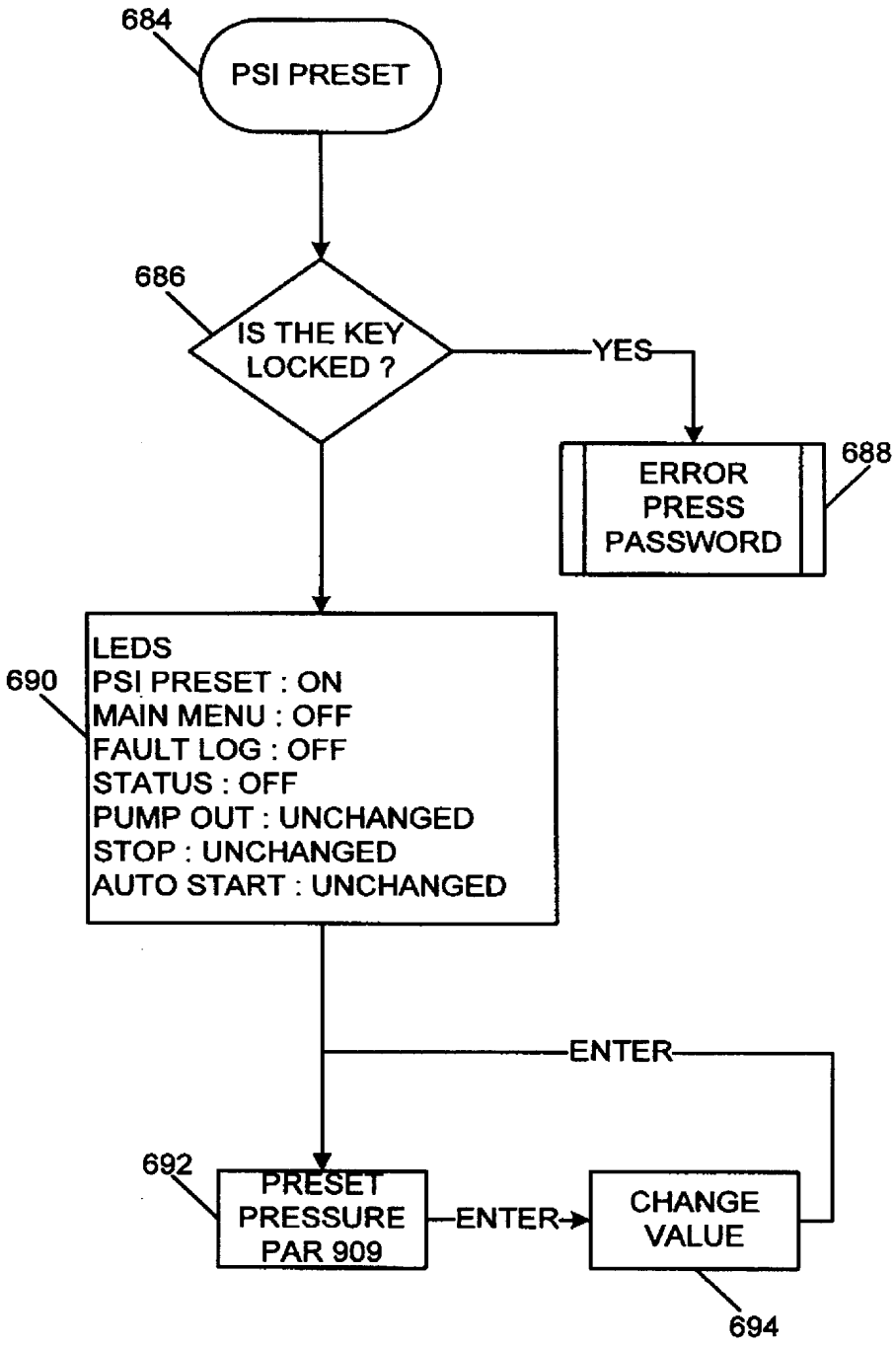

684
PSI PRESET
686
IS THE KEY LOCKED ?
YES
688
ERROR
PRESS
PASSWORD
690
LEDS
PSI PRESET : ON
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
ENTER
692
PRESET
PRESSURE
PAR 909
ENTER
CHANGE
VALUE
694

FIGURE 49

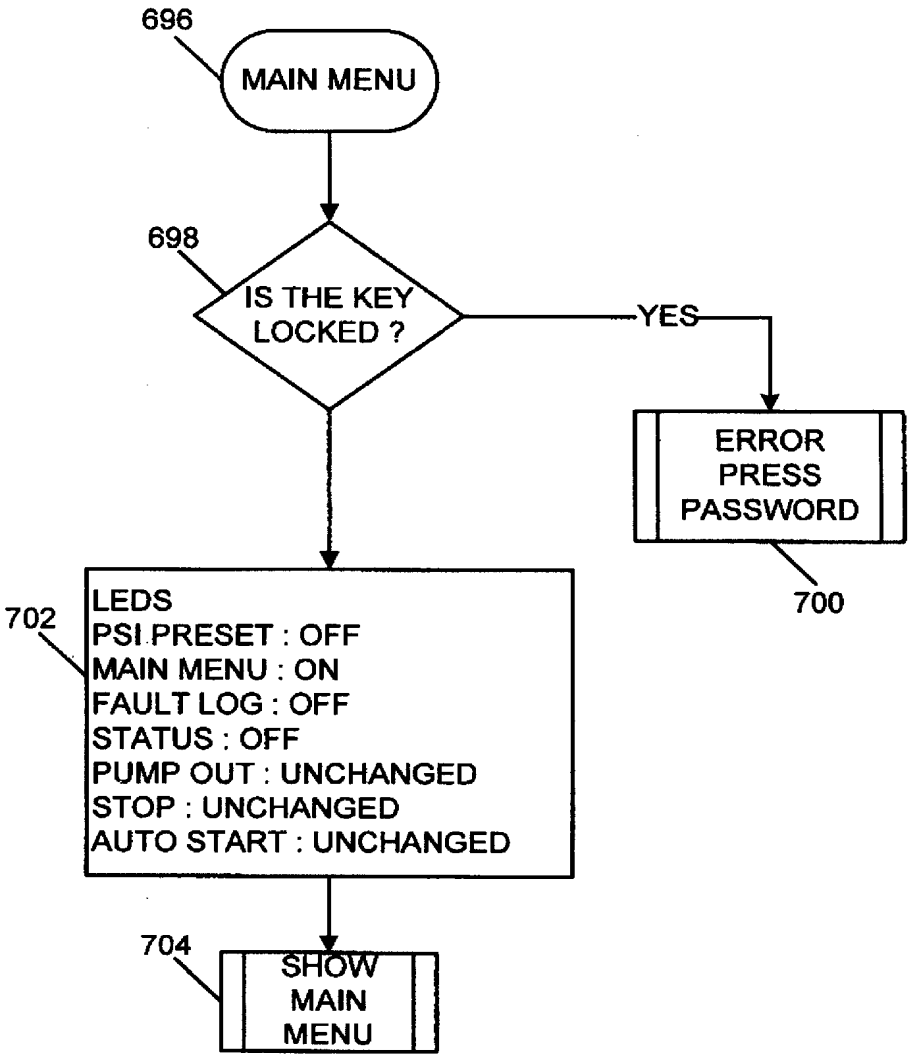

696
MAIN MENU
698
IS THE KEY LOCKED ?
YES
ERROR PRESS PASSWORD
700
702
LEDS
PSI PRESET : OFF
MAIN MENU : ON
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
704
SHOW MAIN MENU

FIGURE 50

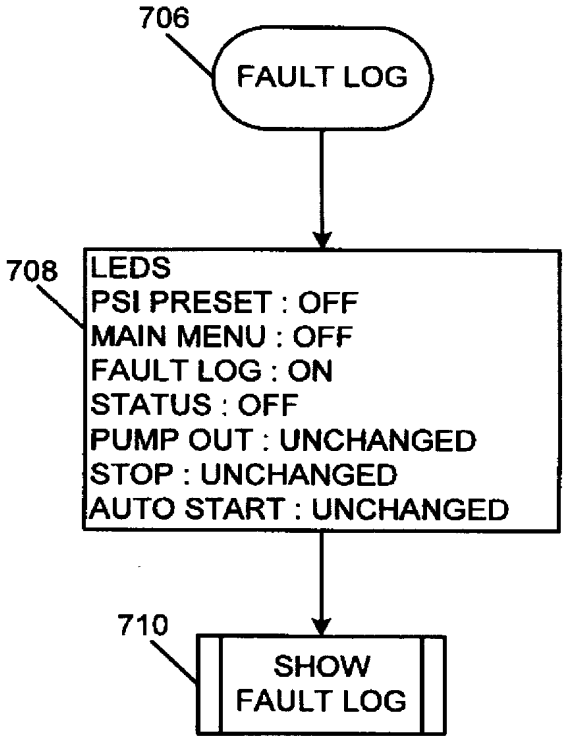

706
FAULT LOG
708
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : ON
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
710
SHOW
FAULT LOG

FIGURE 51

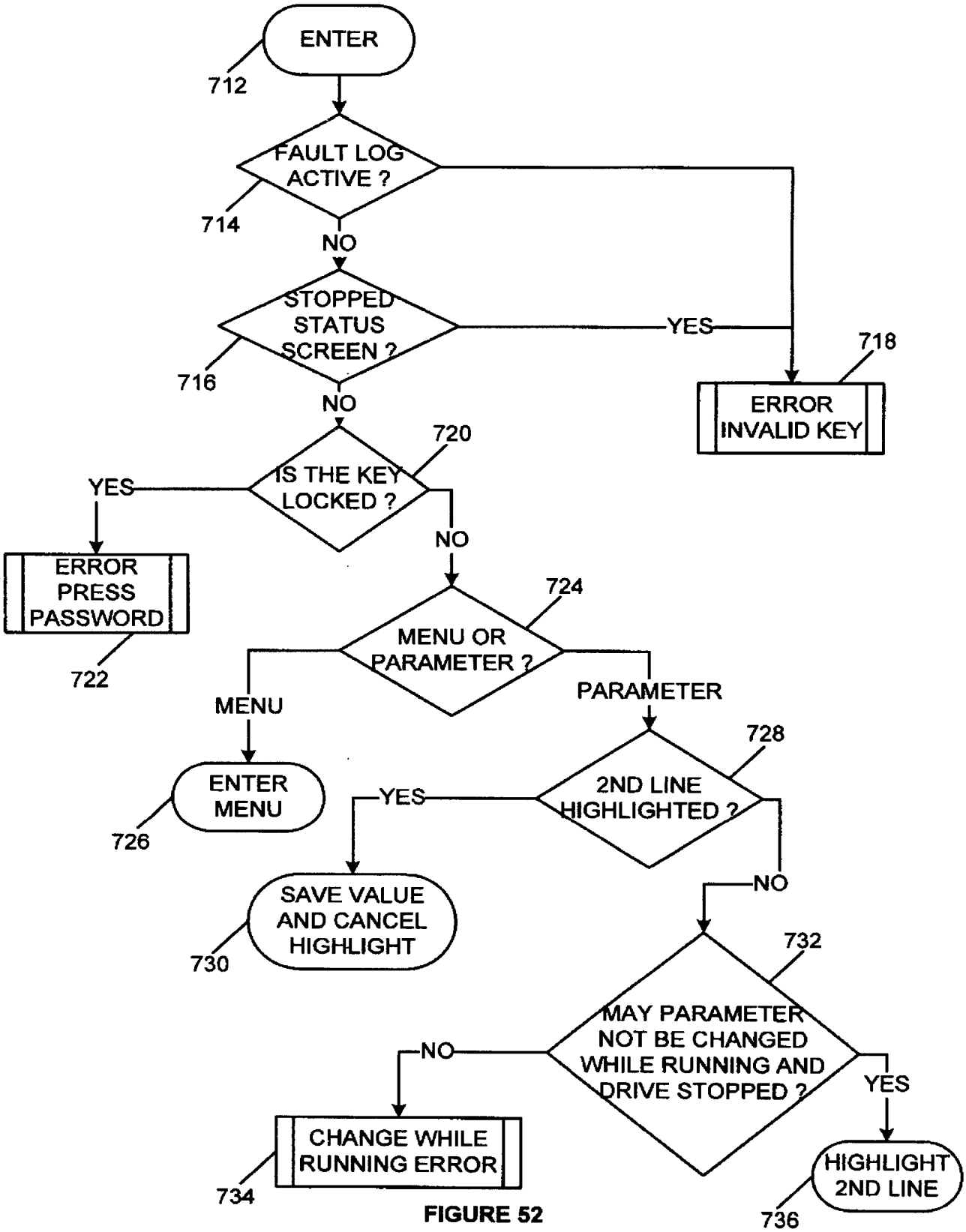

ENTER
712
FAULT LOG ACTIVE ?
714
NO
STOPPED STATUS SCREEN ?
716
YES
718
ERROR INVALID KEY
NO
720
IS THE KEY LOCKED ?
YES
ERROR PRESS PASSWORD
722
NO
724
MENU OR PARAMETER ?
MENU
ENTER MENU
726
PARAMETER
728
2ND LINE HIGHLIGHTED ?
YES
SAVE VALUE AND CANCEL HIGHLIGHT
730
NO
732
MAY PARAMETER NOT BE CHANGED WHILE RUNNING AND DRIVE STOPPED ?
NO
CHANGE WHILE RUNNING ERROR
734
YES
HIGHLIGHT 2ND LINE
736

FIGURE 52

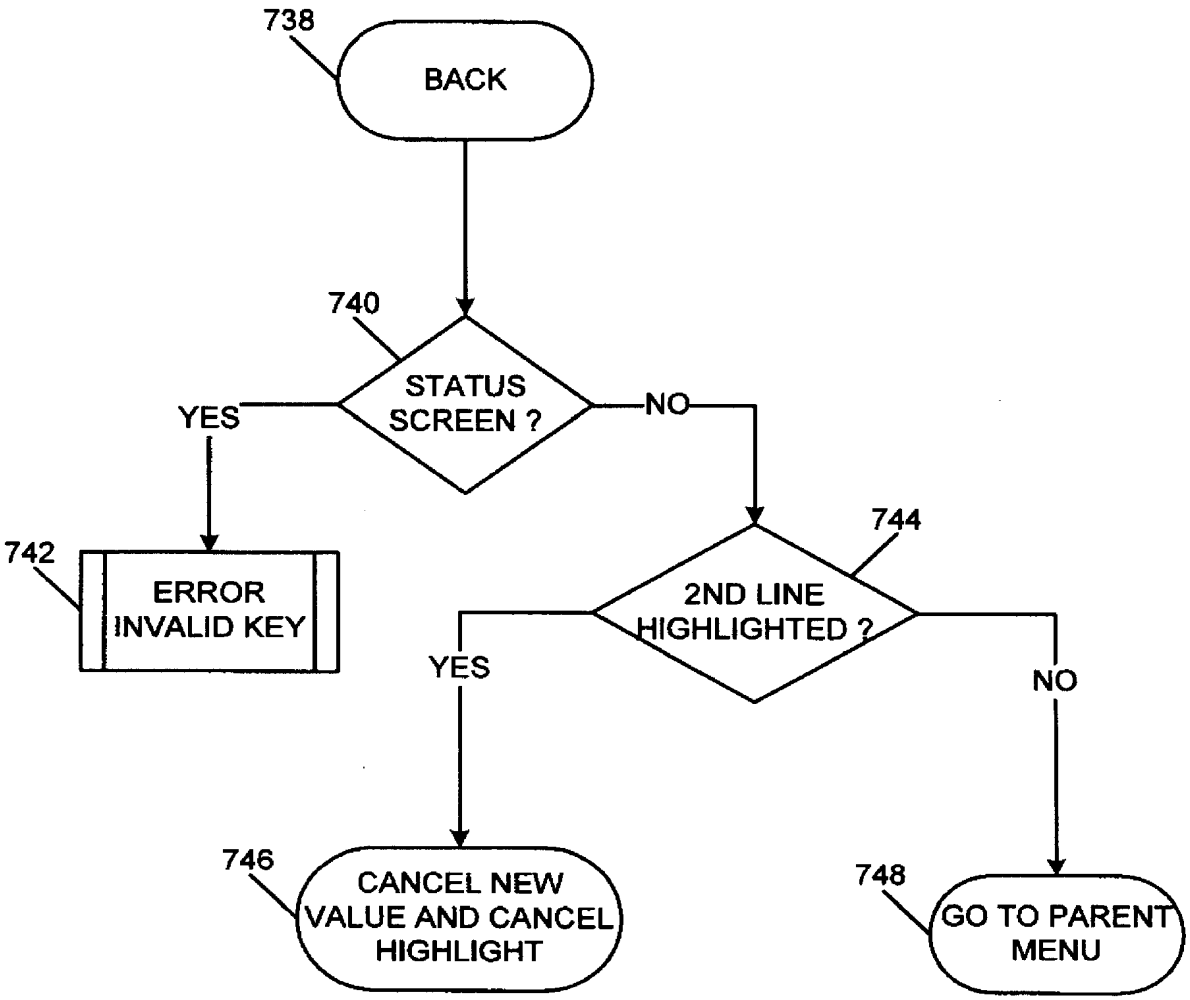

738
BACK
740
STATUS SCREEN ?
YES
NO
742
ERROR INVALID KEY
744
2ND LINE HIGHLIGHTED ?
YES
NO
746
CANCEL NEW VALUE AND CANCEL HIGHLIGHT
748
GO TO PARENT MENU

FIGURE 53

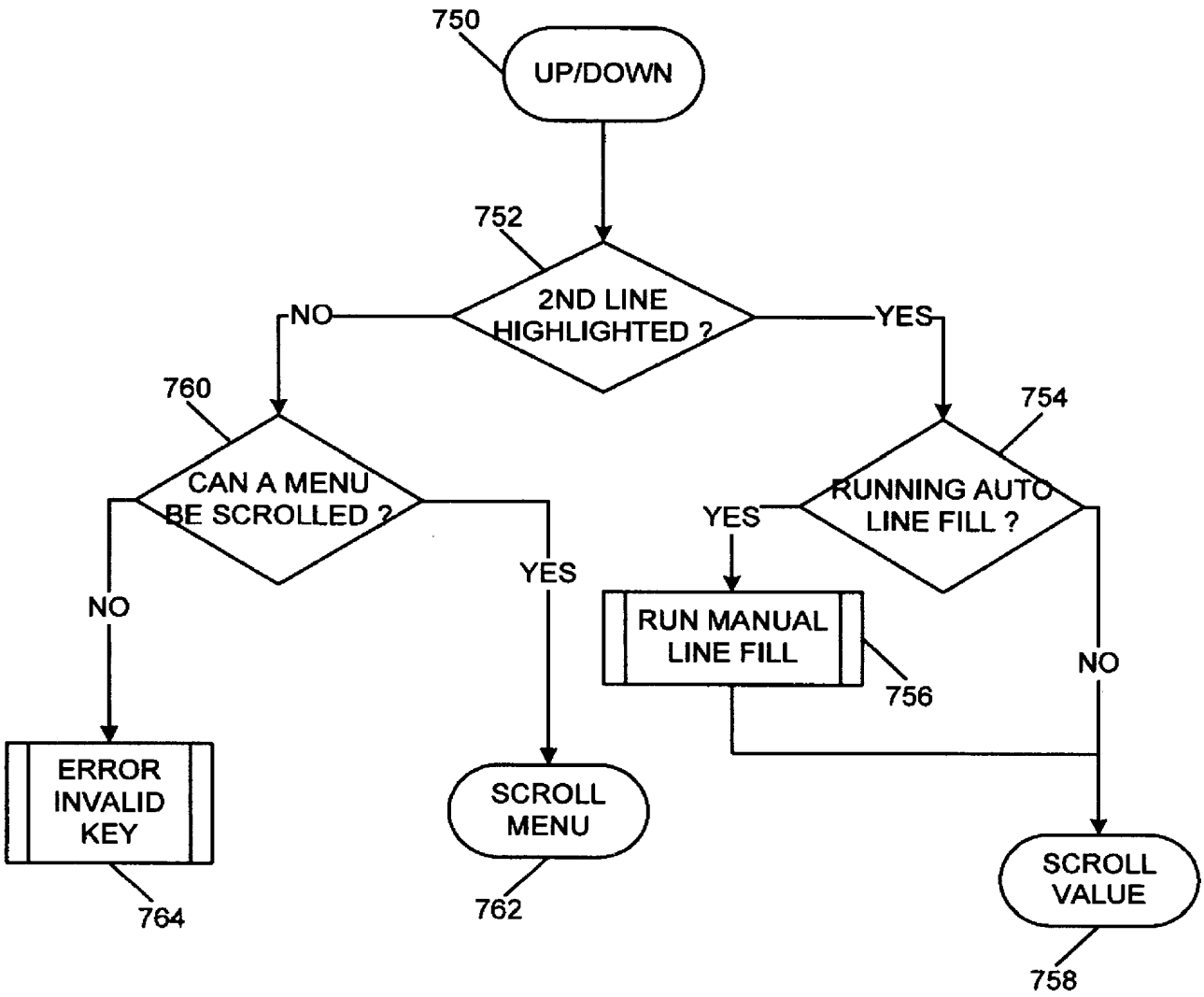

750
UP/DOWN
752
2ND LINE HIGHLIGHTED ?
NO
YES
760
CAN A MENU BE SCROLLED ?
754
RUNNING AUTO LINE FILL ?
YES
NO
YES
NO
RUN MANUAL LINE FILL
756
ERROR INVALID KEY
764
SCROLL MENU
762
SCROLL VALUE
758

FIGURE 54

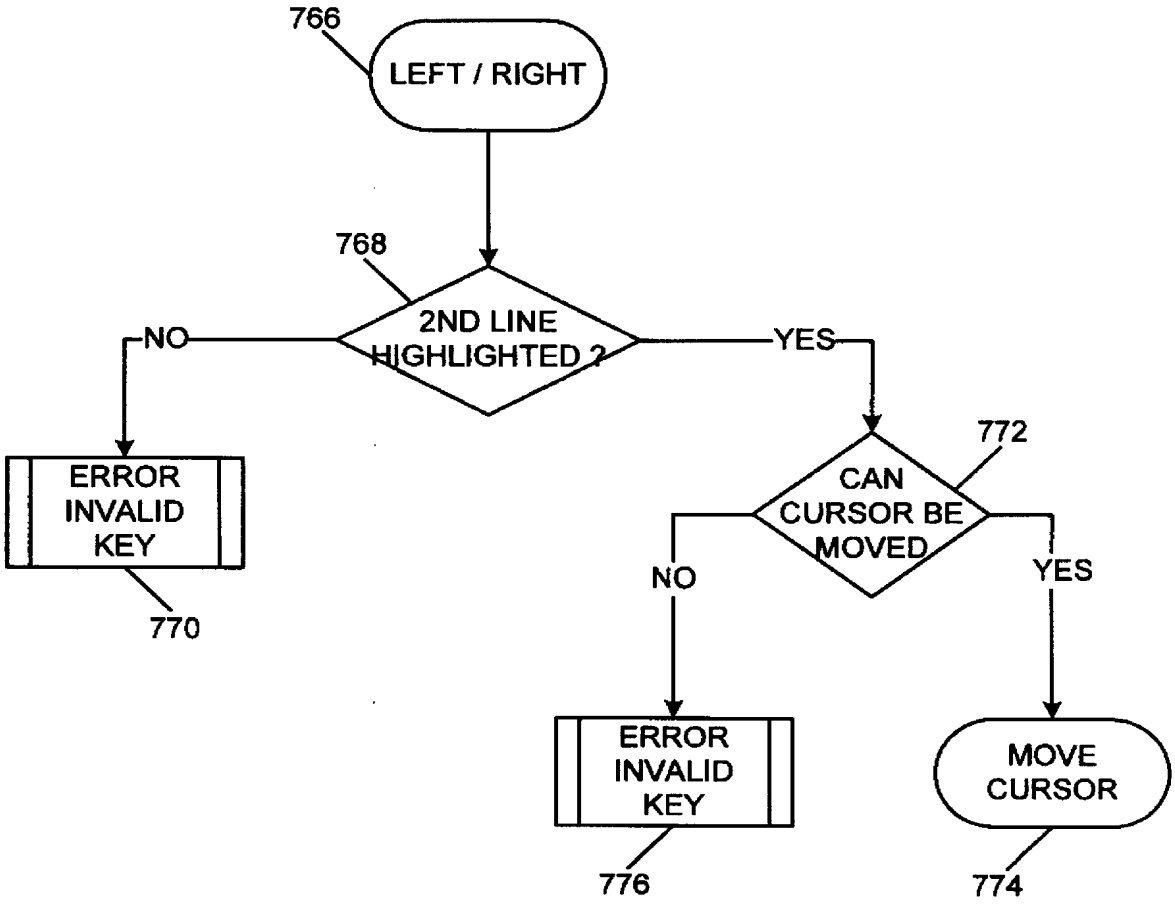

766
LEFT / RIGHT
768
2ND LINE HIGHLIGHTED ?
NO
YES
ERROR INVALID KEY
770
772
CAN CURSOR BE MOVED
NO
YES
ERROR INVALID KEY
776
MOVE CURSOR
774

FIGURE 55

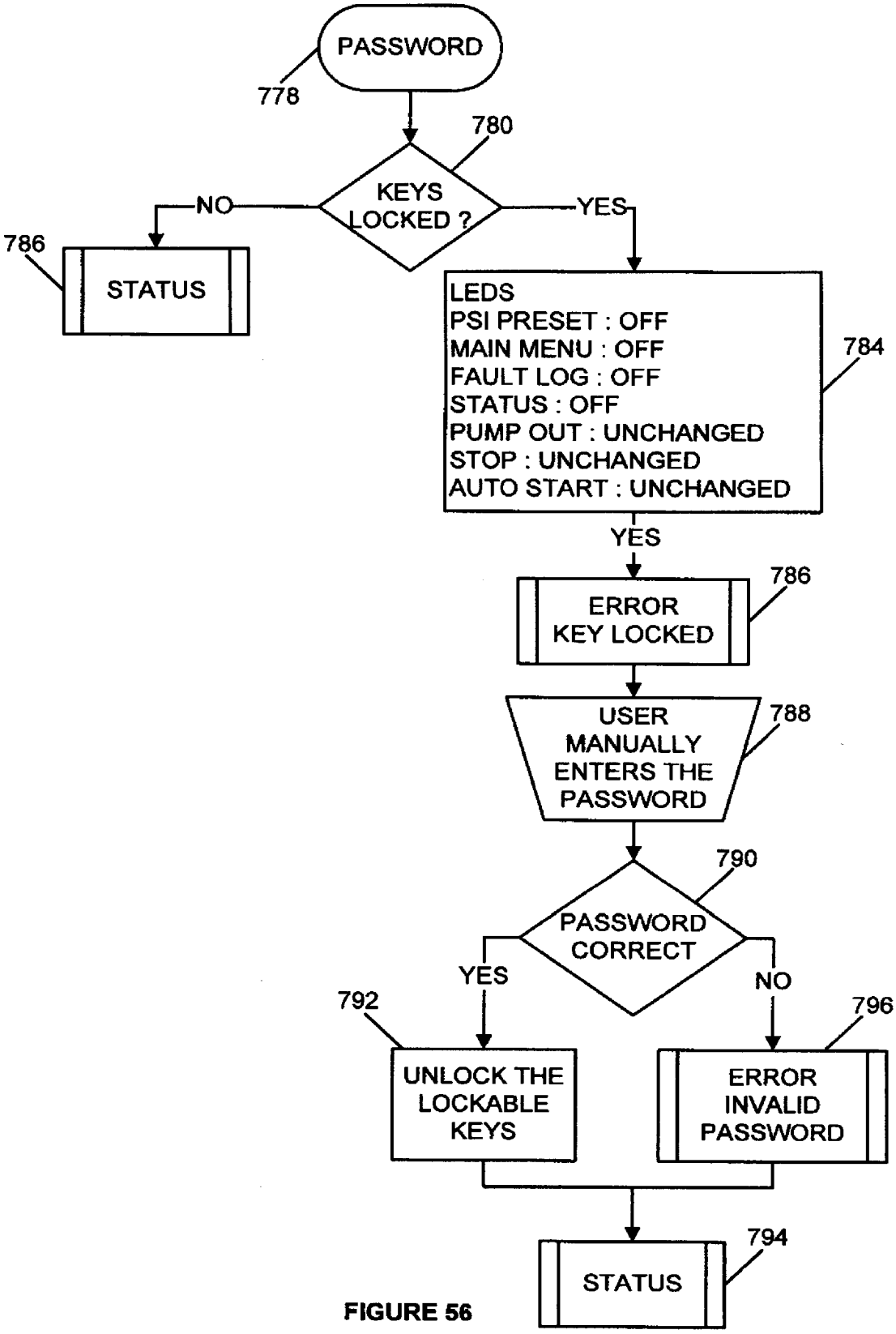

PASSWORD
778
780
KEYS LOCKED ?
NO
YES
786
STATUS
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
784
YES
786
ERROR KEY LOCKED
USER MANUALLY ENTERS THE PASSWORD
788
790
PASSWORD CORRECT
YES
NO
792
796
UNLOCK THE LOCKABLE KEYS
ERROR INVALID PASSWORD
794
STATUS

FIGURE 56

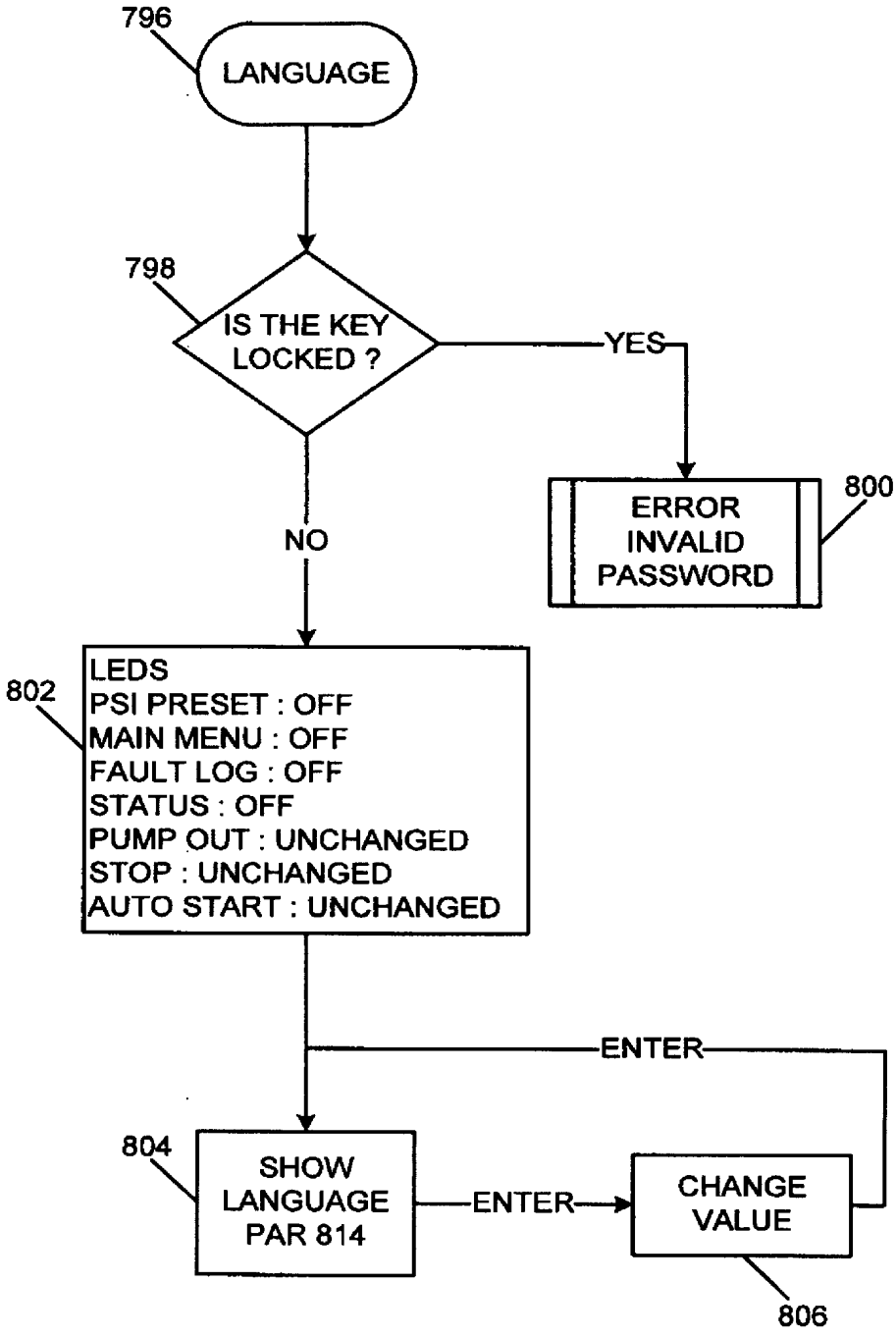

796
LANGUAGE
798
IS THE KEY LOCKED ?
YES
NO
800
ERROR INVALID PASSWORD
802
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
ENTER
804
SHOW LANGUAGE PAR 814
ENTER
CHANGE VALUE
806

FIGURE 57

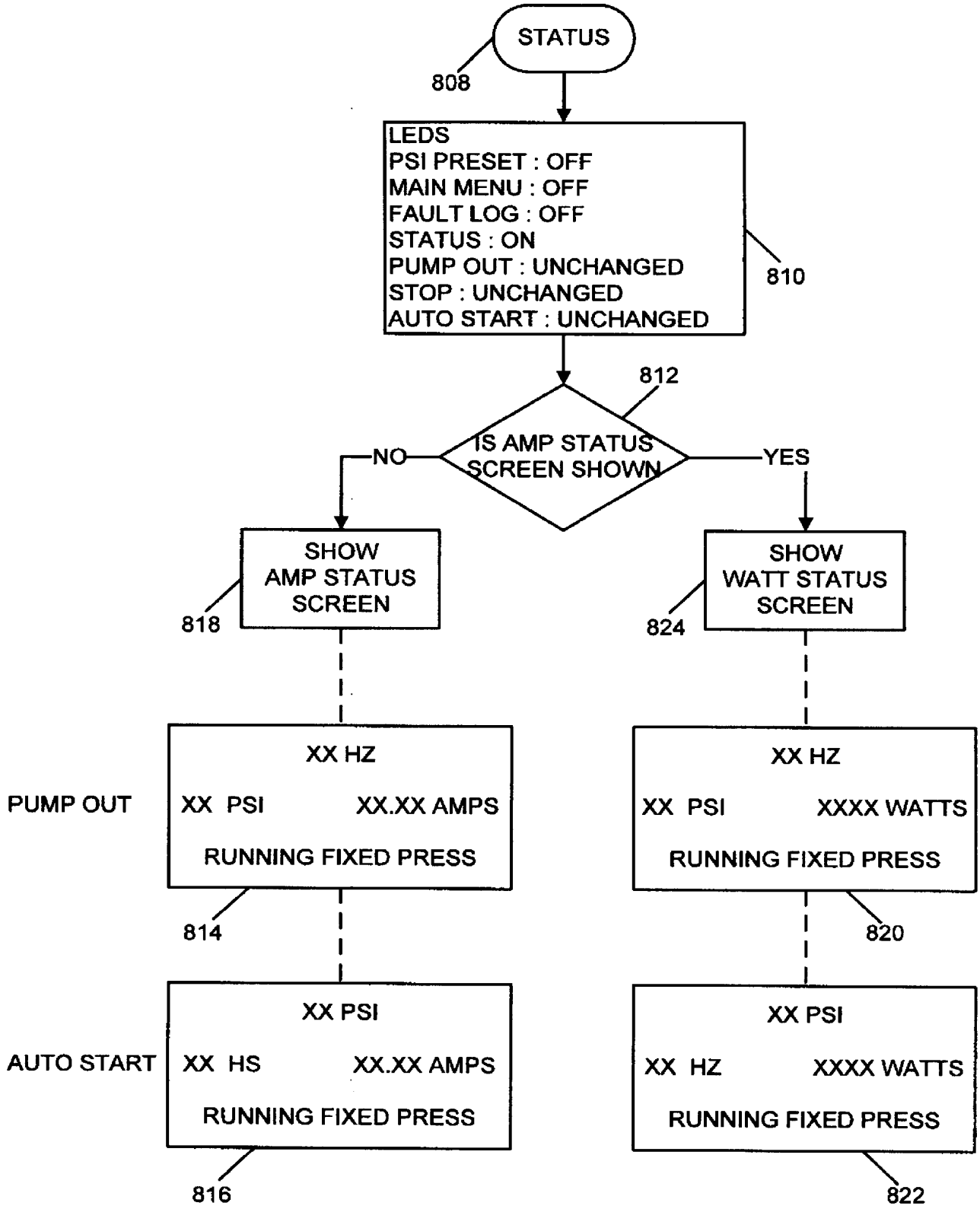

STATUS
808
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : ON
PUMP OUT : UNCHANGED
STOP : UNCHANGED
AUTO START : UNCHANGED
810
812
IS AMP STATUS SCREEN SHOWN
NO
YES
SHOW AMP STATUS SCREEN
818
SHOW WATT STATUS SCREEN
824
XX HZ
PUMP OUT
XX PSI
XX.XX AMPS
RUNNING FIXED PRESS
814
XX HZ
XX 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

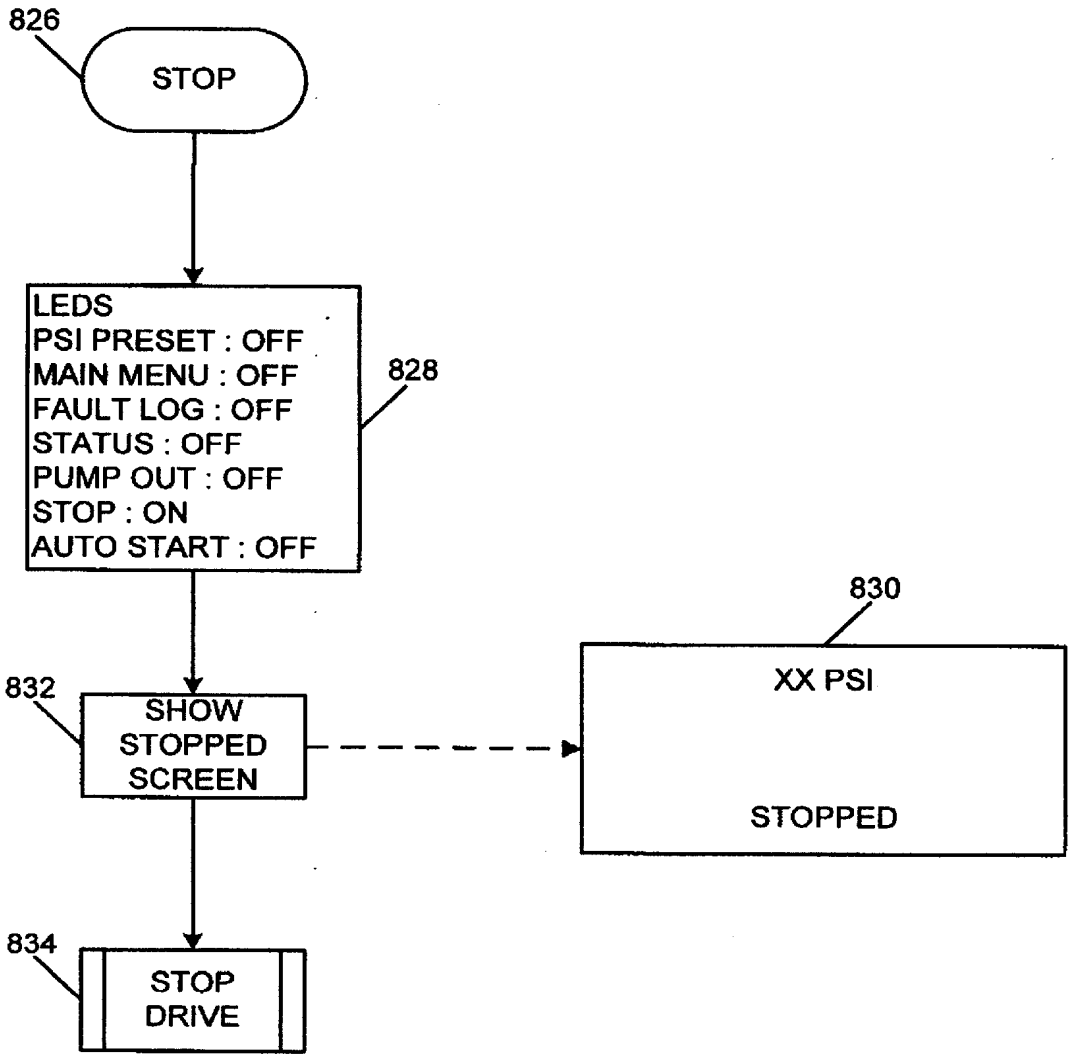

826
STOP
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : OFF
PUMP OUT : OFF
STOP : ON
AUTO START : OFF
828
830
XX PSI
STOPPED
832
SHOW
STOPPED
SCREEN
834
STOP
DRIVE

FIGURE 59

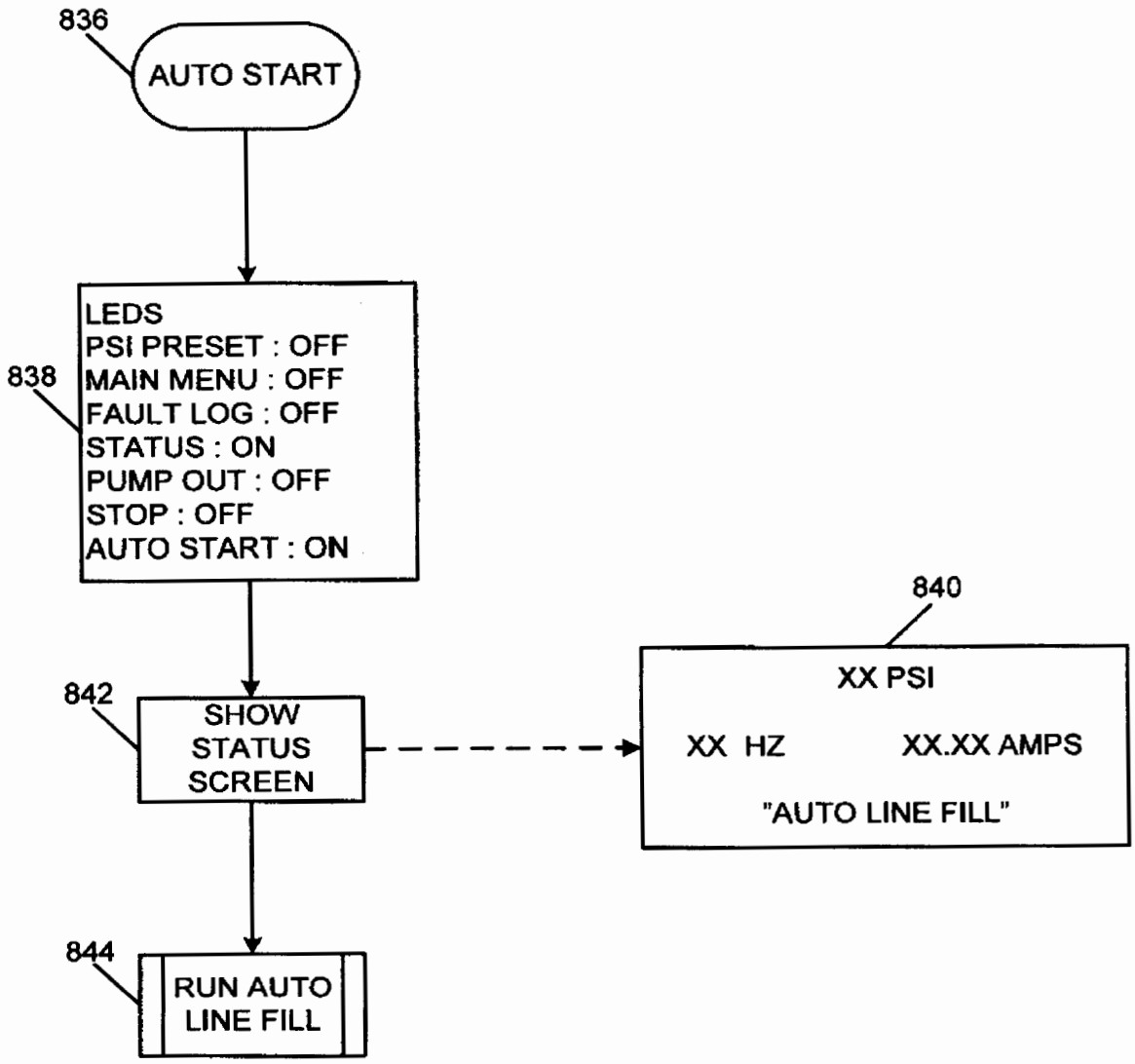

836
AUTO START
LEDS
PSI PRESET : OFF
MAIN MENU : OFF
FAULT LOG : OFF
STATUS : ON
PUMP OUT : OFF
STOP : OFF
AUTO START : ON
838
840
XX PSI
XX HZ
XX.XX AMPS
"AUTO LINE FILL"
842
SHOW STATUS SCREEN
844
RUN AUTO LINE FILL

FIGURE 60

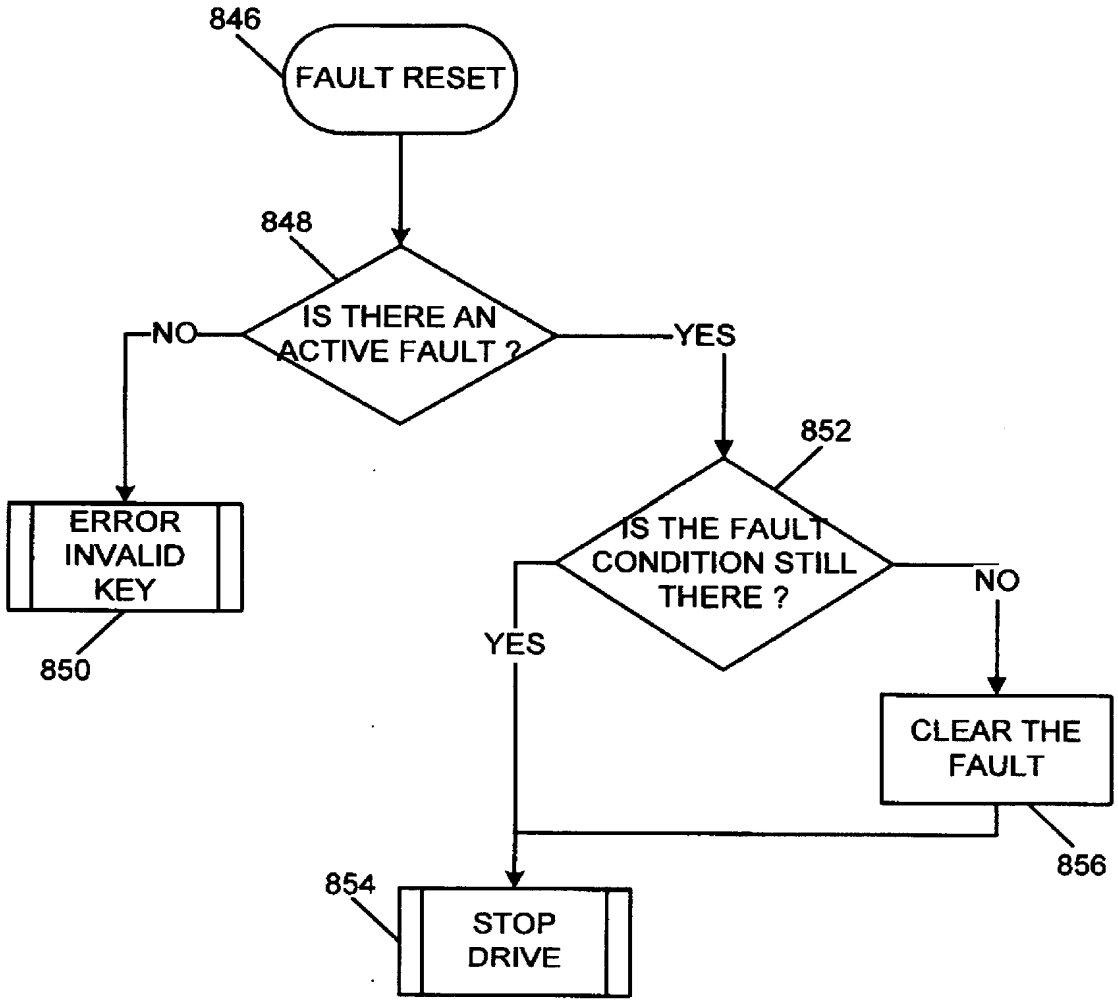

846
FAULT RESET
848
IS THERE AN ACTIVE FAULT ?
NO
YES
ERROR INVALID KEY
850
852
IS THE FAULT CONDITION STILL THERE ?
NO
YES
CLEAR THE FAULT
856
854
STOP DRIVE

FIGURE 61

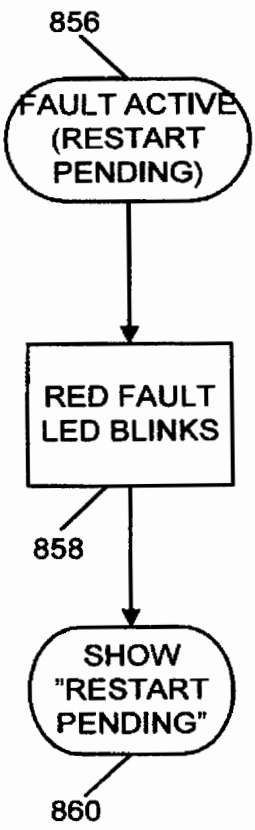


FIGURE 62A

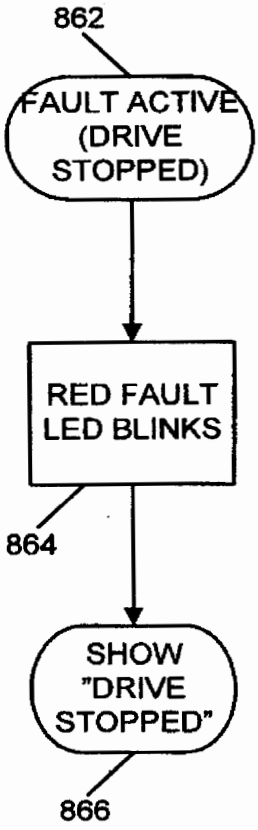


FIGURE 62B

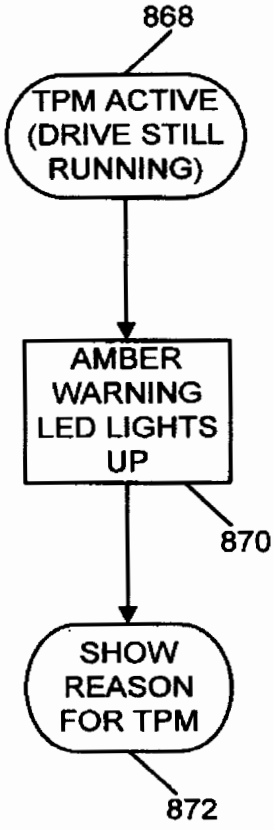


FIGURE 62C

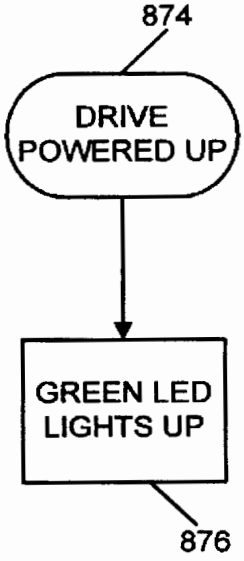


FIGURE 62D

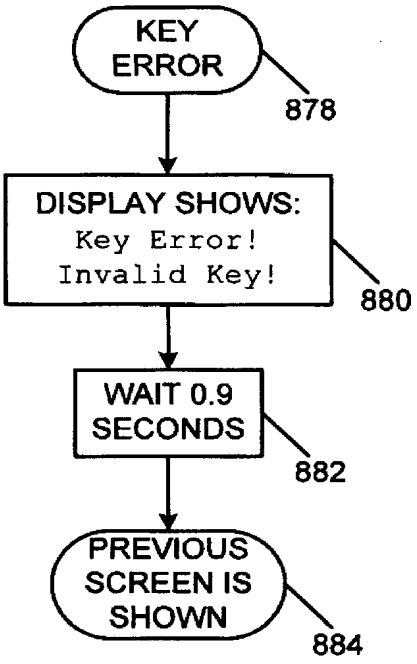


FIGURE 63A

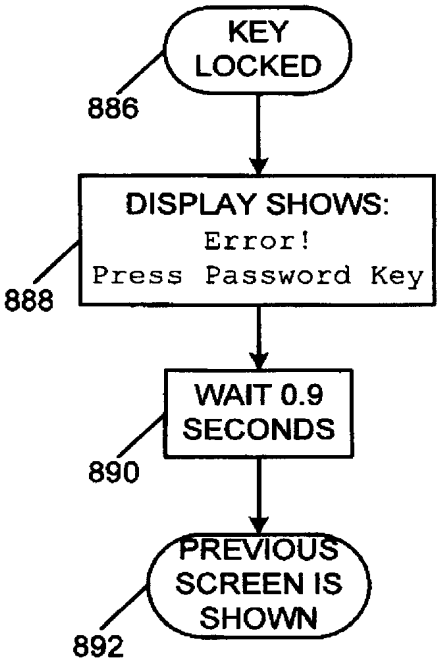


FIGURE 63B

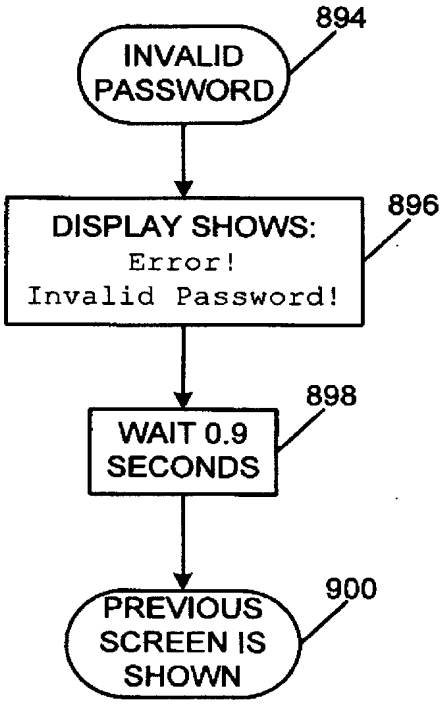


FIGURE 63C

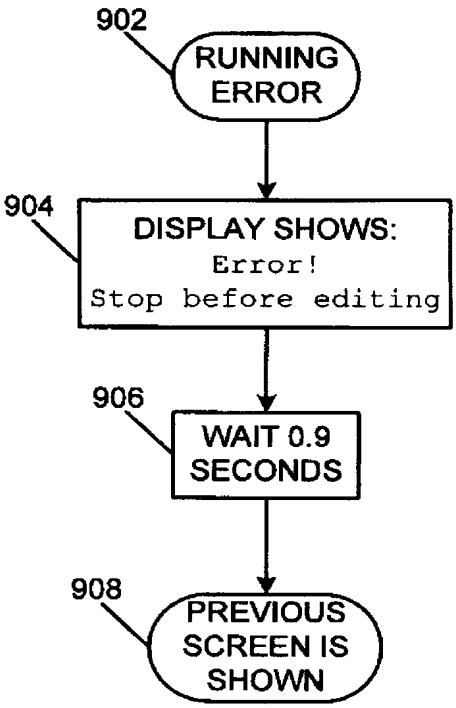
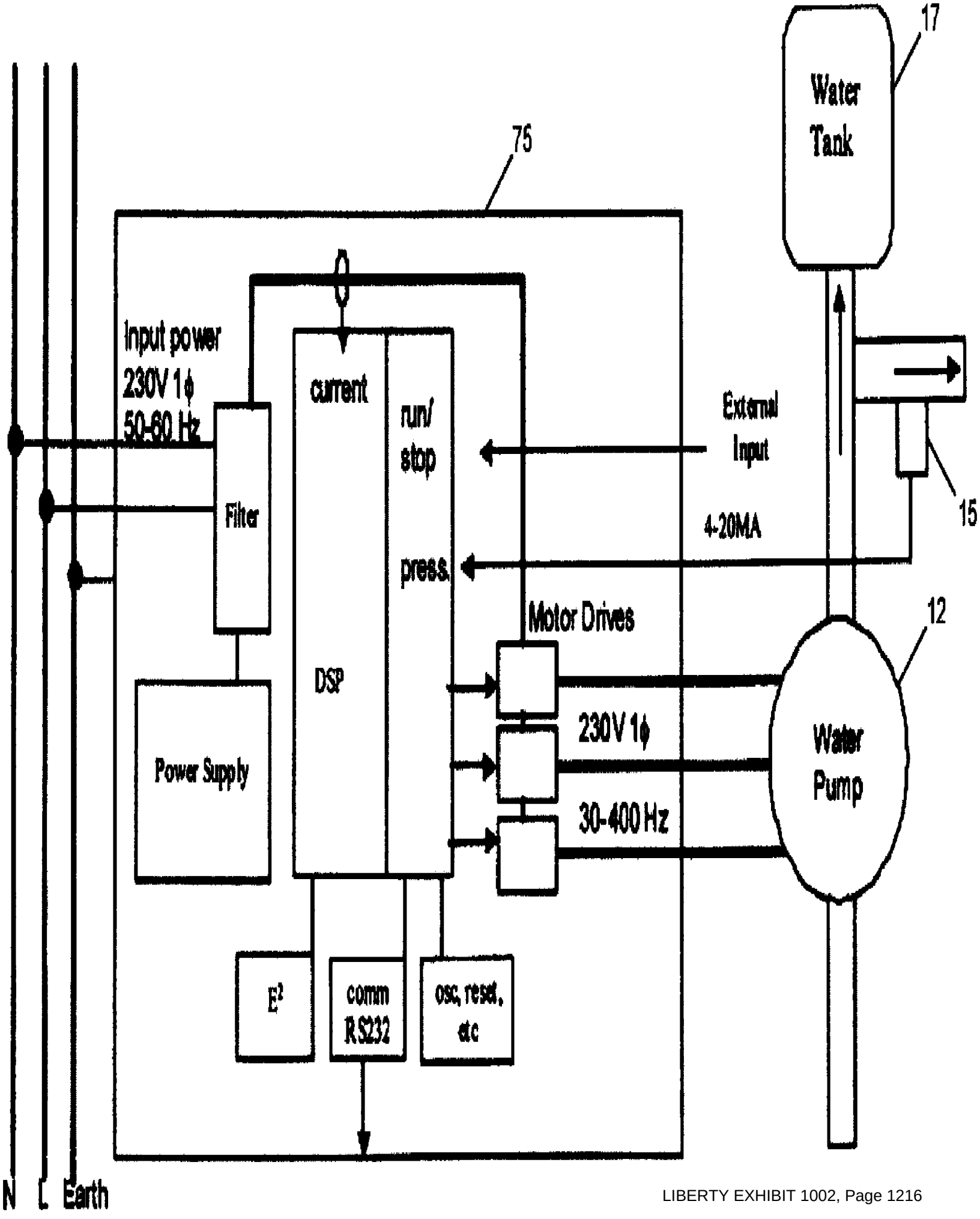


FIGURE 63D


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
Power Supply
Water Pump
30-400 Hz
E²
comm RS232
osc, reset, etc
N
L
Earth

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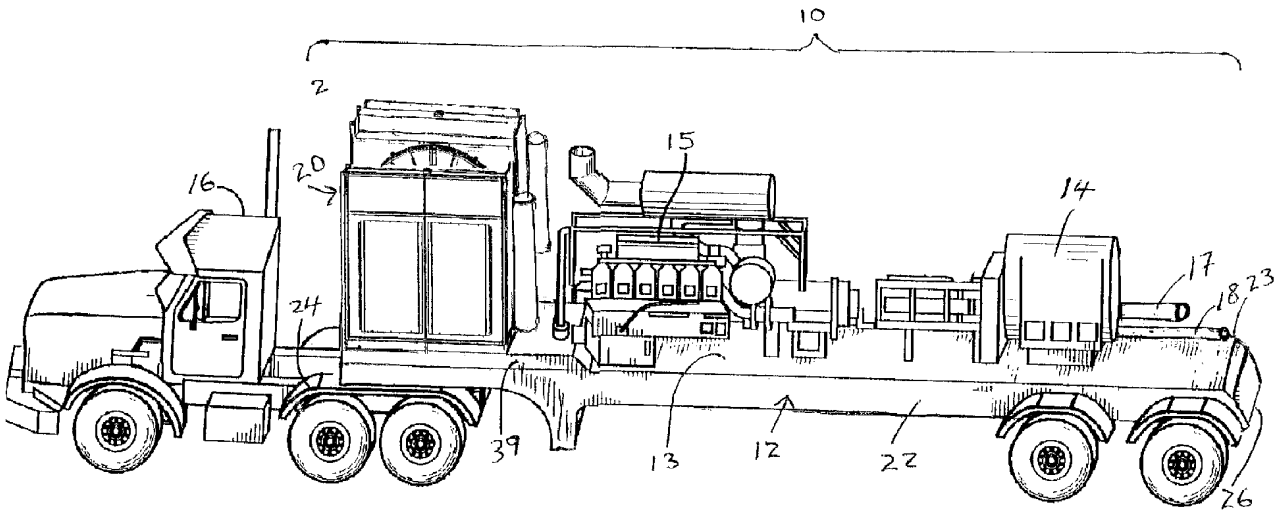
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(54) Titre : CONFIGURATION DE RADIATEUR
(54) Title: RADIATOR CONFIGURATION



(57) Abrégé/Abstract:
A modular mobile fract pump unit having for a radiator with a heat exchanger vertically for generally horizontal flow of air through the radiator and a duct provided on an air exit side of the heat exchanger to direct air exiting the heat exchanger upwardly. Preferably, the duct comprises a retractable duct for movement between an operative position for use in parked cooling operation and a storage position for transport of the unit as a road worthy vehicle, within the storage position the duct not increasing the overall width of the unit and in the operative position the duct extending laterally to the side of the unit beyond the storage position and increasing the overall width of the unit.

ABSTRACT

A modular mobile fract pump unit having for a radiator with a heat exchanger vertically for generally horizontal flow of air through the radiator and a duct provided on an air exit side of the heat exchanger to direct air exiting the heat exchanger upwardly. Preferably, the duct comprises a retractable duct for movement between an operative position for use in parked cooling operation and a storage position for transport of the unit as a road worthy vehicle, within the storage position the duct not increasing the overall width of the unit and in the operative position the duct extending laterally to the side of the unit beyond the storage position and increasing the overall width of the unit.

LIBERTY EXHIBIT 1002, Page 1218

Title

RADIATOR CONFIGURATION

Scope of the Invention

[0001] This invention relates to modular fractoring pump units each comprising a road vehicle carrying a pump, an engine to drive the pump and radiators to cool the engine; and more particularly to a radiator configuration and arrangement for mounting the radiator on the road vehicle to permit advantageous cooling of the engine when a plurality of these road vehicles are parked side to side closely together in an array.

Background of the Invention

[0002] Hydraulic fractoring is known as, for example, disclosed in U.S. Patent 7,063,147 to Siebrits et al, issued June 20, 2006 and U.S. Patent 7,788,037 to Soliman, issued August 31, 2010. U.S. Patent 7,845,413 to Shampine, issued December 7, 2010, the disclosure of which is incorporated herein by reference, teaches a typical manner of providing a plurality modular fract pumping units coupled together.

[0003] Hydraulic fractoring is a known process which requires heavy duty pumps known as fract or fractoring pumps which typically comprise high pressure pumps operating on typically diesel generators generating in the range of 2000 horsepower. A large number of such pumps are generally provided in an array to provide the necessary high pressure and large volume of fluids required for hydraulic fractoring at a remote location. The pumps are known to be provided as part of a modular mobile fract pump unit comprising a road compatible vehicle such as a customized flat bed trailer on which there is mounted the pump, an internal combustion engine to drive the pump and a radiator to cool the engine. The trailers of each unit are typically parked close together in an array side by side with the pump and a typically rigid discharge outlet for the pump at a rear end of the unit and the radiator at a front end of the unit. A central manifold can be provided for coupling of the rigid discharge outlet of each modular mobile fract pump unit at set spaced locations along a central manifold trunk moved towards or away from the manifold trunk. Each modular mobile fract pump unit when accurately located relative the manifold trunk can independently be coupled to the manifold or removed for replacement. The manifold trunk establishes a set spacing of the

trailers of the units in the array side by side as, for example, on 11.5 foot (138 inches) centers. For the modular mobile fract pump unit to be road worthy on Interstate highways in the USA, the unit preferably has a width not greater than 8.5 feet (102 inches.). With, for example, 11.5 foot centers for the pump discharge outlets, this provides for a 3 feet (36 inch) spacing between the sides of adjacent side by side units.

[0004] The internal combustion engine on each mobile fract pump unit typically is a diesel engine. Each diesel engine requires a large radiator to cool the engine. Known radiator structures often provide for two heat exchangers. Prior art devices such as the fractoring system shown in U.S. Patent 7,845,413 to Shampine illustrate horizontally disposed radiators for air flow vertically therethrough. The horizontally disposed radiators extend horizontally for air flow vertically therethrough with the air to pass firstly upwardly through a lower heat exchanger and then secondly upwardly through an upper heat exchanger above the lower heat exchanger. This stacked upper and lower heating exchanger configuration has been selected typically to provide the cooling requirements for the engine within the maximum width for the vehicle unit to be road worthy on Interstate highways in the USA. The stacked upper and lower heating exchanger configuration has the disadvantage that atmospheric air is heated by passing through the lower heat exchanger before the heated air flows upwardly through the second heat exchanger, thus reducing the cooling capacity of the second heat exchanger. As well, the stacked upper and lower heating exchanger arrangement renders it different to clean each heat exchanger after use.

Background of the Invention

[0005] To at least partially overcome these disadvantages of previously known devices, the present invention provides a modular mobile fract pump unit having for a radiator with a heat exchanger vertically for generally horizontal flow of air through the radiator and a duct provided on an air exit side of the heat exchanger to direct air exiting the heat exchanger upwardly. Preferably, the duct comprises a retractable duct for movement between an operative position for use in parked cooling operation and a storage position for transport of the unit as a road worthy vehicle, within the storage position the duct not increasing the overall width of the unit and in the operative position the duct extending laterally to the side

of the unit beyond the storage position and increasing the overall width of the unit. Preferably, the duct is provided with cleaning access doors opening therethrough which can be opened to access the radiator for cleaning. Preferably, a pair of radiators are provided, one along on each side of the vehicle, with the ducts opening outwardly.

[0006] Preferably, a roof member may be provided to bridge laterally between two radiators proximate the top of the radiators. A fan is provided on the interior of each radiator to direct flow laterally outwardly through each radiator. With the roof member in place, the roof member requires air to be passed through the radiators to be drawn laterally from the front or rear or below the radiators reducing the likelihood that heated air discharged vertically from each duct may be drawn down into the fan and passed again through the radiator.

[0007] Vehicles carrying radiators in accordance with the present invention can be parked relatively close together side by side as, for example, within three feet of each other in which the case the ducts would extend to one side, about eighteen inches so that the ducts effectively meet.

[0008] As the radiators preferably have a substantial height and size, to provide for manual closing of the ducts, an arrangement is provided which permits a person on the ground to open and close the radiators avoiding the need to climb the unit and dangers associated therewith. Access doors are provided laterally of the unit through each duct which, preferably when each duct is in a closed position, can be opened by a person on the ground to facilitate the radiators being cleaned as in a known manner by the passage of water through the heat exchangers.

[0009] In one aspect, the present invention provides a modular mobile pump unit comprising:

an elongate mobile trailer having a first side, a second side, a front and a rear,

the trailer having a longitudinal centerline between the first side and the second side,

the trailer having mounted thereon a pump to dispense a fluid, an internal combustion engine to power the pump, a first air cooled radiator to cool the engine and a second air cooled radiator to cool the engine,

the first radiator comprising a vertically extending first heat exchanger for passage of air horizontally therethrough to cool a fluid from the engine circulated within the first heat exchanger and a first fan to blow atmospheric air through the first heat exchanger,

the first radiator mounted to the trailer on the first side of the longitudinal center line proximate the first side with the first heat exchanger adjacent the first side and with the first fan laterally inwardly of the first heat exchanger, the first fan providing for passage of air through the first heat exchanger horizontally and laterally outwardly toward the first side of the trailer,

the first radiator having a first duct member carried on the first radiator at a location laterally outwardly of the first heat exchanger and in the flow path of air from the first fan exiting horizontally and laterally from the first heat exchanger,

the first duct member movable relative to the first radiator from a storage position in which the first duct member does not extend laterally outwardly beyond the first side of the trailer and an operative position in which the first duct member extends laterally outwardly beyond the first side of the trailer,

in the operative position the first duct member receiving air passing laterally from the first heat exchanger and directing this air to exit vertically upwardly from a first duct outlet disposed along an upper edge of the first duct member,

the second radiator comprising a vertically extending second heat exchanger for passage of air horizontally therethrough to cool a fluid from the engine circulated within the second heat exchanger and a second fan to blow atmospheric air through the second heat exchanger,

the second radiator mounted to the trailer directly opposite the first radiator on the second side of the longitudinal center line proximate the second side with the second heat exchanger adjacent the second side and with the second fan laterally inwardly of the second heat exchanger, the second fan providing for passage of air through the second heat exchanger horizontally and laterally outwardly toward the second side of the trailer,

the second radiator having a second duct member carried on the second radiator at a location laterally outwardly of the second heat exchanger and in the flow path of air from the second fan exiting horizontally and laterally from the second heat exchanger,

the second duct member movable relative to the second radiator from a storage position in which the second duct member does not extend laterally outwardly beyond the second side of the trailer and an operative position in which the second duct member extends laterally outwardly beyond the second side of the trailer,

in the operative position the second duct member receiving air passing laterally from the second heat exchanger and directing this air to exit vertically upwardly from a second duct outlet disposed along an upper edge of the second duct member. Preferably, the invention provides an array of such units wherein the units are arranged side by side with a spacing between adjacent units at least equal to a spacing distance represented by the sum of a distance that the first duct member in the operative position extends beyond the first side of the trailer and a distance that the second duct member in the operative position extends beyond the second side of the trailer.

Brief Description of the Drawings

[0010] Further aspects and advantages of the present invention will become apparent from the following description taken together with the accompanying drawings in which:

[0011] Figure 1 is a perspective rear view of a modular mobile pump unit in accordance with the present invention in conjunction with a tractor;

[0012] Figure 2 is a schematic front perspective view of a skid platform and the radiators shown in Figure 1 in a storage position;

[0013] Figure 3 is a front view of Figure 2;

[0014] Figure 4 is a schematic front perspective view the same as Figure 2 but showing the radiators in an operative position;

[0015] Figure 5 is a front view of Figure 4;

[0016] Figure 6 is a schematic cross-sectional front view along section line 6-6′ in Figure 4 showing the right hand side radiator;

[0017] Figure 7 is a schematic perspective view illustrating a mechanism for movement of the duct member between the storage position and the operative position;

[0018] Figure 8 is a perspective view the same as Figure 2 but showing access doors in an open position;

[0019] Figure 9 is a schematic top view showing a plurality of units in accordance with Figure 1 arranged in two rows, one on either side of a central manifold;

[0020] Figure 10 is an enlarged view of the front portions of three of the units shown in Figure 9 showing the units as being spaced an equal distance apart; and

[0021] Figure 11 is a perspective view the same as Figure 4 but additionally showing a roof baffle.

Detailed Description of the Drawings

[0022] Figure 1 shows a modular pump mobile unit 10 in accordance with the present invention. The mobile 10 comprises a standard trailer 12, a fluid pump 14, a diesel motor 15 that drives the pump 14 and a pair of radiators 20 and 21 for cooling the diesel motor 15. The trailer 12 is removably coupled to a tractor 16 for ease of transportation. The pump 14 has a intake pipe 17 for receiving fluid at a low pressure and a discharge pipe 18 for discharging fluid at a high pressure.

[0023] The unit 10 and the trailer 12 have a first side 22, a second parallel side 23, a front 24 and a rear 26. As seen in Figure 10, the unit 10 and the trailer 12 have a longitudinal center line 27 which extends longitudinally of the unit 10 and the trailer 12 between the first side 22 and the second side 23.

[0024] Referring to Figure 9, an array of mobile modular units 10 is arranged on opposite sides of a fluid manifold 30. The manifold 30 extends along a manifold longitudinal 31. The manifold includes a low pressure liquid line 32 and a high pressure discharge line 34. The intake pipe 17 from each unit 10 is adapted to be removably coupled to a corresponding outlet pipe 35 of the low pressure liquid line 32 and the discharge pipe 18 of each unit 10 is adapted to be removably coupled to a corresponding inlet pipe 36 of the high pressure discharge line 34. The low pressure liquid line 32 has the outlet pipe 35 located at equally spaced fixed distances along the longitudinal 31 of the manifold. The high pressure discharge

line 34 has the inlet pipes 36 located at correspondingly spaced fixed distances along the longitudinal 31 of the manifold 30. Each inlet pipe 36 includes a valve 37 and each outlet pipe includes a valve 38 to selectively independently permit or prevent flow. Each unit 10 is preferably located with its longitudinal center line 27 perpendicular to the longitudinal 31 of the manifold 30. Each mobile unit 10 may be disconnected from the manifold 30 and independently moved forwardly or rearwardly for replacement by another modular unit 10.

[0025] As can be seen in Figure 1, the trailer 12 has a deck 13 including a skid portion 39 upon which the radiators 20 and 21 are schematically shown as being mounted. For ease of illustration, in each of Figures 2 to 5, the radiators are shown as mounted on the skid 39 without illustrating other components of the unit 10.

[0026] Reference is made to Figure 6 which is a schematic cross-sectional view along section line 6-6′ of the first radiator 20. The first radiator 20 has a first heat exchanger 40. The first heat exchanger 40 includes a top header 41 and a bottom header 42 with a core 90 of vertically extending cooling tubes 43 extending vertically between the top header 41 and the bottom header 42. A fluid inlet 44 delivers fluid from the cooling system of the motor 15 to the bottom header 42. A fluid outlet 45 is connected to the top header 41 and delivers cooled fluid from the top header 41 back to the cooling system of the motor 15. Thus, cooling fluid from the motor 15 is to be circulated in a cooling circuit, only part of which is shown, to pass from the fluid inlet 44 into the bottom header 42 vertically through the cooling tubes 43 to the top header 41 and then out the fluid outlet 45 to return to the engine. As will be appreciated, a suitable circulating pump (not shown) is provided to circulate the cooling fluid through the first heat exchanger 40.

[0027] The first radiator 20 includes a system for passing atmospheric air through the core of the first heat exchanger past the cooling tubes 43 so as to reduce the temperature of the cooling fluid circulated through the cooling tubes 43. In this regard, as schematically shown in Figure 6, a fan 46 is rotatable about a horizontal fan axis 47 within a cylindrical fan casing 48 so as to draw atmospheric air inwardly through openings 49 in the fan casing and force the air horizontally and laterally outwardly through the core 90 and past the cooling tubes 43. As seen in Figure 6, the fan 46 directs air flow laterally outwardly in a direction

from the longitudinal center line 27 laterally outwardly toward the first side 22. In this regard, the first heat exchanger 40 may be considered to have an air inlet opening 50 on the laterally inward side of the cooling tubes 43 and an air outlet opening 51 on a radially outwardly side of the cooling tubes 43.

[0028] The first radiator 20 has a first duct member 52 which in Figure 6 is illustrated as being in an operative position permitting air flow from the fan 46 laterally outwardly through the air outlet opening 51 and then upwardly through the duct member 52 to exit upwardly through a first duct outlet 54 open to the atmosphere. As seen in Figure 6, the first duct outlet 54 is disposed along an upper edge 55 of the first duct member 52.

[0029] Each of the first radiator 20 and the second radiator 21 has identical components and each is located on a respective side of the longitudinal center line 27 of the trailer 12. The radiators 20 and 21 can be virtually identical but for arrangements so as to be suitably located adjacent either the first side 22 or the second side 23. For ease of discussion, each of the individual elements of the second radiator 21 will be referred to by the same reference numerals used to refer to the elements of the first radiator 20.

[0030] The duct member 52 of the radiators 20 and 21 are movable between operative positions as shown in Figures 4 and 5 which permit air flow upwardly from the duct outlets 54 and storage positions as shown in Figures 2 and 3 which substantially close the air outlets 51. As seen in end view in Figure 3, with the radiators 20 and 21 and the duct members 52 in the storage position, the radiators 20 and 21 do not extend outwardly beyond the trailer first side 22 or the second side 23. In contrast, as seen in end view in Figure 5, in the operative position, the duct members 52 extend laterally beyond the sides of the trailer, with the duct member 52 of the first radiator 20 extending beyond the trailer first side 22 and the duct member 52 of the second radiator 21 extending beyond the second side 23.

[0031] Reference is made to Figure 10 which is a schematic enlargement of front portions of three units 10 shown in Figure 9 arranged side to side and in which the left hand-most trailer is shown with its radiators 20 and 21 having their duct members 52 in the storage position, the middle unit 10 is shown as having its radiators 20 and 21 with its duct members 52 in the operative position and the right hand unit 10 is illustrated as having its second

radiator 21 with its first duct member 52 in an operative position and its first radiator 20 having its duct member 52 in a storage position. In Figure 10, the width of each unit 10 is illustrated as W with a width of each of the three units 10 being indicated as identical. The center line 27 for each unit 10 is shown and the distance between center lines, D_c is shown and is indicated as being identical. The units 10 are shown as arranged side by side with a spacing between units indicated as S and which such spacing S being represented as equal to two times the distance D_e that duct member 52 extends laterally from the respective side of its respective unit 10. In a preferred embodiment as illustrated in Figures 9 and 10, the inlet pipes 36 for the high pressure discharge line 34 and the outlet pipes 35 for the low pressure fluid line 32 may be spaced along the manifold longitudinal 31 a distance equal to D_c shown in Figure 10. Preferably, the distance D_c is equal to the width W of a trailer plus at least twice D_e the distance that each duct member 52 extends from a trailer. Such an arrangement provides for optimal usage of the spacing between units 10 for discharge of air upwardly. Preferably, the width of a trailer is a maximum width which permits the trailer to be roadworthy, for example, 102 inches. Preferably, the distance D_e is in the range of 12 to 24 inches, preferably 18 inches and the units 10 as well as the outlet pipes 35 and the inlet pipes 36 are spaced a distance of D_c of about 138 inches.

[0032] Reference is made to Figure 4 which illustrates a preferred configuration for each duct member 52. The duct member 52 has a side wall 70, a front wall 71 and a rear wall 72. The side wall 70 is mounted to a rectangular frame 73 of a casing 74 for each radiator that contains the heat exchanger 40 and provides the passageway for air flow. The frame 73 effectively defines the air outlet opening 51 for passage of air laterally outwardly through the core and its cooling tubes 43. The duct member 52 is pivotally mounted to the frame 73 for pivoting at its lower end about a horizontal axis generally indicated as 75. Each of the front wall 71 and the rear wall 72 is formed from two triangular gusset members 76 and 77, each mounted by hinge members extending along the edges of each gusset member such that with pivoting of the side wall 70 about the horizontal axis 75, the gusset members fold inwardly upon themselves in a manner not dissimilar to that of a pleat in an accordion.

[0033] An actuator member 79 is provided for moving each of the duct members 52 between the operative position and the storage position. As seen in Figures 4 and 6, a vertical strut 80 is mounted to the frame 73 and pivotably carries a first pivot arm 81 which is pivotably coupled to a second pivot arm 82 pivotably coupled to the center of the side wall 70. As illustrated in Figure 7, the actuator mechanism includes a rotatable rod 83 which is mounted to a lower portion of the frame 73 and extends upwardly to an actuator link 84 engaging the first pivot arm 81. With rotation of a crank handle 85, shown in Figure 7, the actuator link 84 is moved upwardly or downwardly and thus pivots the first and second pivot arms so as to move the duct member 52 toward the operative position by moving the pivot arms upwardly and to move the duct member 52 toward the storage position by moving the pivot arms downwardly.

[0034] The crank handle 85 is located at a height on the unit 10 to be accessible by a person standing on the ground without the need for the person to climb the unit 10 or its trailer 12. The crank handle 85 is to be provided so as to avoid interference in use with other portions of the unit 10 such as the trailer 12 or the skid 39 albeit, in the embodiments for ease of illustration, the crank handle 85 appears to be in interference with the skid 39. As can be seen in Figure 4, with the side wall 70 in the operative position, the duct outlet 54 is open upwardly to the atmosphere for discharge of air upwardly.

[0035] Reference is made to Figure 8 which illustrates the duct members 52 in a closed position, however, with access doors 88 on the duct member 52 shown as being in an open position. As seen in Figure 8, the side wall 70 of each duct member 52 is provided with two rectangular access openings 89 therethrough. An access door 90 is provided coupled by a vertically extending hinge 92 to an edge of each access opening 89. The access doors 88 are movable from a closed position as shown in Figure 2 which closes the side wall 70 to air flow therethrough and an open position as shown in Figure 8 in which the access doors provide access to the heat exchanger 40 therein and, more particularly, to the core of the heat exchanger and the cooling tubes 43. With the access doors 88 in the open position as shown in Figure 8, a person on the ground can access the core 90 and its cooling tubes 43 for cleaning as, for example, with a user to hold a hose to discharge a stream of air or water to engage the

core and its cooling tubes 43 to clean the outside of the cooling tubes from various matters such as dust, dirt, mud and the like which may have come to be engaged upon the cooling tubes during use and typically which impedes efficient heat transfer. Of course, the core and its cooling tubes 43 may have various cooling fins 70 which may be placed close together and from which debris such as dust, dirt and mud may preferably be removed in cleaning on a regular basis to maintain the efficiency of the heat exchanger. Figure 8 schematically shows four vertically extending cooling tubes 43 and two longitudinally extending cooling fins 70 although a large number typically are to be provided.

[0036] The access doors 88 are located on the radiators 20 and 21 at a location that a person standing on the ground can manually move the access doors between the open and closed positions and to latch the doors in the open and closed positions. Various latching arrangements may be used as they are accessible from the ground and are used, for example, to close the doors at the rear of box trailers and the like. A latching arrangement 72 is schematically illustrated in Figure 2 only. Vertically extending lock rod 73 rotatably supported on each door 88 and pivotable by a handle 74 between coupled and uncoupled conditions with cam latches 75 and 76 carried on the front wall 70 above and below each door 88 and are of the type disclosed in U.S. Patent 2,038,876 to Sonabend, issued April 28, 1936. The handle 74 is accessible to a person on the ground. Once unlatched, each door 88 is accessible to a person on the ground to pivot each door between open and closed positions.

[0037] In the preferred embodiments, the heat exchangers are shown with a core which has vertically extending cooling tubes 43. In accordance with the invention, it is not necessary that the cooling tubes 43 extend vertically. For example, in a similar heat exchanger, the cooling tubes may extend horizontally. Referring to Figure 6, in addition to the primary core 90 having vertically extending cooling tubes 43, a secondary core 91 is shown schematically to have horizontally extending cooling tubes 92.

[0038] In the preferred embodiment, the trailer first side 22 and the trailer second side 23 are shown as providing substantially in the same vertical plane, a laterally most extending surface of the unit 10, the trailer 12, the trailer deck 13, its skid 39 and each of the radiators 20 and 21. It is to be appreciated that a unit 10 with the duct members 52 in the storage

position, the unit 10 will have a width defined by a laterally outermost surface. The laterally outermost surface may comprise the side wall 70 of one of the radiators with, for example, the skid 39 or the trailer deck 13 or the portions of the trailer disposed laterally inwardly therefrom.

[0039] In the preferred embodiment, the duct member 52 is illustrated to assume an operative position in which the duct member 52 extends laterally from the unit 10 farther in the operative position than in a storage position. The particular configuration of the duct member 52 is not limited. The preferred duct member 52 illustrated hinges about the horizontal hinge axis 75 at the bottom of the duct member 52. This is not necessary. The duct member 52 could be provided to merely slide laterally to one side and, for example, to extend in the operative position farther laterally outwardly over its whole height than when in the storage position.

[0040] The duct member 52 is shown as having its front wall 71 and its rear wall 72 formed from gusset members which fold to collapse upon themselves when a duct member 52 is moved to the storage position. This is not necessary and each of the front wall 71 and the rear wall 72 could be rigid members which slide laterally into slots provided on the radiator of a casing 74. Similarly, rather than provide the front wall 71 and the rear wall 72 from rigid gusset members, each wall could be provided as from a flexible member as, for example, from a flexible elastomeric member or fabric.

[0041] Reference is made to Figure 11 which illustrates a second embodiment in accordance with the present invention and which is identical to the first embodiment with the first exception that a roof member 93 is provided bridging between the first radiator 20 and the second radiator 21 laterally inwardly of the duct outlet 54 on each side of the unit 10 and above the fans 46 and their fan casings 48. Between the casing 74 enclosing each heat exchanger 40, and beneath the roof member 93, a forward air inlet 94 and rear air inlet 95 is provided via which atmospheric air may be drawn into the fan as indicated by the arrows 96 and 98. Air drawn into the fans 46 is directed through the heat exchangers 40 to exit upwardly from the duct outlets 54 as indicated by the arrows 98 and 99. Providing the roof

member 93 assists in reducing the likelihood that heated air exhausted upwardly from the duct outlets is drawn back into the fans.

[0042] Figure 11 differs from the first embodiment in showing schematically a bottom air inlet 100 provided through the skid portion 39 and which permits air from below the deck 39 of the trailer 12 into the fan 46 as indicated by arrow 101. The bottom air inlet 100 can be accommodated with suitable ducting or apertures through the skid portion 39 and deck underneath the fans 46. Figure 11 further shows as also shown schematically in Figure 6 the deck 39 to be cut away under the fan 46 to provide the bottom air inlet 100 and permit air flow upwardly as indicated by arrow 100. Figures 11 and 6 also show one lower horizontal air inlet 102 shown to be formed internally within the deck 39 to permit air flow horizontally from the side as indicated by arrow 103 to the fan 46. The lower horizontal air inlet 102 may be provided, one on each side, whether or not a bottom air inlet 100 is provided.

[0043] While the invention has been described with reference to the preferred embodiments, many variations and modifications will now occur to a person skilled in the art. For a definition of the invention, reference is made to the accompanying claims.

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I CLAIM:

1. A modular mobile pump unit comprising:

an elongate mobile trailer having a first side, a second side, a front and a rear,

the trailer having a longitudinal centerline between the first side and the second side,

the trailer having mounted thereon a pump to dispense a fluid, an internal combustion engine to power the pump, a first air cooled radiator to cool the engine and a second air cooled radiator to cool the engine,

the first radiator comprising a vertically extending first heat exchanger for passage of air horizontally therethrough to cool a fluid from the engine circulated within the first heat exchanger and a first fan to blow atmospheric air through the first heat exchanger,

the first radiator mounted to the trailer on the first side of the longitudinal center line proximate the first side with the first heat exchanger adjacent the first side and with the first fan laterally inwardly of the first heat exchanger, the first fan providing for passage of air through the first heat exchanger horizontally and laterally outwardly toward the first side of the trailer,

the first radiator having a first duct member carried on the first radiator at a location laterally outwardly of the first heat exchanger and in the flow path of air from the first fan exiting horizontally and laterally from the first heat exchanger,

the first duct member movable relative to the first radiator from a storage position in which the first duct member does not extend laterally outwardly beyond the first side of the trailer and an operative position in which the first duct member extends laterally outwardly beyond the first side of the trailer,

in the operative position the first duct member receiving air passing laterally from the first heat exchanger and directing this air to exit vertically upwardly from a first duct outlet disposed along an upper edge of the first duct member,

the second radiator comprising a vertically extending second heat exchanger for passage of air horizontally therethrough to cool a fluid from the engine circulated within the

second heat exchanger and a second fan to blow atmospheric air through the second heat exchanger,

the second radiator mounted to the trailer directly opposite the first radiator on the second side of the longitudinal center line proximate the second side with the second heat exchanger adjacent the second side and with the second fan laterally inwardly of the second heat exchanger, the second fan providing for passage of air through the second heat exchanger horizontally and laterally outwardly toward the second side of the trailer,

the second radiator having a second duct member carried on the second radiator at a location laterally outwardly of the second heat exchanger and in the flow path of air from the second fan exiting horizontally and laterally from the second heat exchanger,

the second duct member movable relative to the second radiator from a storage position in which the second duct member does not extend laterally outwardly beyond the second side of the trailer and an operative position in which the second duct member extends laterally outwardly beyond the second side of the trailer,

in the operative position the second duct member receiving air passing laterally from the second heat exchanger and directing this air to exit vertically upwardly from a second duct outlet disposed along an upper edge of the second duct member.

2. A unit as claimed in claim 1 wherein:

the first duct member extends vertically throughout the height of the first heat exchanger locating the first duct outlet at a height substantially the same as uppermost portions of the first heat exchanger, and

the second duct member extends vertically throughout the height of the second heat exchanger locating the second duct outlet at a height substantially the same as uppermost portions of the second heat exchanger.

3. A unit as claimed in claim 2 including:

a roof baffle member bridging laterally between the first radiator and the second radiator above the first fan and the second fan at a height below the first duct outlet and the second duct outlet,

the baffle member limiting the direct flow of air discharged upwardly from the first duct outlet and the second duct outlet downwardly into the first fan and the second fan.

4. A unit as claimed in claim 3 wherein:

a front air entrance way is defined between the first radiator and the second radiator below the roof baffle member for passage of atmospheric air rearwardly to the first fan and the second fan,

a rear air entrance way is defined between the first radiator and the second radiator below the roof baffle member for passage of atmospheric air forwardly to the first fan and the second fan.

5. A unit as claimed in claim 2 including:

at least one first access door through the first duct member movable between a closed position and an open position, wherein with the first duct member in the storage position and the first access door in the open position the first access door providing access from the first side of the trailer to the first heat exchanger for cleaning, and

at least one second access door through the second duct member movable between a closed position and an open position, wherein with the second duct member in the storage position and the second access door in the open position the second access door providing access from the second side of the trailer to the second heat exchanger for cleaning.

6. A unit as claimed in claim 5 wherein:

the first heat exchanger having an air flow passageway for air flow therethrough from a laterally inwardly located first air inlet opening to a laterally outwardly located first air outlet opening,

in the operative position the first duct member receiving air from the first air outlet opening of the first heat exchanger and directing the air to exit vertically upwardly from the first duct outlet,

the first duct member in the storage position with the first access door closed extends across the first air outlet opening of the first heat exchanger closing the first air outlet opening,

the second heat exchanger having an air flow passageway for air flow therethrough from a laterally inwardly located second air inlet opening to a laterally outwardly located second air outlet opening,

in the operative position the second duct member receiving air from the second air outlet opening of the second heat exchanger and directing the air to exit vertically upwardly from the second duct outlet,

the second duct member in the storage position with the second access door closed extends across the second air outlet opening of the second heat exchanger closing the second air outlet opening.

7. An array of units as claimed in claim 1 wherein the units are arranged side by side with a spacing between adjacent units at least equal to a spacing distance represented by the sum of a distance that the first duct member in the operative position extends beyond the first side of the trailer and a distance that the second duct member in the operative position extends beyond the second side of the trailer.

8. An array of units as claimed in claim 7 wherein the spacing between adjacent units is substantially equal to the spacing distance.

9. An array of units as claimed in claim 2 including a first mechanism operative by a person on the ground to move the first duct member between the storage position and the operative position; and

a second mechanism operative by a person on the ground to move the second duct member between the storage position and the operative position.

10. An array of units as claimed in claim 5 including a first latching mechanism accessible by a person on the ground to latch and unlatch the first access door; and

a second latching mechanism accessible by a person on the ground to latch and unlatch the second access door

11. An array of units as claimed in claim 7 in combination with a manifold having a plurality of inlet pipes, located longitudinally along the manifold an equal distance equal to at least the width of each trailer between the first side and the second side plus the spacing between adjacent units,

the pump of each unit having a discharge pipe adapted to be removably coupled to the inlet pipes of the manifold,

each mobile unit having its rear located proximate the manifold and its front remote from the manifold,

each unit being independently removably coupled to the manifold and independently movable forwardly away from the manifold for replacement by another similar modular unit.

12. A unit as claimed in claim 3 including at least one of:

a front air entrance way is defined between the first radiator and the second radiator below the roof baffle member for passage of atmospheric air rearwardly to the first fan and the second fan,

a rear air entrance way is defined between the first radiator and the second radiator below the roof baffle member for passage of atmospheric air forwardly to the first fan and the second fan,

a bottom air entranceway is defined for passage of atmospheric air from below the trailer upwardly through the trailer to the first fan and the second fan,

a first lower air entranceway is defined for passage of atmospheric air from below the first radiator from the first side laterally inwardly and underneath the first radiator to the first fan, and

a second lower air entranceway is defined for passage of atmospheric air from below the second radiator from the second side laterally inwardly and underneath the second radiator to the second fan.

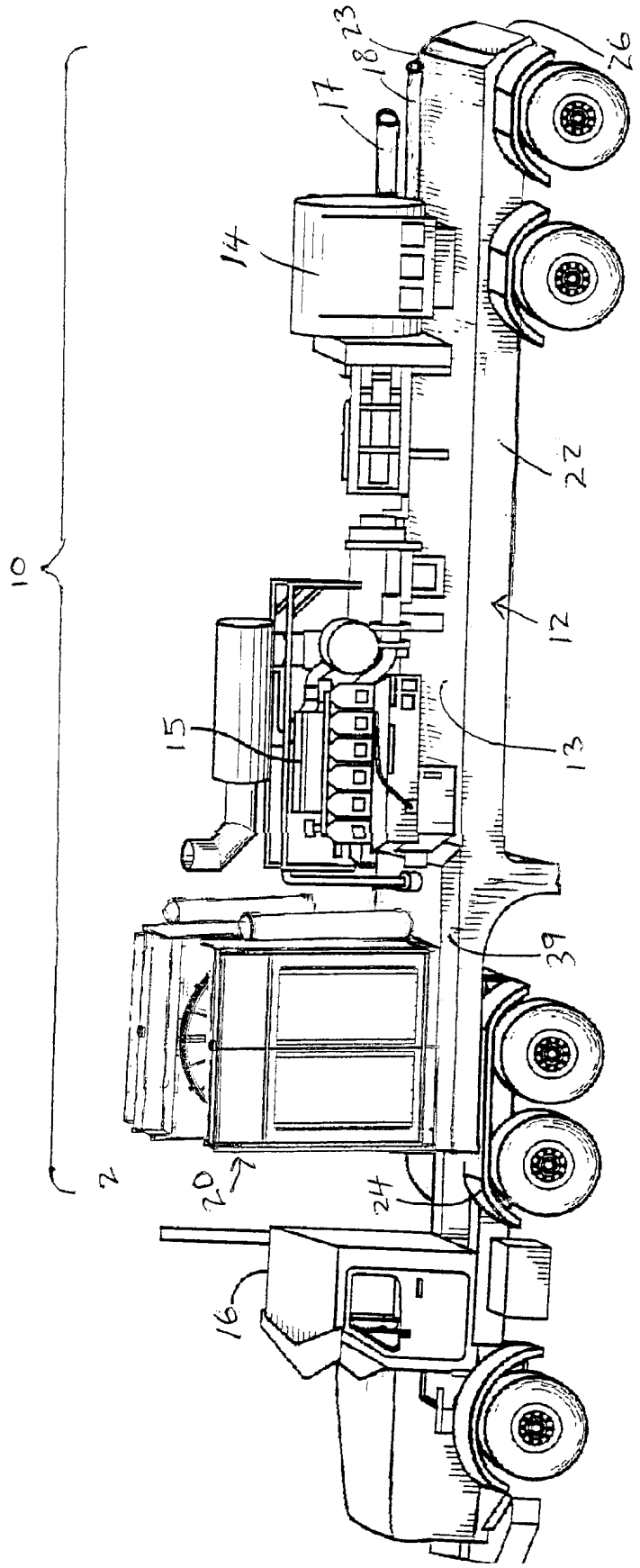


FIG. 1

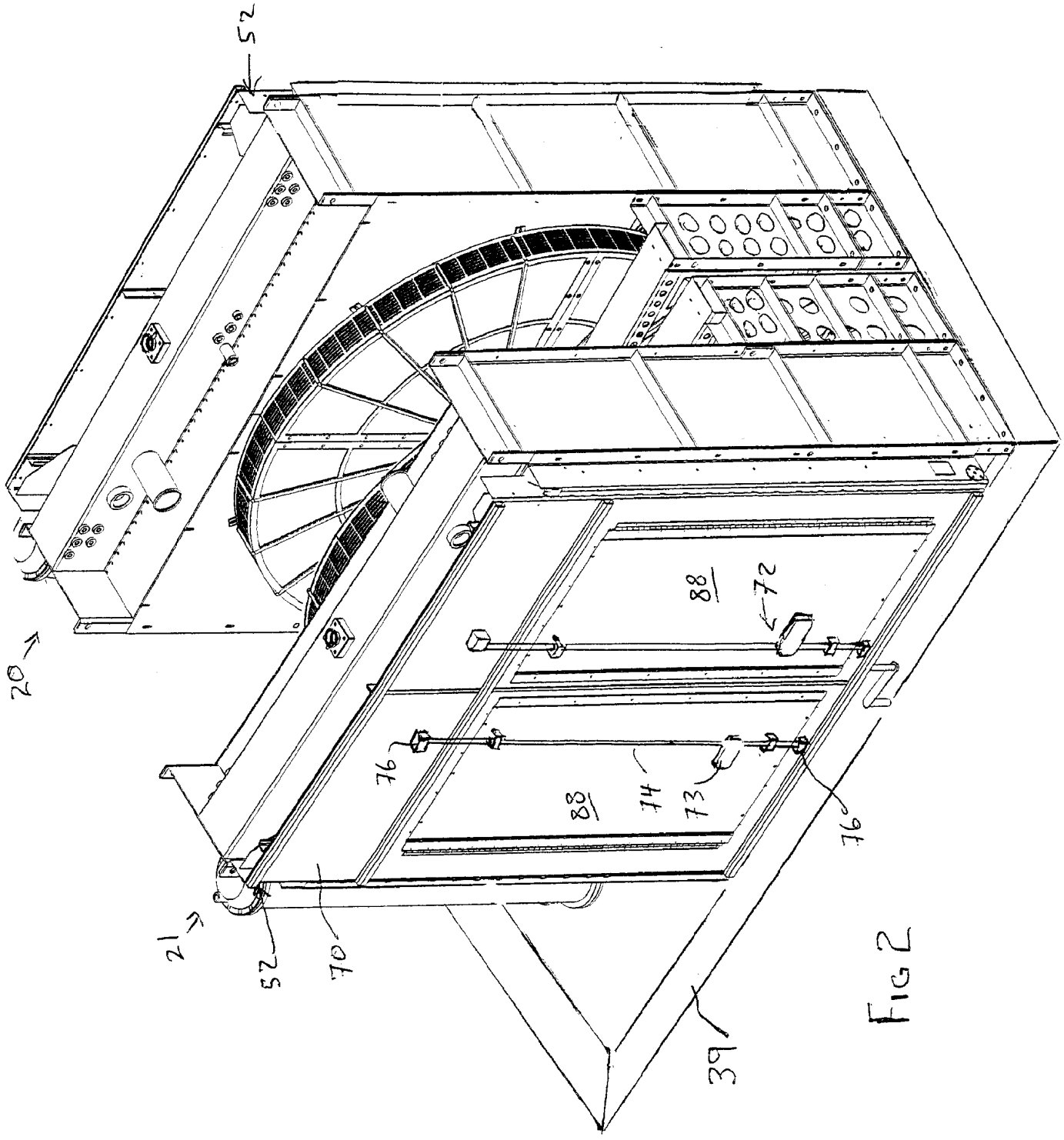


FIG 2

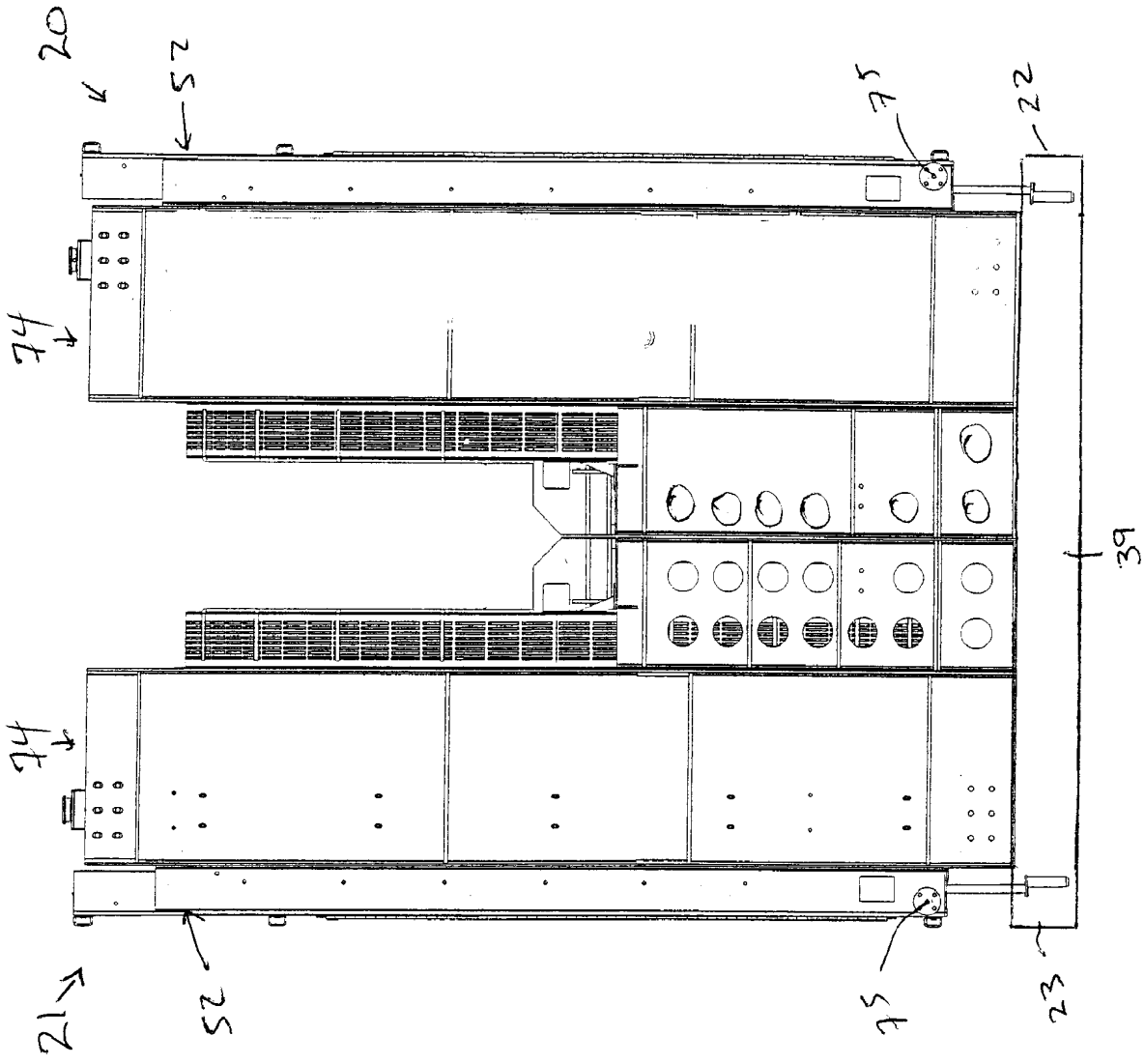


FIG 3

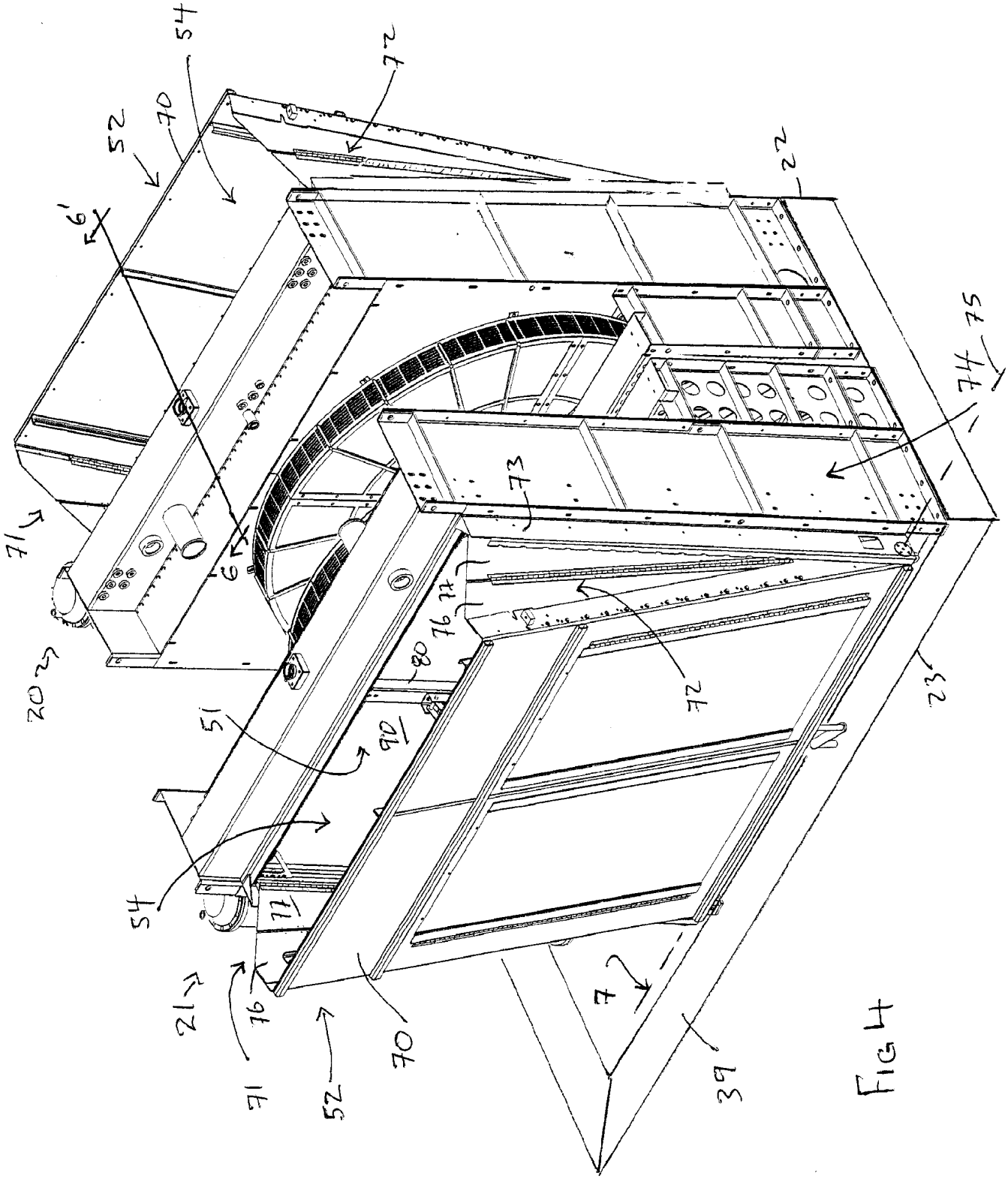


Fig 4

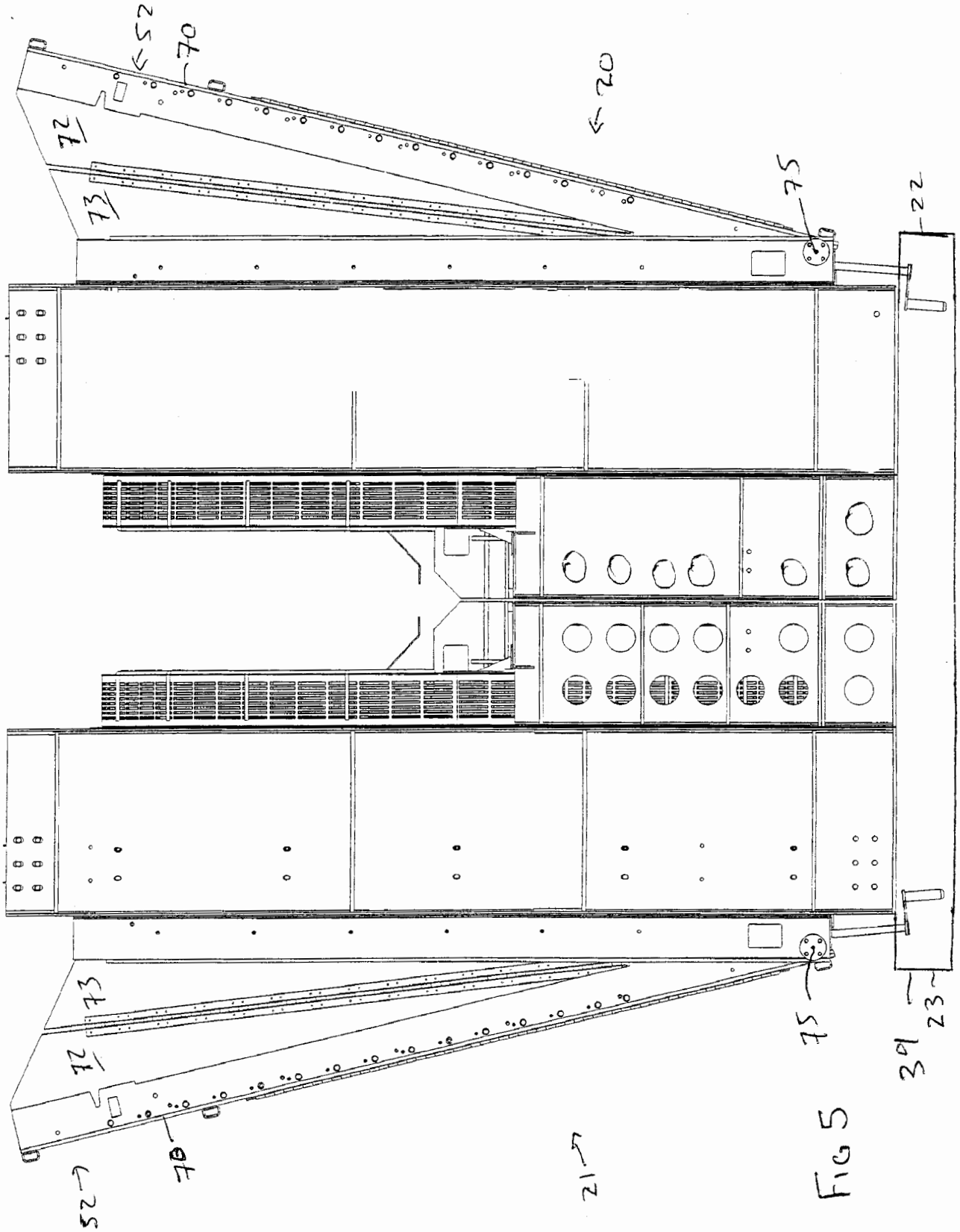


Fig 5

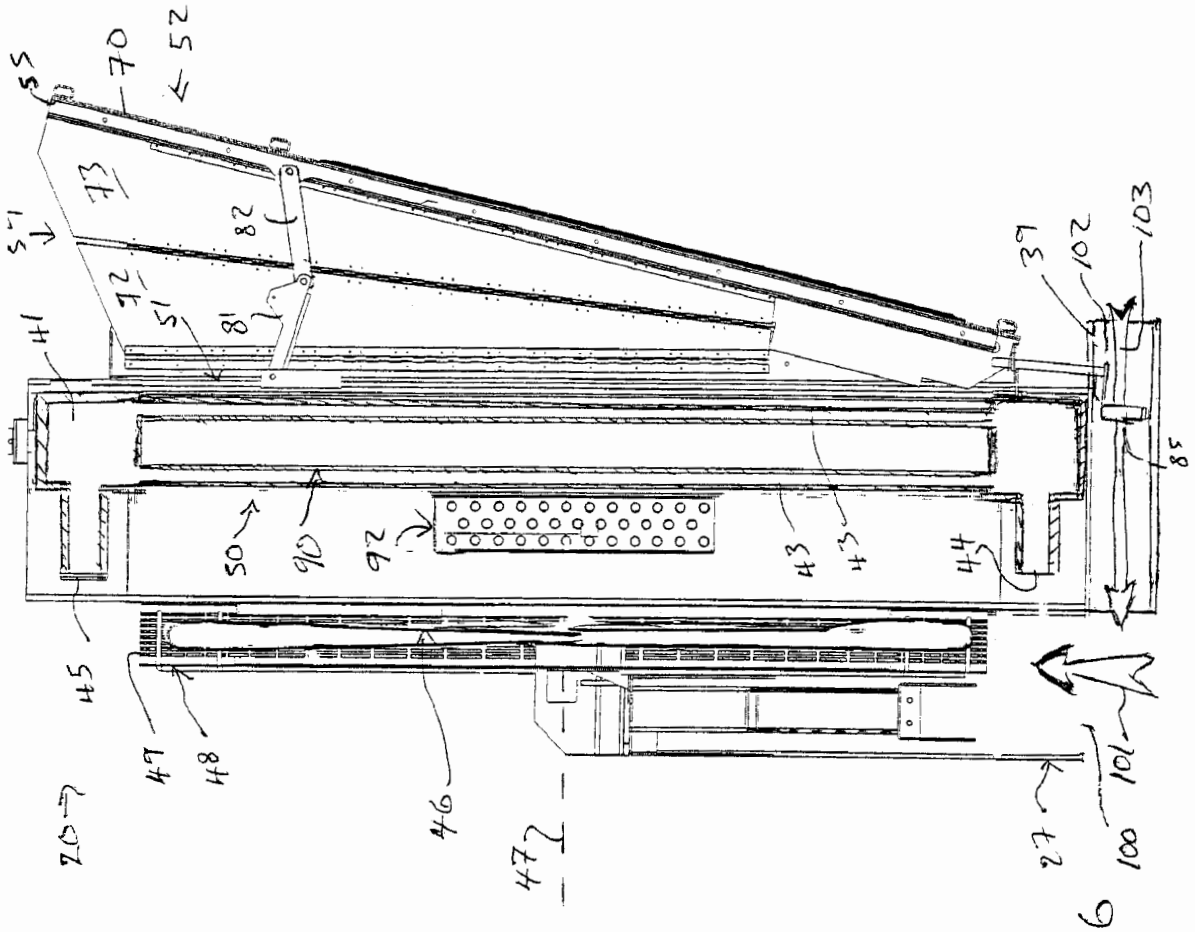

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FIG 6

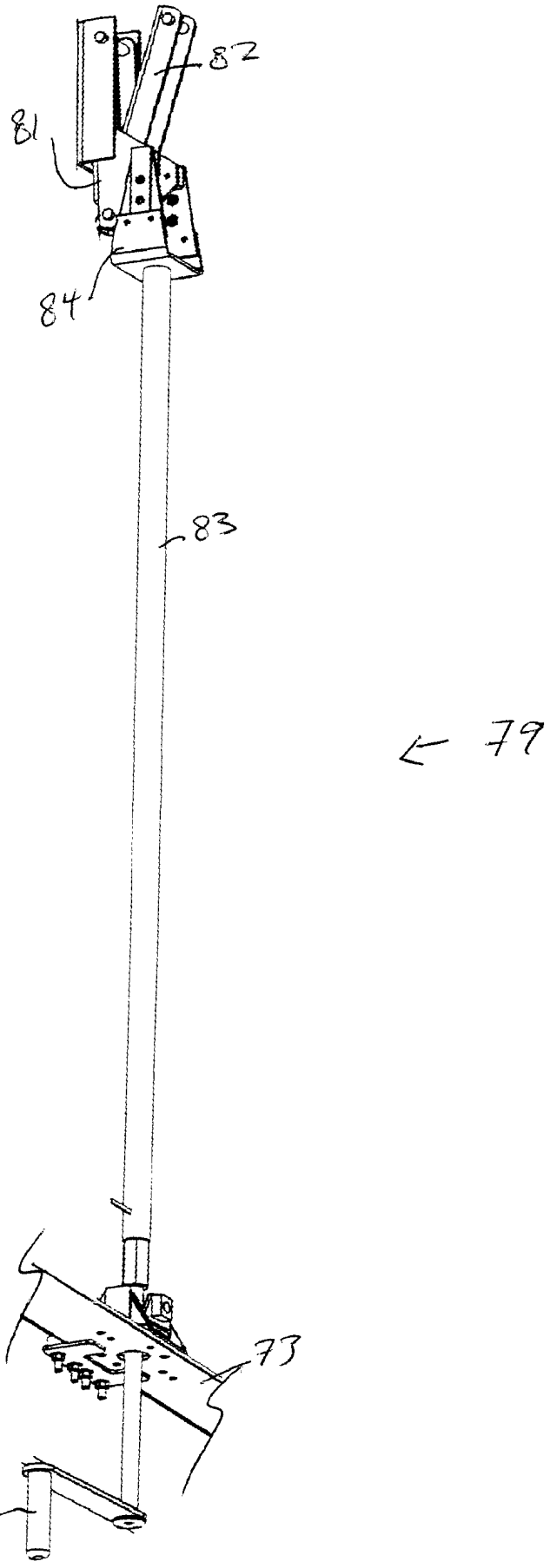


Fig 7

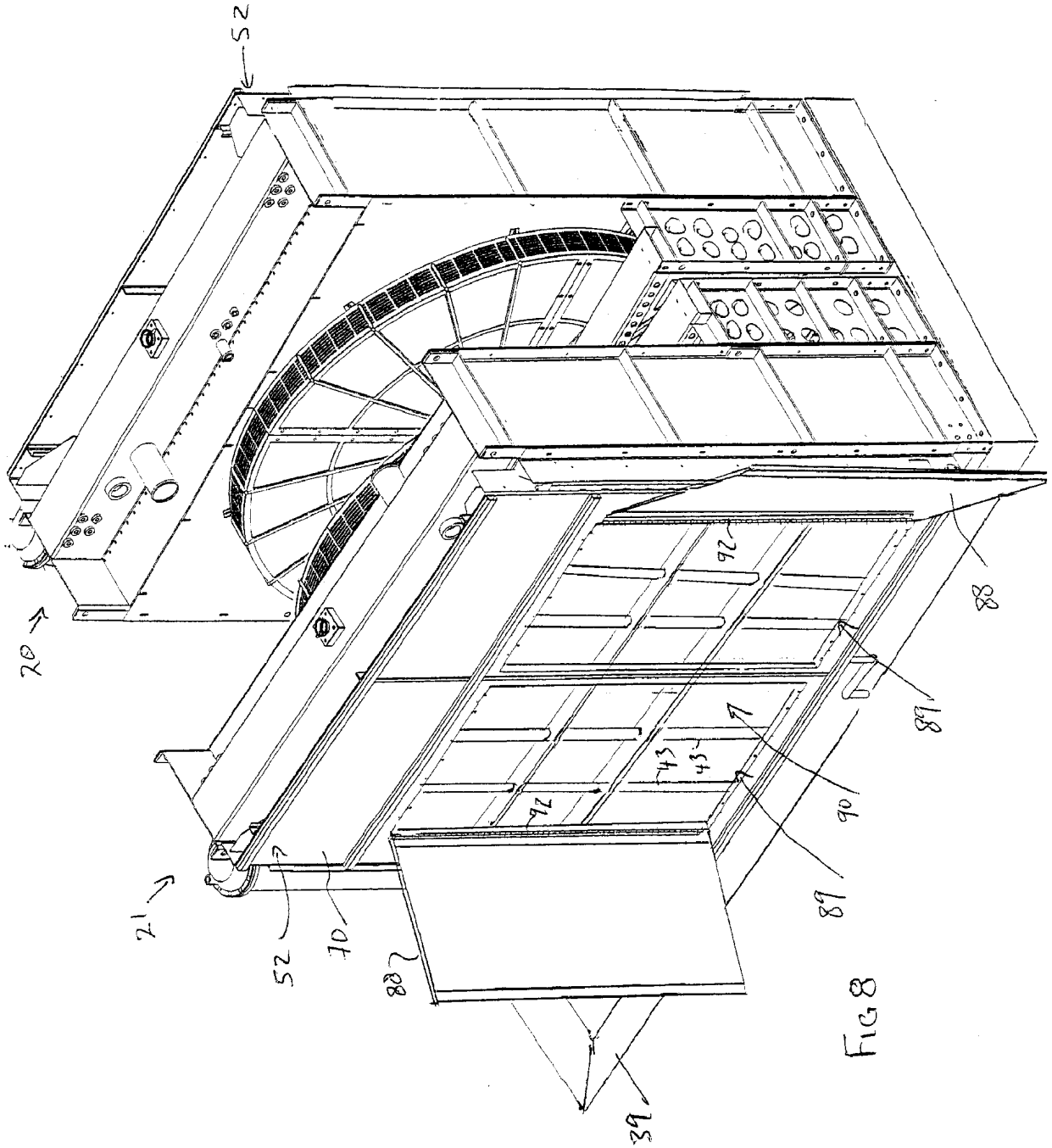


Fig 8

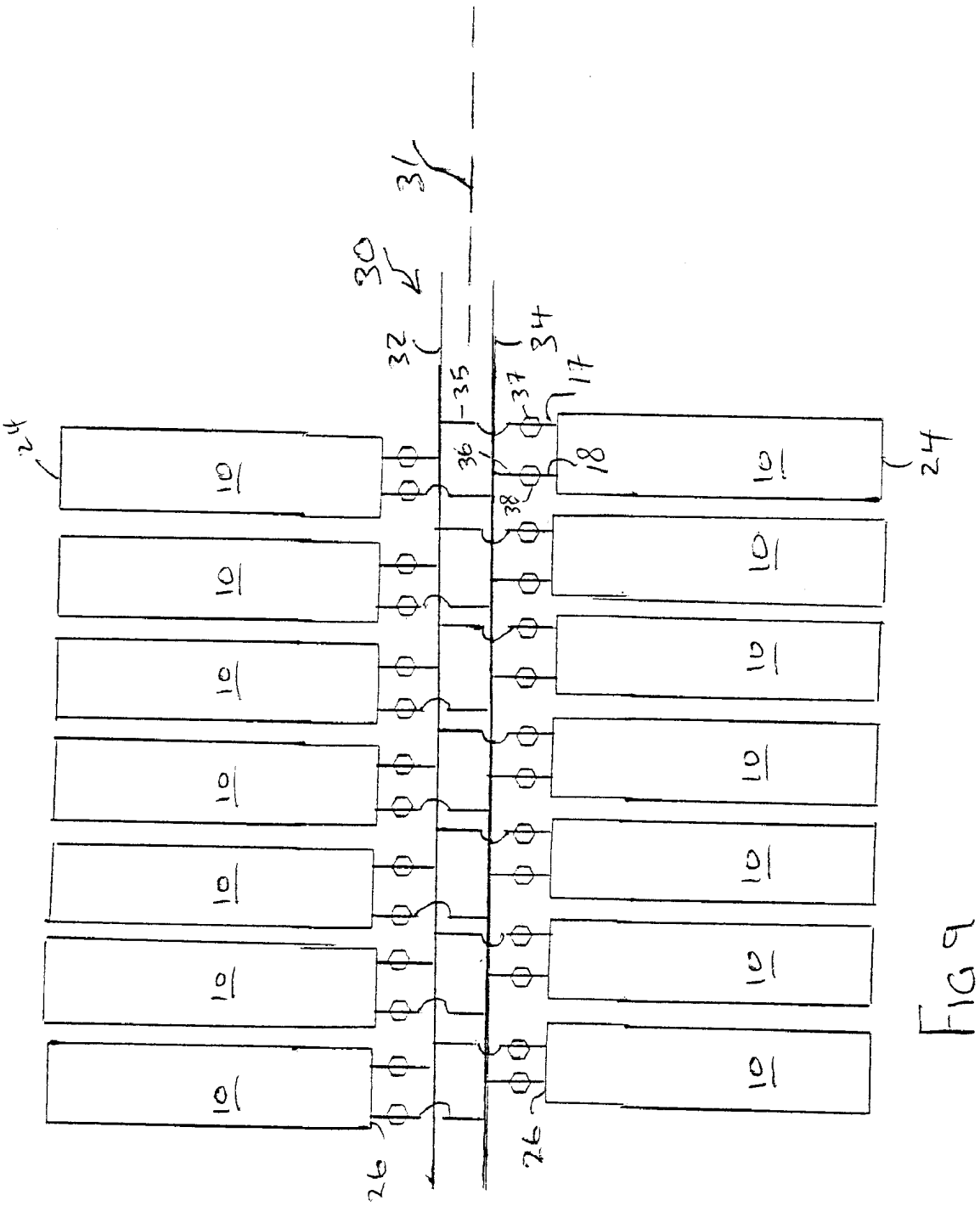


FIG 9

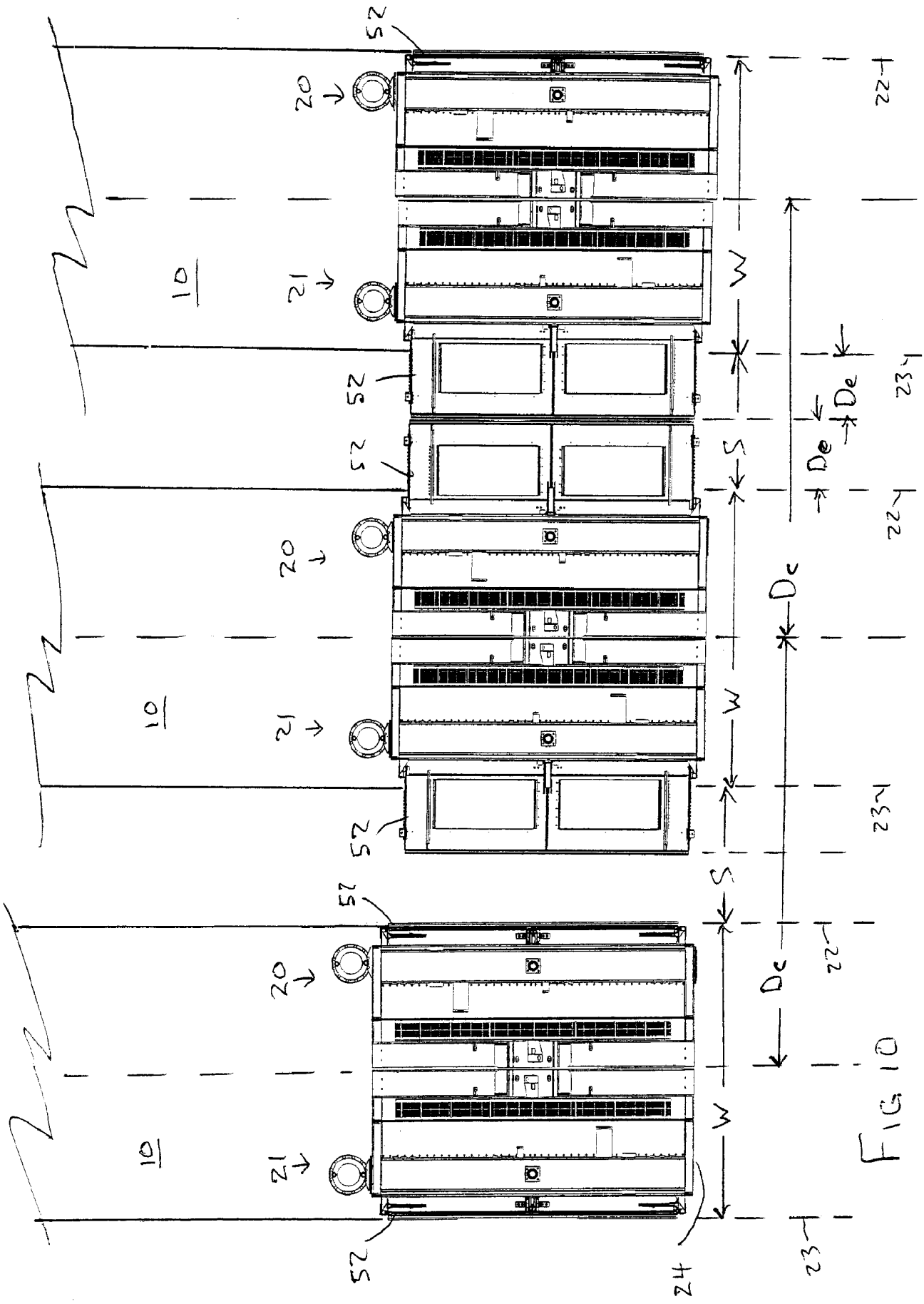


FIG 10

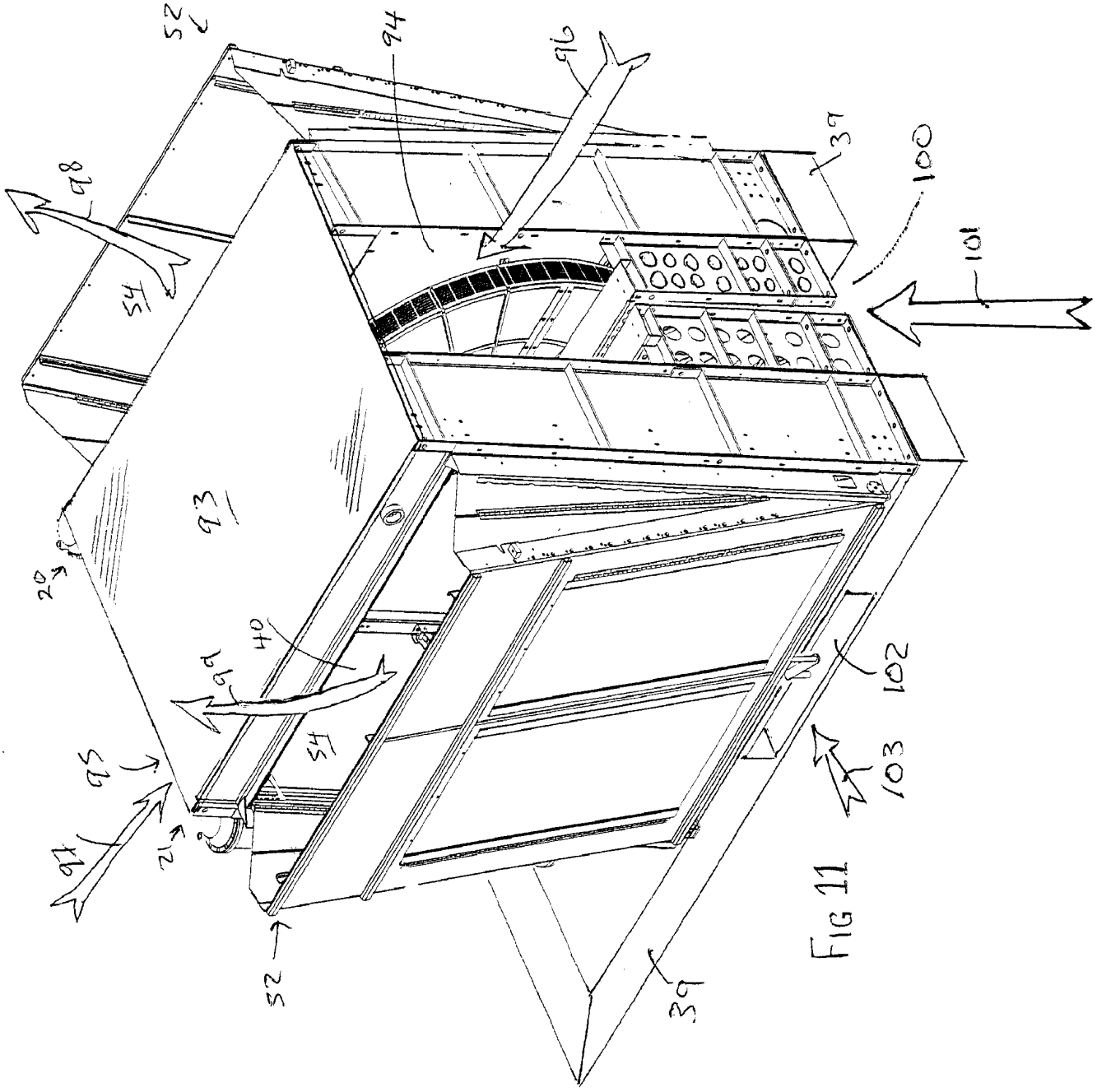
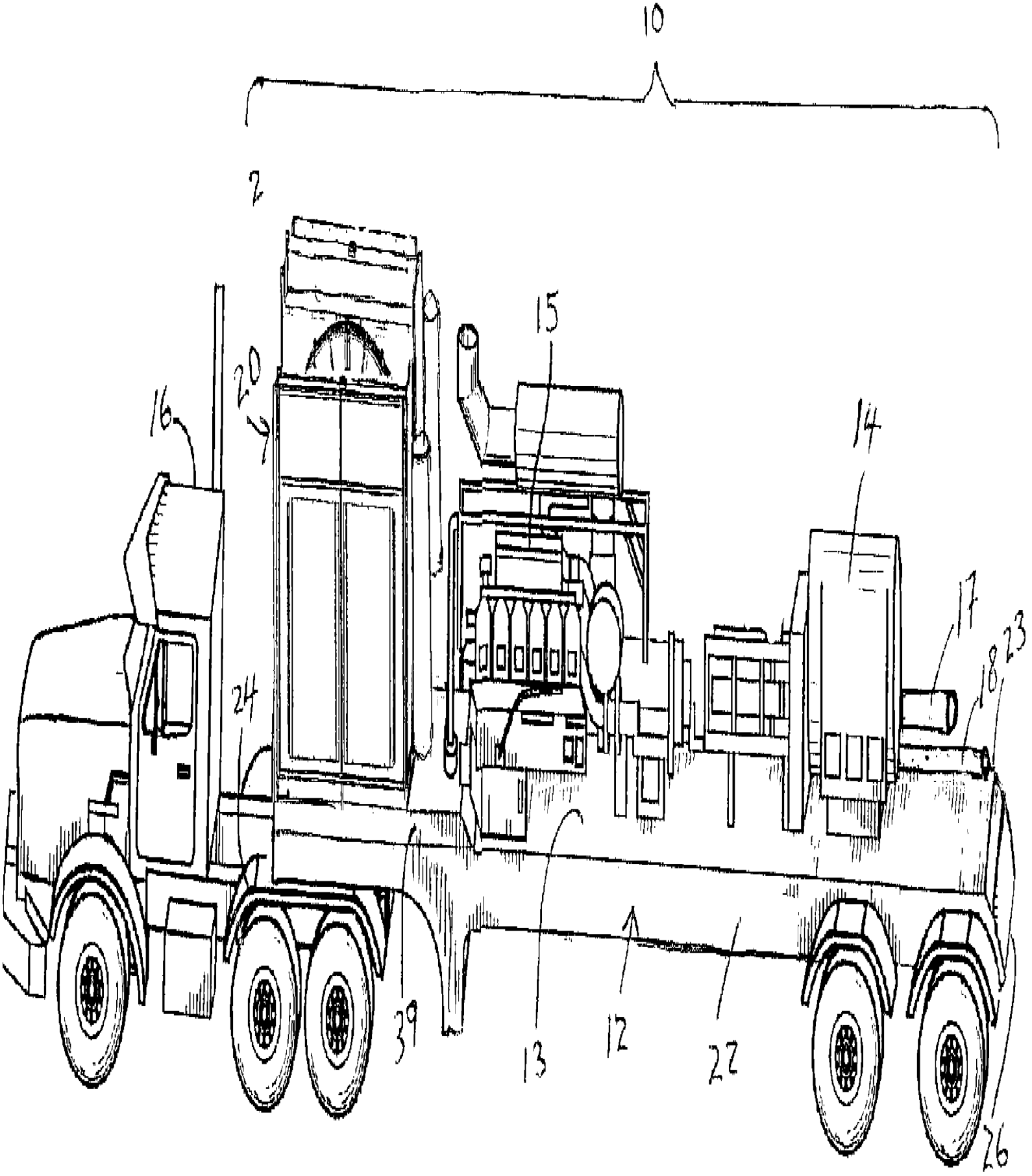


FIG 11


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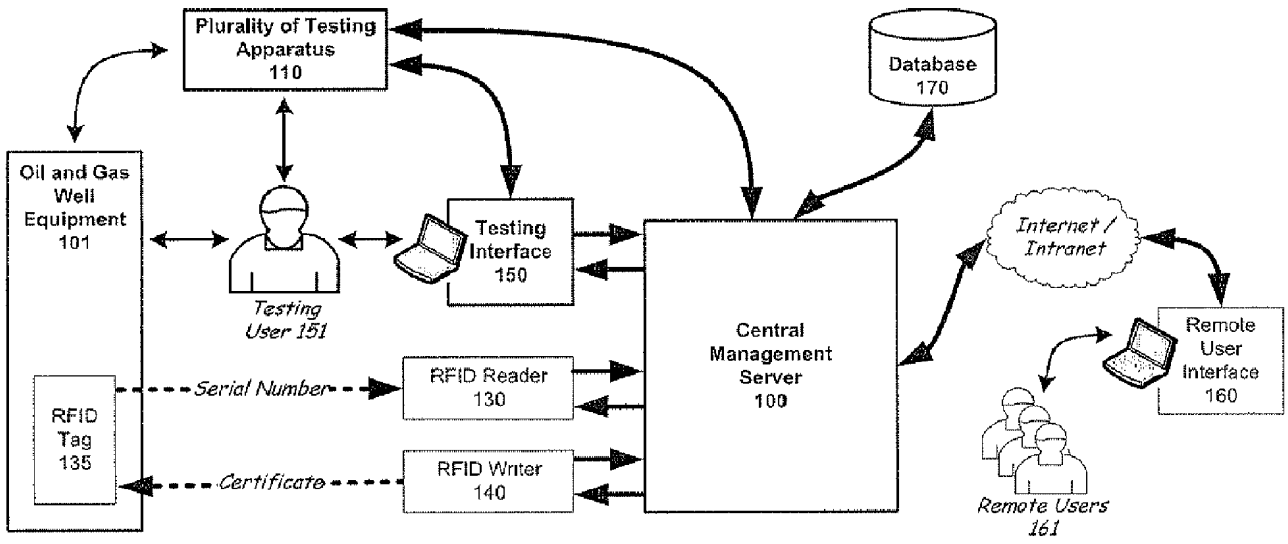
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(54) Title: MACHINES, SYSTEMS, COMPUTER-IMPLEMENTED METHODS, AND COMPUTER PROGRAM PRODUCTS TO TEST AND CERTIFY OIL AND GAS EQUIPMENT

FIG. 1



(57) Abrégé/Abstract:
Embodiments of machines, systems, computer-implemented methods, and computer program products certify oil and gas well equipment. Embodiments identify a selected well equipment device, a device test specification, and testing sequences to be performed by a corresponding testing apparatus. Embodiments select a testing sequence responsive to the selected device. Embodiments control the testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence responsive to the device test specification. Embodiments generate testing data for the selected testing sequence and link the testing data for the selected testing sequence to the device identifier for the device so that a certificate can be generated. Embodiments generate a certificate for the selected device responsive to the testing sequences having been performed upon the selected device and link the certificate for the selected device to the device identifier so that the certificate can be readily recalled.

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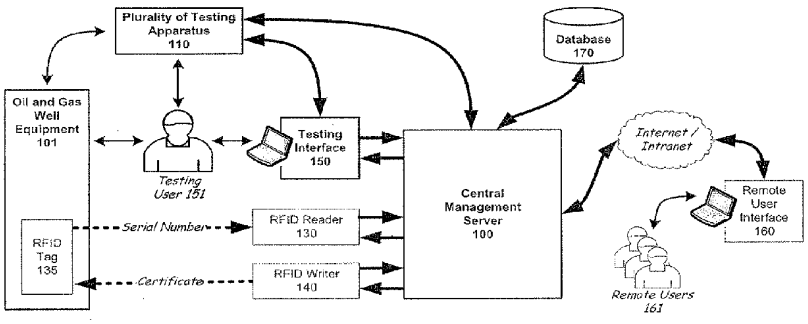
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FIG. 1



(57) Abstract: Embodiments of machines, systems, computer-implemented methods, and computer program products certify oil and gas well equipment. Embodiments identify a selected well equipment device, a device test specification, and testing sequences to be performed by a corresponding testing apparatus. Embodiments select a testing sequence responsive to the selected device. Embodiments control the testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence responsive to the device test specification. Embodiments generate testing data for the selected testing sequence and link the testing data for the selected testing sequence to the device identifier for the device so that a certificate can be generated. Embodiments generate a certificate for the selected device responsive to the testing sequences having been performed upon the selected device and link the certificate for the selected device to the device identifier so that the certificate can be readily recalled.

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MACHINES, SYSTEMS, COMPUTER-IMPLEMENTED METHODS, AND COMPUTER PROGRAM PRODUCTS TO TEST AND CERTIFY OIL AND GAS EQUIPMENT

Related Applications

[0001] This application claims priority and is related to U.S. Provisional Patent Application No. 61/330,248 filed April 30, 2010 titled "**Machines, Systems, Computer-Implemented Methods, And Computer Program Products To Test And Certify Oil And Gas Equipment,**" which is incorporated by reference in its entirety herein.

Field of the Invention

[0002] The present invention relates to oil and gas production. In more particular aspects, the present invention relates to testing and certification of equipment used in oil and gas production.

Background of the Invention

[0003] The production of oil and gas requires specialized well equipment, such as pipes, valves, joints, and fittings that operate in extreme conditions, including, for example, high pressure, temperature, volatility, and corrosivity. Such conditions promote the rapid wear of well equipment and increase the potential for failure. Moreover, when well equipment does fail, the impact of the failure is typically catastrophic. For example, the failure of well equipment can result in massive explosions that hurt workers, destroy property, and halt operations for a significant time—potentially costing millions of dollars in liabilities, repairs, and lost revenue.

[0004] Well equipment particularly susceptible to catastrophic failure includes, for example, the equipment used in the process of hydraulic fracturing known as "fracing" or "fracking." The process of fracing creates or extends fractures in subterranean rock formations by pumping fluid into the formation at high pressure. For example, fluid-driven fractures can be formed at the borehole in a drilling operation and then "grown" or extended into the rock formations. The injected fluid may contain "proppant" particles, such as grains of sand or ceramic, to lodge in the

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fractures thereby keeping them open. Fracing is used to improve the rate at which oil and gas can be produced from a reservoir, and fracing is especially useful for extracting oil and gas from formations having low porosity and permeability, such as shale rock and other formations deep below the earth's surface. The equipment used in hydraulic fracturing for oil and gas wells can include, for example, a slurry blender, high pressure/volume fracturing pumps, high pressure treating iron, and other pipes, joints, valves, and fittings, which are known as "frac iron" or, simply, "iron." For example, frac iron can include swivel joints, pup joints, plug valves, check valves and relief valves.

[0005] To mitigate the likelihood and impact of their failure, frac iron must be periodically inspected and recertified according to certain specifications, which can be provided by, for example, a manufacturer or operator of the frac iron. Because of the likelihood and impact of failure, inspections can be performed as frequently as every 90 days. Inspections and recertifications typically require several different test procedures, which may include, for example, a visual check of bores, connections, seal surfaces; wall thickness measurements to check for erosion or corrosion, for example, using ultrasonic measurement; crack tests, for example, using magnetic particle measurement; and pressure tests, for example, of over 20,000 pounds per square inch (PSI).

[0006] Previously known methods to certify frac iron were lengthy and laborious, often lasting one to three weeks and requiring a human tester to control all testing, to record the results manually, and later to enter the results into a database—costing valuable production capacity due to downtime.

[0007] Also, previously known methods to certify frac iron were susceptible to inconsistencies due to the manually intensive nature of the certification, such as inconsistent performance of testing operations and inconsistent adherence to prescribed test specifications. Also, for example, certification records were created by manual input, introducing human error and recording and measurement variances into the certification records.

[0008] Also, previously known methods to certify frac iron were susceptible to operational inefficiencies. For example, certification records were kept in hard copy, which did not allow on-site operators to readily access certifications while in the field, which may be a remote

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location such as an offshore rig. Furthermore, certification records and the test results associated therewith could not be tracked, updated, or reported on from a central control center.

Summary of the Invention

[0009] Embodiments of the present invention provide systems, methods, and machines for testing and certifying well equipment that enhance testing management, certification management, field operations management, and asset management. For example, embodiments of the present invention increase efficiency in testing and certifying well equipment by providing a systematic solution to control testing operations. Also, embodiments of the present invention increase efficiency in testing and certifying well equipment by seamlessly generating, storing, and processing testing data immediately upon performance of the testing operations, allowing a user to view the testing data in real time. Also, embodiments of the present invention increase efficiency in testing and certifying well equipment by dynamically generating certificates and reports responsive to the testing data according to multiple formats or user criteria.

[0010] Furthermore, well equipment testing according to embodiments of the present invention benefit from an increased likelihood of effective and safe operation because embodiments of the present invention systematically ensuring that testers use the proper test specifications and perform all test operations according to defined test sequences. Also, well equipment tested according to embodiments of the present invention benefit from an increased likelihood of effective and safe operation because embodiments of the present invention systematically ensure that equipment that fail any test sequence according to defined testing specifications are scrapped in the system and are unable to proceed in further testing or operation. Also, well equipment testing according to embodiments of the present invention benefit from an increased likelihood of effective and safe operation because operational crews can more readily access certificates, including comprehensive testing and certification data, on-demand and on-site. Furthermore, manufacturers and suppliers of well equipment can benefit from embodiments of the present invention by enhancing research and development efforts with greater knowledge of real-world wear patterns and wear rates for well equipment devices.

[0011] In view of the foregoing, applicant has provided a machine to manage periodic testing and certification of well equipment devices, the testing and certification being facilitated by a

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plurality of testing apparatus performing one or more testing operations upon the well equipment devices. The machine comprises a processor, a non-transitory memory, an input/output unit to communicate with the plurality of testing apparatus, a database positioned to match a device identifier to a well equipment device, a test specification, and a plurality of testing sequences. The machine also comprises a testing module stored in the memory, the memory being a tangible, non-transitory, computer-readable storage medium, and the testing module being operable by the processor, the testing module comprising a set of instructions that, when executed by the processor, cause the testing module to perform operations. The operations of the testing module include identifying a selected well equipment device, a device test specification, and a plurality of testing sequences, the identifying operation responsive to receiving a device identifier for the selected well equipment device, each testing sequence of the plurality of testing sequences to be performed by a corresponding testing apparatus of the plurality of testing apparatus, each testing sequence defining a sequence of testing operations.

[0012] The operations of the testing module further include selecting a testing sequence of the plurality of testing sequences, the selecting operation responsive to the selected well equipment device being positioned so that the corresponding testing apparatus for the selected testing sequence can perform testing operations upon the selected well equipment device.

[0013] The operations of the testing module further include controlling the corresponding testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence of testing operations upon the selected well equipment device, the sequence of testing operations being performed responsive to the device test specification. The operations of the testing module further include generating testing data for the selected testing sequence responsive to receiving output from the corresponding testing apparatus for selected testing sequence performing the sequence of testing operations.

[0014] The operations of the testing module further include linking the testing data for the selected testing sequence to the device identifier for the selected well equipment device in the database so that a certificate can be generated responsive thereto; and

[0015] The machine also comprises a certification module stored in the memory, the memory being a tangible, non-transitory, computer-readable storage medium, and the certification module

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being operable by the processor, the certification module comprising a set of instructions that, when executed by the processor, cause the certification module to perform certain operations.

[0016] The operations of the certification module include identifying a selected well equipment device, a device test specification, and testing data for a plurality of testing sequences, the identifying operation responsive to receiving a device identifier for the selected well equipment device.

[0017] The operations of the certification module further include generating a certificate for the selected well equipment device responsive to the testing data for the plurality of testing sequences, the plurality of testing sequences having been performed upon the selected well equipment device responsive to the device test specification.

[0018] The operations of the certification module further include linking the certificate for the selected well equipment device to the device identifier for the selected well equipment device in the database so that the certificate can be readily recalled from the database responsive to the device identifier.

[0019] Also in view of the foregoing, applicant has provided a system to certify oil and gas well equipment. The system comprises a plurality of devices to be used in well equipment to define a plurality of well equipment devices, each well equipment device of the plurality of well equipment devices having a device identifier associated therewith. The system further comprises a central management server positioned to identify a device test specification and a plurality of testing sequences for a selected well equipment device responsive to receiving a device identifier for the selected well equipment device, the device test specification and the plurality of testing sequences defining certification criteria for the well equipment device. The system further comprises a plurality of testing apparatus, each testing apparatus positioned to perform a testing sequence upon the well equipment device, the testing sequence being a sequence of testing operations, the sequence of testing operations being performed responsive to the device test specification. The system further comprises a plurality of controllers, each controller positioned to receive commands responsive to the certification criteria from the central management server and to control the plurality of testing apparatus performing the sequence of testing operations upon the selected well equipment device responsive to the device test specification. The system

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further comprises a certificate generated responsive to the plurality of testing apparatus performing the plurality of testing sequences upon the well equipment device, the certificate indicating whether selected well equipment device has been tested according to the certification criteria within a pre-selected period of time.

[0020] Also in view of the foregoing, applicant has also provided a computer-implemented method to manage periodic testing of a plurality of well equipment devices, the testing being facilitated by a plurality of testing apparatus performing one or more testing operations upon the plurality of well equipment devices. The computer-implemented method comprises receiving a device identifier for a selected well equipment device of the plurality of well equipment devices. The computer-implemented method further comprises identifying the selected well equipment device, a device test specification, and plurality of testing sequences, the identifying operation being responsive to the receiving operation, each testing sequence of the plurality of testing sequences to be performed by a corresponding testing apparatus of the plurality of testing apparatus, each testing sequence defining a sequence of testing operations. The computer-implemented method further comprises selecting a testing sequence of the plurality of testing sequences to define a selected testing sequence, the selecting operation responsive to the selected well equipment device being positioned so that the corresponding testing apparatus for the selected testing sequence can perform testing operations upon the selected well equipment device. The computer-implemented method further comprises calibrating the corresponding testing apparatus for the selected testing sequence responsive to the device test specification. The computer-implemented method further comprises controlling the corresponding testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence of testing operations upon the selected well equipment device, the sequence of testing operations being performed responsive to the device test specification. The computer-implemented method further comprises generating testing data for the selected testing sequence responsive to receiving output from the corresponding testing apparatus for selected testing sequence performing the sequence of testing operations. The computer-implemented method further comprises linking the testing data for the selected testing sequence to the device identifier for the selected well equipment device in a database so that a certificate can be generated responsive thereto.

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[0021] Also in view of the foregoing, applicant has also provided a computer program product to manage periodic testing of a plurality of well equipment devices. The computer program product can be stored in a memory, the memory being a tangible, non-transitory, computer-readable storage medium, and the computer program product being operable by a processor. The computer program product comprises a set of instructions that, when executed by the processor, cause the testing module to perform certain operations. The operations performed by the computer program product includes identifying a selected well equipment device, a device test specification, and a plurality of testing sequences, the identifying operation responsive to receiving a device identifier for the selected well equipment device, each testing sequence of the plurality of testing sequences to be performed by a corresponding testing apparatus of the plurality of testing apparatus, each testing sequence defining a sequence of testing operations. The operations performed by the computer program product further includes selecting a testing sequence of the plurality of testing sequences, the selecting operation responsive to the selected well equipment device being positioned so that the corresponding testing apparatus for the selected testing sequence can perform testing operations upon the selected well equipment device. The operations performed by the computer program product further includes controlling the corresponding testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence of testing operations upon the selected well equipment device, the sequence of testing operations being performed responsive to the device test specification. The operations performed by the computer program product further includes generating testing data for the selected testing sequence responsive to receiving output from the corresponding testing apparatus for selected testing sequence performing the sequence of testing operations. The operations performed by the computer program product further includes linking the testing data for the selected testing sequence to the device identifier for the selected well equipment device in the database so that a certificate can be generated responsive thereto. The operations performed by the computer program product further includes identifying a selected well equipment device, a device test specification, and testing data for a plurality of testing sequences, the identifying operation responsive to receiving a device identifier for the selected well equipment device. The operations performed by the computer program product further includes generating a certificate for the selected well equipment device responsive to the testing data for the plurality of testing sequences, the plurality of testing sequences having been

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performed upon the selected well equipment device responsive to the device test specification. The operations performed by the computer program product further includes linking the certificate for the selected well equipment device to the device identifier for the selected well equipment device in the database so that the certificate can be readily recalled from the database responsive to the device identifier.

Brief Description of the Drawings

[0022] So that the manner in which the features and benefits of the invention, as well as others which will become apparent, may be understood in more detail, a more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof which are illustrated in the appended drawings, which form a part of this specification. It is also to be noted, however, that the drawings illustrate only various embodiments of the invention and are therefore not to be considered limiting of the invention's scope as it may include other effective embodiments as well.

[0023] FIG. 1 is a schematic diagram illustrating exemplary data flows and interactions among components of a system to certify well equipment according to an embodiment of the present invention;

[0024] FIG. 2 is a schematic illustrating exemplary components and connections of a central management server to certify well equipment according to an embodiment of the present invention;

[0025] FIG. 3 is a flowchart illustrating exemplary program product logic and computer-implemented methods for certifying well equipment according to an embodiment of the present invention;

[0026] FIG. 4 is a database diagram illustrating exemplary data structures according to an embodiment of the present invention;

[0027] FIG. 5 is an exemplary certificate according to an embodiment of the present invention;

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[0028] FIGs. 6-8 are flowcharts illustrating exemplary process flow according to embodiments of the present invention;

[0029] FIGs. 9-23 are exemplary testing interface displays according to embodiments of the present invention; and

[0030] FIGs. 24-25 are exemplary reporting interface displays according to embodiments of the present invention.

Detailed Description

[0031] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, which illustrate various embodiments of the invention. This invention, however, may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. It is to be fully recognized that the different teachings of the various embodiments discussed below may be employed separately or in any suitable combination to produce desired results. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art upon reading the following detailed description of the various embodiments, and by referring to the accompanying drawings. In the drawings and description that follow, like parts are marked throughout the specification and drawings with the same reference numerals, respectively. The prime notation, if used, indicates similar elements in alternative embodiments. The drawings are not necessarily to scale. Certain features of the disclosure may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness.

[0032] Accordingly, embodiments of the present invention improve safety, effectiveness, and efficiency of operating well equipment by meeting the foregoing objectives to mitigate the likelihood and impact of the failure of such equipment. In embodiments of the present invention, "well equipment devices" includes the equipment and devices used in hydraulic fracturing for oil and gas wells, i.e. "high pressure hydraulic fracturing flow iron," "frac iron," or, simply, "iron."

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Frac iron can include, for example, a slurry blender, high pressure/volume fracturing pumps, high pressure treating iron, and other pipes, joints, valves, and fittings. For example, frac iron can include swivel joints, pup joints, plug valves, check valves and relief valves. Furthermore, by way of example, frac iron can include any type of ball injector, crow's foot, air chamber, crossover, hose, pipes/piping, hose loop, ball injector tee body, tee, wye, lateral, ell, check valve, plug valve, wellhead adapter, swivel joint, plug, relief valve, densometer, cross, frac pump, or cement pump. Those skilled in the art will appreciate that embodiments of the present invention are not limited to uses related to in oil and gas wells, but, rather, embodiments of the present invention are applicable to processes for testing or certifying any industrial equipment or device, and at any stage in the lifespan of the equipment, including during or after manufacturing and before, during, or after use or ongoing operations.

[0033] FIG. 1 illustrates a central management server 100 for performing operations of a testing module 220 and a certification module 210. The central management server 100 is positioned to be in communication with a plurality of testing apparatus 110. The plurality of testing apparatus 110 is capable of performing testing operations on a selected well equipment device 101. The central management server 100 is positioned to systematically control the performing of testing operations upon the well equipment device 101, systematically record and process the results of such testing operations, and systematically generate a certificate responsive to such recording and processing. Embodiments of the present invention providing systems, methods, and machines to certify of well equipment and are further described herein with specific reference to the drawings.

Central Management Server 100

[0034] An embodiment of a central management server 100, as illustrated in FIG. 2, can be configured as a computer, a server, or a machine of distributed computers or servers that at least include non-transitory memory 240, program products 210, 220, and 230, a processor or processors 251, an input/output device or devices ("I/O") 252.

[0035] I/O 252 connects the central management server 100 to a database 170, a testing interface 150, and one or more testing apparatus 110 (although represented as one block, those of skill in the art will appreciate that a plurality of testing apparatus 110 may include one or more

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links to the I/O) to thereby allow central management server 100 to send and receive commands and data. I/O 252 can be any I/O including, but not limited to a network card/controller connected by a PCI (Peripheral Component Interconnect) bus to the motherboard, or hardware built into the motherboard of the central management server 100 to connect same to the forgoing database, interface, and apparatus.

[0036] As those of skill in the art will appreciate, I/O 252 can connect the central management server 100 with any other compatible machine, server, system, device, or equipment having a suitable physical interface and that I/O 252 and/or computer program products 210, 220, and 230 on non-transitory memory 240 may be positioned to understand, convert, or translate application or communication protocols of such machines, servers, systems, devices, or equipment irrespective of native protocols. Also, one of skill in the art will understand that I/O 252 can include or otherwise incorporate any logical or physical technology necessary to effect a connection with any of the aforementioned devices, including, for example, hubs, switches, routers, converters, amplifiers, and wireless transceivers. For example, as is further described herein, I/O 252 can also connect the central management server 100 to devices for interacting with radio frequency identification (RFID) devices, such as an RFID reader or interrogator 130 and an RFID writer 140. The central management server 100 can further connect to a remote user interface 160 for interacting with a remote user 161, as is also discussed further herein. Also, the plurality of testing apparatus 110, RFID reader 130, and the RFID writer 140 may be configured as peripherals to the testing interface 150. Also, there a testing apparatus 110 interface 253, such as a programmable logic controller (PLC), an interface between the I/O 252 and the plurality of testing apparatus 110 to control the plurality of testing apparatus 110.

[0037] As can be seen in FIG. 2, the I/O 252 is connected to a processor 251. The processor 251 is the "brains" of the central management server, and as such executes program products 210, 220, and 230 and works in conjunction with the I/O 252 to direct data to the non-transitory memory 240 and to send data from the non-transitory memory 240 to the database 170, the testing interface 150, and one or more testing apparatus 110. The processor 251 can be any commercially available processor, or plurality of processors, adapted for use in or with the central management server 100, *e.g.*, Intel® Xeon® multicore processors, Intel® micro-

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architecture Nehalem, and AMD Opteron™ multicore processors. As one skilled in the art will appreciate, processor 251 may also include components that allow the central management server 100 to be connected to a display, as will be understood by those skilled in the art, and keyboard or other peripherals that would allow a user to directly or indirectly access the processor 251 and non-transitory memory 240.

[0038] Non-transitory memory 240 stores computer program products 210, 220, and 230 having instructions for execution on the processor 251, and consists of both non-volatile memory, *e.g.*, hard disks, flash memory, optical disks, and the like, and volatile memory, *e.g.*, SRAM, DRAM, and SDRAM as required to support embodiments of the instant invention. As one skilled in the art will appreciate, though the non-transitory memory 240 is depicted on, *e.g.*, a motherboard, of the central management server 100, the non-transitory memory 240 may also be a separate component or device, *e.g.*, FLASH memory, connected to the central management server 100 through the I/O 252. The non-transitory memory 240 may also store applications that various workstations or remote units can access and run on the central management server 100. For example, a testing user 151 may access applications and computer program products stored on the non-transitory memory 240 and run on the processor 251 using the testing interface 150. Importantly, non-transitory memory 240 stores the program products 210, 220, and 230 of the instant invention. As one skilled in the art will understand, the program products 210, 220, and 230, along with one or more databases/tables/fields/records for data associated with the selected well equipment device 101 can be stored either in non-transitory memory 240 or in separate non-transitory memory associated, for example, with a storage medium such as database 170, positioned in communication with the central management server 100.

Database 170

[0039] As seen in FIG. 1 and FIG. 2, the database 170 is in communication with the central management server 100. Although the database 170 is illustrated according to an embodiment in which the database 170 is separate and distinct from the central management server 100, for example, as a database server, the present invention may also include any arrangement of the database 170 in communication with the central management server 100, including the database 170 being incorporated into the same computer, server, machine, or system constituting the

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central management server 100, as one physical unit, for example, as an application or partition in the central management server 100 or as an installed component of the central management server 100 communicating with the processor 251 through the use of the I/O and having, for example, a database memory separate and distinct from memory 240, such as a hard drive, optical storage, or the like. Database 170, as is understood in the art, can include a processor directing data from a bus into the database memory, which can be, for example, a hard drive, optical storage or the like, and computer software that provides computers, including the central management server, access the data therein.

[0040] The database 170 can store therein a data structure or data structures relating to the well equipment devices 101 to be tested and all data generated during the execution of the testing module 211 and certification module 210, as is further discussed herein. In embodiments, database 170 is a relational database positioned to match data by using common data found between data sets, the data sets being organized according to tables 400, 410, 420, 430, 440, and 450 as seen in FIG. 4. As will be understood by those skilled in the art, FIG. 4 illustrates an exemplary set of data structures only, and there may be other unique table structures positioned to relate and match the data in manners commensurate with the embodiments of the present invention. Data stored in the database 170 may be updated as needed, for example, by a user with administrative access to the database to add new well equipment devices to the database as they become supported. As is described further herein with relation to the computer program products, database 170 can be positioned to store data in tables relating to the unique device tested 400, parts in a parts library 410, test specifications in a test specification library 420, test sequences in a test sequence library 430, test data in a test data repository 440, and certificate data in a certificate data repository 450. And as is described further herein, the database 170 is positioned to match common data appearing in the foregoing tables.

Testing Apparatus 110

[0041] As shown in FIG. 1 and FIG. 2, the plurality of testing apparatus 110 are in communication with the central management server 100. The plurality of testing apparatus 110 perform testing operations under the control of the central management server 110 and provide tools or devices to gather testing data 440 as shown in FIG. 4, *i.e.,* the data that serves as the

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basis for the certification. In embodiments, the plurality of testing apparatus 110 at least includes an ultrasonic wall thickness meter ("UT meter") and a pressure test pump having a transducer. The plurality of testing apparatus 110 can include any other device or unit capable of being employed either manually or under automated control by the central management server 100 to interact with the well equipment device 101. Other testing apparatus 110 can include, for example, digital calipers. A local user may employ embodiments of the present invention, for example, by positioning the frac iron to be tested 101 in a testing station adapted for the test performed, and by manually configuring the frac iron 101 to safely and effectively interact with the testing apparatus 110 for the intended test.

[0042] Although shown as separate blocks in FIG. 1, the testing interface 150, which can be a personal computer (PC), can be connected to a peripheral testing apparatus 110 to control or collect data from a testing apparatus 110 connected as a peripheral to an input/output unit of the PC. The combination of the testing apparatus 110 and a PC may be referred to, collectively, as a testing apparatus 110. PC or testing interface 150 can connect to a peripheral testing apparatus 110 via any connection type known to those in the art, such as a Universal Serial Bus connection (USB), and such connection may include analog inputs and digital inputs, wired and wireless, and including analog-to-digital converters and amplifiers for digital inputs.

[0043] The plurality of testing apparatus 110 and a PC incorporated with a peripheral testing apparatus 110 can be a mobile unit or units having remote or wireless connectivity to central management server 100 using any protocols or standards known in the art, including Wi-Fi, GSM, and WIMAX, for example. Mobile units may also be synchronized with central management server through periodic wired or wireless connections when returning from field use. The PC can be, for example, any suitable PC known in the art and is preferably a Panasonic® Toughbook® or other portable, notebook, laptop, or tablet computer preferably designed to withstand vibration, drops, spills, extreme temperature, and other rough handling and conditions common to industrial use.

[0044] The UT meter can be, for example, an Olympus® MG2DL, or any similar UT meter known in the art. The UT meter can include, for example, features such as B-scan, gain adjust, auto sensitivity optimizations, echo-to-echo, differential mode, hi-low alarm, and live A-scan.

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The UT meter can also include a file-based alphanumeric data logger and an interface program for transferring data bi-directionally to and from a PC. The testing apparatus 110 can include a PC, such as described above, for enabling data and control functions of a peripheral testing apparatus 110 such as a UT meter.

[0045] The pressure test pump and transducer can be any suitable pressure test pump known in the art. Preferably, embodiments of the invention employ an X45 series model 345 Viatran® test and control pressure sensor, which can, for example, operate in the range of 0-100,000 psi with output in the range of 4-20 mA. As is known in the art, the testing apparatus 110 can include a control interface such as a programmable logic controller (PLC) for communication with and control of the pressure test pump and transducer.

Testing User 151 and Testing Interface 150

[0046] As described above, a testing user 151 may employ embodiments of the present invention, for example, by positioning the frac iron to be tested 101 in a testing station adapted for the test to be performed, and will manually configure the frac iron 101 to safely and effectively interact with the testing apparatus 110 for the intended test. In other embodiments, the testing user may perform testing operations according to instructions provided by the central management server 110 and displayed, for example, on the testing interface 150. The testing user 151 may provide the means of manually gathering testing data 440 as shown in FIG. 4, *i.e.*, the data that serves as the basis for the certification. Testing operations, as described above with reference to the testing apparatus 110, may be systematic, manual, or hybrid systematic/manual. For example, a sequence of testing operations for testing wall thickness of the frac iron may include systematic test operations to be performed by a testing apparatus 110, such as a UT meter, and manual operations to be performed by a testing user 151, such as using digital calipers to measure wall thickness or other dimensions of the frac iron, as can be seen in FIGS. 15-16, for example. Likewise, other sequences of testing operations may be fully manual, such as the mag particle test discussed further herein.

[0047] Also as described above, the testing interface 150 may be a PC, which may be any desktop, laptop, notebook, tablet, or portable computer known to those in the art. As is known the art, the testing interface 150 can include any number of peripheral devices to interact with the

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testing user 151, including a keyboard, mouse, control stick/joystick, and memory reader for receiving data input and a display screen, printer, and local storage device for outputting or storing data. Furthermore, embodiments of invention have a testing interface with a touch-sensitive screen (*e.g.,* using a stylus) for interactive display/input so that users can select parts responsive to viewing them on the display of the testing interface 150 and thereafter performing testing operations responsive to the selection, in communication with the testing module 210. The testing interface 150 may connect with the central management server 100 via any communications interface known to those of skill in the art, wired or wireless, and is preferably a secure local Intranet or other authenticated and encrypted communications network, including a VPN over the Internet.

Certificate 500

[0048] FIG. 5 sets forth an exemplary certificate 500 generated responsive to embodiments of the present invention. The certificate 500 relates to data stored in the database 170, for example, the certificate data 450 as shown in FIG. 4. The certificate 500, as is appreciated by those skilled in the art, can be a paper document printout or an electronic document in a format such as Adobe® Portable Document Format (.PDF), Microsoft® Word (.DOC or .DOCX), or a similar format. The certificate 500, for example, can be a paper document printout, as it is the custom in drilling and fracing operations for a paper document printout of a certificate to be presented to company personnel when well equipment is brought on-site in field operations. The company personnel takes possession of the physical document and reviews the testing parameters and testing results documented thereon to verify the quality of the equipment brought on site.

[0049] The certificate 500 can reference the well equipment device 101 by a unique device identifier, such as the serial number 501, which can relate to data stored in database 170 in the device information table 400. The certificate 500 can contain a summary indication as to whether certain test sequences were graded as a "PASS" or a "FAIL" 502. The grading operation, for example, can be performed by a certification module 220 computer program product operating on the central management server 100. The PASS or FAIL grading 502 can relate to data stored in the database 170, for example, the certificate data 450 and the testing data 440 shown in FIG. 4. The certificate 500 can also contain a summary or other rendering of

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testing data responsive to testing operations being performed on the well equipment device 101, for example, a graphical representation of a pressure test 503. Graphical representation 503 can relate to data stored in the database 170 in the certificate data table 450 and the testing data table 440.

[0050] The certificate 500 can also contain a summary indication as to measured qualities of the selected well equipment device 101 and their relation to the qualities demanded by the test specification. For example, measured wall thickness value 505 appears adjacent to demanded wall thickness value 506. Additionally, drawing 504 shows a graphical representation of the parameters measured according to the test specification, as referenced by letter key (*e.g.*, "A," "B," and "C".).

[0051] In certain embodiments of the present invention, a certificate can be stored in a proprietary data table format so that a lightweight electronic copy of the certificate, and an "RFID certificate" can be stored directly onto RFID tag 135 attached to the selected well equipment 101. For example, as understood by those skilled in the art, the RFID certificate can be written to an RFID tag 135 attached to the well equipment so that the certificate can be readily accessed in the field using an RFID reader device 130 capable of recognizing the proprietary data table format. The RFID certificate can include all fields available on the paper certificate 500, including device identifier 501, pass or fail grading 502, tabular summary or rendering of test data 503, drawing 504, measured values 505, and demanded values 506. The tabular summary or rendering 503 and the drawing 504 can be encoded, for example, using lightweight vector-based primitive formats. Also, RFID certificate will allow new schemes for protecting certificate data heretofore unavailable for field use, for example, by having individual cells in the table that are protected according to user access schemes such as read-only, read-write, or no access. For example, the serial number and the certification may be read-only to all; the certificate data may be read-only to many and read-write to few; and custom fields may be user-configurable.

Testing Module 210

[0052] As is shown in FIG. 2, the testing module 210 may be a computer program product stored in the memory 240 on the central management server 100 and operable on the processor

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251 thereof. Computer program product 210 contains instructions that are operable on the processor 251 that cause the testing module 210 and the central management server 100 to perform the operations discussed further herein.

[0053] The testing module 210 can interact with the processor to receive or transmit data, instructions, and other information from or to any of the devices connected to I/O 252. In embodiments discussed below, the testing module 210 at least interacts with the testing interface 150, testing apparatus 110, RFID reader 130, and database 170. Although testing interface 150 has been described to be a personal computer (PC), testing interface 150 can also be implemented in whole or in part as a user terminal interface on the central management server 100 itself, or using a keyboard, display, or media inputs and outputs connecting to the I/O 252. Testing interface 150 can also be a lightweight graphical user interface (GUI) operable over a web browser and viewable on any browser-enabled device, such as a PC, smart phone, or other equipment having a processor and computer functionality. Testing interface 150, for example, can receive user-selected identifiers or other user-selected values or parameters from a testing user as will be described in further detail below and can display identifiers, values, parameters, and other specification data, for example, as can be shown with reference to the selection, input, or display fields 900, 1000, 1100-1101, and 1200-1205 in FIGS. 9-12. Other user selection, input, or display fields are also shown elsewhere in FIGS. 13-25, as will be apparent to those having skill in the art.

[0054] The testing module 210 can receive a device identifier for a selected well equipment device 101, the selected well equipment device being a well equipment device positioned to undergo testing and certification, *i.e.,* in the testing warehouse, on a testing trailer, or otherwise positioned at a testing station. In the embodiment of the present invention, only one well equipment device is tested at any given time using any particular testing apparatus 110. It is possible, however, that multiple instances or threads of the testing module 210 can run on the processor 251 concurrently, with each instance being directed to the testing of a different piece of well equipment positioned for testing. It is also possible that multiple testing apparatus 110 of the same type may be employed to perform the same test sequence in simultaneous testing operations performed on multiple well equipment devices 101.

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[0055] The testing module 210 can receive a serial number as a device identifier as shown in FIG. 6. The testing module 210 can receive a serial number as a device identifier, for example, by receiving input from the testing interface 150 as entered therein by a testing user 151. The testing module 210 can also receive a device identifier, such as a serial number, from a peripheral device, such as an RFID reader 130, as is discussed further herein.

[0056] The testing module 210 can identify the selected well equipment device responsive to the device identifier as shown in and match the selected well equipment to: (i) device library information as shown in FIG. 4 at table 400, the device library information including a part number, and (ii) a part library information at table 410 including type, test specification, and test profile, as shown in FIG. 7. If the testing module 210 is unable to identify the foregoing information as shown in FIG. 8 (*i.e.*, the device has not yet been tested), then the testing module 210 can prompt the testing user 151 to enter information to identify the device as shown in FIG. 9. Once the testing module 210 has matched the device 101 to a part number, the testing module 210 can match the device to a test specification and a test profile as shown in FIG. 4 at tables 420 and 430. The test specification can be criteria to which the testing operations will be performed, for example, as specified by the manufacturer or the customer. Test specifications can include, for example, a series of benchmark parameters as shown in FIG. 5 at 506. Test specifications can also include, for example, a schematic associated with the series of parameters as shown in FIG. 5 at 504.

[0057] The test profile as shown in FIG. 4 at table 430 may be a plurality of test sequences that are to be performed upon the well equipment device. A test profile may indicate that certain test sequences shall be run on certain parts, but not on others. For example, test profiles may be defined by "levels" as set forth by the logical process flows shown in FIGS. 6-9.

[0058] Level 1, as set forth in FIG. 6, can include, for example, making an inventory of all iron and entering al serial numbers or parts and specifications into the system. Then a testing user can visually examine and record any defects, damage, worn bodies, threads, and wing nuts on the iron. If the visual examine is acceptable, the tester can proceed with a wall thickness test, as discussed further herein. If the visual examination is unsuccessful, the user can scrap the iron in the database, mark the part with orange paint, and return or destroy the iron so that it becomes

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unusable. If the wall thickness is acceptable, the customer can be contacted if the wall thickness is within 5% of the minimum value set forth in the testing specification. If not, the testing user can proceed to the pressure test. If the pressure test is acceptable, the final inspection to be signed off by leading supervisor. If continued testing is desired, the tester can proceed to Level 2 before performing the pressure test.

[0059] Level 2, as set forth in FIG. 7, can include, for example, dismantling and stripping down and discarding all rubber seals and worn or corroded parts, then cleaning and removing grease from affected parts with solvent. Also, the testing user can perform a surface preparation in caustic solution tank, de-scale surfaces area to remove dirt scale, rust, and paint, and pressure rinse to remove caustic solution. The testing user then performs the visual examination as specified for Level 1, and may scrap the part also as specified for Level 1. If proceeding to Level 3 is acceptable, the testing user goes to Level 3 before performing the pressure test. Otherwise, the pressure test can be performed as specified for Level 1.

[0060] Level 3, as set forth in FIG. 8, can include, for example, inspecting the part to make sure its free from all oil, grease, paint, scale, rust, and all contaminates that might degrade the result of this inspection. The testing user then coats area to be inspected with wet fluorescent bath and puts a yoke on the part to create magnetic field. The user can pass the part for the magnetic particle test if, using a black light to check for indications of cracks and rechecking at right angles, the user finds no indications of cracks. If the magnetic particle test fails, the user can scrap the iron in the database as set forth for Level 1. After cleaning the part and completing the inspection buyoff, the testing user can reassemble and fit with news seals and any spare parts required. Thereafter the testing user can perform the pressure test as specified for Level 1 and proceed to paint per the customer's specifications or according to standardized paint schemes as set forth in FIG. 8. After painting, the supervising leader must sign off on the final inspection.

[0061] Test sequences 1300 can include, for example, visual inspection, wall thickness inspection, disassembly/assembly, magnetic ("mag") particle inspection, pressure test, paint, and final inspection. As shown in FIG. 13, test sequences available for the device 101, (*i.e.*, available according to the test profile 430) can be displayed to the testing user 151 using the

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testing interface 150 so that the testing user 151 may select one of the available test sequences to be performed.

[0062] Test sequences as shown in FIG. 13 may correspond to one of a plurality of testing apparatus 110. For example, the test sequence "wall thickness inspection" corresponds to the UT meter testing apparatus 110 and the test sequence "pressure test" corresponds to the pressure test pump and transducer. Other test sequences shown in FIG. 13 may correspond to manual procedures; for example, the test sequence "visual inspection" corresponds only to operations to be performed by the testing user 151. Each test sequence, as shown in table 440 of FIG. 4, corresponds to a sequence of testing operations to be performed upon the well equipment device 101.

[0063] Once the testing interface 150 displays the plurality of test sequences 440 available for the well equipment device, the testing user 151 can select a test sequence to be performed. The test sequence should correspond to the testing user positioning the selected well equipment device so that the testing apparatus 110 can perform the testing operations. For example, if the testing user 151 has selected the pressure test sequence, the testing user must also ensure that the appropriate testing apparatus 110 (*e.g.*, the pressure pump and transducer) is positioned upon the selected well equipment device so that the test can be properly performed.

[0064] If the testing user 151 has selected the pressure test sequence or the wall thickness inspection sequence, the testing module 210 will calibrate the testing apparatus 110 as shown in FIG. 14 and FIG. 15. In certain embodiments, the calibration 1400, 1500 can be performed responsive to the tolerances as specified in the test specification 420. Calibration can be performed, for example, by shoring a transducer of the testing apparatus 110 to return a rated pressure value or a baseline calibration setting by the manufacturer, as will be understood by those skilled in the art. Embodiments of the present invention can receive the baseline calibration setting returned and configure a calibration setting responsive thereto.

[0065] According to certain embodiments of the present invention, the testing module 210 systematically controls the performance of testing operations in certain test sequences. For such testing modules having full systematic control of performing the testing operations, *e.g.*, the pressure test sequence, the testing user 151 can initiate the performance of the testing operations

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to be controlled by the central management server 100, as shown at control deck 1600 in FIG. 16. The testing module 210 can control the corresponding testing apparatus 110 for the selected testing sequence so that the corresponding testing apparatus 110 performs the sequence of testing operations upon the selected well equipment device 101. For example, the pressure test sequence can be performed responsive to the pressure criteria set forth in the test specification. As shown in FIG. 17, the pressure test proceeds systematically as shown in test chart 1700 and the test module controls the performance of a pressurization of the selected well equipment device 101 for a preselected period of time, for example, as specified in the test specification.

[0066] In further embodiments of the present invention, the testing module 210 systematically controls the performance of some testing operations and requires manual performance of other testing operations ("hybrid systematic/manual"). For testing modules having hybrid systematic/manual performance of testing operations, such as for wall thickness inspection, the testing user 151 can initiate the performance of the testing operations to be controlled by the central management server 100, and the central management server 100 can control the testing apparatus 110 as discussed above with respect to fully systematic testing. Also, the testing module 210 can prompt the testing user 151 with instructions for the testing user 151 to perform testing operations pursuant to the test specification. As shown in FIG. 18 and FIG. 19, the thickness at "Location A" can be measured and input 1800, 1900 either by the UT Meter or by the testing user 151 manually measuring Location A with a digital caliper. The testing module 210 transmits the schematic from the test specification to the testing interface 150 so that it may be displayed 1901 to the testing user 151 and instructs the testing user 151 how to perform the test operations with respect to the information set forth in the schematic and test specification.

[0067] In further embodiments of the present invention, the testing module 210 requires full manual performance of the testing operations for certain test sequences. For testing modules having full manual performance of testing operations, such as for the visual inspection sequence, the testing module 210 can prompt the testing user 151 with instructions for the testing user 151 to perform testing operations pursuant to the test specification. As shown in FIGs. 20-21, band information 2000 and paint parameters 2100 can be input by the testing user 151 responsive to instructions provided by the testing module 210 to the test interface 150, the testing module 210 providing such instructions responsive to the sequence of testing operations and the test

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specification. As can be seen in FIG. 17, for example, the testing interface 150 can display the schematic 2001 from the test specification to the testing user 151 and instructs the user how to perform the test operations with respect to information set forth in the schematic and the test specification.

[0068] Responsive to systematic, manual, or hybrid systematic/manual performance of the test operation described above, the testing module 210 receives testing data either as captured by the testing apparatus 110 for the corresponding testing sequence or as captured by the testing user 151 and entered into the testing interface 150 according to specific instructions provided by the testing module 210, e.g., at banding menu 2000. As shown in FIG. 4, the testing data is stored in the table 440 and linked to the device library 400 for the selected well equipment device 101. Also as shown in FIG. 4, an exemplary embodiment of the testing data in table 440 can have individual cells for each testing sequence (*e.g.*, wall thickness, pressure test, visual inspection, etc.). The testing data in table 440 can be used, as is discussed further herein, to generate certification data by execution of the certification module 220 on the processor 251.

[0069] Additionally, further embodiments of the present invention include certain test sequences as described in FIGS. 6-9. These test sequences, for example, can include disassembly/assembly, magnetic particle ("mag particle") inspection, paint, and final inspection. Although an embodiment of the invention includes manual performance of the test operations for these sequences, each of these test sequences may be implemented either by systematic, manual, or hybrid systematic/manual performance of the testing operations. Regardless of whether the performance of the testing operations are performed systematically or manually, those skilled in the art will realize that all testing operations are performed responsive to a command or instruction being systematically issued by the testing module 210 when executed on the central management server 100. As such, any test operation described herein as manual can be performed systematically provided there exists a testing apparatus 110 that can receive an instruction from the central management server 100 to perform the operation. For example, the performance of test operations using a digital caliper may be performed either manually or systematically, although an embodiment employs manual performance of such operations. Those skilled in the art will understand that it is within the scope of the invention to employ a testing apparatus 110 having a digital caliper, actuator, and an control device to systematically

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perform a wall thickness measurement using a digital caliper in addition to the embodiment employing manual performance. Likewise, it will be understood by those in the art that any manual operation described herein may also be performed systematically under the architecture of the central management server as set forth in FIG. 2.

Certification Module 220

[0070] As is shown in FIG. 2, the certification module 220 may be a computer program product stored in the non-transitory memory 240 on the central management server 100 and operable on the processor 251 thereof. Computer program product 220 contains instructions that are operable on the processor 251 that cause the certification module 220 and the central management server 100 to perform the operations discussed further herein.

[0071] The certification module 220 can interact with the processor to receive or transmit data, instructions, and other information from or to any of the devices connected to I/O 252. In addition both the certification module 220 and the testing module 210 are in communication with the processor 251 and the non-transitory memory 240 so that modules can pass or return variables between modules according to a shared API or access global variables being stored on the non-transitory memory 240 to ensure interoperability and open communication between computer program products in communication with the processor 251. Likewise, those skilled in the art will understand that computer program products 220 and 210 are capable of passing, returning, or referencing common variables regardless of whether computer program products are executed on the same processor 251, but that a common API will allow interoperability and open communications. In embodiments discussed below, the certification module 220 at least interacts with the testing interface 150, RFID reader 130, RFID writer 140, and database 170. Although testing interface 150 has been described to be a PC, testing interface 150 can also be implemented in whole or in part as a user terminal interface on the central management server 100 itself, using a keyboard, display, or media inputs and outputs connecting to the I/O 252. The testing interface 150 can also be a lightweight graphical user interface (GUI) operable over a web browser and viewable on any browser-enabled device, such as a PC, smart phone, or other equipment having a processor and computer functionality.

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[0072] The certification module 220 can receive a device identifier for a selected well equipment device 101. As described above, "well equipment devices" includes the equipment and devices used in hydraulic fracturing for oil and gas wells, i.e. "high pressure hydraulic fracturing flow iron," "frac iron," or, simply, "iron." Frac iron can include, for example, a slurry blender, high pressure/volume fracturing pumps, high pressure treating iron, and other pipes, joints, valves, and fittings. For example, frac iron can include swivel joints, pup joints, plug valves, check valves and relief valves. Furthermore, by way of example, frac iron can include any type of ball injector, crow's foot, air chamber, crossover, hose, pipes/piping, hose loop, ball injector tee body, tee, wye, lateral, ell, check valve, plug valve, wellhead adapter, swivel joint, plug, relief valve, densometer, cross, frac pump, or cement pump. The selected well equipment device is a well equipment device that has previously undergone testing, for example, as described above with respect to the testing module 210. The certification module 220 can receive a device identifier, for example, responsive to receiving input from the testing interface 150 as entered therein by a testing user 151. The certification module 220 can also receive a device identifier, for example, responsive to receiving input from a remote user interface as entered therein by a remote user 161. Furthermore, the certification module 220 can receive a device identifier from the testing module 210 responsive to the testing module 210 having completed execution of the testing operations and the generation and linking of the testing data in the database 170. The certification module 220 can identify a selected well equipment device responsive to the device identifier and generate and link certification data in database 170, for example, in certification table 450, responsive to the testing data. For example, the certification data 450 can include all data as can be entered onto certificate 500 as a summary or other rendering of testing data responsive to testing operations being performed on the well equipment device 101, for example, a graphical representation of a pressure test 503. The certification module 220 can include logic to generate charts and data modeling based upon testing data, which is raw data stored, for example, in table 440. Further examples of summaries or renderings of raw testing data responsive to the testing operations appear on the face of certificate 500. As a result of the linking operation, the certification data 440 can be readily accessed or queried according to a serial number for a well equipment device.

[0073] The certification module 220 can also generate certification data in a format responsive the proprietary data table format for the exemplary RFID certificate. For example,

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certification module 220 may generate certificate data according to specific standards or protocols employed in the proprietary standard, for example, cell size, packet size, header length, payload length, etc. The RFID certificate can be generated so that it is ready to be stored to the media attached to the well equipment without further processing. The certification module 220 may also include logic for rendering graphics stored as certification data, such as the schematics and charts, into a lightweight graphics formats such as vector graphics formats. The RFID certificate, for example, can include all fields available on the paper document, including device identifier 501, pass or fail grading 502, tabular summary or rendering of test data 503, drawing 504, measured values 505, and demanded values 506. The tabular summary or rendering 503 and the drawing 504 can be encoded in lightweight vector graphics formats, for example.

Reporting Module 230 and Enterprise Resource Planning Interface

[0074] As is shown in FIG. 2, the reporting module 230 may be a computer program product stored in the non-transitory memory 240 on the central management server 100 and operable on the processor 251 thereof. Computer program product 230 contains instructions that are operable on the processor 251 that cause reporting module 230 and the central management server 100 to perform the operations discussed further herein.

[0075] The reporting module 230 can interact with the processor 251 to receive or transmit data, instructions, and other information from or to any of the devices connected to I/O 252. In addition, both the reporting module 230 and the testing module 210 are in communication with the processor 251 and non-transitory memory 240 so that these two modules can pass or return variables between each other according to a common application programming interface (API) or shared global variables being stored on the non-transitory memory 240, thereby enhancing interoperability and open communication between the modules. Likewise, those skilled in the art will understand that computer program products 230 and 220 are capable of passing, returning, or referencing common variables regardless of whether computer program products are executed on the same processor 251 and that a common API will allow interoperability and open communications as described above. In embodiments discussed below, the reporting module 230 at least interacts with the testing module 210, certification module 220, and database 170. Although remote user interface 160 may be a PC as has been described for testing interface 150,

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remote user interface 160 can also be implemented in whole or in part as a user terminal interface on the central management server 100 itself, using a keyboard, display, or media inputs and outputs connecting to the I/O 252. Remote user interface 160 can also be a lightweight graphical user interface (GUI) operable over a web browser and viewable on any browser-enabled device, such as a PC, smart phone, or other equipment having a processor and computer functionality.

[0076] The reporting module 230 can receive a device identifier for a selected well equipment device 101, the selected well equipment device being a well equipment device that has previously undergone testing, for example, as described above with respect to the testing module 210. The reporting module 230 can receive a device identifier, for example, responsive to receiving input from the testing interface 150 as entered therein by a testing user 151. The reporting module 230 can also receive a device identifier from any other module, as discussed above. In response to receiving the device identifier, the reporting module 230 can match the device identifier to any desired data in the database 170, for example, testing data in the database at testing data table 440, certification data in the certification data table 450, device library data from the device library table 410, and test specification data from the specification library 420. The reporting module, responsive to the device identifier, can return any of the test specification for the selected well equipment device 101, testing data for a plurality of testing sequences performed on the selected well equipment device 101, and certificate data for the selected well equipment device 101, for example, according to the database structure provided in FIG. 4.

[0077] The reporting module 230 may also receive an indication or selection of additional variables for reporting purposes, for example, a part number, work order number, etc. In the event that the reporting module 230 receives an additional variable, the reporting module 230 can or expand or refine the matched data with respect to the additional variable. For example, the reporting module 230 may receive a device identifier, a work order number, and the reporting module 230 will return a list of all certifications, tests, or specifications for that device identifier according to the tests performed under the received work order number. On the other hand, a reporting module 230 may receive a device identifier and a part number, and the reporting module 213 will return a list of all certifications, tests, or specifications for either the selected well device 101 or all well devices tested having the selected the part number.

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[0078] Embodiments of the present invention employing the reporting module 230 are beneficial in that they transform the task of testing and certification—once a costly operational hurdle—into a robust data-point in business and operational management decisions. For example, manufacturers may use embodiments of the reporting module in research and development to better understand wear patterns and rates in real-world applications, to build a better product, and to manage customer relations. As those skilled in the art will appreciate, the reporting module 230 can be a powerful tool in achieving management-level value from systematic testing and certifications, which provides a comprehensive and reliable (*i.e.*, consistent) pool of data pertaining to asset management, inventory management, purchasing, risk management, and other business analytics. Exemplary reports generated by the reporting module 13 are shown in FIGS. 24-25.

[0079] Furthermore, embodiments of the present invention can employ an ERP (Enterprise Resource Planning) interface (not pictured) connected to the I/O of the central management server 100 to provide the foregoing benefits realized by the reporting module, but in a manner that is more fully integrated into enterprise-wide information systems and providing high levels of cross-functional integration, network scalability, and real-time data synchronization. In particular, embodiments of the present invention employ an ERP interface for the purposes of invoicing the testing and certification operations, for example, responsive to work order information entered by a testing user 151 to the testing interface 150 as shown in FIG. 6.

RFID 130, 135, 140

[0080] Furthermore, embodiments of the present invention can achieve some or all of the foregoing objectives by providing a central management server 200 that can communicate with one or more well equipment devices 101. For example, the central management server 200 can be in communication with the one or more well equipment devices using wireless communication technologies, for example, radio frequency identification (RFID) technologies. The one or more well equipment devices 101 can include an RFID tag 135, and the central management server 200 can communicate with the RFID tag 135 on the one or more well equipment devices using an RFID reader 130 in communication with the central management server 200 through the I/O 252. In an embodiment, the RFID tag is a UHF Gen-2 RFID tag that

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is attached to the frac iron using a clamp designed to be sufficiently robust so that the RFID tag is not affected by the harsh operating conditions of the downhole environment.

[0081] In an embodiment, the RFID reader 130 and RFID 140 are peripherals to the testing interface 150, attaching thereto by known connection means in the art, such as a USB cable or cables. In certain embodiments, the RFID reader and RFID writer may be one unit, such as an RFID reader/writer device.

[0082] The RFID reader 130 can read a device identifier from the RFID tag on a selected well equipment device 101 through radio frequency communication and transmit the device identifier to the central management server 200. The central management server is positioned to receive the device identifier from the RFID reader 130. Any of the computer program products discussed herein, such as the testing module 210, can receive a device identifier responsive to the central management server 200 receiving a device identifier from the RFID reader 130. An embodiment of a computer-implemented method for using the RFID reader 130 includes the testing user 151 having a handheld and/or remote RFID reader 130 in physical proximity to the selected well equipment device 101 and the RFID tag 135 thereon so that the testing user can interrogate the RFID tag 135 and so that the RFID tag can transmit the device identifier to the RFID reader 130.

[0083] The RFID writer 140 can write an RFID certificate to the RFID tag on a selected well equipment device 101 through radio frequency communication and transmit the device identifier to the central management server 200. The RFID certificate can have the qualities and properties as described herein, preferably including at least a serial number. The central management server is positioned to transmit the RFID certificate or any data included therein to the RFID writer 140 responsive to any of the computer program products discussed herein, such as the certification module 220. An embodiment of a computer-implemented method for using the RFID writer 140 includes the testing user 151 having a handheld or remote RFID writer 140 in physical proximity to the selected well equipment device 101 and the RFID tag 135 thereon so that the testing user can establish a communication link with the RFID tag 135 and so that the RFID writer can transmit and store the RFID certificate or the information therein to the RFID tag 135.

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[0084] This application claims priority and is related to U.S. Provisional Patent Application No. 61/330,248 filed April 30, 2010 titled "Machines, Systems, Computer-Implemented Methods, And Computer Program Products To Test And Certify Oil And Gas Equipment," which is incorporated by reference in its entirety herein.

[0085] The foregoing has broadly outlined certain features, and technical advantages of the present invention and a detailed description of the invention so that embodiments of the invention may be better understood in light of features and advantages of the invention as described herein, which form the subject of certain claims of the invention. It should be appreciated that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized that such equivalent constructions do not depart from the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further advantages are better understood from the description when considered in connection with the accompanying figures. It is to be expressly understood, however, that such description and figures are provided for the purpose of illustration and description only and are not intended as a definition of the limits of the present invention. For example, although the example embodiments discussed herein are directed to oil and gas hydraulic fracturing operations, it should be specifically noted that the systems, machines, methods, and computer program products to test and certify well equipment devices may be employed to carry out similar functions for other equipment or devices requiring routine testing and certification, including without limitation, aircraft maintenance and construction, ship maintenance and construction, facilities maintenance and construction, and so on.

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That Claimed Is:

1. A central management server to manage periodic testing and certification of well equipment devices, the testing and certification being facilitated by a plurality of testing apparatus performing one or more testing operations upon the well equipment devices, the machine comprising:

a processor;

a non-transitory memory;

an input/output unit to communicate with the plurality of testing apparatus;

a database positioned to match a device identifier to a well equipment device, a test specification, and a plurality of testing sequences;

a testing module stored in the memory, the memory being a tangible, non-transitory, computer-readable storage medium, and the testing module being operable by the processor, the testing module comprising a set of instructions that, when executed by the processor, cause the testing module to perform the following operations:

identifying a selected well equipment device, a device test specification, and a plurality of testing sequences, the identifying operation responsive to receiving a device identifier for the selected well equipment device, each testing sequence of the plurality of testing sequences to be performed by a corresponding testing apparatus of the plurality of testing apparatus, each testing sequence defining a sequence of testing operations,

selecting a testing sequence of the plurality of testing sequences, the selecting operation responsive to the selected well equipment device being positioned so that the corresponding testing apparatus for the selected testing sequence can perform testing operations upon the selected well equipment device,

controlling the corresponding testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence of testing operations upon the selected well equipment device, the sequence of testing operations being performed responsive to the device test specification,

generating testing data for the selected testing sequence responsive to receiving output from the corresponding testing apparatus for selected testing sequence performing the sequence of testing operations, and

linking the testing data for the selected testing sequence to the device identifier for the selected well equipment device in the database so that a certificate can be generated responsive thereto; and

a certification module stored in the memory, the memory being a tangible, non-transitory, computer-readable storage medium, and the certification module being operable by the processor, the certification module comprising a set of instructions that, when executed by the processor, cause the certification module to perform the following operations:

identifying a selected well equipment device, a device test specification, and testing data for a plurality of testing sequences, the identifying operation responsive to receiving a device identifier for the selected well equipment device,

generating a certificate for the selected well equipment device responsive to the testing data for the plurality of testing sequences, the plurality of testing sequences having been performed upon the selected well equipment device responsive to the device test specification, and

linking the certificate for the selected well equipment device to the device identifier for the selected well equipment device in the database so that the certificate can be readily recalled from the database responsive to the device identifier.

2. A central management server as defined in Claim 1, wherein the input/output unit is further positioned to communicate with a testing interface, the testing module further performing the following operation:

calibrating the corresponding testing apparatus for the selected testing sequence responsive to the device test specification responsive to receiving a selection of a test sequence from the testing interface.

3. A central management server as defined in Claim 1 or Claim 2, the testing module further performing the following operations:

delivering to the testing interface the device test specification and instructions for performing the sequence of testing operations so that a local user may view the device test specification on a graphical display of the testing interface and so that the local user may perform the sequence of testing operations upon the selected well equipment device responsive to the device test specification;

generating testing data for the selected testing sequence responsive to receiving user data from the testing interface, the user data having been input to the testing interface responsive to the user performing the sequence of testing operations upon the selected well equipment device.

4. A central management server as defined in Claim 1, wherein the input/output unit is further positioned to communicate with a remote user interface, the central management server further comprising:

a reporting module stored in the memory, the memory being a tangible, non-transitory, computer-readable storage medium, and the reporting module being operable by the processor, the reporting module comprising a set of instructions that, when executed by the processor, cause the reporting module to perform the following operations:

identifying a selected well equipment device, a device test specification, testing data for a plurality of testing sequences, and a certificate, the identifying operation

responsive to receiving a device identifier for the selected well equipment device from the remote user interface,

delivering to the remote user interface at least one of the testing data, the device test specification, and the certificate responsive to the identifying operation.

5. A central management server as defined in Claim 1, wherein:

the input/output unit is further positioned to communicate with an RFID reader; and

the receiving a device identifier for the selected well equipment device is responsive to interrogating a device RFID tag using the RFID reader, the device RFID tag being attached to the selected well equipment device and having the device identifier encoded thereon.

6. A central management server as defined in Claim 5, wherein the input/output unit is further positioned to communicate with an RFID writer, the certification module further performing the following operations:

generating an RFID certificate responsive to the certificate, the RFID certificate being formatted so that the RFID certificate is recognizable by a remote interrogation device having an RFID reader; and

delivering an RFID certificate to the device RFID tag using the RFID writer so that the RFID certificate can be readily accessed by the remote interrogation device.

7. A system to certify oil and gas well equipment, the system comprising:

a plurality of devices to be used in well equipment to define a plurality of well equipment devices, each well equipment device of the plurality of well equipment devices having a device identifier associated therewith;

a central management server positioned to identify a device test specification and a plurality of testing sequences for a selected well equipment device responsive to receiving a device identifier for the selected well equipment device, the device test

specification and the plurality of testing sequences defining certification criteria for the well equipment device;

a plurality of testing apparatus, each testing apparatus positioned to perform a testing sequence to test physical characteristics of the well equipment device, the testing sequence being a sequence of testing operations, the sequence of testing operations being performed responsive to the device test specification;

a plurality of controllers, each controller positioned to receive commands responsive to the certification criteria from the central management server and to control the plurality of testing apparatus performing the sequence of testing operations upon the selected well equipment device responsive to the device test specification; and

a certificate generated responsive to the plurality of testing apparatus performing the plurality of testing sequences upon the well equipment device, the certificate indicating whether selected well equipment device has been tested according to the certification criteria within a pre-selected period of time.

8. A system as defined in Claim 7, the system further comprising:

a plurality of device RFID tags, each device RFID tag of the plurality of device RFID tags being attached to a well equipment device of the plurality of well equipment devices and having a device identifier for the well equipment device encoded thereon; and

an RFID reader in communication with the central management server and the plurality of device RFID tags, wherein the central management server is positioned to receive the device identifier for a well equipment device having a device RFID tag attached thereto responsive to the RFID reader interrogating the device RFID tag.

9. A system as defined in Claim 8, the system further comprising an RFID writer in communication with the central management server and the plurality of device RFID tags, wherein the central management server is positioned to generate an RFID certificate responsive to the certificate and deliver the RFID certificate to a device RFID tag using the RFID writer.

10. A system as defined in any one of Claims 7 to 9, the system further comprising database positioned to match a device identifier to a well equipment device, a device test specification, and a plurality of testing sequences, wherein the central management server identifies a device test specification and a plurality of testing sequences for a selected well equipment device responsive to matching the device identifier in the database.

11. A system as defined in any one of Claims 7 to 10, the system further comprising a testing interface in communication with the central management server, wherein:

each testing apparatus of the plurality of testing apparatus is positioned to perform a testing sequence responsive to receiving a selection of the testing sequence from the testing interface; and

the certificate is also generated responsive to user data received from the testing interface, the user data having been input to the testing interface responsive to the user performing the sequence of testing operations upon the selected well equipment device responsive to the device test specification.

12. A method to manage periodic testing of a plurality of well equipment devices, the testing being facilitated by a plurality of testing apparatus performing one or more testing operations upon the plurality of well equipment devices, the method comprising:

receiving by a computer a device identifier for a selected well equipment device of the plurality of well equipment devices;

identifying the selected well equipment device, a device test specification, and plurality of testing sequences, the identifying operation being responsive to the receiving operation, each testing sequence of the plurality of testing sequences to be performed by a corresponding testing apparatus of the plurality of testing apparatus, each testing sequence defining a sequence of testing operations;

selecting a testing sequence of the plurality of testing sequences to define a selected testing sequence, the selecting operation responsive to the selected well equipment device

being positioned so that the corresponding testing apparatus for the selected testing sequence can perform testing operations upon the selected well equipment device;

calibrating the corresponding testing apparatus for the selected testing sequence responsive to the device test specification;

controlling the corresponding testing apparatus for the selected testing sequence so that the corresponding testing apparatus performs the sequence of testing operations upon the selected well equipment device, the sequence of testing operations being performed responsive to the device test specification;

generating testing data for the selected testing sequence responsive to receiving output from the corresponding testing apparatus for selected testing sequence performing the sequence of testing operations; and

linking the testing data for the selected testing sequence to the device identifier for the selected well equipment device in a database so that a certificate can be generated responsive thereto.

13. A method as defined in Claim 12 wherein selecting a testing sequence is responsive to receiving a selection of the test sequence from a testing interface.

14. A method as defined in Claim 12 or Claim 13, further comprising:

calibrating the corresponding testing apparatus for the selected testing sequence responsive to the device test specification responsive to receiving a selection of a test sequence from the testing interface.

15. A method as defined in any one of Claims 12 to 14, further comprising

delivering to the testing interface the device test specification and instructions for performing the sequence of testing operations so that a local user may view the device test specification on a graphical display of the testing interface and so that the local user may perform the sequence of testing operations upon the selected well equipment device responsive to the device test specification;

generating testing data for the selected testing sequence responsive to receiving user data from the testing interface, the user data having been input to the testing interface responsive to the user performing the sequence of testing operations upon the selected well equipment device.

16. A method as defined in any one of Claims 12 to 15 wherein receiving a device identifier for the selected well equipment device is responsive to interrogating a device RFID tag using a RFID reader, the device RFID tag being attached to the selected well equipment device and having the device identifier encoded thereon.

17. A method as defined in any one of Claims 12 to 16, further comprising: generating a certificate for the selected well equipment device responsive to the testing data for the plurality of testing sequences, the plurality of testing sequences having been performed upon the selected well equipment device responsive to the device test specification; and

linking the certificate for the selected well equipment device to the device identifier for the selected well equipment device in the database so that the certificate can be readily recalled from the database responsive to the device identifier.

18. A computer program comprising computer program code means adapted to perform all the steps of any one of Claims 12 to 17 when said computer program is run on a computer.

19. A computer program comprising computer program code means adapted to perform all the steps of any one of Claims 12 to 17 when said program is run on a computer, the computer program embodied on a computer readable medium.

20. A method to manage periodic certification of a plurality of well equipment devices, the certification based upon testing data generated responsive to a plurality of testing apparatus

performing one or more testing operations to test physical characteristics of the plurality of well equipment devices, the method comprising:

identifying by a computer a selected well equipment device and a device test specification responsive to receipt of physical testing data for a plurality of physical testing sequences, the selected well equipment device corresponding to a device identifier for the selected well equipment device;

generating a certificate for the selected well equipment device responsive to receipt of the physical testing data for the plurality of testing sequences, the plurality of testing sequences having been performed upon the selected well equipment device responsive to the device test specification; and

linking the certificate for the selected well equipment device to the device identifier for the selected well equipment device in a database so that the certificate can be readily recalled from the database responsive to the device identifier.

21. A method as defined in Claim 20, the method further comprising:

delivering an RFID certificate to a device RFID tag using an RFID writer so that the RFID certificate can be readily accessed by the remote interrogation device, the device RFID tag being attached to the selected well equipment device and having the device identifier encoded thereon.

FIG. 1

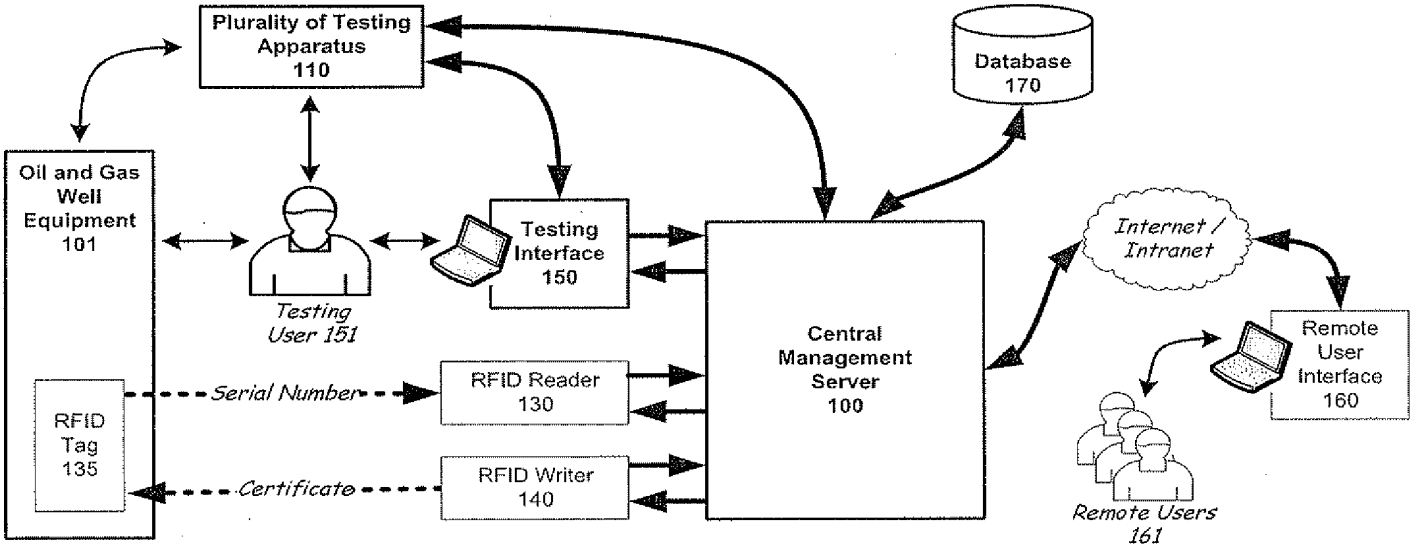

Plurality of Testing Apparatus 110
Database 170
Oil and Gas Well Equipment 101
Testing Interface 150
Testing User 151
Central Management Server 100
Internet / Intranet
Remote User Interface 160
RFID Tag 135
Serial Number
RFID Reader 130
Certificate
RFID Writer 140
Remote Users 161

FIG. 2

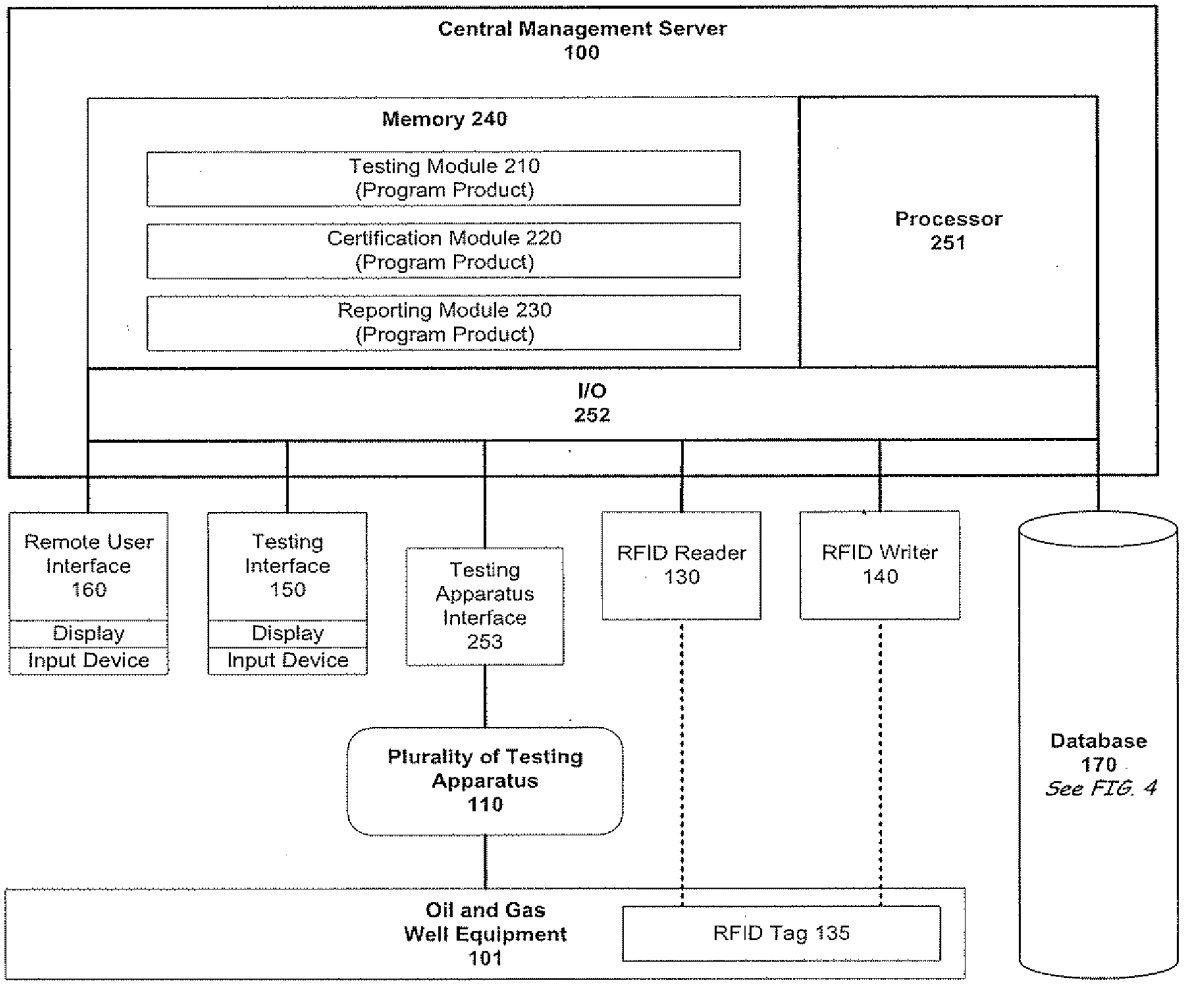

Central Management Server 100
Memory 240
Testing Module 210 (Program Product)
Certification Module 220 (Program Product)
Reporting Module 230 (Program Product)
Processor 251
I/O 252
Remote User Interface 160
Display
Input Device
Testing Interface 150
Display
Input Device
Testing Apparatus Interface 253
RFID Reader 130
RFID Writer 140
Database 170 See FIG. 4
Plurality of Testing Apparatus 110
Oil and Gas Well Equipment 101
RFID Tag 135

FIG. 3

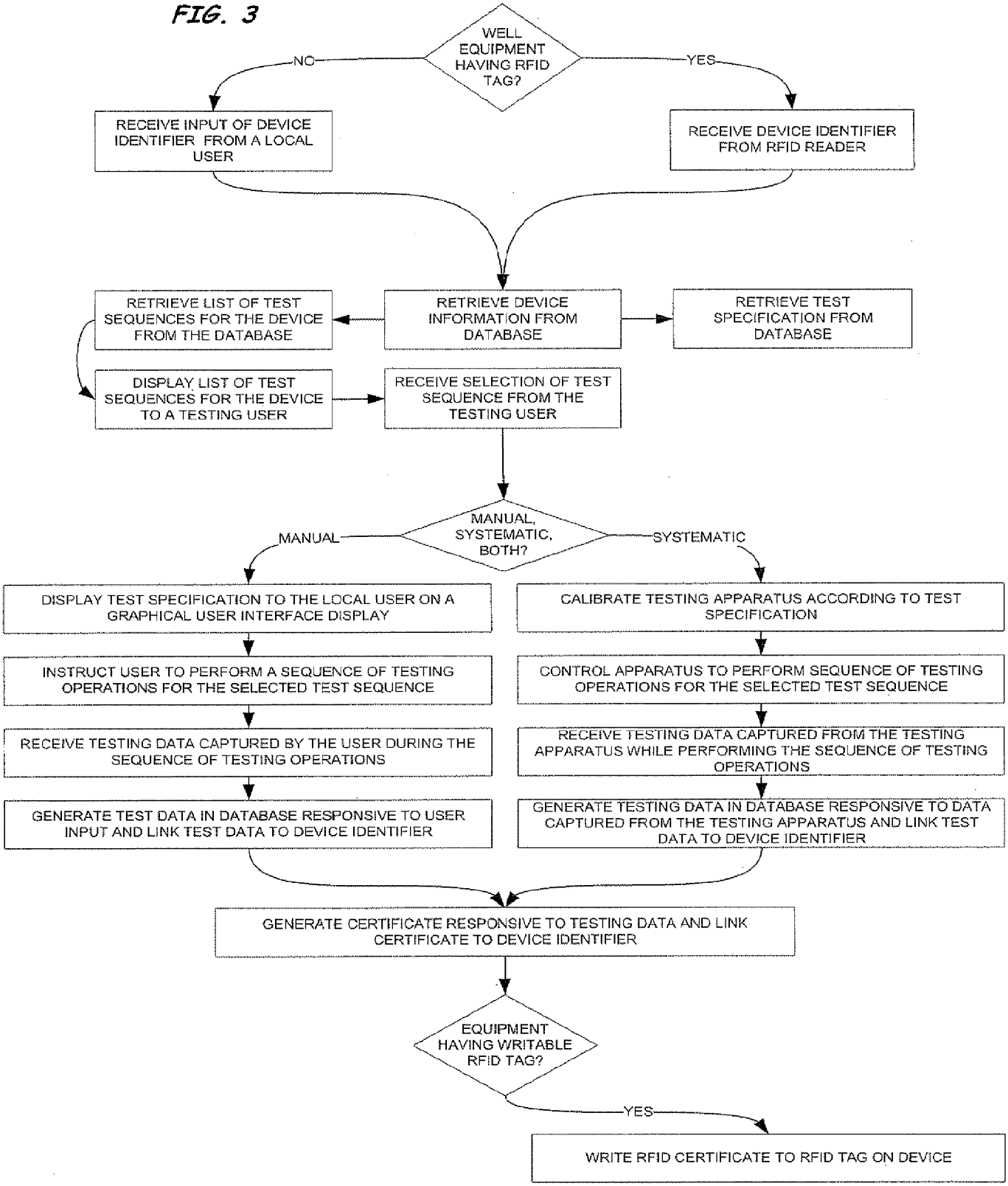
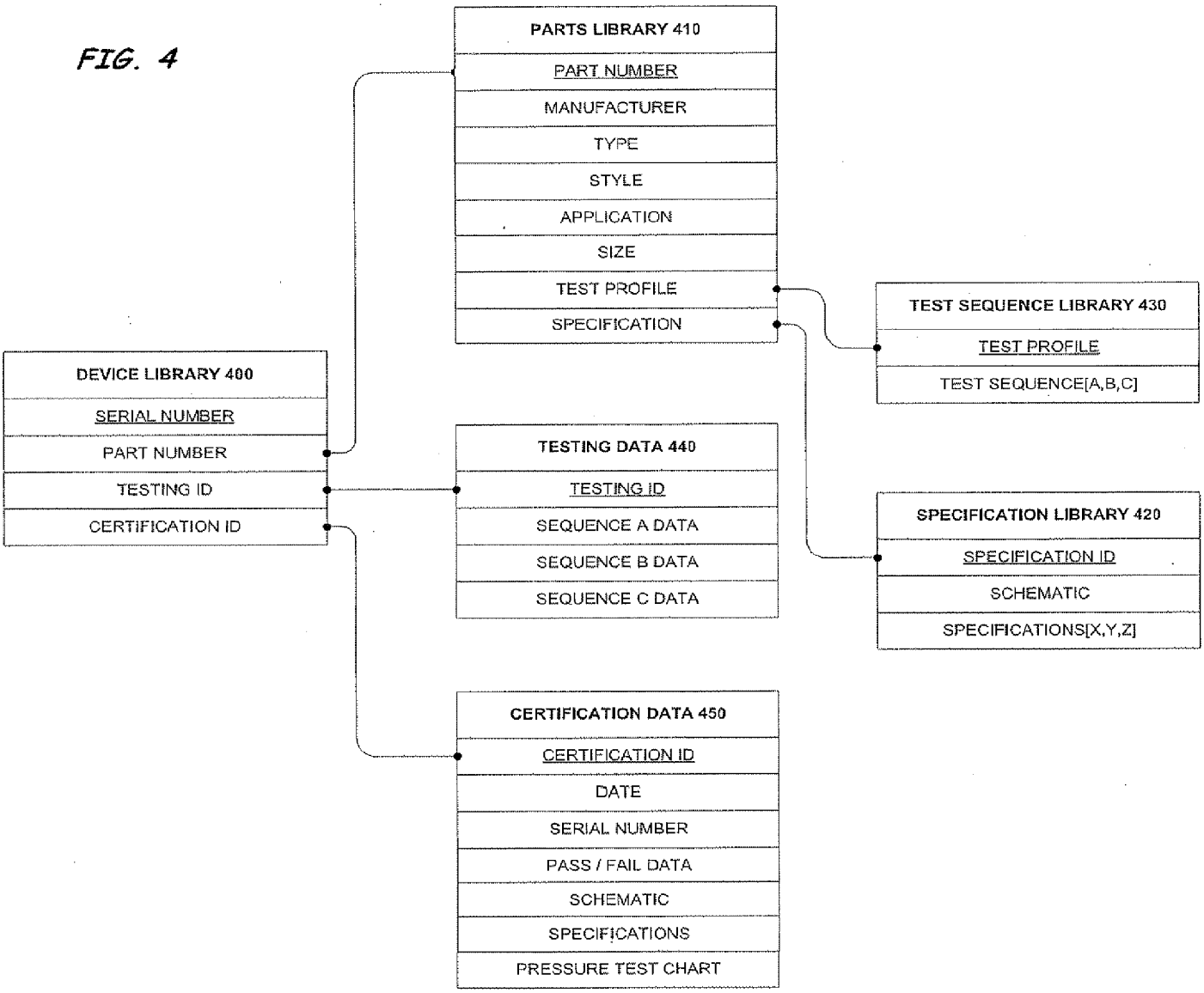

WELL EQUIPMENT HAVING RFID TAG?
NO
YES
RECEIVE INPUT OF DEVICE IDENTIFIER FROM A LOCAL USER
RECEIVE DEVICE IDENTIFIER FROM RFID READER
RETRIEVE LIST OF TEST SEQUENCES FOR THE DEVICE FROM THE DATABASE
RETRIEVE DEVICE INFORMATION FROM DATABASE
RETRIEVE TEST SPECIFICATION FROM DATABASE
DISPLAY LIST OF TEST SEQUENCES FOR THE DEVICE TO A TESTING USER
RECEIVE SELECTION OF TEST SEQUENCE FROM THE TESTING USER
MANUAL, SYSTEMATIC, BOTH?
MANUAL
SYSTEMATIC
DISPLAY TEST SPECIFICATION TO THE LOCAL USER ON A GRAPHICAL USER INTERFACE DISPLAY
CALIBRATE TESTING APPARATUS ACCORDING TO TEST SPECIFICATION
INSTRUCT USER TO PERFORM A SEQUENCE OF TESTING OPERATIONS FOR THE SELECTED TEST SEQUENCE
CONTROL APPARATUS TO PERFORM SEQUENCE OF TESTING OPERATIONS FOR THE SELECTED TEST SEQUENCE
RECEIVE TESTING DATA CAPTURED BY THE USER DURING THE SEQUENCE OF TESTING OPERATIONS
RECEIVE TESTING DATA CAPTURED FROM THE TESTING APPARATUS WHILE PERFORMING THE SEQUENCE OF TESTING OPERATIONS
GENERATE TEST DATA IN DATABASE RESPONSIVE TO USER INPUT AND LINK TEST DATA TO DEVICE IDENTIFIER
GENERATE TESTING DATA IN DATABASE RESPONSIVE TO DATA CAPTURED FROM THE TESTING APPARATUS AND LINK TEST DATA TO DEVICE IDENTIFIER
GENERATE CERTIFICATE RESPONSIVE TO TESTING DATA AND LINK CERTIFICATE TO DEVICE IDENTIFIER
EQUIPMENT HAVING WRITABLE RFID TAG?
YES
WRITE RFID CERTIFICATE TO RFID TAG ON DEVICE

FIG. 4


PARTS LIBRARY 410
PART NUMBER
MANUFACTURER
TYPE
STYLE
APPLICATION
SIZE
TEST PROFILE
SPECIFICATION
TEST SEQUENCE LIBRARY 430
TEST PROFILE
TEST SEQUENCE[A,B,C]
DEVICE LIBRARY 400
SERIAL NUMBER
PART NUMBER
TESTING ID
CERTIFICATION ID
TESTING DATA 440
TESTING ID
SEQUENCE A DATA
SEQUENCE B DATA
SEQUENCE C DATA
SPECIFICATION LIBRARY 420
SPECIFICATION ID
SCHEMATIC
SPECIFICATIONS[X,Y,Z]
CERTIFICATION DATA 450
CERTIFICATION ID
DATE
SERIAL NUMBER
PASS / FAIL DATA
SCHEMATIC
SPECIFICATIONS
PRESSURE TEST CHART

500

501

CERTIFICATION

SERIAL NUMBER:

Customer: **Cust Num:** **Plant:**
Work Order: **Part Num:** 2A1 **Mfr:**
Description: MXF/INT/4 LR10 WR
District

Visual Inspection - PASS 502

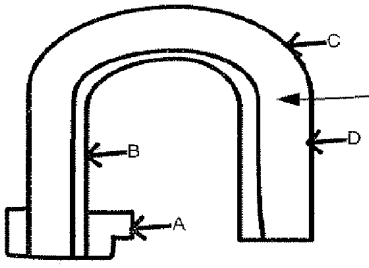
Comments:
Inspected By: SCOTT H **Test Date:** March 18, 2010

504

Wall Thickness Inspection - PASS 502

Comments:
Thickness Gauge: VERSION: 1.13 /1.01s
Gauge Cal Date: March 18, 2010
Wall Thickness Values (minimum in parenthesis):
A: 0.60"(0.40"), B: 0.60"(0.44"), C: 0.88"(0.36"), D: 0.89"(0.39"),

505
506



Inspected By:
Test Date:

Disassembly/Assembly - PASS 502

Comments:
Inspected By: **Test Date:** March 18, 2010

Magnetic Particle Inspection - N/A 502

Comments: THIS TEST WAS NOT PERFORMED FOR THIS IRON.
Mag Part **Gauge Cal Date:**
Inspected By: **Test Date:**

Pressure Test - PASS 502

Comments: good
Required Test Pres: 10000 PSI
Rated Working Pres: 10000 PSI
Test Duration: minutes
Tested By:
Approved By:
Test Date: March 18, 2010
Pres Gauge: 357808
Gauge Cal Date: March 16, 2010
Pres Recorder:
Recorder Cal Date:

503

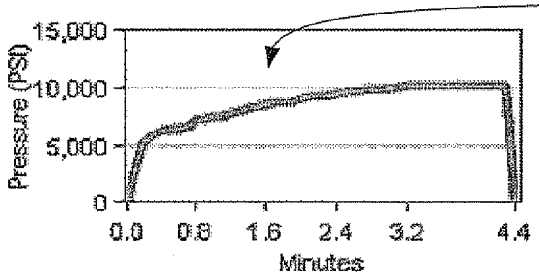


FIG. 5

FIG. 6

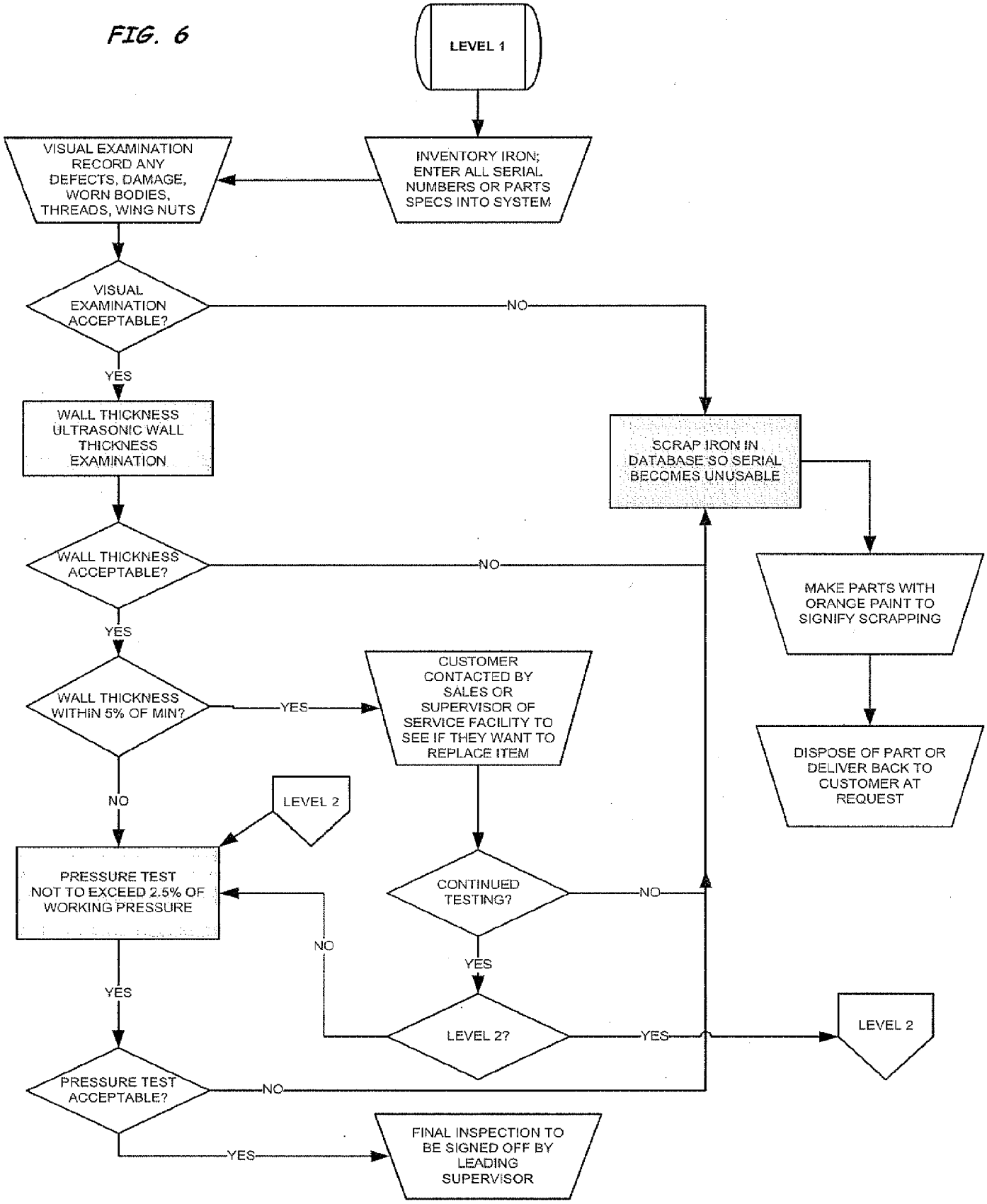
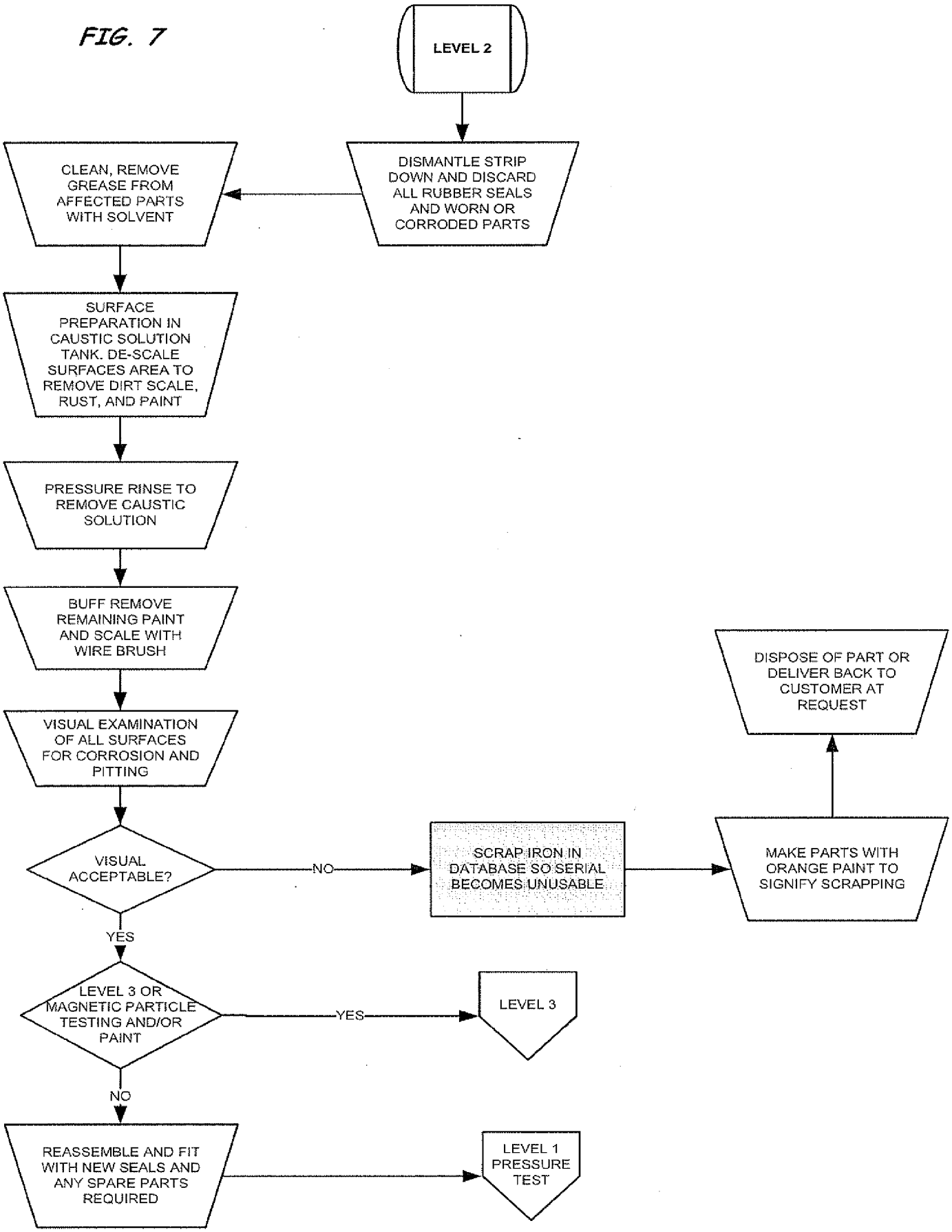

LEVEL 1
INVENTORY IRON; ENTER ALL SERIAL NUMBERS OR PARTS SPECS INTO SYSTEM
VISUAL EXAMINATION RECORD ANY DEFECTS, DAMAGE, WORN BODIES, THREADS, WING NUTS
VISUAL EXAMINATION ACCEPTABLE?
NO
YES
WALL THICKNESS ULTRASONIC WALL THICKNESS EXAMINATION
SCRAP IRON IN DATABASE SO SERIAL BECOMES UNUSABLE
WALL THICKNESS ACCEPTABLE?
NO
YES
MAKE PARTS WITH ORANGE PAINT TO SIGNIFY SCRAPPING
WALL THICKNESS WITHIN 5% OF MIN?
YES
CUSTOMER CONTACTED BY SALES OR SUPERVISOR OF SERVICE FACILITY TO SEE IF THEY WANT TO REPLACE ITEM
DISPOSE OF PART OR DELIVER BACK TO CUSTOMER AT REQUEST
NO
LEVEL 2
PRESSURE TEST NOT TO EXCEED 2.5% OF WORKING PRESSURE
CONTINUED TESTING?
NO
NO
YES
YES
LEVEL 2?
YES
LEVEL 2
PRESSURE TEST ACCEPTABLE?
NO
YES
FINAL INSPECTION TO BE SIGNED OFF BY LEADING SUPERVISOR

FIG. 7


LEVEL 2
DISMANTLE STRIP DOWN AND DISCARD ALL RUBBER SEALS AND WORN OR CORRODED PARTS
CLEAN, REMOVE GREASE FROM AFFECTED PARTS WITH SOLVENT
SURFACE PREPARATION IN CAUSTIC SOLUTION TANK. DE-SCALE SURFACES AREA TO REMOVE DIRT SCALE, RUST, AND PAINT
PRESSURE RINSE TO REMOVE CAUSTIC SOLUTION
BUFF REMOVE REMAINING PAINT AND SCALE WITH WIRE BRUSH
VISUAL EXAMINATION OF ALL SURFACES FOR CORROSION AND PITTING
VISUAL ACCEPTABLE?
NO
SCRAP IRON IN DATABASE SO SERIAL BECOMES UNUSABLE
MAKE PARTS WITH ORANGE PAINT TO SIGNIFY SCRAPPING
DISPOSE OF PART OR DELIVER BACK TO CUSTOMER AT REQUEST
YES
LEVEL 3 OR MAGNETIC PARTICLE TESTING AND/OR PAINT
YES
LEVEL 3
NO
REASSEMBLE AND FIT WITH NEW SEALS AND ANY SPARE PARTS REQUIRED
LEVEL 1 PRESSURE TEST

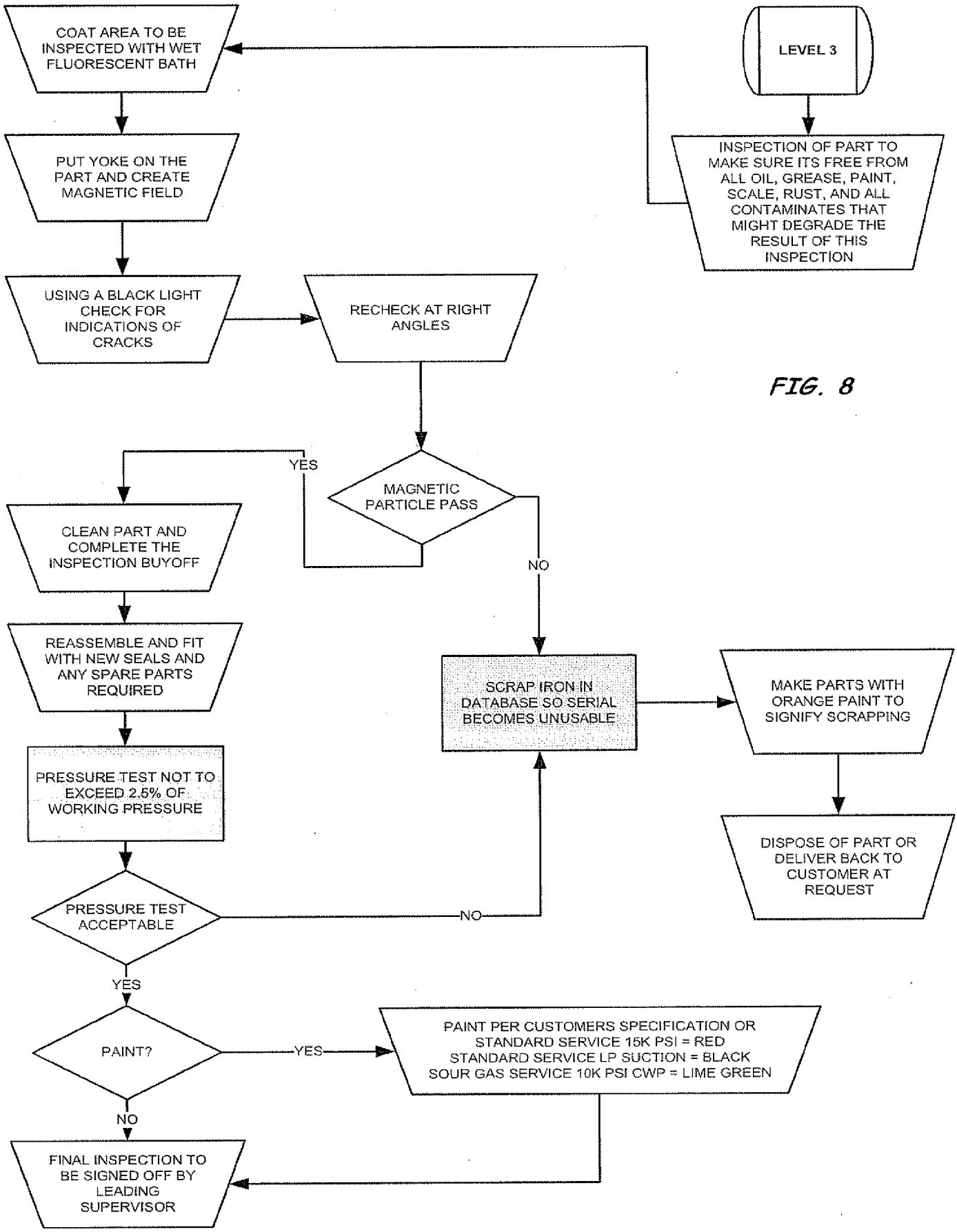

COAT AREA TO BE INSPECTED WITH WET FLUORESCENT BATH
PUT YOKE ON THE PART AND CREATE MAGNETIC FIELD
USING A BLACK LIGHT CHECK FOR INDICATIONS OF CRACKS
RECHECK AT RIGHT ANGLES
MAGNETIC PARTICLE PASS
YES
NO
CLEAN PART AND COMPLETE THE INSPECTION BUYOFF
REASSEMBLE AND FIT WITH NEW SEALS AND ANY SPARE PARTS REQUIRED
PRESSURE TEST NOT TO EXCEED 2.5% OF WORKING PRESSURE
PRESSURE TEST ACCEPTABLE
NO
YES
PAINT?
YES
NO
PAINT PER CUSTOMERS SPECIFICATION OR
STANDARD SERVICE 15K PSI = RED
STANDARD SERVICE LP SUCTION = BLACK
SOUR GAS SERVICE 10K PSI CWP = LIME GREEN
FINAL INSPECTION TO BE SIGNED OFF BY LEADING SUPERVISOR
SCRAP IRON IN DATABASE SO SERIAL BECOMES UNUSABLE
MAKE PARTS WITH ORANGE PAINT TO SIGNIFY SCRAPPING
DISPOSE OF PART OR DELIVER BACK TO CUSTOMER AT REQUEST
LEVEL 3
INSPECTION OF PART TO MAKE SURE ITS FREE FROM ALL OIL, GREASE, PAINT, SCALE, RUST, AND ALL CONTAMINATES THAT MIGHT DEGRADE THE RESULT OF THIS INSPECTION

FIG. 8

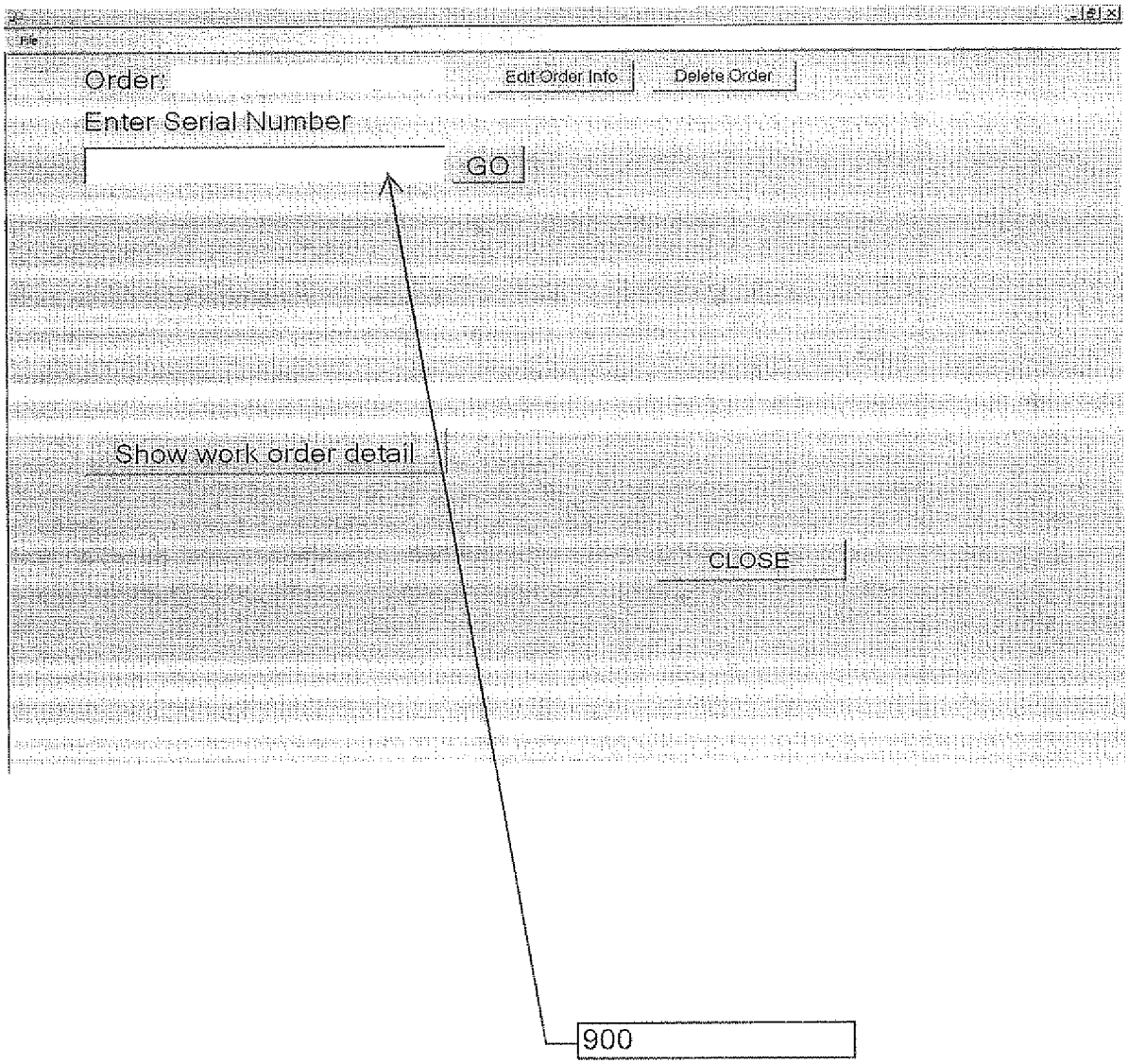

File
Order:
Edit Order Info
Delete Order
Enter Serial Number
GO
Show work order detail
CLOSE
900

FIG. 9

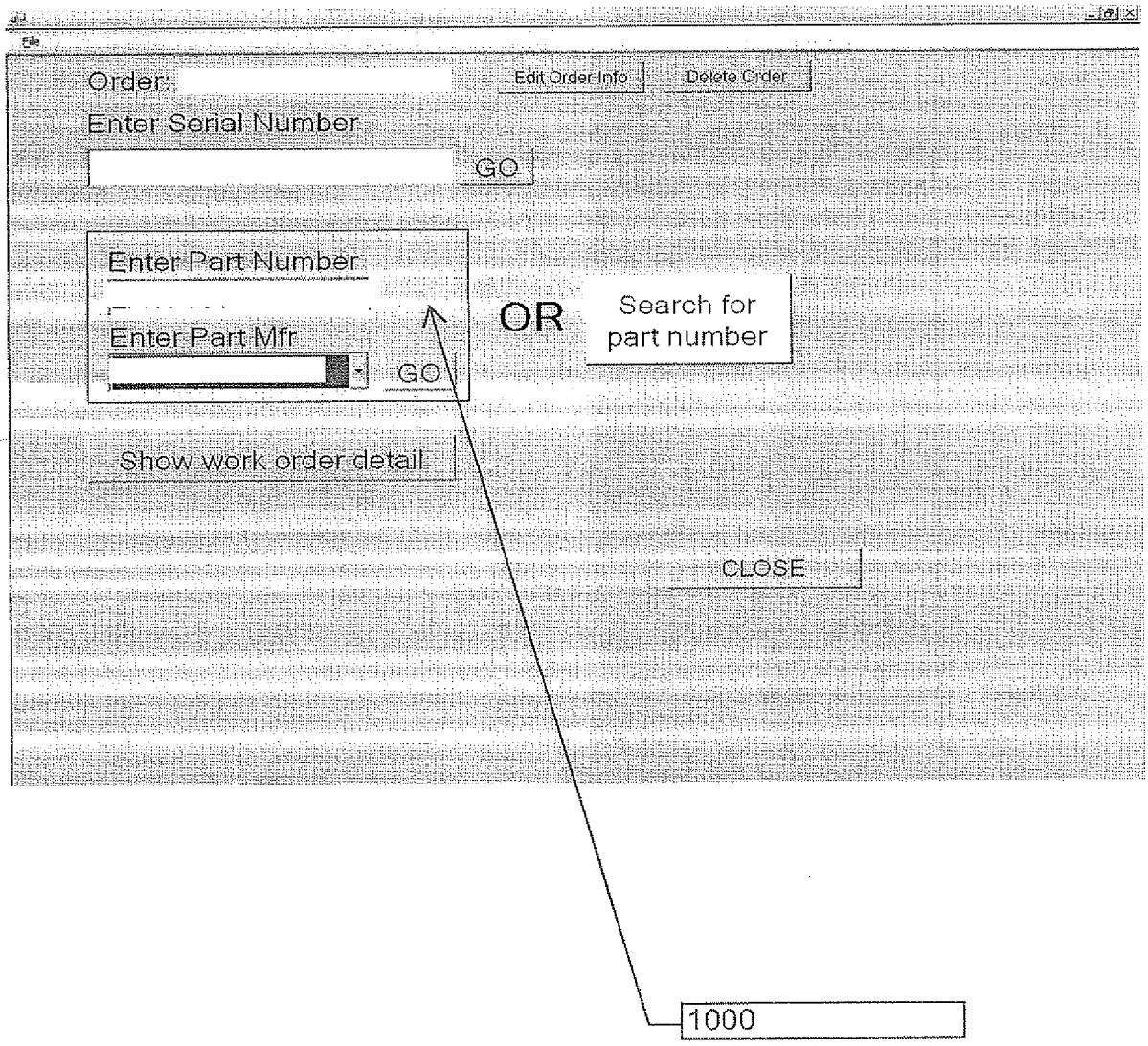

Order:
Edit Order Info
Delete Order
Enter Serial Number
GO
Enter Part Number
Enter Part Mfr
GO
OR
Search for part number
Show work order detail
CLOSE
1000

FIG. 10

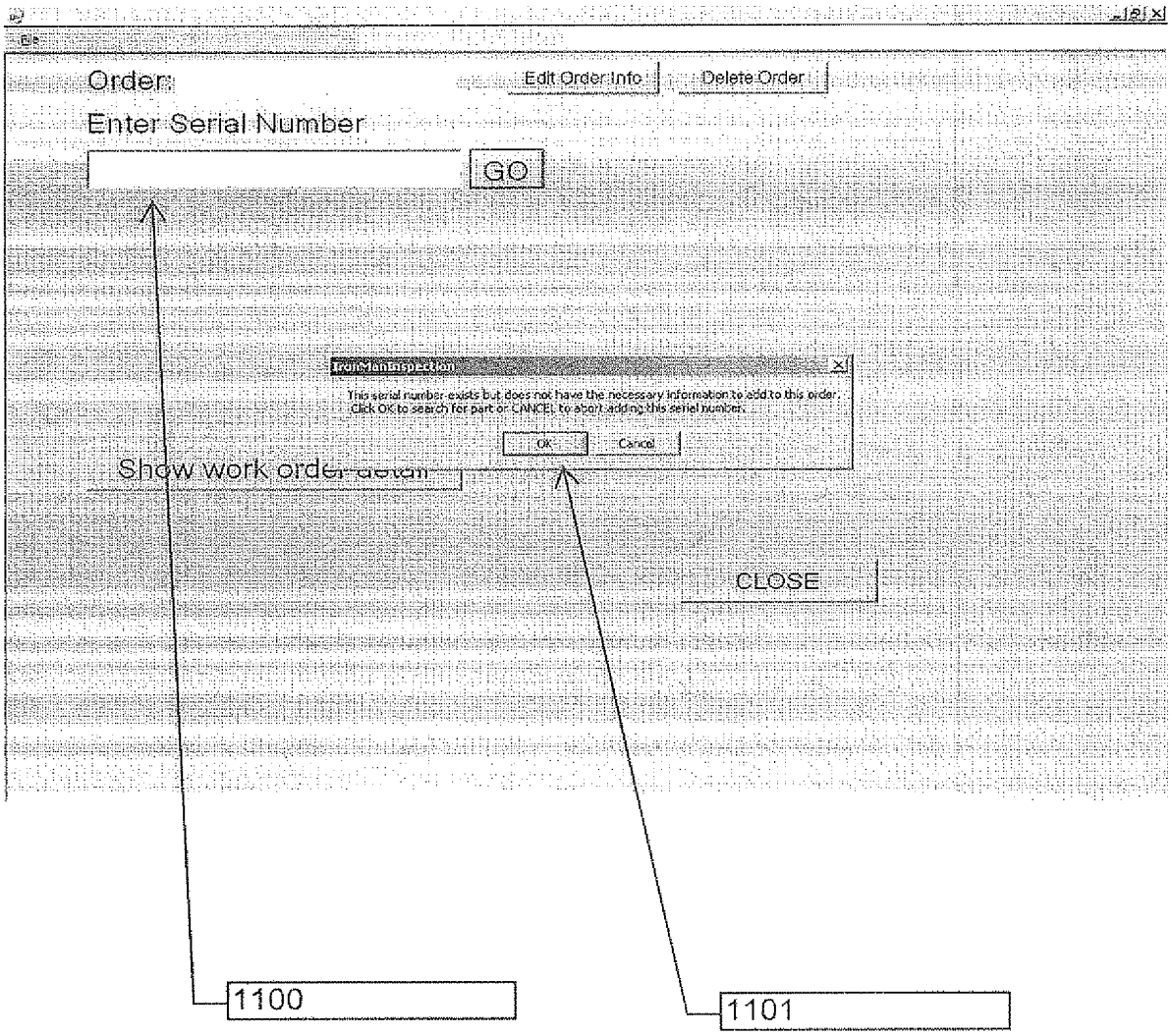

Order
Edit Order Info
Delete Order
Enter Serial Number
GO
This serial number exists but does not have the necessary information to add to this order.
Click OK to search for part or CANCEL to abort adding this serial number.
OK
Cancel
Show work orders
CLOSE
1100
1101

FIG. 11

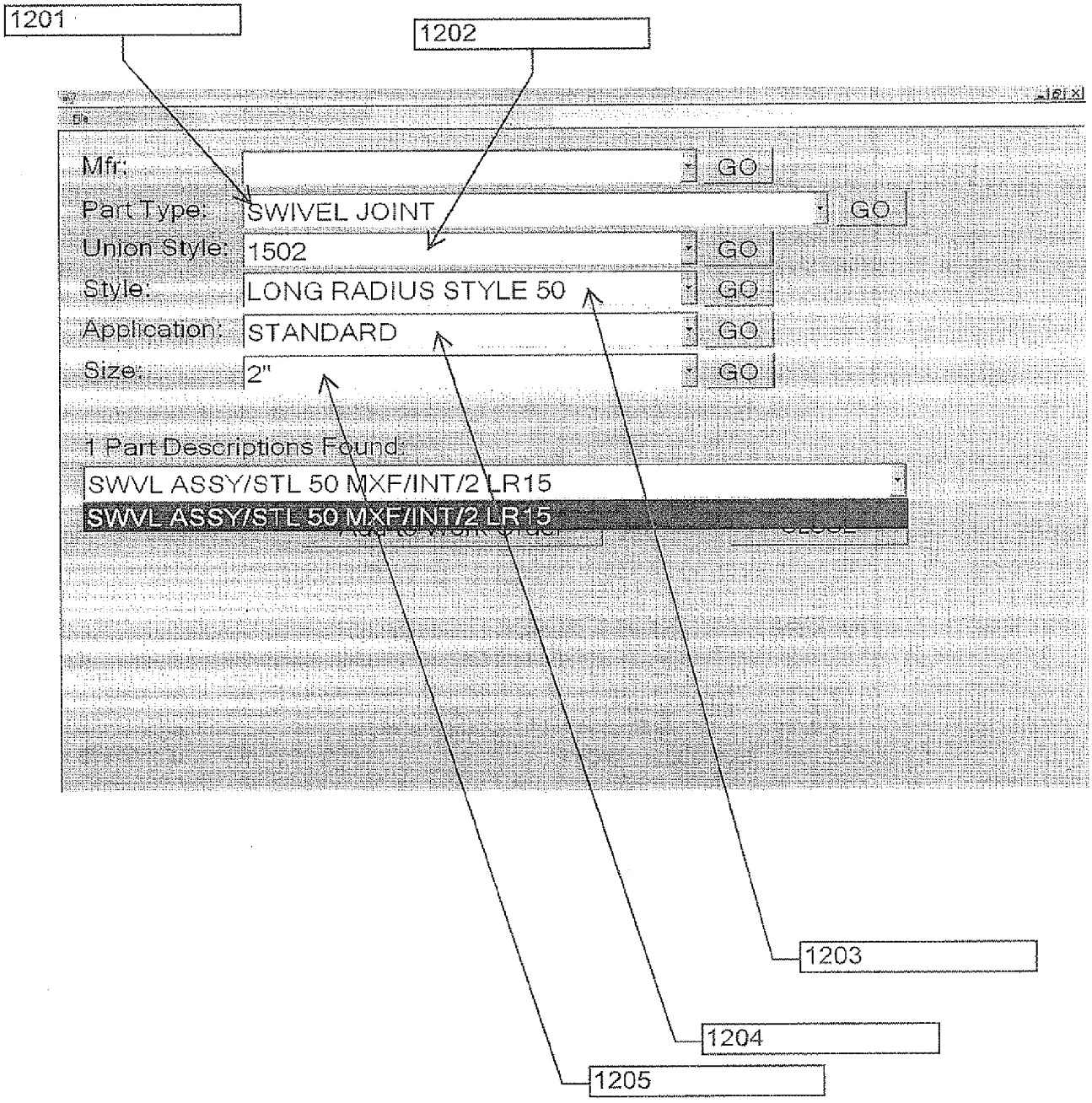

1201
1202
Mfr:
GO
Part Type:
SWIVEL JOINT
GO
Union Style:
1502
GO
Style:
LONG RADIUS STYLE 50
GO
Application:
STANDARD
GO
Size:
2"
GO
1 Part Descriptions Found:
SWVL ASSY/STL 50 MXF/INT/2 LR15
SWVL ASSY/STL 50 MXF/INT/2 LR15
1203
1204
1205

FIG. 12

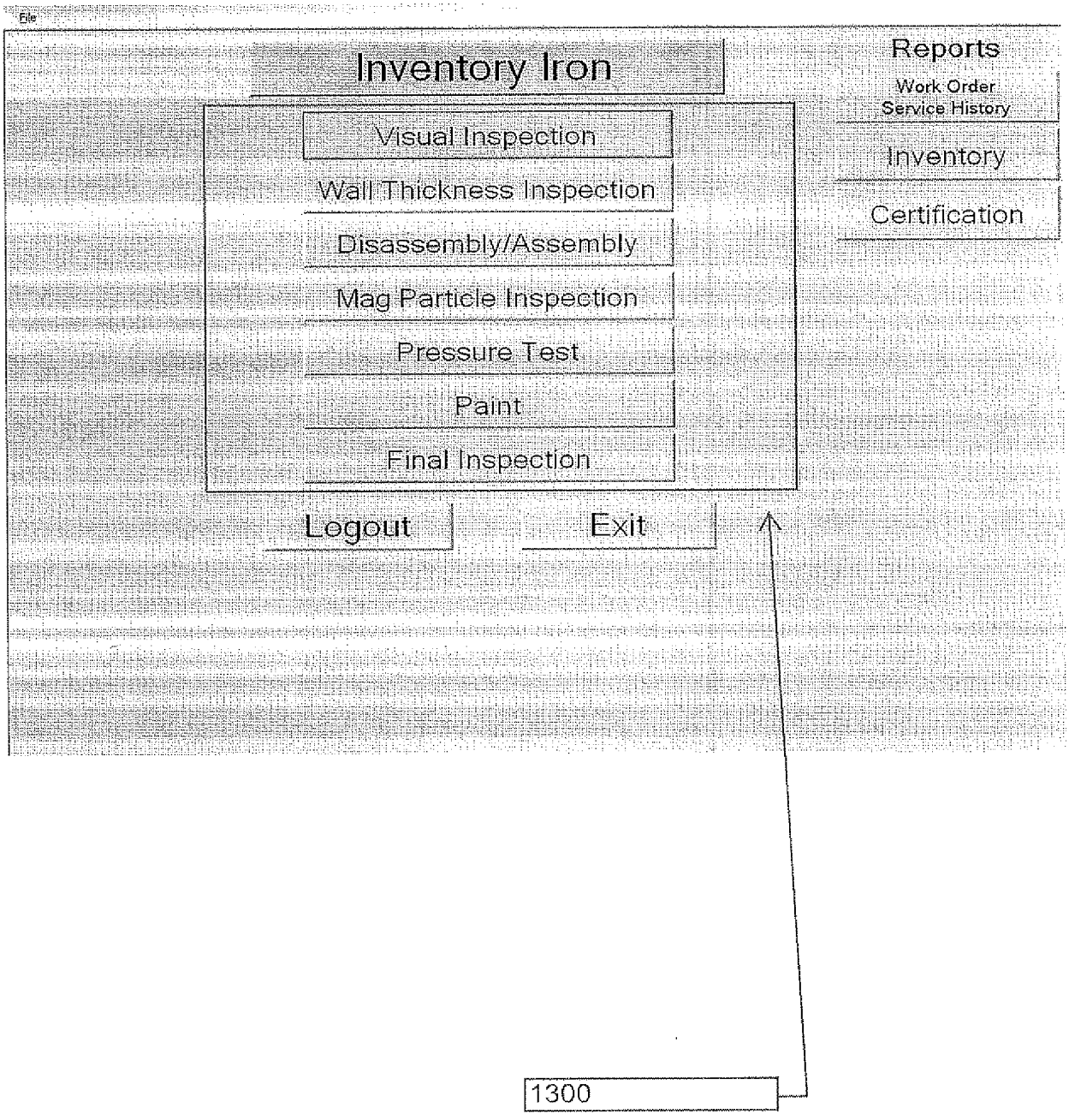

File
Inventory Iron
Visual Inspection
Wall Thickness Inspection
Disassembly/Assembly
Mag Particle Inspection
Pressure Test
Paint
Final Inspection
Logout
Exit
Reports
Work Order
Service History
Inventory
Certification
1300

FIG. 13

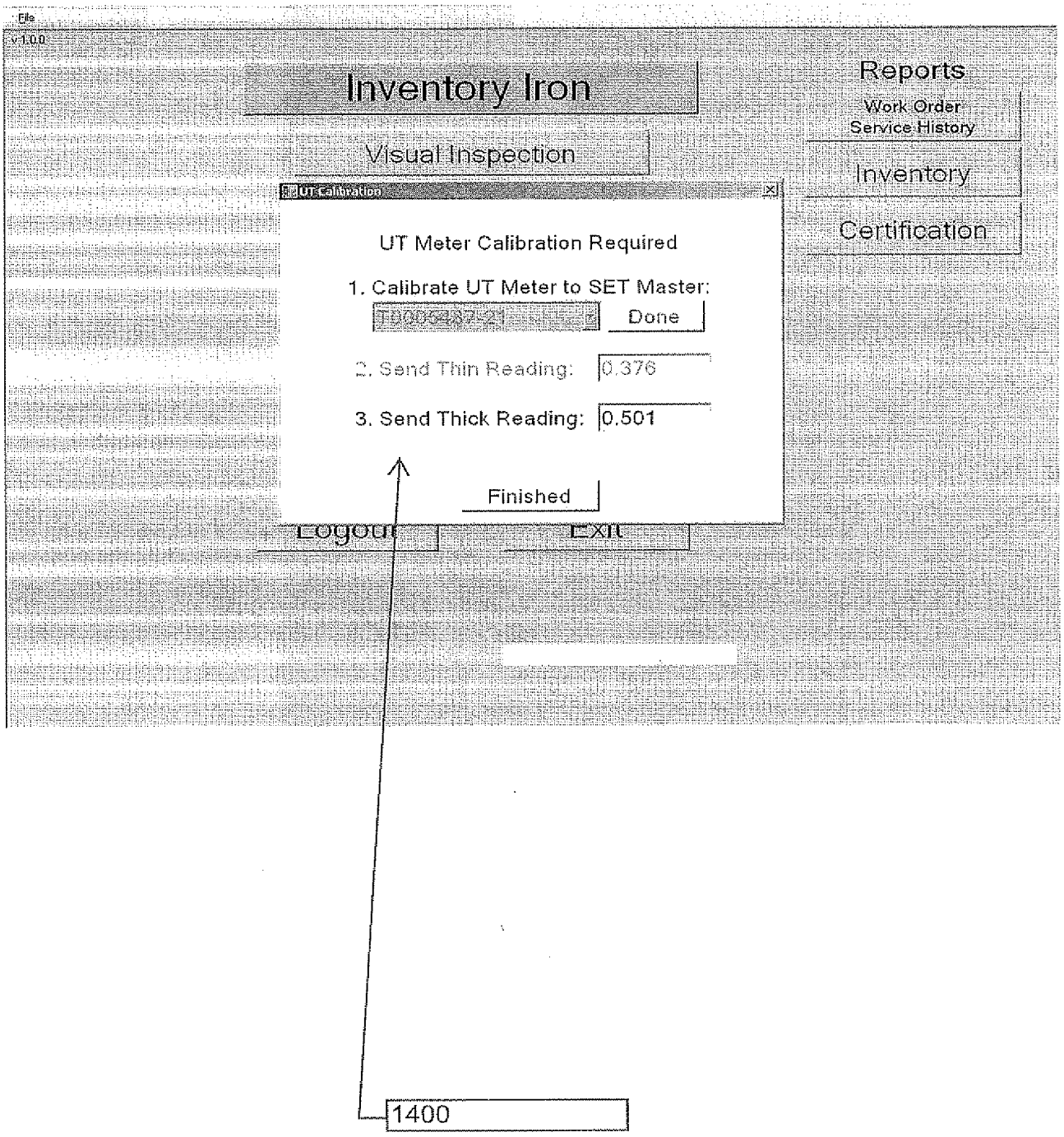

File
v.1.0.0
Inventory Iron
Visual Inspection
Reports
Work Order
Service History
Inventory
Certification
UT Calibration
UT Meter Calibration Required
1. Calibrate UT Meter to SET Master:
Done
2. Send Thin Reading:
0.376
3. Send Thick Reading:
0.501
Finished
Logout
Exit
1400

FIG. 14

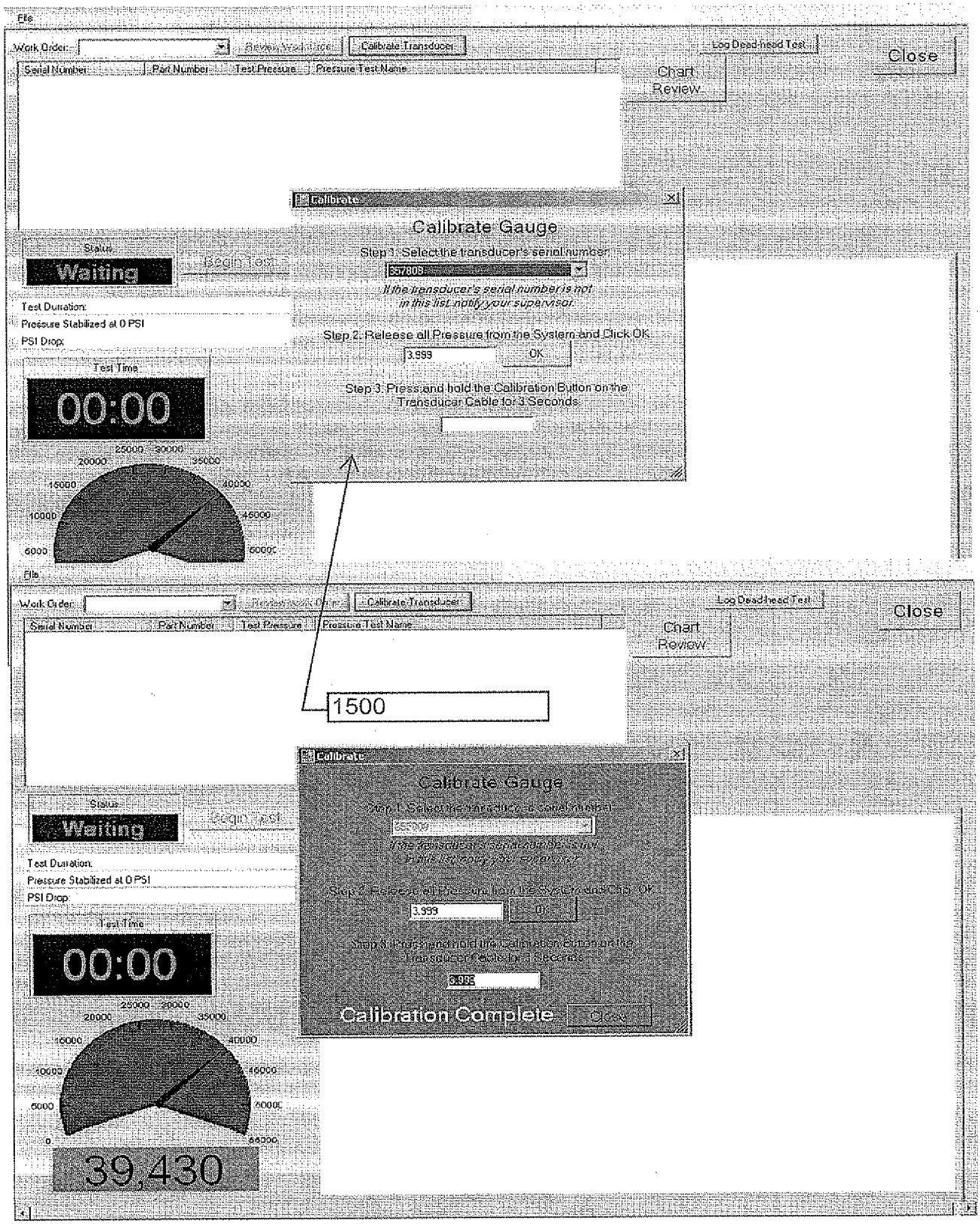

File
Work Order:
Review Work Order
Calibrate Transducer
Log Deadhead Test
Close
Serial Number
Part Number
Test Pressure
Pressure Test Name
Chart Review
Calibrate
Calibrate Gauge
Step 1: Select the transducer's serial number
If the transducer's serial number is not in this list notify your supervisor.
Step 2: Release all Pressure from the System and Click OK
3.999
OK
Step 3: Press and hold the Calibration Button on the Transducer Cable for 3 Seconds
Status
Waiting
Begin Test
Test Duration:
Pressure Stabilized at 0 PSI
PSI Drop:
Test Time
00:00
1500
Calibration Complete
Close
39,430

FIG. 15

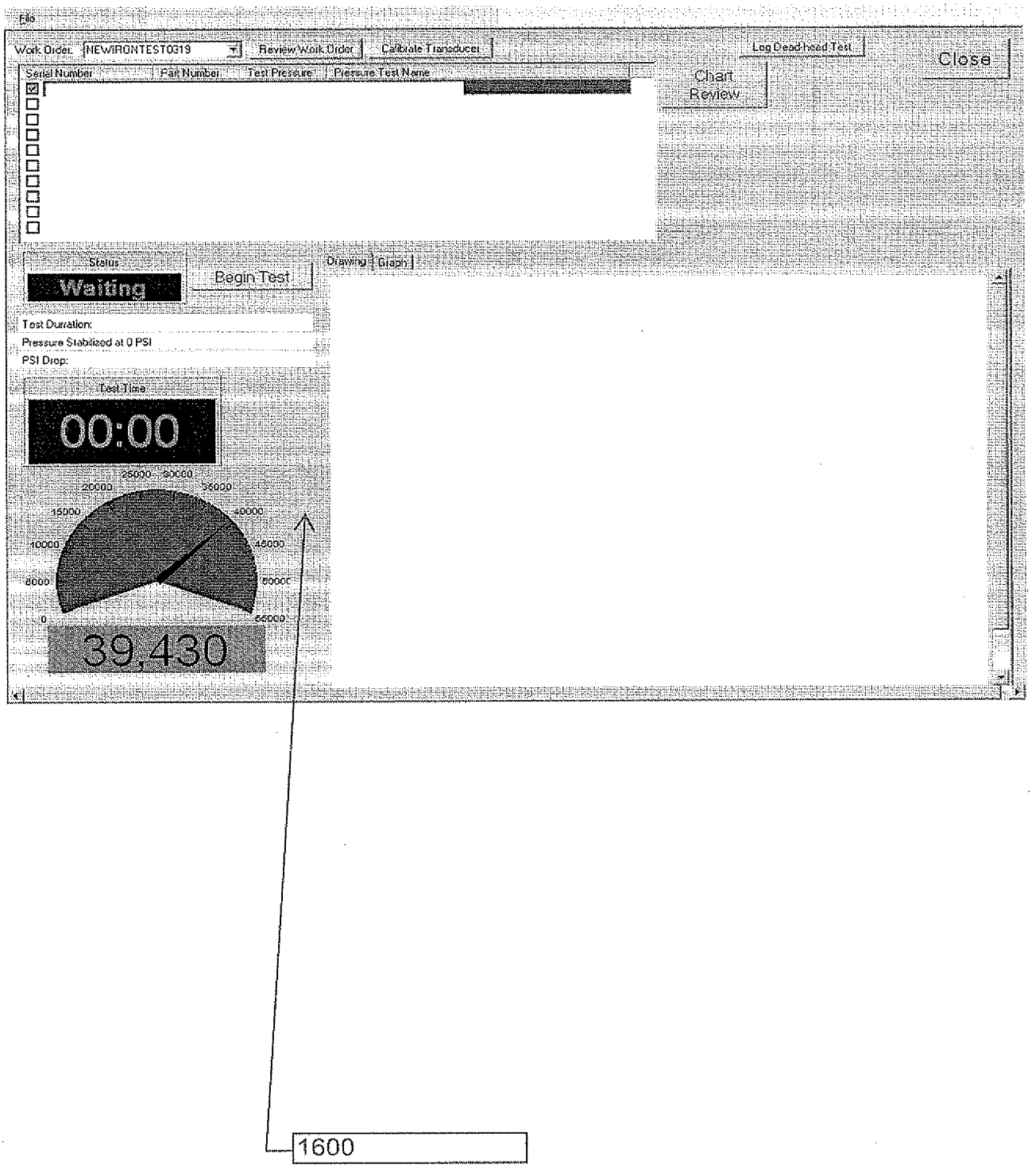

File
Work Order: NEWIRONTEST0319
Review Work Order
Calibrate Transducer
Log Deadhead Test
Close
Serial Number
Part Number
Test Pressure
Pressure Test Name
Chart Review
Status
Waiting
Begin Test
Drawing
Graph
Test Duration:
Pressure Stabilized at 0 PSI
PSI Drop:
Test Time
00:00
39,430
1600

FIG. 16

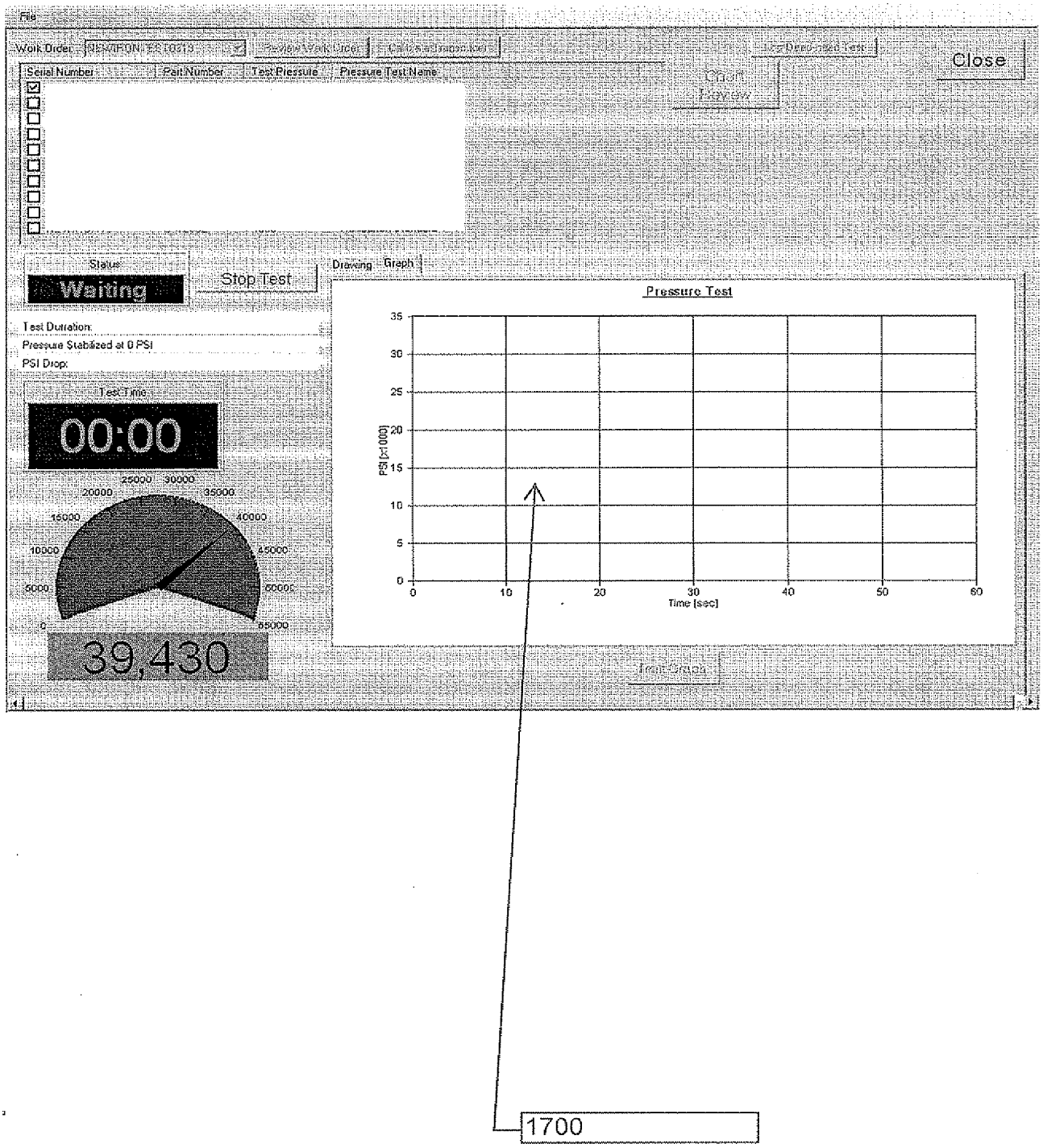

File
Work Order
Serial Number
Part Number
Test Pressure
Pressure Test Name
Close
Status
Waiting
Stop Test
Drawing
Graph
Pressure Test
Test Duration:
Pressure Stabilized at 0 PSI
PSI Drop:
Test Time
00:00
39,430
PSI [x1000]
Time [sec]
1700

FIG. 17

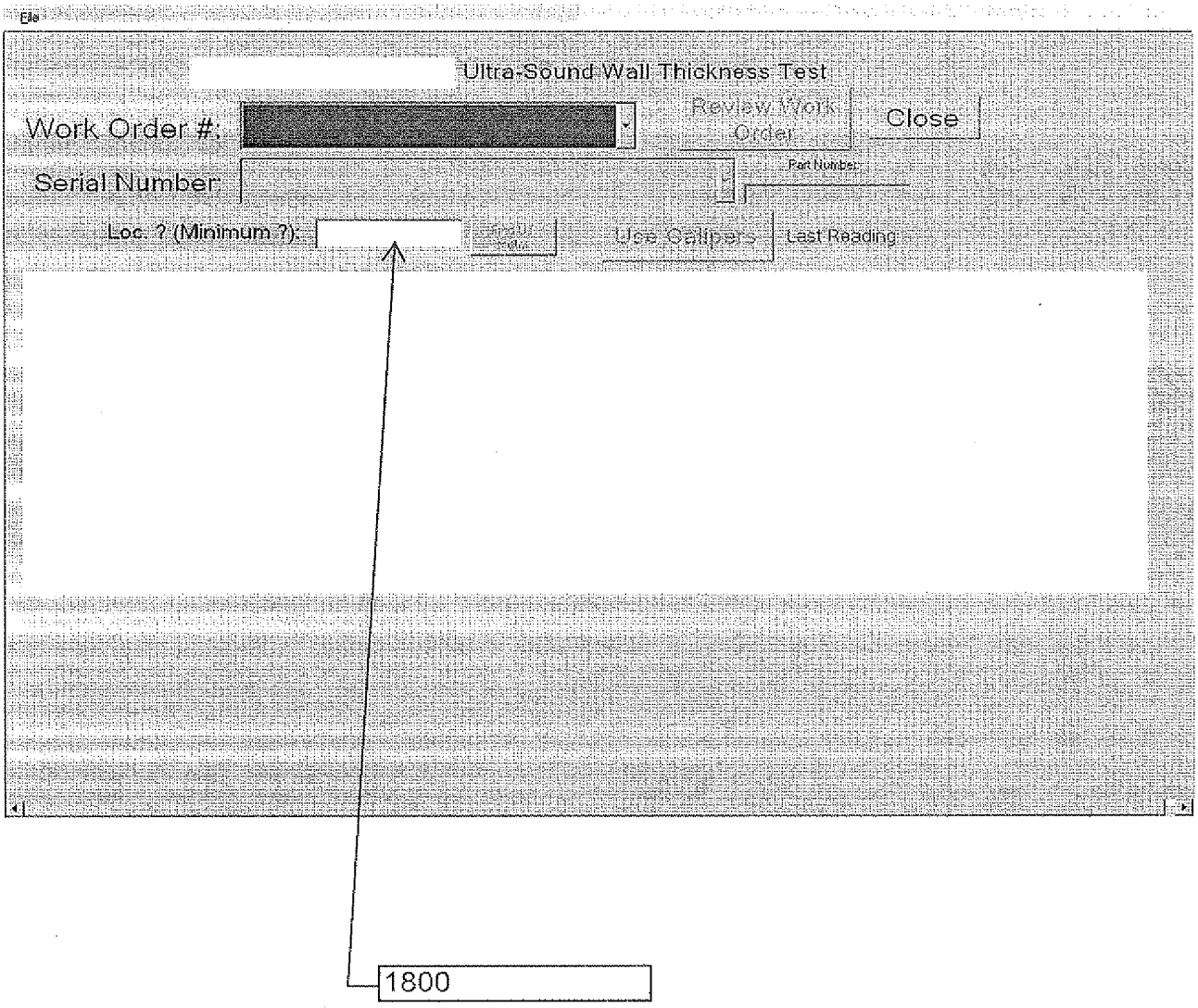

File
Ultra-Sound Wall Thickness Test
Work Order #:
Review Work Order
Close
Serial Number:
Part Number:
Loc. ? (Minimum ?):
Use Calipers
Last Reading
1800

FIG. 18

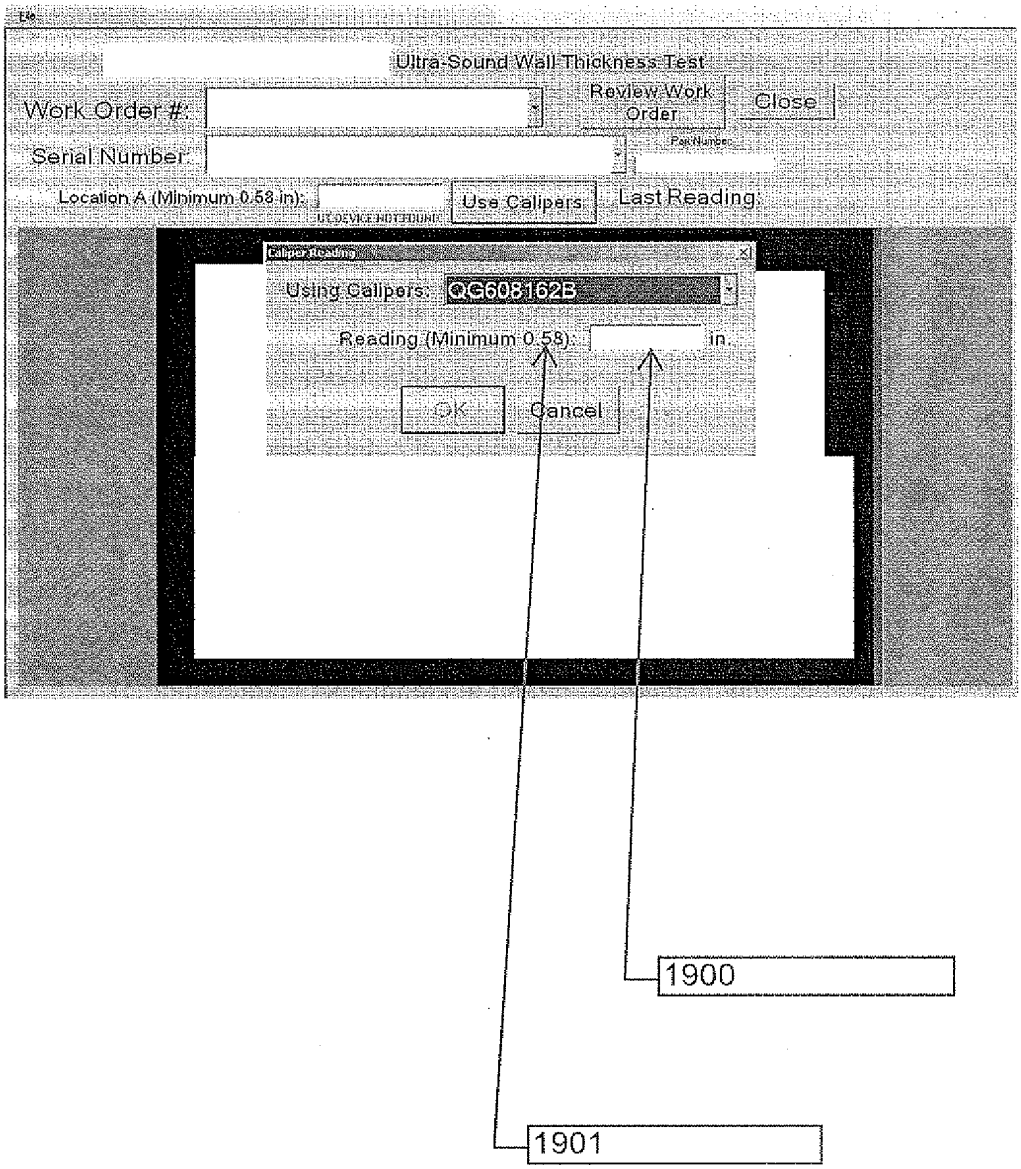

Ultra-Sound Wall Thickness Test
Work Order #:
Review Work Order
Close
Serial Number:
Location A (Minimum 0.58 in):
Use Calipers
Last Reading:
Using Calipers:
QG6053162B
Reading (Minimum 0.58):
in.
OK
Cancel
1900
1901

FIG. 19

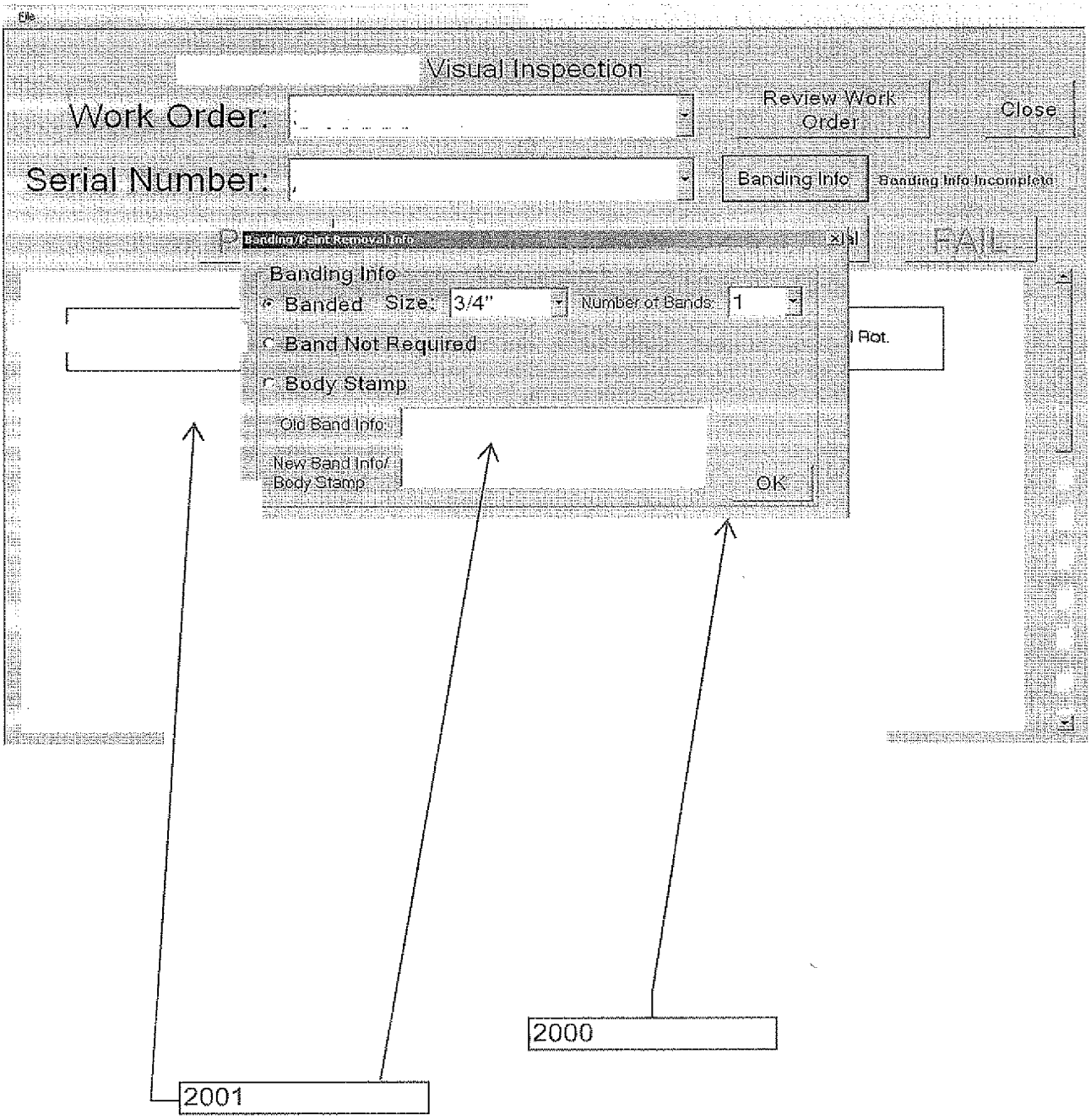

File
Visual Inspection
Work Order:
Review Work Order
Close
Serial Number:
Banding Info
Banding Info Incomplete
Banding/Paint Removal Info
FAIL
Banding Info
Banded
Size:
3/4"
Number of Bands:
1
Band Not Required
Body Stamp
Old Band Info:
New Band Info/ Body Stamp
OK
Rot.
2000
2001

FIG. 20

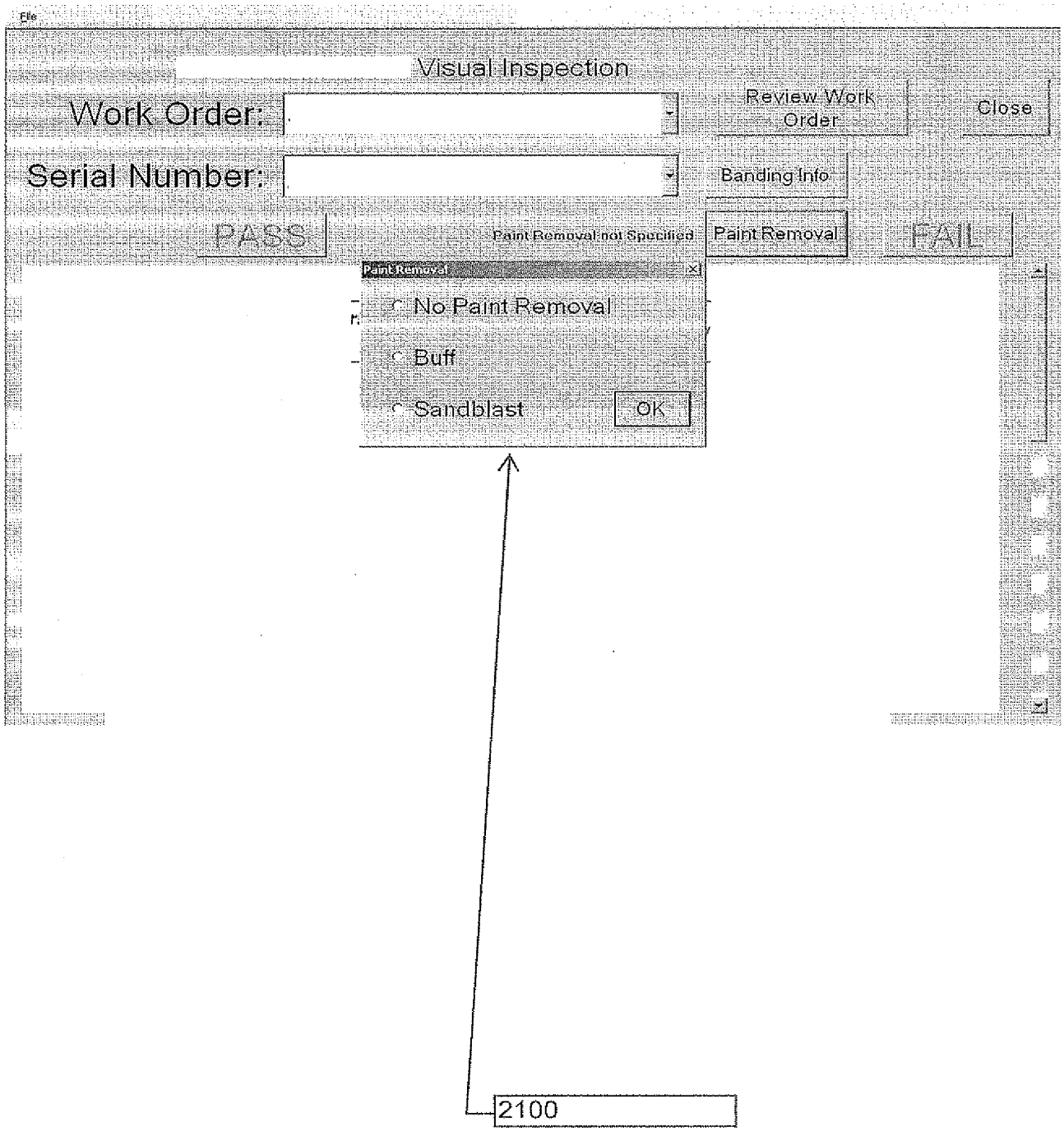

File
Visual Inspection
Work Order:
Review Work Order
Close
Serial Number:
Banding Info
PASS
Paint Removal not Specified
Paint Removal
FAIL
Paint Removal
No Paint Removal
Buff
Sandblast
OK
2100

FIG. 21

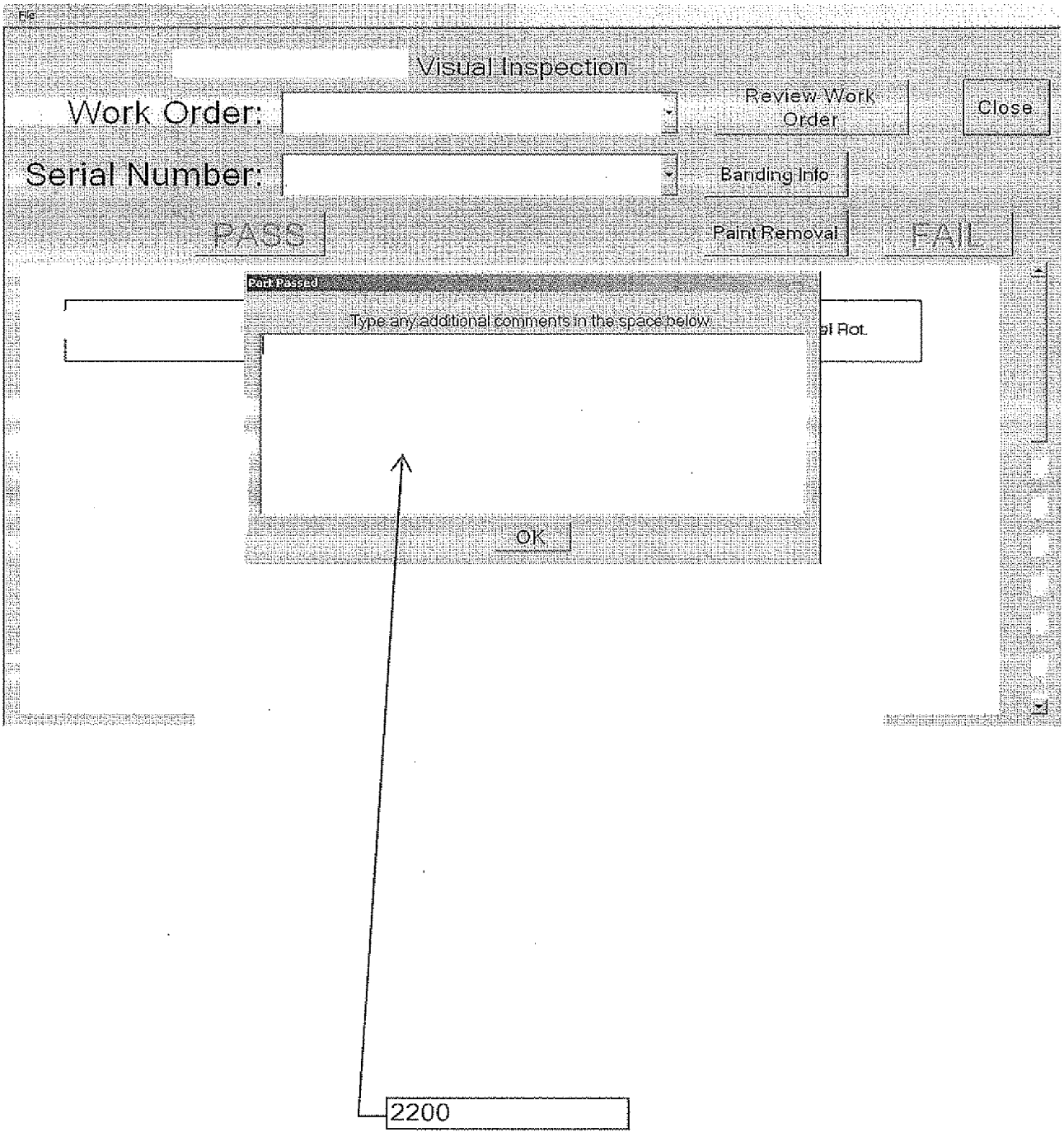

File
Visual Inspection
Work Order:
Review Work Order
Close
Serial Number:
Banding Info
PASS
Paint Removal
FAIL
Port Passed
Type any additional comments in the space below
OK
2200

FIG. 22

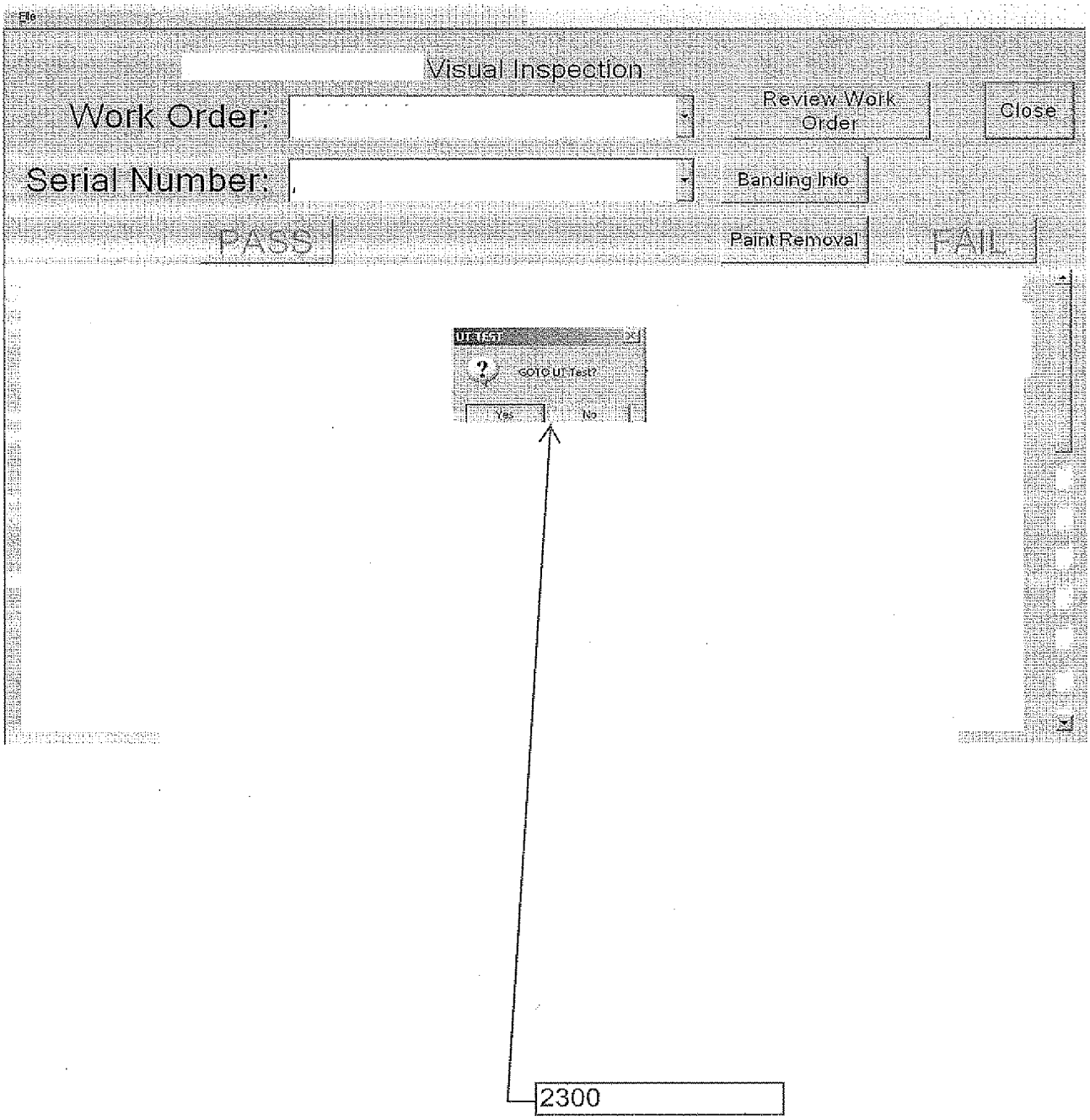

File
Visual Inspection
Work Order:
Review Work Order
Close
Serial Number:
Banding Info
PASS
Paint Removal
FAIL
GOTO UT Test?
Yes
No
2300

FIG. 23

Service Center Service History

Date: 02/24/2010	Customer:
Location:	Group ID / Unit #:
Description: 5 piece Rental	Quantity: 6
Inspection: Rental	Start Date: 02/24/2010
	Finish Date:
Wo / Sro #:	Approved By:

Specifications to be followed: SERVICE COMPANY

Product Description

Cust P/N: 100011214	Cust S/N: TEST003	Size: 1.5"		Svc:	
Mfr P/N:	Mfr S/N:	Style: DART		Pressure Rating:	15,000.00
		Connections: UNION CONNECTIONS		Test Pressure:	15,000.00
Mfr:	Product Type: CHECK VALVE	Configuration: F X M		Test Duration:	min

Inspections Performed

	Pass/Fail	Inspector	Date
Visual:			
UT Wall Thickness:			
Disamb/Asmbly:	N/A		
Magnetic Particle:	N/A		
Pressure:			
Paint:			
Final:			

Gauges Used

	Serial Number		Serial Number
Calipers:		No Go Gauge Kit:	
UT Meter:			
MPI Equip:			
Pres Gauge:		Pres Recorder:	

Wall Thickness Information

Inspection Point:	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
New Wall Thickness (if reqd):	1.01	0.64	1.19	0.47											
Min Allowable Wall Thick (Spec:	0.72	0.80	1.05	0.33											
Actual Measurement:															

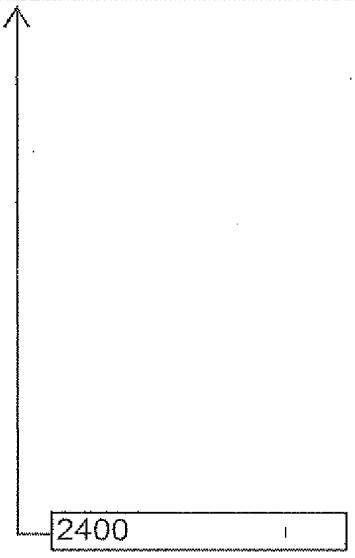


FIG. 24

Iron Inventory

Date:	02/24/2010	Customer:	
Location:		Group ID / Unit #:	
Description:	5 piece Rental	Quantity:	6
Inspection:	Rental	Start Date:	02/24/2010
		Finish Date:	
WO / SRO #:		Approved By:	

Specifications to be followed: SERVICE COMPANY

Serial Number	Part Number	Status	Description
		Visual Inspection (PENDING)	1.5 X 1.5-1502 DART STYLE CHECK VALVE UNION CONNECTIONS
		Visual Inspection (PENDING)	PPG ASSY/2-1502 PS 240.00
		Wall Thickness (PENDING)	SWVL ASSY/STL 10 MXF/INT/2 LR15
		Wall Thickness (PENDING)	SWVL ASSY/STL 50 MXF/INT/2 LR15
		Wall Thickness (PENDING)	SWVL ASSY/STL 50 MXF/INT/2 LR15

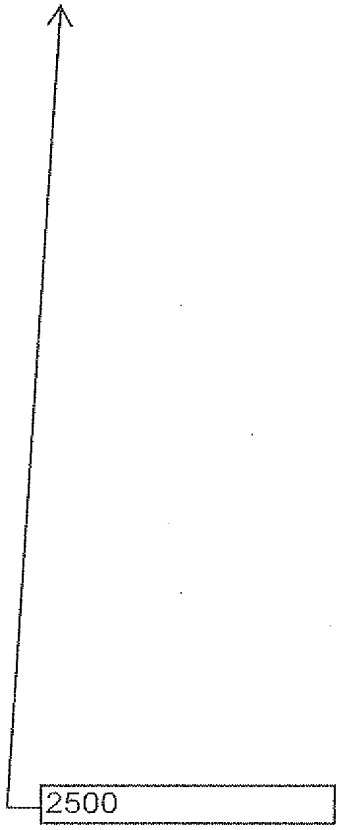
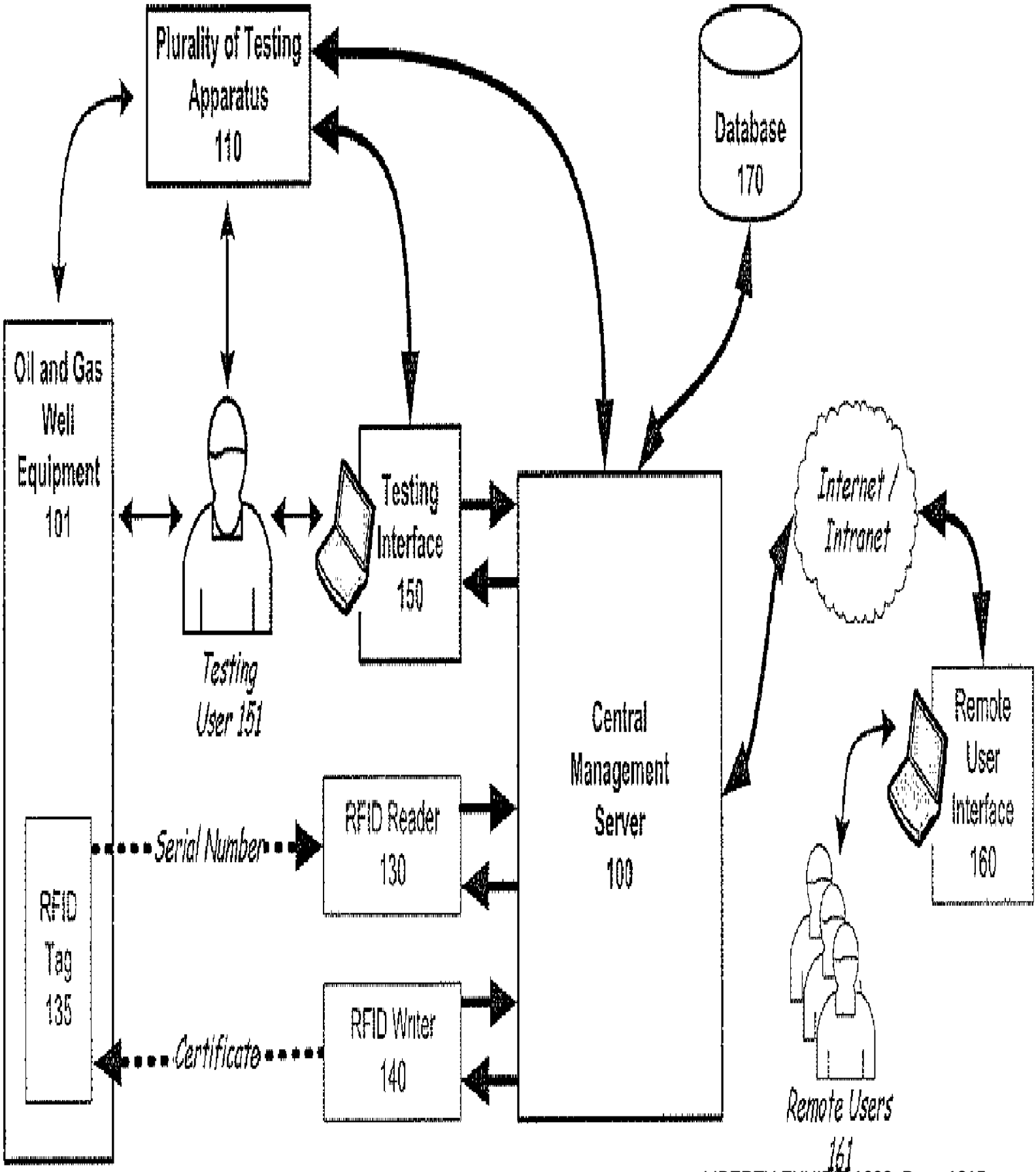


FIG. 25

FIG. 1


Plurality of Testing Apparatus 110
Database 170
Oil and Gas Well Equipment 101
Testing Interface 150
Testing User 151
Internet / Intranet
Central Management Server 100
Remote User Interface 160
RFID Reader 130
Serial Number
RFID Tag 135
RFID Writer 140
Certificate
Remote Users 161