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UNITED STATES DEPARTMENT OF COMMERCE
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Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/262,642	02/13/2018	9890609	SAFO/0012USPC01	6248

26290 7590 01/24/2018

PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

David LYMBEROPOULOS, Houston, TX;
SAFOCO, INC., Houston, TX;
Benjamin R. MATTHEWS, Missouri City, TX;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 1

Doc Code: IFEE PTOL/85B-EFS

Document Description: Issue Fee Payment (PTO-85B)

Issue Fee Transmittal Form

Application Number	Filing Date	First Named Inventor	Atty. Docket No.	Confirmation No.
15262642	12-Sep-2016	David LYMBEROPOULOS	SAFO/0012USPC01	6248

TITLE OF INVENTION :

SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

Entity Status	Application Type	Art Unit	Class - Subclass	EXAMINER
~~Regular Undiscounted~~ Small	Utility under 35 USC 111(a)	3753	488000	WILLIAM MCCALISTER

Issue Fee Due	Publication Due	Total Fee(s) Due	Date Due	Prev. Paid Fee
~~$960~~ $480	$0	~~$960~~ $480	05-Jan-2018	$0

1.Change of Correspondence Address and/or Indication Of Fee Address (37 CFR 1.33 & 1.363)

Current Correspondence Address:	Current Indicated Fee Address :
26290 PATTERSON & SHERIDAN, L.L.P. 24 Greenway Plaza, Suite 1600 Houston TX 77046 UNITED STATES 713-623-4844 PSDocketing@pattersonsheridan.com	
☐ Change of correspondence address requested, system generated AIA/122-EFS form attached	☐ Fee Address indication requested, system generated SB/47-EFS form attached

2.Entity Status

Change in Entity Status

○ Applicant certifying micro entity status; system generated Micro Entity certification form attached. See 37 CFR 1.29.
Note: Absent a valid certification of micro entity status, issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment. If this box is checked, you will be prompted to choose a micro entity status on the gross income basis (37 CFR 1.29(a)) or the institution of higher education basis (37 CFR 1.29(d)), and make the applicable certification online.

◉ Applicant asserting small entity status. See 37 CFR 1.27.
Note: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

○ Applicant changing to regular undiscounted fee status.
Note: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

Doc Code: IFEE PTOL/85B-EFS

Document Description: Issue Fee Payment (PTO-85B)

3.The Following Fee(s) Are Submitted:

☒ Issue Fee	☐ I authorize USPTO to apply my previously paid issue fee to the current fees due
☐ Publication Fee	☐ The Director is hereby authorized to apply my previously paid issue fee to the current fee due and to charge deficient fees to Deposit Account Number _____
☐ Advance Order - # of copies _____	☒ If **in addition to** the payment of the issue fee amount submitted with this form, there are any discrepancies in any amount(s) due, the Director is authorized to charge any deficiency, or credit any overpayment, to Deposit Account Number 20-0782/SAFO/0012 . The **issue fee must be submitted** with this form. **If payment of the issue fee does not accompany this form, checking this box and providing a deposit account number will NOT be effective to satisfy full payment of the fee(s) due.**

4.Firm and/or Attorney Names To Be Printed

NOTE: If no name is listed, no name will be printed
For printing on the patent front page, list to be displayed as entered

1. Patterson & Sheridan, L.L.P.
2.
3.

5.Assignee Name(s) and Residence Data To Be Printed

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

Name	City	State	Country	Category
SAFOCO, INC.	Houston		united states	corporation

6.Signature

I certify, in accordance with 37 CFR 1.4(d)(4) that I am an attorney or agent registered to practice before the Patent and Trademark Office who has filed and has been granted power of attorney in this application. I also certify that this Fee(s) Transmittal form is being transmitted to the USPTO via EFS-WEB on the date indicated below.

Signature	/Jessie D. Herrera/	**Date**	01-03-2018
Name	Jessie D. Herrera	**Registration Number**	63799

WEB IFEE 1.0

Electronic Patent Application Fee Transmittal

Application Number:	15262642
Filing Date:	12-Sep-2016
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Filer:	Jessie D. Herrera/Stephanie Dominguez
Attorney Docket Number:	SAFO/0012USPC01

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY APPL ISSUE FEE	2501	1	480	480
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**480**

Electronic Acknowledgement Receipt	
EFS ID:	31385018
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	03-JAN-2018
Filing Date:	12-SEP-2016
Time Stamp:	11:14:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$480
RAM confirmation Number	010318INTEFSW11142700
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Web85b.pdf	47083 1d782b3b8e682e7883859c605103bc797e883546	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	32043 0d4132d433ef95260dbf7c526db6f82071c23fb5	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	79126		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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NOTICE OF ALLOWANCE AND FEE(S) DUE

26290 7590 10/05/2017

PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

EXAMINER
MCCALISTER, WILLIAM M

ART UNIT	PAPER NUMBER
3753	

DATE MAILED: 10/05/2017

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01	6248

TITLE OF INVENTION: SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	01/05/2018

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PTOL-85 (Rev. 02/11)

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
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PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

26290 7590 10/05/2017
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01	6248

TITLE OF INVENTION: SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	01/05/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
MCCALISTER, WILLIAM M	3753	137-488000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:
❑ Issue Fee
❑ Publication Fee (No small entity discount permitted)
❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): (**Please first reapply any previously paid issue fee shown above**)
❑ A check is enclosed.
❑ Payment by credit card. Form PTO-2038 is attached.
❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
❑ Applicant certifying micro entity status. See 37 CFR 1.29
NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
❑ Applicant asserting small entity status. See 37 CFR 1.27
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
❑ Applicant changing to regular undiscounted fee status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 9

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01	6248

26290 7590 10/05/2017

PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

EXAMINER	
MCCALISTER, WILLIAM M	
ART UNIT	PAPER NUMBER
3753	

DATE MAILED: 10/05/2017

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. 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 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

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

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

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/262,642	Applicant(s) LYMBEROPOULOS ET AL.	
	Examiner WILLIAM MCCALISTER	Art Unit 3753	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Approval of the terminal disclaimer filed 9/13/17*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-18*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☒ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/WILLIAM MCCALISTER/
Primary Examiner, Art Unit 3753

The present application is being examined under the pre-AIA first to invent provisions.

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in an interview with Jessie Herrera on 9/20/17. Also note that a previous conversation was held with Mr. Herrera on 8/30/17 requesting that the terminal disclaimer be filed to obviate a double patenting rejection over US 9,671,794.

The application has been amended as follows:

IN THE CLAIMS:

Claims 12-18 are each amended to depend directly from independent claim 11.

This amendment is made to correct a typographical error, whereby claims 12-18 all depended directly from claim 12.

Allowable Subject Matter

As amended, claims 1-18 are allowed.

The following is an examiner's statement of reasons for allowance: see the prosecution history of parent Application 13/480,704.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning this communication or earlier communications from the examiner should be directed to **William McCalister**, whose telephone number **571-270-1869**. The examiner can normally be reached on Monday-Friday (7:00AM-5:30PM EST).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisors can be reached by phone. Craig Schneider can be reached at 571-272-3607, John Fristoe can be reached at 571-272-4926 and Mary McManmon can be reached at 571-272-6007. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public

PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/WILLIAM MCCALISTER/
Primary Examiner, Art Unit 3753

9/20/17

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15262642	LYMBEROPOULOS ET AL.
	Examiner	Art Unit
	WILLIAM MCCALISTER	3753

CPC- SEARCHED		
Symbol	Date	Examiner
G05D16/2086	5/12/2017	WM
F16K 17/00; 37/0091; 31/1262	5/12/2017	WM
E21B 34/02, 06, 10, 16	5/12/2017	WM
Y10T 137/7761, 7762, 7769, 777, 0318	5/12/2017	WM
F15B 20/00; 2211/31576, 6303, 665, 7052	5/12/2017	WM

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
137	488, 492, 492.5	5/12/2017	WM

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

SEARCH NOTES		
Search Notes	Date	Examiner
EAST ccls and cpc in parent, ky words, f/b citations, inventor name	5/12/2017	wm

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

EAST Search History

EAST Search History (Prior Art)

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L3	4829	e21b34/02,10,16,06.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/09/20 15:20
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S3	170	S2 and (pump or compressor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	OFF	2014/07/02 13:17

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S100	133	matthews.in. near2 benjamin.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:00
S101	161	S99 or S100	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:00
S102	21	S101 and pump and safety and valve	US-PGPUB; USPAT; USOCR;	OR	OFF	2017/05/12 16:00

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Page 25

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S103	8409	137/485-492.5.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:06
S104	133640	("20110311389" | "8511991" | "20110076155" | "20130017094" | "20030127436" | "20110100580" | "5383593" | "7578655" | "4736504" | "5253419" | "5636440" | "3736638" | "6355086" | "8568090" | "5165860" | "20090252612" | "7455740" | "9085989" | "5048743" | "7665979" | "5165860" | "20110311389" | "20050112230" | "6391251" | "8066483")".PN"	US-PGPUB; USPAT	OR	OFF	2017/05/13 07:12
S105	23	("20110311389" | "8511991" | "20110076155" | "20130017094" | "20030127436" | "20110100580" | "5383593" | "7578655" | "4736504" | "5253419" | "5636440" | "3736638" | "6355086" | "8568090" | "5165860" | "20090252612" | "7455740" | "9085989" | "5048743" | "7665979" | "5165860" | "20110311389" | "20050112230" | "6391251" | "8066483").PN.	US-PGPUB; USPAT	OR	OFF	2017/05/13 07:13
S106	0	14/994989	US-PGPUB; USPAT	OR	OFF	2017/05/13 08:09
S107	20	("20010022009" | "20020069477" | "20050183228" | "20070174991" | "4634197" | "4664457" | "4846712" | "4894020" | "4895528" | "5069635" | "5430978" | "5526842" | "5578795" | "5740581" | "5740582" | "6143996" | "6158080" | "7010829" | "7226302" | "8479353").PN.	US-PGPUB; USPAT	OR	OFF	2017/05/15 12:29
S108	1	"4540022".pn.	US-PGPUB; USPAT	OR	OFF	2017/05/15 13:17
S109	1	"4569370".pn.	US-PGPUB; USPAT	OR	OFF	2017/05/15 13:18
S110	1	"5431188".pn.	US-PGPUB; USPAT	OR	OFF	2017/05/15 13:18
S111	1	"6105614".pn.	US-PGPUB; USPAT	OR	OFF	2017/05/15 13:18

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L7	3	(fluid and supply and first and line and pump and second and downstream and return and safety and valve and controller and actuator and drive and gate).clm.	US-PGPUB; USPAT	OR	OFF	2017/09/20 15:20
S84	0	(fluid and supply and first and line and pump and second and downstream and return and safety and valve and controller and actuator and drive and gate).clm.	US-PGPUB; USPAT	OR	OFF	2016/06/09 11:43

9/20/2017 3:25:41 PM
C:\Users\wmccalister\Documents\EAST\Workspaces\13480704.wsp

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15262642	LYMBEROPOULOS ET AL.
	Examiner	**Art Unit**
	WILLIAM MCCALISTER	3753

CPC						
Symbol					**Type**	**Version**
E21B		34	/	06	F	2013-01-01
Y10T		137	/	7761	A	2015-04-01
Y10T		137	/	0318	A	2015-04-01
Y10T		137	/	7762	A	2015-04-01
Y10T		137	/	7769	A	2015-04-01
Y10T		137	/	777	A	2015-04-01
G05D		16	/	2086	A	2013-01-01
E21B		34	/	02	I	2013-01-01
E21B		34	/	10	I	2013-01-01
E21B		34	/	16	I	2013-01-01
F15B		20	/	00	I	2013-01-01
F15B		2211	/	31576	A	2013-01-01
F15B		2211	/	6303	A	2013-01-01
F15B		2211	/	665	A	2013-01-01
F15B		2211	/	7052	A	2013-01-01
F16K		37	/	0091	I	2013-01-01
F16K		31	/	1262	I	2013-01-01
E21B		41	/	00	I	2013-01-01
F16K		3	/	0254	I	2013-01-01
Y10T		137	/	2635	A	2015-04-01
E21B		41	/	0021	I	2013-01-01
F16K		17	/	00	A	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
			/					
			/					

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 18	
/WILLIAM MCCALISTER/ Primary Examiner.Art Unit 3753 (Primary Examiner)	09/20/2017 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 14

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15262642	LYMBEROPOULOS ET AL.
	Examiner	**Art Unit**
	WILLIAM MCCALISTER	3753

US ORIGINAL CLASSIFICATION		INTERNATIONAL CLASSIFICATION										
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED					
		E	2	1	B	34 / 06 (2006.01.01)						
CROSS REFERENCE(S)												
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)											

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 18	
/WILLIAM MCCALISTER/ Primary Examiner.Art Unit 3753 (Primary Examiner)	09/20/2017 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 14

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15262642	LYMBEROPOULOS ET AL.
	Examiner	**Art Unit**
	WILLIAM MCCALISTER	3753

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 18	
/WILLIAM MCCALISTER/ Primary Examiner.Art Unit 3753 (Primary Examiner)	09/20/2017 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 14

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 30

PTO/AIA/26 (04-14)
Approved for use through 07/31/2016. OMB 0651-0031
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TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT	Docket Number (Optional) SAFO/0012USPC01

In re Application of: David Lymberopoulos

Application No.: 15/262,642

Filed: September 12, 2016

For: SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

The applicant, SAFOCO, INC., owner of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of **prior patent** No. 9,671,794 as the term of said **prior patent** is presently shortened by any terminal disclaimer. The applicant hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior patent** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the applicant does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the **prior patent**, "as the term of said **prior patent** is presently shortened by any terminal disclaimer," in the event that said **prior patent** later:

expires for failure to pay a maintenance fee;
is held unenforceable;
is found invalid by a court of competent jurisdiction;
is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
has all claims canceled by a reexamination certificate;
is reissued; or
is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ The undersigned is the applicant. If the applicant is an assignee, the undersigned is authorized to act on behalf of the assignee.

I hereby acknowledge that any willful false statements made are punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

2. ☑ The undersigned is an attorney or agent of record. Reg. No. 63,799

/Jessie D. Herrera/ — Signature
September 13, 2017 — Date

Jessie D. Herrera — Typed or printed name

Attorney for Applicant — Title
713-623-4844 — Telephone Number

☑ Terminal disclaimer fee under 37 CFR 1.20(d) included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

This collection of information is required by 37 CFR 1.321. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:	15262642
Filing Date:	12-Sep-2016
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Filer:	Jessie D. Herrera/Stephanie Dominguez
Attorney Docket Number:	SAFO/0012USPC01

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
STATUTORY OR TERMINAL DISCLAIMER	1814	1	160	160
		Total in USD ($)		**160**

Electronic Acknowledgement Receipt

EFS ID:	30349466
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	13-SEP-2017
Filing Date:	12-SEP-2016
Time Stamp:	13:04:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$160
RAM confirmation Number	091317INTEFSW13051800
Deposit Account	
Authorized User	
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Terminal Disclaimer Filed	Terminal_Disclaimer.pdf	159996 df9aa4fdc27b1e51ba40b284176cc057223d46f4	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30430 d58cdc72b53d619aa869ba994668197f78164c29	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	190426		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	15/262,642	LYMBEROPOULOS ET AL.	

Document Code - DISQ	Internal Document – DO NOT MAIL

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 13 September, 2017	This patent is subject to a Terminal Disclaimer	

Approved/Disapproved by:

CHARRISSA BROWN

Technology Center: PLRC

Telephone: (571)272-1558

U.S. Patent and Trademark Office

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: David Lymberopoulos	§	
Serial No.: 15/262,642	§	Group Art Unit: 3753
Filed: September 12, 2016	§	
	§	Examiner: McCalister, William M.
Confirmation No.: 6248	§	
For: SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	§	

MAIL STOP Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

RESPONSE TO OFFICE ACTION DATED MAY 18, 2017

In response to the Office Action dated May 18, 2017, please enter this response and reconsider the claims pending in the application for reasons discussed below. Although Applicant believes that no additional fees are due in connection with this response, the Commissioner is hereby authorized to charge counsel's Deposit Account No. 20-0782/SAFO/0012USPC01/JDH for any fees required to make this response timely and acceptable to the Office.

Amendments to the Claims begin on page 2 of this paper.

Remarks begin on page 6 of this paper.

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AMENDMENTS TO THE CLAIMS

1. (Currently Amended) A control system for controlling fluid flow through a flow line at a wellsite, the control system comprising:

a fluid supply;

a first fluid line in fluid communication with the fluid supply;

a pump in fluid communication with the first fluid line and configured to pump fluid from the fluid supply to one or more wellheads through the first fluid line;

a second fluid line in fluid communication with the first fluid line at a location downstream of the pump and configured to return fluid from the first fluid line back to the fluid supply or direct fluid from the first fluid line to a different reservoir;

a safety valve in-line with the second fluid line and [[in]] movable into a closed positon to close fluid flow through the second fluid line;

a valve actuator configured to actuate the safety valve from the closed position to an open position to open fluid flow through the second fluid line;

an electronic controller assembly programmed with a predetermined condition and configured to receive a signal from a transducer connected to the first fluid line, wherein the signal corresponds to a measured physical property;

a valve assembly in communication with the controller assembly; and

a fluid drive assembly in communication with the controller assembly, wherein the controller assembly is operable to actuate the fluid drive assembly to supply fluid to the valve actuator to move the safety valve into the closed position, and wherein the controller assembly is operable to actuate the valve assembly in response to a comparison of the measured physical property to the predetermined condition to release the fluid from the valve actuator to move the safety valve into the open position and thereby open fluid flow through the second fluid line to return fluid in the first fluid line back to the fluid supply or direct fluid in the first fluid line to the different reservoir.

2. (Original) The system of claim 1, further comprising a housing for supporting the controller assembly, the valve assembly, and the fluid drive assembly.

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Page 39

3. (Original) The system of claim 2, wherein the fluid supplied to the valve actuator by the fluid drive assembly is supplied from a reservoir disposed outside of the housing.

4. (Original) The system of claim 1, wherein the fluid drive assembly is a compressor and the fluid supplied to the valve actuator by the fluid drive assembly is a pneumatic fluid.

5. (Original) The system of claim 1, wherein the fluid drive assembly is a pump and the fluid supplied to the valve actuator by the fluid drive assembly is a hydraulic fluid.

6. (Original) The system of claim 1, further comprising a power source for supplying power to the controller assembly, the valve assembly, and the fluid drive assembly.

7. (Original) The system of claim 1, further comprising a housing for supporting the fluid drive assembly, and a filter attached to the housing for filtering fluid entering the housing by the fluid drive assembly.

8. (Original) The system of claim 1, wherein the fluid supplied to the valve actuator by the fluid drive assembly is ambient air.

9. (Original) The system of claim 1, wherein the controller assembly is operable to communicate a signal corresponding to the measured physical property to a remote computer system.

10. (Original) The system of claim 1, wherein the controller assembly is a programmable logic controller.

11. (Currently Amended) A method for controlling fluid flow through a flow line at a wellsite, the method comprising:

providing a control system comprising:

a fluid supply;

a first fluid line in fluid communication with the fluid supply;

a pump in fluid communication with the first fluid line and configured to pump fluid from the fluid supply to one or more wellheads through the first fluid line;

a second fluid line in fluid communication with the first fluid line at a location downstream of the pump and configured to return fluid from the first fluid line back to the fluid supply or direct fluid from the first fluid line to a different reservoir;

a safety valve in-line with the second fluid line;

a valve actuator configured to actuate the safety valve;

a housing;

an electronic controller assembly;

a fluid drive assembly; and

a valve assembly;

supplying fluid to the valve actuator using the fluid drive assembly to actuate the valve actuator to move the safety valve into a closed position;

maintaining the safety valve in the closed position to close fluid flow through the second fluid line;

monitoring a physical property in the first fluid line using the controller assembly; and

actuating the valve assembly using the controller assembly to release the fluid from the valve actuator to move the safety valve into an open position and thereby open fluid flow through the second fluid line based upon a comparison of the monitored physical property to a predetermined condition to return fluid from the first fluid line back to the fluid supply or direct fluid from the first fluid line to the different reservoir.

12. (Original) The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a pneumatic fluid disposed external to the housing, and further comprising filtering the pneumatic fluid as it enters the housing by the fluid drive assembly.

13. (Original) The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a hydraulic fluid disposed in a reservoir within the housing that is in fluid communication with the fluid drive assembly.

14. (Original) The method of claim 12, further comprising measuring the physical property using a transducer configured to communicate a signal corresponding to the measured physical property to the controller assembly.

15. (Original) The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a pneumatic fluid, and wherein the fluid drive assembly is a compressor.

16. (Original) The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a hydraulic fluid, and wherein the fluid drive assembly is a pump.

17. (Original) The method of claim 12, further comprising communicating a signal from the controller assembly to a remote computer system, wherein the signal corresponds to an operational characteristic of the safety valve.

18. (Original) The method of claim 12, further comprising actuating the safety valve by communicating a signal from a remote computer system to the controller assembly.

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REMARKS

This is intended as a full and complete response to the Office Action dated May 25, 2017. Claims 1-18 remain pending in the application and are shown above. Claims 1-18 stand rejected by the Examiner. Reconsideration of the rejected claims is requested for the reasons presented below.

Claim Amendments

Claims 1 and 11 have been amended. No new matter has been added. Support for the amendments can be found in at least paragraphs [0085]-[0088] of the specification as filed.

Double Patenting

Claims 1-18 stand rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-18 of U.S. Patent 9,441,453.

Applicant submits herewith a terminal disclaimer of the pending claims over claims 1-18 of U.S. Patent No. 9,441,453. Applicant respectfully requests withdrawal of the rejection.

Conclusion

Having addressed all issues set out in the office action, Applicant respectfully submits that the claims are in condition for allowance and respectfully requests that the claims be allowed.

Respectfully submitted,

/Jessie D. Herrera/
Jessie D. Herrera
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PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046
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Attorney for Applicant

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 43

Electronic Patent Application Fee Transmittal

Application Number:	15262642
Filing Date:	12-Sep-2016
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Filer:	Jessie D. Herrera/Stephanie Dominguez
Attorney Docket Number:	SAFO/0012USPC01

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
STATUTORY OR TERMINAL DISCLAIMER	1814	1	160	160
		Total in USD ($)		**160**

Electronic Acknowledgement Receipt	
EFS ID:	30120167
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	18-AUG-2017
Filing Date:	12-SEP-2016
Time Stamp:	13:12:45
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$160
RAM confirmation Number	081817INTEFSW13132300
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Terminal Disclaimer Filed	Terminal_Disclaimer.PDF	160013 efcf58d8b52218dd546328621f0618bc5b805148	no	2
Warnings:					
Information:					
2		Response.pdf	67782 fdc1b23cd933dfb27cb12dc9603e7c1af628f64b	yes	6

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	5
	Applicant Arguments/Remarks Made in an Amendment	6	6

Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30430 0ddae26eefce3aee08e13383c0d0fe18a4a7823d	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	258225		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/AIA/26 (04-14)
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TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT	Docket Number (Optional) SAFO/0012USPC01

In re Application of: David Lymberopoulos

Application No.: 15/262,642

Filed: September 12, 2016

For: SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

The applicant, SAFOCO, INC., owner of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of **prior patent** No. 9,441,453 as the term of said **prior patent** is presently shortened by any terminal disclaimer. The applicant hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior patent** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the applicant does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the **prior patent**, "as the term of said **prior patent** is presently shortened by any terminal disclaimer," in the event that said **prior patent** later:

expires for failure to pay a maintenance fee;
is held unenforceable;
is found invalid by a court of competent jurisdiction;
is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
has all claims canceled by a reexamination certificate;
is reissued; or
is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ The undersigned is the applicant. If the applicant is an assignee, the undersigned is authorized to act on behalf of the assignee.

I hereby acknowledge that any willful false statements made are punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

2. ☑ The undersigned is an attorney or agent of record. Reg. No. 63,799

/Jessie D. Herrera/ — Signature
August 18, 2017 — Date

Jessie D. Herrera — Typed or printed name

Attorney for Applicant — Title
713-623-4844 — Telephone Number

☑ Terminal disclaimer fee under 37 CFR 1.20(d) included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

This collection of information is required by 37 CFR 1.321. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

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

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

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	15/262,642	LYMBEROPOULOS ET AL.	

Document Code - DISQ	Internal Document – DO NOT MAIL

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 18 August, 2017	**This patent is subject to a Terminal Disclaimer**	

Approved/Disapproved by:

/CRYSTAL QUEEN/

Technology Center: PLRC

Telephone: _____

U.S. Patent and Trademark Office

PTO/SB/06 (09-11)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 15/262,642	Filing Date 09/12/2016	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)		
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	08/18/2017	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 18	Minus	** 20	= 0	X $80 =	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X $420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
THERESA LINDSAY

This collection of information is required by 37 CFR 1.16. 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 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 — Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
Mr.	David		LYMBEROPOULOS	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	State/Province	Country of Residence
Houston	TX	US

Mailing Address of Inventor:

Address 1	8310 North Tahoe Drive
Address 2	
City	Houston
State/Province	TX
Postal Code	77040
Country	US

Inventor 2 — Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
Mr.	Benjamin	R.	MATTHEWS	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	State/Province	Country of Residence
Missouri City	TX	US

Mailing Address of Inventor:

Address 1	3522 Rolling Green Lane
Address 2	
City	Missouri City
State/Province	TX
Postal Code	77459
Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	26290		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE		
Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	15	**Suggested Figure for Publication (if any)**	13

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	26290		

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	~~Pending~~ Patented		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	13/480704	2012-05-25
Prior Application Status	~~Pending~~ Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13/480704	Claims benefit of provisional	61/551319	2011-10-25
Prior Application Status	~~Expired~~ Abandoned		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
~~61/551319~~ 13/480704	Continuation of ~~in part of~~	13/195662	2011-08-01
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13/195662	Claims benefit of provisional	61/415238	2010-11-18
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13/195662	Claims benefit of provisional	61/370721	2010-08-04
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.			Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

PTO/AIA/14 (11-15)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	SAFOCO, INC.		
Mailing Address Information For Applicant:			
Address 1	11421-A TODD ROAD		
Address 2			
City	Houston	**State/Province**	TX
Country	US	Postal Code	77055
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Jessie D. Herrera/			Date (YYYY-MM-DD)	2017-05-25 ~~2016-09-12~~
First Name	Jessie D.	Last Name	Herrera	Registration Number	63,799

Additional Signature may be generated within this form by selecting the Add button. Add

PTO/AIA/14 (11-15)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	~~FETI/0012USPC01~~ SAFO/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

This collection of information is required by 37 CFR 1.76. 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 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet 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 records.

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 CooperationTreaty.

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.

Electronic Acknowledgement Receipt

EFS ID:	29311831
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	25-MAY-2017
Filing Date:	12-SEP-2016
Time Stamp:	12:43:52
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	Application Data Sheet	Corrected_ADS.pdf	1369736 272e1a29afff7b41685deb20aa187ca7e1027b99	no	9

Warnings:

Information:	
This is not an USPTO supplied ADS fillable form	
Total Files Size (in bytes):	1369736

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01	6248

26290 7590 05/18/2017

PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

EXAMINER
MCCALISTER, WILLIAM M

ART UNIT	PAPER NUMBER
3753	

NOTIFICATION DATE	DELIVERY MODE
05/18/2017	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

PSDocketing@pattersonsheridan.com
pair_eofficeaction@pattersonsheridan.com
jcardenas@pattersonsheridan.com

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Office Action Summary	Application No. 15/262,642	Applicant(s) LYMBEROPOULOS ET AL.	
	Examiner WILLIAM MCCALISTER	Art Unit 3753	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *9/12/16*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-18* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-18* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *9/12/16* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011

The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on nonstatutory double patenting provided the reference application or patent either is shown to be commonly owned with the examined application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. See

MPEP § 717.02 for applications subject to examination under the first inventor to file provisions of the AIA as explained in MPEP § 2159. See MPEP §§ 706.02(l)(1) - 706.02(l)(3) for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO Internet website contains terminal disclaimer forms which may be used. Please visit www.uspto.gov/patent/patents-forms. The filing date of the application in which the form is filed determines what form (e.g., PTO/SB/25, PTO/SB/26, PTO/AIA/25, or PTO/AIA/26) should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to www.uspto.gov/patents/process/file/efs/guidance/eTD-info-I.jsp.

Claims 1-18 rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-18 of U.S. Patent No. 9,441,453. Although the claims at issue are not identical, they are not patentably distinct from each other because the differences amount to the patented claims reciting more than the pending claims.

Allowable Subject Matter

Claims 1-18 are allowable but for the double patenting rejection.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to **William McCalister**, whose telephone number **571-270-1869**. The examiner can normally be reached on Monday-Friday (7:00AM-5:30PM EST).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisors can be reached by phone. Craig Schneider can be reached at 571-272-3607, John Fristoe can be reached at 571-272-4926 and Mary McManmon can be reached at 571-272-6007. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/WILLIAM MCCALISTER/
Primary Examiner, Art Unit 3753

5/12/17

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	15374	E21B34/06,02,10,16.CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 14:26
L2	2587	y10t137/7761.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/05/12 14:26
L3	4645	e21b34/02,10,16,06.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/05/12 14:26
L4	303	f15b20/00,31576,6303,665,7052,0091,1262.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/05/12 14:26
L5	18231	L1 or L2 or L3 or L4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 14:26
L6	1942	l5 and @pd>"20160601"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 14:26
L7	2	"9441453".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 14:27
L8	89	l5 and @pd>"20160601" and pump and controller	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 14:36
L9	150	"wear layer" near4 groove	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	OFF	2017/05/12 14:55

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			IBM_TDB			
L10	8	"wear layer" and turbomachine	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 15:10
L11	36	(indicat$4 near2 layer) and turbomachine	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 15:15
L12	21	"1956195"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 15:24
L13	41	lymberopoulos.in. near2 david.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:00
L14	133	matthews.in. near2 benjamin.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:00
L15	161	l13 or l14	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:00
L16	21	l15 and pump and safety and valve	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/05/12 16:00
S1	1	13/480704	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/07/02 12:52
S2	626	137/492.5.ccls.	US-PGPUB; USPAT; USOCR; FPRS;	OR	OFF	2014/07/02 13:17

			EPO; JPO; DERWENT; IBM_TDB			
S3	170	S2 and (pump or compressor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/07/02 13:17
S5	138	S2 and pump	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/07/02 13:18
S6	44	("6349772" | "20100154894" | "20020108747" | "20020112632" | "20060159569" | "20110036415" | "20110240126" | "5275086" | "6772718" | "4082147" | "6199629" | "3741116" | "5335730" | "6435282" | "20100025045" | "20110094752" | "20020124889" | "4213480" | "5273113" | "5526883" | "6854704" | "7004445" | "20130008519" | "20130008519" | "20120031494" | "20050236594" | "4667570" | "5490564" | "6412510" | "RE39583" | "6296052" | "4215746" | "5684451" | "20050087712" | "3788341" | "4527429" | "5097857" | "5132904" | "6450477" | "7231971" | "20100154894" | "20090126798" | "4461449" | "20040135112" | "20110094752" | "6633236" | "7635029").PN.	US-PGPUB; USPAT	OR	OFF	2014/07/02 13:18
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S9	72	S8 and pump and hydraulic	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/07/02 16:51
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S11	21	("1223326" | "3225785" | "4037619" | "4414882" | "4431159" | "4585205" | "4613111" | "4774980" | "4778351" | "5094267" | "5158108" | "5158230" | "5197328" | "5318272" | "5431182" | "5460196").PN. OR	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/02 17:01

		("6202681").URPN.				
S12	3	("2010/0154894").URPN.	USPAT	OR	OFF	2014/07/03 13:51
S13	19	("2132132" | "2203243" | "3227171" | "3367355" | "3467129").PN. OR ("3788341").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/03 13:53
S14	11	("3788341" | "4186766" | "4240463" | "4319603" | "5293910" | "5396923").PN. OR ("7044156").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/03 13:54
S15	18	(US-20100154894-$ or US-20110240126-$ or US-20120031494-$ or US-20120227983-$).did. or (US-3788341-$ or US-4186766-$ or US-4213480-$ or US-4240463-$ or US-4774980-$ or US-6116268-$ or US-6202681-$ or US-6289737-$ or US-6450477-$ or US-6854704-$ or US-7004445-$ or US-7044156-$ or US-7934562-$ or US-8763983-$).did.	US-PGPUB; USPAT	OR	OFF	2014/07/03 14:01
S16	6	S15 and control$4 near4 pump	US-PGPUB; USPAT	OR	OFF	2014/07/03 14:01
S17	18	(US-20100154894-$ or US-20110240126-$ or US-20120031494-$ or US-20120227983-$).did. or (US-3788341-$ or US-4186766-$ or US-4213480-$ or US-4240463-$ or US-4774980-$ or US-6116268-$ or US-6202681-$ or US-6289737-$ or US-6450477-$ or US-6854704-$ or US-7004445-$ or US-7044156-$ or US-7934562-$ or US-8763983-$).did.	US-PGPUB; USPAT	OR	OFF	2014/07/07 07:40
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S20	12	("3788341" | "4335744" | "4337788" | "4461450" | "4503878").PN. OR ("4774980").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/07 08:55
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S22	313	137/492,492.5.ccls. and well	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/07 09:06
S23	61	137/492,492.5.ccls. and well and controller	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/07 09:06
S24	5	11/426109	US-PGPUB; USPAT; USOCR	OR	OFF	2014/07/07 09:10
S25	10	("2006/0219299").URPN.	USPAT	OR	OFF	2014/07/07 09:12
S26	10	"6450477"	USPAT	OR	OFF	2014/07/07 09:19
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KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 72

		4186766-$ or US-4213480-$ or US-4240463-$ or US-4774980-$ or US-6056008-$ or US-6116268-$ or US-6202681-$ or US-6289737-$ or US-6450477-$ or US-6854704-$ or US-7004445-$ or US-7044156-$ or US-7934562-$ or US-8763983-$).did.				
S28	9	S27 and pump with control$4	US-PGPUB; USPAT	OR	OFF	2014/07/07 12:21
S29	12	S27 and housing	US-PGPUB; USPAT	OR	OFF	2014/07/07 12:25
S30	20	(US-20060219299-$ or US-20100154894-$ or US-20110240126-$ or US-20120031494-$ or US-20120227983-$).did. or (US-3788341-$ or US-4186766-$ or US-4213480-$ or US-4240463-$ or US-4774980-$ or US-6056008-$ or US-6116268-$ or US-6202681-$ or US-6289737-$ or US-6450477-$ or US-6854704-$ or US-7004445-$ or US-7044156-$ or US-7934562-$ or US-8763983-$).did.	US-PGPUB; USPAT	OR	OFF	2014/07/07 14:46
S31	16	S30 and hydraulic	US-PGPUB; USPAT	OR	OFF	2014/07/07 14:46
S32	9	S30 and hydraulic and pump	US-PGPUB; USPAT	OR	OFF	2014/07/07 15:12
S33	592	g05d16/2086.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/07/07 15:44
S34	2283	f16k17/00.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/07/07 15:55
S35	20	(US-20060219299-$ or US-20100154894-$ or US-20110240126-$ or US-20120031494-$ or US-20120227983-$).did. or (US-3788341-$ or US-4186766-$ or US-4213480-$ or US-4240463-$ or US-4774980-$ or US-6056008-$ or US-6116268-$ or US-6202681-$ or US-6289737-$ or US-6450477-$ or US-6854704-$ or US-7004445-$ or US-7044156-$ or US-7934562-$ or US-8763983-$).did.	US-PGPUB; USPAT	OR	OFF	2015/03/19 08:04
S36	10	S35 and gate	USPAT	OR	OFF	2015/03/19 08:05
S37	13	S35 and gate	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/03/19 08:05
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S39	5	S38 and gate	US-PGPUB;	OR	OFF	2015/03/19

			USPAT; USOCR			08:10
S40	21	("2132132" | "2203243" | "3227171" | "3367355" | "3467129").PN. OR ("3788341").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/03/19 08:11
S41	5	S40 and gate	US-PGPUB; USPAT; USOCR	OR	OFF	2015/03/19 08:12
S42	432	137/487.5,488.ccls. and safety and (oil or gas or pipeline or well or wellhead)	US-PGPUB; USPAT; USOCR	OR	OFF	2015/03/19 08:16
S43	80	137/487.5,488.ccls. and safety and (oil or gas or pipeline or well or wellhead) and gate	US-PGPUB; USPAT; USOCR	OR	OFF	2015/03/19 08:17
S44	38	("3198207" | "3252476" | "3338302" | "3389718" | "3452592" | "3712129" | "3898877" | "3920040" | "3963050" | "4046006" | "Re29638").PN. OR ("4230187").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/03/19 08:26
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S47	1	"5335730".pn.	USPAT	OR	OFF	2015/03/19 08:58
S48	0	"20030051881"	USPAT	OR	OFF	2015/03/19 08:59
S49	11	"20030051881"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/03/19 08:59
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S52	0	g05d16/2086.ccls. and @pd>"20141215"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/03/19 13:10
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S54	651	137/492.5.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/25 12:35
S55	50	S54 and (bias$3 near4 open$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/25 12:36
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S58	30	("1893462" | "1918891" | "2203243" | "2278952" | "2637946" | "2707483" | "3227171" | "3788341" | "3991784").PN. OR ("4240463").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/06/25 13:42
S59	9	("3613070" | "4087073" | "4240463" | "4649704" | "4687014" | "6332315").PN. OR ("6729130").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/06/25 13:42
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S61	11	("4091832" | "4240463").PN. OR ("4319603").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/06/25 13:44
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S63	41	137/488,492,492.5.ccls. and @pd>"20150301"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/26 14:10
S64	0	g05d16/2086.ccls. and @pd>"20150301"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/26 14:11
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			EPO; JPO; DERWENT; IBM_TDB			
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S68	4	"5271428".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/29 10:10
S69	1	13/480704	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/12/29 10:46
S70	81	(G05D16/2086.CPC. OR F16K17/00.CPC.) AND @PD>"20150601"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/12/29 14:01
S71	1	13/345660	USPAT	OR	OFF	2016/06/06 13:10
S72	2	13/345660	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/06/06 13:10
S73	1	13/645660	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/06/06 13:11
S74	1627	g05d16/2086.cpc. or f16k17/00.cpc. or 137/488,492,492.5.ccls. and @pd>"20140707"	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/08 12:32
S75	2377	y10t137/7762,7769,777.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/08 12:33

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KLX - Exhibit No. 1011
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S76	2377	y10t137/7762,7769,777.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/08 13:36
S77	279	S76 not 137/488,492,492.5.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/08 13:36
S78	13041	E21B34/06,02,10,16.CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/06/09 10:52
S79	2505	y10t137/7761.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/09 10:57
S80	4130	e21b34/02,10,16,06.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/09 10:57
S81	272	f15b20/00,31576,6303,665,7052,0091,1262.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/09 10:58
S82	6886	S78 or S79 or S80 or S81	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/09 10:58
S83	1	13/480704	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/09 11:03
S85	1	14/208509	US-PGPUB; USPAT; USOCR	OR	OFF	2016/06/10 15:27
S86	1	"5983398".pn.	USPAT	OR	OFF	2017/03/01 11:28

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S84	0	(fluid and supply and first and line and pump and second and downstream and return and safety and valve and controller and actuator and drive and gate).clm.	US-PGPUB; USPAT	OR	OFF	2016/06/09 11:43

5/12/2017 4:02:11 PM
C:\Users\wmccalister\Documents\EAST\Workspaces\13480704.wsp

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CONFIRMATION NO. 6248

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
15/262,642	09/12/2016	137	3753	SAFO/0012USPC01

APPLICANTS
SAFOCO, INC., Houston, TX;

INVENTORS
David LYMBEROPOULOS, Houston, TX;
Benjamin R. MATTHEWS, Missouri City, TX;

**** CONTINUING DATA ***************************
This application is a CON of 13/480,704 05/25/2012 PAT 9441453
which claims benefit of 61/551,319 10/25/2011

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****
09/21/2016

Foreign Priority claimed ❑ Yes ☑ No 35 USC 119(a-d) conditions met ❑ Yes ☑ No Verified and Acknowledged /WILLIAM M MCCALISTER/ Examiner's Signature	❑ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		TX	15	18	2

ADDRESS
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046
UNITED STATES

TITLE
SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15262642	LYMBEROPOULOS ET AL.
	Examiner	Art Unit
	WILLIAM MCCALISTER	3753

CPC- SEARCHED		
Symbol	Date	Examiner
G05D16/2086	5/12/2017	WM
F16K 17/00; 37/0091; 31/1262	5/12/2017	WM
E21B 34/02, 06, 10, 16	5/12/2017	WM
Y10T 137/7761, 7762, 7769, 777, 0318	5/12/2017	WM
F15B 20/00; 2211/31576, 6303, 665, 7052	5/12/2017	WM

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
137	488, 492, 492.5	5/12/2017	WM

SEARCH NOTES		
Search Notes	Date	Examiner
EAST ccls and cpc in parent, ky words, f/b citations, inventor name	5/12/2017	wm

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

	/WILLIAM MCCALISTER/ Primary Examiner.Art Unit 3753

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

PTO/SB/08a (03-15)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15262642
Filing Date	2016-09-12
First Named Inventor	David LYMBEROPOULOS
Art Unit	3753
Examiner Name	Not Yet Assigned
Attorney Docket Number	SAFO/0012USPC01

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Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3695878		1972-10-03	W.L. Salyer et al.	
	2	3741116		1973-06-26	Green et al.	
	3	3776249		1973-12-04	Wailes et al.	
	4	3788341		1974-01-29	Athy, Jr. et al.	
	5	3908959		1975-09-30	Fichtner	
	6	3922111		1975-11-25	Deters	
	7	4062379		1977-12-13	Clinton	
	8	4082147		1978-04-04	Wolff et al.	

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	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	9	4213480		1980-07-22	Orum et al.	
	10	4215746		1980-08-05	Hallden et al.	
	11	4240463		1980-12-23	Moore	
	12	4461449		1984-07-24	Turner	
	13	4527429		1985-07-09	Combest et al.	
	14	4667570		1987-05-26	Jensen, Jr. et al.	
	15	4774980		1988-10-04	Etheridge	
	16	5097857		1992-03-24	Mayhew	
	17	5132904		1992-07-21	Lamp	
	18	5273113		1993-12-28	Schultz	
	19	5275086		1994-01-04	Stallings, Jr.	

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	20	5335730		1994-08-09	Cotham, III	
	21	5490564		1996-02-13	Schultz et al.	
	22	5526883		1996-06-18	Breaux	
	23	5684451		1997-11-04	Seberger et al.	
	24	5758686		1998-06-02	Ohtsuka et al.	
	25	6116268		2000-09-12	Johnson	
	26	6199629		2001-03-13	Shirk et al.	
	27	6289737		2001-09-18	Kouketsu et al.	
	28	6296052		2001-10-02	Sidwell	
	29	6349772		2002-02-26	Mullen et al.	
	30	6412510		2002-07-02	Johnson	

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	Attorney Docket Number	SAFO/0012USPC01

	31	6435282		2002-08-20	Robison et al.	
	32	6450477		2002-09-17	Young	
	33	6633236		2003-10-14	Vinegar et al.	
	34	6772718		2004-08-10	Allen	
	35	6854704		2005-02-15	Young	
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	37	7231971		2007-06-19	McCalvin	
	38	7635029		2009-12-22	MacDougall et al.	
	39	9441453		2016-09-13	Lymberopoulos et al.	
	40	RE39583		2007-04-24	Upchurch	

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	First Named Inventor	David LYMBEROPOULOS
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	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

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	20020108747	A1	2002-08-15	Dietz et al.	
	2	20020112632	A1	2002-08-22	Faibish	
	3	20020124889	A1	2002-09-12	Sundararajan	
	4	20030051881	A1	2003-03-20	Vinegar et al.	
	5	20040135112		2004-07-15	Greeb et al.	
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	7	20050236594	A1	2005-10-27	Lilly et al.	
	8	20060159569	A1	2006-07-20	Biester	
	9	20060219299	A1	2006-10-05	Snowbarger	
	10	20090126798	A1	2009-05-21	Mather	

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	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	11	20100025045		2010-02-04	Lake et al.	
	12	20100154894	A1	2010-06-24	Kotapish et al.	
	13	20100236790	A1	2010-09-23	SMITHSON	
	14	20110036415	A1	2011-02-17	Lymberopoulos	
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	18	20130008519	A1	2013-01-10	Crawford	

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	1	0647770	EP	A2	1995-04-12	Ford Motor Co		

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	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	2	2391880	GB	A	2004-02-18	Reeves Wireline Tech Ltd		
	3	07042856	JP		1995-02-10	Nakai Kazuo		X
	4	0165061	WO	A1	2001-09-07	Shell Oil Co		☐
	5	0225612	WO	A1	2002-03-28	Keyspan Energy		☐
	6	2005097792	WO	A1	2005-10-20	Westlock Controls Corp		☐

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	1	Versa Series B Valves Bulletin B-2011; Versa Products Company, Inc.; 2011, 8 Pages.	
	2	Rotowink Indicators; Norgren 1996; 2 Pages.	

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	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01

CONFIRMATION NO. 6248

26290
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
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Date Mailed: 04/18/2017

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 04/13/2017.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/mbeyene/

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
Approved for use through 11/30/2014. OMB 0651-0051
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TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	15/262,642
Filing Date	September 12, 2016
First Named Inventor	David LYMBEROPOULOS
Title	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
Art Unit	3753
Examiner Name	William M. MCCALISTER
Attorney Docket Number	SAFO/0012USPC01

SIGNATURE of Applicant or Patent Practitioner

Signature	/Jessie D. Herrera/	Date (Optional)	April 13, 2017
Name	Jessie D. Herrera	Registration Number	63,799
Title (if Applicant is a juristic entity)	Attorney for Applicant		
Applicant Name (if Applicant is a juristic entity)	SAFOCO, INC.		

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ *Total of 1 forms are submitted.

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82B (07-13)
Approved for use through 11/30/2014. OMB 0651-0051
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date
15/262,642	September 12, 2016

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 26290

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

SAFOCO, INC.

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	/DL/	Date (Optional)	
Name	David Lymberopoulos		
Title	President of SAFOCO, INC.		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ Total of forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	28924363
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	13-APR-2017
Filing Date:	12-SEP-2016
Time Stamp:	17:57:12
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	Power of Attorney	SAFO0012USPC01_POA_.pdf	322125 7f982e6c9c8402077b61817e3a945258216 5c35e	no	2

Warnings:

Information:	
Total Files Size (in bytes):	322125

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01

CONFIRMATION NO. 6248

26290
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

PUBLICATION NOTICE



Title:SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

Publication No.US-2017-0060144-A1
Publication Date:03/02/2017

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PTO/AIA/01 (06-12)
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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

As the below named inventor, I hereby declare that:

This declaration is directed to:

- [ ] The attached application, or
- [x] United States application or PCT international application number 15/262,642 filed on 09/12/2016.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

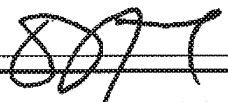
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: David LYMBEROPOULOS Date (Optional): 9-28-16

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

As the below named inventor, I hereby declare that:

This declaration is directed to:

- [ ] The attached application, or
- [x] United States application or PCT international application number 15/262,642 filed on 09/12/2016.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

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LEGAL NAME OF INVENTOR

Inventor: Benjamin R. MATTHEWS Date (Optional): 2/13/17

Signature:

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

Electronic Acknowledgement Receipt

EFS ID:	28355755
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	14-FEB-2017
Filing Date:	12-SEP-2016
Time Stamp:	17:35:15
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	SAFO0012USPC01_Declaration.pdf	438792 be7dac12b71c17a9e5afbb116ad12994f47c547b	no	2

Warnings:

Information:	
Total Files Size (in bytes):	438792

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
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National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/262,642

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	18 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*				x 420 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1600

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/262,642	09/12/2016	3753	1740	SAFO/0012USPC01	18	2

CONFIRMATION NO. 6248

UPDATED FILING RECEIPT

26290
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

OC000000087437229

Date Mailed: 11/25/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

David LYMBEROPOULOS, Houston, TX;
Benjamin R. MATTHEWS, Missouri City, TX;

Applicant(s)

SAFOCO, INC., Houston, TX;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/480,704 05/25/2012 PAT 9441453
which claims benefit of 61/551,319 10/25/2011

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 09/21/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/262,642**

Projected Publication Date: 03/02/2017

Non-Publication Request: No

Early Publication Request: No
Title

SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

Preliminary Class

137

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 100

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/262,642	09/12/2016	David LYMBEROPOULOS	SAFO/0012USPC01

CONFIRMATION NO. 6248

26290
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

INFORMAL NOTICE

OC000000087437230

Date Mailed: 11/25/2016

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  David LYMBEROPOULOS
  Benjamin R. MATTHEWS

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/dgela/

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 102

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: David Lymberopoulos et al.	§	
Serial No.: 15/262,642	§	Group Art Unit: 3753
Confirmation No.: 6248	§	
	§	Examiner: Unknown
Filed: September 12, 2016	§	
For: SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	§	

MS Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO NOTICE TO FILE MISSING PARTS OF APPLICATION

Applicant files this Response to a Notice to File Missing Parts dated September 23, 2016, within the two-month period set to expire on November 23, 2016. The Notice indicates that the application was not filed with the required fees.

In response, Applicant submits herewith a payment of the required fees, including the surcharge, via credit card. The Commissioner is hereby authorized to charge, or to credit any overpayment, to Deposit Account No. 20-0782/SAFO/0012USPC01/JDH for any additional fees required to make this response timely and acceptable to the Office.

Respectfully submitted,

/Jessie D. Herrera/
Jessie D. Herrera
Registration No. 63,799
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046
Telephone: (713) 623-4844
Facsimile: (713) 623-4846
Attorney for Applicant

KLX Energy Services LLC v. Safoco, Inc.
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Page 103

Electronic Patent Application Fee Transmittal

Application Number:	15262642
Filing Date:	12-Sep-2016
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Filer:	Jessie D. Herrera/Stephanie Dominguez
Attorney Docket Number:	SAFO/0012USPC01

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY APPLICATION FILING	1011	1	280	280
UTILITY SEARCH FEE	1111	1	600	600
UTILITY EXAMINATION FEE	1311	1	720	720
Pages:				
Claims:				
Miscellaneous-Filing:				
LATE FILING FEE FOR OATH OR DECLARATION	1051	1	140	140
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1740**

Electronic Acknowledgement Receipt

EFS ID:	27573320
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	21-NOV-2016
Filing Date:	12-SEP-2016
Time Stamp:	15:11:33
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1740
RAM confirmation Number	112216INTEFSW15125700
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Response to Pre-Exam Formalities Notice	Response.pdf	56198 adfca5f72e581013320ae461db63343ea6d14dec	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	37162 ed04f994369755be8adf9262225be22370281c0c	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	93360		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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

PTO/SB/08a (03-15)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15262642
Filing Date	2016-09-12
First Named Inventor	David LYMBEROPOULOS
Art Unit	3753
Examiner Name	Not Yet Assigned
Attorney Docket Number	SAFO/0012USPC01

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	3695878		1972-10-03	W.L. Salyer et al.	
	2	3741116		1973-06-26	Green et al.	
	3	3776249		1973-12-04	Wailes et al.	
	4	3788341		1974-01-29	Athy, Jr. et al.	
	5	3908959		1975-09-30	Fichtner	
	6	3922111		1975-11-25	Deters	
	7	4062379		1977-12-13	Clinton	
	8	4082147		1978-04-04	Wolff et al.	

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	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	9	4213480		1980-07-22	Orum et al.	
	10	4215746		1980-08-05	Hallden et al.	
	11	4240463		1980-12-23	Moore	
	12	4461449		1984-07-24	Turner	
	13	4527429		1985-07-09	Combest et al.	
	14	4667570		1987-05-26	Jensen, Jr. et al.	
	15	4774980		1988-10-04	Etheridge	
	16	5097857		1992-03-24	Mayhew	
	17	5132904		1992-07-21	Lamp	
	18	5273113		1993-12-28	Schultz	
	19	5275086		1994-01-04	Stallings, Jr.	

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	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	20	5335730		1994-08-09	Cotham, III	
	21	5490564		1996-02-13	Schultz et al.	
	22	5526883		1996-06-18	Breaux	
	23	5684451		1997-11-04	Seberger et al.	
	24	5758686		1998-06-02	Ohtsuka et al.	
	25	6116268		2000-09-12	Johnson	
	26	6199629		2001-03-13	Shirk et al.	
	27	6289737		2001-09-18	Kouketsu et al.	
	28	6296052		2001-10-02	Sidwell	
	29	6349772		2002-02-26	Mullen et al.	
	30	6412510		2002-07-02	Johnson	

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	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	31	6435282		2002-08-20	Robison et al.	
	32	6450477		2002-09-17	Young	
	33	6633236		2003-10-14	Vinegar et al.	
	34	6772718		2004-08-10	Allen	
	35	6854704		2005-02-15	Young	
	36	7004445		2006-02-28	Lymberopoulos	
	37	7231971		2007-06-19	McCalvin	
	38	7635029		2009-12-22	MacDougall et al.	
	39	9441453		2016-09-13	Lymberopoulos et al.	
	40	RE39583		2007-04-24	Upchurch	

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KLX - Exhibit No. 1011
Page 111

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15262642
	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

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	20020108747	A1	2002-08-15	Dietz et al.	
	2	20020112632	A1	2002-08-22	Faibish	
	3	20020124889	A1	2002-09-12	Sundararajan	
	4	20030051881	A1	2003-03-20	Vinegar et al.	
	5	20040135112		2004-07-15	Greeb et al.	
	6	20050087712	A1	2005-04-28	Lymberopoulos	
	7	20050236594	A1	2005-10-27	Lilly et al.	
	8	20060159569	A1	2006-07-20	Biester	
	9	20060219299	A1	2006-10-05	Snowbarger	
	10	20090126798	A1	2009-05-21	Mather	

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	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	11	20100025045		2010-02-04	Lake et al.	
	12	20100154894	A1	2010-06-24	Kotapish et al.	
	13	20100236790	A1	2010-09-23	SMITHSON	
	14	20110036415	A1	2011-02-17	Lymberopoulos	
	15	20110094752	A1	2011-04-28	Hudson et al.	
	16	20110240126	A1	2011-10-06	Lymberopoulos et al.	
	17	20120031494	A1	2012-02-09	Lymberopoulos	
	18	20130008519	A1	2013-01-10	Crawford	

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	0647770	EP	A2	1995-04-12	Ford Motor Co		

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15262642
	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

	2	2391880	GB	A	2004-02-18	Reeves Wireline Tech Ltd		
	3	07042856	JP		1995-02-10	Nakai Kazuo		X
	4	0165061	WO	A1	2001-09-07	Shell Oil Co		
	5	0225612	WO	A1	2002-03-28	Keyspan Energy		
	6	2005097792	WO	A1	2005-10-20	Westlock Controls Corp		

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

NON-PATENT LITERATURE DOCUMENTS Remove

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.	T5
	1	Versa Series B Valves Bulletin B-2011; Versa Products Company, Inc.; 2011, 8 Pages.	
	2	Rotowink Indicators; Norgren 1996; 2 Pages.	

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15262642
	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

[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	15262642
	Filing Date	2016-09-12
	First Named Inventor	David LYMBEROPOULOS
	Art Unit	3753
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	SAFO/0012USPC01

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	/Jessie D. Herrera/	Date (YYYY-MM-DD)	2016-10-04
Name/Print	Jessie D. Herrera	Registration Number	63,799

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

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

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

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.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 647 770 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **94120028.9**

(51) Int. Cl.[6]: **F01L 9/02**, F02D 13/02

(22) Date of filing: **04.06.92**

This application was filed on 17 - 12 - 1994 as a divisional application to the application mentioned under INID code 60.

(30) Priority: **24.06.91 US 720115**

(43) Date of publication of application:
12.04.95 Bulletin 95/15

(60) Publication number of the earlier application in accordance with Art.76 EPC: **0 520 633**

(84) Designated Contracting States:
DE FR GB

(71) Applicant: **FORD MOTOR COMPANY LIMITED**
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F-92506 Rueil-Malmaison Cédex (FR)
(84) **FR**

(72) Inventor: **Schechter, Michael Moses**
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(74) Representative: **Messulam, Alec Moses**
A. Messulam & Co.
24 Broadway
Leigh on Sea
Essex SS9 1BN (GB)

(54) Hydraulically operated valve control system for an internal combustion engine.

(57) An engine valve control system of an internal combustion engine in which the valve stroke is controlled by varying timing and duration of electric signals sent to individually dedicated engine valve controlling means, comprises :

a controller programmed to send variable electric control signals (512) to the said engine valve controlling means (64),said control signals duration comprising the algebraic sum of a basic signal duration (508) and a correction signal duration (510)

means (504) for generating a basic signal duration determined by the controller as a function of engine operating conditions and being equal for all engine intake valves and equal for all engine exhaust valves; and

means (500,502) for generating a correction signal predetermined for each of the engine valve controlling means as a measure of the extent the performance of each engine valve controlling means varies from a predetermined standard, said correction signal generating means being operative in timed sequence to supply to the controller said predetermined correction signal just prior to a respective engine valve controlling means being activated.

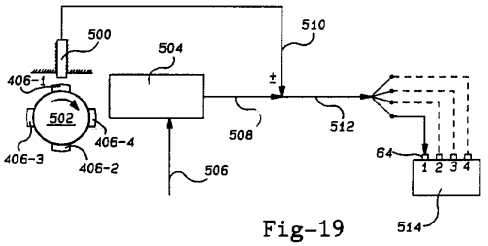


Fig-19

EP 0 647 770 A2

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 118

This invention relates to systems for variably controlling internal combustion engine intake and exhaust valves. More specifically, it relates to engine valve systems of the type in which hydraulic pressure of a pressurised fluid is used through action of solenoid valves to control the engine valves motion.

The enhancement of engine performance to be attained by being able to vary the acceleration, velocity and travel time of the intake and exhaust valves in an engine is well known and appreciated in the art. However, the technology for providing a straight-forward, relatively inexpensive and highly reliable system has not been forthcoming. Increased use and reliance on micro electronic control systems for automotive vehicles and increased confidence in hydraulic as opposed to mechanical systems is now making substantial progress possible. In the area of intake and exhaust engine valves, prior development has been largely dependent upon sophisticated mechanical systems such as mechanically varying phase shift and other aspects of valve timing. increased use of multiple valve engines has also been promoted.

The use or adoption of hydraulically controlled engine valves has been quite slow. Examples of known systems include those as shown in U.S. Patent Nos. 2,915,052; 3,240,191; 3,361,121; 3,534,718; 3,926,159; 3,963,006; and 4,200,067. In some instances, such as shown in U.S. Patent No. 3,361,121 the poppet valve is maintained in a closed position by a mechanical coil spring, yet utilises a hydraulic actuator to bias the valves in the open position. Several of the aforementioned patents also disclose the use of a rotary distributor valve to alternately couple the hydraulic actuator ports to a source of pressurised fluid, such as shown in U.S. Patent Nos. 2,915,052 and 4,200,067. In certain of the aforementioned patents, it is also shown that the hydraulic fluid system is used to both open and close the engine valve, such feature being shown in U.S. Patent Nos. 2,915,052 and 3,963,006.

However, none of the aforementioned systems provide a variable engine valve control system offering the simplicity, reliability, flexibility and efficiency believed necessary for use in the high production, high performance automotive engines being produced today and those that will be required in the near future.

According to the present invention, there is provided an engine valve control system of an internal combustion engine in which the valve stroke is controlled by varying timing and duration of electric signals sent to individually dedicated engine valve controlling means, the system comprising a controller programmed to send variable electric control signals to the said engine valve controlling means, said control signals duration comprising the algebraic sum of a basic signal duration and a correction signal duration; means for generating a basic signal duration determined by the controller as a function of engine operating conditions and being equal for all engine intake valves and equal for all engine exhaust valves; and means for generating a correction signal predetermined for each of the engine valve controlling means as a measure of the extent the performance of each engine valve controlling means varies from a predetermined standard, said correction signal generating means being operative in timed sequence to supply to the controller said predetermined correction signal just prior to a respective engine valve controlling means being activated.

The engine valve controlling means may suitably be an hydraulic system as described below and as claimed in co-pending European Patent Application No. 92305111.4. In this system, sources of high and low pressure are connected by solenoid operated valves to a double acting piston acting to open and close each engine valve. Selective actuation and deactuation of the controlling means causes an inflow of pressurised fluid into a space at one end of said piston and an outflow of fluid from the space at the other end of the piston, such action leading to a change in the balance of forces acting on the piston and causing controlled motion of the valve from one fixed position to another.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which :

Figure 1 is a schematic diagram showing a single hydraulically controlled engine valve and the entire hydraulic system for supplying fluid to the valve controlling means according to the invention;

Figures 2a, 2b and 2c are elevation views showing a single engine valve and associated valve controlling means, with the valve being shown in three different stages of its being fully opened;

Figures 3a, 3b and 3c are elevation views showing a single engine valve and associated valve controlling means, with the valve being shown in three different stages of its being fully closed;

Figure 4 is a schematic diagram showing an alternative embodiment of the present invention wherein a single pair of control valves is used to control the operation of two valves associated with the same engine cylinder, thereby allowing the single engine valve to be functional or both valves to be functional through selective activation of the two control valves of the system;

Figure 5 is an alternate embodiment of the present invention and showing an elevation view of a engine valve and its control means utilising

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a single spring bias pressure relief valve and a double acting high pressure rail solenoid valve;

Figures 6 and 7 show as an elevation view and front view, respectively, a rotary hydraulic distributor in accordance with the present invention for distributing both high pressure and low pressure fluid to a plurality of engine valves;

Figures 8a, 8b and 8c are basically schematic representations of an engine valve being hydraulically opened using a modified hydraulic control system including the rotary distributor of Figures 6 and 7, all in accordance with the present invention;

Figures 9a, 9b and 9c show schematic representations of an engine valve being hydraulically closed using a modified hydraulic control system including the rotary distributor of Figures 6 and 7, all in accordance with the present invention;

Figure 10 is a schematic diagram of an alternative embodiment of the present invention wherein the control means including the rotary hydraulic distributor is used to control a plurality of engine valves, one each for each of the engine cylinders and all the other intake valves or exhaust valves;

Figures 11-13 are similar to Figure 10 but showing the engine valves at another point in the engine's cycle;

Figures 10a through 13a are schematic diagrams of yet another embodiment of the present invention wherein a pair of control valves including a hydraulic rotary distributor is used for controlling the valve operation of a pair of engine cylinders and wherein each distributor alternately controls the functions of both intake valves and exhaust valves, one each in each of the cylinders;

Figure 14 is a schematic representation of the engine valves and control valve system therefor of a pair of engine cylinders as shown in Figures 10a-13a.

Figure 15 is a schematic valve lift diagram showing the valve lift pattern for the system shown in Figure 14;

Figure 16 is a schematic diagram of a conventional lost motion type, cam-operated, hydraulic engine valve control system;

Figure 17 is a composite graph showing the operating characteristics of a single solenoid valve as a function of time versus solenoid valve travel, current and voltage;

Figure 18 is a schematic diagram of yet another embodiment of the present invention wherein each solenoid valve used in the above-mentioned systems can be calibrated to allow adjusting the current input to the solenoid valve to produce an identical valve stroke for all of the variably hydraulically controlled valves in a system in accordance with the present invention as equipped with different solenoids; and

Figure 19 is a schematic diagram of a control system utilising a plurality of calibrated solenoid valves and adjusting the valve opening characteristics in each of the cylinders of the internal combustion engine in accordance with the present invention.

A system that provides variable control of engine valve timing, lift and velocity is illustrated in Figure 1. The system exploits elastic properties of compressed hydraulic fluid which, acting as a liquid spring, accelerates and decelerates the valve during its opening and closing motions. During acceleration, some of the potential energy of the fluid is converted into kinetic energy of the valve. During deceleration, the energy of the valve motion is returned to the fluid. With the exception of leakage, most of the energy of the fluid is conserved.

In Figure 1, an engine valve 10 is located within a cylinder head 12 which includes a port 14 for inlet air or exhaust, as the case may be. Valve 10 includes a valve head 16 and a stem portion 18. Valve stem portion 18 includes a series of concentric cylindrical sections 20, 22, 24 and 26 of varying outer diameter. The sections 20 and 24 guide the valve for reciprocation within guide bore 28. Section 26 constitutes a valve piston slidable within the limits of piston chamber 30 which is concentric with guide bore 28 and also constitutes a part of the cylinder head.

Fluid is selectively supplied to the piston 26 from a high pressure rail 40 and a low pressure rail 42 hydraulically connected through lines 44 and 46, respectively, to high pressure port 48 and low pressure port 50, respectively.

Hydraulic systems maintaining necessary fluid pressures in the high and low pressure rails can be arranged in a variety of ways. A variable displacement pump 52 is included between a reservoir 54 and the high pressure rail. Since the fluid in the high pressure rail is subject only to expansion and contraction, the pumping work of the pump is largely limited to that necessary to compensate for internal leakage through clearances. The variable displacement pump 52 may be under automatic control whereby a pressure sensor 56 will produce a pressure feedback signal to a pump controller 58 in the event pressure in the high pressure rail drops below the set minimum required at any particular vehicle speed or other operating condition. This then varies the pump displacement to maintain the required pressure in the high pressure rail. Fluid in the low pressure rail 42 is maintained at a fixed low pressure by means of pressure pump 60 supplying fluid from reservoir 54 and pressure regulator 62.

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The volume above the piston 26 can be connected to the high pressure rail through a solenoid valve 64 or a check valve 66, or to the low pressure rail through solenoid valve 68 or a check valve 70. The volume below the piston 26 is always connected to the high pressure rail. Fluid return line 72 completes the system and provides the means for returning to the reservoir 54 any fluid which leaks past the piston 26 at either end to the chamber formed between guide bore 28 and the reduced diameter section 22 of the valve.

The process of a single valve 10 opening and closing is illustrated in Figures 2a-c and 3a-c. The arrows indicate the direction of fluid flow and valve motion as the case may be.

During the engine valve opening, the solenoid valve 64 opens and the net pressure force acting on the piston 26 accelerates the engine valve downward (Figure 2a). When the solenoid valve 64 closes, pressure above the piston 26 drops, and the piston decelerates pushing the fluid from the volume below it back into the high pressure rail (Figure 2b). Low pressure fluid flowing through the check valve 70 prevents void formation in the volume above the piston 26 during deceleration. When the downward motion of the valve stops, the low pressure check valve 70 closes and the engine valve remains locked in its open position (Figure 2c).

The process of engine valve closing is similar, in principle, to that of the valve opening. The solenoid valve 68 opens, pressure above the piston 26 drops and the net pressure force accelerates the engine valve upward (Figure 3a). Then the solenoid valve 68 closes and the rising pressure above the piston 26 opens the high pressure check valve 66 (Figure 3b). The direction of the net pressure force is reversed, and the engine valve decelerates pushing the fluid from the volume above the piston 26 back into the high pressure rail. When the engine valve exhausts its kinetic energy, the high pressure check valve 66 closes and the engine valve remains locked in its closed position (Figure 3c). A brief reopening of the solenoid valve 68 assures that the engine valve is firmly pressed against its seat.

Varying the timing of activation of the two solenoid valves varies the timing of the engine valve opening and closing. Valve lift can be controlled by varying the duration of the solenoid voltage pulse. Changing fluid pressure in the high pressure rail permits control of valve acceleration, velocity and travel time. All this permits considerably greater flexibility in engine valve operation control than is possible in conventional cam driven valve trains; flexibility which, in effect, is equivalent to ability to vary the size and the shape of the cam while the engine is running.

In engines with more than two valves per cylinder, a single pair of solenoid valves can activate several intake (or exhaust) valves simultaneously. This is shown in Figure 4 where the high pressure and low pressure solenoid valves 64 and 68, respectively, activate two engine valves 10 and 110 when the control valves 74 and 76 are open. if the control valves 74 and 76 are closed, only the engine valve 10 is activated. The manner of operation of each engine valve 10,110 is otherwise as described above with reference to Figures 1-3. Like reference numerals are used to illustrate this structural identity except with the second engine valve 110, components identical to the first valve 10 are prefixed in the "100" series.

In Figure 5, there is shown another embodiment wherein the high pressure line 44 to the piston 26 includes only a single solenoid valve 70. The high pressure check valve 66 from Figures 1-4 is eliminated. Otherwise, structurally, the system is the same as shown in the embodiments of Figures 1-4.

In operation, solenoid valve 64 is actuated twice during each valve cycle, rather than once as previously described, since its actuation must duplicate the functioning of the eliminated check valve 68. Specifically, during the closing stroke, to effect deceleration of engine valve 10 (Figure 3b of the previous embodiment), the solenoid valve 64 is opened to allow fluid to be pushed back into the high pressure rail. At a point in time when the kinetic energy of the engine valve is calculated to be expended, the solenoid valve 64 is closed and the engine valve remains locked in position.

In the arrangements shown in Figures 6-15, there is provided a system whereby the two solenoid valves 64 and 68 control the operation of a group of two or more engine valves. One of the solenoid valves 64 controls the opening motion of the engine valves while the other one 68 is dedicated to control of the closing motion, as previously described. During each cycle of a solenoid valve opening and closing one of the engine valves is brought into motion, in much the same manner previously described in regard to Figures 1-4.

One of the key components of the system is a pair of rotary hydraulic distributors each coupled with a respective solenoid valve 64,68. An example of the rotary hydraulic distributor, generally designated 200, is illustrated in Figures 6 and 7. A normally closed solenoid valve 64 separates the inside of a rotatable distributor sleeve 210 from the source of pressurised fluid, namely for purposes of this discussion, the high pressure rail 40. The distributor sleeve 210 can rotate within an outside stationary sleeve 212, which has several equally radially spaced ports 214 about its circumference, each connected to a separate outlet line 48a-d. The

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distributor sleeve 210 has a single radial passage 218 which, during each revolution, connects the inside of the distributor sleeve with each of the outlet ports 214 in succession. During engine operation, the distributor sleeve rotates with half the crankshaft speed, and the solenoid valve is opened each time the radial passage 218 is in register with one of the ports 214. The timing and duration of solenoid valve opening may vary within the window of the passage 218 and each port 214 registration.

During the valve opening, the high pressure solenoid valve 64 is connected to the engine valve through its rotary distributor. The solenoid valve 64 opens and the net pressure force acting on the piston 26 accelerates the engine valve 10 downward (Figure 8a). When the solenoid valve 64 closes, pressure above the piston 26 drops, and the piston decelerates pushing the fluid from the volume below it back into the high pressure rail (Figure 8b). Low pressure fluid flowing through the check valve 70 prevents void formation in the volume above the piston 26 during deceleration. When the downward motion of the valve stops, the check valve 70 closes and the engine valve remains locked in its open position (Figure 8c). During the opening period, the action at the solenoid valve 68 has no effect on this engine valve, since there is no connection between them through the rotary hydraulic distributor 200 of the solenoid valve 68.

The process of valve closing is similar, in principle, to that of the valve opening. This time, it is the low pressure solenoid valve 68 which is connected to the engine valve through its rotary distributor, while the high pressure solenoid valve 66 is disconnected. The low pressure solenoid valve 68 opens, pressure above the piston 26 drops and the net pressure force accelerates the engine valve upward (Figure 9a). Then the solenoid valve 68 closes and the rising pressure above the piston 26 opens the check valve 66 (Figure 9b). The direction of the net pressure force is reversed, and the engine valve decelerates pushing the fluid from the volume above the piston 26 through line 44 and back into the high pressure rail 40. When the engine valve exhausts its kinetic energy, the check valve 66 closes and the engine valve remains locked in its closed position (Figure 9c). Proper selection of solenoid valve 68 opening duration is, of course, to be determined to assure proper engine valve closing.

As with the previously described embodiment, varying the (i) timing of activation of the two solenoid valves varies the timing of the engine valve opening and closing, (ii) duration of the solenoid voltage pulse controls valve lift, and (iii) fluid pressure in the high pressure rail permits control of valve acceleration, velocity and travel time. Again, the advantage incurred is greater flexibility in engine valve operation control than is possible in conventional cam driven valve trains.

The previous description, which was illustrated in Figures 8a-c and 9a-c was limited to a case of a single valve operation. Figures 10-13 illustrate a case in which a pair of solenoid valves with rotary hydraulic distributors successively operate four valves in four engine cylinders, namely either four intake valves or four exhaust valves. Taken together, Figures 10-13 depict a series of events taking place during a single 720° engine cycle and separate from each other by 90° of rotary distributor angle (180° crankshaft angle). The engine firing order is cylinder Nos. 1-3-2-4.

In Figure 10, the high pressure solenoid valve 64 is open and the engine valve No. 1 is accelerated toward opening. The low pressure solenoid valve 68 is open also and engine valve No. 4 accelerates while moving toward its closed position. only lines in which fluid motion takes place are shown in the drawing.

In Figure 11, the solenoid valves 64 and 68 are open again, but, due to new positions of their rotary distributors 200, this time it is valve No. 3 which moves toward opening, while valve No. 1 is closing.

In Figure 12, the position of rotary distributors 200 is such that valve No. 2 is opening while valve No. 3 is closing, and in Figure 13 valve No. 4 is opening while valve No. 2 is closing. After that, the entire sequence is repeated again during each engine cycle.

As mentioned, the engine valves shown in Figures 10-13 could be four intake valves or four exhaust valves in four engine cylinders. However, they could also be one intake and one exhaust valve in one cylinder and another pair of intake and exhaust valves in another cylinder which is 360° crankshaft out of phase with the first one (for example, cylinders No. 1 and 2). In that case, the operational order would be: No. 1 exhaust, No. 1 intake, No. 2 exhaust, No. 2 intake. This is illustrated in Figures 10a-13a. As it was the case in Figures 10-13, the solenoid valves 64 and 68 are open in every case but, in each case, the rotary distributors 200 connect the solenoid valves to a different pair of engine valves. In Figure 10a, the No. 1 exhaust valve accelerates toward the opening and the No. 2 intake valve accelerates toward closing. In Figures 11a, the No. 1 intake valve accelerates toward opening, and the No. 1 exhaust valve accelerates toward closing. In Figure 12a, the No. 2 exhaust valve accelerates toward opening, and the No. 1 intake valve accelerates toward closing. In Figure 13a, the No. 2 intake valve accelerates toward opening, and the No. 2 exhaust valve accelerates toward closing. In a similar manner, the

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valves in cylinders No. 3 and 4 can be controlled. The operational order would be: No. 4 intake, No. 3 exhaust, No. 3 intake, No. 4 exhaust.

Figure 14 is a schematic diagram of hydraulic connections between the solenoid valves with their rotary hydraulic distributors and the engine valves they control as discussed above and illustrated in Figures 10a-13a. Solenoid valves 64 and 68 control the intake and exhaust engine valves in cylinders No. 1 and No. 2, and another pair of solenoid valves, 64' and 68', identical to valves 64 and 68, control the intake and exhaust engine valves in cylinders No. 3 and No. 4. Figure 15 shows an example of valve lift profiles in the four cylinder engine valve control system depicted in Figure 14.

The system of solenoid valves coupled with rotary hydraulic distributors was described above as applied to a specific concept of variable valve control. It is clear, however, that application of such a system is not limited to any specific concept and can be applied to many other variable valve control systems in which solenoid valves are used to control the engine valves motion.

Valve motion control by means of solenoid type control valves is also used in variable valve systems known as "lost motion" systems. An example of a lost motion valve control system is diagrammatically shown in Figure 16. It is a well known system and as such forms no part of this invention.

A cam 300 drives a cam plunger 302. The motion of the plunger 302 is transmitted through fluid filling a passage 304 to a valve plunger 306 driving the valve 308. Fluid leaking out of the system is replenished from a supply gallery 310 through a check valve 312. As long as the solenoid valve 314 remains closed, the motion of the valve 308 is determined by the profile of the cam 300. Opening the solenoid valve 314 permits some of the fluid to escape from the passage 304 into the supply gallery 310. As a result, motion of the valve 308 becomes different from that dictated by the profile of the cam 300. By varying the solenoid voltage pulse timing and duration, various shapes of the valve lift versus time curve can be obtained.

One of the most important advantages of the variable valve control is the ability to control the amount of air inducted into the engine cylinders by controlling the valve operation rather than by means of throttling the air flow. This permits elimination of a substantial portion of engine throttling losses and improvement in the fuel efficiency. In addition to improved fuel efficiency, skillful application of variable valve control can lead to improvements in combustion stability, maximum power and exhaust emissions. It is important, however, to prevent cylinder-to-cylinder intake air maldistribution. In engines with carburettors or with single point central fuel injection, uneven intake air distribution would lead to unequal power developed by individual cylinders. in engines with multi-point port fuel injection or with direct in-cylinder injection, intake air maldistribution would result in cylinder-to-cylinder variations in air-to-fuel ratios. Such deficiencies can cancel out the benefits of variable valve control.

The amount of air inducted into an engine cylinder is dependent on the engine intake valve lift and opening duration. Therefore, to assure equal air distribution, it is imperative that the valve lift and duration of opening in all cylinders are the same. Since the motion of the valves is controlled by solenoid valves, this amounts to a requirement that all solenoid valves in the system, given the same signal, produce identical results in terms of valve motion.

The accuracy of the cylinder-to-cylinder air distribution is also affected by the accuracy of exhaust valve motion control. Therefore, in variable valve control systems controlling both intake and exhaust valves, similar requirements should be applied to both kinds of valves.

Referring to Figure 17, the normally closed solenoid valve parameter which determines the engine valve motion is the solenoid valve opening duration $\underline{t}$. In systems using normally open solenoid valves it would be the closing duration. It is a function of the solenoid voltage pulse duration $\underline{t}_s$, but it differs from the latter by solenoid valve activation and deactivation delays, $\underline{t}_a$ and $\underline{t}_d$, respectively. This is illustrated in Figure 17 showing a graph of the solenoid voltage pulse versus time and corresponding graphs of the solenoid current and valve motion versus time. The activation and deactivation delays can vary from solenoid to solenoid due to differences associated with inevitable manufacturing tolerances. As a result, different solenoid valves receiving the same control voltage signal may exhibit different solenoid valve opening durations and, consequently, have different effects on the engine valve motion.

To ensure that the engine valve motion of all common valves (intake or exhaust) in all cylinders is identical, the solenoid valve opening duration in each solenoid must be the same. This is accomplished by modifying the duration of the voltage pulse sent to each individual solenoid, so as to compensate for variations in the activation and deactivation delays. The required correction in control pulse duration can be determined experimentally during solenoid testing and encoded on a tag attached to the solenoid valve. Subsequently, the information on the tag can be read and used by the engine electronic control system.

A conventional calibration device (not part of this invention) may be used to determine the cor-

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rection required for individual solenoid valves. The device is intended for calibration of high pressure solenoid valves for a system such as illustrated in Figures 1-13. The calibration device would be connected to high and low fluid pressure sources. The device would need to include two solenoid valves. One of the two solenoid valves would be a permanent part of the device and have a verified standard characteristic. The other solenoid valve, e.g. the solenoid valve 64 shown in Figure 1, would be the one subject to testing.

During the test, both the solenoid valves in the calibration device are activated by voltage signals of a predetermined duration with some frequency, and the stroke of an engine valve forming a part of the calibration device and preferably identical to the engine valve 10 would be measured by a sensor. If the measured stroke differs from the expected standard one, the duration of the pulse applied to the solenoid valve 64 being calibrated is modified until the stroke of the engine valve corresponds to the required one. The final incremental value of the pulse duration added to or subtracted from the initial predetermined duration can be called the correction number of the solenoid valve. Different solenoid valves may have different correction numbers, but what is important is that if any of them is activated by a voltage pulse consisting of standard pulse duration, to which its individual correction number is added or subtracted, they will all produce the same valve lift. Since the correction number compensates for solenoid-to-solenoid variations in activation and deactivation delays, which do not vary with change in pulse duration and frequency, the correction determined under one set of conditions remains valid for any pulse duration and frequency.

Figure 18 shows a diagram of a solenoid valve calibration system which includes the above described calibration device and individually calibrates at least each high pressure solenoid valve 64 to be used in the variable engine valve control system of this invention. The calibration device 400 is operated and controlled by an electronic controller 402 programmed to send out an initial standard solenoid control pulse, to receive and interpret the valve stroke signal, and to modify the duration of the control signal until the required valve stroke is achieved. when this is accomplished, the controller activates a printer 404 which prints and issues a tag 406 with the solenoid valve correction number ex-pressed in the form of a binary bar code. The tag 406 can be glued or otherwise attached to the solenoid valve. When each solenoid valve 64 is installed on the engine, its tag is detached from it and glued or otherwise attached to a rotatable member as described below which rotates with half the crankshaft speed during engine operation (in case of a two-stroke engine, this would be equal to crankshaft speed). The location of each tag on the rotating member depends on which cylinder its solenoid valve is installed.

As shown diagrammatically in Figure 19, a sensor is installed in proximity of a rotating member 502 and reads the bar code on each tag 406 as it passes by the sensor and sends this information to the engine electronic control system 504. The relative location of all the tags 406 on the rotating member is such that the engine control system successively receives information encoded in each tag just before its solenoid is to be actuated. The duration of the basic control signal computed for all solenoid valves controlling all engine intake (or exhaust) valves is determined by the control system as a function of engine operating parameters designated generally as input line 506, such as speed, load, etc. and is common to all intake (or exhaust) valves. The basic signal 508 is modified by addition or subtraction of the most recently received value of correction signal 510 and the corrected signal 512 is then relayed to the appropriate control solenoid valve 64, for example at cylinder No. 1 of engine 514 as shown, for that particular engine valve operation. Thus, tag 406-1 corrects the solenoid valve 64 at cylinder No. 1, as does tag 406-2 at cylinder 2, and so on. Therefore, each solenoid valve receives its own individualised corrected control signal which compensates for solenoid-to-solenoid differences and assures that at a given value of the basic control signal all engine intake (or exhaust) valves will perform in an identical manner.

The above described method of determining correction required for individual solenoid valves is not limited to the system illustrated in Figures 10-13. It is fully applicable to a variety of other systems. In each case the tested solenoid valve is installed in a calibration device representing a variably controlled single engine valve and run with a predetermined pulse which is subsequently modified until the required standard pattern of valve motion is achieved. The method is applicable to the lost motion system and numerous other systems.

Claims

1. An engine valve control system of an internal combustion engine in which the valve stroke is controlled by varying timing and duration of electric signals sent to individually dedicated engine valve controlling means, the system comprising:

   a controller programmed to send variable electric control signals (512) to the said engine valve controlling means (64),said control sig-

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nals duration comprising the algebraic sum of a basic signal duration (508) and a correction signal duration (510)

means (504) for generating a basic signal duration determined by the controller as a function of engine operating conditions and being equal for all engine intake valves and equal for all engine exhaust valves; and

means (500,502) for generating a correction signal predetermined for each of the engine valve controlling means as a measure of the extent the performance of each engine valve controlling means varies from a predetermined standard, said correction signal generating means being operative in timed sequence to supply to the controller said predetermined correction signal just prior to a respective engine valve controlling means being activated.

2. A system as claimed in claim 8, wherein said correction signal generating means (50,502) comprises:

a rotatable member (502) having individual codings thereon in spaced sequence, each coding representing a specific engine valve controlling means and containing information on the correction signal required by the said specific engine valve controlling means; and

a sensor (500) installed in proximity of the said rotatable member, said sensor being capable of reading the information contained in each coding on the rotatable member as it passes the sensor and transmitting said reading as a correction signal to said controller.

3. A system as claimed in claim 2, wherein each said coding is in the form of a tag and each tag is affixed to said rotatable member;

means for rotating said rotatable member during engine operation with an angular velocity equal to half the crankshaft velocity on a four-stroke engine and equal to crankshaft velocity on a two-stroke engine, whereby said sensor will read the information on individual tags successively passing the proximity of the sensor and transmit a respective correction signal to the controller, the location of individual tags on said rotatable member being such that the information on each tag is read and sent to the control system just before the engine valve controlling means for which the tag was coded must be actuated.

4. A system as claimed in claim 1, including:

a high pressure source of fluid and a low pressure source of fluid;

a cylinder head member adapted to be affixed to the engine and including a plurality of enclosed cavities; a plurality of poppet valves, each being associated with a respective one of said plurality of enclosed cavities;

each said poppet valve being shiftable between a first and second position within said cylinder head member;

a hydraulic actuator including a piston coupled to each said poppet valve and reciprocable within the respective enclosed cavity which thereby varies in displacement as each poppet valve moves;

said cylinder head member having a high pressure port extending between the enclosed cavities and the high pressure source of fluid and a low pressure port extending between the enclosed cavities and the low pressure source of fluid;

a high pressure valve and a low pressure valve for respectively regulating the flow of fluid in the high pressure and the low pressure ports of each of said plurality of enclosed cavities;

control means co-operating with the high and low pressure valves for selectively coupling the enclosed cavities to the high pressure and low pressure sources to oscillate each poppet valve in timed relation to engine operation, wherein the net fluid flow between the high pressure and low pressure sources is substantially less than the volume swept by the piston;

said control means including means for controlling (i) the notion of each said poppet valve by varying the timing and duration of the said control means actuation, (ii) the timing of the valve opening and closing motions of each poppet valve by varying the timing of said control means actuation, and (iii) the stroke of each said poppet valve by varying the duration of said control means actuation; and

means for varying the pressure of the pressurised fluid whereby the acceleration, velocity and travel time of each poppet valve may also be controlled.

5. A system as claimed in claim 4, wherein said control means includes said individual engine valve controlling means for each said poppet valve, whereby the duration of the control signal may be individually adjusted for each engine valve controlling means in all cylinders so as to assure equal poppet valve strokes in all cylinders.

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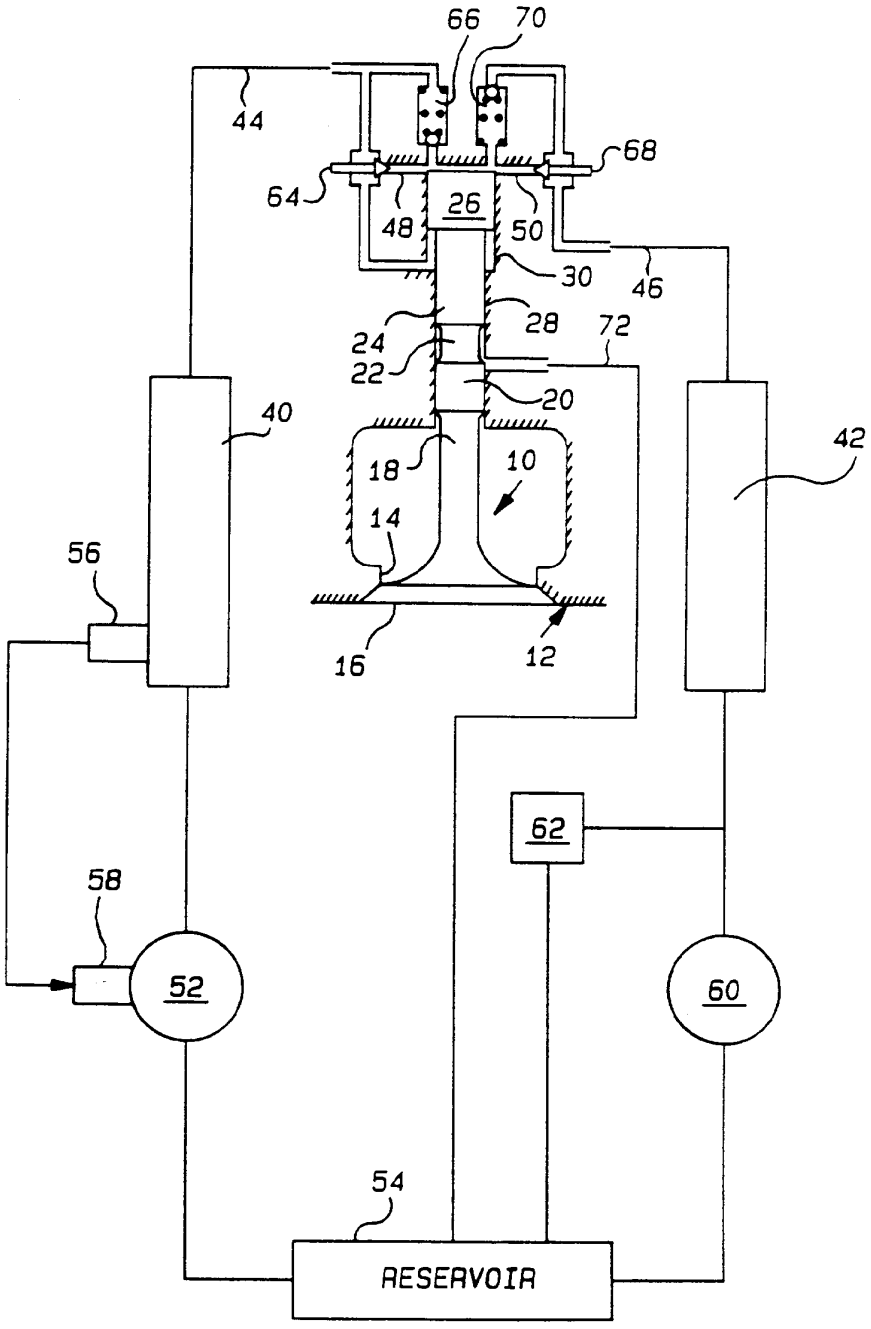


Fig-1

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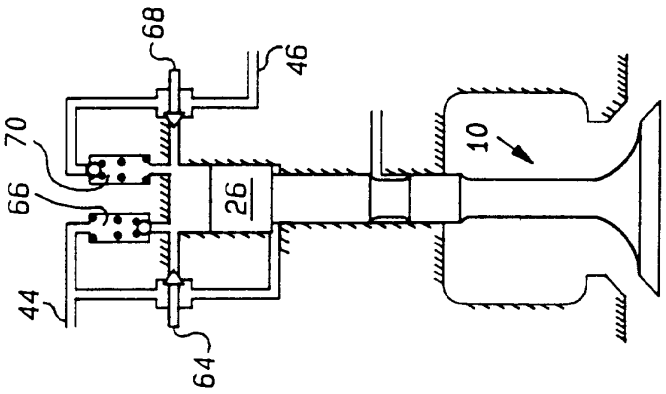


Fig-2c

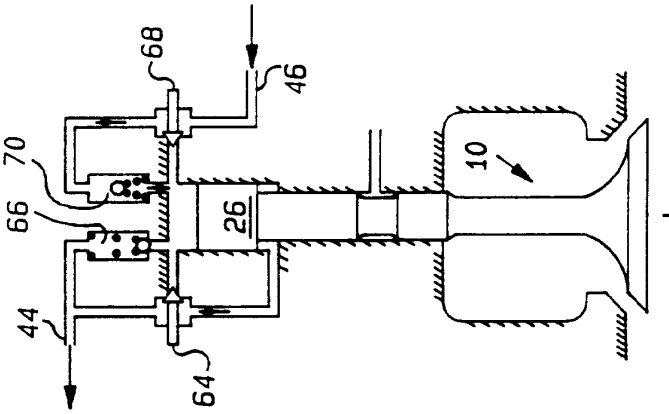


Fig-2b

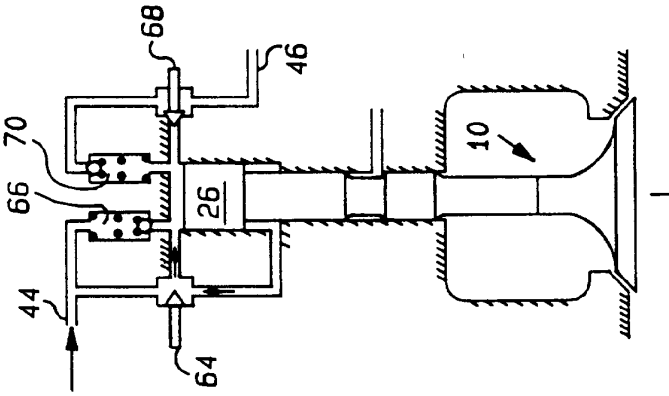


Fig-2a

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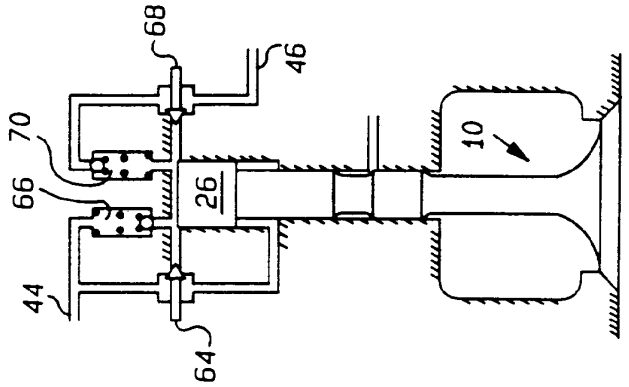


Fig-3c

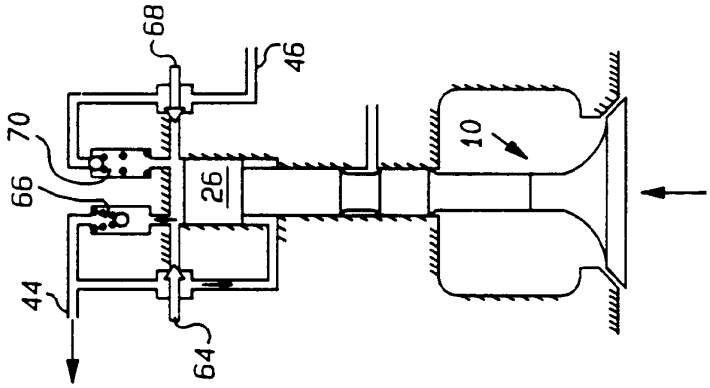


Fig-3b

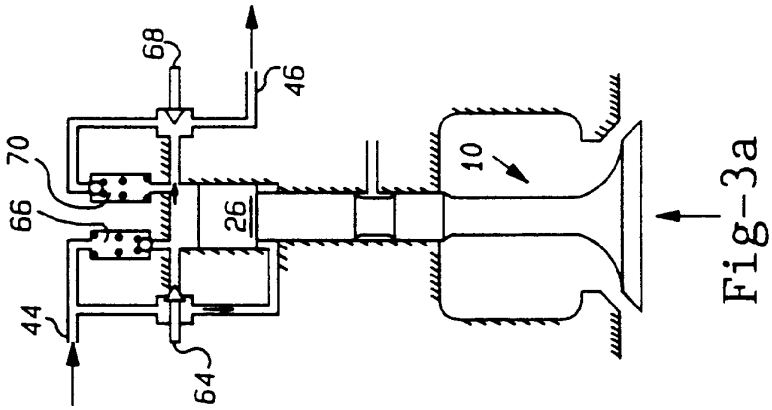


Fig-3a

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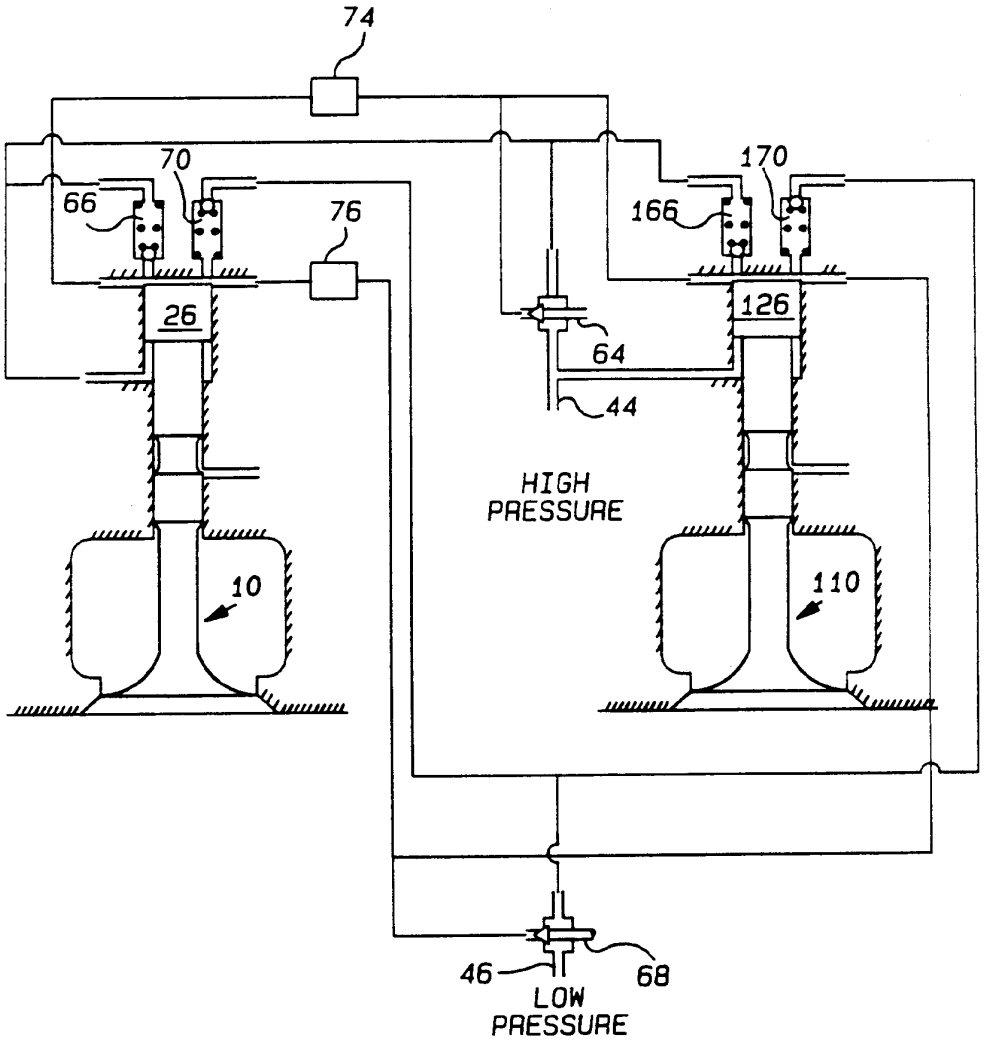


Fig-4

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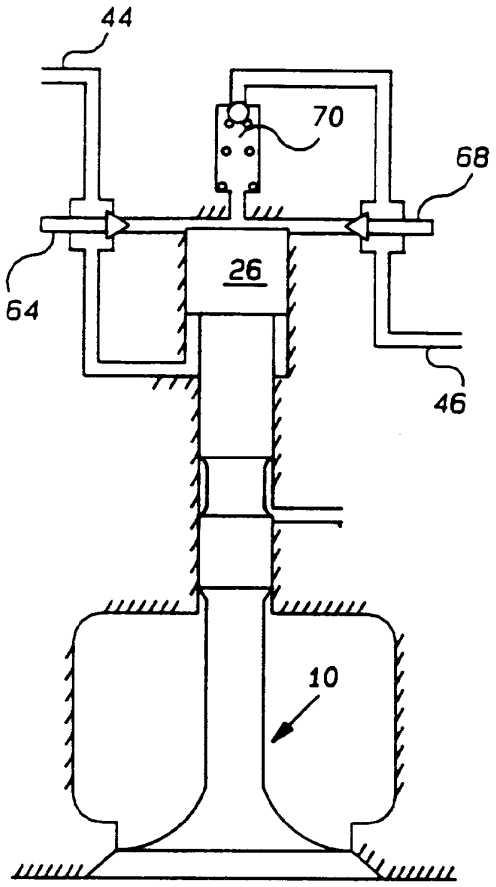


Fig-5

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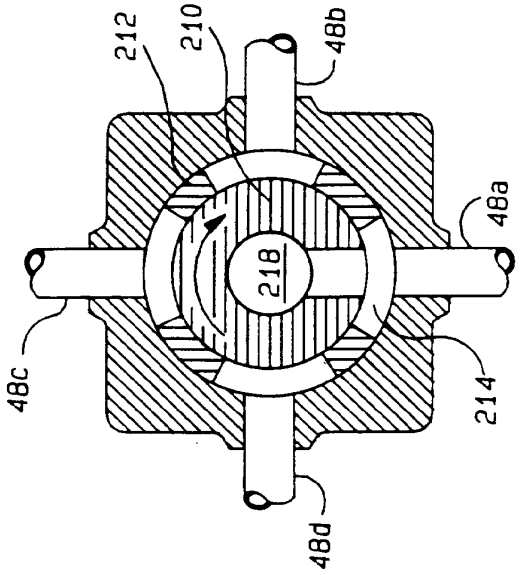


Fig-7

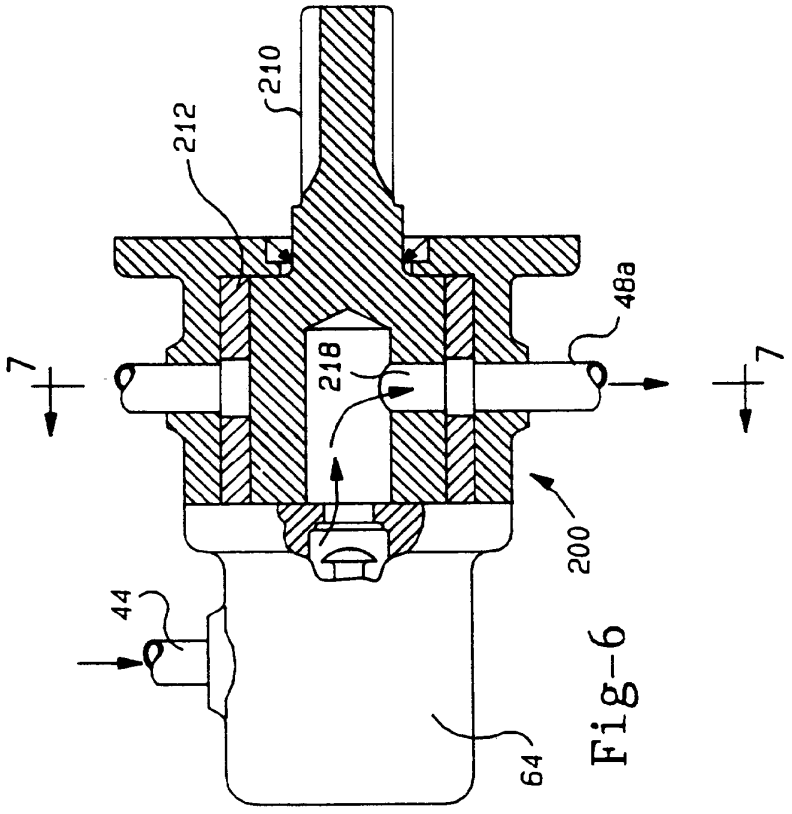


Fig-6

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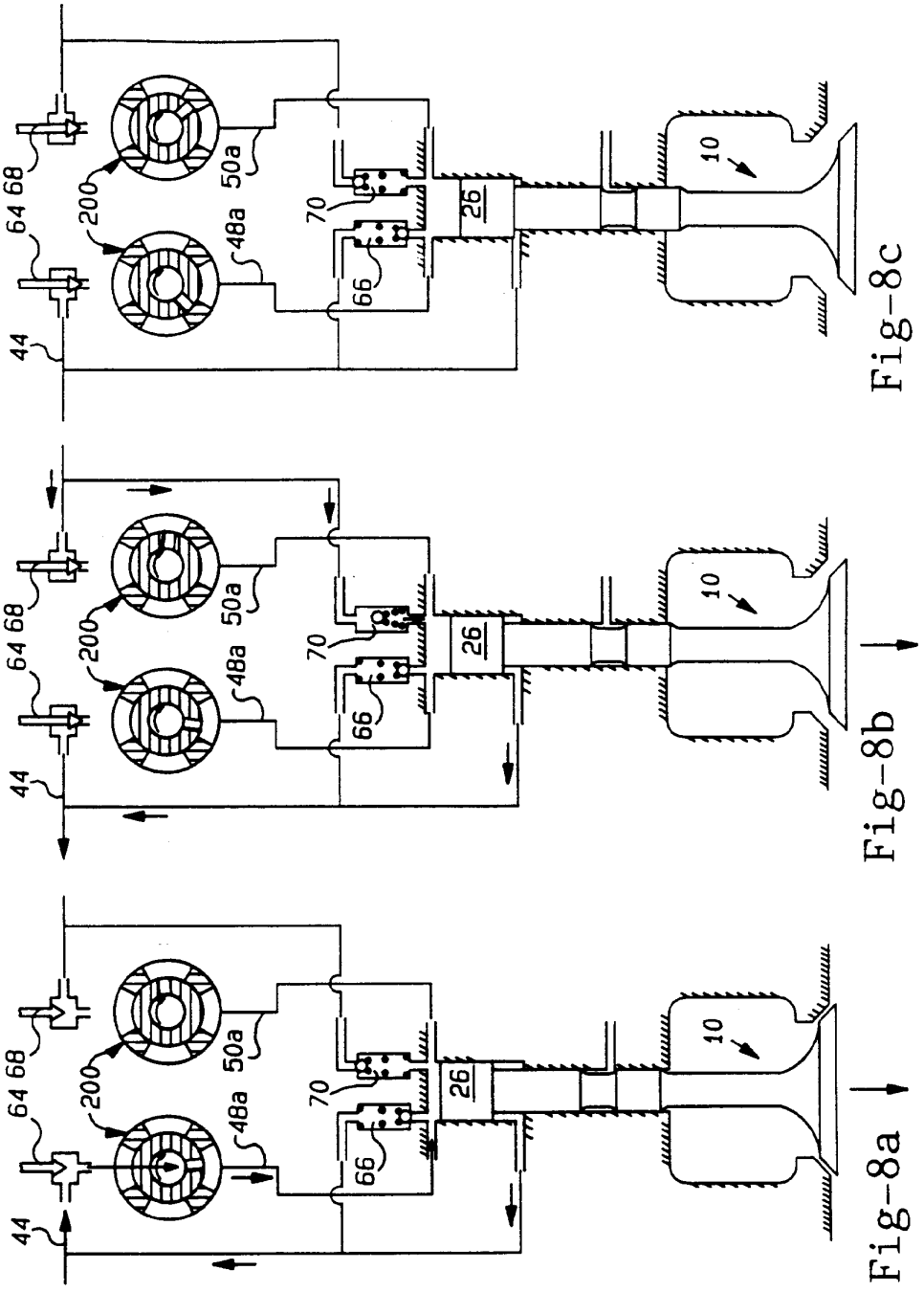


Fig-8c

Fig-8b

Fig-8a

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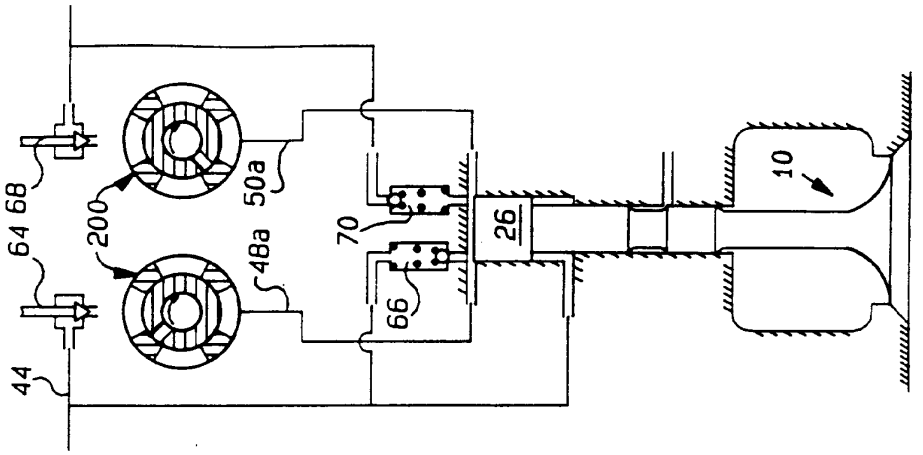


Fig-9c

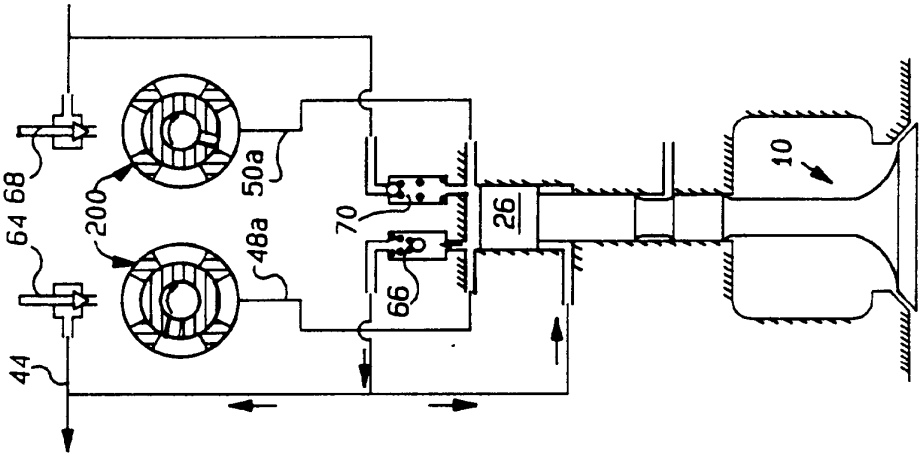


Fig-9b

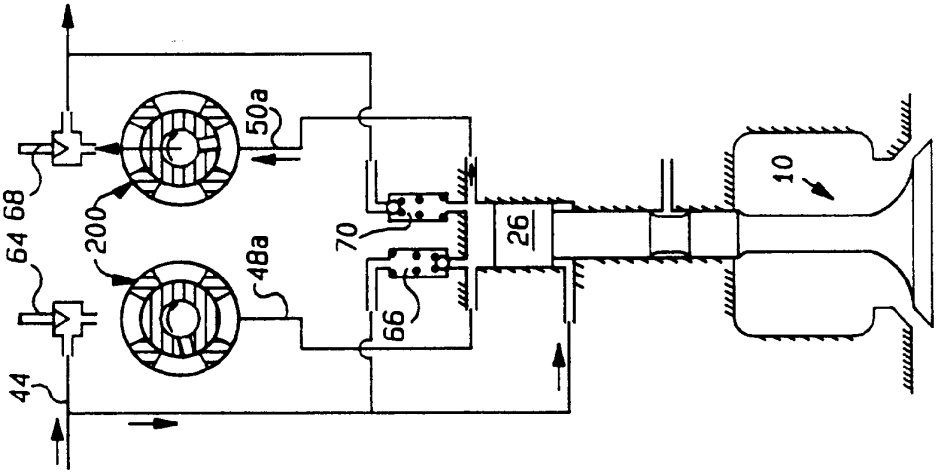


Fig-9a

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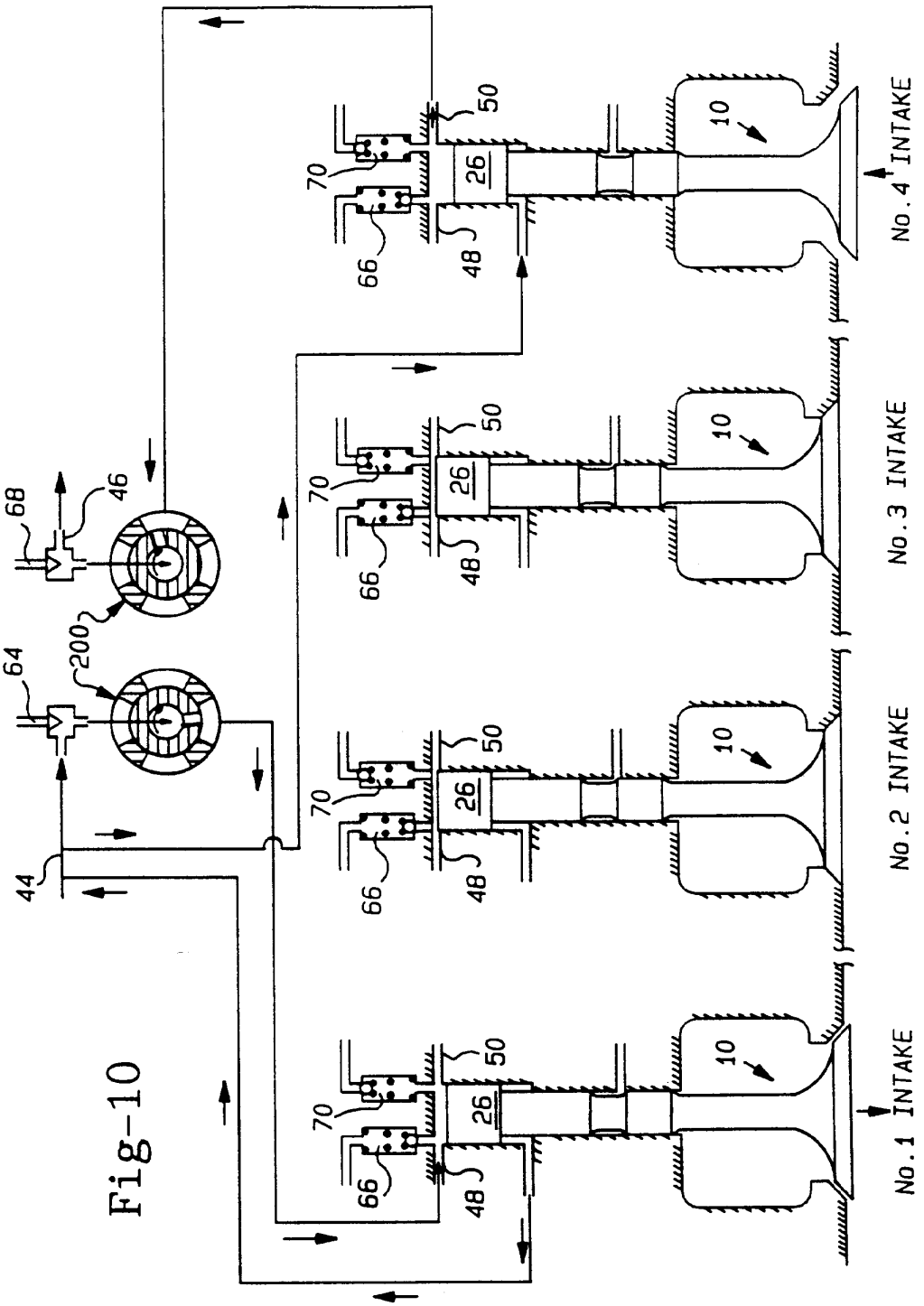


Fig-10

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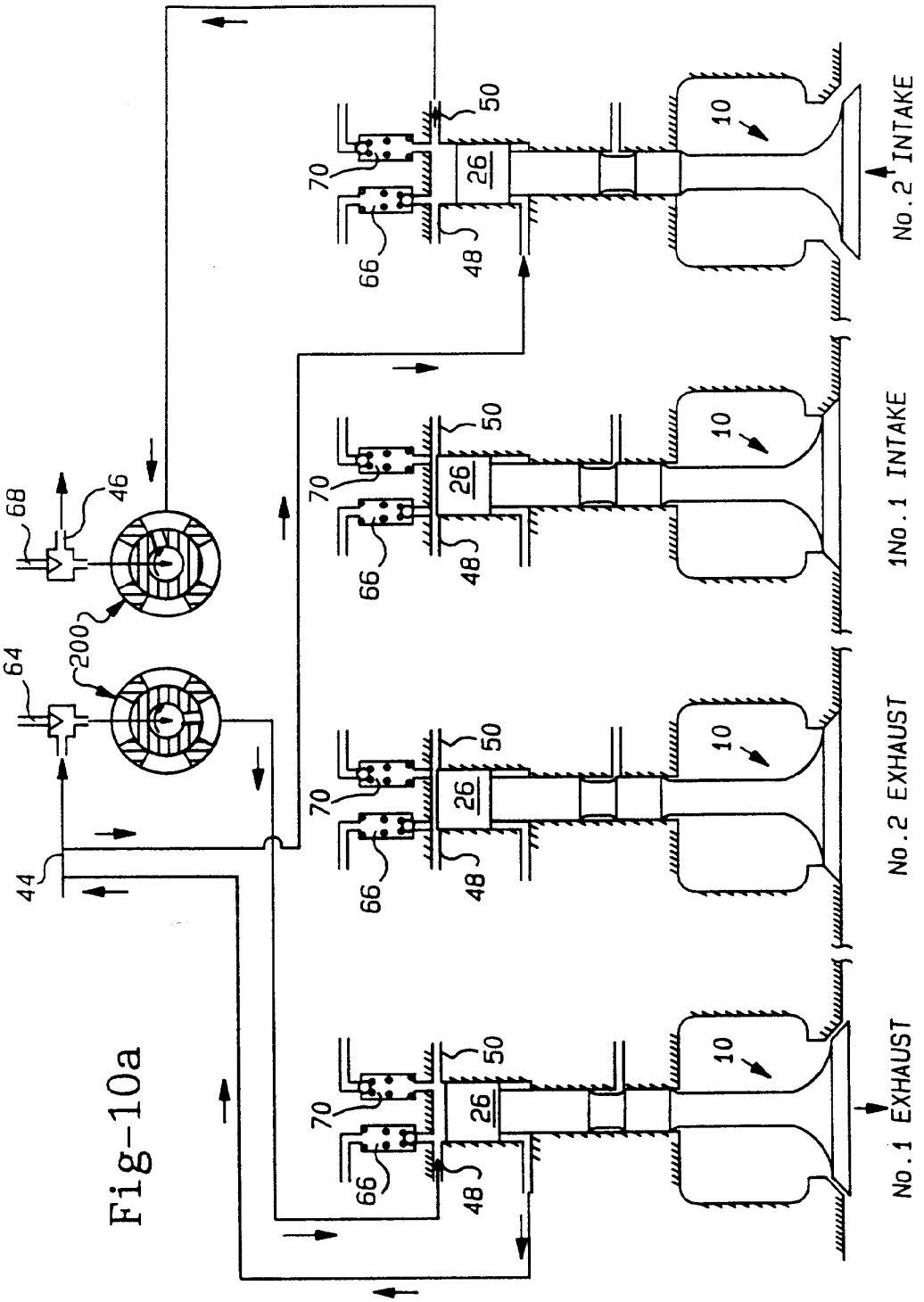
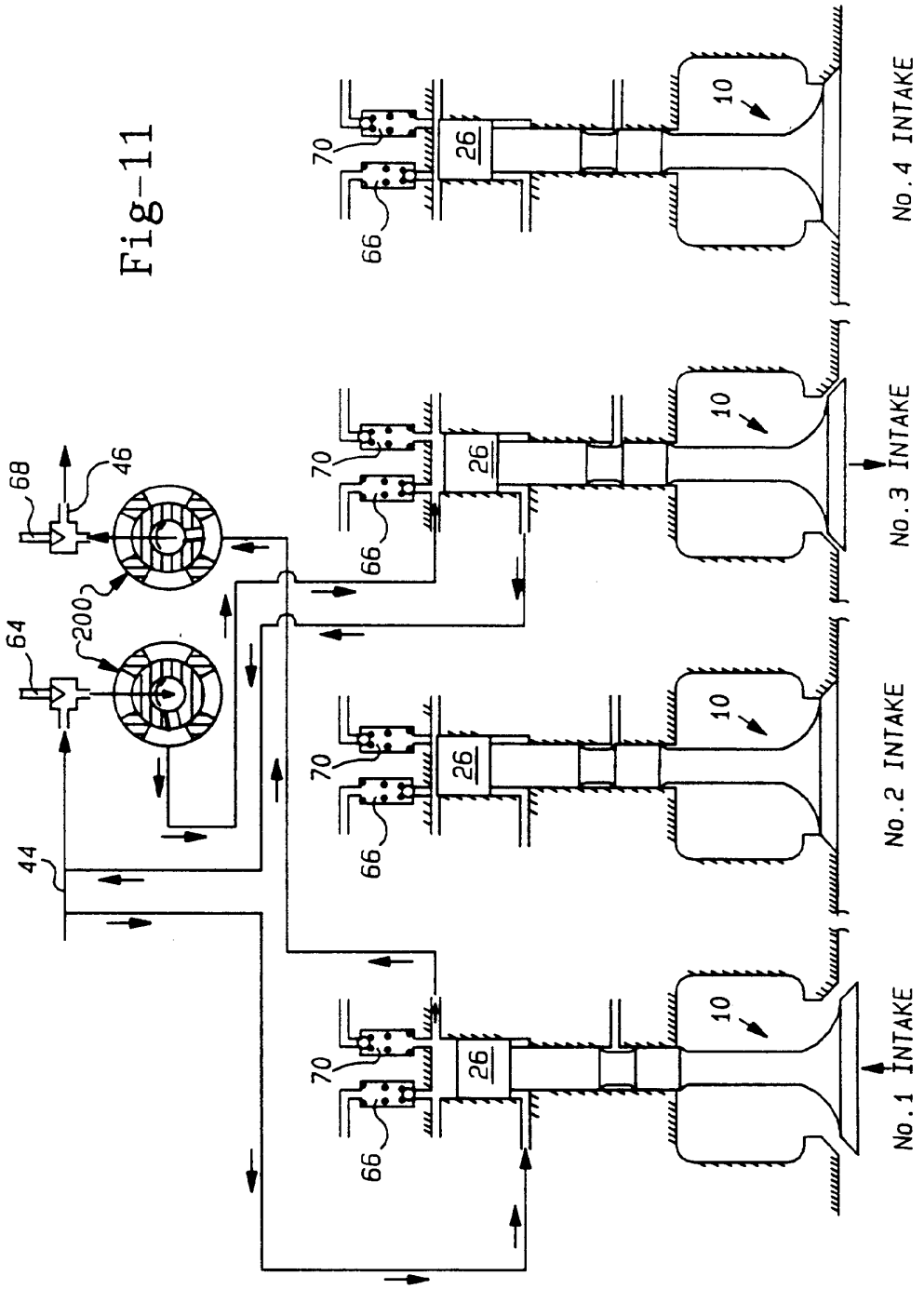


Fig-10a

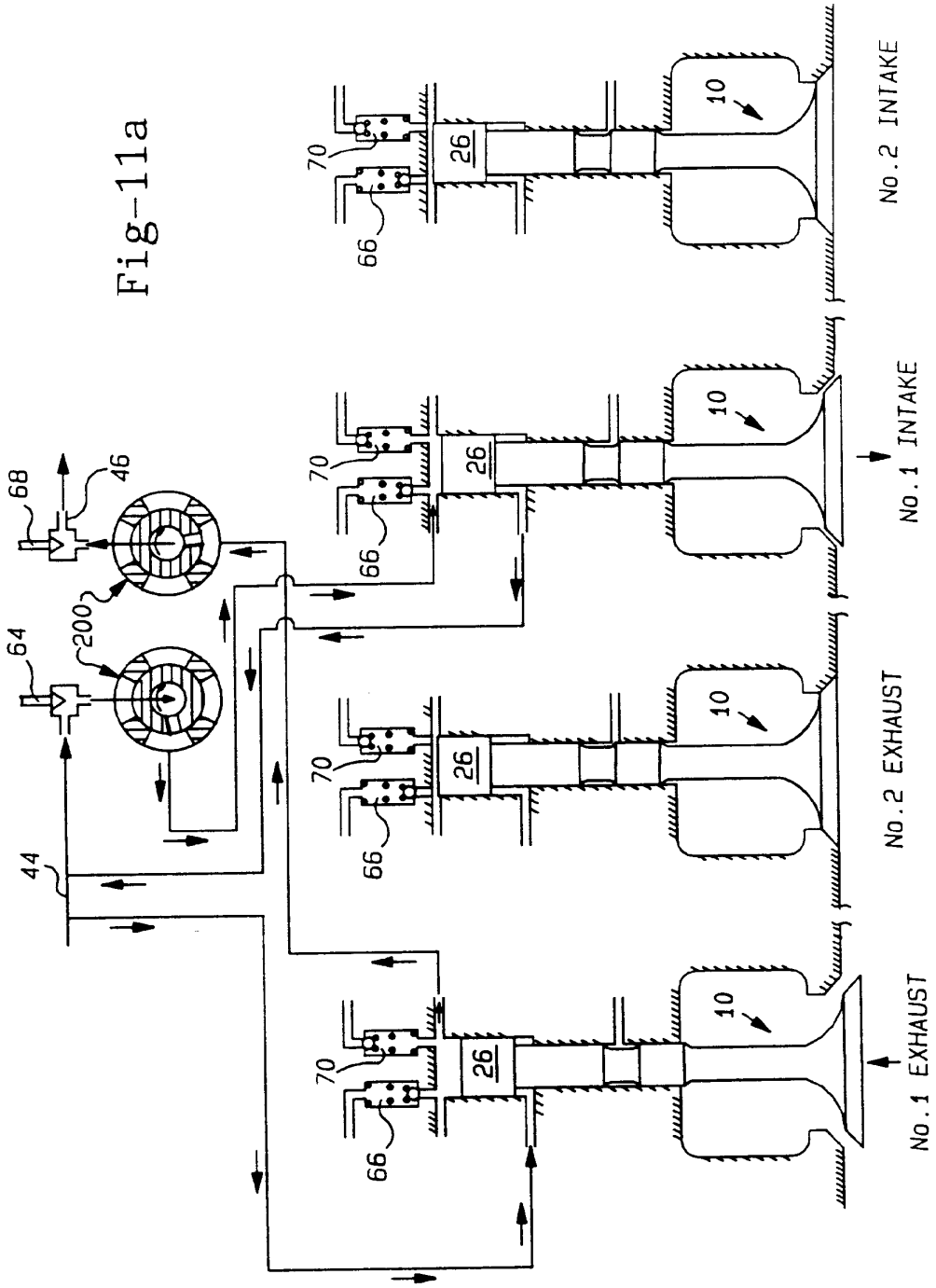
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Fig-11



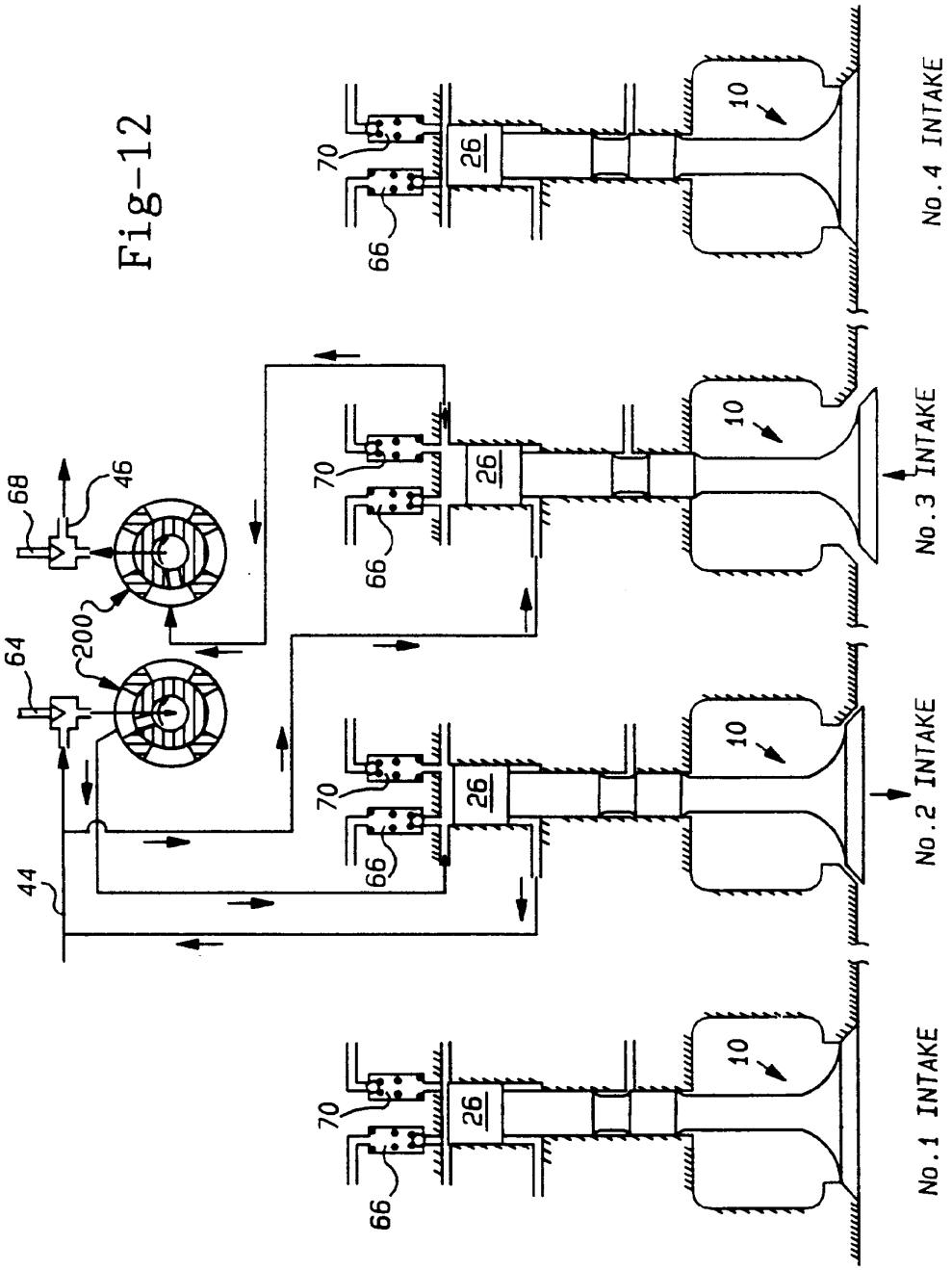
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Fig-11a



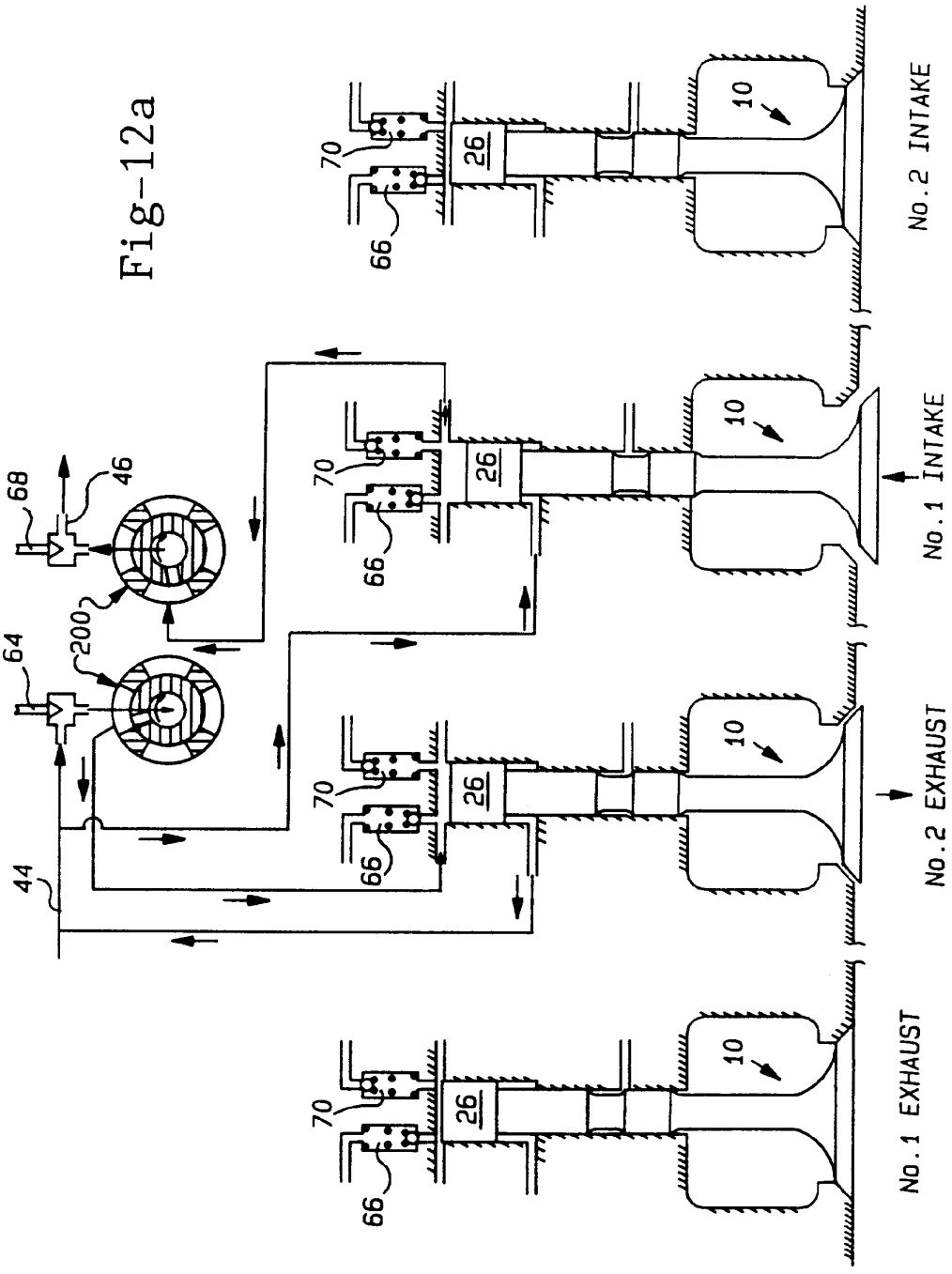
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Fig-12



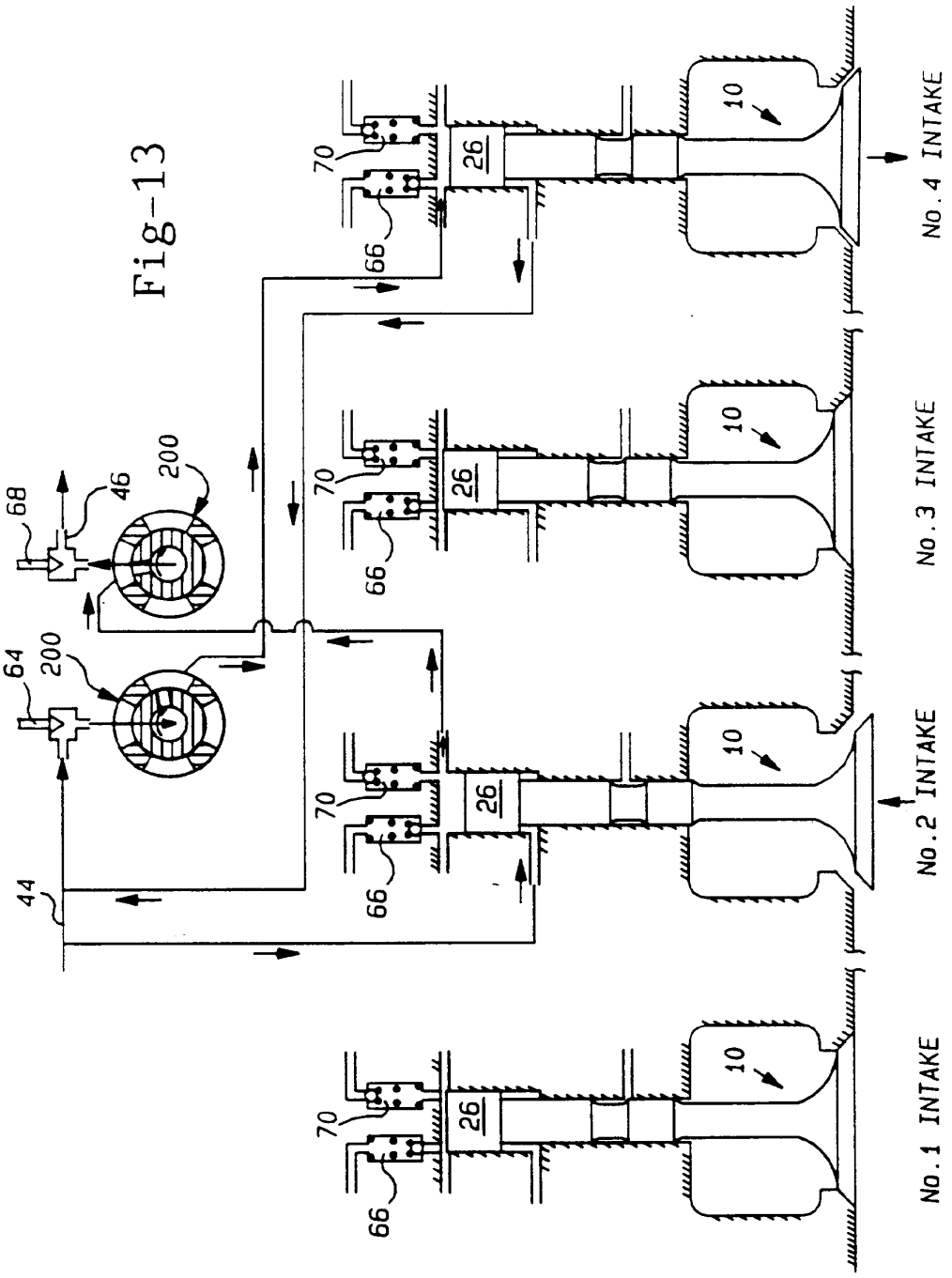
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Fig-12a



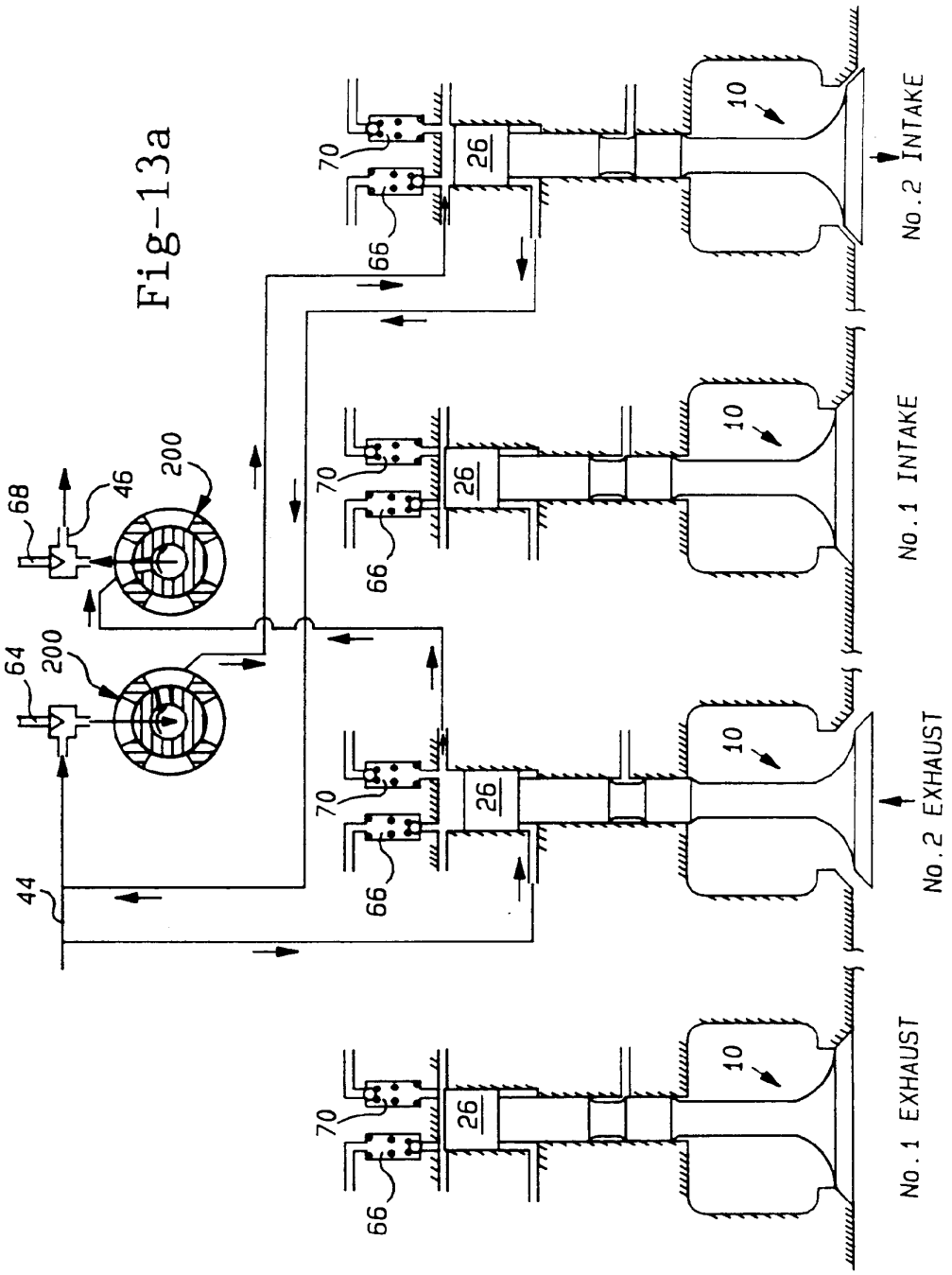
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Fig-13



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Fig-13a



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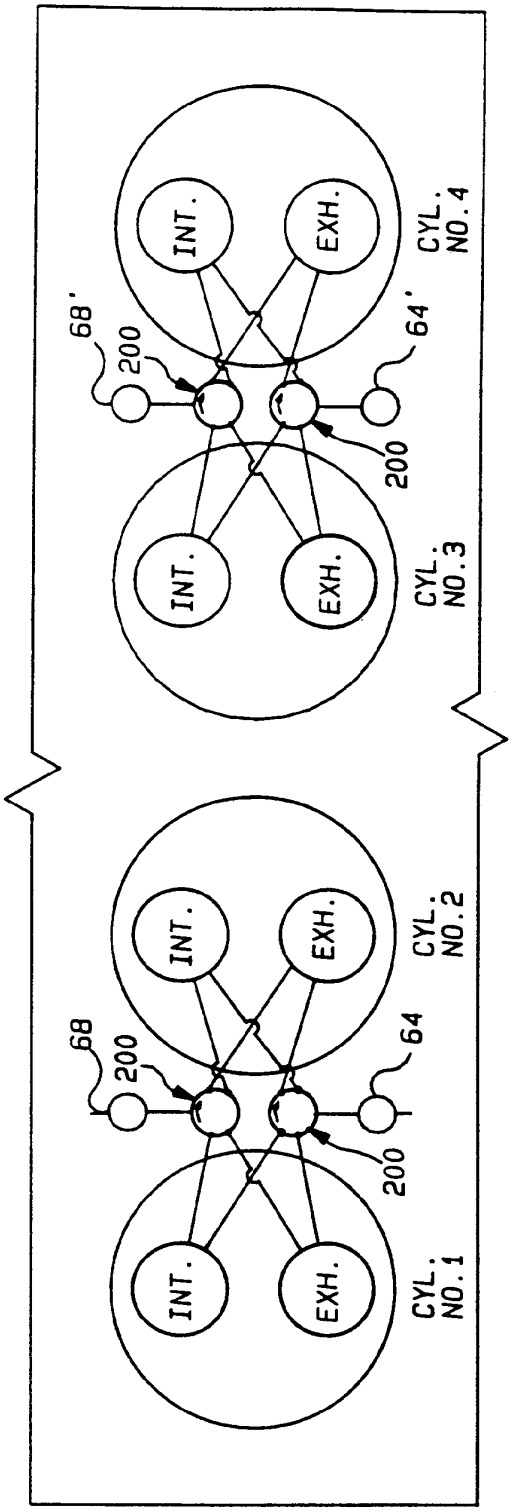


Fig-14

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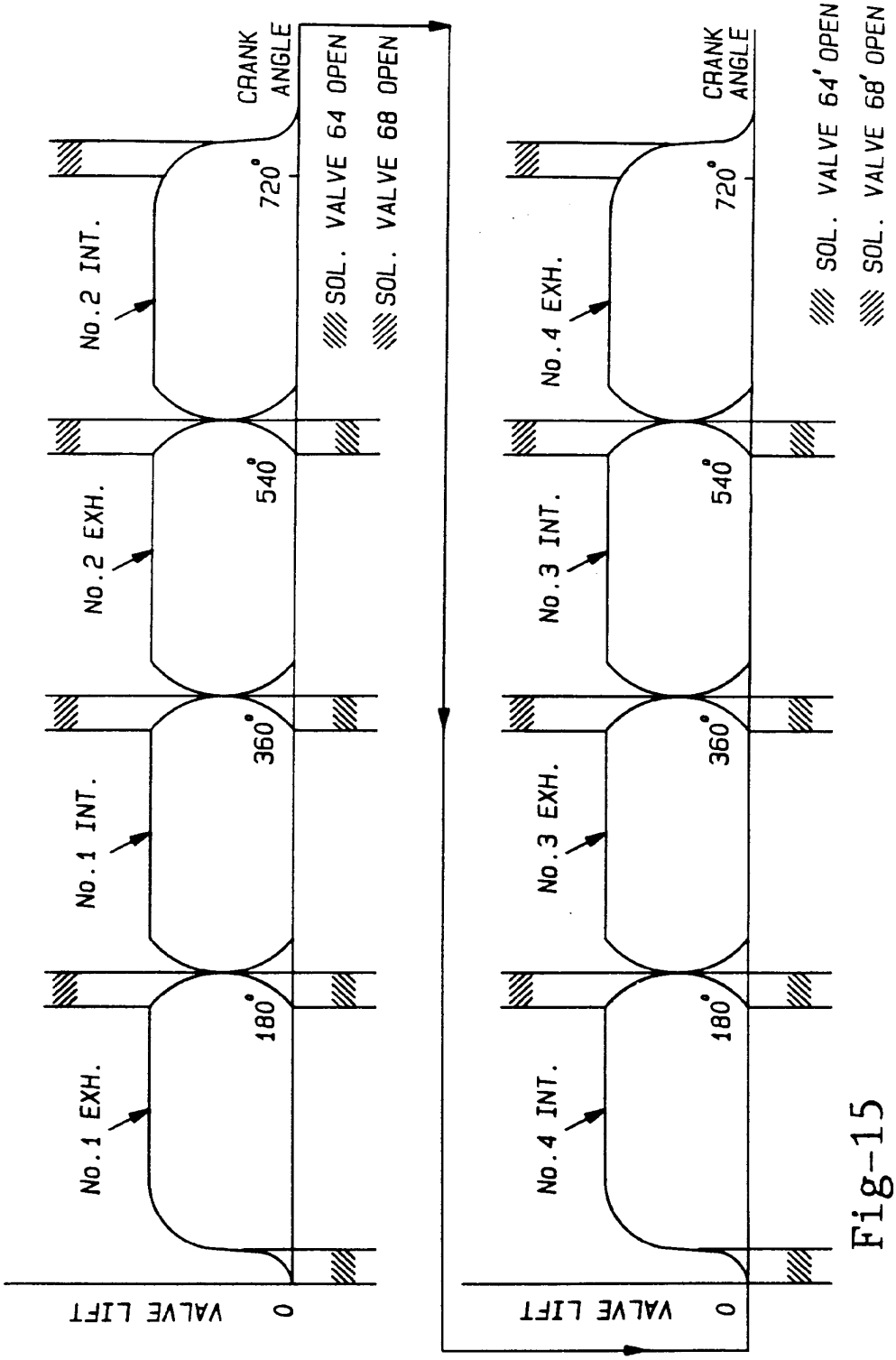


Fig-15

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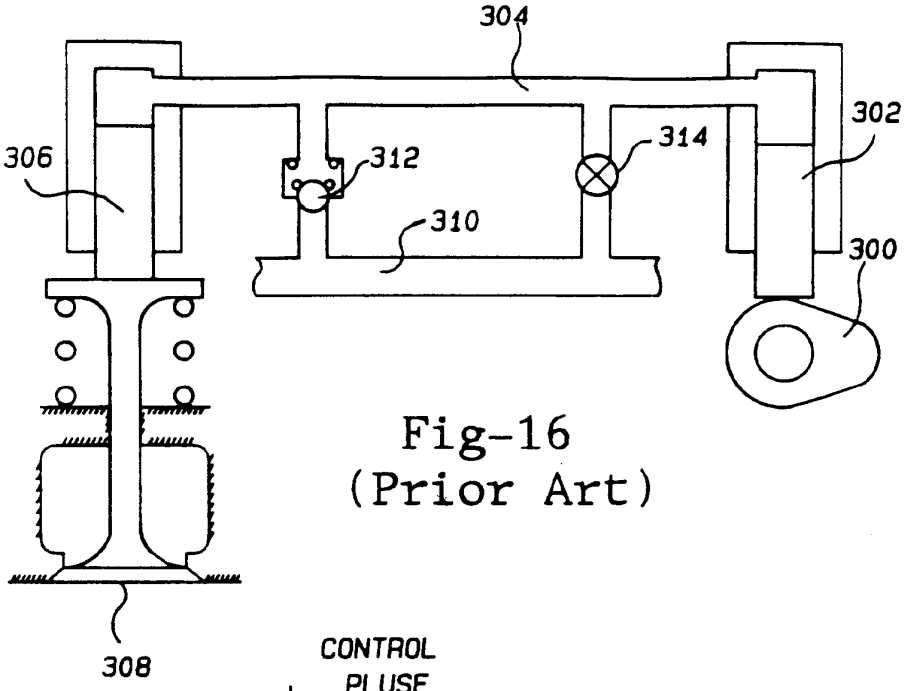


Fig-16
(Prior Art)

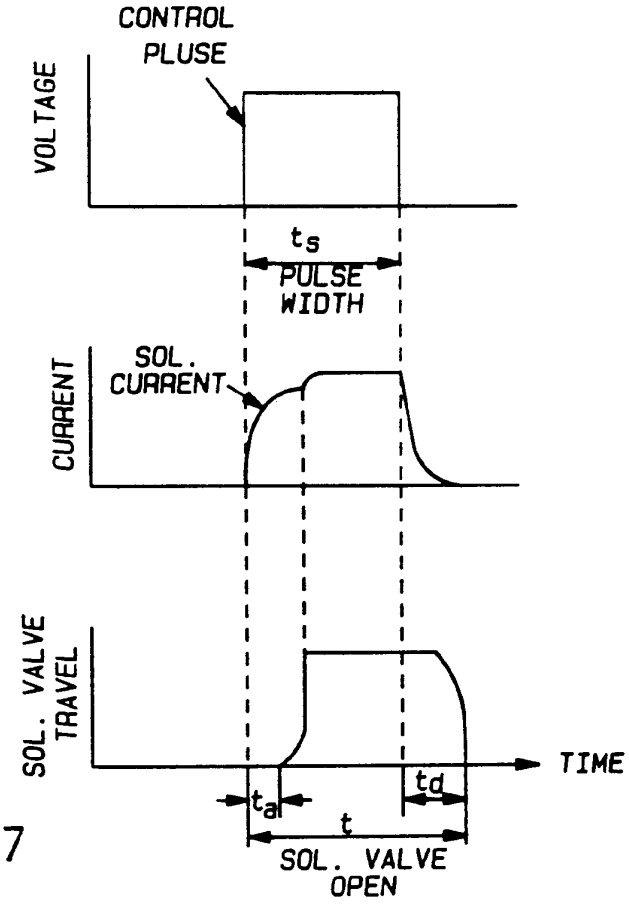


Fig-17

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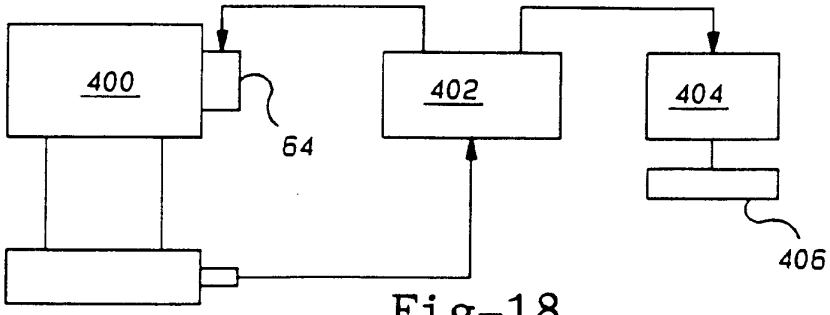


Fig-18

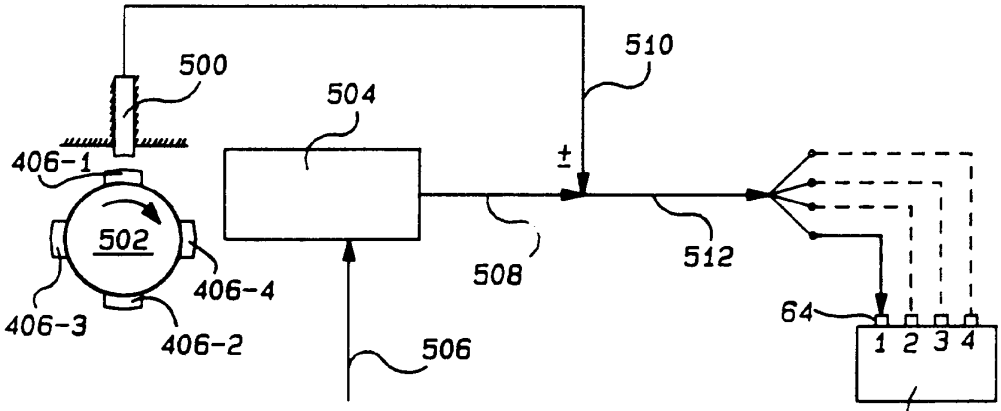


Fig-19

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WO 1994/029572 A
US 6105690 A
WO 1999/054591 A
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US 4896722 A

(58) Field of Search:
UK CL (Edition T) E1F FHK FHU FKD FKE FKF FKG FKU
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(54) Abstract Title: **Apparatuses and methods for deploying logging tools and signalling in boreholes**

(57) In the field of tools for use in boreholes, an apparatus (10) which includes a pump (11) for circulating fluid under pressure in a wellbore (12).
A control device (13) controls the speed of the pump (11). A conduit (17) interconnects the pump and the wellbore (12).
Within the wellbore a downhole transducer (21) that is capable of detecting changes in the pressure of fluid at a downhole location and generating signals indicative thereof.
A processor (23) generates actuator commands in dependence on the generated signals.
One or more actuators (24) is operable to activate at least part of a downhole tool in dependence on a said actuator command.
A modulating valve (26) is capable of modulating the pressure of fluid in the conduit.
A remote transducer (27) that may be eg. at a surface location, is capable of detecting pressure of fluid in the conduit at a location remote from the downhole transducer (21).
The control device causes the pump to generate one or more digital acoustic signals in the fluid, the wave forms of which are detectable by the downhole transducer (21).
The modulating valve (26) is capable of generating digital or analogue wave forms in the fluid.
In operation the control device sends control signals via the fluid that are detected by the downhole transducer (21). Consequently the processor (23) causes actuation of one or more tools.
Following correct actuation the modulating valve (26) generates signals in the form of pressure changes in the fluid. The remote transducer (17) detects and displays such signals, to indicate at a surface location whether deployment of the tool has occurred successfully.

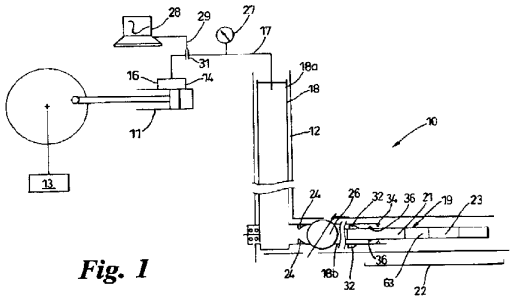
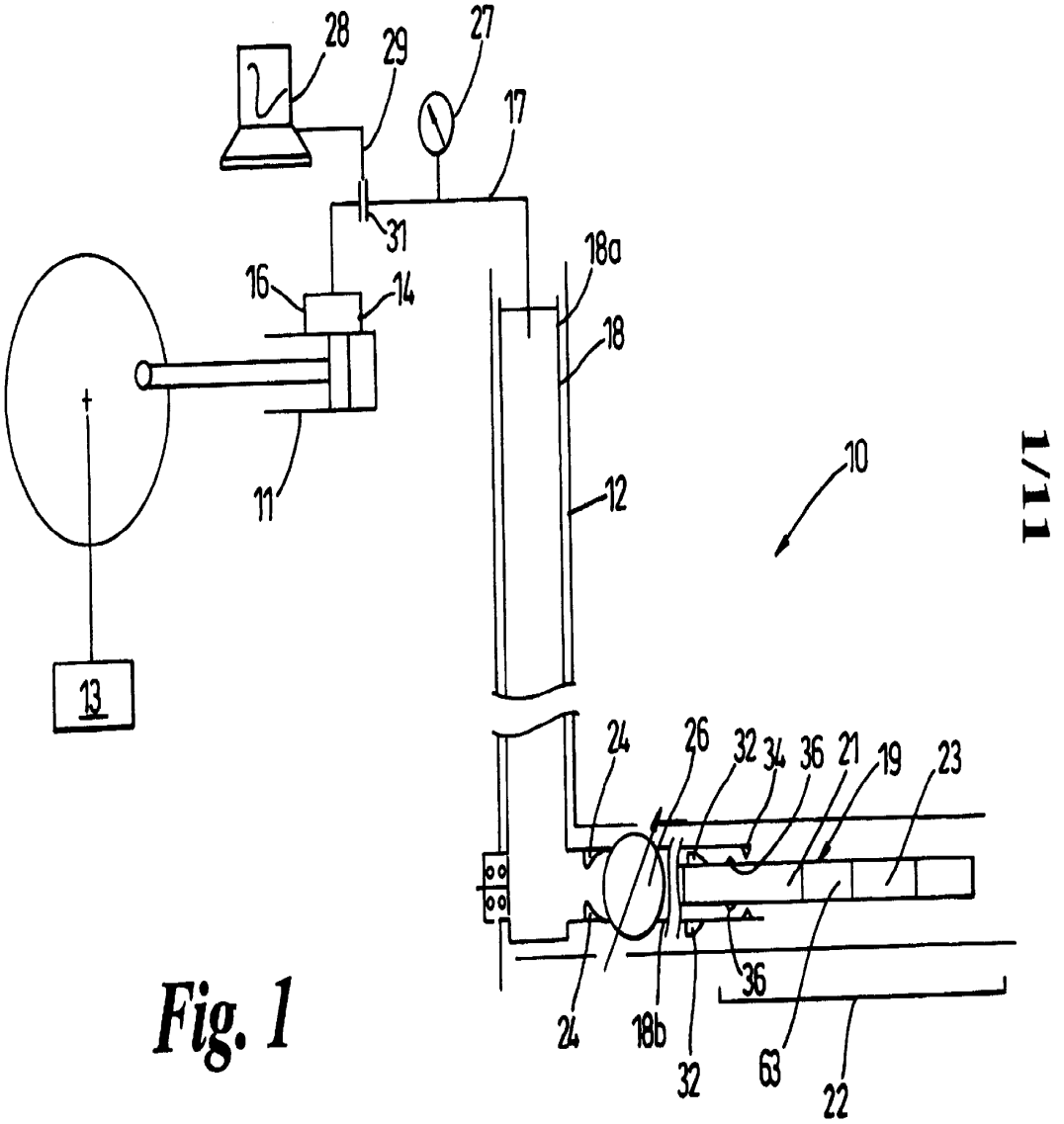


Fig. 1

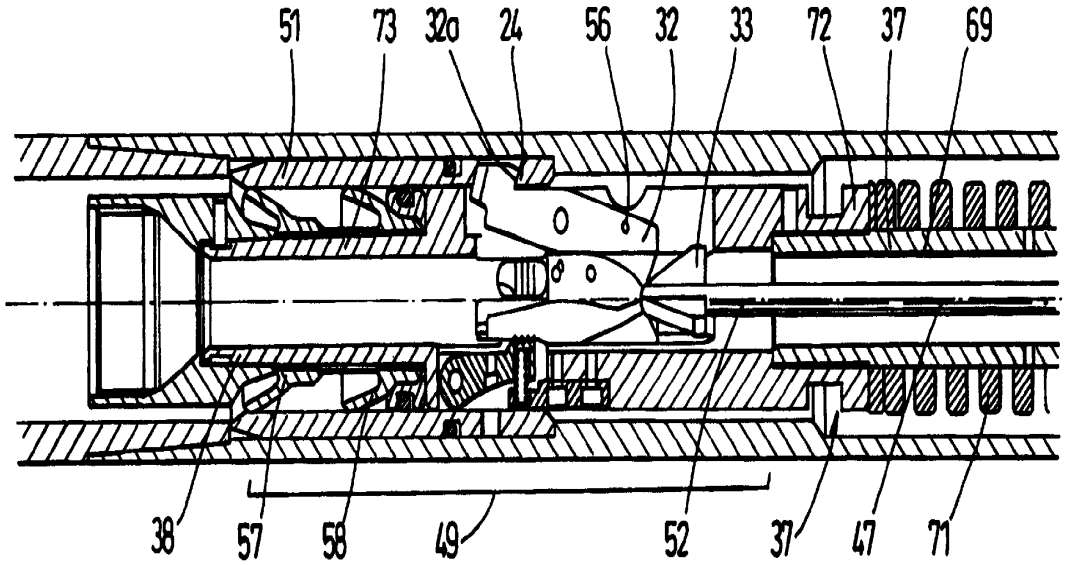
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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


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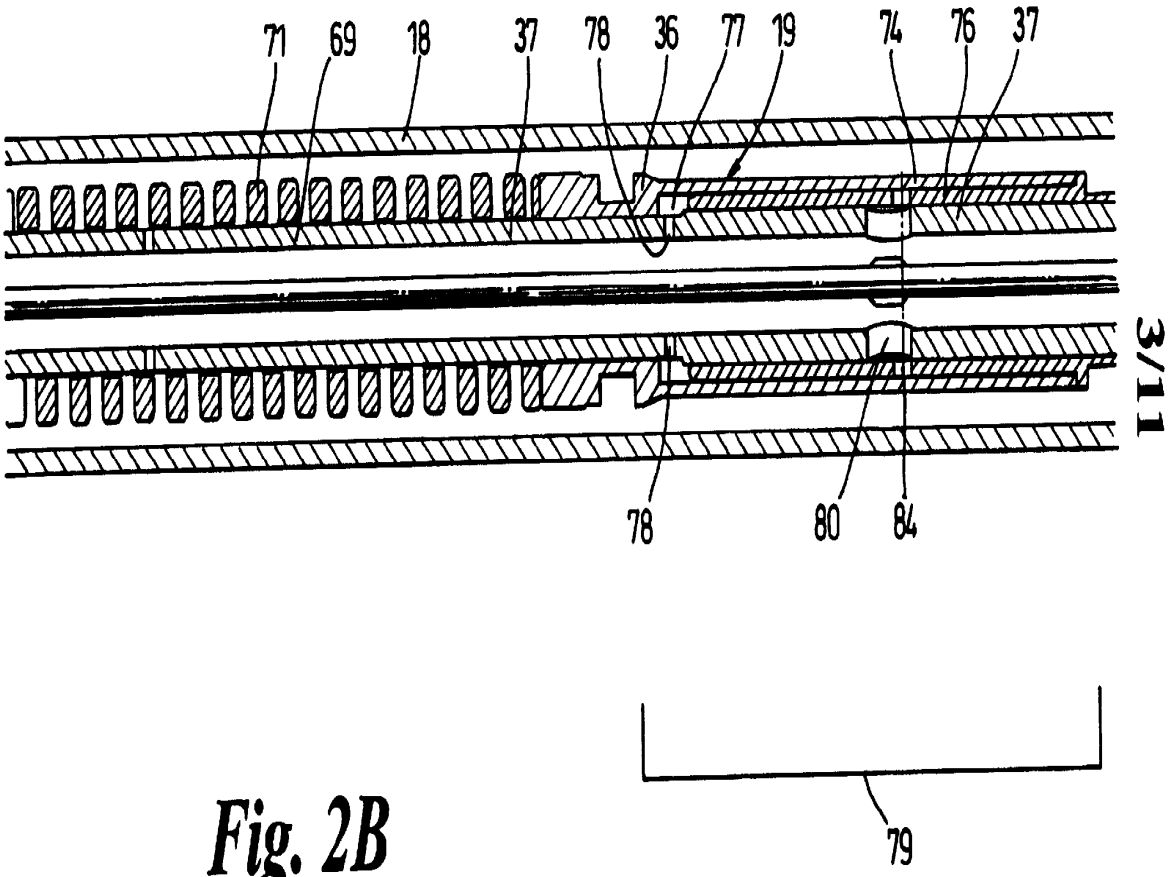
Fig. 1



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Fig. 2A

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Fig. 2B

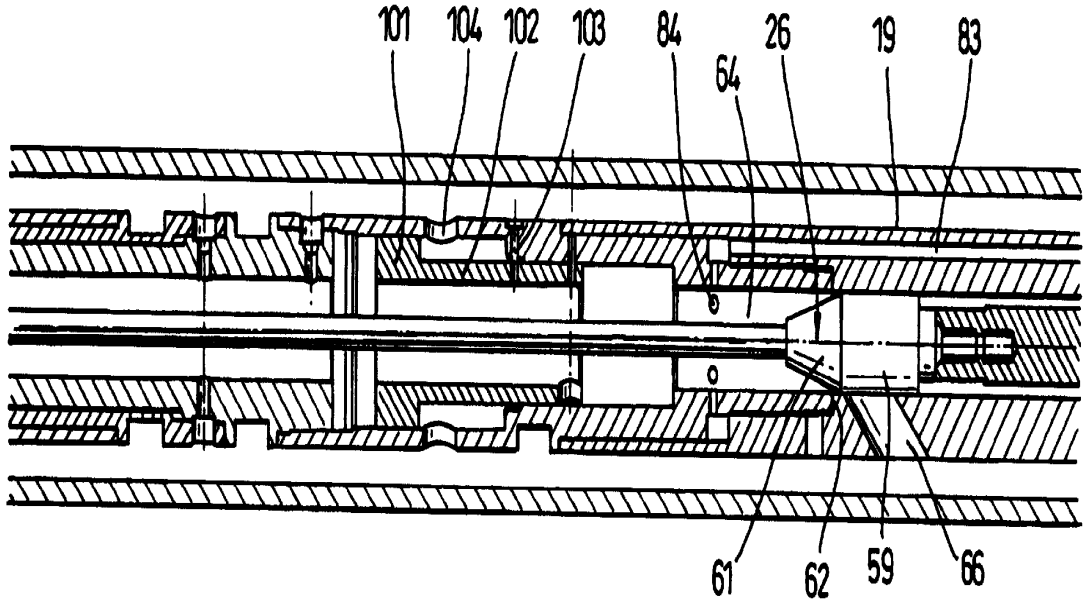


Fig. 2C

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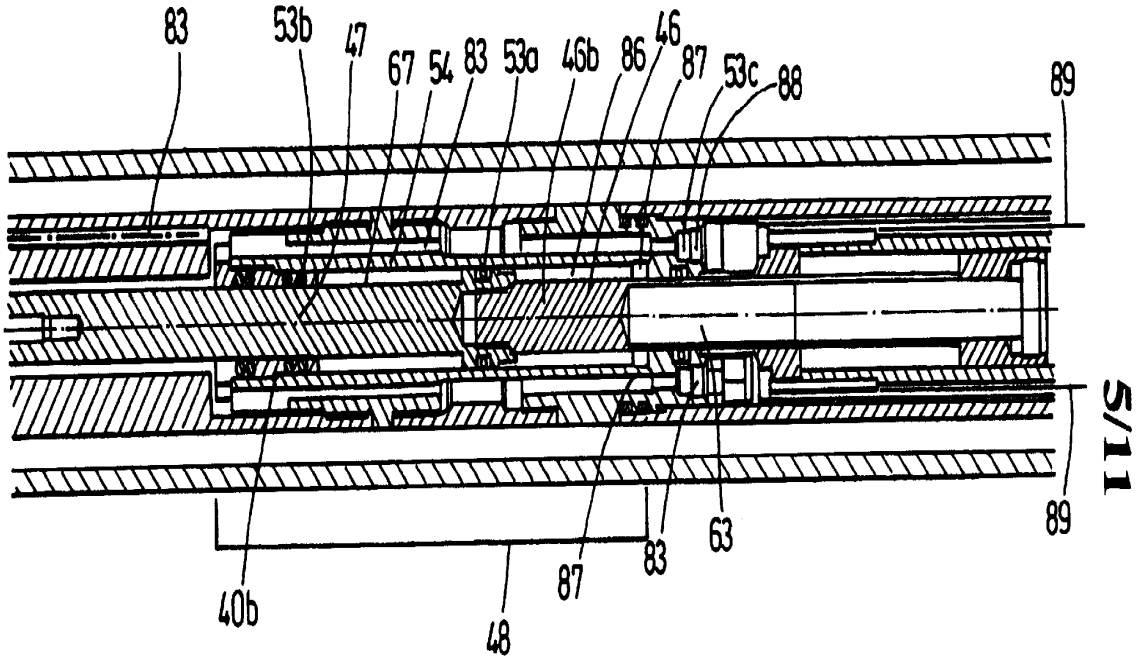
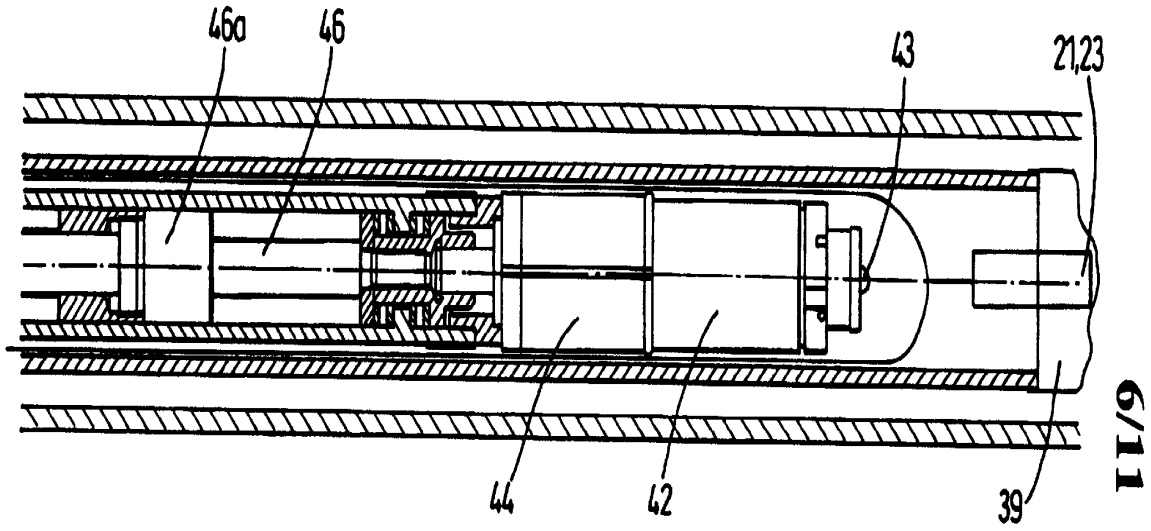


Fig. 2D



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Fig. 2E

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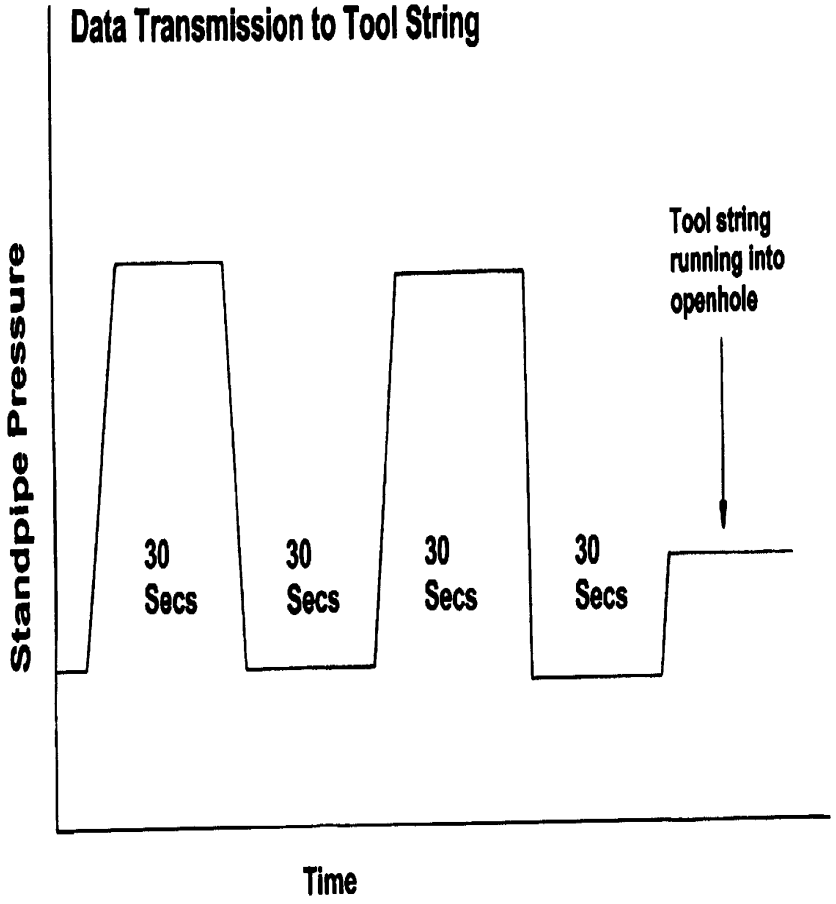

Data Transmission to Tool String
Standpipe Pressure
Tool string running into openhole
30 Secs
30 Secs
30 Secs
30 Secs
Time

Fig. 3

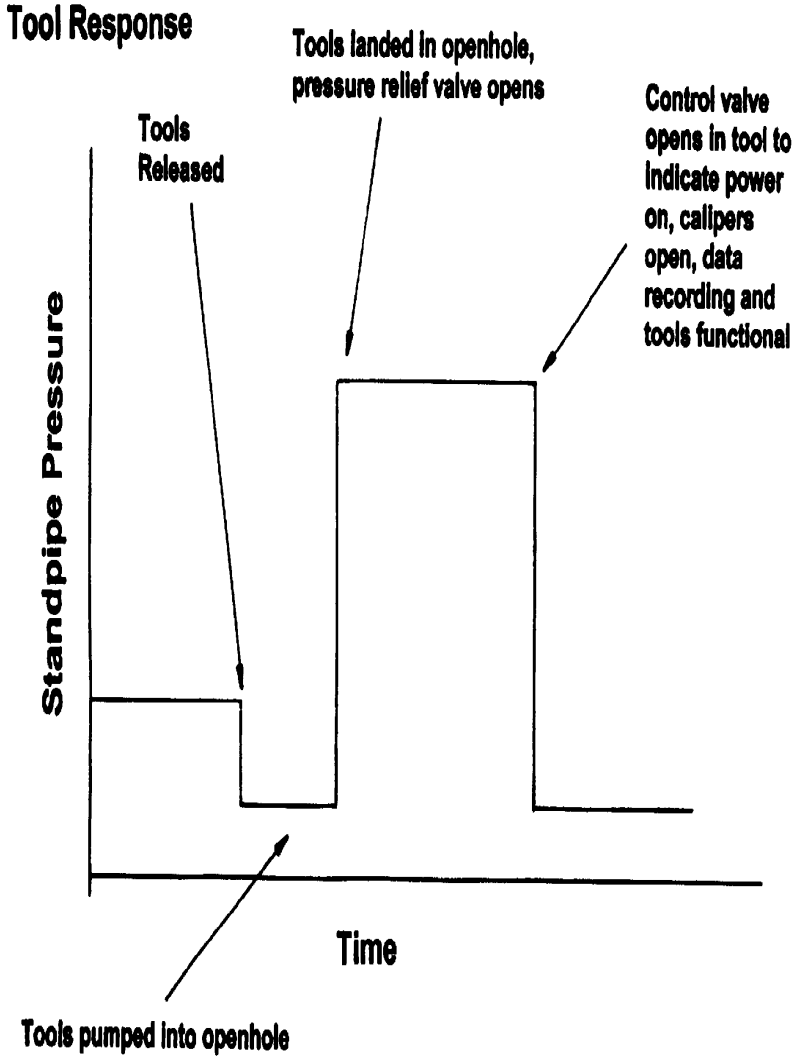


Fig. 4

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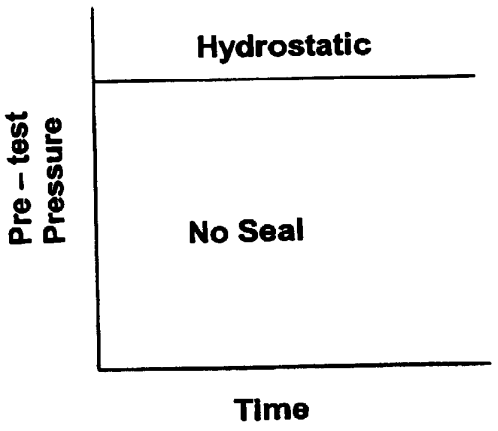

Pressure Tester Responses
Hydrostatic
Pre – test Pressure
No Seal
Time

Fig. 5

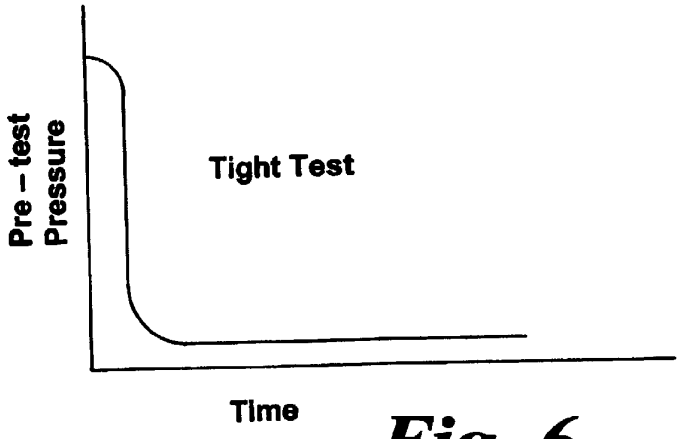

Pre – test Pressure
Tight Test
Time

Fig. 6

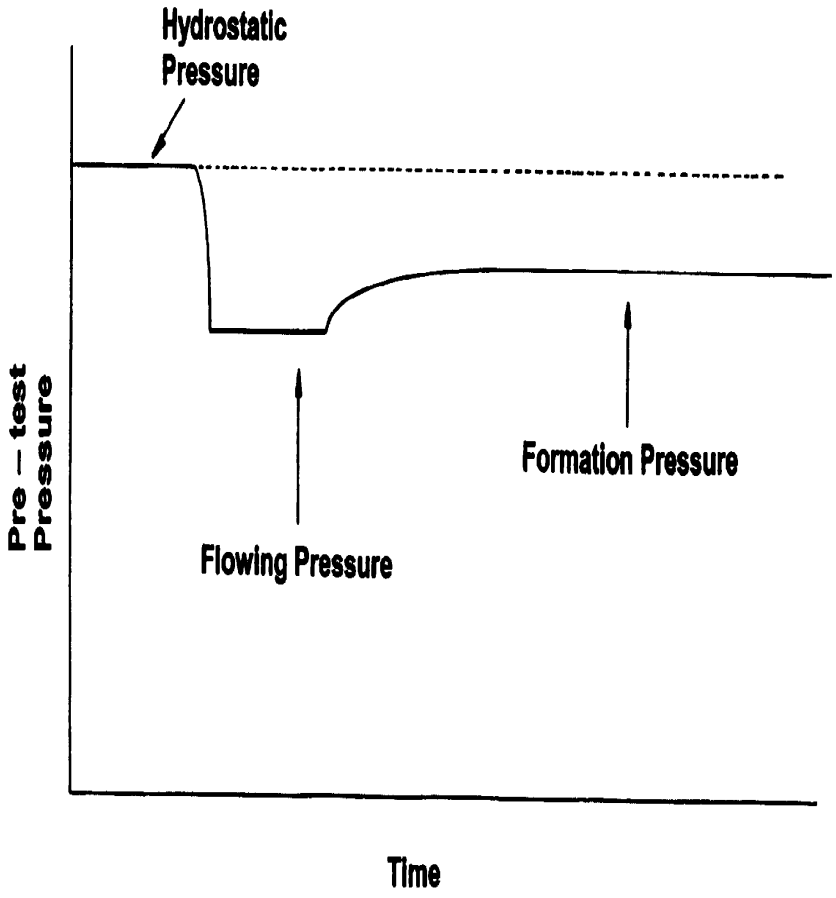


Fig. 7

Good Test

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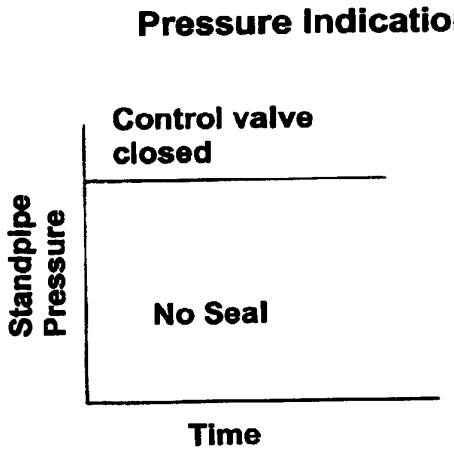


Fig. 8

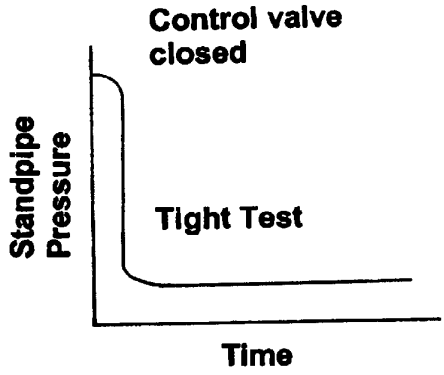


Fig. 9

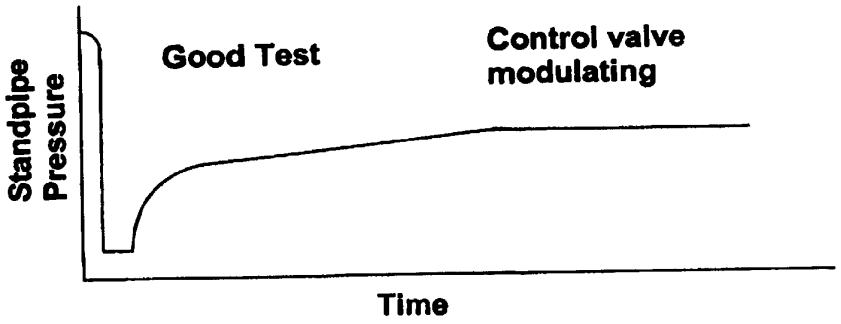


Fig. 10

APPARATUSES AND METHODS FOR DEPLOYING LOGGING TOOLS AND SIGNALLING IN BOREHOLES

This invention relates to apparatuses and methods for deploying logging tools and signalling in boreholes.

The logging of boreholes hitherto has used techniques that are well known in the oil and gas industries. The advantages of such an activity are known to those skilled in the art of oil and gas production.

When a borehole is drilled, it is seldom smooth and regular. Sections of the borehole sometimes cave in. Sometimes there are other sections of rock, in particular shales and clays, that squeeze into the borehole as a result of pressure exerted by overlying strata.

Traditionally, borehole logging has involved the use of a so-called wireline logging tool. The wireline logging tool is lowered on a wireline or pushed on drillpipe into the borehole to a downhole, logging location. The wireline logging tool is connected by a wireline to eg. data processing and recording apparatus at a surface location external of the borehole.

Wireline logging tools are of comparatively large diameter. Consequently it is difficult to push or lower a wireline logging tool into a borehole having caved in or squeezed sections as aforesaid.

In recent years it has become known to employ, for the logging of boreholes, a so-called compact logging tool comprising logging tool sections and battery / memory sections. This logging tool typically is of considerably less diameter than a conventional wireline logging tool. It includes a self-contained power supply in the form of a series of batteries; and one or more memory devices, whose function is to record data logged

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by the logging tool.

Battery / memory logging tools in many circumstances offer advantages over traditional, wireline tools.

It is now known to deploy such a battery / memory logging tool using a so-called "garaging" technique, in which the tool lies retracted within one or more joints of drillpipe during running in of the drillpipe at tripping speed. Once the drillpipe reaches the total depth ("TD") of the well, a mechanism is actuated to cause delatching of a delatchable running sub that during running in of the drillpipe causes retention of the battery / memory logging tool within the drillpipe.

Delatching of the running sub causes deployment of the logging tool to a location protruding from the downhole end of the drillpipe, at which location the logging tool is available for logging operations. Such operations then occur as the drillpipe is withdrawn upwardly from the wellbore. The battery / memory logging tool logs data on the open hole well as it travels upwards towards an uphole location, supported on the end of the drillpipe.

Following withdrawal of all the joints of drillpipe in the wellbore, the memory section of the battery / memory logging tool is recovered. The data recorded therein is downloaded, enhanced and/or analysed as desired.

The known technique for deploying the logging tool includes circulating the well with fluid under pressure, by means of a positive displacement pump connected to the drillpipe at an uphole (surface) location.

This permits the insertion into the drillpipe of a messenger sub. Such a sub is pumpable within the drillpipe to the downhole end thereof, where it

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operates a release tool. Operation of the release tool causes delatching of the running sub and deployment of the logging tool as aforesaid.

The above-described method has proved highly successful in the data logging art.

Nonetheless there is a need for further improvements in the efficiency of deployment of logging tools.

Rig time is costed at several hundred or thousand dollars per hour. Therefore it is strongly desirable to complete data logging operations in as short a time as possible. However the time taken to pump the messenger sub from an uphole location to approximately the TD of the well can be significant, not least because most oil wells are many hundreds or thousands of metres long.

The drillpipe must be of the correct diameter, and drifted, to ensure that the messenger will pass through the drillpipe and any bottom hole restrictions. Such preparation of the drillpipe is also time-consuming.

The known garaging technique for the deployment of logging tools includes method steps aimed at signalling from a downhole location to an uphole location whether deployment of the logging tool has commenced. There is however a greater need for communication between downhole and uphole locations in oil wells as the logging tools become more complex.

There have been numerous proposals in the past aimed at providing such communication without resorting to wireline connections between the downhole and uphole ends of a drillpipe. In the main such prior art proposals attempt to provide encoded communication between the downhole and uphole locations, by means of acoustic signals generated as

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pressure pulses in the fluid circulating in the well.

The approach in the prior art has been to develop a language using which it is possible digitally to transmit packets of data within the drillpipe.

This approach suffers from several disadvantages.

Principal among these is the use in the prior art of electromechanical pulsing techniques to generate fluid pressure signals at downhole locations. Typically such techniques involve the use of electrically actuated, mechanical valving members to interrupt the flow of mud (or other fluid) thereby creating pulses of sufficient amplitude to be detectable at a surface location. Since the mass of mud typically requiring to be arrested by the valving members is several thousand kilogrammes the service lives and general reliability of the prior art devices are poor.

A further disadvantage of the prior art techniques is that the speed of data transmission is poor, because of the limited bandwidth of the transmission medium (mud). This problem is acute when attempting to multiplex data transmissions.

According to a first aspect of the invention there is provided apparatus for remotely activating a tool in a wellbore, the apparatus comprising:

a positive displacement pump for causing circulation of a fluid under pressure in the wellbore;

a control device for controlling the speed of operation of the pump;

a conduit that is operatively connected to the pump and extends into the wellbore for conveying the fluid thereinto on operation of the pump;

a downhole transducer, that is capable of detecting changes in the pressure of the fluid and generating one or more detected pressure signals indicative thereof;

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a processor that is capable of generating one or more actuator commands in dependence on detected pressure signals generated by the downhole transducer;

one or more actuators that are each operable to activate at least a part of a tool in dependence on a said actuator command;

an activatable tool at a downhole location;

a modulating valve for modulating the pressure of fluid in the conduit; and

a remote transducer that is operatively connected to detect pressure of the fluid in the conduit at a location remote from the downhole pressure transducer, wherein operation of the modulating valve is dependent on a downhole event.

Advantageously the apparatus of the invention allows the practising of the garaging method for the rapid deployment of logging tools without the need to pump a messenger sub to a downhole location to initiate releasing of the tool.

The downhole transducer and the processor are capable of initiating a tool deployment operation following the generation of an acoustic signal at a remote location that preferably is a surface location.

The transmission of such an acoustic signal occurs more rapidly than the pumping of the messenger sub to the downhole location. On the other hand, the data requiring transmission to the downhole location in order to initiate tool deployment can be simple. Consequently it can be transmitted in digital or analogue form.

There is no need for multiplexing of data in the acoustic signals, since the presence of the processor at the downhole location means that the acoustic signals need only initiate a further, more complex process that occurs under

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the control of the processor that is appropriately programmed.

The presence of the modulating valve allows the apparatus to signal from the downhole location to eg. an uphole location that a particular event (such as but not limited to correct deployment of a logging tool) has occurred.

The data necessary for such signalling also are simple, and hence suitable for propagation as analogue or digital acoustic signals in wellbore fluids.

As is explained in more detail below, within the scope of the invention there is no need to attempt the transmission of complex borehole log data by means of acoustic signals.

Conveniently the control device is operable to cause the pump to generate one or more analogue acoustic signals, in the fluid, the waveforms of which are detectable by the downhole transducer.

Preferably the control device is operable to cause the pump to generate one or more digital acoustic signals, in the fluid, the waveforms of which are detectable by the downhole transducer; and the modulating valve is operable to generate one or more analogue or digital acoustic signals, in the fluid, the waveforms of which are detectable by the remote transducer.

Thus the operation of the apparatus according to the invention may if desired be a hybrid of digital and analogue signalling techniques. This confers maximum flexibility on the data transmission, with digital signals being used when there is a need to transmit simple data with a high degree of reliability; and analogue signals being used when it is necessary to transmit from the downhole end of a drillpipe to a remote location an indication of instantaneously prevailing conditions at the downhole end of the wellbore. There may be a short delay of a few seconds, as a result of

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propagation of the acoustic signal along the drillpipe, before the indication is detectable at the remote location; but this delay is within acceptable limits.

A further advantageous feature of the apparatus of the invention is that it permits timebase modulation of the data generated at the downhole location. This allows matching of the data transmission rate to the bandwidth of the transmission medium (the mud or other fluid).

Preferably the conduit is a drillpipe that is moveable within the wellbore; the activatable tool is moveable relative to the drillpipe; and the drillpipe and the activatable tool include mutually engageable latch parts that, when mutually engaged, retain at least part, or all, of the activatable tool in a retracted position relative to the drillpipe and when disengaged permit movement of the tool to an advanced position in which at least part of the tool protrudes or protrudes further from the downhole end of the drillpipe, the apparatus including a release tool activator that is operable to cause disengagement of the latch parts from one another.

The release tool activator preferably includes or is controlled by a programmable device that is programmed to cause disengagement of the latch parts on the downhole transducer detecting a predetermined sequence of pressure changes in the fluid.

As a consequence the apparatus of the invention is able to detect an encoded, digital signal indicative of a need to deploy a logging tool; and cause releasing of the tool.

The foregoing features of the apparatus of the invention suit it for use in a garaging technique similar to the prior art method outlined hereinabove.

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Conveniently the drillpipe when present includes on its interior surface one or more landing stops and the activatable tool includes protruding from an exterior surface one or more landing dogs that are each engageable with a said landing stop on the activatable tool moving to its advanced position relative to the drillpipe.

Even more preferably the landing stop is or includes an annular landing collar extending about the interior surface of the drillpipe.

The foregoing features assist in the deployment of the activatable tool (that in preferred embodiments is a logging tool), since it is desirable for release of the tool from a retracted position to be limited so that the drillpipe and the tool remain in contact with one another. This in turn permits travel of the tool along the wellbore protruding from the drillpipe, during logging operations.

Preferably the operation of the release tool activator to cause disengagement of the latch parts also causes the modulating valve to close whereby movement of the tool to its advanced position causes dethrottling of the flow of fluid at the downhole location, such dethrottling being detectable at the remote location as a period of reduced fluid pressure.

Thus the apparatus of the invention advantageously is capable of signalling to an uphole location the commencement of deployment of an activatable tool or a part thereof.

In preferred embodiments of the invention the apparatus includes a pressure relief valve, whose opening threshold is predetermined; and the engagement of the or each said landing dog with a said landing stop causes the pressure relief valve to generate an analogue, acoustic signal that is indicative of landing of the tool in its advanced position relative to the drillpipe.

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The foregoing features assure that the signals generated by the movement of the toolstring and pressure relief valve on initiation of tool release and tool landing are easily detected at a surface or other remote location and are distinctive of the tool deployment action.

The modulating valve optionally is a proportional valve including a valve needle and a valve seat; and acoustic signals generated thereby conveniently are fluid pressure decreases that are proportional to the displacement of the valve needle relative to the seat.

The modulating valve preferably is a proportional valve including a valve needle and a seat therefor; and the acoustic signal is an increase in pressure that is proportional to the displacement of the valve needle relative to the seat.

It is further preferable that the apparatus includes an actuator member that is common to the release tool and the modulating valve whereby operation of the release tool causes movement of the modulating valve.

In a particularly preferred embodiment of the invention the common actuator member is a rod extending centrally within a toolstring, mutually spaced parts of the rod being secured respectively to the release tool, the valve member of the modulating valve and a servomechanism (ie. a speed- and position-controllable device) that moves the rod longitudinally in the toolstring in dependence on one or more said actuator commands.

Connection of the rod to a servomechanism conveniently permits the generation of actuator commands within a processor or other programmable device forming part of the apparatus at a downhole location; and conversion of such commands into an acoustic signal that is detectable at an uphole or

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other location that is remote from the downhole one.

In other words the apparatus is capable of generating an acoustic signal, that is transmissible to eg. an uphole location, that is distinctive of landing of the activatable tool in its deployed position. Thus the apparatus clearly signals correct deployment of the tool. A surface-located engineer, or software programmed in a microprocessor forming part of or connected to the apparatus, may then know that it is possible to commence logging operations (or other operations carried out by the activatable tool, if the latter is other than a logging tool), without fear that the operations would be a waste of valuable rig time as a result of failed deployment of the tool. In the event of the engineer, or the software, identifying sub-optimal deployment, it is possible under some circumstances promptly to take corrective action such as but not limited to relocating the tool in the borehole.

Preferably the activatable tool includes one or more reaction surfaces against which fluid pressure in the conduit acts.

The presence of such surfaces advantageously permits the pumping, using pressure of fluid in the wellbore, of the activatable tool from its retracted position to its deployed position following releasing thereof.

Preferably the reaction surfaces include one or more flexible, annular sealing members encircling a cylindrical part of the activatable tool so as to seal between the exterior of the tool and the interior of the conduit. The or each reaction surface conveniently is moveable longitudinally of the activatable tool relative to the landing dogs; and the apparatus includes a resiliently deformable member operatively interconnecting the or each reaction surface and a said landing dog.

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The resiliently deformable member, that in preferred embodiments of the invention is a coiled spring encircling a cylindrical part of the apparatus of the invention, causes gradual deceleration of the reaction surfaces and the mass of equipment and drilling fluid supported thereby on landing of the tool.

Such controlled deceleration minimises the risk of damage to components of the apparatus on engagement of the landing dogs with the landing stops.

Preferably the logging toolstring includes a cylindrical member that is moveable relative to a chamber, the chamber including one or more ports providing communication between the interior and the exterior of the chamber and the cylindrical member closing the or each said port during deployment of the toolstring, the or each reaction surface being operatively connected to the cylindrical member such that on landing of the tool the cylindrical member moves to open the or each said port to limit the pressure of fluid in the chamber.

It is also preferable that the chamber has formed therein an orifice, the orifice providing fluid communication between the chamber and a further chamber the volume of which changes on movement of the cylindrical member.

Conveniently the coiled spring interconnects the or each reaction member and the cylindrical member.

The foregoing feature permits the forcing of fluid via the orifice into the variable volume chamber. This damps the motion of the reaction surfaces, the components of the apparatus connected thereto and the mass of drilling fluid supported thereby and consequently prevents unwanted oscillations.

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It is also preferable that the said chamber includes a wall member having defined therein each said port, the wall member including a perforated sleeve that is releasably secured on the chamber. This feature advantageously permits modification of the port size, by changing of the sleeve to suit the density and viscosity of the fluid in the drillpipe so as to provide for the correct acoustic signal waveform shape.

The apparatus of the invention also conveniently includes a pressure relief valve that opens to vent fluid pressure from within a hollow part of the activatable tool should the pressure within the hollow part exceed a predetermined threshold.

Preferably the apparatus includes a first pressure balancer for balancing fluid pressure on the uphole and downhole sides of the modulating valve.

In practical embodiments of the invention the first pressure balancer is such as to equalise pressures in the chambers on either side of the modulating valve.

The pressure balancer is such that the modulating valve when operating does not have to act against the full pressure, that may be up to several thousand psi, of fluid in the wellbore.

Preferably the apparatus also includes a further pressure balancer that in use lies downhole of the modulating valve and is operatively connected to equalise pressures acting on the uphole and downhole sides of the servomechanism. The purpose of the further pressure balancer is to maintain the loadings on the servomechanism within acceptable values, so that the servomechanism does not have to overcome the borehole pressure during its operation.

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In one embodiment of the invention the activatable tool is or includes a formation pressure tester; and the processor is programmed to generate one or more actuator commands for causing operation of the formation pressure tester.

The apparatus of the invention is particularly suitable for use in the deployment of a formation pressure tester.

More specifically, when the apparatus includes the servomechanism as aforesaid the processor is preferably connected and programmed to generate commands for causing one or more of:

(i) operation of the servomechanism to cause unlatching of the mutually engageable latch parts and thereby cause movement of the toolstring that generates an acoustic signal that is indicative of tool release; followed by

(ii) operation of the pressure relief valve to signal landing of one or more landing dogs in a landing stop;

(iii) deployment of one or more deployable components of the formation pressure tester;

(iv) powering up and/or self-testing of one or more tools in a toolstring.

When the apparatus of the invention includes the servomechanism as aforesaid, conveniently the activatable tool includes a logging device and a memory device capable of recording data logged by the logging device, the processor being programmed to generate actuator commands for commanding the servomechanism to operate the modulating valve to generate fluid pressure signals in dependence on the recorded, logged data.

Thus the apparatus of the invention is suitable for use with a "wireless" battery / memory logging tool.

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In the preferred embodiment of the invention the logged data that is the subject of the signals generated by the programmed device are indicative of the conditions prevailing in the vicinity of the formation pressure tester, rather than entire borehole plots (that preferably are stored in the memory device and subsequently downloaded or otherwise manipulated, following recovery of the formation pressure tester or at least the memory device to a surface location at the end of a logging operation).

Conveniently the apparatus includes a remote transducer that detects pressure of the fluid in the conduit at a location remote from the downhole pressure transducer and generates signals indicative thereof.

More specifically, the remote transducer preferably detects fluid pressure in a standpipe that interconnects the outlet of the pump and the interior of the conduit.

The remote transducer may be, but is not limited to, a pressure gauge, a piezoelectric transducer operatively connected to a display device such as a computer monitor or a pen recorder; a strain gauge; or any of a range of other transducing devices from which a pressure signal may be generated.

In preferred embodiments of the invention at least an output device forming part of or connected to the pressure transducer is located such that a human operator may view it. Consequently the pressure transducer may provide an immediately visible indication of the signals generated by operation of the modulating valve at a downhole location.

Conveniently the apparatus includes an on-board source of electrical power.

Preferably this is in the form of a sub, forming part of a toolstring, that

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includes a plurality of batteries connected for powering the various components of the apparatus.

According to a second aspect of the invention there is provided apparatus for signalling between a downhole location in a wellbore and a further location that is remote from the downhole location, the apparatus comprising a conduit extending into the wellbore; a pump connected to supply fluid under pressure in the conduit; a modulating valve, at a downhole location, for modulating the pressure of fluid in the conduit; a programmable processor for controlling operation of the modulating valve; a memory device; and a remote transducer for detecting fluid pressure at the further location.

This apparatus contrasts with prior art signalling apparatuses in that it is capable of transmitting analogue data to the further location that preferably is a surface location at which computers, processing apparatus and/or human operators may be located.

Preferably the memory device includes stored therein data logged in the wellbore; and the programmable processor is programmed to cause the modulating valve to modulate the pressure of fluid in the conduit in a fashion that is characteristic of the logged data.

In use of the apparatus the stored data that is transmitted by means of the apparatus of the invention is not, generally, an entire log of a wellbore. On the contrary, the stored data so transmitted preferably relates to instantaneously prevailing conditions in the vicinity of eg. an activatable tool at the time of its activation. Such data are used to confirm successful activation and/or deployment of a tool.

Conveniently the programmable processor is programmed to cause the

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modulating valve to modulate the pressure of fluid in the conduit in a fashion that is characteristic of two types of data logs (eg. gamma ray and formation pressure logs) carried out at different times.

It is also preferable that the earlier of the two logs is a low frequency Gamma log.

Such features of the apparatus allow for example the use of an accurate Gamma log of a borehole to confirm the position of a formation pressure tester during use, with signals indicative of the position of the formation pressure tester being transmitted via the borehole fluid to an uphole location.

Since the accurate positioning of formation pressure testers (and some other logging tools) is known potentially to consume large amounts of logging time, the foregoing features are highly advantageous.

In preferred embodiments of the invention the formation pressure tester is conventional and of a *per se* known kind. The formation pressure tester logs and transmits data in a *per se* conventional manner. A key difference however between the arrangement of the invention and those of prior art devices is that the formation log *per se* is stored in a downhole memory device. Typically the data transmitted via the medium of the borehole fluid are indicative eg. of whether the formation pressure tester has deployed correctly.

Preferably the modulating valve includes a valve member; a valve seat on which the valve is seatable to raise fluid pressure in the conduit and from which the valve member is removable to reduce fluid pressure in the conduit; a servomechanism connected to operate in dependence on signals generated by the programmable processor; and an actuator member

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operatively interconnecting the servomechanism and the valve member whereby the valve is openable and closeable in dependence on the signals generated by the programmable processor.

Such an arrangement advantageously is simple and reliable. Operation of this arrangement results in the instantaneous generation of modulating signals in the borehole fluid, on the occurrence of a downhole event.

Conveniently the apparatus includes a logging tool that is capable of logging data characteristic of the wellbore and/or a formation proximate thereto, the logging tool and the memory device being connectable one to the other so that the memory device stores data logged by the logging tool.

The use of such a tool and memory combination conveniently permits the downloading of logged data following completion of logging operations and the recovery of the logging tool to an uphole location, for example as a result of withdrawal of drillpipe from the borehole.

More specifically the logging tool preferably is a formation pressure tester that is deployable against the wellbore in dependence on commands generated by the programmable device.

The programmable device may be programmed to generate signals that cause the modulating valve to generate analogue pressure changes in the fluid in the conduit, the pressure changes mimicking pressure changes experienced by the formation pressure tester in use.

Such signals may be used to signify at an uphole location the correct deployment of a formation pressure tester forming part of the apparatus of the invention.

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In a preferred embodiment of the invention the pressure changes generated by the modulating valve include, in the case of a good test carried out by the formation pressure tester:

an initial pressure increase that mimics sealing of the formation pressure tester pad against the borehole;

a subsequent pressure decrease caused by operation of the pretest piston of the formation pressure tester that mimics exposure of the formation pressure tester transducer to formation fluid pressure; and

a subsequent pressure recovery that mimics the building up of formation fluid pressure within the formation pressure tester when the pretest is halted.

Another possibility is for the pressure generated by the modulating valve to include, in the case of the formation pressure tester experiencing a so-called "no seal" condition, a period of substantially invariant fluid pressure that mimics the fluid pressure exerted on the formation pressure tester when carrying out a no-seal test.

Yet a further possibility is for the pressure generated by the modulating valve to include, in the case of the formation pressure tester engaging a so-called "tight formation", a pressure drop (that mimics the fluid pressure experienced by the formation pressure tester when carrying out a pressure test on a tight formation); and a subsequent period without a substantial pressure recovery.

Each of the aforementioned types of pressure modulation generated by the modulating valve is distinctive of a particular instantaneously prevailing downhole condition.

Of the three conditions specified, the "no-seal" and "tight formation" indications would suggest to a human operator that the formation pressure

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tester is incorrectly located for the acquisition of useful data. It is therefore a highly significant advantage of the apparatus of the invention to be able to signal to a human operator whether the formation pressure tester is incorrectly located. The human operator would then be able as necessary to adjust the position of the formation pressure tester (for example by running in or withdrawing a few inches of drillpipe at a time), with the aim of obtaining from the apparatus of the invention a transmitted indication that a good test has resulted.

The aforementioned formation type data are the kinds of data (that may either be transmitted in real time or stored in the memory device, when present, and subsequently transmitted) that it is envisaged to signal to an uphole location using the apparatus of the invention. The actual formation logs (that typically are highly complex and require detailed analysis and/or manipulation) would be fed from the formation pressure tester to the memory device and stored in the latter. On retrieval of the formation pressure tester and memory device to an uphole location the formation log data could be downloaded in a *per se* known manner.

Conveniently the apparatus of the invention includes a source of electrical power operatively connected to power as necessary the programmable device, the modulating valve and the logging tool. Consequently the apparatus is of the wireless type, that is associated with significant advantages.

Preferably the programmable device, the modulating valve, the logging tool and the source of electrical power are secured one to another in a discrete toolstring.

Thus the toolstring may be assembled at a surface location and deployed according to a modified version of the so-called garaging technique. The

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apparatus of the invention may then signal to the uphole location whether the tool is correctly deployed and operating (and hence whether formation logging operations should commence).

According to a third aspect of the invention there is provided a method of deploying a logging tool in a wellbore using an apparatus as defined herein, the method comprising the steps of:

(i) running the downhole transducer, the processor, the release tool actuator, the activatable tool and the modulating valve to a downhole location on a length of drillpipe defining the conduit;

(ii) operating the pump under control of the control device to:

(a) circulate the wellbore; and

(b) generate one or more changes in fluid pressure, in the conduit, that are detectable by the downhole transducer whereby the downhole transducer generates one or more detected pressure signals that are indicative of the generated fluid pressure changes such that the processor generates one or more actuator commands that cause operation of the tool actuator so as to activate at least part of the activatable tool at the downhole location, activation of the activatable tool causing the modulating valve to modulate the pressure of fluid in the conduit; and

(iii) detecting the modulation of fluid pressure in the conduit at the remote location by means of the remote transducer.

Advantages of the apparatuses of the invention described hereinabove inure to the aforementioned method.

Preferably the sub-step of operating the pump to generate one or more changes in fluid pressure in the conduit includes the further sub-step of generating a waveform, in the fluid in the conduit, that is detectable at the remote location.

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Conveniently the sub-step of operating the pump to generate one or more changes in fluid pressure in the conduit includes the further sub-step of generating a sequence of digital pressure pulses in the fluid in the conduit; and the operation of the modulating valve includes the generation of one or more analogue pressure changes in the fluid in the conduit.

In other words the method of the invention preferably involves a combination of digital and analogue signals generated in wellbore fluid. The digital signals are employed when it is appropriate to do so (for example when transmitting simple data intended to initiate deployment of a logging tool). The analogue signals are used to indicate prevailing conditions at a downhole location.

Conveniently the step (i) includes the step of running mutually engaged latch parts, that secure at least part of the activatable tool and the drillpipe together, to the downhole location. This aspect of the method permits the use of a modified version of the *per se* known garaging tool deployment technique.

Preferably during the step of running the mutually engaged latch parts to the downhole location at least part of the activatable tool is retained in the retracted position relative to the drillpipe; and on operation of the release tool actuator at least part or all of the activatable tool moves relative to the drillpipe so as to protrude from the downhole end thereof.

It is also preferable that operation of the release tool actuator causes disengagement of the mutually engageable latch parts from one another.

The method of the invention also advantageously includes engagement of a landing dog secured to the activatable tool with a landing stop secured on the drillpipe.

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Such engagement of a landing stop and a landing dog ensures that the activatable tool does not detach from the drillpipe in which it is conveyed to a downhole location.

Conveniently, following engagement of the landing dog and the landing stop, one part of the activatable tool moves relative to another part, such relative movement between parts of the tool being subject to one or more of:

deceleration by virtue of deformation of a resiliently deformable member and/or

damping by forcing of a fluid via an orifice into an expandable chamber.

As noted hereinabove, these aspects of the method prevent potential damage to the components of apparatus carrying out the method of the invention by virtue of sudden deceleration of a large mass of borehole fluid and toolstring components. The damping using the orifice additionally helps to prevent the generation of spurious acoustic signals in the borehole fluid.

In addition the aforesaid damping and deceleration assist in the generation of the tool release and landing signals.

The method of the invention preferably includes operation of a servomechanism to move an actuator member to cause operation of the modulating valve, operation of the servomechanism being dependent on the generation of signals by the processor.

The use of a servomechanism to operate a modulating valve ensures accuracy of such operation. It also allows the use of a self-contained apparatus for carrying out the steps of the method, including an on-board

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power supply for powering the servomechanism.

Preferably the method of the invention includes the sub-step of pumping at least part of the activatable tool between retracted and protruding positions relative to the downhole end of the drillpipe, using the pressure of fluid circulating in the wellbore.

More specifically the pumping of at least part of the activatable tool includes causing fluid under pressure in the conduit to act on at least one flexible, annular sealing member encircling a cylindrical part of the activatable tool so as slidingly to seal between the exterior of the tool and the interior of the conduit.

These aspects of the method of the invention advantageously make use of the circulating borehole fluid pressure to cause deployment of a logging tool.

Optionally the method also includes opening of a pressure release valve to vent fluid pressure from within a hollow part of the activatable tool if the pressure within the hollow part exceeds a predetermined threshold value.

Preferably the method of the invention includes balancing of fluid pressure in the hollow portion and fluid pressure in the conduit. Such balancing reduces the energy demand of the components needed to carry out the method steps.

In a particularly preferred embodiment of the invention activation of the activatable tool includes activation and operation of a formation pressure tester.

Conveniently activation of the formation pressure tester includes:

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(iv) unlatching of the mutually engageable latch parts;

(v) landing of one or more landing dogs in a landing stop;

(vi) deployment of one or more deployable components of the formation pressure tester; and

(vii) powering up and/or self testing of the formation pressure tester

and wherein the method includes causing the modulating valve to generate signals in the fluid in the conduit that are indicative of one or more of (iv) to (vii).

Consequently the method of the invention is capable of signalling correct deployment of a logging tool.

The method of the invention also typically includes logging of data characteristic of a wellbore using a downhole logging tool; and recording of logged data using a downhole memory device. Subsequently the method typically includes the step of recovering the downhole memory device to an uphole location following the recording of data; and the subsequent analysis, modification, display and/or transmission of the recorded data.

Such steps highlight the versatility of the method of the invention, since the use of a downhole memory device obviates the need to try and transmit large amounts of complex formation data in digital form to an uphole location.

The method also preferably includes the steps of detecting changes in the pressure of fluid in the conduit, using a transducer at a location remote from the downhole transducer; the method further including generating one or more signals indicative of such detections of pressure changes. Consequently the method of the invention is capable of indicating to eg. a surface-located, human operator the initiation or completion of various

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actions at a downhole location.

In a preferred embodiment of the invention the method includes as necessary powering the downhole transducer, the processor, the release tool actuator, the modulating valve and the activatable tool using a power source conveyed to the downhole location.

According to a fourth aspect of the invention there is provided a method of signalling between a downhole location in a wellbore and a further location that is remote therefrom, the method comprising the steps of:

pumping fluid, using a pump, in a conduit extending into the wellbore so as to pressurise fluid in the conduit;

operating a modulating valve at the downhole location to modulate the pressure of fluid in dependence on signals generated by a processor at the downhole location, the signals being characteristic of conditions at the downhole location; and

detecting modulations in the pressure of fluid in the conduit, resulting from operation of the modulating valve, at the further location.

More specifically the modulations caused by operation of the modulating valve are analogue mimics of data logged by the logging tool, especially data indicative of prevailing wellbore conditions. Such data are readily transmissible as narrow bandwidth signals that do not require a complex or high level transmission language.

Conveniently the processor is operatively connected to a servomechanism that when activated causes operation of the modulating valve by means of an actuator member, the method including causing the processor to operate the modulating valve.

Preferably the method includes the step of storing data logged by the

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logging tool in a memory device at the downhole location.

Even more specifically, the method includes the step of logging data indicative of the pressure of fluid proximate the wellbore at the downhole location, using a formation pressure tester.

Advantages of steps as aforesaid are set out herein in relation to other aspects of the apparatus and method of the invention.

Conveniently the modulations effected by the modulating valve in the case of a good pressure test include:

an initial pressure increase that mimics sealing of the formation pressure tester pad against the borehole;

a subsequent pressure decrease caused by operation of the pretest piston of the formation pressure tester that mimics exposure of the formation pressure tester transducer to formation fluid pressure; and

a subsequent pressure recovery that mimics the building up of formation fluid pressure within the formation pressure tester.

Another possibility is for the modulations effected by the modulating valve in the case of the formation pressure tester experiencing a "no-seal" formation to include:

a period of substantially invariant fluid pressure that mimics the fluid pressure experienced by the formation pressure tester when carrying out a test that fails to seal.

Yet a further possibility is for the modulations effected by the modulating valve in the case of the pressure tests encountering a tight formation to include:

a pressure drop that mimics the fluid pressure experienced by the formation pressure tester when carrying out a pressure test on a tight

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formation; and a subsequent period without a substantial pressure recovery.

Thus the method of the invention is suitable for signifying whether a pressure test is correctly deployed to obtain good test data; or whether an operator or a control device should act to adjust the position of the formation pressure tester away from a no-seal or tight formation area of the wellbore.

The method of the invention may optionally include powering the modulating valve, the processor and the logging tool using a source of electrical power at the downhole location. Thus the method of the invention is suited to being carried out by a wireless, compact, battery / memory logging tool of a kind that is in general known.

There now follows a description of preferred embodiments of the invention, by way of non-limiting example, with reference being made to the accompanying drawings in which:

Figure 1 is a schematic overview of apparatus according to the invention;

Figures 2a-2e are a longitudinally sectioned view of a toolstring forming part of the Figure 1 apparatus;

Figure 3 is a plot of standpipe pressure against time in apparatus according to the invention, illustrating a series of acoustic signals that are transmissible in accordance with the method of the invention;

Figure 4 is a plot of standpipe pressure against time, illustrating the response of a toolstring such as shown in Figures 2a-2e to a series of acoustic signals as illustrated by Figure 3, the response being detected at an uphole location;

Figure 5 shows the typical response of a *per se* known formation pressure tester when carrying out a so-called "no-seal" test;

Figure 6 shows the response of a *per se* known formation pressure

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tester when testing a so-called "tight formation";

Figure 7 shows the response of a *per se* known formation pressure tester when carrying out a good test; and

Figures 8 to 10 are plots of standpipe pressure against time to illustrate the signalling of formation pressure tester responses as shown in Figures 4 to 7 at an uphole location using the apparatuses and methods of the invention.

Referring to Figure 1, apparatus 10 according to the invention includes a positive displacement pump 11 of a *per se* known kind for circulating fluid under pressure in a wellbore 12. A control device such as a microprocessor or other programmable device 13 controls the speed at which pump 11 pumps fluid in the wellbore 12.

Pump 11 is connected via appropriately valved connections 14, 16 in a *per se* known manner for circulating fluid in wellbore 12.

Programmable device 13 is in the embodiment of the invention shown capable of adjusting the output of pump 11 to provide a constant flow rate regardless of the fluid pressure in the wellbore 12. Techniques for achieving a constant flow rate pump output are known to those skilled in the relevant art.

The connections 14, 16 are connected as shown in Figure 1 to a standpipe 17 that in the embodiment shown is at surface level, such that it is possible to gain physical access to the pressure in standpipe 17.

The end of standpipe 17 remote from pump 11 is connected in a fluid-transmitting, pressure-tight manner to a conduit in the form of drillpipe 18.

As shown schematically in Figure 1, drillpipe 18 extends into the

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wellbore 12.

It is known in the oil and gas production art that the extent to which a drillpipe protrudes into a wellbore is controllable, by virtue of the addition and/or removal of drillpipe joints at the uphole (surface) end 18a thereof. As a result it is common for the downhole end 18b of the drillpipe to be several hundreds or thousands of metres removed from the uphole end 18a.

As represented schematically in Figure 1, the wellbore 12 is unlikely to be straight, parallel sided and of constant diameter along its entire length.

The use of drillpipe as part of the apparatus of the invention is preferred; but it is possible for the conduit represented by reference numeral 18 in Figure 1 to take other forms if desired.

For example conduit 18 could in alternative embodiments of the invention be a length of so-called "coiled tubing" techniques for the deployment of which are known to those skilled in the oil and gas production arts.

At its downhole end 18b drillpipe 18 supports several components, forming part of the apparatus of the invention, that are for convenience shown in schematic form. Several of such components 21, 23 are in practical embodiments of the invention constituted as part of a logging toolstring 19

Toolstring 19 includes a transducer 21 that in use of the apparatus 10 is near the downhole end 18b of drillpipe 18, but that is moveable towards uphole end 18a of drillpipe 18 during and following data logging operations.

Transducer 21 is a pressure transducer such as, but not limited to, a strain gauge that is capable of detecting changes in the pressure of fluid surrounding it within drillpipe 18.

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An electronics section 23 of toolstring 19 contains various electronic components including a processor that is capable of generating one or more actuator commands, whereby to control one or more actuators located at the downhole end 18b of drillpipe 18; and a memory device such as a flash memory that is capable of logging data relating to the geological formations that the wellbore 12 perforates.

The downhole components constituting the toolstring 19 include a source of electrical power, in the form of a battery section 63.

An actuator represented schematically by reference numeral 24 is shown supported on the interior of drillpipe 18, a short distance uphole from end 18b.

In practice the apparatus of the invention may include more than one actuator. The actuators may be variously located on the drillpipe and/or the toolstring, depending on their precise function. For the purpose of the overview represented by Figure 1, a single pair of fixed latching detents 24 and corresponding, moveable dogs 32 represent the actuator function in the apparatus 10. In a practical embodiment of the invention, such as the arrangement shown in Figure 2, there might typically be three latching detents that are equi-spaced about the hollow interior of the drillpipe for example by means of a sleeve 51 inserted into the drillpipe end, and in which the detents 24 are formed as angled perforations.

Toolstring 19 exemplifies an activatable tool that in use of the apparatus occupies a downhole position.

Shown schematically in the drillpipe between latching arms 24 and downhole end 18b is a modulating valve 26. Modulating valve 26 is

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capable of modulating the pressure of fluid in the drillpipe 18 in a manner described in more detail below.

Operation of modulating valve 26 to modulate fluid pressure in the drillpipe depends on the occurrence of one or more downhole events such as commencement of the deployment of toolstring 19; completion of the deployment of toolstring 19; and commencement of operation of a logging tool such as a formation pressure tester that is not visible in Figure 1.

Apparatus 10 additionally includes a remote transducer that is connected to detect pressure of fluid in the conduit at a location remote from downhole transducer 21.

The remote transducer is shown in Figure 1 as a pressure gauge 27 connected to indicate the pressure of fluid in standpipe 17. In practical embodiments of the invention the remote transducing function would additionally be provided by a processor such as laptop computer 28 shown connected via a suitable data cable 29 to a transducing device such as but not limited to a piezoelectric transducer or strain gauge 31, the various components being schematically shown operatively connected to measure and record fluid pressures in standpipe 17.

As is known in the relevant art, it is a common practice when carrying out operations at a downhole location to circulate the wellbore 12 with a pressurised fluid intended to perform various functions in the wellbore.

The composition and nature of wellbore fluids varies greatly from wellbore to wellbore. Methods within the scope of the invention include the use of a great variety of such fluids.

Control device 13 is programmable and in accordance with the invention is

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programmed to cause pump 11 to circulate wellbore 12 with fluid under pressure.

The precise fluid pressure is dictated by numerous factors such as the nature of the wellbore fluid and the conditions prevailing at various downhole locations in wellbore 12. It is typical for the pressure of fluid circulating in wellbore 12 to be for example several thousand pounds per square inch (psi). The precise fluid pressure is chosen to permit circulation of the particular well under investigation.

Pump 11 is capable of generating such pressures in the wellbore fluid.

Control device 13 is programmed in accordance with the invention to cause the pump 11 to generate digital or analogue acoustic signals, in the form of pressure pulses, by way of modulation of the prevailing fluid pressure in wellbore 12.

Figure 3 shows a sequence of pressure pulses that pump 11 under the control of device 13 is capable of generating in the wellbore fluid.

Figure 3 plots the pressure detected in standpipe 17 against time. As shown, the pressure pulses are in the preferred embodiment of the invention digital pulses each having a timebase of 30 seconds.

Other sequences of pressure pulses are possible within the scope of the invention.

Figure 3 shows the modulating effect of the control device 13 on the fluid pressure. Figure 3 is not intended to indicate absolute wellbore fluid pressure values.

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In contrast to pump 11, modulating valve 26 is capable of producing analogue acoustic signals in the form of pressure pulses in a manner described in more detail hereinbelow.

As noted, drillpipe 18 is moveable within wellbore 12. Various techniques are known for adding and removing joints of drillpipe so as to vary the extent to which drillpipe 18 protrudes into wellbore 12.

Toolstring 19 includes at its uphole end one or more latching dogs 32 that during running in of the drillpipe 18 into wellbore 12 engage with the latching detents 24 so as to retain toolstring 19 in a retracted position in which it lies completely within drillpipe 18.

Movement of the latching dogs 32 in a predetermined manner causes them to disengage from latching detents 24. This allows the toolstring 19 to be pumped in a downhole direction by the pressurised fluid within drillpipe 18, so that the major part of toolstring 19 protrudes from the downhole end 18b thereof as shown in Figure 1.

Latching dogs (ie. arms) 32 operate under the control of a release tool activator 33 that is not visible in Figure 1 but is described in more detail hereinbelow.

The release tool activator 33 is in turn controlled by the programmable device represented schematically by electronics section 23 of toolstring 19. The programmable part of electronics section 23 is in accordance with the invention programmed to cause disengagement of the latching dogs 32 from the latching detents 24, in the event of the downhole transducer 21 detecting a predetermined sequence of acoustic signals in the borehole fluid. Preferably the predetermined sequence of acoustic signals is that shown in Figure 3, that is a simple series of digital pressure pulses the number of

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which is controlled.

The simple sequence represented by Figure 3 may be simply and reliably generated by the pump 11, and does not require a complicated communications protocol or language.

Downhole end 18b of drillpipe 18 includes on its interior surface a landing stop in the form of an annular landing collar 34. Toolstring 19 includes a further annular landing collar 36. The landing collars 34 and 36 are mutually engageable upon the toolstring 19 being pumped beyond its position shown in Figure 1 protruding from downhole end 18b of drillpipe 18. The primary purpose of such engagement is to prevent the toolstring 19 from separating completely from the end of drillpipe 18.

The overview of the structure of apparatus 10 represented by Figure 1 indicates that in simple terms the apparatus performs a modified version of the garaging technique for the deployment and use of logging tools.

The essence of such use of the apparatus lies in part in the running in of drillpipe with the latching detents 24 serving to retain the toolstring 19 within downhole end 18b. This allows the running in over the majority of the depth of the well at tripping speed, thereby minimising rig time. Additionally the latching of the toolstring within the drillpipe allows rotation of the latter. This assists the running in operation.

When the downhole end 18b of drillpipe 18 approaches the TD of the well the rate of running in is reduced and then stopped as the TD is tagged. Throughout this process the pump 11 circulates the well in accordance with commands from control device 13.

Various methods of determining the drillpipe depth are possible within the

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scope of the invention. Regardless of the precise drillpipe depth measuring technique adopted, the next stage in operation of the apparatus involves the generation of digital pressure pulses as exemplified by Figure 3.

Transducer 21 detects the pressure pulses at the downhole end of the wellbore 12. Assuming that the electronics section 23 identifies the sequence of pressure pulses, according to its programming, as being indicative of a need to deploy the toolstring 19, the latching dogs 32 are withdrawn temporarily to free them from the detents 24 and allow them to pass through the drillpipe 18. The toolstring 19 is then pumped out of the downhole end 18b into the openhole section 22 of wellbore 12, until the landing collar 36 engages the landing collar 34 in order to retain the toolstring 19 in position ready to log the formation in the vicinity of open hole section 22.

Referring now to Figures 2a to 2e, there is shown an embodiments of apparatus according to the invention that illustrates the above-described principles in more detail and additionally includes numerous further features that are within the scope of the invention.

Figure 2 shows a toolstring 19 prior to its deployment from the drillpipe 18.

The uphole end of toolstring 19 includes a hollow, cylindrical body 37 that is open at its uphole end 38 to allow the circulation of fluid within cylindrical body 37.

The downhole end 39 of toolstring 19 is constituted by an essentially non-hollow cylinder supporting a plurality of toolstring sections.

At its extreme downhole end downhole section 39 may include a formation pressure tester. The formation pressure tester is, for simplicity, omitted

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from Figure 2. However the formation pressure tester preferably is of a *per se* known design. As noted, the formation pressure tester could be augmented or replaced by one or more other logging tools.

The formation pressure tester is deployable from a compact configuration, in which all the parts of the formation pressure tester lie within an annular housing at downhole end 39 of toolstring 19; and an active position.

In the latter position of the formation pressure tester, one or more calliper arms protrudes radially outwardly therefrom to press an annular pad against the wall of wellbore 12 (that is omitted from Figure 2 for clarity). The formation pressure tester includes for this purpose a further pressure transducer (that is omitted from Figure 2).

The formation pressure tester includes an electronics section that is known *per se*.

A further electronics section 23, whose function is to control operation of modulating valve 26 that is described in more detail below, includes a programmable device in the form of a microprocessor; a memory device arranged to store data logged by the formation pressure tester; and an on-board power source in the form of a plurality of series- and parallel-connected batteries. The formation pressure tester and the components of the electronics section 23 are appropriately wired to one another so as to permit acquisition of data generated by the transducer in the formation pressure tester and its storage in the memory device.

Electronics section 23 is connected at its uphole end to a servomechanism consisting, in the embodiment shown, of an electric motor 42 whose rotary output shaft 43 is connected via an uphole gearbox 44 to a threaded lead screw 46 and ball nut 46a that convert the rotary output motion of motor 42

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to linear form. At least the microprocessor of electronics section 23 is wired to the servomechanism such that the servomechanism operates under the command of the microprocessor. In practical embodiments of the invention it also is desirable for the memory device to be directly or indirectly connectable to the inputs of the servomechanism, so that (as desired) the servomechanism is operable in dependence on logged data stored in the memory device.

An actuator shaft 47 is secured to the uphole end of ball nut 46a and extends longitudinally through the hollow part 38 of the cylindrical body 37. Consequently actuator shaft 47 is moveable longitudinally in body section 38.

Downhole pressure transducer 21 is located adjacent the downhole end of electric motor 42. Transducer 21 is mounted within hollow body section 38 on the downhole side of a pressure balancer 48 described in more detail below.

At the uphole end of actuator shaft 47 the latching arms 32 pivotably secured thereto are, in the position of the apparatus shown in Figure 2, engaged with latching detent perforations 24 described schematically in relation to Figure 1. The perforations 24 are formed in the aforementioned sleeve 51 that is secured eg. 3 or 4 drillpipe joints uphole of the downhole end of the drillpipe 18. As is visible in Figure 2a the perforations 24 are angled relative to the longitudinal axis of the apparatus. The latching arms 32 include similarly angled protuberances 32a so that the arms 32 are capable of, before its deployment, retaining the toolstring 19 in the drillpipe 18 in a harpoon-like manner as shown.

At its uphole end, actuator shaft 47 terminates in a release tool 49 comprising the hollow sleeve 51 within which the free, uphole end 52 of

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actuator shaft 47 is longitudinally slideable. The uphole end 52 of shaft 47 protrudes into sleeve 51. Within sleeve 51 shaft 47 terminates in an activator cam 33 that is engageable with the latching arms 32 to cause their release from the detent perforations 24.

Operation of the electric motor 42 under the control of the processor in the electronics section 23 causes shaft 43 to rotate. Lead screw 46 and ball nut 46a convert such motion into longitudinal, linear motion of actuator shaft 47.

Upon the processor sending an appropriate command to motor 42, cam 33 therefore moves longitudinally within sleeve 51 towards the latching arms 32.

The three release arms 32 are pivotably secured within the release sleeve 51. On such movement of cam 33 towards latching arms 32 the cam 33 engages the arms 24 and causes them to pivot out of engagement with the latching perforations 24, following shearing of shear pins 56 that retain the latching arms 24 in place until such movement of cam 33 as aforesaid.

On the cam 33 engaging the latching arms 32 the toolstring 19 is released with the result that it is free to slide towards the right of Figure 2.

At its uphole end the exterior of cylindrical portion 38 is encircled by a pair of *per se* known swab cups 57, 58. On such releasing of toolstring 19 following withdrawal of the latching arms 24 and release arms 56 the pressure of fluid in the drillpipe 18 acts on the swab cups 57, 58 and drives the toolstring 19 towards the right of Figure 2 so that the downhole components 39 protrude from the end of the drillpipe 18 in the manner outlined in connection with Figure 1.

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Intermediate its two ends actuator shaft 47 has secured thereon a valving member 59 including a circular, conical valving surface 61 that is seatable in a valve seat 62. Member 59 and seat 61 constitute the modulating valve 26 shown schematically in Figure 1. Conical valving surface 61 constitutes a somewhat large diameter, proportional valve needle.

Valving member 59 is rigidly secured to the exterior of actuator shaft 47. Consequently the longitudinal movement of actuator shaft 47 to the left and right in Figure 2 respectively causes unseating and re-seating of the valving member 59 in the seat 61.

As is evident from Figure 2, unseating of the valve surface 61 from the seat 62 opens a fluid flow path via a chamber 64, whence the fluid under pressure vents from within the tool via one or more radial ports 66 perforating cylindrical body 37.

Consequently opening of the modulating valve 26 causes a drop in the fluid pressure in the drillpipe 18. Such a pressure drop is detectable by the remote transducer 27 or 31 at the standpipe 17, and is proportional to the extent of unseating of the valve 26.

On re-seating of the valving member 59 on the seat 62 the flow of fluid via port 66 is blocked. Consequently the pressure in the drillpipe 18 increases, again in a proportional manner. This too is detectable by means of the transducer 27/31 at the uphole, standpipe location.

Movement of the toolstring 19 to the right of Figure 2 (ie. release of the toolstring as aforesaid) also causes a detectable pressure drop in the drillpipe 18, by virtue of removal of the blockage in drillpipe 18 caused by the presence of the toolstring in its latched position. Such a pressure drop is indicative of tool release.

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In Figure 2 the landing dogs 36 are shown as an annular collar encircling cylindrical body 37 near its uphole end 38 in the region between the swab cups 57, 58 and the modulating valve 26.

Immediately uphole of the landing dogs 36 hollow, cylindrical portion 38 is of reduced diameter as signified by reference numeral 69 and is encircled by a coiled spring 71.

At its uphole end spring 71 is retained by a further annular collar 72 encircling the cylindrical body 37. Collar 72 is secured to a hollow cylinder 73 on which the swab cups 57, 58 are secured.

Reduced diameter portion 69 is slideable in the manner of a telescope section within cylinder 73, against the resilience of coiled spring 71.

As a consequence of the landing dogs 36 engaging the drillpipe landing collar 34 (that is not visible in Figure 2), cylinder 73 slides towards landing dogs 36 against the resilience of coiled spring 71. This action gradually decelerates the mass of the toolstring 19 that is, in effect, supported by cylinder 73 during delatching and deployment operations; and also the mass of drillpipe fluid acting on the swab cups 57, 58. The mass of the fluid may be several tonnes, so it is important that the rate of the spring 71 is correctly chosen.

On the downhole side of the landing dogs 36 there is defined, by concentric, hollow, external cylindrical parts 74, 76 and cylindrical body 37 an annular chamber 77. Cylinder 74 is rigidly secured to collar 36.

The cylindrical parts 74, 76 are slideable one relative to another so that the

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length of chamber 77 is variable.

Adjacent the landing dogs 36 chamber 77 includes an annulus of (in the preferred embodiment) six damper ports 78.

In use of the apparatus annular chamber 77 is charged with drillpipe fluid via the damper ports 78. Upon the landing dogs engaging the landing collar chamber 77 elongates longitudinally by virtue of relative movement between the cylindrical parts 74 and 76, with the result that its volume increases.

As a consequence, fluid is drawn into chamber 77 via the damper ports 78 thereby damping the spring – mass – damper system defined by:

the mass of toolstring 19 and of the fluid acting uphole of the swab cups 57, 58;

the spring 67; and

the damper represented by the damper ports 78.

Consequently on landing of the landing dogs 36 in the landing collar (not shown) there is little or no likelihood of oscillation of the toolstring 18 in the drillpipe 18. Consequently the likelihood of spurious, acoustic signals being generated in the drillpipe is reduced or eliminated.

The apparatus of the invention additionally includes a pressure relief arrangement 79 valve that is openable to vent pressure from within a hollow part of the activatable tool should the pressure exceed a predetermined threshold such as 500 psi. In the embodiment shown the pressure relief valve is constituted by features of cylinders 74 and 76. As is evident from Figure 2, following landing of the landing dogs 36 in the landing collar pressure within the hollow, cylindrical section 37 continues to act on the swab cups 57, 58 tending to drive the toolstring 19 to the right of Figure 2.

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This causes sliding of cylinder 76 relative to (by then fixed) cylinder 74. Mutually aligned pressure relief ports 80, 81 perforate cylinders 37 and 74. The pressure acting on swab cups 57, 58 causes the cylinder 76 to move to the right of Figure 2 to expose pressure relief ports 81 via which pressure within body 37 may vent.

Thus pressure relief valve is arranged to open when landing of the landing dogs in the landing collar occurs. This curtails the increase of pressure within hollow section 37 following landing, in a way that is detectable in standpipe 17.

A secondary pressure relief valve 101 is present downhole of relief valve 79 to allow valve 26 to be disabled and to prevent the drillpipe pulling "wet". The resulting pressures cause a sleeve 102 that is secured to toolstring 19 by means of shear pins 103 to move to the right of Figure 2 and open one or more normally closed vent ports 104 to allow venting of fluid from within toolstring 19.

The swab cups 57, 58 are, as illustrated, of conventional design. In an alternative arrangement the swab cups may each be effectively a pair of conventional swab cups arranged "back-to-back" in a siamesed frustoconical shape so as to create a flexible, annular bulge encircling the cylindrical part of the drillstring and defining a sliding seal against the interior wall of the drillpipe 18.

Optionally a fishing neck, may be secured at the uphole end of toolstring 19 to permit retrieval of toolstring 19 from the borehole.

Such a fishing neck is when required secured to toolstring 19 before running in of the drillpipe 18.

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The fishing neck is perforated whereby to permit circulation of fluid via the hollow interior 37 of uphole section 38 of toolstring 19.

As shown in Figure 3, the typical digital acoustic signal generated by pump 11 under the control of controller 13 is a series of two pressure pulses each of 30 seconds duration and spaced by pressure decreases each of 30 seconds duration.

The pressure transducer 21 in the toolstring 19 detects such pulses and generates signals indicative thereof. By virtue of the wiring of the transducer such signals pass to the processor in the electronics section 23. Since the processor is programmed to recognise the sequence of pulses it generates commands to the electric servomotor 42 to cause the actuator shaft 47 to move to the left in Figures 2 to 5 and initiate release of the toolstring 19 from its retracted position to its operative position.

The diameter of the valving member 59 is such that it is moveable longitudinally in chamber 64 while still maintaining its seated condition. During running in of the drillpipe modulating valve 26 is in its open position (ie. with member 59 unseated from seat 62). On operation of the motor 42 as aforesaid member 59 seats in seat 62 to close modulating valve 26.

The motor 42 then continues to drive the valving member 59 to the left of Figure 2, causing it to pass more fully into chamber 64. By virtue of the rigid connection of cam 33 to member 59 (by means of shaft 47) this action causes cam 33 to engage the latching arm 32, shear the shear pins 56 and allow release of the toolstring 19.

As illustrated in Figure 4 by "tools released", this causes a drop in the drillpipe fluid pressure that is detectable at the standpipe 17, as the

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toolstring 19 commences its movement to the right and consequently dethrottles the fluid in drillpipe 18.

Figure 4 shows that the pressure reduction continues while the fluid pressure acts to pump the toolstring 19 to its deployed position. This period is signified by "tools pumped into openhole" in Figure 4.

On landing of the landing dogs 36 in the landing collar (not shown) halting of the toolstring causes a pressure build up in the hollow part 38 of toolstring 19 and hence in the standpipe 17. The pressure build up is visible in Figure 4, as signified by "tools landed in openhole,".

Once the pressure within hollow portion 38 of toolstring 19 exceeds the threshold pressure set for the pressure relief valve 79, the latter opens with the result that the standpipe pressure stabilises.

The pressure transducer 21 is capable of detecting this condition. It consequently generates a further signal that is interpreted by the processor in the electronics section 23 to initiate an activation procedure for a logging tool such as but not limited to a formation pressure tester.

The initiation routine of the formation pressure tester can include deployment of a calliper having a pad secured thereto; powering up of the electronic parts of the formation pressure tester; a self-testing routine.

On completion of such activities, such that the formation pressure tester is ready for use, the processor generates commands to the servomechanism causing the valve member 59 to unseat from seat 62 thereby causing a further pressure drop (signified by "control valve opens in tool to indicate power on, callipers open, data recorded and tools functional" in Figure 4) that is also detectable in standpipe 17.

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It follows from the foregoing that in use of the apparatus of the invention it is possible to initiate deployment of downhole components using signals generated at an uphole location. It is subsequently possible for the downhole components to signal correct deployment to the uphole location represented by standpipe 17.

Figure 5 shows the pressure response of the formation pressure tester in the event of it encountering a no-seal condition. In such circumstances the pad fails to seal adequately, for example because of excessive porosity of the surrounding strata.

As indicated in Figure 5, this leads to a constant pressure response within the formation pressure tester.

Figure 6 shows the pressure response of the formation pressure tester when encountering a so-called tight formation.

In this circumstance the pad seals correctly against the surrounding strata, and the pretest causes an initial pressure drop with the formation pressure tester. The pressure detected by the formation pressure tester however remains at a lower value thereafter.

A good pressure test is illustrated in Figure 7. In this circumstance the initial pressure drop is followed a short time later by a build up of formation pressure within the active chamber of the formation pressure tester. Such a pressure response in the formation pressure tester represents good data.

The apparatus of the invention is arranged such that the processor in the electronics section 23 analyses the pressure responses of the formation pressure tester, either in real time or following recording of the pressure

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responses in the memory device forming part of the electronics section. The processor then is capable of commanding the servomotor 42 to open and close the modulating valve 26 in dependence on the formation pressure tester responses. This causes analogue modulation of the drillpipe fluid pressure with the result that the fluid pressure in the standpipe 17 modulates similarly.

Figures 8 to 10 show the standpipe pressures resulting from such operation of the processor, servomotor 42 and modulating valve 26. As is clear from Figures 8 to 10 in use of the apparatus of the invention the standpipe pressures closely mimic the actual formation pressure tester responses at the downhole location. Consequently an operator at a surface location (or indeed appropriately programmed software in a control computer) may interpret the standpipe pressure indications in order to ascertain whether conditions are correct for operation of the formation pressure tester.

In the event of the standpipe pressure indication signifying either a no-seal or a tight formation, the operator can run in or withdraw a short length of drillpipe 18 in order to reposition the formation pressure tester (following withdrawal of the pad thereof from the borehole wall) until a region of good formation quality is encountered, as signified by a pressure indication like that of Figure 10.

Modulating valve 26 is pressure balanced by virtue of conduit 83 providing drillpipe pressure on both the uphole and downhole ends of valving member 59. Conduit 83 connects to drillpipe pressure via ports 84 as shown in Figure 2c.

A further pressure balancer 48 balances the fluid pressures exerted on lead screw (ball screw) 46.

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Pressure balancer 48 includes a hollowed portion 63 of an end cap 46b secured on lead screw 46. Hollowed portion 63 is slightly downhole of solid end cap 46b that connects to rigid shaft 47. The threaded portion of lead screw 46 is threadedly received in hollow portion 63.

Annular O-ring seal 53a seals the uphole end of end cap 46b relative to an encircling cylinder 54. A further O-ring seal 53b uphole of end cap 40b, on shaft 47, defines an annular chamber 67 that is filled with air at atmospheric pressure. Downhole of end cap 46b the exterior of chamber 63 is sealed by a third O-ring 53c to the wall of toolstring 19.

The hollow portion 63 also contains air at atmospheric pressure. Consequently the borehole pressure acting in an annular chamber 67 encircling end cap 46b confers no net force on lead screw 46, as a result of atmospheric pressure acting on the components to either side thereof.

Thus a further annular chamber 86 lies, externally of end cap 46b, between O-rings 53a and 53c. Chamber 86 is connected via ports 87 to conduit 83. Hence borehole (drillpipe) pressure acts in chamber 86.

Conduit 83 extends further downhole to beyond the seals 53c.

Conduit 83 terminates at a pressure bulkhead 88 of *per se* known design. A pair of capillary tubes 89 connect the pressure transducer 21 to the bulkhead 88, whereby transducer 21 is able to detect the various pressure changes in the drillpipe 18.

One mode of use of the device of the invention, is following completion of a natural Gamma log of a borehole. The results of the Gamma log can be stored in the memory device of electronics section 23 before deployment thereof. The electronics section 23 can then cause operation of the

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modulating valve 26 partly in dependence on the Gamma log data. Consequently the apparatus is able to transmit to the uphole transducer 27 an absolute indication of the position of the toolstring 19 in the borehole at any given time.

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CLAIMS

1. Apparatus for remotely activating a tool in a wellbore, the apparatus comprising:

a positive displacement pump for causing circulation of a fluid under pressure in the wellbore;

a control device for controlling the speed of operation of the pump;

a conduit that is operatively connected to the pump and extends into the wellbore for conveying the fluid thereinto on operation of the pump;

a downhole transducer, that is capable of detecting changes in the pressure of the fluid and generating one or more detected pressure signals indicative thereof;

a processor that is capable of generating one or more actuator commands in dependence on detected pressure signals generated by the downhole transducer;

one or more actuators that are each operable to activate at least a part of a tool in dependence on a said actuator command;

an activatable tool at a downhole location;

a modulating valve for modulating the pressure of fluid in the conduit; and

a remote transducer that is operatively connected to detect pressure of the fluid in the conduit at a location remote from the downhole transducer, wherein operation of the modulating valve is dependent on a downhole event.

2. Apparatus according to Claim 1 wherein the control device is operable to cause the pump to generate one or more analogue acoustic signals, in the fluid, the waveforms or which are detectable by the downhole transducer.

3. Apparatus according to Claim 1 wherein the control device is

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operable to cause the pump to generate one or more digital acoustic signals, in the fluid, the waveforms of which are detectable by the downhole transducer; and wherein the modulating valve is operable to generate one or more analogue or digital acoustic signals, in the fluid, that are detectable by the remote transducer.

4. Apparatus according to any of Claims 1 to 3 wherein the conduit is a drillpipe that is moveable within the wellbore; wherein the activatable tool is moveable relative to the drillpipe; and wherein the drillpipe and the activatable tool include mutually engageable latch parts that, when mutually engaged, retain at least part, or all, of the activatable tool in a retracted position relative to the drillpipe and when disengaged permit movement of the tool to an advanced position in which at least part of the tool protrudes or protrudes further from the downhole end of the drillpipe, the apparatus including a release tool activator that is operable to cause disengagement of the latch parts from one another.

5. Apparatus according to Claim 4 wherein the release tool activator includes or is controlled by a programmable device that is programmed to cause disengagement of the latch parts on the downhole transducer detecting a predetermined sequence of pressure changes in the fluid.

6. Apparatus according to Claim 4 or Claim 5 wherein the drillpipe includes on its interior surface one or more landing stops and the activatable tool includes protruding from an exterior surface one or more landing dogs that are each engageable with a said landing stop on the activatable tool moving to its advanced position relative to the drillpipe.

7. Apparatus according to Claim 5 or Claim 6 wherein the landing stop is or includes an annular landing collar extending about the interior surface of the drillpipe.

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8. Apparatus according to any of Claims 4 to 7 wherein operation of the release tool activator to cause disengagement of the latch parts also causes the modulating valve to close whereby movement of the tool to its advanced position causes dethrottling of the flow of fluid at the downhole location, such dethrottling being detectable at the remote location as a period of reduced fluid pressure.

9. Apparatus according to any of Claims 6 to 8 wherein the apparatus includes a pressure relief valve, whose opening threshold is predetermined; and the engagement of the or each said landing dog with a said landing stop causes the pressure relief valve to generate an analogue, acoustic signal that is indicative of landing of the tool in its advanced position relative to the drillpipe.

10. Apparatus according to Claim 8 or Claim 9 when dependent from Claim 8 wherein the modulating valve optionally is a proportional valve including a valve needle and a valve seat; and acoustic signals generated thereby conveniently are fluid pressure decreases that are proportional to the displacement of the valve needle relative to the seat.

11. Apparatus according to Claim 8 or Claim 9 when dependent from Claim 8 wherein the modulating valve preferably is a proportional valve including a valve needle and a seat therefor; and the acoustic signal is an increase in pressure that is proportional to the displacement of the valve needle relative to the seat.

12. Apparatus according to Claim 8 or any preceding claim dependent therefrom including an actuator member that is common to the release tool and the modulating valve whereby operation of the release tool causes movement of the modulating valve.

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13. Apparatus according to Claim 10 when dependent from Claim 9 wherein the common actuator member is a rod extending centrally within a toolstring, mutually spaced parts of the rod being secured respectively to the release tool, the valve member of the modulating valve and a servomechanism that moves the rod longitudinally in the toolstring in dependence on one or more said actuator commands.

14. Apparatus according to Claim 4 or any preceding claim dependent therefrom, the activatable tool including one or more reaction surfaces against which fluid pressure in the conduit acts.

15. Apparatus according to Claim 14 wherein the reaction surfaces include one or more flexible, annular sealing members encircling a cylindrical part of the activatable tool so as to seal between the exterior of the tool and the interior of the conduit.

16. Apparatus according to Claim 14 or Claim 15 when dependent from Claim 5 wherein the or each reaction surface is moveable longitudinally of the activatable tool relative to the landing dogs; and the apparatus includes a resiliently deformable member operatively interconnecting the or each reaction surface and a said landing dog.

17. Apparatus according to Claim 14 or any preceding claim dependent therefrom, wherein the logging toolstring includes a cylindrical member that is moveable relative to a chamber, the chamber including one or more ports providing communication between the interior and the exterior of the chamber and the cylindrical member closing the or each said port during deployment of the toolstring, the or each reaction surface being operatively connected to the cylindrical member such that on landing of the tool the cylindrical member moves to open the or each said port to limit the

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pressure of fluid in the chamber.

18. Apparatus according to Claim 17 wherein the chamber has formed therein an orifice, the orifice providing fluid communication between the conduit and a further chamber the volume of which changes on movement of the cylindrical member.

19. Apparatus according to Claim 17 or any preceding claim dependent therefrom wherein the resiliently deformable member is a coiled spring interconnecting the or each reaction member and the cylindrical member.

20. Apparatus according to Claim 17 or any preceding claim dependent therefrom wherein the chamber includes a wall member having defined therein each said port, the wall member including a perforated sleeve that is releasably secured on the chamber.

21. Apparatus according to Claim 18 or any preceding claim that depends therefrom including a pressure relief valve that opens to vent fluid pressure from within a hollow part of the activatable tool should the pressure within the hollow part exceed a predetermined threshold.

22. Apparatus according to Claim 21 including a first pressure balancer for balancing fluid pressure in the uphole and downhole sides of the modulating valve.

23. Apparatus according to Claim 22 including a further pressure balancer that in use lies downhole of the modulating valve and is operatively connected to equalise pressures acting on the uphole and downhole sides of the servomechanism.

24. Apparatus according to any preceding claim wherein the activatable

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tool includes a formation pressure tester; and wherein the processor is programmed to generate one or more actuator commands for causing operation of the formation pressure tester.

25. Apparatus according to Claim 24 when dependent from Claim 13 wherein the processor is connected and programmed to generate commands for causing one or more of:

(i) operation of the servomechanism to cause unlatching of the mutually engageable latch parts and thereby cause movement of the toolstring, that generates an acoustic signal that is indicative of tool release; followed by

(ii) operation of the pressure relief valve;

(iii) deployment of one or more deployable components of the formation pressure tester; and

(iv) powering up and/or self-testing or one or more tools in a toolstring.

26. Apparatus according to Claim 13 or any preceding claim depending therefrom wherein the activatable tool includes a logging device and a memory device capable of recording data logged by the logging device, the processor being programmed to generate actuator commands for commanding the servomechanism to operate the modulating valve to generate fluid pressure signals in dependence on the recorded, logged data.

27. Apparatus according to any preceding claim, including a remote transducer that detects pressure of the fluid in the conduit at a location remote from the downhole pressure transducer and generates signals indicative thereof.

28. Apparatus according to Claim 27 wherein the remote transducer detects fluid pressure in a standpipe that interconnects the outlet of the

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pump and the interior of the conduit.

29. Apparatus according to any preceding claim including an on-board source of electrical power.

30. Apparatus for signalling between a downhole location in a wellbore and a further location that is remote from the downhole location, the apparatus comprising a conduit extending into the wellbore; a pump connected to supply fluid under pressure in the conduit; a modulating valve, at a downhole location, for modulating the pressure of fluid in the conduit; a programmable processor for controlling operation of the modulating valve; a memory device; and a remote transducer for detecting fluid pressure at the further location.

31. Apparatus according to Claim 30 wherein the memory device includes stored therein data logged in the wellbore; and wherein the programmable processor is programmed to cause the modulating valve to modulate the pressure of fluid in the conduit in a fashion that is characteristic of the logged data.

32. Apparatus according to Claim 31 wherein the programmable processor is programmed to cause the modulating valve to modulate the pressure of fluid in the conduit in a fashion that is characteristic of two data logs carried out at different times.

33. Apparatus according to Claim 32 wherein the earlier of the two logs is a low frequency Gamma log.

34. Apparatus according to any of Claims 30 to 33 wherein the modulating valve includes a valve member; a valve seat on which the valve is seatable to raise fluid pressure in the conduit and from which the valve

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member is removable to reduce fluid pressure in the conduit; a servomechanism connected to operate in dependence on signals generated by the programmable processor; and an actuator member operatively interconnecting the servomechanism and the valve member whereby the valve is openable and closeable in dependence on the signals generated by the programmable processor.

35. Apparatus according to any of Claims 31 to 34 including a logging tool that is capable of logging data characteristic of the wellbore and/or a formation proximate thereto, the logging tool and the memory device being connectable one to the other so that the memory device stores data logged by the logging tool.

36. Apparatus according to Claim 35 wherein the logging tool is a formation pressure tester that is deployable against the wellbore in dependence on commands generated by the programmable device.

37. Apparatus according to Claim 36 wherein the programmable device is programmed to generate signals that cause the modulating valve to generate analogue pressure changes in the fluid in the conduit, the pressure changes mimicking pressure changes experienced by the formation pressure tester in use.

38. Apparatus according to Claim 37 wherein the pressure changes generated by the modulating valve include, in the case of a good test carried out by the formation pressure tester:

an initial pressure increase that mimics sealing of the formation pressure tester pad against the borehole;

a subsequent pressure decrease caused by operation of the pretest piston of the formation pressure tester that mimics exposure of the formation pressure tester transducer to formation fluid pressure; and

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a subsequent pressure recovery that mimics the building up of formation fluid pressure within the formation pressure tester when the pretest is halted.

39. Apparatus according to Claim 37 wherein the pressure changes generated by the modulating valve includes, in the case of the formation pressure tester experiencing a no-seal condition, a period of substantially invariant fluid pressure that mimics the fluid pressure exerted on the formation pressure tester when carrying out a no-seal test.

40. Apparatus according to Claim 37 wherein the pressure generated by the modulating valve includes, in the case of the formation pressure tester engaging a tight formation, an initial pressure drop; and a subsequent period without a substantial pressure recovery.

41. Apparatus according to any of Claims 30 to 40 including a source of electrical power operatively connected to power as necessary the programmable device, the modulating valve and the logging tool.

42. Apparatus according to Claim 41 wherein the programmable device, the modulating valve, the logging tool and the source of electrical power are secured one to another in a discrete toolstring.

43. A method of deploying a logging tool in a wellbore using an apparatus according to any of Claims 1 to 42, the method comprising the steps of:

(i) running the downhole transducer, the processor, the release tool actuator, the activatable tool and the modulating valve to a downhole location on a length of drillpipe defining the conduit;

(ii) operating the pump under control of the control device to:

(a) circulate the wellbore; and

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(b) generate one or more changes in fluid pressure, in the conduit, that are detectable by the downhole transducer whereby the downhole transducer generates one or more detected pressure signals that are indicative of the generated fluid pressure changes such that the processor generates one or more actuator commands that cause operation of the tool actuator so as to activate at least part of the activatable tool at the downhole location, activation of the activatable tool causing the modulating valve to modulate the pressure of fluid in the conduit; and

(iii) detecting the modulation of fluid pressure in the conduit at the remote location of means of the remote transducer.

44. A method according to Claim 43 wherein the sub-step of operating the pump to generate one or more changes in fluid pressure in the conduit includes the further sub-step of generating a waveform, in the fluid in the conduit, that is detectable at the remote location.

45. A method according to Claim 43 wherein the sub-step of operating the pump to generate one or more changes in fluid pressure in the conduit includes the further sub-step of generating a sequence of digital pressure pulses in the fluid in the conduit; and wherein the operation of the modulating valve includes the generation of one or more analogue pressure changes in the fluid in the conduit.

46. A method according to any of Claims 43 to 45 wherein the step (i) includes the step of running mutually engaged latch parts, that secure at least part of the activatable tool and the drillpipe together, to the downhole location.

47. A method according to Claim 46 wherein during the step of running the mutually engaged latch parts to the downhole location at least part of the activatable tool is retained in the retracted position relative to the

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drillpipe; and wherein on operation of the release tool actuator at least part, or all, of the activatable tool moves relative to the drillpipe so as to protrude from the downhole end thereof.

48. A method according to Claim 47 wherein operation of the release tool actuator causes disengagement of the mutually engageable latch parts from one another.

49. A method according to Claim 47 or Claim 48 including engagement of a landing dog secured to the activatable tool with a landing stop secured on the drillpipe.

50. A method according to Claim 49 wherein following engagement of the landing dog and the landing stop one part of the activatable tool moves relative to another part, such relative movement between parts of the tool being subject to one or more of:

deceleration by virtue of deformation of a resiliently deformable member and/or

damping by forcing of a fluid via an orifice into an expandable chamber.

51. A method according to any of Claims 43 to 50 including operation of a servomechanism to move an actuator member to cause operation of the modulating valve, operation of the servomechanism being dependent on the generation of signals by the processor.

52. A method according to any of Claims 43 to 51 including the sub-step of pumping at least part of the activatable tool between retracted and protruding positions relative to the downhole end of the drillpipe, using the pressure of fluid circulating in the wellbore.

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53. A method according to Claim 52 wherein the pumping of at least part of the activatable tool includes causing fluid under pressure in the conduit to act on at least one flexible, annular sealing member encircling a cylindrical part of the activatable tool so as slidingly to seal between the exterior of the tool and the interior of the conduit.

54. A method according to any of Claims 43 to 53 including opening of a pressure relief valve to vent fluid pressure from within a hollow part of the activatable tool if the pressure within the hollow part exceeds a predetermined threshold value.

55. A method according to Claim 54 including balancing of fluid pressure in the hollow portion and fluid pressure in the conduit.

56. A method according to any of Claims 43 to 55 wherein activation of the activatable tool includes activation and operation of a formation pressure tester.

57. A method according to Claim 56 wherein activation of the formation pressure tester includes:

(iv) unlatching of the mutually engageable latch parts;

(v) landing of one or more landing dogs in a landing stop;

(vi) deployment of one or more deployable components of the formation pressure tester; and

(vii) powering up and/or self testing of the formation pressure tester

and wherein the method includes causing the modulating valve to generate signals in the fluid in the conduit that are indicative of one or more of (iv) to (vii).

58. A method according to any of Claims 43 to 57 including logging of

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data characteristic of a formation perforated by a wellbore using a downhole logging tool; and recording of logged data using a downhole memory device.

59. A method according to Claim 58 including the step of recovering the downhole memory device to an uphole location following the recording of data; and the subsequent analysis, modification, display and/or transmission of the recorded data.

60. A method according to any of Claims 43 to 59 including the detecting of changes in the pressure of fluid in the conduit, using a transducer at a location remote from the downhole transducer; the method further including generating one or more signals indicative of such detections of pressure changes.

61. A method according to any of Claims 43 to 60 including the sub-step of as necessary powering the downhole transducer, the processor, the release tool actuator, the modulating valve and the activatable tool using a power source conveyed to the downhole location.

62. A method of signalling between a downhole location in a wellbore and a further location that is remote therefrom, the method comprising the steps of:

pumping fluid, using a pump, in a conduit extending into the wellbore so as to pressurise fluid in the conduit;

operating a modulating valve at the downhole location to modulate the pressure of fluid in dependence on signals generated by a processor at the downhole location, the signals being characteristic of conditions at the downhole location; and

detecting modulations in the pressure of fluid in the conduit, resulting from operation of the modulating valve, at the further location.

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63. A method according to Claim 62 wherein the modulations caused by operation of the modulating valve are analogue mimics of data logged by the logging tool.

64. A method according to Claim 62 or Claim 63 wherein the processor is operatively connected to a servomechanism that when activated causes operation of the modulating valve by means of an actuator member, the method including causing the processor to operate the modulating valve.

65. A method according to any of Claims 62 to 64 including the step of storing data logged by the logging tool in a memory device at the downhole location.

66. A method according to any of Claims 62 to 65 including the step of logging data on the pressure of fluid proximate the wellbore at the downhole location, using a formation pressure tester.

67. A method according to Claim 66 wherein the modulations effected by the modulating valve in the case of a good pressure test include:

an initial pressure increase that mimics sealing of the formation pressure tester pad against the borehole;

a subsequent pressure decrease caused by operation of the pretest piston of the formation pressure tester that mimics exposure of the formation pressure tester transducer to formation fluid pressure; and

a subsequent pressure recovery that mimics the building up of formation fluid pressure within the formation pressure tester.

68. A method according to Claim 66 wherein modulations effected by the modulating valve in the case of the formation pressure tester experiencing a "no-seal" formation include:

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a period of substantially invariant fluid pressure that mimics the fluid pressure experienced by the formation pressure tester when carrying out a test that fails to seal.

69. A method according to Claim 66 wherein modulations effected by the modulating valve in the case of the pressure tests encountering a tight formation include:

a pressure drop that mimics the fluid pressure experienced by the formation pressure tester when carrying out a pressure test on a tight formation; and a subsequent period without a substantial pressure recovery.

70. A method according to any of Claims 62 to 69 including powering the modulating valve, the processor and the logging tool using a source of electrical power at the downhole location.

71. A method according to any of Claims 43 to 61 or any of Claims 62 to 70 including the step of modulating acoustic signals generated in the borehole fluid with one or more waveforms that are characteristic of a low frequency Gamma log of the borehole.

72. A method according to any of Claims 43 to 61 including the step of causing operation of one or more pressure relief valves generally to equalise uphole and downhole fluid pressures acting on one or more components of the apparatus.

73. Apparatus generally as herein described, with reference to and/or as illustrated in the accompanying drawings.

74. Methods generally as herein described, with reference to and/or as illustrated in the accompanying drawings.

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Amendments to the claims have been filed as follows

1. Apparatus for remotely activating a tool in a wellbore, the apparatus comprising:

a positive displacement pump for causing circulation of a fluid under pressure in the wellbore;

a control device for controlling the speed of operation of the pump;

a conduit that is operatively connected to the pump and extends into the wellbore for conveying the fluid thereinto on operation of the pump;

a downhole transducer, that is capable of detecting changes in the pressure of the fluid and generating one or more detected pressure signals indicative thereof;

a processor that is capable of generating one or more actuator commands in dependence on detected pressure signals generated by the downhole transducer;

one or more actuators that are each operable to activate at least a part of a tool in dependence on a said actuator command;

an activatable tool at a downhole location;

a modulating valve for modulating the pressure of fluid in the conduit; and

a remote transducer that is operatively connected to detect pressure of the fluid in the conduit at a location remote from the downhole transducer; wherein operation of the modulating valve is dependent on a downhole event, wherein the control device is operable to cause the pump to generate one or more digital acoustic signals, in the fluid, the waveforms of which are detectable by the downhole transducer; and wherein the modulating valve is operable to generate one or more analogue acoustic signals, in the fluid, that are detectable by the remote transducer.

2. Apparatus according to Claim 1 wherein the control device is operable to cause the pump to generate one or more analogue acoustic

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signals, in the fluid, the waveforms or which are detectable by the downhole transducer.

3. Apparatus according to Claim 1 or Claim 2 wherein the conduit is a drillpipe that is moveable within the wellbore; wherein the activatable tool is moveable relative to the drillpipe; and wherein the drillpipe and the activatable tool include mutually engageable latch parts that, when mutually engaged, retain at least part, or all, of the activatable tool in a retracted position relative to the drillpipe and when disengaged permit movement of the tool to an advanced position in which at least part of the tool protrudes or protrudes further from the downhole end of the drillpipe, the apparatus including a release tool activator that is operable to cause disengagement of the latch parts from one another.

4. Apparatus according to Claim 3 wherein the release tool activator includes or is controlled by a programmable device that is programmed to cause disengagement of the latch parts on the downhole transducer detecting a predetermined sequence of pressure changes in the fluid.

5. Apparatus according to Claim 3 or Claim 4 wherein the drillpipe includes on its interior surface one or more landing stops and the activatable tool includes protruding from an exterior surface one or more landing dogs that are each engageable with a said landing stop on the activatable tool moving to its advanced position relative to the drillpipe.

6. Apparatus according to Claim 4 or Claim 5 wherein the landing stop is or includes an annular landing collar extending about the interior surface of the drillpipe.

7. Apparatus according to any of Claims 3 to 6 wherein operation of the release tool activator to cause disengagement of the latch parts also

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causes the modulating valve to close whereby movement of the tool to its advanced position causes dethrottling of the flow of fluid at the downhole location, such dethrottling being detectable at the remote location as a period of reduced fluid pressure.

8. Apparatus according to any of Claims 5 to 7 wherein the apparatus includes a pressure relief valve, whose opening threshold is predetermined; and the engagement of the or each said landing dog with a said landing stop causes the pressure relief valve to generate an analogue, acoustic signal that is indicative of landing of the tool in its advanced position relative to the drillpipe.

9. Apparatus according to Claim 7 or Claim 8 when dependent from Claim 8 wherein the modulating valve optionally is a proportional valve including a valve needle and a valve seat; and acoustic signals generated thereby conveniently are fluid pressure decreases that are proportional to the displacement of the valve needle relative to the seat.

10. Apparatus according to Claim 7 or Claim 8 when dependent from Claim 8 wherein the modulating valve preferably is a proportional valve including a valve needle and a seat therefor; and the acoustic signal is an increase in pressure that is proportional to the displacement of the valve needle relative to the seat.

11. Apparatus according to Claim 7 or any preceding claim dependent therefrom including an actuator member that is common to the release tool and the modulating valve whereby operation of the release tool causes movement of the modulating valve.

12. Apparatus according to Claim 9 when dependent from Claim 8 wherein the common actuator member is a rod extending centrally within a

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toolstring, mutually spaced parts of the rod being secured respectively to the release tool, the valve member of the modulating valve and a servomechanism that moves the rod longitudinally in the toolstring in dependence on one or more said actuator commands.

13. Apparatus according to Claim 3 or any preceding claim dependent therefrom, the activatable tool including one or more reaction surfaces against which fluid pressure in the conduit acts.

14. Apparatus according to Claim 13 wherein the reaction surfaces include one or more flexible, annular sealing members encircling a cylindrical part of the activatable tool so as to seal between the exterior of the tool and the interior of the conduit.

15. Apparatus according to Claim 13 or Claim 14 when dependent from Claim 4 wherein the or each reaction surface is moveable longitudinally of the activatable tool relative to the landing dogs; and the apparatus includes a resiliently deformable member operatively interconnecting the or each reaction surface and a said landing dog.

16. Apparatus according to Claim 13 or any preceding claim dependent therefrom, wherein the logging toolstring includes a cylindrical member that is moveable relative to a chamber, the chamber including one or more ports providing communication between the interior and the exterior of the chamber and the cylindrical member closing the or each said port during deployment of the toolstring, the or each reaction surface being operatively connected to the cylindrical member such that on landing of the tool the cylindrical member moves to open the or each said port to limit the pressure of fluid in the chamber.

17. Apparatus according to Claim 16 wherein the chamber has formed

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therein an orifice, the orifice providing fluid communication between the conduit and a further chamber the volume of which changes on movement of the cylindrical member.

18. Apparatus according to Claim 16 or any preceding claim dependent therefrom wherein the resiliently deformable member is a coiled spring interconnecting the or each reaction member and the cylindrical member.

19. Apparatus according to Claim 16 or any preceding claim dependent therefrom wherein the chamber includes a wall member having defined therein each said port, the wall member including a perforated sleeve that is releasably secured on the chamber.

20. Apparatus according to Claim 17 or any preceding claim that depends therefrom including a pressure relief valve that opens to vent fluid pressure from within a hollow part of the activatable tool should the pressure within the hollow part exceed a predetermined threshold.

21. Apparatus according to Claim 20 including a first pressure balancer for balancing fluid pressure in the uphole and downhole sides of the modulating valve.

22. Apparatus according to Claim 21 including a further pressure balancer that in use lies downhole of the modulating valve and is operatively connected to equalise pressures acting on the uphole and downhole sides of the servomechanism.

23. Apparatus according to any preceding claim wherein the activatable tool includes a formation pressure tester; and wherein the processor is programmed to generate one or more actuator commands for causing operation of the formation pressure tester.

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24. Apparatus according to Claim 23 when dependent from Claim 12 wherein the processor is connected and programmed to generate commands for causing one or more of:

(i) operation of the servomechanism to cause unlatching of the mutually engageable latch parts and thereby cause movement of the toolstring, that generates an acoustic signal that is indicative of tool release; followed by

(ii) operation of the pressure relief valve;

(iii) deployment of one or more deployable components of the formation pressure tester; and

(iv) powering up and/or self-testing or one or more tools in a toolstring.

25. Apparatus according to Claim 12 or any preceding claim depending therefrom wherein the activatable tool includes a logging device and a memory device capable of recording data logged by the logging device, the processor being programmed to generate actuator commands for commanding the servomechanism to operate the modulating valve to generate fluid pressure signals in dependence on the recorded, logged data.

26. Apparatus according to any preceding claim, including a remote transducer that detects pressure of the fluid in the conduit at a location remote from the downhole pressure transducer and generates signals indicative thereof.

27. Apparatus according to Claim 26 wherein the remote transducer detects fluid pressure in a standpipe that interconnects the outlet of the pump and the interior of the conduit.

28. Apparatus according to any preceding claim including an on-board

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source of electrical power.

29. Apparatus for signalling between a downhole location in a wellbore and a further location that is remote from the downhole location, the apparatus comprising a conduit extending into the wellbore; a pump connected to supply fluid under pressure in the conduit; a modulating valve, at a downhole location, for modulating the pressure of fluid in the conduit; a programmable processor for controlling operation of the modulating valve; a memory device; and a remote transducer for detecting fluid pressure at the further location.

30. Apparatus according to Claim 29 wherein the memory device includes stored therein data logged in the wellbore; and wherein the programmable processor is programmed to cause the modulating valve to modulate the pressure of fluid in the conduit in a fashion that is characteristic of the logged data.

31. Apparatus according to Claim 30 wherein the programmable processor is programmed to cause the modulating valve to modulate the pressure of fluid in the conduit in a fashion that is characteristic of two data logs carried out at different times.

32. Apparatus according to Claim 31 wherein the earlier of the two logs is a low frequency Gamma log.

33. Apparatus according to any of Claims 29 to 32 wherein the modulating valve includes a valve member; a valve seat on which the valve is seatable to raise fluid pressure in the conduit and from which the valve member is removable to reduce fluid pressure in the conduit; a servomechanism connected to operate in dependence on signals generated by the programmable processor; and an actuator member operatively

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interconnecting the servomechanism and the valve member whereby the valve is openable and closeable in dependence on the signals generated by the programmable processor.

34. Apparatus according to any of Claims 30 to 33 including a logging tool that is capable of logging data characteristic of the wellbore and/or a formation proximate thereto, the logging tool and the memory device being connectable one to the other so that the memory device stores data logged by the logging tool.

35. Apparatus according to Claim 34 wherein the logging tool is a formation pressure tester that is deployable against the wellbore in dependence on commands generated by the programmable device.

36. Apparatus according to Claim 35 wherein the programmable device is programmed to generate signals that cause the modulating valve to generate analogue pressure changes in the fluid in the conduit, the pressure changes mimicking pressure changes experienced by the formation pressure tester in use.

37. Apparatus according to Claim 36 wherein the pressure changes generated by the modulating valve include, in the case of a good test carried out by the formation pressure tester:

an initial pressure increase that mimics sealing of the formation pressure tester pad against the borehole;

a subsequent pressure decrease caused by operation of the pretest piston of the formation pressure tester that mimics exposure of the formation pressure tester transducer to formation fluid pressure; and

a subsequent pressure recovery that mimics the building up of formation fluid pressure within the formation pressure tester when the pretest is halted.

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38. Apparatus according to Claim 36 wherein the pressure changes generated by the modulating valve includes, in the case of the formation pressure tester experiencing a no-seal condition, a period of substantially invariant fluid pressure that mimics the fluid pressure exerted on the formation pressure tester when carrying out a no-seal test.

39. Apparatus according to Claim 36 wherein the pressure generated by the modulating valve includes, in the case of the formation pressure tester engaging a tight formation, an initial pressure drop; and a subsequent period without a substantial pressure recovery.

40. Apparatus according to any of Claims 29 to 39 including a source of electrical power operatively connected to power as necessary the programmable device, the modulating valve and the logging tool.

41. Apparatus according to Claim 40 wherein the programmable device, the modulating valve, the logging tool and the source of electrical power are secured one to another in a discrete toolstring.

42. A method of deploying a logging tool in a wellbore using an apparatus according to any of Claims 1 to 41, the method comprising the steps of:

(i) running the downhole transducer, the processor, the release tool actuator, the activatable tool and the modulating valve to a downhole location on a length of drillpipe defining the conduit;

(ii) operating the pump under control of the control device to:

(a) circulate the wellbore; and

(b) generate one or more changes in fluid pressure, in the conduit, that are detectable by the downhole transducer whereby the downhole transducer generates one or more detected pressure signals that

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are indicative of the generated fluid pressure changes such that the processor generates one or more actuator commands that cause operation of the tool actuator so as to activate at least part of the activatable tool at the downhole location, activation of the activatable tool causing the modulating valve to modulate the pressure of fluid in the conduit; and

(iii) detecting the modulation of fluid pressure in the conduit at the remote location of means of the remote transducer, wherein the sub-step of operating the pump to generate one or more changes in fluid pressure in the conduit includes the further sub-step of generating a sequence of digital pressure pulses in the fluid in the conduit; and wherein the operation of the modulating valve includes the generation of one or more analogue pressure changes in the fluid in the conduit.

43. A method according to Claim 42 wherein the sub-step of operating the pump to generate one or more changes in fluid pressure in the conduit includes the further sub-step of generating a waveform, in the fluid in the conduit, that is detectable at the remote location.

44. A method according to Claim 42 or Claim 43 wherein the step (i) includes the step of running mutually engaged latch parts, that secure at least part of the activatable tool and the drillpipe together, to the downhole location.

45. A method according to Claim 44 wherein during the step of running the mutually engaged latch parts to the downhole location at least part of the activatable tool is retained in the retracted position relative to the drillpipe; and wherein on operation of the release tool actuator at least part, or all, of the activatable tool moves relative to the drillpipe so as to protrude from the downhole end thereof.

46. A method according to Claim 45 wherein operation of the release

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tool actuator causes disengagement of the mutually engageable latch parts from one another.

47. A method according to Claim 45 or Claim 46 including engagement of a landing dog secured to the activatable tool with a landing stop secured on the drillpipe.

48. A method according to Claim 47 wherein following engagement of the landing dog and the landing stop one part of the activatable tool moves relative to another part, such relative movement between parts of the tool being subject to one or more of:

deceleration by virtue of deformation of a resiliently deformable member and/or

damping by forcing of a fluid via an orifice into an expandable chamber.

49. A method according to any of Claims 42 to 48 including operation of a servomechanism to move an actuator member to cause operation of the modulating valve, operation of the servomechanism being dependent on the generation of signals by the processor.

50. A method according to any of Claims 42 to 49 including the sub-step of pumping at least part of the activatable tool between retracted and protruding positions relative to the downhole end of the drillpipe, using the pressure of fluid circulating in the wellbore.

51. A method according to Claim 50 wherein the pumping of at least part of the activatable tool includes causing fluid under pressure in the conduit to act on at least one flexible, annular sealing member encircling a cylindrical part of the activatable tool so as slidingly to seal between the exterior of the tool and the interior of the conduit.

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52. A method according to any of Claims 42 to 51 including opening of a pressure relief valve to vent fluid pressure from within a hollow part of the activatable tool if the pressure within the hollow part exceeds a predetermined threshold value.

53. A method according to Claim 52 including balancing of fluid pressure in the hollow portion and fluid pressure in the conduit.

54. A method according to any of Claims 42 to 53 wherein activation of the activatable tool includes activation and operation of a formation pressure tester.

55. A method according to Claim 54 wherein activation of the formation pressure tester includes:

(iv) unlatching of the mutually engageable latch parts;

(v) landing of one or more landing dogs in a landing stop;

(vi) deployment of one or more deployable components of the formation pressure tester; and

(vii) powering up and/or self testing of the formation pressure tester

and wherein the method includes causing the modulating valve to generate signals in the fluid in the conduit that are indicative of one or more of (iv) to (vii).

56. A method according to any of Claims 42 to 55 including logging of data characteristic of a formation perforated by a wellbore using a downhole logging tool; and recording of logged data using a downhole memory device.

57. A method according to Claim 56 including the step of recovering the

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downhole memory device to an uphole location following the recording of data; and the subsequent analysis, modification, display and/or transmission of the recorded data.

58. A method according to any of Claims 42 to 57 including the step of detecting of changes in the pressure of fluid in the conduit, using a transducer at a location remote from the downhole transducer; the method further including generating one or more signals indicative of such detections of pressure changes.

59. A method according to any of Claims 42 to 58 including the sub-step of as necessary powering the downhole transducer, the processor, the release tool actuator, the modulating valve and the activatable tool using a power source conveyed to the downhole location.

60. A method of signalling between a downhole location in a wellbore and a further location that is remote therefrom, the method comprising the steps of:

pumping fluid, using a pump, in a conduit extending into the wellbore so as to pressurise fluid in the conduit;

operating a modulating valve at the downhole location to modulate the pressure of fluid in dependence on signals generated by a processor at the downhole location, the signals being characteristic of conditions at the downhole location; and

detecting modulations in the pressure of fluid in the conduit, resulting from operation of the modulating valve, at the further location.

61. A method according to Claim 60 wherein the modulations caused by operation of the modulating valve are analogue mimics of data logged by the logging tool.

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62. A method according to Claim 60 or Claim 61 wherein the processor is operatively connected to a servomechanism that when activated causes operation of the modulating valve by means of an actuator member, the method including causing the processor to operate the modulating valve.

63. A method according to any of Claims 60 to 62 including the step of storing data logged by the logging tool in a memory device at the downhole location.

64. A method according to any of Claims 60 to 63 including the step of logging data on the pressure of fluid proximate the wellbore at the downhole location, using a formation pressure tester.

65. A method according to Claim 64 wherein the modulations effected by the modulating valve in the case of a good pressure test include:

an initial pressure increase that mimics sealing of the formation pressure tester pad against the borehole;

a subsequent pressure decrease caused by operation of the pretest piston of the formation pressure tester that mimics exposure of the formation pressure tester transducer to formation fluid pressure; and

a subsequent pressure recovery that mimics the building up of formation fluid pressure within the formation pressure tester.

66. A method according to Claim 65 wherein modulations effected by the modulating valve in the case of the formation pressure tester experiencing a "no-seal" formation include:

a period of substantially invariant fluid pressure that mimics the fluid pressure experienced by the formation pressure tester when carrying out a test that fails to seal.

67. A method according to Claim 64 wherein modulations effected by

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the modulating valve in the case of the pressure tests encountering a tight formation include:

a pressure drop that mimics the fluid pressure experienced by the formation pressure tester when carrying out a pressure test on a tight formation; and a subsequent period without a substantial pressure recovery.

68. A method according to any of Claims 60 to 67 including powering the modulating valve, the processor and the logging tool using a source of electrical power at the downhole location.

69. A method according to any of Claims 42 to 59 or any of Claims 60 to 68 including the step of modulating acoustic signals generated in the borehole fluid with one or more waveforms that are characteristic of a low frequency Gamma log of the borehole.

70. A method according to any of Claims 42 to 59 including the step of causing operation of one or more pressure relief valves generally to equalise uphole and downhole fluid pressures acting on one or more components of the apparatus.

71. Apparatus generally as herein described, with reference to and/or as illustrated in the accompanying drawings.

72. Methods generally as herein described, with reference to and/or as illustrated in the accompanying drawings.

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INVESTOR IN PEOPLE

Application No: GB 0218784.7 **Examiner:** Nicholas Mole
Claims searched: 1-29, 43-61, 71-72 **Date of search:** 18 November 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F FKU FHK FHU FKD FKE FKF FKG

Int Cl (Ed.7): E21B 23/00 23/04 47/12 47/14 47/16 47/18

Other: Online: WPI EPODOC JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0551163 A	(HALLIBURTON)	
X	WO 1999/054591 A	(SCHLUMBERGER) see esp. abstract	1 at least
X	WO 1994/029572 A	(BAKER HUGHES) see esp. page 25 line 13 to page 30 line 19 and claim 50	1 at least
A	US 6310829 B	(GREEN)	
X	US 6105690	(BIGLIN) see esp. col. 5 lines 26-39 and col. 6 lines 44-67	1 at least
X	US 4896722	(UPCHURCH) see esp. col. 13 line 66 to col. 15 line 10	1 at least

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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PATENT ABSTRACTS OF JAPAN

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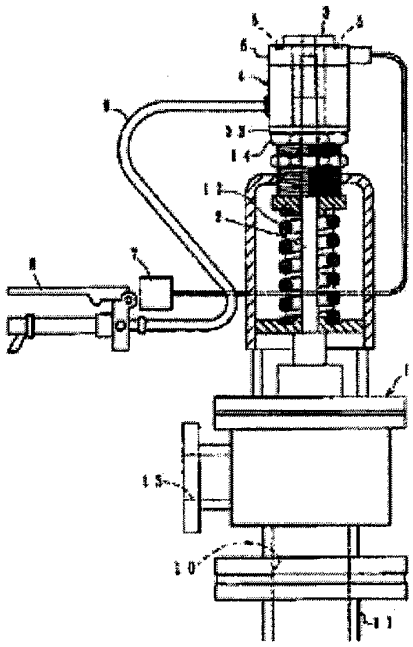
(71)Applicant : NAKAI KAZUO
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(54) VALVE OPENING PRESSURE MEASURING DEVICE OF SAFETY VALVE

(57)Abstract:

PURPOSE: To provide a valve opening pressure measuring device of a safety valve capable of making accurate measurement in a short time.

CONSTITUTION: A valve opening pressure measuring device is provided with a cylinder 4 received by a nut 3 communicated with the stem 2 of a safety valve 1 and a pressure adjustment spring **14** of the safety valve 1 and driving the stem 2 on the valve opening direction, via the nut 3 and a pressure detection element 5 provided between the cylinder 4 and the nut 3 or the pressure adjustment spring 14 for detecting output of the cylinder 4, and a display device 6 for displaying the pressure of the cylinder detected by the pressure detection element 5.



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審査請求　未請求　請求項の数１　ＯＬ　（全　６　頁）

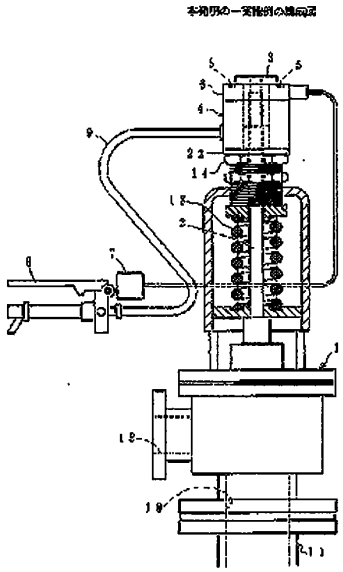
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(54)【発明の名称】　安全弁の開弁圧測定装置

(57)【要約】
【目的】　安全弁の開弁圧測定装置に関し、短時間内に正確な測定ができるようにした安全弁の開弁圧測定装置を提供することを目的とする。
【構成】　安全弁１のステム２に連結されるナット３と、安全弁１の圧力調整ネジ１４に受け止められ、上記ナット３を介してステム２を開弁方向に駆動するシリンダ４と、シリンダ４とナット３、又は、圧力調整ネジ１４との間に設けられ、シリンダ４の出力を検出する圧力検出素子５と、この圧力検出素子５が検出したシリンダの圧力を表示する表示装置６とを備える構成とする。



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【特許請求の範囲】

【請求項１】　安全弁(1) のステム(2) に連結されるナット(3) と、安全弁(1) の圧力調整ネジ(14)に受け止められ．上記ナット(3) を介してステム(2) を開弁方向に駆動するシリンダ(4) と．シリンダ(4) とナット(3) 、又は．安全弁(1) の圧力調整ネジ(14)との間に設けた圧力検出素子(5) と、圧力検出素子(5)が検出したシリンダ(4) の圧力を表示する表示装置(7) とを備えることを特徴とする安全弁の開弁圧測定装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、安全弁の開弁圧測定装置に関する。

【０００２】

【従来の技術】ボイラなどの圧力配管には内圧が一定以上に上昇することを防止するため、安全弁が設けられる。安全弁が開弁する設定圧の誤差の範囲は、５ｋｇ未満で±０．１４ｋｇ以内．５ｋｇ～２３ｋｇでは±３％以内．２３～７０ｋｇｆでは±０．７ｋｇ以内．７０以上では±１．０％以内であることが求められている。

【０００３】安全弁の設定圧を設定するために圧力配管の内圧を実際に設定圧の近傍まで上昇させることは危険が伴い、また．エネルギーや労力の浪費、弁の損傷、騒音の発生等の問題が伴う。そこで、図３の原理説明図に示すように、圧力配管Ｔの内圧を例えば吹出し圧力の７５％以上、吹止まり圧力以下の任意の圧力にして．外部から安全弁１０１のステム１０２を油圧シリンダ１０３で牽引し、開弁する時の油圧を油圧計１１０で測定するという方法が採用されている。

【０００４】この安全弁の開弁圧の測定に用いられる装置としては、例えば図４に示すように．ヨーク１０４を安全弁１０１の圧力設定ネジ１０５に受け止めさせ、圧力設定ネジ１０５と反対側でヨーク１０４に支持させた油圧シリンダ１０３のピストンロッド１０６と安全弁１０１のステム１０２とをターンバックル１０７で連結するように構成している。

【０００５】油圧シリンダ１０３には．所定長さの高圧用ホース１０８を介して手動操作式の油圧ポンプ１０９が接続され、油圧ポンプ１０９の吐出口にアダプタを介して圧力計１１０が接続される。

【０００６】また、例えば図５に示すように、安全弁１０１の圧力設定ネジ１０５に受け止められるマウンティングプレート１１１にボルト１１２及びナット１１３で油圧シリンダ１１４を連結し、マウンティングプレート１１１を貫通して油圧シリンダ１１４側に突出させた安全弁１０１のステム１０２と油圧シリンダ１１４のピストンロッド１１５とを接続金具１１６で連結するように構成している。この接続金具１１６は互いにボルト１１７によって連結される１対の半割部材１１８を備え、両半割部材１１８の互いに対向する面にステム１０２に螺

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合される半割ネジ１１９とピストンロッド１１５に対応する半割ネジ１２０が形成される。

【０００７】この場合にも．油圧シリンダ１１４には、所定長さの高圧用ホース１０８を介して手動操作式の油圧ポンプ１０９が接続され．油圧ポンプ１０９の吐出口にアダプタを介して圧力計１１０が接続される。

【０００８】上記構成により、安全弁１０１の開弁方向に作用する力は．圧力配管Ｔの内圧と．油圧シリンダ１０３．１１４の出力との合計で与えられ、この出力が設定圧以上になると安全弁１０１が開弁し、安全弁１０１から圧力配管Ｔ内の圧力流体が吹き出す状態を模擬的に形成することができる。

【０００９】圧力配管Ｔの内圧は分かっているので、この吹出し音を確認した時の油圧シリンダ１０３．１１４の出力に基づいて安全弁１０１の開弁圧を測定することができる。ここで、油圧シリンダ１０３、１１４の出力は油圧シリンダ１０３、１１４のピストンの有効受圧面積と油圧シリンダ１０３．１１４の内圧の積で求められ．ピストンの有効受圧面積は一定であるので．油圧シリンダ１０３．１１４の内圧を測定すれば、安全弁１０１の開弁圧を測定できることになる。

【００１０】

【発明が解決しようとする課題】図３ないし図５に示した従来の安全弁の開弁圧測定装置においては、測定作業を一人で行えるようにするため、油圧シリンダ１０３、１１４の内圧を測定するための圧力計１１０が油圧ポンプ１０９の吐出口にアダプタを介して接続されている。

【００１１】従って、圧力計１１０と油圧シリンダ１０３．１１４との間には所定の長さのホース１０８が介在することになり、ホース１０８内で生じる圧力損失によって圧力計１１０の測定値よりも実際の油圧シリンダ１０３、１１４の内圧が低くなることがある。この圧力損失は、ホース１０８の引き回し方によって変化するが．ホース１０８に圧油を送り込むと．例えばホース１０８の曲がっている部分の曲率半径が圧油によって大きくなるので、圧力損失が変化する。また、弁の摩擦損失も測定の度に変化し、測定の安定性が得られないことがある。

【００１２】このため、従来の安全弁の開弁圧測定装置を用いて安全弁の開弁圧を測定する場合には、ホース１０８の経路が安定してホース１０８内で生じる圧力損失が安定するまで．あるいは．弁の摩擦損失が安定するまで．何度か測定を繰り返さないと正しい測定値を得ることができず、測定のために長い時間と労力とが必要とされる。更に、測定ゲージは機械的に構成され、ピークホールドし難い性質となっているので．精度よくゲージを読み取ることが容易でない。

【００１３】本発明は、上記の事情を鑑みてなされたものであり、短時間内に正確な測定ができるようにした安全弁の開弁圧測定装置を提供することを目的とする。

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【００１４】

【課題を解決するための手段】上記の目的を達成するため、本発明は、例えば図１に示すように、安全弁１のステム２に連結されるナット３と、安全弁１の圧力調整ネジ１４に受け止められ、上記ナット３を介してステム２を開弁方向に駆動するシリンダ４と、シリンダ４とナット３、又は、圧力調整ネジ１４との間に設けられ、シリンダ４の出力を検出する圧力検出素子５と、この圧力検出素子５が検出したシリンダの圧力を表示する表示装置６とを備えることを特徴とする。

【００１５】

【作　用】本発明によれば、安全弁１にかかる圧力が直接に圧力検出素子５によって検出されるので、シリンダ４に作動流体を供給するホースの圧力損失と無関係に、１回の測定で正確にシリンダ４の出力を測定できる。

【００１６】本発明において、シリンダ４の構成は特に限定されないが、安全弁の圧力調整ネジに受け止められる筒体、この筒体内に進退可能に挿入され、外周面が異径に形成された中空ピストン、及び筒体と中空ピストンとによって区画された加圧室を有する中空シリンダ４を用いることができる。

【００１７】このような中空シリンダ４を用いる場合には、シリンダの中空部内で安全弁のステム２とナット３とを連結させることにより、小型化及びコンパクト化を図ることができる。

【００１８】

【実施例】以下、本発明の一実施例を図面に基づいて具体的に説明する。図１は本発明の構成図であり、この安全弁の開弁圧測定装置は、安全弁１のステム２に連結されるナット３と、このナット３を介してステム２を開弁方向に駆動するシリンダ４と、シリンダ４とナットとの間に設けた圧力検出素子５を内蔵した圧力検出ブロック６と、圧力検出素子５が検出したシリンダ４の圧力を表示する表示装置７とを備える。

【００１９】上記シリンダ４には、手動式の油圧ポンプ８が所定の長さ程度の高圧用ホース９を介して接続される。安全弁１の入口１０は例えばボイラの圧力配管１１に連通され、この圧力配管１１の内圧を例えば吹出し圧力の７５％以上、吹止まり圧力以下の任意の圧力にした後、上記油圧ポンプ８を操作してシリンダ４を伸長させることにより安全弁１の圧力設定バネ１２を圧縮し、安全弁１を開弁させる。安全弁１の開弁は圧力配管１１内の作動流体が安全弁１の出口１３から吹出す音によって認識され、この吹出し音が発生したときのシリンダ４の圧力を測定することにより安全弁１の開弁圧が測定される。

【００２０】上記シリンダ４は、複数本用いることも可能であるが、この実施例では構成を簡単にするために１本のシリンダ４を用い、又、装置の小型化及びコンパクト化を図るため、中空シリンダを用いている。

【００２１】すなわち、図２の断面図に示すように、このシリンダ４は、段付き異径内周面を有し、安全弁１の圧力調整ネジ１４に受け止められる筒体１５とこの筒体１５内に進退可能に挿入され、段付き異径外周面を有する中空ピストン１６とを備え、これら筒体１５と中空ピストン１６とによって加圧室１７が区画される。

【００２２】筒体１５の外周部には、加圧室１７に連通させたネジ孔１８が形成され、このネジ孔１８に上記ホース９の先端に設けた継手が螺合される。上記中空ピストン１６の大径部と小径部とにはそれぞれ、中空ピストン１６と筒体１５との間の隙間を油密状に封止するＯリング１９・２０が外嵌され、これにより、加圧室１７からシリンダ４の両端からの作動油の漏れが防止される。

【００２３】なお、この加圧室１７はエア抜き孔２１を介して外部に連通され、このエア抜き孔２１は、油圧ポンプ８からホース９を介して加圧室１７に圧油を供給し、加圧室１７から空気が完全に排出された後、図示しないプラグで閉塞される。

【００２４】シリンダ４の筒体１５は、直接に圧力調整ネジ１４に受け止めさせてもよいが、この実施例では、シリンダ４を装着したまま圧力調整ネジ１４を回転調整できるようにするため、筒体１５と圧力調整ネジ１４との間にスリップ板２２を介在させている。

【００２５】上記圧力検出ブロック６は、適当な剛性と弾性とを有する素材、例えば一般構造用圧延鋼、機械構造用炭素鋼などで形成され、その周縁部がシリンダ４の筒体１５に固定される。

【００２６】上記圧力検出素子５は、１個以上設けてあればよいが、この実施例では、複数個の圧力検出素子５を周方向に等間隔を置いて配置し、これらの検出値の平均値を求めて表示装置７に表示させるようにしている。

【００２７】圧力検出素子５は、圧力を加えた時にその圧力の大きさに対応する信号値を有する電気信号を出力するように構成してあればよく、例えば金属抵抗ひずみゲージ、半導体ひずみゲージなどのひずみゲージやピエゾ抵抗方式、ＰＮ接合方式の感圧素子を用いることができる。

【００２８】上記表示装置７は、従来の圧力計１１０の表示部に代わるものであり、圧力検出素子５が検出したシリンダ４の圧力を表示するように構成してあればよく、その表示方式はデジタル表示であっても、指針などによるアナログ表示であってもよい。また、表示装置７はピークホールド機能を持たせることによって読み取りがより正確になる。

【００２９】上記ナット３は、圧力検出ブロック６の中空部及び中空ピストン１６の中空部に挿入されるスリーブ２３を備え、シリンダ４をスリップ板２２を介して圧力調整ネジ１４の上に載せ、更に、圧力検出ブロック６を載せてからスリーブ２３を圧力検出ブロック６の中空部及び中空ピストン１６の中空部に挿入し、安全弁１の

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ステム2に形成されたネジ24に螺合される。

【0030】ナット3の締結力は、ステム2とナット3との間のがたつきがなくなる程度であればよく、例えば、手回しで締め込み始めて回せなく成った後、該ナット3を1／3～3／4回転程度手で戻す程度でよい。

【0031】この後、シリンダ4にホース9を介して油圧ポンプ8を接続し、エア抜きをした後、油圧ポンプ8により圧抜きをして、シリンダ4の内圧を大気圧に調整するとともに、表示装置7の表示の0点合わせをする。

【0032】予め、あるいはこの後、圧力配管11の内圧を例えば吹出し圧力の75%以上、吹止まり圧力以下の任意の圧力に設定し、上記油圧ポンプ8を操作してシリンダ4に圧油を送る。

【0033】圧油の供給により加圧室17の内圧が上昇すると、中空ピストン16が開弁方向（図上、上方向）に移動し、やがて、圧力検出ブロック6の外周部に中空ピストン16が受け止められる。この後、加圧室17の内圧を更に上昇させると、中空ピストン16が更に強く圧力検出ブロック6の外周部を押出そうとする。

【0034】しかし、シリンダ4の圧力が圧力設定バネ12の圧力以下である場合には、圧力検出ブロック6の内周部が圧力設定バネ12に牽制されるので、ステム2やナット3は開弁方向に移動しない。

【0035】シリンダ4の圧力が圧力設定バネ12の圧力を上回ると、ステム2及びナット3が圧力検出ブロック6の内周部とともに中空ピストン16に駆動されて開弁方向に移動し、安全弁1が開弁され、作動流体（ここでは、飽和蒸気）が安全弁1から吹出す時に発する吹出し音が耳に入ることになる。

【0036】中空ピストン16がステム2、ナット及び圧力検出ブロック6の内周部に加える圧力、すなわち、シリンダ4の圧力は圧力検出素子5によって検出され、表示装置7に表示されているので、測定者は吹出し音が耳に入った時の表示装置7の表示を確認し、予め与えられた換算表によって安全弁1の開弁圧を読出すことができる。

【0037】したがって、表示装置7を油圧ポンプ8の近傍に配置して、測定者が容易に観察できるようにすれば、安全弁1に掛かる圧力が直接に圧力検出素子5で計測されるので、ホース9の膨脹、収縮、漏洩抵抗などの影響を全く受けることなく、シリンダ4の圧力を測定することができ、しかも、1回の測定のみで正確にシリンダ4の圧力を測定することができる。

【0038】測定者としては、実際の開弁圧が予め定められている開弁圧に対して所定の誤差内であるか否かが分かればよいので、予め定められている開弁圧に対応するシリンダ4の圧力を換算テーブルから読み取り、シリンダ4の圧力が読み取った圧力になるまで油圧ポンプ8を操作してシリンダ4の圧力を上げ、シリンダ4の圧力が所定の範囲内で吹出し音が発生するか否かを確認することにより、安全弁1の合否を決定することができる。

【0039】不合格の場合には、この後、シリンダ4の圧力を降下させた状態で、吹出し音が出ていない場合には吹出し音が出るまで圧力調整ネジ14を緩めて開弁圧を低くし、所定の範囲よりも下回る圧力で吹出し音が出た場合には所定の範囲内まで吹出し音が出なくなるように圧力調整ネジ14を締めて開弁圧を高くする。すなわち、シリンダ4、圧力検出ブロック6及びナット3を付けたまま安全弁1の開弁圧調整ができる。

【0040】なお、上記の一実施例においては、圧力検出ブロック6を設け、この圧力検出ブロック6に圧力検出素子5を設けているが、圧力検出素子5をシリンダ4の出力端（上記の一実施例では中空ピストン16）に圧力検出素子5を支持させ、このシリンダ4の出力端からナット3に作用する圧力を検出するように構成することも可能であり、シリンダ4の筒体15に圧力検出素子5を支持させ、圧力調整ネジ14に受け止められる筒体15の圧力を検出するように構成することも可能である。

【0041】

【発明の効果】以上に説明したように、本発明は、安全弁のステムに連結されるナットと、このナットを介してステムを開弁方向に駆動するシリンダと、シリンダとナットとの間に設けた圧力検出素子と、圧力検出素子が検出したシリンダの圧力を表示する表示装置とを備えるので、簡単な構成で、安全弁に掛かる圧力を直接に測定することができ、1回の測定で正確にシリンダの圧力を測定できる。その結果、安全弁の開弁圧を短時間内に正確に測定できる。

【0042】本発明において、特にシリンダとして中空シリンダを用いる場合には、装置全体を小型で、コンパクトにすることができる。

【図面の簡単な説明】

【図1】本発明の一実施例の構成図である。

【図2】本発明の一実施例の要部の断面図である。

【図3】従来例の原理説明図である。

【図4】従来例の要部の断面図である。

【図5】他の従来例の要部の断面図である。

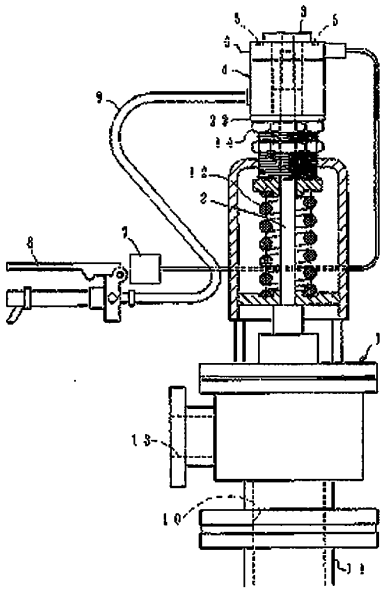
【符合の説明】

1 安全弁
2 ステム
3 ナット
4 シリンダ
5 圧力検出素子
7 表示装置
14 圧力調整ネジ

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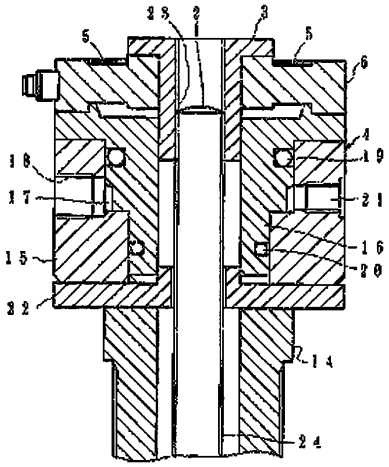
【図１】

本発明の一実施例の構成図



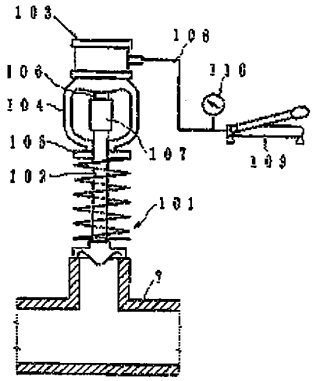
【図２】

本発明の一実施例の要部の断面図



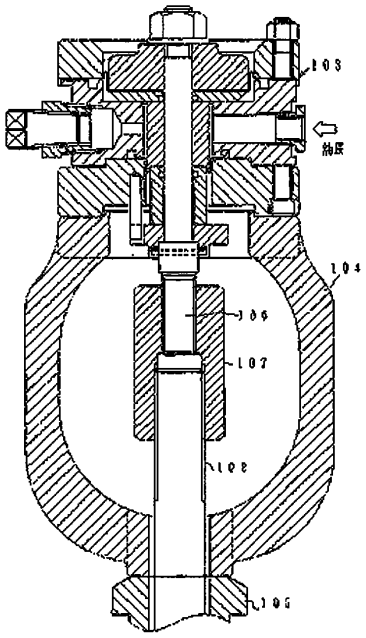
【図３】

従来例の原理説明図



【図４】

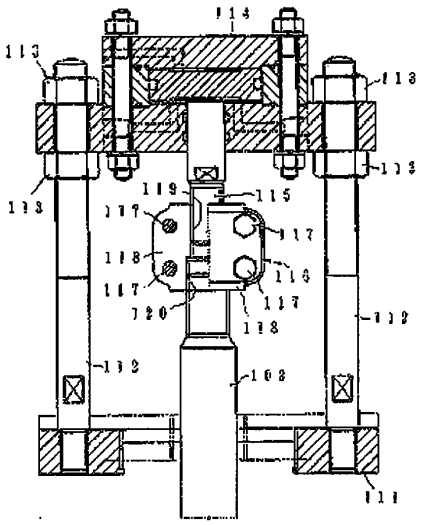
従来例の要部の断面図



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【図5】

他の従来例の要部の断面図



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(72) Inventors; and

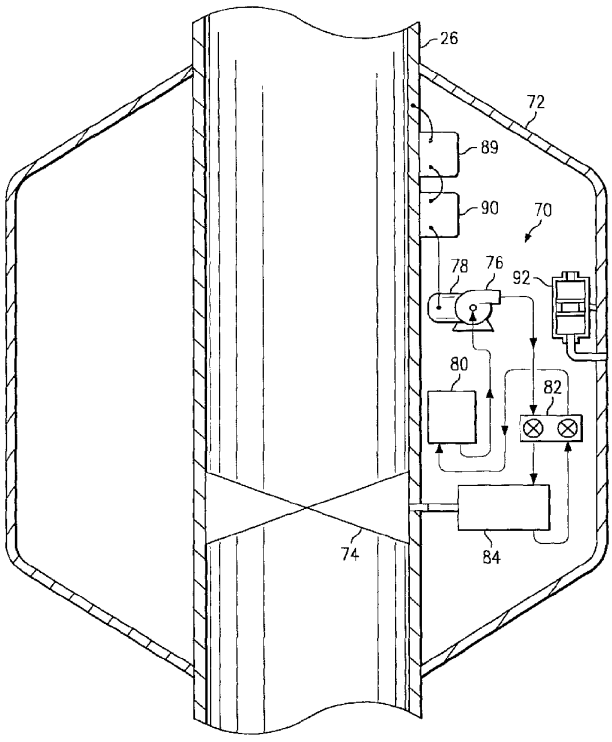
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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

[Continued on next page]

(54) Title: ELECTRO-HYDRAULICALLY PRESSURIZED DOWNHOLE VALVE ACTUATOR



(57) Abstract: A petroleum well having a communication system and a hydraulic system is provided. The petroleum well includes a borehole and a piping structure positioned within the borehole. The communication system supplies a time varying electric current downhole along the piping structure. The hydraulic system (70), which is positioned downhole proximate the piping structure (26), receives the time varying current to operate an electric motor (78). The motor drives a pump (76) which pressurizes hydraulic fluid to selectively drive an actuator (84). The actuator (84) is operably connected to a downhole device, such as a shutoff valve, and operates the downhole device as the actuator (84) is driven by the pressurized hydraulic fluid.

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

Published:
— *with international search report*

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.

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Electro-hydraulically pressurized downhole valve actuator

CROSS-REFERENCES TO RELATED APPLICATIONS

10 This application claims the benefit of the following U.S. Provisional Applications, all of which are hereby incorporated by reference:

COMMONLY OWNED AND PREVIOUSLY FILED U.S. PROVISIONAL PATENT APPLICATIONS			
T&K #	**Serial Number**	**Title**	**Filing Date**
TH 1599	60/177,999	Toroidal Choke Inductor for Wireless Communication and Control	Jan. 24, 2000
TH 1600	60/178,000	Ferromagnetic Choke in Wellhead	Jan. 24, 2000
TH 1602	60/178,001	Controllable Gas-Lift Well and Valve	Jan. 24, 2000
TH 1603	60/177,883	Permanent, Downhole, Wireless, Two-Way Telemetry Backbone Using Redundant Repeater, Spread Spectrum Arrays	Jan. 24, 2000
TH 1668	60/177,998	Petroleum Well Having Downhole Sensors, Communication, and Power	Jan. 24, 2000
TH 1669	60/177,997	System and Method for Fluid Flow Optimization	Jan. 24, 2000
TS 6185	60/181,322	A Method and Apparatus for the Optimal Predistortion of an Electromagnetic Signal in a Downhole Communications System	Feb. 9, 2000
TH 1599x	60/186,376	Toroidal Choke Inductor for Wireless Communication and Control	Mar. 2, 2000
TH 1600x	60/186,380	Ferromagnetic Choke in Wellhead	Mar. 2, 2000
TH 1601	60/186,505	Reservoir Production Control from Intelligent Well Data	Mar. 2, 2000
TH 1671	60/186,504	Tracer Injection in a Production Well	Mar. 2, 2000
TH 1672	60/186,379	Oilwell Casing Electrical Power Pick-Off Points	Mar. 2, 2000
TH 1673	60/186,394	Controllable Production Well Packer	Mar. 2, 2000
TH 1674	60/186,382	Use of Downhole High Pressure Gas in a Gas Lift Well	Mar. 2, 2000
TH 1675	60/186,503	Wireless Smart Well Casing	Mar. 2, 2000

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TH 1677	60/186,527	Method for Downhole Power Management Using Energization from Distributed Batteries or Capacitors with Reconfigurable Discharge	Mar. 2, 2000
TH 1679	60/186,393	Wireless Downhole Well Interval Inflow and Injection Control	Mar. 2, 2000
TH 1681	60/186,394	Focused Through-Casing Resistivity Measurement	Mar. 2, 2000
TH 1704	60/186,531	Downhole Rotary Hydraulic Pressure for Valve Actuation	Mar. 2, 2000
TH 1705	60/186,377	Wireless Downhole Measurement and Control For Optimizing Gas Lift Well and Field Performance	Mar. 2, 2000
TH 1722	60/186, 381	Controlled Downhole Chemical Injection	Mar. 2, 2000
TH 1723	60/186,378	Wireless Power and Communications Cross-Bar Switch	Mar. 2, 2000

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The current application shares some specification and figures with the following commonly owned and concurrently filed applications, all of which are hereby incorporated by reference:

COMMONLY OWNED AND CONCURRENTLY FILED U.S PATENT APPLICATIONS			
T&K #	**Serial Number**	**Title**	**Filing Date**
TH 1601US	09/_____	Reservoir Production Control from Intelligent Well Data	
TH 1671US	09/_____	Tracer Injection in a Production Well	
TH 1672US	09/_____	Oil Well Casing Electrical Power Pick-Off Points	
TH 1673US	09/_____	Controllable Production Well Packer	
TH 1674US	09/	Use of Downhole High Pressure Gas in a Gas-Lift Well	
TH 1675US	09/_____	Wireless Smart Well Casing	
TH 1677US	09/_____	Method for Downhole Power Management Using Energization from Distributed Batteries or Capacitors with Reconfigurable Discharge	
TH 1679US	09/_____	Wireless Downhole Well Interval Inflow and Injection Control	
TH 1681US	09/_____	Focused Through-Casing Resistivity Measurement	
TH 1705US	09/_____	Wireless Downhole Measurement and Control For Optimizing Gas Lift Well and Field Performance	
TH 1722US	09/_____	Controlled Downhole Chemical Injection	
TH 1723US	09/_____	Wireless Power and Communications Cross-Bar Switch	

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The current application shares some specification and figures with the following commonly owned and previously filed applications, all of which are hereby incorporated by reference:

COMMONLY OWNED AND PREVIOUSLY FILED U.S PATENT APPLICATIONS			
T&K #	**Serial Number**	**Title**	**Filing Date**
TH 1599US	09/_____	Choke Inductor for Wireless Communication and Control	
TH 1600US	09/_____	Induction Choke for Power Distribution in Piping Structure	
TH 1602US	09/_____	Controllable Gas-Lift Well and Valve	
TH 1603US	09/_____	Permanent Downhole, Wireless, Two-Way Telemetry Backbone Using Redundant Repeater	
TH 1668US	09/_____	Petroleum Well Having Downhole Sensors, Communication, and Power	
TH 1669US	09/_____	System and Method for Fluid Flow Optimization	
TH 1783US	09/_____	Downhole Motorized Flow Control Valve	
TS 6185US	09/_____	A Method and Apparatus for the Optimal Predistortion of an Electro Magnetic Signal in a Downhole Communications System	

The benefit of 35 U.S.C. § 120 is claimed for all of the above referenced commonly owne applications. The applications referenced in the tables above are referred to herein as the "Related Applications."

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to petroleum wells and in particular to petroleum wells having a communication system for delivering power and communications to a downhole hydraulic system, the hydraulic system being operably connected to a downhole device for operating the downhole device.

Description of Related Art

Several methods have been devised to place electronics, sensors, or controllable valve downhole along an oil production tubing string, but all such known devices typically use a

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internal or external cable along the tubing string to provide power and communications downhol It is, of course, highly undesirable and in practice difficult to use a cable along the tubing strin either integral to the tubing string or spaced in the annulus between the tubing string and th casing. The use of a cable presents difficulties for well operators while assembling and insertin the tubing string into a borehole. Additionally, the cable is subjected to corrosion and heavy wea due to movement of the tubing string within the borehole. An example of a downhol communication system using a cable is shown in PCT/EP97/01621.

U. S. Patent No. 4,839,644 describes a method and system for wireless two-wa communications in a cased borehole having a tubing string. However, this system describes communication scheme for coupling electromagnetic energy in a TEM mode using the annul between the casing and the tubing. This inductive coupling requires a substantially nonconductiv fluid such as crude oil in the annulus between the casing and the tubing. Therefore, the inventio described in U. S. Patent No. 4,839,644 has not been widely adopted as a practical scheme fo downhole two-way communication. Another system for downhole communication using mu pulse telemetry is described in U. S. Patent Nos. 4,648,471 and 5,887,657. Although mud puls telemetry can be successful at low data rates, it is of limited usefulness where high data rates ar required or where it is undesirable to have complex, mud pulse telemetry equipment downhol Other methods of communicating within a borehole are described in U.S. Patent Nos. 4,468,66 4,578,675; 4,739,325; 5,130,706; 5,467,083; 5,493,288; 5,576,703; 5,574,374; and 5,883,51 Similarly, several permanent downhole sensors and control systems have been described in U.S Pat. Nos. 4,972,704; 5,001,675; 5,134,285; 5,278,758; 5,662,165; 5,730,219; 5,934,371; an 5,941,307.

The Related Applications describe methods for providing electrical power and communications to various downhole devices in petroleum wells. These methods use either the production tubing as a supply and the casing as a return for the power and communications transmission circuit, or alternatively, the casing as the supply with a formation ground as the return. In either configuration, electrical losses in the transmission circuit are highly variable, depending on the specific conditions for a particular well. Power supplied along the casing with a formation ground as the return is especially susceptible to current losses. Electric current leakage generally occurs through the completion cement into the earthen formation. The more conductive the cement and earthen formation, the greater the current loss as the current travels along the casing.

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A need therefore exists to accommodate power losses which will be experienced when using a downhole wireless communication system. Since these losses place limits on the availabl amount of instantaneous electrical power, a need also exists for a system and method of storing energy for later use with downhole devices, especially high energy devices such as emergency shutoff valves, or other safety equipment. Although one solution to downhole energy storage problems could be provided by electrical storage such as capacitors, or chemical storage such as batteries, the limited lifetimes of such devices makes the use of the devices less than ideal in an operating petroleum well.

All references cited herein are incorporated by reference to the maximum extent allowabl by law. To the extent a reference may not be fully incorporated herein, it is incorporated b reference for background purposes and indicative of the knowledge of one of ordinary skill in th art.

BRIEF SUMMARY OF THE INVENTION

The problems presented in accommodating energy losses along a transmission path and in providing a usable source of instantaneous downhole energy are solved by the systems and methods of the present invention. In accordance with one embodiment of the present invention, a method for operating a downhole device in a borehole of a petroleum well is provided. The petroleum well includes a piping structure positioned within the borehole of the well. The metho includes delivering a time-varying current along the piping structure, the current being used to operate a motor. The motor drives a pump, which performs the step of pressuring a hydraulic fluid. Finally, the step of operating the downhole device is accomplished using the pressurized hydraulic fluid.

In another embodiment of the present invention, a petroleum well having a borehole and a piping structure positioned within the borehole is provided. The petroleum well includes a communications system and a hydraulic system. The communications system is operably associated with the piping structure of the well and transmits a time varying current along the piping structure. The hydraulic system is electrically connected to the piping structure and is configured to operate a downhole device.

In another embodiment of the present invention, a hydraulic actuation system includes a motor that is configured to receive a time varying current along a pipe member. A pump is operably connected to and is driven by the motor such that the pump pressurizes a hydraulic fluid.

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An actuator is hydraulically connected to the pump and is selectively driven by the pressurized hydraulic fluid supplied by the pump. The actuator is configured for operable attachment to a target device, the actuator operating the target device as the actuator is driven by the pressurized hydraulic fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of a petroleum well having a wireless communication system and a hydraulic pressure system according to the present invention.

FIG. 2 is a schematic of an offshore petroleum well having a wireless communication system and a hydraulic pressure system according to the present invention.

FIG. 3 is an enlarged schematic of a piping structure of a petroleum well, the piping structure having an enlarged pod that houses a hydraulic pressure system according to the present invention.

FIG. 4 is an electrical and plumbing schematic of the hydraulic pressure system of FIG. 3.

FIG. 5 is an enlarged schematic of a piping structure of a petroleum well, the piping structure having an enlarged pod that houses a hydraulic adjustment system according to an alternate embodiment of the present invention.

FIG. 6 is an electrical and plumbing schematic of the hydraulic adjustment system of FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As used in the present application, a "piping structure" can be one single pipe, a tubing string, a well casing, a pumping rod, a series of interconnected pipes, rods, rails, trusses, lattices, supports, a branch or lateral extension of a well, a network of interconnected pipes, or other structures known to one of ordinary skill in the art. The preferred embodiment makes use of the invention in the context of an oil well where the piping structure comprises tubular, metallic, electrically-conductive pipe or tubing strings, but the invention is not so limited. For the present invention, at least a portion of the piping structure needs to be electrically conductive, such electrically conductive portion may be the entire piping structure (e.g., steel pipes, copper pipes) or a longitudinal extending electrically conductive portion combined with a longitudinally extending non-conductive portion. In other words, an electrically conductive piping structure is one that provides an electrical conducting path from one location where a power source is

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electrically connected to another location where a device and/or electrical return is electrically connected. The piping structure will typically be conventional round metal tubing, but the cross-sectional geometry of the piping structure, or any portion thereof, can vary in shape (e.g., round, rectangular, square, oval) and size (e.g., length, diameter, wall thickness) along any portion of the piping structure.

A "valve" is any device that functions to regulate the flow of a fluid. Examples of valves include, but are not limited to, bellows-type gas-lift valves and controllable gas-lift valves, each o which may be used to regulate the flow of lift gas into a tubing string of a well. The internal workings of valves can vary greatly, and in the present application, it is not intended to limit the valves described to any particular configuration, so long as the valve functions to regulate flow. Some of the various types of flow regulating mechanisms include, but are not limited to, ball valv configurations, needle valve configurations, gate valve configurations, and cage valve configurations. Valves generally fall into one or the other of two classes: regulating valves intended to regulate flow continuously over a dynamic range from fully closed to fully open, and valves intended to be operated only fully open or fully closed, with intermediate positions considered transient. The latter class of valves may be operated to protect personnel or equipmen during scheduled maintenance or modification, or may form part of the emergency shut-in syster of a well, in which case they must be capable of operating rapidly and without lengthy preparatio Sub-surface safety valves are an example of this type of valve. Valves can be mounted downhole in a well in many different ways, some of which include tubing conveyed mounting configurations, side-pocket mandrel configurations, or permanent mounting configurations such a mounting the valve in an enlarged tubing pod.

The term "modem" is used generically herein to refer to any communications device for transmitting and/or receiving electrical communication signals via an electrical conductor (e.g., metal). Hence, the term is not limited to the acronym for a modulator (device that converts a voic or data signal into a form that can be transmitted)/demodulator (a device that recovers an original signal after it has modulated a high frequency carrier). Also, the term "modem" as used herein is not limited to conventional computer modems that convert digital signals to analog signals and vice versa (e.g., to send digital data signals over the analog Public Switched Telephone Network). For example, if a sensor outputs measurements in an analog format, then such measurements may only need to be modulated (e.g., spread spectrum modulation) and transmitted—hence no analog-

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to-digital conversion is needed. As another example, a relay/slave modem or communication device may only need to identify, filter, amplify, and/or retransmit a signal received.

The term "processor" is used in the present application to denote any device that is capabl of performing arithmetic and/or logic operations. The processor may optionally include a control unit, a memory unit, and an arithmetic and logic unit.

The term "sensor" as used in the present application refers to any device that detects, determines, monitors, records, or otherwise senses the absolute value of or a change in a physical quantity. Sensors as described in the present application can be used to measure temperature, pressure (both absolute and differential), flow rate, seismic data, acoustic data, pH level, salinity levels, valve positions, or almost any other physical data.

As used in the present application, "wireless" means the absence of a conventional, insulated wire conductor e.g. extending from a downhole device to the surface. Using the tubing and/or casing as a conductor is considered "wireless."

The term "electronics module" in the present application refers to a control device. Electronics modules can exist in many configurations and can be mounted downhole in many different ways. In one mounting configuration, the electronics module is actually located within a valve and provides control for the operation of a motor within the valve. Electronics modules can also be mounted external to any particular valve. Some electronics modules will be mounted within side pocket mandrels or enlarged tubing pockets, while others may be permanently attache to the tubing string. Electronics modules often are electrically connected to sensors and assist in relaying sensor information to the surface of the well. It is conceivable that the sensors associatec with a particular electronics module may even be packaged within the electronics module. Finally, the electronics module is often closely associated with, and may actually contain, a modem for receiving, sending, and relaying communications from and to the surface of the well. Signals that are received from the surface by the electronics module are often used to effect changes within downhole controllable devices, such as valves. Signals sent or relayed to the surface by the electronics module generally contain information about downhole physical conditions supplied by the sensors.

In accordance with conventional terminology of oilfield practice, the descriptors "upper," "lower," "uphole," and "downhole" as used herein are relative and refer to distance along hole depth from the surface, which in deviated or horizontal wells may or may not accord with vertical elevation measured with respect to a survey datum.

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Referring to FIG. 1 in the drawings, a petroleum well 10 according to the present inventio is illustrated. Petroleum well 10 includes a borehole 11 extending from a surface 12 into a production zone 14 located downhole. A production platform 20 is located at surface 12 and includes a hanger 22 for supporting a casing 24 and a tubing string 26. Casing 24 is of the type conventionally employed in the oil and gas industry. The casing 24 is typically installed in sections and is cemented in borehole 11 during well completion. Tubing string 26, also referred t as production tubing, is generally conventional comprising a plurality of elongated tubular pipe sections joined by threaded couplings at each end of the pipe sections. Production platform 20 also includes a gas input throttle 30 to permit the input of compressed gas into an annular space 3 between casing 24 and tubing string 26. Conversely, output valve 32 permits the expulsion of oil and gas bubbles from an interior of tubing string 26 during oil production.

Petroleum well 10 includes a communication system 34 for providing power and two-way communications downhole in well 10. Communication system 34 includes a lower induction choke 42 that is installed on tubing string 26 to act as a series impedance to electric current flow. The size and material of lower induction choke 42 can be altered to vary the series impedance value; however, the lower induction choke 42 is made of a ferromagnetic material. Induction choke 42 is mounted concentric and external to tubing string 26, and is typically hardened with epoxy to withstand rough handling.

An insulating tubing joint 40 (also referred to as an electrically insulating joint) is positioned on tubing string 26 near the surface of the well. Insulating tubing joint 40, along with lower induction choke 42, provide electrical isolation for a section of tubing string 26 located between insulating tubing joint 40 and induction choke 42. The section of tubing string 26 between insulating tubing joint 40 and lower choke 42 may be viewed as a power and communications path. In alternative to or in addition to the insulating tubing joint 40, an upper induction choke (not shown) can be placed about the tubing string 26 or an insulating tubing hanger (not shown) could be employed.

A computer and power source 44 including a power supply 46 and a spread spectrum communications device 48 (e.g. modem) is disposed outside of borehole 11 at surface 12. The computer and power source 44 is electrically connected to tubing string 26 below insulating tubin joint 40 for supplying time varying current to the tubing string 26. A return feed for the current is attached to casing 24. In operation the use of tubing string 26 as a conductor is fairly lossy because of the often great lengths of tubing string along which current is supplied. However, the

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spread spectrum communications technique is tolerant of noise and low signal levels, and can operate effectively even with losses as high as -100db.

The method of electrically isolating a section of the tubing string as illustrated in FIG.1 is not the sole method of providing power and communications signals downhole. In the preferred embodiment of FIG. 1, power and communication signals are supplied on tubing string 26, with the electrical return being provided by casing 24. Instead, the electrical return could be provided by an earthen ground. An electrical connection to earthen ground could be provided by passing a wire through casing 24 or by connecting the wire to the tubing string below lower choke 42 (if the lower portion of the tubing string was grounded).

An alternative power and communications path could be provided by casing 24. In a configuration similar to that used with tubing string 26, a portion of casing 24 could be electrically isolated to provide a telemetry backbone for transmitting power and communication signals downhole. If induction chokes were used to isolate a portion of casing 24, the chokes would be disposed concentrically around the outside of the casing. Instead of using chokes with the casing 24, electrically isolating connectors could be used similar to insulating tubing joint 40. In embodiments using casing 24 to supply power and communications signals downhole, an electrical return could be provided either via the tubing string 26 or via an earthen ground.

A packer 49 is placed within casing 24 below lower induction choke 42. Packer 49 is located above production zone 14 and serves to isolate production zone 14 and to electrically connect metal tubing string 26 to metal casing 24. Typically, the electrical connections between tubing string 26 and casing 24 would not allow electrical signals to be transmitted or received up and down borehole 11 using tubing string 26 as one conductor and casing 24 as another conductor. However, the disposition of insulating tubing joint 40 and lower induction choke 42 create an electrically isolated section of the tubing string 26, which provides a system and method to provide power and communication signals up and down borehole 11 of petroleum well 10.

Referring to FIG. 2 in the drawings, an offshore petroleum well 60 is illustrated. Petroleum well 60 includes a main production platform 62 at an aqueous surface 63 anchored to a earthen floor 64 with support members 66. Petroleum well 60 has many similarities to petroleum well 10 of FIG. 1. The borehole 11 of petroleum well 60 begins at earthen floor 64. Casing 24 is positioned within borehole 11, and tubing hanger 22 provides downhole support for tubing string 26. One of the primary differences between petroleum well 10 and petroleum well 60 is that tubing string 26 in petroleum well 60 extends through water 67 before reaching borehole 11.

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Induction choke 42 is positioned on tubing string 26 just above a wellhead 68 at earthen floor 64. An insulating tubing joint (similar to insulating tubing joint 40, but not shown) is provided at a portion of the tubing string 26 on production platform 62. Time varying current is imparted to a section of tubing string 26 between the insulating tubing joint and induction choke 42 to supply power and communications at wellhead 68.

A person skilled in the art will recognize that under normal circumstances a short circuit would occur for current passed along tubing string 26 since the tubing string is surrounded by electrically conductive sea water. However, corrosion inhibiting coatings on tubing string 26 are generally non-conductive and can provide an electrically insulating "sheath" around the tubing string, thereby allowing current transfer even when tubing string 26 is immersed in water. In an alternative arrangement, power could be supplied to wellhead 68 by an insulated cable (not shown) and then supplied downhole in the same manner provided in petroleum well 10. In such an arrangement, the insulating tubing joint and induction choke 42 would be positioned within the borehole 11 of petroleum well 60.

Referring still to FIG. 2, but also to FIGS. 1 and 3 in the drawings, a hydraulic system 70 provided for operating a downhole device, or a target device (not shown). Hydraulic system 70 is disposed within an enlarged pod 72 on tubing string 26. In FIG. 3 the downhole device is a shut-off valve 74; however, a number of different downhole devices could be operated by hydraulic system 70. Shut-off valve 74 is driven incrementally by hydraulic fluid pressurized by a pump 76. An electric motor 78 is powered by time varying current passed along tubing string 26. Motor 78 is operably connected to pump 76 for driving the pump 76. The electric motor 78 driving hydraulic pump 76 consumes small amounts of power such that it may operate with the limited power available at depth in the well. By appropriate design of hydraulic pump 76 and other components of hydraulic system 70, especially in the design of seals that minimize hydraulic fluid leakage in these components, the low amount of available power does not restrict the hydraulic pressure that can be generated, but rather restricts the flow rate of the hydraulic fluid.

Referring now to FIG. 4 in the drawings, the plumbing and electrical connections for hydraulic system 70 are illustrated in more detail. In addition to pump 76 and motor 78, hydraulic system 70 includes a fluid reservoir 80, a pilot valve 82, a valve actuator 84, and the necessary tubing and hardware to route hydraulic fluid between these components. Reservoir 80 is hydraulically connected to pump 76 for supplying hydraulic fluid to the pump 76. Pilot valve 82 is hydraulically connected to pump 76, actuator 84, and reservoir 80. Pilot valve 82 selectively

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routes pressurized hydraulic fluid to actuator 84 for operating the actuator 84. Actuator 84 includes a piston 86 having a first side 87 and a second side 88. Piston 86 is operably connected to valve 74 for opening and closing the valve 74. By selectively routing pressurized hydraulic fluid to different sides of piston 86, valve 74 can be selectively opened or closed. For example, in one configuration, hydraulic fluid might be routed to a chamber just above first side 87 of piston 86. The pressurized fluid would exert a force on piston 86, causing the piston 86 to move downward, thereby closing valve 74. Fluid in a chamber adjacent the second side 88 of piston 86 would be displaced into reservoir 80. In this configuration, valve 74 could be opened by adjusting pilot valve 82 such that pressurized hydraulic fluid is supplied to the chamber adjacent the second side 88 of piston 86. The pressurized fluid would exert an upward force on piston 86, thereby moving piston 86 upward and opening valve 74. Displaced hydraulic fluid in the chamber adjacent front side 87 would be routed to reservoir 80.

As previously mentioned, electric current is supplied to motor 78 along tubing string 26. A modem 89 is positioned within enlarged pod 72 for receiving signals from modem 48 at surface 12. Modem 89 is electrically connected to a controller 90 for controlling the operation of motor 78. Controller 90 is also electrically connected to pilot valve 82 for controlling operation of the pilot valve, thereby insuring that the valve properly routes hydraulic fluid from the pump 76 to the actuator 84 and the reservoir 80.

In operation, electric current is supplied downhole along tubing string 26 and is received by modem 89. Controller 90 receives instructions from modem 89 and routes power to motor 78. Controller 90 also establishes the setting for pilot valve 82 so that hydraulic fluid is properly routed throughout the hydraulic system 70. As motor 78 is powered, it drives pump 76 which draws hydraulic fluid from reservoir 80. Pump 76 pressurizes the hydraulic fluid, pushing the fluid into pilot valve 82. From pilot valve 82, the pressurized hydraulic fluid is selectively routed to one side of piston 86 to drive the actuator 84. Depending on the side of piston 86 to which fluid was delivered, valve 74 will be opened or closed. As the piston 86 moves, displaced hydraulic fluid is routed from actuator 84 to reservoir 80.

Hydraulic system 70 may also include a bottom hole pressure compensator 92 (see FIG. 3) to balance the static pressure of the hydraulic fluid circuit against the static pressure of downhole fluids in the well. Use of a pressure compensator minimizes differential pressure across any rotary or sliding seals between the hydraulic circuit and the well fluids if these seals are present in the design, and thus minimizes stress on such seals.

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Enlarged pod 72 is filled with oil, the pressure of which is balanced with the pressure of any fluid present in annulus 31. By porting one side of the pressure compensator 92 to the exteric of pod 72, the pressure of oil within the enlarged pod 72 can be matched to the pressure of fluid within the annulus 31. The adjustment of internal pod pressure allows many of the components o the hydraulic system 70 to operate more efficiently.

Referring now to FIGS. 5 and 6 in the drawings, an alternate embodiment for hydraulic system 70 is illustrated. The components for this hydraulic system are substantially similar to those illustrated in FIGS. 3 and 4. In this particular embodiment, however, an accumulator 96 is hydraulically connected between pump 76 and pilot valve 82 for collecting pressurized hydraulic fluid supplied by the pump 76. The control of hydraulic system 70 is identical to that previously described, except that accumulator 96 is now used to supply the pressurized hydraulic fluid to actuator 84. Accumulator 96 allows instantaneous hydraulic operations to be intermittently performed (e.g. quick opening or closing of a valve). This is in contrast to the previous embodiment, which used a pump to supply hydraulic fluid to the actuator 84 more gradually.

Accumulator 96 includes a piston 98 slidingly and sealingly disposed within a housing, the piston being biased in one direction by a spring 100. A compensator port 102 is disposed in the housing and allows pressurized oil within enlarged pod 72 to exert an additional force on piston 9 which is complementary to the force exerted by spring 100. Motor 78 and pump 76 charge accumulator 96 to a high pressure by pushing hydraulic fluid into a main chamber 104 against the biased piston 98. When the force exerted by hydraulic fluid within main chamber 104 equals the forces on the opposite side of piston 98, pump 76 ceases operation, and the hydraulic fluid is stored within accumulator 96 until needed.

The stored, pressurized hydraulic fluid is released under control of pilot valve 82 to drive actuator 84 and thus actuate the main valve 74. Because of the energy stored in the accumulator 96, valve 74 can be opened or closed immediately upon receipt of an open or close command. Accumulator 96 is sized to enable at least one complete operation (open or close) of valve 74. Thus the methods of the present invention provide for the successful operation of valves which require transient high transient power, such as sub-surface safety valves.

It will be clear that a variety of hydraulic devices may be substituted for shutoff valve 74, which has been described for illustrative purposes only. It should also be clear that communication system 34 and hydraulic system 70 provided by the present invention, while

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located on tubing string 26 in the preceding description, could be disposed on casing 24 of the well, or any other piping structure associated with the well.

Even though many of the examples discussed herein are applications of the present invention in petroleum wells, the present invention also can be applied to other types of wells, including but not limited to water wells and natural gas wells.

One skilled in the art will see that the present invention can be applied in many areas where there is a need to provide a communication system and a hydraulic system within a borehole, well, or any other area that is difficult to access. Also, one skilled in the art will see tha the present invention can be applied in many areas where there is an already existing conductive piping structure and a need to route power and communications to a hydraulic system located proximate the piping structure. A water sprinkler system or network in a building for extinguishing fires is an example of a piping structure that may be already existing and may have same or similar path as that desired for routing power and communications to a hydraulic system. In such case another piping structure or another portion of the same piping structure may be used as the electrical return. The steel structure of a building may also be used as a piping structure and/or electrical return for transmitting power and communications to a hydraulic system in accordance with the present invention. The steel rebar in a concrete dam or a street may be used as a piping structure and/or electrical return for transmitting power and communications to a hydraulic system in accordance with the present invention. The transmission lines and network o piping between wells or across large stretches of land may be used as a piping structure and/or electrical return for transmitting power and communications to a hydraulic system in accordance with the present invention. Surface refinery production pipe networks may be used as a piping structure and/or electrical return for transmitting power and communications in accordance with the present invention. Thus, there are numerous applications of the present invention in many different areas or fields of use.

It should be apparent from the foregoing that an invention having significant advantages has been provided. While the invention is shown in only a few of its forms, it is not just limited but is susceptible to various changes and modifications without departing from the spirit thereof.

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CLAIMS

We claim:

1. A method of operating a downhole device in a petroleum well having a borehole and a piping structure positioned within the borehole, comprising the steps of:
delivering a time varying current along the piping structure to a downhole location;
pressurizing a hydraulic fluid using the time varying current at the downhole location; and
operating the downhole device using the pressurized hydraulic fluid.

2. The method according to claim 1, including the steps of:
operating a motor at the downhole location; and
driving a pump with said motor to pressurize the hydraulic fluid.

3. The method according to claim 1 wherein the delivering step further comprising:
impeding the time-varying current on the piping structure to define a conductive section; and
routing the time varying current along the conductive section of the piping structure.

4. The method according to claim 2 wherein the step of operating the downhole device further comprises the steps of:
providing an actuator operably connected to the downhole device and hydraulically connected to the pump; and
selectively driving the actuator with the pressurized hydraulic fluid such that the downhole device is actuated.

5. The method according to claim 4 wherein the step of selectively driving further comprises
providing a pilot valve hydraulically connected between the pump and the actuator; and
adjusting the pilot valve to selectively drive the actuator.

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6. The method according to claim 1 further comprising the step of:
storing hydraulic fluid in a reservoir; and
drawing hydraulic fluid from the reservoir.

7. The method according to claim 1 further comprising the steps of:
collecting pressurized hydraulic fluid in an accumulator; and
selectively releasing pressurized hydraulic fluid from the accumulator to operate the downhole device.

8. The method according to claim 1 further comprising:
collecting pressurized hydraulic fluid in an accumulator;
providing an actuator operably connected to the downhole device and hydraulically connected to the accumulator; and
selectively releasing pressurized hydraulic fluid from the accumulator to drive the actuator, thereby operating the downhole device.

9. The method according to claim 8 wherein the step of selectively releasing further comprises:
providing a pilot valve hydraulically connected between the accumulator and the actuator; and
adjusting the pilot valve to selectively drive the actuator.

10. The method according to claim 1 further comprising the steps of:
impeding the time varying current on the piping structure;
routing the time varying current along the piping structure to the downhole location;
providing an actuator operably connected to the downhole device and hydraulically connected to a pump; and
selectively operating a pilot valve hydraulically connected between the pump and the actuator to drive the actuator, thereby operating the downhole device.

11. The method according to claim 10 wherein the downhole device is a main valve and the actuator opens and closes the main valve.

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12. The method according to claim 1 further comprising the steps of:
impeding the time varying current on the piping structure;
routing the time varying current along the piping structure;
collecting pressurized hydraulic fluid in an accumulator;
providing an actuator operably connected to the downhole device and hydraulically connected to the accumulator; and
selectively operating a pilot valve hydraulically connected between the accumulator and the actuator to drive the actuator, thereby operating the downhole device.

13. The method according to claim 12 wherein the downhole device is a main valve and the actuator opens and closes the main valve.

14. A petroleum well having a borehole and a piping structure positioned within the borehole comprising:
a communications system operably associated with the piping structure for transmitting a time varying signal along the piping structure; and
a hydraulic system electrically connected to the piping structure and configured for connection to a downhole device, wherein the hydraulic system is configured to receive power from said time varying signal and to operate the downhole device

15. The petroleum well of claim 14 wherein the time varying signal includes a communications signal to selectively operate the downhole device.

16. The petroleum well of claim 14 wherein the communication system further comprises:
an impedance device positioned around the piping structure to define a conducting portion; and
wherein the time varying current is passed along the conducting portion of the piping structure.

17. The petroleum well of claim 14 wherein the downhole device is a downhole emergency shutoff valve.

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18. The petroleum well of claim 14 wherein the hydraulic system further comprises:
a motor for receiving the time varying current from the piping structure;
a pump for selectively pressurizing a hydraulic fluid, the pump being operably connected to and driven by the motor;
an actuator hydraulically connected to the pump and operably connected to the downhole device; and
wherein the pressurized hydraulic fluid is used to drive the actuator, thereby operating the downhole device.

19. The petroleum well of claim 14 wherein the hydraulic system further comprises:
a motor for receiving the time varying current from the piping structure;
a pump for selectively pressurizing a hydraulic fluid, the pump being operably connected to and driven by the motor;
a pilot valve hydraulically connected to the pump;
an actuator hydraulically connected to the pilot valve and operably connected to the downhole device; and
wherein the pilot valve selectively routes pressurized hydraulic fluid to the actuator, thereby driving the actuator and operating the downhole device.

20. The petroleum well of claim 19, wherein the downhole device is a valve.

21. The petroleum well of claim 14 wherein the hydraulic system further comprises:
a motor for receiving the time varying current from the piping structure;
a pump for selectively pressurizing a hydraulic fluid, the pump being operably connected to and driven by the motor;
an accumulator hydraulically connected to the pump for collecting pressurized hydraulic fluid;
an actuator hydraulically connected to the accumulator and operably connected to the downhole device; and
wherein the pressurized hydraulic fluid supplied by the accumulator drives the actuator thereby operating the downhole device.

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22. The petroleum well of claim 14 wherein the hydraulic system further comprises:
a motor for receiving the time varying current from the piping structure;
a pump for selectively pressurizing a hydraulic fluid, the pump being operably connected to and driven by the motor;
an accumulator hydraulically connected to the pump for collecting pressurized hydraulic fluid;
a pilot valve hydraulically connected to the accumulator;
an actuator hydraulically connected to the pilot valve and operably connected to the downhole device; and
wherein the pilot valve selectively routes pressurized hydraulic fluid to the actuator, thereby driving the actuator and operating the downhole device.

23. A hydraulic actuation system comprising:
a motor configured to receive a time varying signal delivered along a piping structure;
a pump for pressurizing a hydraulic fluid, the pump being operably connected to and being driven by the motor; and
an actuator hydraulically connected to the pump and configured for operable attachmen to a target device, wherein the actuator is selectively driven by the pressurized hydraulic fluid, thereby operating the target device.

24. The hydraulic actuation system according to claim 23, including:
an impedance device positioned around the piping structure to define a conducting portion; and
wherein the time varying current is passed along the conducting portion of the piping structure.

25. The hydraulic actuation system according to claim 23, wherein the time varying signal includes a communications signal to selectively operate said target device

26. The hydraulic actuation system according to claim 23 further comprising:
a pilot valve hydraulically connected between the pump and the actuator; and
wherein the pilot valve selectively routes pressurized hydraulic fluid to the actuator.

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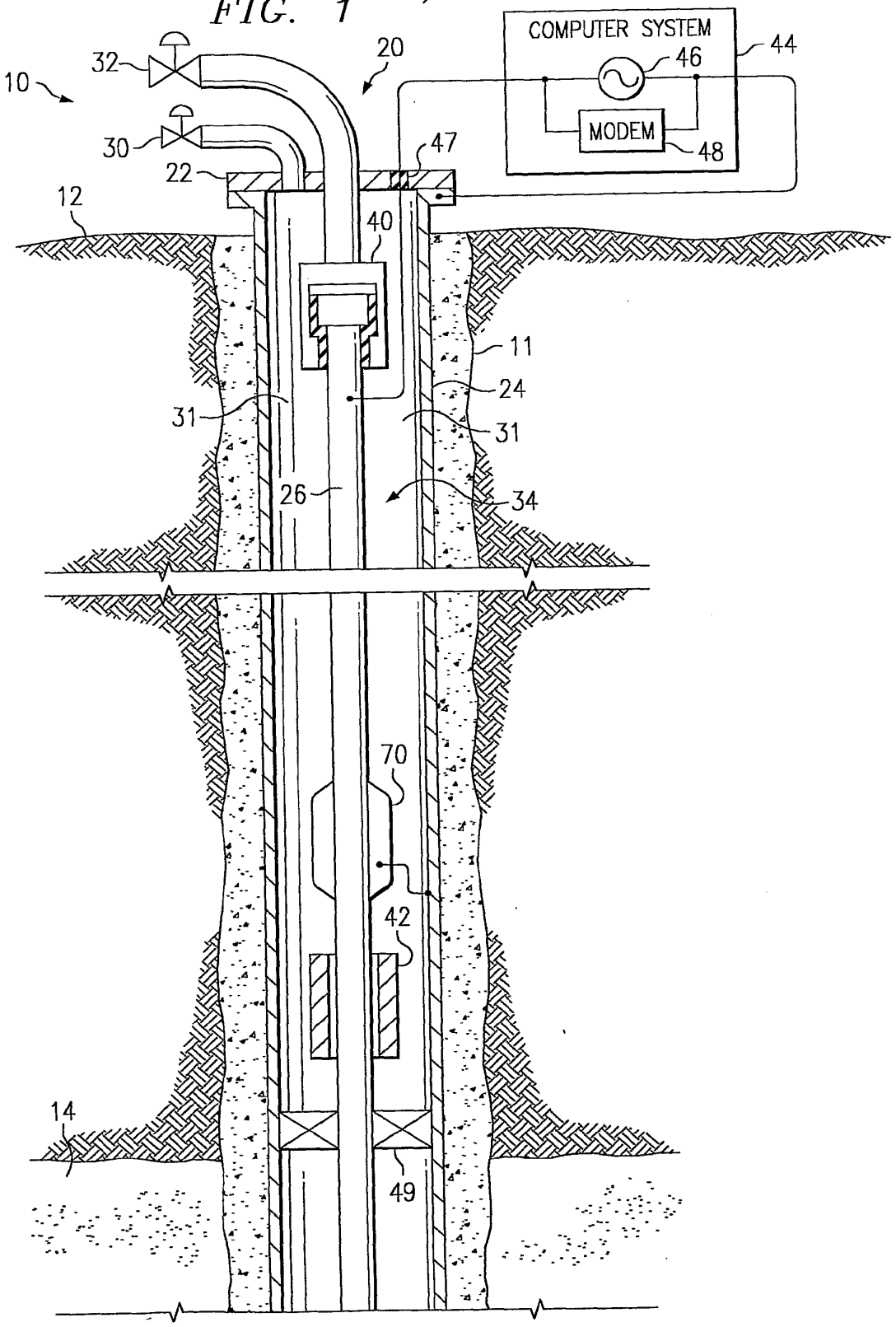
27. The hydraulic actuation system according to claim 23 further comprising an accumulator hydraulically connected to the pump for collecting pressurized hydraulic fluid.

28. The hydraulic actuation system according to claim 23 further comprising:
an accumulator hydraulically connected to the pump for collecting pressurized hydraulic fluid; and
a pilot valve hydraulically connected between the accumulator and the actuator, wherei the pilot valve selectively routes pressurized hydraulic fluid to the actuator

29. The hydraulic actuation system according to claim 23 further comprising:
an accumulator hydraulically connected to the pump for collecting pressurized hydraulic fluid;
a pilot valve hydraulically connected between the accumulator and the actuator, wherei the pilot valve selectively routes pressurized hydraulic fluid to the actuator;
wherein an electrically insulating joint is positioned on the pipe member;
wherein an induction choke is positioned around the pipe member; and
wherein the time varying current is routed along the pipe member between the electrically insulating joint and the induction choke.

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FIG. 1


COMPUTER SYSTEM
44
46
MODEM
48
47
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32
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30
22
12
40
11
24
31
31
26
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70
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14
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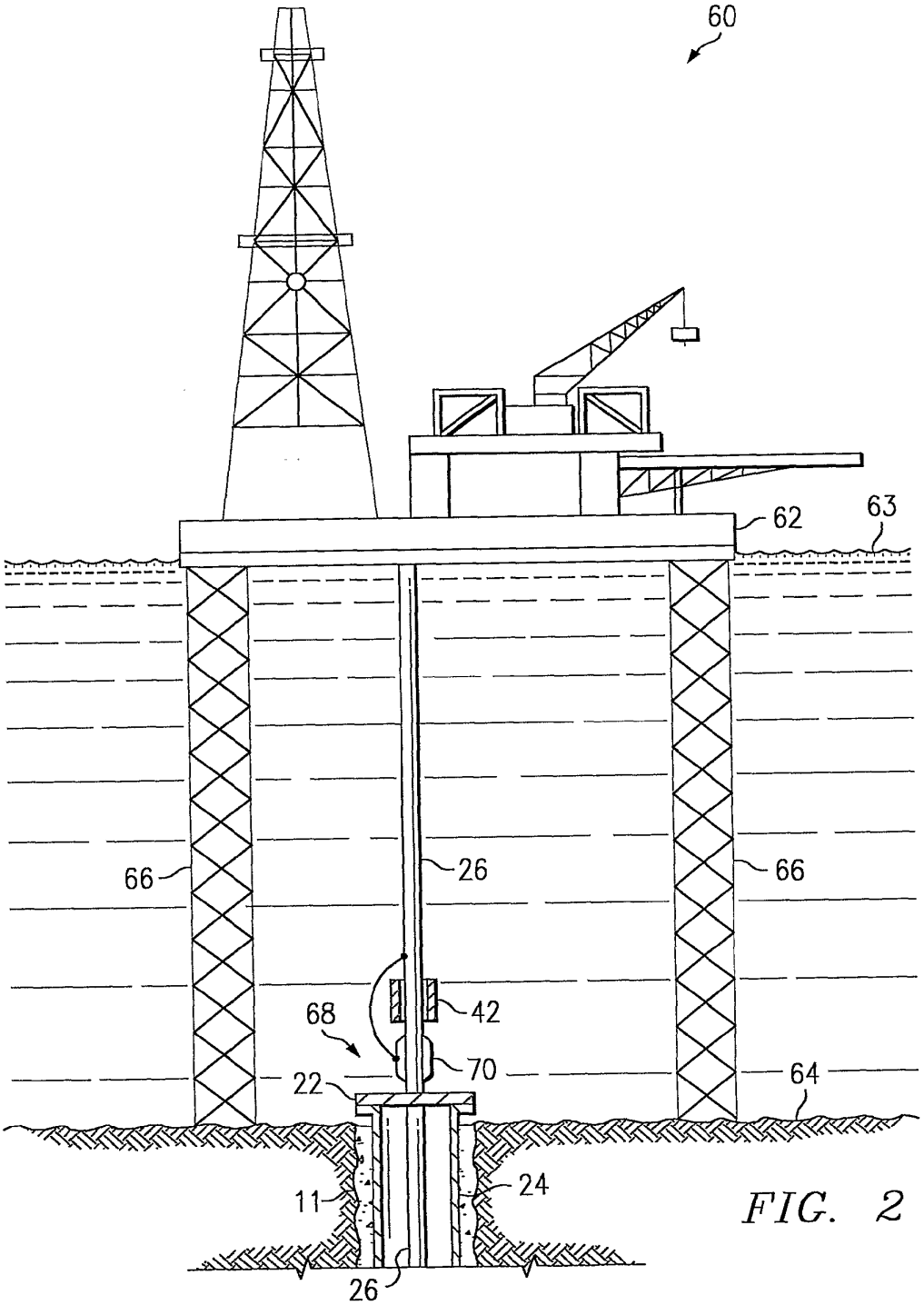
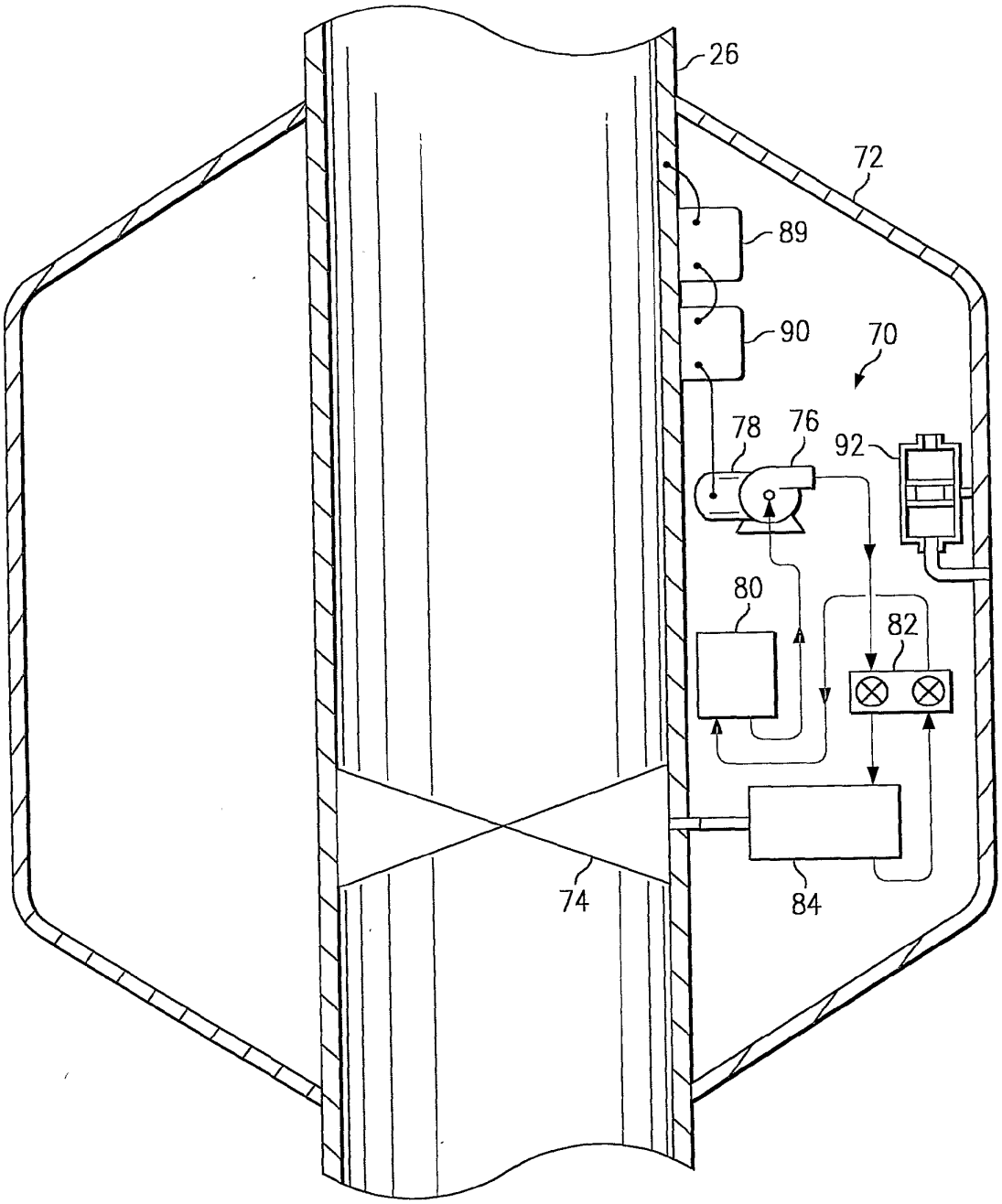


FIG. 2

FIG. 3



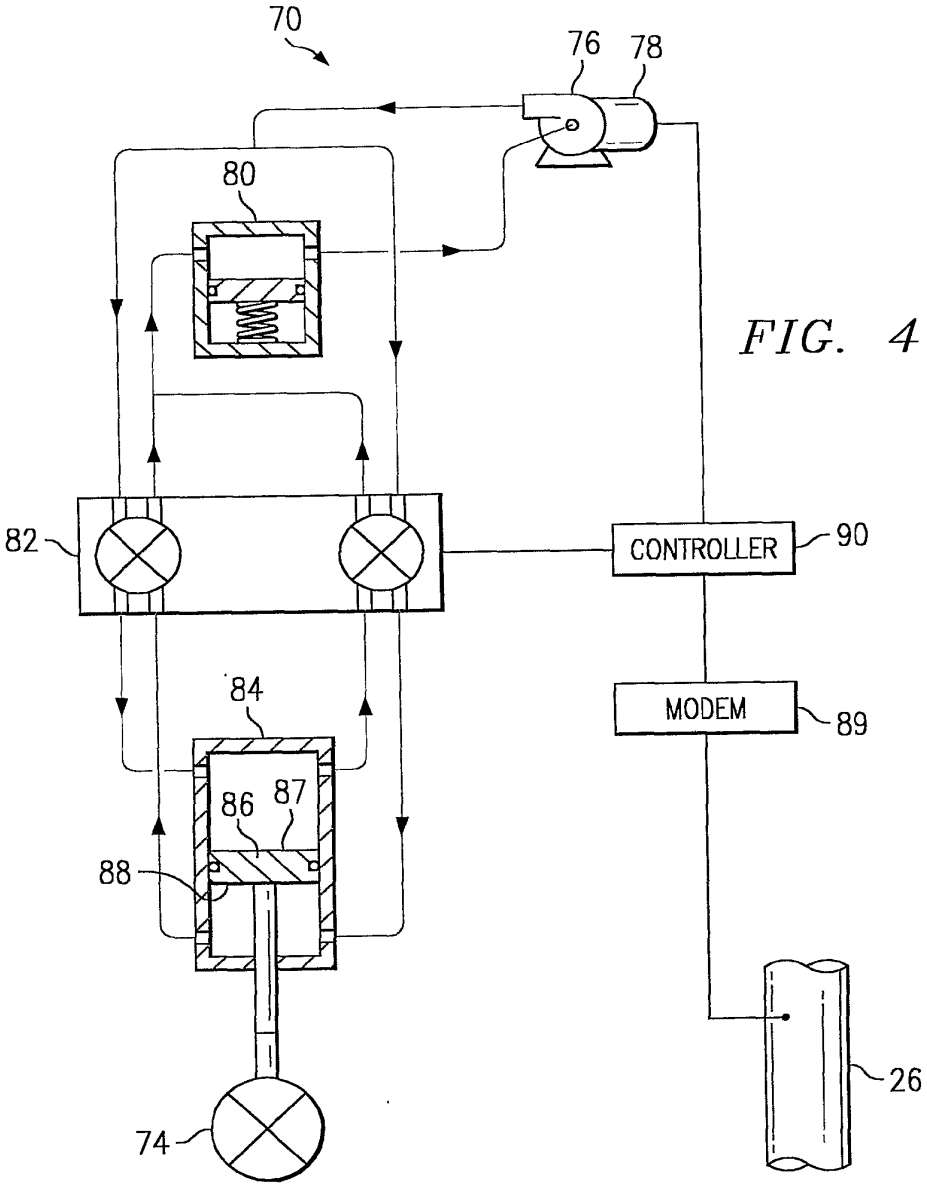
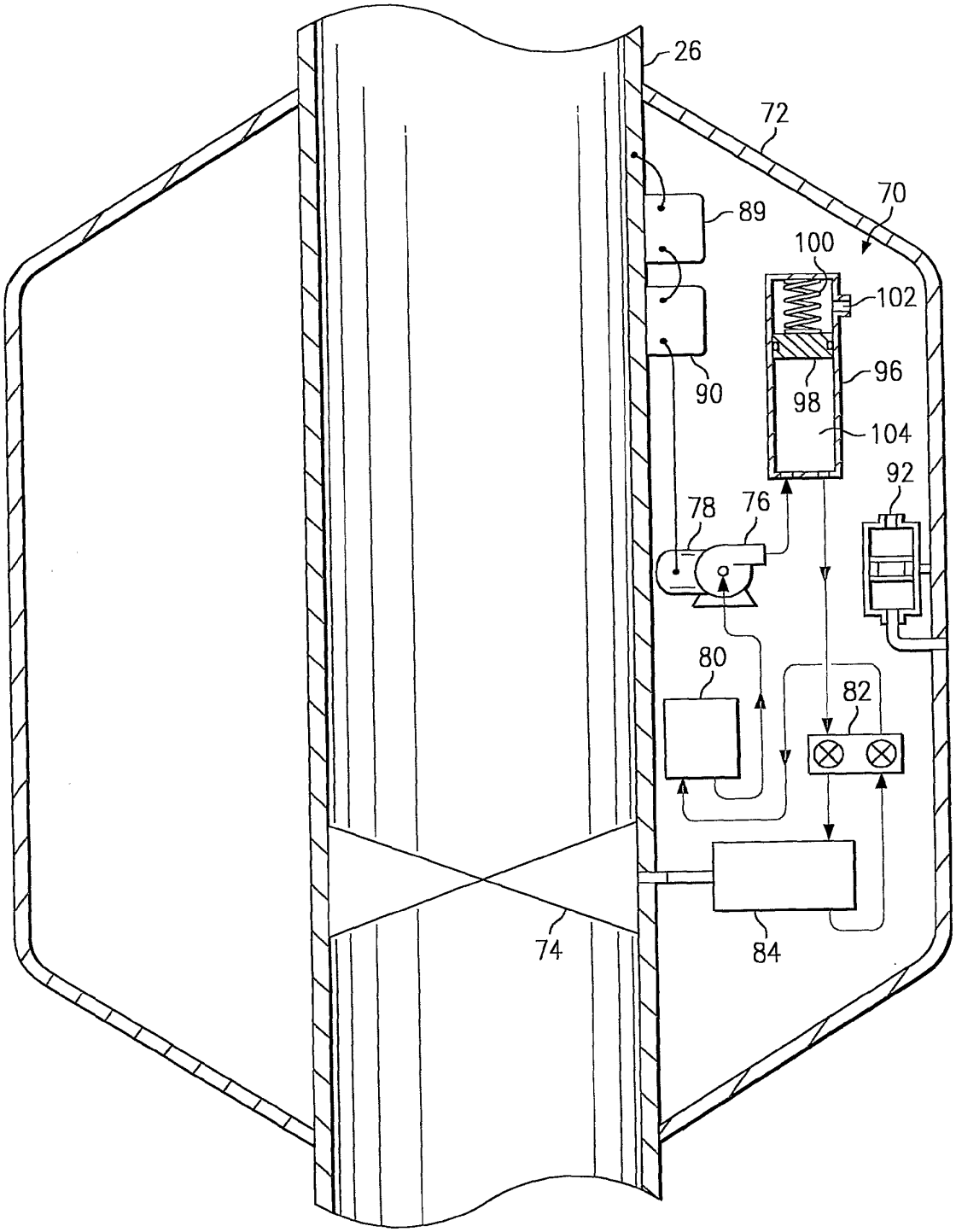


FIG. 4

FIG. 5



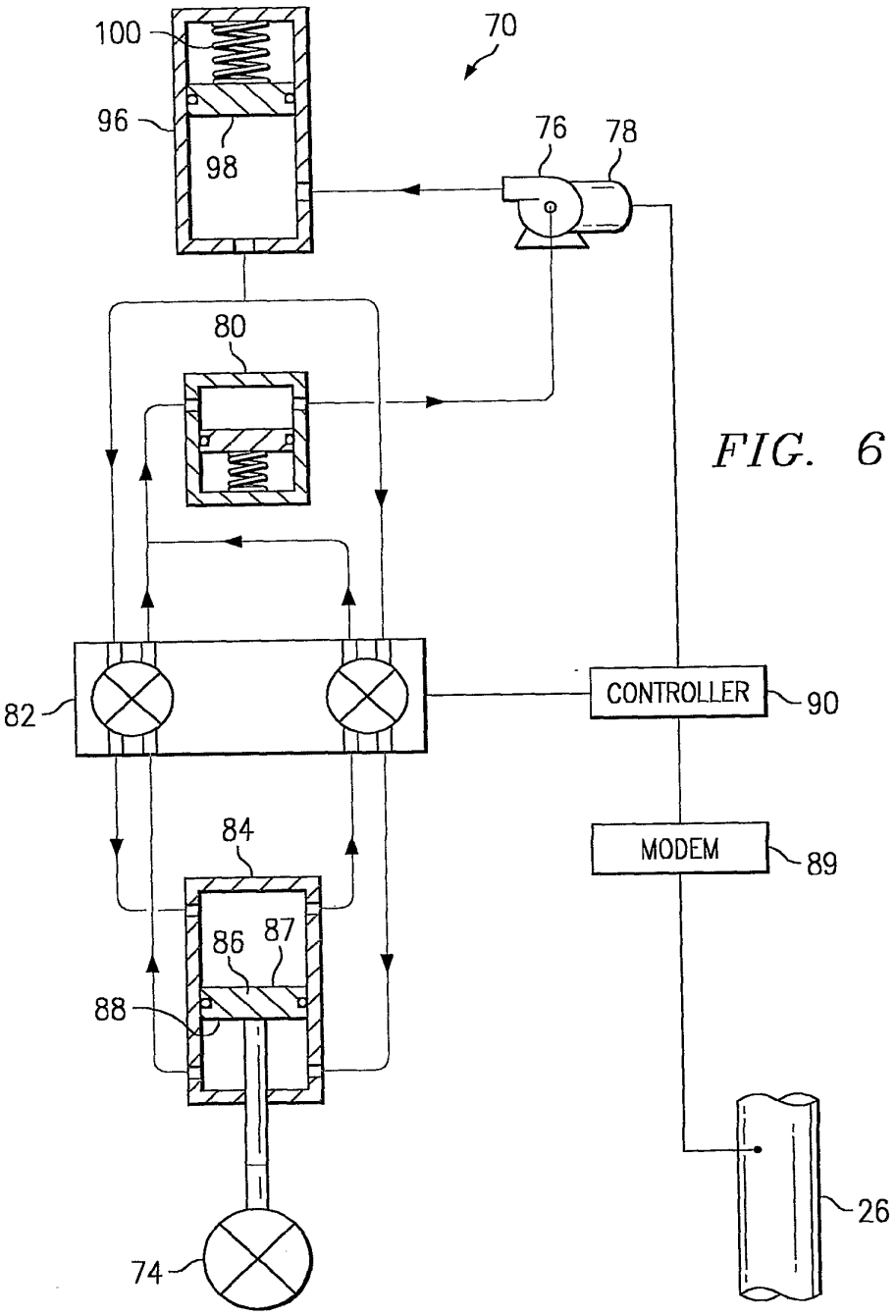


FIG. 6

INTERNATIONAL SEARCH REPORT

Internal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B34/06 E21B17/00 E21B47/12 F16K31/06

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)
IPC 7 E21B F16K

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, TULSA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 257 663 A (MORRIS ARTHUR J ET AL) 2 November 1993 (1993-11-02) column 8, line 34-59; figure 3B	1,2,4, 6-8,23, 25,27
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-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 May 2001	30/05/2001

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	van Berlo, A

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INTERNATIONAL SEARCH REPORT

Internat[illegible]l Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

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INTERNATIONAL SEARCH REPORT

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Internat Application No
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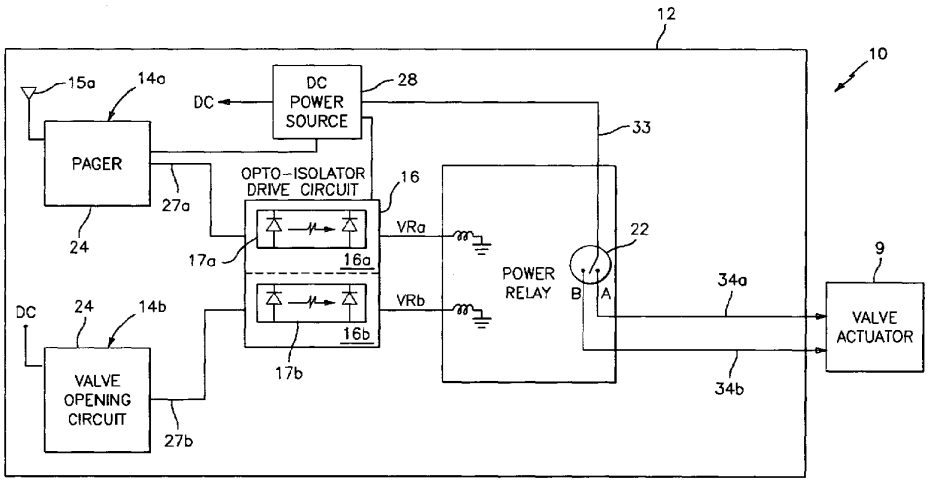
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(54) Title: PAGER-BASED GAS VALVE CONTROLLER



(57) Abstract: A pager-based controller including at least one pager configured to receive a signal from a remote location, the at least one pager being further configured to provide an output to control an on-off state of a valve actuator; a valve opening circuit to provide an output to locally control an on-off state of a valve actuator; a DC power source for supplying a required DC voltage to electrical components within the pager-based controller; a relay electrically connected to the at least one pager and the valve opening circuit; an isolation circuit electrically connected to the at least one pager and the relay, the isolation circuit configured to receive the output from the at least one pager and the valve opening circuit and supply a corresponding signal to the relay; the relay configured to receive the corresponding singal and control the valve actuator accordingly in response.

WO 02/25612 A1

PAGER-BASED GAS VALVE CONTROLLER

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part and claims the benefit of U.S. Utility Application No. 09/010,278, filed January 21, 1998, and incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present disclosure relates generally to remote control systems for remotely controlling electrical equipment. More particularly, this disclosure relates to a controller which receives pager signals from a pager network to control electrical/electronic equipment, including electronic gas valve actuators.

2. Description of the Related Art

Remote control systems which are capable of generating and transmitting control signals to remotely control electronic equipment are known in the prior art. Electric utility companies, for example, typically utilize a private remote control system with a private radio network to remotely control on/off switching of capacitor banks in accordance with daily electric power requirements. Such systems, however, are costly

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in that they require implementation and maintenance of the private radio network. In addition, their utility is generally limited to a narrow geographical region.

Hence, a need exists for a generally inexpensive remote control system which uses the public system telephone network (PSTN) to transmit control signals over a wide geographical region to remotely control equipment.

SUMMARY OF THE INVENTION

The present invention relates to a remote control system in which RF pager signals transmitted by means of a wide area pager network, are received by a pager-based controller to control electrical or electronic equipment. A human operator or automated computer at a telecommunication station connected to the PSTN, initiates the transmission of RF pager signals via the pager network to the pager-based controller at the remote equipment site. In a preferred embodiment, the pager-based controller includes at least one conventional pocket pager which has been modified by having its vibrator or other indicator removed. Each time the pocket pager receives a page, it outputs a control voltage normally used to drive the vibrator. This control voltage is used to change the switching state of a relay within the controller to thereby control the on-off state of external electronics connected to the relay such as gas valve actuators.

In an exemplary embodiment, at least one pager is employed within the controller having a pager (telecommunication) number. The pager is paged to set the valve actuator to a CLOSED state, while a separate valve opening circuit is activated

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locally to set the valve activator to an open state. The relay switches power to the valve actuator. As such, the valve actuator can be switched closed merely by the remote operator or automated computer dialing the telecommunication number of the respective pager as allocated by the PSTN and pager network. The valve actuator is then closed locally.

A pager-based controller is provided which includes at least one pager configured to receive a signal from a remote location, the at least one pager being further configured to provide an output to close a valve; a valve opening circuit to provide an output to open the valve; a DC power source supplying DC voltage to electrical components within the pager-based controller; a relay electrically connected to the at least one pager and the valve opening circuit.

A method of remotely controlling an electronic device is also provided which includes the steps of transmitting a first pager signal from a pager network to a pager-based controller having at least one pager therein; outputting a first control voltage from the at least one pager controller to change a switching state of a relay within the pager-based controller to thereby control a valve actuator which is electrically connected to the relay; and locally initiating a second control voltage to change the switching state of the relay within the controller to control a valve actuator to a state which is opposite that which was caused by the first control voltage.

Advantageously, the use of conventional pocket pagers within the controller requires minimal set-up and maintenance costs and provides a reliable

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method of controlling the capacitor bank via the use of the pager network. Set-up costs are minimal since a customized private radio network for the transmission of control signals is not necessary.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference is made to the following description of exemplary embodiments thereof, and to the accompanying drawings, wherein:

FIG. 1 is a block diagram of a pager-based controller in accordance with the present invention;

FIG. 1A is a schematic diagram illustrating a valve opening circuit in accordance with a preferred embodiment of the present invention;

FIG. 2 is a block diagram of a conventional pocket pager configured to be utilized within the pager-based capacitor bank controller of the present invention; and

FIG. 3 is a block diagram of an illustrative remote control system including a pager network and multiple pager-based controllers of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a simplified block diagram of the internal components of a pager-based controller 10 in accordance with the present invention. Controller 10

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includes a pocket pager 14a which receives paging signals from a pager network. Pager 14a is registered with the pager network and is allocated a pager (telephone) number. Each time a remote operator or automated computer dials the respective pager number through the PSTN, the pager 14a receives the page signal via the PSTN and pager network. Whenever the page signal is received, the pager 14a outputs a control signal to an opto-isolator drive circuit 16a, which in turn changes a switching state of a power relay 20. A valve opening circuit 14b operates to switch the power relay 20 to an OFF state via opto-isolator drive circuit 16b, as described further with reference to FIG. 1A.

In a preferred embodiment, the switching of power relay 20 is used to switch an external gas valve actuator on or off. However, it is to be understood that pager-based controller 10 may alternatively be employed to control other types of electrical or electronic equipment, such as valve actuators for controlling the supply of water or oil. In addition, while it is preferable to employ a single pager 14, multiple pagers could be alternatively utilized within each controller 10.

Controller 10 is preferably embodied as a small portable unit deployable in the field, with a housing 12 to environmentally protect the circuitry therein. Alternatively, the circuitry may be entirely encased in a protective material. Pocket pager 14a may be a modified conventional pager (e.g., Motorola Bravo, Bravo Plus or Advisor pagers) and can be maintained within its original housing 24 to simplify mounting within the controller 10. Also, electromagnetic shielding may be used along

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the inner surface of the pager housing 24 to reduce electromagnetic interference (EMI) susceptibility. The pocket pager typically operates in a one-way pager system, although two-way pagers can also be used. Pager 14a is modified from its commercial design simply by having its batteries and vibrator removed. Conventional pagers include a vibrator which vibrates whenever a page is received to convey vibrational movement to the person wearing the pager. Vibrating action is typically selected by the user via a mode switch on the pager. When vibrating action is selected, the audio output of the pager is deactivated such that the user can effectively receive pages without an accompanying (disturbing) audible tone.

DC power is preferably supplied to controller 10 via a DC source 28, such as batteries or solar power. Here, DC is preferable since it meets the requirement for "intrinsically safe" control of gas equipment. This DC voltage is used to power the electronics within controller 10, including pagers 14a (which has its batteries removed) and valve opening circuit 14b. The DC power supply may supply multiple voltages as needed, or multiple DC power supplies may be used. As an alternative, an alternative energy source known to one having ordinary skill in the art, such as an AC line voltage and converter, could be used to power the various components.

When a page signal is transmitted to controller 10, pager 14a receives the page and responds by outputting the control voltage normally used to drive the respective vibrator. The control voltage is supplied to an opto-isolator drive circuit 16a on line 27a. The valve opening circuit 24 provides a local control output to opto-

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isolator drive circuit 16b on line 27b. Drive circuit 16 includes two portions, 16a and 16b, each including respective opto-isolator electronics 17a or 17b. Drive circuit 16 responds to the control voltage on line 27a or 27b by outputting a respective output voltage VRa or VRb at an appropriate level to power relay 20. When one of these voltages is applied to relay 20, the switching state of the relay changes.

The power relay 20 includes a relay switch 22 that activates one of two positions A or B corresponding to an energized or de-energized state of the gas valve actuator, until electrically reset by a new application of the voltage VRa or VRb from drive circuit 16. The switch 22 input is connected to the DC power source on line 33. The switch output connects to either line 34a or 34b which sends a "close" or "open" command, respectively, to valve actuator 9. Valve actuator 9 is preferably a magnetically latching type valve actuator and remains in a latched state. As such, when power relay 20 changes switching state, the operational state of the valve actuator is correspondingly changed. Alternatively, the relay may be a latching type relay to provide a maintained closure to the valve actuator.

The opto-isolators within drive circuit 16 operate to isolate the pager 14a and valve opening circuit 14b from the relatively high voltage/current levels at the power relay 20. The drive circuit 16 thus prevents voltage spikes from reaching the pager 14a during operation of the external electrical device. A fuse may also be provided on lines 33 and/or 34a, 34b to avoid damage to the relay 20 if current is excessively high.

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DC power source 28 supplies DC voltage to pager 14a, valve opening circuit 14b and drive circuit 16. Typically, the energy requirement of each pager is 80 mA at 1.5 VDC.

Each controller 10 may include a heater and fan (not shown) within the enclosure to maintain the pagers and other electronics within a proper operating temperature range.

The present invention is particularly advantageous for use by utility companies supplying natural gas to homes. In such a case, the utility company may actuate the gas valve, as described above, remotely via the pager 14a. Controlling the gas valve via pager 14a effectively shuts off the gas supply to a home or business. The present invention therefore provides a means to shut off the gas supply remotely from a utility office, for example. This represents a labor savings to the utility, and represents an advantageous safety feature in that potential safety hazards can be eliminated without risk to personnel.

Continuing the exemplary application described above, it is further advantageous to provide a means for the utility to reset the valve locally. While remote shut off of gas service is preferable, turning the gas service back on remotely presents obvious safety concerns. Therefore, it is more advantageous to turn the gas service back on locally, on-premises, preferably using a safe and reliable means.

Referring to FIG. 1A, a simplified schematic diagram of a preferred embodiment of the valve opening circuit 14b is shown. The valve opening circuit 14b

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preferably includes an infra-red (IR) transistor 6, a magnetic reed switch 7, and a current limiting resistor 8. In operation, a pulse of current from the DC power supply source causes relay 20 to change state, thereby gas valve actuator 9 to open the valve. The current source is limited by current limiting resistor 8 and isolated by opto-isolator 16b. Both the IR transistor 6 and the magnetic reed switch must be in a conductive state for at least a temporary period to provide a pulse to power relay 20. Preferably, two different technologies are used to increase reliability and safety by preventing false trigers of the relay. Here, a technician, or any trained user, must apply both an IR source and a magnetic source to the circuit simultaneously to complete the circuit, thereby triggering power relay 20. Both IR and magnetic sources are preferable to limit any possibility of sparking. A magnetic reed switch is also preferable, since it is encapsulated in a glass tube, limiting the possibility of sparking. Limiting the possibility of sparking is preferable due to the potential for igniting the near-by gas supply.

Accordingly, the valve opening circuit of FIG. 1A provides a safe and reliable means to control the gas valve actuator 9 to turn the gas supply on locally. While an IR transistor 6 and reed switch are employed in the preferred embodiment, it is understood that many variations of the valve opening circuit may be made by one having ordinary skill in the art. For example, only an IR transistor 6 or magnetic reed switch 7 may be employed, or only an IR transistor 6 with a decoder, such that a predetermined sequence of IR pulses are required to activate power relay 20.

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With reference now to FIG. 2, a simplified block diagram of the conventional pocket pager 14a modified for use within the pager-based controller 10 is illustrated. Pocket pager 14a has the battery and vibrator removed and the battery contact points T1, T2 coupled to the DC power source 28 to receive the proper operating voltage for the electronics within the pager. A motor drive circuit 35 is coupled to the opto-isolator drive circuit 16 via connection at terminal points T3, T4 normally connected to the vibrator. A mode switch 35 is set to the vibrator position such that when a page is received by receiver/control circuit 32 via antenna 15, it responds by sending a command to motor drive circuit 34 rather than to the audio driver 36. Motor drive circuit 34 responds by outputting a voltage V1 of approximately 1.5 volts for a short duration. Pager 14a also includes LED driver 38, LED display 39 and audio transducer 37. These components are preferably not removed, since they can be used to verify reception of pages for testing purposes. It is noted that in alternative embodiments of the controller 10, it is possible to tap into the LED driver 38 and/or audio driver 36 (rather than or in addition to the motor drive circuit 34) to derive control signals for controlling the power relay switching state.

Furthermore, conventional pocket pagers are normally programmed by the pager company prior to delivery. A standard program used by the pager company requires the pager to give a reminder beep or vibration if the page is not acknowledged by pressing a button. The vibration is caused by a small motor with an unbalanced

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shaft which vibrates the pager. Since the pagers will be unattended, the typical pager programming needs to be modified to disable the reminder function.

Referring now to FIG. 3, a remote control system 100 is illustrated which includes the pager-based controller 10 of the present invention. The system 100 controls the operational states of external electrical devices 50. System 100 includes a remote telecommunication terminal 70 which is connected to the PSTN 110 by a conventional telephone line 108. Terminal 70 can be as simple as a single telephone 80 operated by a human operator, or as complex as a fully automated computer 90 which maintains, *inter alia*, a memory of the operational state of each external electrical device. In the latter case, computer 90 automatically dials the pager numbers of pagers 14 within associated controllers 10 to dynamically switch specific external electrical devices 50 into and out of operation based on the desired result. For example, an electric generating station or capacitor bank may be switched in and out of service based on electric power requirements within a certain geographical area. When a page is initiated at terminal 70, the call is relayed through the PSTN 110 to a paging messaging center 60 via a wireline or wireless communication link 105. Messaging center 60 is coupled to each of a number of paging base stations 40 by means of wireline or wireless communication links 120. Typically, with one-way pager networks, each pager registered in the system can receive pages only within specific geographical regions associated with a particular one or more pager base stations 40. As such, when a call to a specific pager number is routed by the PSTN to messaging

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center 60, the messaging center relays the call to the particular base station 40 associated with that pager. Each associated base station 40 then transmits the page signal. In the exemplary system described herein, since the external electrical devices controlled by each controller 10 are typically at fixed locations, only a single base station 40 need transmit the specific page signal to change the switching state of the corresponding external electrical device 50. The pager within controller 10 receives the specific page signal and switches the relay state accordingly. (It is noted that in some pager networks, each pager base station may transmit all pages to every pager registered with the system. The exemplary system of this invention can operate with this type of pager network as well).

A security measure may be incorporated to prevent persons other than the responsible operator or computer system at terminal 70 from dialing the pager numbers and thus changing the states of capacitor banks. For example, a security/access code can be allocated by the pager network service provider to each pager 14a. Therefore, in order to communicate with the pager 14a in the pager system 100, the security/access code must be transmitted followed by the corresponding telephone number (or vice versa) for that particular pager 14a.

Thus disclosed is a pager-based remote control system and controller particularly useful for controlling switching states of electronic equipment. Advantageously, since conventional pocket pagers are used to receive RF paging signals through a paging network, there are minimal costs in setting up and maintaining

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the remote control system of the present disclosure. Further, customized transceiver circuitry and a radio network are not necessary to operate the pager-based controller 10 of the present disclosure.

It is to be understood that the embodiments described herein are merely exemplary and that one skilled in the art can make many modifications and variations to the disclosed embodiments without departing from the spirit or scope of the invention. For example, the present invention is not to be understood to be limited to employment in a pager system, but rather may be employed into numerous wireless communication systems, such as a Personal Communication Network (PCN) or into communication systems utilizing Personal and/or Terminal Mobility managers. According, all such modifications and variations are intended to be included within the scope and spirit of the present invention.

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IN THE CLAIMS:

1. A system for controlling an on-off state of a remote electrical valve actuator, said system comprising:

a pager-based controller; and

a terminal for transmitting a signal to the pager-based controller;

wherein the pager-based controller comprises a housing; at least one pager positioned within the housing and configured to receive a signal from a remote location, said at least one pager being further configured to provide an output to control the on-off state of the valve actuator; and a valve opening circuit operative to provide local control of the on-off state of the valve actuator.

2. The system recited in claim 1, wherein the valve opening circuit comprises an infra-red (IR) transistor and a magnetic reed switch connected in series and configured to change the on-off state of the valve actuator when an IR source and a magnetic source are brought into close proximity of the valve opening circuit.

3. The system recited in claim 1, wherein the pager-based controller further comprises a relay, the relay electrically connected and configured to receive the output from the at least one pager and supply a corresponding signal to the valve actuator.

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4. The system recited in claim 1, wherein the terminal is one of a telephone or a computer.

5. A pager-based controller which comprises:

a housing;

at least one pager positioned within the housing and configured to receive a signal from a remote location, said at least one pager being further configured to provide an output to change an on-off state of a valve actuator; and

a valve opening circuit positioned within the housing and operative to locally control the on-off state of the valve actuator.

6. The paper-based controller as recited in claim 5, further comprising:

a DC power source supplying DC power to the at least one pager, the valve opening circuit and the valve actuator.

7. The pager-based controller as recited in claim 5, further comprising a relay, the relay electrically connected and configured to receive the output from the at least one pager and supply a corresponding signal to the valve actuator.

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8. The pager-based controller as recited in claim 5, wherein the valve opening circuit comprises an infra-red (IR) transistor and a magnetic reed switch connected in series and configured to change the on-off state of the valve actuator when an IR source and a magnetic source are brought into close proximity of the valve opening circuit.

9. The pager-based controller as recited in claim 5, further comprising an isolation circuit configured to electrically isolate the at least one pager and the valve opening circuit from at least one of a high voltage and a high current.

10. The pager-based controller as recited in claim 9, wherein the isolation circuit is an opto-isolator drive circuit.

11. The pager-based controller as recited in claim 5, wherein the output of the at least one pager is a voltage from a motor drive circuit within the at least one pager.

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12. A method of remotely controlling a valve actuator comprising the steps of:

transmitting a first pager signal from a pager network to a pager-based controller located at a remote site, the pager-based controller having at least one pager therein; and

outputting a first control signal from the at least one pager to change a switching state of a relay within the pager-based controller to thereby control an on-off state of the valve actuator which is electrically connected to the relay.

13. The method recited in claim 12, further comprising the step of:

locally initiating a second control signal to change the switching state of the relay within the controller to switch the on-off state of the valve actuator to a state which is opposite that which was caused by the first control signal.

14. The method recited in claim 12, wherein the step of transmitting a first pager signal is automatically initiated by a computer.

15. The method recited in claim 13, wherein the step of locally initiating the second control signal includes bringing an IR source and a magnetic source within close proximity of the pager based controller.

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16. A gas system for controlling an on-off state of a remote electrical gas valve actuator, said gas system comprising:

a pager-based controller; and

a terminal for transmitting a signal to the pager-based controller;

wherein the pager-based controller comprises a housing; at least one pager positioned within the housing and configured to receive a signal from a remote location, said at least one pager being further configured to provide an output to control the on-off state of the gas valve actuator; and a valve opening circuit operative to provide local control of the on-off state of the gas valve actuator.

17. The system recited in claim 16, wherein the valve opening circuit comprises an infra-red (IR) transistor and a magnetic reed switch connected in series and configured to change the on-off state of the valve actuator when an IR source and a magnetic source are brought into close proximity of the valve opening circuit.

18. The system recited in claim 16, wherein the pager-based controller further comprises a relay, the relay electrically connected and configured to receive the output from the at least one pager and supply a corresponding signal to the valve actuator.

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19. The system recited in claim 16, wherein the terminal is one of a telephone or a computer.

20. The pager-based controller as recited in claim 16, further comprising an isolation circuit configured to electrically isolate the at least one pager and the valve opening circuit from at least one of a high voltage and a high current.

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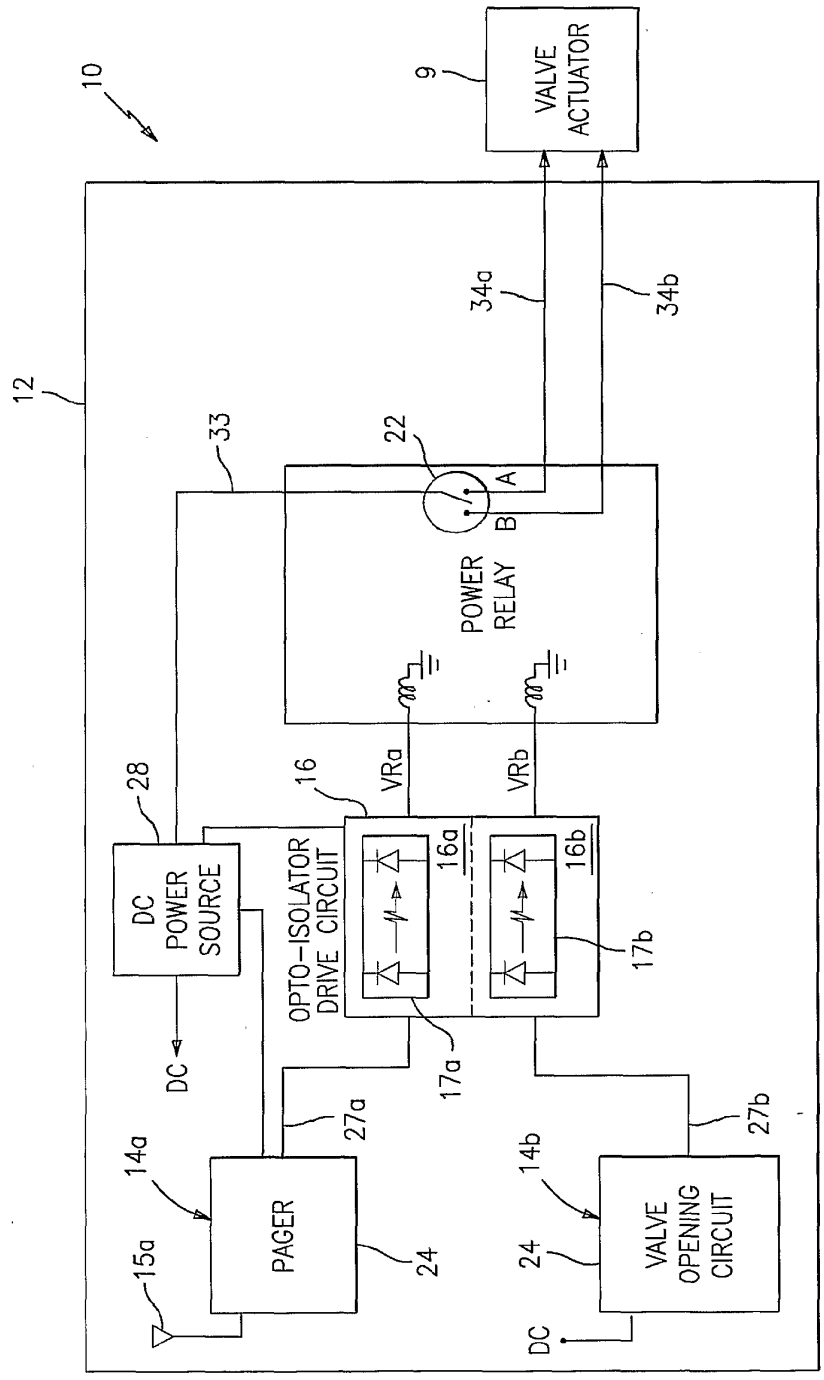


FIG. 1

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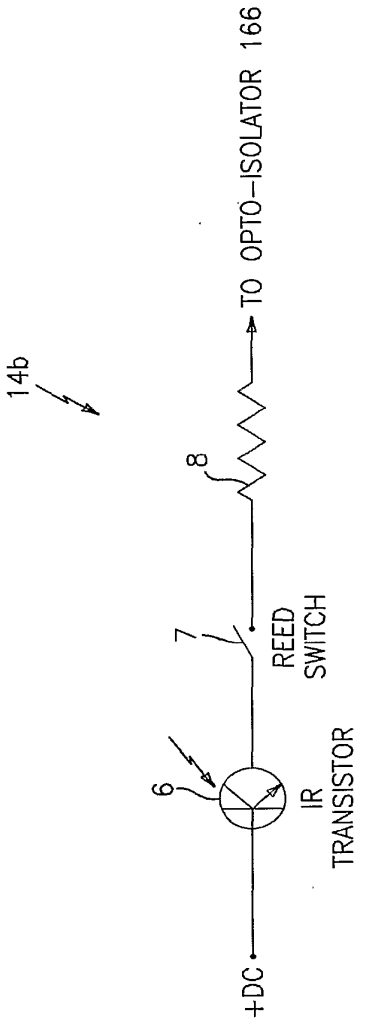


FIG. 1A

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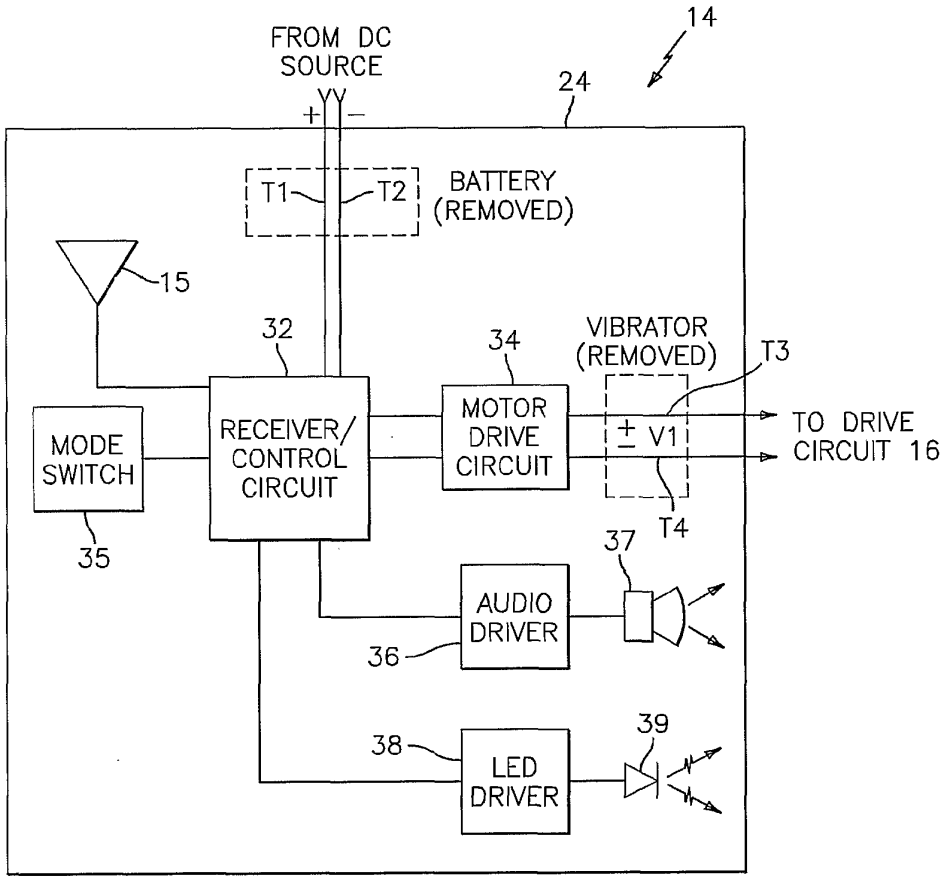


FIG. 2

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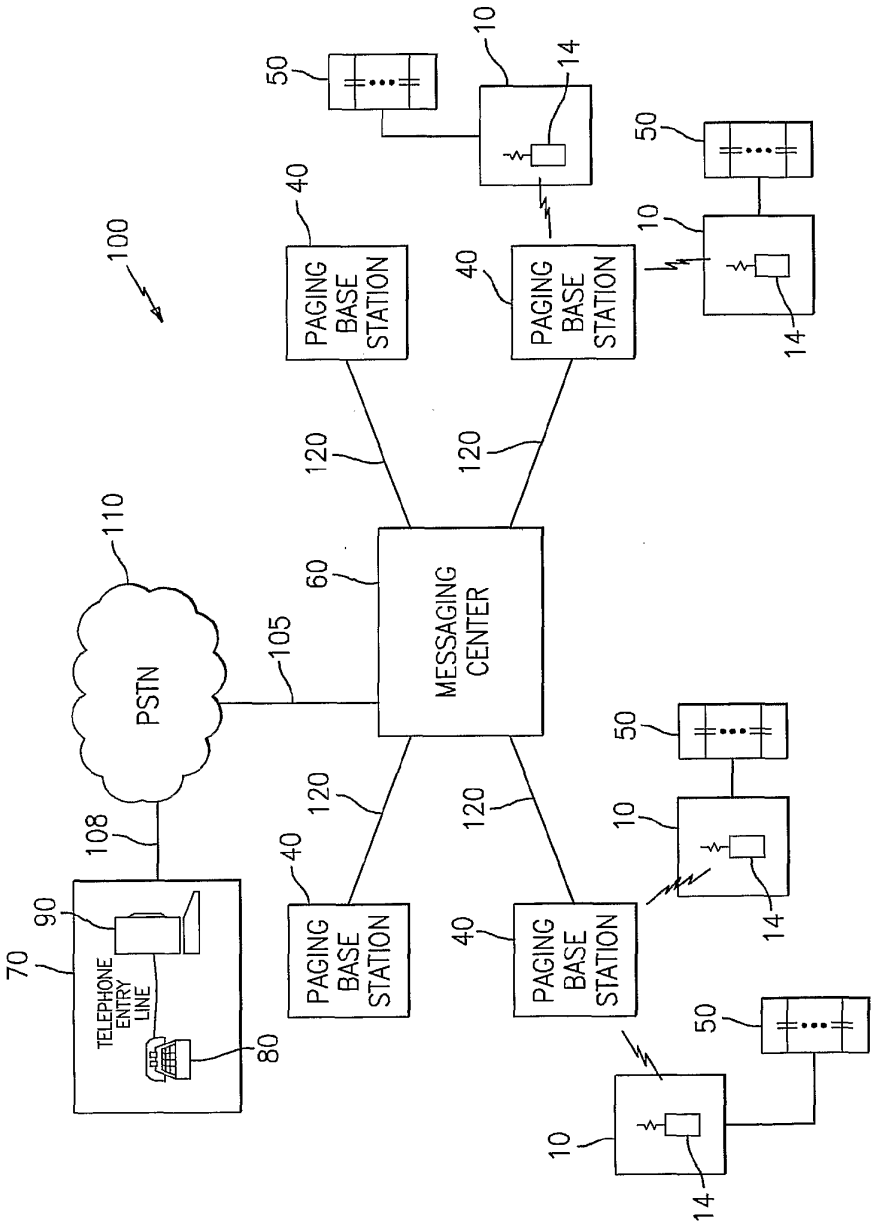


FIG. 3

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INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/US 01/29764

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G08B5/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G08B B60R

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 94 29148 A (RONDISH CO LTD ;WILLIAMS STEVEN ALFRED (GB)) 22 December 1994 (1994-12-22) the whole document	1,3-7, 9-14,16, 18-20
X	WO 98 33153 A (GELBIEN LAWRENCE) 30 July 1998 (1998-07-30) claims 1-19	1,3-7, 9-14,16, 18-20
A	US 5 654 689 A (DEMOUY OLIVIER ET AL) 5 August 1997 (1997-08-05) abstract	2,8,15, 17
A	EP 0 716 553 A (MOTOROLA INC) 12 June 1996 (1996-06-12) abstract	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern: I Application No
PCT/US 01/29764

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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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.

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(54) Title: DEVICE AND METHOD FOR PNEUMATIC VALVE CONTROL

(57) Abstract: A valve control apparatus (10) includes an enclosure (12, 14) that defines first and second chambers (16), an indicator (24) that is proximate the first and second chambers (16), an operating media distribution system (20) that is disposed in the first chamber (12), an electronic control unit that is disposed in the second chamber, and a plurality of connection ports (34). The first and second chambers (16) are spaced from each other along a longitudinal axis. The indicator (24) has a visual symbol (388) that identifies an operational state of at least one process valve (3). The operating media distribution system (20) includes an operating media supply passage (28), an operating media exhaust passage (30), at least three operating media transmission passages (32), and a plurality of valves (64, 66, 68, 70) in fluid communication with the operating media supply passage (28), the operating media exhaust passage (30), and the at least three operating media transmission passages (32). The electronic control unit operates at least one of the plurality of valves (64, 66, 68, 70) to control operating media flow in the operating media distribution system (20). And the plurality of connection ports (34) communicate with the operating media supply passage (28), the operating media exhaust passage (30), and the at least three operating media transmission passages (32).

DEVICE AND METHOD FOR PNEUMATIC VALVE CONTROL

Cross-Reference to Related Applications

This application claims the benefit of the earlier filing date of U.S. Provisional Application No. 60/559,002, filed 5 April 2004, which is incorporated by reference herein in its entirety.

Field of the Invention

The present invention relates generally to a valve controller, further to an actuator within an integrated valve controller. The present invention also relates to systems that include the valve controller and operational methods for monitoring the operational characteristics of a valve through knowledge-based valve performance criteria.

Background of the Invention

Valve control systems are known in the related art. A valve control system may be used, for example, to continuously control the position of a valve based on pneumatic pressure. A valve control system may also have the capability to indicate valve position. A valve control system may further have the capability to monitor valve operation and signal an error message, if a failure condition occurs.

Summary of the Invention

The present invention relates to a low profile multi-purpose pneumatic valve controller with an operating media distribution system. The valve controller may be used to control one process valve with increased air flow dynamics, provide redundant control for one process valve, or control two independent valves. The valve controller may be configured with integral pressure sensors to allow for advanced diagnostics that can be tailored to a particular valve and/or actuator. The valve controller may also be configured to automatically acquire and process data to create advanced diagnostic methods and systems.

The valve controller may have an enclosure that includes various features that can be utilized to achieve other functions in addition to simply house the valve controller.

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For example, the valve controller may have separate enclosures for mechanical and electronic components, and the separate enclosures may define chambers for all components to avoid exposure to operative conditions. The valve controller enclosure may be configured to integrate with an actuator, such that the integrated valve controller may have separate chambers for mechanical and electronic components. The integrated actuator and valve controller with separate chambers may allow for a method of maintenance for the valve controller that only requires access to either mechanical or electrical chambers. The valve controller may have a height profile of no more than 3 inches. The valve controller with a height profile of no more than 3 inches may be capable of providing two pneumatic control signals from a single pneumatic control supply, and may be provided with an integrated actuator.

According to a preferred embodiment, a valve control apparatus includes an enclosure that defines first and second chambers, an indicator proximate the first and second chambers, an operating media distribution system disposed in the first chamber, an electronic control unit disposed in the second chamber, and a plurality of connection ports. The first and second chambers are spaced from each other along a longitudinal axis. The indicator has a visual symbol that identifies an operational state of at least one valve. The operating media distribution system includes an operating media supply passage, an operating media exhaust passage, at least three operating media transmission passages, and a plurality of valves in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least three operating media transmission passages. The electronic control unit operates at least one of the plurality of valves to control operating media flow in the operating media distribution system. And the plurality of connection ports communicate with the operating media supply passage, the operating media exhaust passage, and the at least three operating media transmission passages.

According to another preferred embodiment, a valve control apparatus includes an enclosure, an operating media distribution system that is disposed in the enclosure, an electronic control unit that is disposed in the enclosure, at least one sensor that is disposed in the enclosure, and a plurality of connection ports. The operating media distribution system includes an operating media supply passage, an operating media exhaust passage, at least two operating media transmission passages, and a valve that is

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in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least two operating media transmission passages. The electronic control unit operates the valve to control operating media flow in the operating media distribution system. The sensor evaluates the operating media distribution system and provides information to the electronic control unit about at least one operating condition in at least one of the passages. And the plurality of connection ports are in fluid communication with the operating media supply passage the operating media exhaust passage, and the at least two operating media transmission passages.

The valve controller may have a beacon (position indicator) located between separate chambers for mechanical and electronic components. The size of the beacon (position indicator) may be selected to allow for viewing by an observer from a remote location. The beacon (position indicator) may operate via a non-contact position sensor. The valve controller with a beacon (position indicator) disposed adjacent operative components may be viewed from a site range both above and below the centerline of a position indicator. The position indicator may be a rotary or linear configuration. The valve controller and beacon (position indicator) may also be integrated with an actuator to provide an integrated actuator and valve controller, the valve controller having a beacon (position indicator) located between separate chambers for mechanical and electronic components. The integrated actuator and valve controller may be configured to provide the valve controller with a beacon (position indicator) disposed adjacent operative components so that it can be viewed by an observer from a site range both above and below the center line of a position indicator.

Design aspects of the valve controller package are unique. For example, the valve controller enclosure or package may have a housing with the enclosure being a bow-tie configuration, or may be contained within a limited size space.

According to a preferred embodiment, an apparatus that distributes operating media includes an enclosure, an indicator proximate the enclosure, an operating media distribution system disposed in the enclosure, and a plurality of connection ports that communicate with the operating media distribution system. The enclosure includes upper and lower surfaces that respectively define first and second parallel planes, and the enclosure is located entirely within a distance between the first and second planes. The indicator includes a visual symbol that identifies an operational state of the at least one

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process valve. The visual symbol is visible from above the first plane and from below the second plane.

According to another preferred embodiment, a valve control apparatus for at least one process valve that has a maximum exterior package dimension. The apparatus includes an enclosure that is disposed entirely between first and second parallel planes. The first and second parallel planes are spaced apart a distance that is less than or equal to the exterior package dimension. The apparatus further includes an indicator that is proximate the enclosure, an operating media distribution system, an electronic control unit and at least one sensor that are disposed in the enclosure, and a plurality of connection ports that communicate with the operating media distribution system. The indicator includes a visual symbol that identifies an operational state of the at least one process valve. The visual symbol is visible from above the first plane and from below the second plane. And the at least one sensor evaluates the operating media distribution system and provides the electronic control unit information about at least one operating condition in the operating media distribution system.

The valve controller may have a manifold assembly having one, two three or four integral coils and one or two spools. The valve controller may use the same fasteners to secure the cover to the manifold and the manifold assembly to the base of a housing. The valve controller may include a pneumatic manifold assembly that uses a cover to define pneumatic operative paths. The valve controller may have a housing with a single pneumatic supply path, two separate pilot paths, a single exhaust path, and an individual pressure sensor for each path. Two of the sensors can be differential pressure sensors.

According to a preferred embodiment, a manifold apparatus that distributes operating media includes a first member that defines an operating media supply cavity, an operating media exhaust cavity, and at least four operating media transmission cavities in communication with the operating media supply cavity and the operating media exhaust cavity. The apparatus further includes a surface that communicates a flow of operating media flow between a minimum of two of the at least four operating media transmission cavities.

According to another preferred embodiment, an apparatus for distributing an operating media includes a manifold that has an operating media supply passage, an operating media exhaust passage, and first, second, third and fourth operating media

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transmission passages. The apparatus further includes a means for directing the operating media from the operating media supply passage to the first and third operating media transmission passages, and a means for directing the operating media to the operating media exhaust passage from the second and fourth operating media transmission passages.

The valve controller may provide for different operative arrangements. The valve controller may have a single pneumatic supply port that allows for two operational control signals. The two operational control signals may provide a first command signal and a second command signal to a single valve. The first command signal may be a discrete command signal. The second command signal may be a modulating command signal. The valve controller may be integrated with an actuator, the valve controller having a single pneumatic supply port that allows for two operational control signals. The valve controller may be used to operate a valve with two different command signals from a single pneumatic supply port. The valve controller may be used in a method of operating an integrated actuator with two different command signals from a single pneumatic supply port. The valve controller may have a single pneumatic supply port that allows for two operational control signals. The two operational control signals may provide a discrete command signal to a first valve and a separate discrete command signal to a second valve. The valve controller may be integrated with an actuator, the valve controller having a single pneumatic supply port that allows for two separate and identical operational control signals. The valve controller may be configured to provide a method of controlling fail-safe operation of two valves with a single supply.

According to a preferred embodiment, a system, which controls two process valves, includes a manifold, a surface, and first and second process valves. The manifold defines a member that defines an operating media supply cavity, an operating media exhaust cavity, and at least four operating media transmission cavities in communication with the operating media supply cavity and the operating media exhaust cavity. The surface communicates a flow of operating media between a minimum of two of the at least four operating media transmission cavities. The first process valve actuator includes a first operating media port that is connected to the first operating media transmission cavity, and a second operating media port that is connected to the second operating media transmission cavity. And the second process valve actuator includes a

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third operating media port that is connected to the third operating media transmission cavity, and a fourth operating media port that is connected to the fourth operating media transmission cavity.

According to another preferred embodiment, a method of distributing operating media includes introducing an operating media supply to a manifold, allotting within the manifold the operating media supply to at least four operating media transmission passages, transporting to a first actuator operating media from a first minimum of two of the at least four operating media transmission passages, and collecting in an operating media exhaust passage exiting the manifold operating medium from a minimum of two of the at least four transmission passages.

According to another preferred embodiment, a method of distributing operating media include connecting an operating media supply to a manifold. The manifold defines an operating media supply passage, an operating media exhaust passage, a first operating media transmission passage, a second operating media transmission passage, a third operating media transmission passage, and a fourth operating media transmission passage. The method further includes directing operating media from the operating media supply to the first and third operating media outlet passages, and directing operating media from the second and fourth operating media outlet passages to the operating media exhaust passage.

The valve controller may have knowledge-based valve performance ("performance") attributes. The functionality of the microprocessor and methods for implementing performance attributes are developed by generic process flow charts that relate the evaluated pressures and the valve condition determined from the evaluated pressures. The valve controller with integral pressure sensors can be used to profile pressures of a single supply port and a single exhaust port so that diagnostics and fault monitoring can be accomplished with a microprocessor. Diagnostics for the performance attributes may include: (1) a "Factory Torque Profile", (2) a "Commissioned Torque Profile" and (3) a "Maintenance Torque Profile". Performance attribute fault monitoring may include: (1) "Insufficient Line Pressure to Guarantee Correct Operation", (2) "Supply Pressure Failure", (3) "Valve Shaft Bent", (4) "Valve Not Achieving Full Stroke", (5) "Backlash Detection", (6) "Torque Demand of Valve Approaching Actuator limit", (7) "Valve Seating/ Break-Out Torque Monitoring", (8)

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"Torque Limit Exceeded", (9) "Close on Torque", (10) "Shaft Broken", (11) "Valve Exercise", (12) "Valve Packing Torque", (13) "Line Filter and Silencers Conditions", and (14) "Solenoid Spool Sticking".

Methods of valve diagnostics and fault monitoring provided by a valve controller with integrated pressure sensors are described. Each of the diagnostic capabilities of the valve controller has a separate method. For example, the "Commissioned Torque Profile" or "Maintenance Torque Profile" may be used to compare with a factory torque profile to detect any fouling of the valve disc or deformation of the valve seat. In another example, the "Insufficient Line Pressure to Guarantee Correct Operation" fault monitoring can be used to indicate that the air supply pressure to a valve may not be sufficient to guarantee either opening or closing. In another example, the "Supply Pressure Failure" fault monitoring may be used to indicate that supply line pressure has fallen bellow a required amount. In yet another example, "Valve Shaft Bent" fault monitoring may be used with a phase shift of torque profile to determine if a valve shaft is bent.

Remote communication with the valve controller can be provided via wire or wireless technology. Each of the features for protection with respect to the valve operative arrangements and knowledge based valve performance can be used with a short-range wireless protocol, or a communication method via the Internet. The combination of knowledge based valve performance with remote communications via the Internet provides various opportunities to implement maintenance and monitoring of valves at a location remote from the location of maintenance staff. For example, the valve controller can be used with a method of maintaining the operative performance of two valves, including evaluating the operative conditions of two valves with a single valve controller, communicating the operative conditions of the two valves to a remote location via an internet communication link, and changing operative commands of the valve controller via an internet communication link.

Sub-components of the valve controller may have preferred embodiments. For instance, features of the pneumatic manifold assembly/manifold may have a preferred embodiment. In one example, the manifold assembly may include a manifold with coils and spools. In another example, the manifold assembly may have a single supply path, two pilot paths, and a single exhaust path. The manifold assembly may further be a

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monolithic member or a two-piece member. The two-piece member may include a base and a cover, the cover defining paths within the base. In another example, the manifold assembly may include a manifold with two coils, two spools, and sensors. In another example, the manifold assembly may a single supply path, two pilot paths, and single exhaust path that can be used as a stand alone valve controller island. In yet another example, the manifold assembly may be operatively associated with an electronic controller disposed in the enclosure, the manifold assembly having a single supply path, two pilot paths, and single exhaust path. In another embodiment, the manifold assembly may be operatively associated with existing smart valve controllers. Moreover, features of the mechanical enclosure may be preferred. For example, in one embodiment the mechanical enclosure may include a pneumatic manifold assembly and a manifold block. In another embodiment, the mechanical enclosure may be packaged together with a separate electronic enclosure. In another embodiment, the mechanical enclosure may be used as a stand-alone valve controller island. Additionally, features of the beacon (position indicator) housing and beacon (position indicator) may be preferred. For example in one embodiment, the beacon (position indicator) may have a housing that defines a viewing window for a position indicator and a mounting surface generally parallel to a longitudinal axis of the position sensor.

According to a preferred embodiment, a manifold apparatus, which distributes operating media, includes first and second members. The first member has a plurality of cavities, including an operating media supply cavity, that transport operating media, and the second member defines a surface that cooperates with the first member so as to contain and transport operating media between at least two cavities.

Systems that include the valve controller or utilize a feature on the valve controller are described. For example, the valve controller can be used in a system of piping including a first pipe, a second pipe proximate the first pipe, a valve disposed between the first pipe and the second pipe, a valve actuator that operates the valve, and a valve controller that operates the valve actuator, the valve controller including a housing having a single supply path that feeds two separate pilot paths, the two separate pilot paths having a common exhaust path. Further details of the system are described to specify various illustrative uses of the valve controller. For example, piping to the controller can be defined.

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According to a preferred embodiment, a piping system includes a first pipe, a first process valve that is connected to the first pipe, a first actuator that operates the first process valve, and a device that controls the first actuator. The device includes an enclosure that defines first and second chambers, an indicator proximate the first and second chambers, an operating media distribution system disposed in the first chamber, and an electronic control unit disposed in the second chamber. The first and second chambers are spaced from each other along a longitudinal axis. The indicator has a visual symbol that identifies an operational state of at least one valve. The operating media distribution system includes an operating media supply passage, an operating media exhaust passage, at least three operating media transmission passages, and a plurality of valves in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least three operating media transmission passages. And the electronic control unit operates at least one of the plurality of valves to control operating media flow in the operating media distribution system.

According to another preferred embodiment, a piping system includes a first pipe, a first process valve that is connected to the first pipe, a first actuator that operates the first process valve, and a device that controls the first actuator. The device includes an enclosure, an operating media distribution system disposed in the enclosure, an electronic control unit that is disposed in the enclosure, and at least one sensor that is disposed in the enclosure. The operating media distribution system includes an operating media supply passage, an operating media exhaust passage, at least two operating media transmission passages, and a valve that is in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least two operating media transmission passages. The electronic control unit operates the valve to control operating media flow in the operating media distribution system. And the sensor evaluates the operating media distribution system and provides information to the electronic control unit about at least one operating condition in at least one of the passages.

According to yet another preferred embodiment, a piping system includes a first pipe, a first process valve that is proximate the first pipe, a first actuator that operates the first process valve, and an operating media distribution system that controls the first actuator. The operating media distribution system includes a manifold. The manifold

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defines an operating media supply passage that introduces operating media into the operating media distribution system from outside the housing, an operating media exhaust passage that discharges operating media from the operating media distribution system to outside the housing, and at least four operating media transmission passages that are in fluid communication with the operating media supply and exhaust passages. A minimum of two of the at least four operating media transmission passages are in fluid communication with the first actuator.

Brief Descriptions of the Drawings

The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate an embodiment of the invention, and, together with the general description given above and the detailed description given below, serve to explain the features of the invention.

Figure 1A is a perspective view of an exemplary embodiment of a system including a preferred embodiment of a pneumatic valve controller, the valve controller having separate chambers for mechanical and electrical components.

Figure 1B is a perspective view, with the cover removed, of the valve controller illustrated in Figure 1A.

Figure 2 is a view, taken along line 2-2 in Figure 1A, showing in cross-section an enclosure for the pneumatic valve controller illustrated in Figure 1B, and showing in elevation internal components of the pneumatic valve controller.

Figure 3A is a perspective view of a pneumatic manifold assembly for the valve controller illustrated in Figure 1B.

Figure 3B is a schematic diagram of selected features of the manifold assembly illustrated in Figure 3A.

Figures 4A is a top plan view, showing internal cavities in hidden lines, of a bottom portion of the manifold assembly illustrated in Figure 3A.

Figures 4B is a left-side plan view of a bottom portion of the manifold assembly illustrated in Figure 3A.

Figures 4C is a back plan view of a bottom portion of the manifold assembly illustrated in Figure 3A.

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Figures 4D is a bottom plan view, showing internal cavities in hidden lines, of a bottom portion of the manifold assembly illustrated in Figure 3A.

Figures 4E is a right-side plan view of a bottom portion of the manifold assembly illustrated in Figure 3A.

Figures 5A is a left-side plan view of a top portion of the manifold assembly illustrated in Figure 3A.

Figures 5B is a top plan view of a top portion of the manifold assembly illustrated in Figure 3A.

Figures 5C is a right-side plan view of a top portion of the manifold assembly illustrated in Figure 3A.

Figures 5D is a front plan view of a top portion of the manifold assembly illustrated in Figure 3A.

Figures 5E is a bottom plan view of a top portion of the manifold assembly illustrated in Figure 3A.

Figure 5F is a back plan view of a top portion of the manifold assembly illustrated in Figure 3A.

Figure 6 is a front plan view of the pneumatic manifold assembly illustrated in Figure 3A.

Figures 6A is a cross-section view taken along line 6A-6A in Figure 6.

Figures 6B is a cross-section view taken along line 6B-6B in Figure 6.

Figures 6C is a cross-section view taken along line 6C-6C in Figure 6.

Figures 6D is a cross-section view taken along line 6D-6D in Figure 6.

Figures 6E is a cross-section view taken along line 6E-6E in Figure 6.

Figures 6F is a cross-section view taken along line 6F-6F in Figure 6.

Figures 6G is a cross-section view taken along line 6G-6G in Figure 6.

Figures 6H is a cross-section view taken along line 6H-6H in Figure 6.

Figure 7A is a top plan view of a cap portion of the manifold assembly illustrated in Figure 3A.

Figure 7B is a front plan view of a cap portion of the manifold assembly illustrated in Figure 3A.

Figure 7C is a bottom plan view of a cap portion of the manifold assembly illustrated in Figure 3A.

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Figure 8 is a partial top plan view including tubing connecting pressure sensors to monitoring ports on the manifold assembly illustrated in Figure 3A.

Figure 9A is a view, taken along a portion of line 2-2 in Figure 1A, showing in cross-section an enclosure for the pneumatic valve controller illustrated in Figure 1B, and showing partially in cross-section and partially in elevation a valve position indicator of the pneumatic valve controller. Figure 9A accurately depicts the scale and relative proportion of the features shown therein.

Figure 9B is a perspective view of the valve position indicator illustrated Figure 9A. Figure 1B accurately depicts the scale and relative proportion of the features shown therein.

Figure 10A is a plan view of electrical components of the valve controller illustrated in Figure 1B.

Figure 10B is a front view of electrical components illustrated in Figure 10A.

Figures 11A, 11B and 11C are schematic diagrams illustrating an electrical circuit of the valve controller illustrated in Figure 1B.

Figure 12A is a schematic diagram illustrating a first preferred embodiment of a piping system with a valve controller, as shown in Figure 1B, in an exemplary configuration for independently controlling two process valves. Valve actuators for both process valves are show in a zeroed position.

Figure 12B is a schematic diagram similar to Figure 12A except showing in a spanned position the valve actuators for both process valves.

Figure 13A is a schematic diagram illustrating a second preferred embodiment of a piping system with a valve controller, as shown in Figure 1B, in an exemplary configuration for controlling one process valve. The valve actuator for the process valve is shown in a zeroed position.

Figure 13B is a schematic diagram similar to Figure 13A except showing in a spanned position the valve actuator for the process valve.

Figure 13C is a schematic diagram similar to Figures 13A and 13B except showing in a partially stroke position the valve actuator for the process valve.

Figure 14A is a schematic diagram illustrating a third preferred embodiment of a piping system with a valve controller, as shown in Figure 1B, in an exemplary

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configuration for controlling one process valve. The valve actuator for the process valve is shown in a zeroed position.

Figure 14B is a schematic diagram similar to Figure 14A except showing in a spanned position the valve actuator for the process valve.

Figure 15 is a chart showing exemplary data describing the relationship between valve controller air supply pressure and valve position.

Figures 1A, 1B, 2, 3A, 4A-4E, 5A-5F, 6, 6A-6H, 7A-7C, 8, 9A and 9B accurately depict the scale and relative proportion of the features shown therein.

Detailed Description of the Preferred Embodiments

Figure 1A illustrates an exemplary embodiment of a piping system 1 including a process valve 3, an actuator 5 for the process valve 3, and a valve controller 10 with enclosures 12,14 for mechanical and electronic components. Referring additionally to Figure 1B, the enclosures define chambers 16 for all components to avoid exposure to operative conditions. Referring back to Figure 1A, releaseably securable enclosure covers 18a,18b, which may be independently removed, separately cover enclosures 12,14, respectively. The enclosure covers 18a,18b allow for maintenance of the valve controller 10 such that access to either the mechanical or electrical chamber only is required for service. Alternatively, a single cover could be used in place of separate enclosure covers 18a,18b.

As shown in Figure 1B, the valve controller 10 may have separate enclosures 12, 14 for mechanical and electronic components, one enclosure 12 may provide housing for mechanical components such as a pneumatic manifold assembly 20 and another enclosure 14 may provide space in the chamber 16 for electronic components such as circuit boards including a microprocessor and/or other circuits, as will be described further with respect to Figure 10A. The enclosures may have any shape and configuration as long as they define at least one chamber for all components to avoid exposure to operative conditions. For instance, the separate enclosures 12,14 may abut or be situated adjacent to one another, and form a particular shape. For example, the valve controller 10 may have a polygonal shape with each enclosure 12,14 forming a portion of the polygonal shape. According to a preferred embodiment, the valve controller 10 may have a bow-tie shape.

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The enclosures 12,14 for mechanical and electrical components may be separated by a third enclosure 22 for housing a valve position indicator 24. The third enclosure 22 may include an independently and releasably securable cover 22a. The third enclosure cover 22a may also have a bow tie configuration, the tapered sides of the third cover 22a allowing the valve position indicator 24 to be directly visible from a site range above the centerline of the position indicator 24. The third enclosure cover 22a, however, may have any shape or configuration provided it allows the valve position indicator to be viewed from a position above the valve controller. Further, the three enclosures 12,14,22, may have any configuration that provides direct visibility of the position indicator 24. For example, the valve controller 10 may have a suitable shape such as, for example, square, rectangular, oval-like or circular configuration such that the shape allows the valve position indicator 24 to be directly visible to an observer from a site range both above and below the center line of the position indicator 24. Similarly, any number of members may be used to cover the enclosures provided the members cooperate with the enclosures to define at least one chamber for all components to avoid exposure to operative conditions. Thus, in one example, the cover may be a unitary member. In another example, the cover may have two members.

The valve controller enclosures 12,14,22 and covers 18a,18b,22a may be formed from any suitable metal, alloy, composite, or plastic material. For example, one or more of the independently removable enclosure covers 18a,18b,22a may be formed from a transparent plastic material. Similarly, as shown in Figure 1A, one or more of the enclosures 12,14 and enclosure covers 18a,18b may be fashioned from opaque plastic materials. The valve controller enclosures 12,14,22 and covers 18a,18b,22a may further be made from corrosion resistant materials such as polypropylene. The enclosure and covers may also be adapted for approved use in hazardous atmospheres.

As shown in Figure 2, the valve controller 10 of Figure 1B has a height profile h that is measured from between parallel planes 17a,17b. According to a preferred embodiment, the top and bottom surfaces of the enclosure of valve controller 10 coincide with parallel planes 17a,17b. Essentially, the process valve 3, including the actuator 5, has a maximum exterior package dimension, i.e., the distance between the distal most points of the combination process valve 3 and actuator 5, that is greater than the height profile h. Preferably, height profile h of the enclosure of valve controller 10 is about

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three inches. In the preferred embodiment illustrated in Figure 2, height profile h is about 2.725 inches.

Referring back to Figures 1A and 1B, the valve position indicator 24 may also have a beacon or position indicator 26 or visual signal for identifying the position or operating state of one or more process valves that are being controlled by the controller. For example, the beacon 26 may provide a distinct visual signal for a process valve operating under normal conditions in an open position, closed position, or an intermediate position between the open and span position. As described further below with respect to Figure 9B, the valve position indicator 24 may also have a distinct visual beacon signal 26 for identifying the state of at least one, and preferably two, independent process valves that are being controlled by the controller. The valve position indicator 24 may be a rotary or linear, and may be located between separate chambers 12,14 for mechanical and electronic components. The size of the beacon 26 may be selected to allow for viewing from a remote location. The valve position indicator 24 may be disposed adjacent operative components so that beacon 26 can be viewed from a site range both above and below the centerline of the position indicator. The beacon 26 may operate, for example, via a non-contact position sensor (not shown) such that the valve controller 10 need not be integrally connected to a process valve actuator. Alternatively, the valve position indicator 24 may have a shaft (not shown) that is operatively coupled directly to the actuator for the process valve 3, so that movement of the actuator directly rotates the beacon 26 to indicate the position of the process valve 3.

Referring to Figure 3A, valve controller 10 has one manifold inlet operating media supply port 28, one manifold outlet operating media exhaust port 30, and four operating media transmission ports 32 for process valve actuator operation. The ports 28,30,32 are adapted to connect to one-half inch NPT or M20 conduit (not shown) with suitable conduit attachment members 34 on a port manifold 36 of the valve controller 10. The port manifold 36 is located at the base of manifold assembly 20. Manifold assembly 20 includes port manifold 36 (lower manifold portion), manifold 38 (upper manifold portion), spool valve assembly 40, manifold cap 42, and coil bank assembly 44. As shown in Figure 1B, manifold assembly 20 may also include one or more pressure sensors (two exemplary pressure sensors 346 and 356 are indicated in Figure 1B).

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Referring to Figures 3A and 3B, manifold assembly 20 has one inlet air supply that is directed to two spool valves 48,50, via separate supply cavities 52,54. The inlet air supply is also directed to four separate poppet cavities 56,58,60,62, which set the configuration of the spool valves 48,50. The supply of inlet air to the poppet cavities 56,58,60,62 is regulated by four actuators, for example, electromagnetic solenoid valves or micro-poppets 64,66,68,70. For example, valves 64,66,68,70 can be part number A00SC231P solenoid valves manufactured by Parker Hannifin Corporation® (Richland, Michigan). The single exhaust outlet 30 is diverted into eight exhaust cavities 72,74,76,78,80,82,84,86. Exhaust cavities 80,82,84,86 are not depicted in Figure 3B, but are shown in Figures 5A-5F as described further below. Exhaust cavities 72,74,76,78 of manifold 38 join four cavities 88,90,92,94 of port manifold 36.

Referring additionally to Figures 4A-4E, port manifold 36 accepts an external operating media, e.g., air, supply to inlet air supply port 28, which transports the inlet air supply to the manifold 38 via a pair of supply cavities 52,54. Inlet air supply cavity 28 also has a secondary external port 96 for possible emergency pressure relief. Port manifold 36 collects manifold 38 exhaust for discharge to the ambient atmosphere at exhaust port 30. Port manifold 36 separately collects and transports spool valve 48,50 exhaust from four cavities 72,74,76,78 in the manifold 38 to external ports 88,90,92,94, which can be used to operate up to two pneumatic valve actuators. Port manifold 36 can also serve as a structural base for seating the manifold 38, spool valve assemblies 48,50 and/or the mechanical enclosure 12. Port manifold 36 has a groove 36a for receiving a gasket 98, four fastener holes 100 for securing the port manifold 36 to the manifold 38, and four fastener holes 102 for securing the manifold assembly 36,38 to the medial portion of the enclosure 12.

Referring to Figures 5A-5F, manifold 38 contains and transports compressed air between the port manifold 36, spool valves 48,50 and coil bank assembly 44 in conjunction with the manifold cap 42. Manifold 38 preferably includes a monolithic member 104. As it is used herein, the term "monolithic" refers to a single, uniform whole member, preferably formed of a homogeneous material. The monolithic member 104 has at least one outer surface 106. As shown in Figures 5A-5E, the manifold 38 preferably includes six outer surfaces or sides 108,110,112,114,116,118 (e.g., "left-side", "top", " right-side", "front", "bottom", and "rear" surfaces). The six outer surfaces

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108,110,112,114,116,118 form a rectangular block having a length, width and height, such that a distance measured between the front and rear surfaces 114,118 defines the length of the block, a distance measured between the top and bottom surfaces 110,116, defines the height of the block, and a distance measured between the right-side and left-side surfaces 108,112 defines the width of the block. Preferably, the length of the manifold 38 is greater than the width, and the width is greater than the height. As described further below the outer surfaces 108,110,112,114,116,118 of the manifold 38 have openings that are in fluid communication with a plurality of internal cavities. The manifold has openings on five sides 108,110,112,114,116, such that the rear side 118 of the block does not have a cavity opening. The manifold 38 can be made of any suitable material, such as for example, metal, alloy, composite, and plastic materials. At ambient temperatures, the block material and internal cavity configuration should be capable of containing and transporting operating media, for example, non-lubricated air filtered to about 20 microns (or some other fluid), at temperatures between about –4 degrees Fahrenheit to 180 degrees Fahrenheit and at pressures of between about 45 to 120 pounds per square inch gauge.

As shown in Figure 5A, left side surface 108 includes three fastener holes 150, one inlet air supply cavity 52 and one inlet air supply transfer cavity 132f, two poppet cavity transfer cavities 124,138, two spool valve exhaust cavities 72,74, and two poppet cavity exhaust cavities 80,82.

As shown in Figure 5B, top surface 110 includes four fastener holes 120, four spool valve exhaust pressure monitoring port cavities 72,74,76,78, four poppet cavity exhaust cavities 80,82,84,86, one manifold exhaust cavity 122, four poppet cavity transfer cavities 124,126,128,130, and two inlet air supply transfer cavities 132,134.

As shown in Figure 5C, right side surface 112 includes three fastener holes 150, one inlet air supply cavity 54 and one inlet air supply transfer cavity 132e, two poppet cavity transfer cavities 140,128, two spool valve exhaust cavities 76,78, and two poppet cavity exhaust cavities 84,86.

As shown in Figure 5D, front surface 114 includes four fastener holes 136, four inlet air supply transfer cavities 132a,132b,132c,132d, four poppet cavity transfer cavities 138,126,130,140, and four solenoid (or micro-poppet) exhaust cavities

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142,144,146,148. The four solenoid exhaust cavities discharge to poppet cavity exhaust cavities 82,86.

As shown in Figure 5E, bottom surface 116 includes four fastener holes 120, two manifold inlet air supply cavities 52,54, four spool valve exhaust cavities 72,74,76,78, one manifold exhaust cavity 122, and one gasket seat cavity 152.

As shown in Figure 5F, the rear surface 118 does not include any openings.

Figures 6A-6H illustrate the internal pathways, connections and spatial relationships between the internal cavities identified in Figures 4A-4E and 5A-5F. These pathways, connections and spatial relationships between the internal cavities provide means for directing operating media flow between the operating media supply passage 28, the operating media exhaust passage 30, and the media transmission passages 32.

Referring to Figure 6H, spool valve 48 and spool valve 50 direct airflow though the manifold 38 to operate one or more pneumatic valve actuators. Each spool valve 48,50 includes a spool valve assembly 40. Each spool valve 48,50, which may be constructed according to known techniques, includes a valve body 154 and a spool assembly 156, and two valve caps 158. For example, spool valves 48,50 can be part number 92273U-1 spool assemblies manufactured by Numatics® (Highland, Michigan).

As shown in Figure 6H, valve body 154 encloses spool assembly 156 and includes and two poppet cavities 160, 162 that operate to contain operating media from poppet transport cavities (e.g., 128,140) in manifold 38, and to direct manifold inlet air supply to an appropriate exhaust cavity (e.g., 78,76). Valve body 154 includes outer surfaces (e.g., six according to the preferred embodiment), some or all of which may have openings in fluid communication with a plurality of internal cavities.

According to a preferred embodiment, the manifold assembly 20 includes a first operating media distribution valve, e.g., spool valve 48, in fluid communication with the operating media supply cavity 28, first and second ones of the operating media transmission cavities 32, and the operating media exhaust cavity 30. The first operating media distribution valve 48 includes a first configuration that A) connects the operating media supply cavity 28 with the first one of operating media transmission cavities 32, and B) connects the second one of the operating media transmission cavities 32 with the operating media exhaust cavity 30. The first operating media distribution valve 48 also includes a second configuration that C) connects the operating media supply cavity 28

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with the second one of the operating media transmission cavities 32, and D) connects the first one of the operating media transmission cavities 32 with the operating media exhaust cavity 30. The manifold assembly 20 also includes a second operating media distribution valve, e.g., spool valve 50, in fluid communication with the operating media supply cavity 28, first and second ones of the operating media transmission cavities 32, and the operating media exhaust cavity 30. The second operating media distribution valve 50 includes a third configuration that A) connects the operating media supply cavity 28 with the third one of operating media transmission cavities 32, and B) connects the fourth one of the operating media transmission cavities 32 with the operating media exhaust cavity 30. The second operating media distribution valve 50 also includes a fourth configuration that C) connects the operating media supply cavity with the fourth one of the operating media transmission cavities 40, and D) connects the third one of the operating media transmission cavities 32 with the operating media exhaust cavity 30. The first, second, third and fourth configurations provide means for directing operating media flow between the operating media supply passage 28, the operating media exhaust passage 30, and the media transmission passages 32.

The valve body 154 can be made of any suitable material, such as for example, metal, alloy, composite, and plastic materials. At ambient temperatures, the valve material and internal cavity configuration should be capable of containing and transporting operating media, for example, non lubricated air filtered to about 20 microns (or some other fluid), at a temperature between about –4 degrees Fahrenheit to 180 degrees Fahrenheit and at pressures of between about 45 to 120 pounds per square inch gauge. The valve material and internal cavity configuration should also be capable of containing and transporting operating media, preferably air, at a flow rate of about 5 standard cubic feet per minute at about 40 pounds per square inch to about 100 standard cubic feet per minute at about 120 pounds per square inch.

Referring additionally to Figure 3A, the valve body 154 includes at least one fastener 164 (e.g., three are shown per valve body 154) securing the valve body 154 to the manifold 38. Each of the valve caps 158 is secured to the valve body 154 by at least one fastener 166 (e.g., two are shown per valve cap 158). Individual valve caps 158 are configured and dimensioned to be releasably secured to opposite surfaces of valve body

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154 so as to retain spool assembly 156 within valve body 154 and to contain operating media in spool valve poppet cavities 160,162.

Spool assembly 156 selectively directs spool valve inlet air supply from cavity 180 to one of two spool valve exhaust cavities 182,184. The spool assembly 156, in a known manner, has a length measured from end to end that is less than the length of a bore of the valve body 154. Spool assembly 156 includes at least one internal bore (not shown) and a plurality of apertures 214 extending from the outer surface of spool assembly 156 to the bore. Apertures 214 are preferably of equal size and are preferably spaced in a uniform pattern uniformly about at least one designated portion of spool assembly 156. According to a preferred embodiment, a pattern including five rings of radially aligned apertures 214 is alternately disposed with six radial grooves 215 spaced equidistant along spool assembly 156. Each radial groove 215 is configured and dimensioned to receive a gasket material such as an o-ring (not shown). The inner surface of the bore of valve body 154 is generally smooth and has a diameter that is sized and configured to telescopically receive spool assembly 156.

Referring to Figures 7A-7C, as well as to Figures 6A-6G, manifold cap 42 is releasably securable to manifold 38 to contain and transport operating media, such as compressed air, between four poppet cavity exhaust cavities 80,82,84,86 and the manifold exhaust cavity 122, two pairs of poppet cavity transfer cavities 124,126,128,130, and one pair of inlet air supply transfer cavities 132,134.

Manifold cap 42 includes a generally planar member having top and bottom surfaces 288,290 and four bores or fastener holes 292 extending from the top surface 288 to the bottom surface 290. The bores 292 are generally located around the periphery of the top surface 288. The bottom surface 290 is generally flat and smooth. The bottom surface 290 has four recesses 294 extending from the bottom surface toward the top surface. One recess 294a is generally U-shaped and three recesses 294b-294d are generally linear in shape. Each recess 294 has a bottom surface generally parallel in orientation to the bottom surface 290 of the manifold cap 42, and one or more sidewalls extending from the bottom surface of each recess 294 to the bottom surface 290 of manifold cap 42. The sidewalls are generally perpendicular to the bottom surfaces of both recess 294 and manifold cap 42. The bottom surface of one or more of the recesses 294 may be located above a portion of the top surface 286 of the manifold cap 42, such

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that one or more of the recesses 294 may form a structure in relief relative to a base area of top surface 288 of manifold cap 42. Each recess 294 defines an isolated portion in the manifold cap 42. When the manifold cap 42 is secured to the manifold 38, each of the recesses 294a-d form a separate chamber, and each chamber communicates with two or more cavity openings on top surface 110 of manifold 38. The recesses, however, may have any shape provided each recess defines a separate chamber and each chamber communicates with the proper cavity openings as described below. A manifold cap gasket may be placed between the manifold cap 42 and the manifold 38 to maintain chamber isolation.

Figures 6A-6G show four "air ports" 396a-d formed by recesses 294 in the manifold cap 42 when the manifold cap 42 is secured to the manifold 38. U-shaped "air port" 396a communicates with four poppet cavity exhaust cavities 80,82,84,86, and one manifold exhaust cavity 122. A first linear "air port" 396b communicates with one pair of poppet cavity transfer cavities 124,126. A second linear "air port" 396c communicates with a second pair of poppet cavity transfer cavities 128,130. And, a third linear "air port" 396d communicates with a pair of inlet air supply transfer cavities 132,134. As shown in Figure 3A, the manifold cap 42 can also include external sample ports 302 that are in fluid communication with underlying cavities. The sample ports 302 can also have attachment sites for plastic tubing, as shown in Figures 1B and 2.

Fastener holes 292 in the manifold cap 42 allow at least one fastener 102 (*see* Figure 6F) to secure the manifold cover 42 to manifold 38, and to secure the manifold 38 to the base of the port manifold 36. The manifold cap 42, manifold 38, and port manifold 36, therefore, may be fastened together using a set of common fasteners. For instance, the fasteners may be screws. Any number of fasteners or type of mechanical fastening system may be used to sure the manifold cap 42, manifold 38, and port manifold 36 together provided the assembly is securely fastened and capable of operation.

Referring to Figure 3A, coil bank assembly 44 selectively diverts inlet air and exhaust from the poppet cavities 56,58,60,62 of the two spool valves 48 and 50 to control the position of the respective process valve shafts. The four micro-poppet solenoids 64,66,68,70 are individually and independently associated with a

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corresponding poppet cavity in spool valves 48 and 50. Solenoid valves 64,66,68,70 are operatively associated with poppet cavities 144,142,146,148, respectively.

Coil bank assembly 44 includes four micro-poppet solenoid valves 64,66,68,70, a coil bank gasket 310, a coil plate 312, and coil bank gasket 314. The front of the each micro-poppet solenoid valve 64,66,68,70 has a receptacle 318 for receiving an electrical signal, and two holes 320 for receiving fastening elements. The back surface of each micro-poppet solenoid valve 64,66,68,70 has three openings 324 for receiving or conveying airflow with the manifold 38.

Coil bank gasket 310 includes a thin flexible sheet gasket with openings 312 for transmitting airflow and fastening elements. One side of the coil bank gasket 310 abuts the rear side of the coil bank assembly 44, and a second side of the coil bank gasket 310 abuts coil plate 312. Coil plate 312 includes a planar member having first and second sides and a side surface between the first and second sides. The first side abuts the coil bank gasket 310 and the second side abuts coil bank gasket 314. Coil plate 312 has sixteen bores extending from the first side to the second side. Twelve of the bores are for transmitting airflow, and four are for receiving fastening elements. The four fastener bores are countersunk on the first side. Coil plate 312 also has eight bores extending into the coil plate 312 from the first side. Coil bank gasket 314 includes a planar member or thin flexible sheet with openings for transmitting airflow and fastening elements. One side of coil bank gasket 314 abuts the rear side of coil plate 312. A second side of coil bank gasket 314 abuts manifold 38.

Referring to Figure 8, pressure sensors can be used to measure manifold inlet air pressure, manifold exhaust air pressure, and the differential pressure across the exhaust cavities of each spool valve. Inlet air pressure and manifold exhaust air pressure sensors 344,346 are pressure transducers with one port for receiving airflow. Each pressure transducer 344,346 has six leads 350 for receiving electrical current and transmitting electrical signals to the electronic controller. The inlet air pressure sensor and manifold air pressure sensor are mounted to a bracket 352 adjacent the coil bank assembly 44 within the enclosure. Differential pressure sensors 354,356 are pressure transducers with two ports 358,360 for receiving airflow. The pressure transducers 354,356 have six leads 362 for receiving electrical current and transmitting electrical signals to the electronic controller. The differential pressure sensors 354,356 are each individually

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mounted adjacent their respective spool valve 48,50. Plastic tubing 366 is used to connect each pressure transducer to the designated sample ports.

Referring also to Figure 8, one-half of a so-called "bow-tie" shape is illustrated with respect to enclosure 12. As it is used herein, the term "bow-tie" refers to a shape of an elongated body that extends along a longitudinal axis between end portions, and has a middle portion that is relatively constricted with respect the end portions. According to a preferred embodiment, enclosure 12, for example, includes a wall that extends around the manifold assembly 20. The wall includes a first segment 12a and a second segment 12b that, at least in part, mutually define a portion of the chamber 16 in which the manifold assembly 20 is disposed. As shown in Figure 8, the first and second segments 12a,12b extend transversely with respect to a longitudinal axis L, and have respective lengths L1,L2 One-half of the "bow tie" shape is achieved when the first segment 12a, which is closer to enclosure 14 than second segment 12b, is also shorter than segment 12b (i.e., L1 is less than L2).

Although segments 12a,12b are shown extending transversely with respect to longitudinal axis L, they may alternatively extend obliquely and/or may not extend along a line, e.g., they may be curved. In any event, one –half of the bow-tie shape is still formed as long as a projection along the longitudinal axis of the segment 12b has a transverse length L2 with respect to the longitudinal axis L that is greater than the transverse length L1 of a similar projection along the longitudinal axis of the segment 12a, which is closer than segment 12b to the middle of valve controller 10.

Referring to Figures 1A, 9A and 9B, the valve position indicator 24 includes a cage 374 and a beacon (position indicator) 376. The cage 374 is preferably formed integrally with either or both of the enclosures 12,14, but may be separately formed and subsequently secured to the enclosure for the mechanical components 12 and/or the enclosure for the electronic components 14. Cage 374 defines a volume 378 in which the beacon 376 is received and includes a projection 386 for slidably receiving beacon (position indicator) 376. As shown in Figure 9B, an exemplary beacon (position indicator) 376 has markings 388 that show the position of two valves. The cage 374 and exemplary beacon (position indicator) 376 can be mounted on to a rotary actuator or remotely wired to a position sensor on the actuator. For instance, the position sensor can be a non-contact Hall effect sensor as described in Avid position monitors technical

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publications "tech-251/DW011930", "tech-260/D.W.O.11030", and "tech-300/D.W.O.13882", the contents of each of these publication are herein incorporated by reference herein their entirety, and were attached as Appendix A to U.S. Provisional Application No. 60/559,002, filed 5 April 2004, which is also incorporated by reference herein in its entirety.

Referring to Figures 1A, 9A and 9B, the valve controller 10 may also have a separate enclosure 14 and enclosure cover 18b for electronic components so that an electronic controller may be disposed on or within the electronic enclosure 14 in manner which may provide for access to the electronic components independently from the mechanical assembly. As is the case for the enclosure cover 18a for mechanical components in the enclosure 12, the electronic enclosure cover 18b may be attached or releasably securable to the enclosure 14 by any suitable means. For instance, the covers 18a,18b may be fastened to the enclosures 12,14 with one or more fasteners, such as a screw.

Referring to Figures 10A and 10B, electronic components 390 may be arranged or disposed in any suitable fashion within the enclosure 14. For example, circuit boards 392 and other electronic components in the enclosure may be stacked vertically and connected by cable. As shown in Figure 10B, an exemplary configuration of electronic components has four circuit boards 392 stacked over top each other and spaced apart by varying distances as may be appropriate for the components of each circuit board. Some or all of the components on lower boards 392 located vertically below one or more other boards may still be visible from a plan view. For example, solenoid valve output connections may be located on the third circuit board as enumerated from the top board, yet may still be visible and accessible from the top of the electronic enclosure. Such an arrangement may facilitate installation, maintenance, testing or ascertaining faulty electronic components or circuits.

Referring to Figures 11A-11C, the electronic components of the valve controller may include a universal mother board having: a 2 Line by 16 Character liquid-crystal display (LCD) 400; Programming buttons (e.g., Select, Next↑, Next↓) 402; Analog Inputs (e.g., one position sensor for measuring valve position from 0.0 to 100.0% (e.g., a Hall Effect Position Sensor), and five Pressure Sensors for measuring air pressure of the supply and manifold) 404; Analog Outputs (e.g., one primary 0-5 milliamps output for

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driving a transducer, and one secondary 0-5 milliamps output for driving a transducer) 406; Discrete Outputs (e.g., four open collectors for driving solenoids, and one open collector for driving an light emitting diode) 408; Discrete Inputs (e.g., two dry contact sensing inputs for "Open & Close Limit Switches", one dry contact sensing input for "Partial Stroke Switch", and one voltage input for "Sensing SIS Power") 410.

The valve controller electronics may further include: a communications port (e.g., one RS232 for local diagnostics), 412; and a microprocessor 414 with associated peripherals such as, for example, various memory, controllers and converters. For instance, microprocessor CPU 414 can be a Motorola® MC68CK331CPV16 32 bit Microprocessor; Program Memory 416 can include AMD® Am29LV400BT-55REI, 256K x 16bit Flash memory; Data Memory 418 can include a CYPRESS® CY62146VLL-70ZI, 256K x 16 bit Static RAM; and Non-Volatile Memory 420 can include an ATMEL® AT25256W-10SI-2.7, 32K x 8 bit EEPROM. The valve controller electronics may also include: an Analog to Digital Converter 422 (e.g., Maxim® MAX1295BEEI, 6 Channel 12 bit); a Digital to Analog Converter 424 (e.g., Analog Devices® AD5342BRU, 2 Channel 12 bit); and Analog Instrument Amplifiers 426 (e.g., Texas Instruments® TLC27L4BID, Op-Amps). The valve controller electronics may further include: Discrete Output drivers 428 (e.g., Fairchild® NDS9945, 60V FET's); and Inter-processor communication circuitry 430 (e.g., TI® CD74HC40105M96, 16 Word FIFO). The valve controller electronics has a power supply 432, and may further have a plug-in network card 434 (e.g., ASi®, DeviceNet®, Profibus®, Foundation Fieldbus®, Modbus®, and/or HART®) for additional communication and other capabilities.

The valve controller may include short-range radio links 436 for local interface with the electronic components to provide for a peer-to peer wireless area network. The wireless network may be used, for example, to configure, calibrate, or perform diagnostics on the valve controller electronic systems. As described in more detail below, the wireless network may also be used to monitor and implement knowledge based performance systems. One known technology that uses short-range radio links for local interface is Bluetooth® technology. The valve controller electronics may include a "Bluetooth" radio module so that the controller is Bluetooth-capable. When Bluetooth-capable devices 438 (e.g., Personal Digital Assistants (PDAs), laptop computers, hand

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phones) come within range of one another, an electronic conversation takes place to determine whether one needs to control the other. The user does not have to press a button or give a command -- the electronic conversation happens automatically. Once the conversation has occurred, the devices form a personal-area network or "piconet." Once the piconet is established, the members randomly hop frequencies in unison so they stay in touch with one another. The wireless system may further include one or more security measures which restricts access to the piconet.

In use, the electronic controller monitors electrical signals from the pressure sensors and valve position indicator to control the flow of an appropriate operating medium such as, for example, air through the manifold assembly. Specifically, each solenoid valve or micro poppet 64,66,68,70 opens and closes pathways to one spool valve poppet cavity 144,142,146,148, respectively. In one configuration, the solenoid valve or micro-poppet allows inlet air supply to the spool valve poppet cavity. In a second configuration, the solenoid valve or micro-poppet blocks inlet air supply to the spool valve poppet cavity, and opens an exhaust path to the atmosphere via the manifold. In this fashion, spool valve poppet cavities are energized or de-energized. Each spool valve 48,50 has a pair of opposing poppet cavities. For example, poppet cavity 142 and 144 can constitute the poppet cavities of spool valve 48, and poppet cavities 146 and 148 can constitute the poppet cavities of spool valve 50. When one spool valve cavity is energized, (i.e., 142) the opposing poppet cavity (i.e., 144) is de-energized. Energizing one poppet cavity while de-energizing another poppet cavity causes a pressure differential across the spool valve assembly, that pushes the spool shaft toward the de-energized cavity and allows segments on the shaft to selectively direct inlet air supply to the spool cavity of one of two exhaust cavities. Reversing the state of the poppet cavities moves the position of the shaft, and allows segments on the shaft to direct the inlet air supply to the second exhaust cavity. Exhaust from the spool valve drives the process valve actuator.

Figures 12A and 12B illustrate an exemplary manifold design for an operative arrangement that provides control for two independent valves. In particular, the schematic of Figures 12A and 12B describe two independent valve controls with one inlet air supply and one exhaust outlet. The single inlet air supply (I/A) is diverted into

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six separate supply cavities. The single exhaust outlet (E) is diverted into eight exhaust cavities. The inlet air supply cavities are as follows:

- Cavity I/A 1 is to spool cavity SA, 52 -- This feeds I/A to a primary pneumatic actuator, which energizes and de-energizes a critical valve and / or damper.
- Cavity I/A 2 is to spool cavity SB, 54 -- This feeds I/A to a secondary pneumatic actuator, which energizes and de-energizes a non-critical valve and / or damper.
- Cavity I/A 3 is to poppet cavity A1, 56 -- This feeds I/A to the poppet coil E1, 64 that energizes primary spool A, 48.
- Cavity I/A 4 is to poppet cavity A2, 53 -- This feeds I/A to the poppet coil A2, 66 which de-energizes primary spool A, 48. This cavity may not be required if the application uses a spring return primary spool.
- Cavity I/A 5 is to poppet cavity B1, 60 -- This feeds I/A to the poppet coil B1, 68 that energizes secondary spool B, 50.
- Cavity I/A 6 is to poppet cavity B2, 62 -- This feeds I/A to the poppet coil B2, 70 which de-energizes secondary spool B, 50. This cavity may not be required if the application uses a spring return secondary spool.

The EX exhaust cavities are as follows:

- Cavity EX 1 is to exhaust cavity EA1, 72 -- This allows exhaust to atmosphere of the energizing primary pneumatic actuator port on a de-energizing command of the primary valve.
- Cavity EX 2 is to exhaust cavity EA2, 74 -- This allows exhaust to atmosphere of the de-energizing primary pneumatic actuator port on an energizing command of the primary valve.
- Cavity EX 3 is to exhaust cavity EB1, 76 -- This allows exhaust to atmosphere of the energizing secondary pneumatic actuator port on a de-energizing command of the secondary valve.
- Cavity EX 4 is to exhaust cavity EB2, 78 -- This allows exhaust to atmosphere of the de-energizing secondary pneumatic actuator port on an energizing command of the secondary valve.

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- Cavity EX 5 is to exhaust cavity PEA1, 80 -- This allows exhaust to atmosphere of the energizing primary poppet coil port on a de-energizing command of the primary valve.
- Cavity EX 6 is to exhaust cavity PEA2, 82 -- This allows exhaust to atmosphere of the de-energizing primary poppet coil port on an energizing command of the primary valve.
- Cavity EX 7 is to exhaust cavity PEB1, 84 -- This allows exhaust to atmosphere of the energizing secondary poppet coil port on a de-energizing command of the secondary valve.
- Cavity EX 8 is to exhaust cavity PEB2, 86 -- This allows exhaust to atmosphere of the de-energizing secondary poppet coil port on an energizing command of the secondary valve.

Figures 13A-C illustrate an exemplary manifold design for an operative arrangement that provides control for a single process valve. In particular, the schematics of Figures 13A-C describe a single valve control by two dependent spool valves with one inlet air supply and one exhaust outlet. The single inlet air supply (I/A) is diverted into five (5) separate supply cavities. The single exhaust outlet (EX) is diverted into eight exhaust cavities. The I/A supply cavities are as follows:

- Cavity I/A 1 is to spool cavity SB, 54 -- This feeds I/A to the secondary spool B, 50, which when energized will supply I/A to the primary spool A, 48, authorizing control of the pneumatic actuator. This is intended for use in Emergency Shut Down and Partial Stroke Testing of a critical valve and / or damper.
- Cavity I/A 2 is to poppet cavity A1, 56 -- This feeds I/A to the poppet coil A1, 64 that energizes primary spool A, 48.
- Cavity I/A 3 is to poppet cavity A2, 58 -- This feeds I/A to the poppet coil A2, 66, which de-energizes primary spool A, 48. (This cavity may not be required if the application uses a spring return primary spool.)
- Cavity I/A 4 is to poppet cavity B1, 60 -- This feeds I/A to the poppet coil B1, 68 that energizes secondary spool B, 50.

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- Cavity I/A 5 is to poppet cavity B2, 62 -- This feeds I/A to the poppet coil B2, 70 which de-energizes secondary spool B, 50. (This cavity may not be required if the application uses a spring return secondary spool.)

The EX exhaust cavities are as follows:

- Cavity EX 1 is to exhaust cavity EA1, 72 -- This allows exhaust to atmosphere of the energizing pneumatic actuator port on a de-energizing command of the valve and / or damper under normal operating conditions.
- Cavity EX 2 is to exhaust cavity EA2, 74 -- This allows exhaust to atmosphere of the de-energizing pneumatic actuator port on an energizing command of the valve and / or damper under normal operating conditions.
- Cavity EX 3 is to exhaust cavity EB1, 76 -- This allows exhaust to atmosphere of the energizing port of the authorization spool B on a de-energizing command for Emergency Shut Down and / or Partial Stroke Test requirements.
- Cavity EX 4 is to exhaust cavity EB2, 78 -- This allows exhaust to atmosphere of the de-energizing of the authorization spool B on an energizing command for normal operating conditions.
- Cavity EX 5 is to exhaust cavity PEA1, 80 -- This allows exhaust to atmosphere of the energizing primary poppet coil port on a de-energizing command of the valve and / or damper under normal operating conditions.
- Cavity EX 6 is to exhaust cavity PEA2, 82 -- This allows exhaust to atmosphere of the de-energizing primary poppet coil port on an energizing command of the valve and/or damper under normal operating conditions.
- Cavity EX 7 is to exhaust cavity PEB1, 84 -- This allows exhaust to atmosphere of the energizing authorization poppet coil port on a de-energizing command for Emergency Shut Down and / or Partial Stroke Test requirements. A data sheet for "Foundation Fieldbus Partial Stroke ESD Valve Monitor, Model 7345-ESD," by Westlock Controls Corp., Saddle Brook, New Jersey, describes a known Emergency Shut Down valve monitor and discusses of partial stroke testing. The contents of this publication is herein incorporated by reference herein its entirety, and was attached as Appendix B to U.S. Provisional Application No. 60/559,002,

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filed 5 April 2004, which is also incorporated by reference herein in its entirety.

- Cavity EX 8 is to exhaust cavity PEB2, 86 -- This allows exhaust to atmosphere of the de-energizing authorization poppet coil port on an energizing command for normal operating conditions.

According to the preferred embodiment shown in Figures 13A-13C, a valve controller 10 with a single operating media supply port 28 allows for two operational control signals via . The two operation control signals can provide a first command signal and a second command signal to a single process valve 3. The first command signal could be a discrete command signal, e.g., to produce full and generally immediate operation by the process valve actuator 5, such as OPEN/CLOSE. The second command signal could be a modulating command signal, e.g., to produce a progressive and measured operation by the process valve actuator 5, such as to move between different partially open positions, e.g., 15%, 42%, 75%, etc.

Figures 14A and 14B illustrate another exemplary manifold design for an operative arrangement that provides control of a single process valve by two spool valves. In particular, the schematics of Figures 14A and 14B describe two dependent spool valves controlling one primary pneumatic actuator with one inlet air supply and one exhaust outlet. These operative arrangements may allow for increased airflow dynamics for the pneumatic actuator while utilizing a single inlet supply and single outlet exhaust. The single inlet air supply (I/A) is diverted into six (6) separate supply cavities. The single exhaust outlet (EX) is diverted into eight exhaust cavities. The I/A supply cavities are as follows:

- Cavity I/A 1 is to spool cavity SA, 52 -- This feeds I/A to a primary pneumatic actuator, which energizes and de-energizes a valve or damper.
- Cavity I/A 2 is to spool cavity SB, 54 -- This feeds I/A to a primary pneumatic actuator, which energizes and de-energizes a valve or damper.
- Cavity I/A 3 is to poppet cavity A1, 56 -- This feeds I/A to the poppet coil A1, 64 that energizes spool A, 48.

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- Cavity I/A 4 is to poppet cavity A2, 58 -- This feeds I/A to the poppet coil A2, 66 that de-energizes spool A, 48. This cavity may not be required if the application uses a spring return spool.
- Cavity I/A 5 is to poppet cavity B1, 60 -- This feeds I/A to the poppet coil B1, 68 that energizes spool B, 50.
- Cavity I/A 6 is to poppet cavity B2, 62 -- This feeds I/A to the poppet coil B2, 70 that de-energizes spool B, 50. This cavity may not be required if the application uses a spring return spool.

The EX exhaust cavities are as follows:

- Cavity EX 1 is to exhaust cavity EA1, 72 -- This allows exhaust to atmosphere of the energizing pneumatic actuator port on a de-energizing command of the valve.
- Cavity EX 2 is to exhaust cavity EA2, 74 -- This allows exhaust to atmosphere of the de-energizing pneumatic actuator port on an energizing command of the valve.
- Cavity EX 3 is to exhaust cavity EB1, 76 at the same time as the EA1, 72 -- This allows exhaust to atmosphere of the energizing pneumatic actuator port on a de-energizing command of the valve.
- Cavity EX 4 is to exhaust cavity EB2, 78 at the same time as the EA2, 74 -- This allows exhaust to atmosphere of the de-energizing pneumatic actuator port on an energizing command of the valve.
- Cavity EX 5 is to exhaust cavity PEA1, 80 this allows exhaust to atmosphere of the energizing poppet coil port on a de-energizing command of the valve.
- Cavity EX 6 is to exhaust cavity PEA2, 82 this allows exhaust to atmosphere of the de-energizing poppet coil port on an energizing command of the valve.
- Cavity EX 7 is to exhaust cavity PEB1, 84 at the same time as the PEA1, 80 this allows exhaust to atmosphere of the energizing poppet coil port on a de-energizing command of the valve.

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- Cavity EX 8 is to exhaust cavity PEB2, 86 at the same time as the PEA2, 82 this allows exhaust to atmosphere of the de-energizing poppet coil port on an energizing command of the valve.

The electronic and mechanical components of the valve controller according to the preferred embodiments may further provide for intelligent diagnostics for integrated actuator/valve packages. For instance, operational data from the valve controller may be collected and analyzed to signal maintenance information and/or prevent potentially dangerous process conditions. Environmental learning and diagnostics and fault monitoring may be referred to collectively as developing and implementing a knowledge based valve performance program. For example, a valve controller with integral pressure sensors may be used to profile pressures of a single supply port and a single exhaust port so that diagnostics and fault monitoring can be accomplished with a microprocessor. The diagnostics may comprise developing the following non-limiting and exemplary profiles:

- a "Factory Torque Profile" – this function may record the un-installed valve/actuator torque demand versus position; and
- a "Commissioned and/or Maintenance Torque Profile" – this function may record the installed valve actuator torque demand. It may be used, for example, for comparison to the Factory Torque Profile to determine whether any fouling of the disc or deformation of the seat to has occurred. In addition, during shutdown a "Maintenance Profile" may be obtained for comparison to an initial installed Torque profile and/or the factory torque profile. Moreover, a commission torque profile may also be developed during start-up operations (a start-up profile) that may be used as the reference profile for use by the continuous diagnostics. Initially, such comparisons would require the skill and knowledge of the commissioning and maintenance engineers. However, such comparisons may also be analyzed by an integrated actuator controller according to the preferred embodiments.

The fault monitoring may comprise the following non-limiting exemplary functions:

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- "Insufficient Line Pressure to Guarantee Correct Operation" – the purpose of this function may be to warn that air supply pressure may not be sufficient to guarantee either opening or closing of the valve;
- "Supply Pressure Failure" – the purpose of this function may be to raise an alarm if line pressure falls below the maximum average differential requirements or is zero;
- "Valve Shaft Bent" – the purpose of this function may be to detect if the shaft is bent (for example, this may be achieved by detecting a phase shift of the torque profile);
- "Valve Not Achieving Full Stroke" – the purpose of this function may be to evaluate the span of movement of the valve and issue a warning if pre-defined limits are exceeded;
- "Backlash Detection" – the purpose of this function may be to detect and identify dynamic loading on the valve and provide an opportunity to prevent premature valve/actuator failure (the torque/speed profile and the transients produced by conditions of dynamic loading may be used to detect the presence of backlash, which may be caused by a worn actuator, slack mountings, ill fitting of shaft to valve or other correctable features of the valve actuator system;
- "Torque Demand of Valve Approaching Actuator limit" – the purpose of this function may be to raise a warning or alarm if differential pressure reaches 90% of the line pressure at any time during cycle (a bypass time, however, may be included to inhibit or suppress the warning or alarm, immediately after control signal is received;
- "Valve Seating/ Break-Out Torque Monitoring" – the purpose of this function is to identify the torque required to seat and unseat the valve and then give an indication of seat wear, liner failure and/or other mechanical conditions that may require maintenance or immediate attention (values may be compared to acceptable limits for particular valve types and warnings issued under triggering conditions);
- "Torque Limit Exceeded" – the purpose of this function may be to prevent the torque on the valve stem from exceeding a pre-set limit

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that may be programmable and which may be set as a function of a published limit (an alarm may be set if appropriate);

- "Close on Torque" -- the purpose of this function may be to ensure that actuators would have sufficient torque to unseat the valve, remove any dependence on spring rate vs. air supply pressure to achieve a closing torque, and may relate to the use of a dual coil spring center of spool to limit torque output;
- "Shaft Broken" -- the purpose of this function may be to determine whether the valve shaft is broken or the valve actuator is not attached to the valve, each of these conditions may have a torque profile with a torque level lower than the historical demand;
- "Valve Exercise" -- the purpose of this function may be to exercise and monitor valves that remain in one position, such as the closed or open position, for extended periods;
- "Valve Packing Torque" -- the purpose of this function may be to extract valve packing hysteresis between the open and closed cycle for applications such as BFV applications with sufficient dynamic torques;
- "Line Filter and Silencers Conditions" -- the purpose of this function may be to identify and signal whether air supply or air exhaust is restricted by measuring and evaluating time constants of charging and discharging of actuator cylinder pressures;
- "Solenoid Spool Sticking" -- this function may be used to identify and signal whether the solenoid valve is sticking by measuring and evaluating the time from solenoid control signal to pressure response.

Safety integration levels may be used to define the goals and identify unacceptable levels of operational risk. The techniques and methods for identifying and quantifying safety integrity levels, calculating average probability of failure on demand, and failure and test strategies to reduce the overall failure rate are known from the related art. Thus, the electronic components of the valve controller according to the preferred embodiments may combine real time monitoring data with risk assessment models and safety algorithms identified in a logic solver either remotely or through the use of an on-

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board microprocessor to reduce the average probability of potentially dangerous failures of process valves and ancillary equipment and systems.

To implement such a diagnostic program, a data-sampling rate can be used to develop an accurate representation of all the valve failure trends of interest. For example, Figure 15 shows a graph with 200 samples representing a valve movement, which may detect many if not all valve failure trends. The hardware and software of the valve controller according to the preferred embodiments may be configured to handle 4000 samples to further ensure that valve failure trends of interest are captured by the diagnostic program.

Hardware requirements may be determined as follows. If 100 samples per second were collected and each sample consists of reading the analog value of the valve position, and 5 analog pressure readings and each analog value requires 2 bytes then approximately 100 Samples/Second X 6 Analog Values X 2 bytes/Analog Value or 1200 bytes/Second would be required. In addition, if 4000 bytes for one Sequence of Samples were collected, this may provide about 3.3 seconds worth of data for one Sequence of Samples. A slower moving valve may require more time than this to complete it's movement, so a sampling rate of 50 Samples/Second, 25 Samples/Second, or 12.5 Samples/Second may be used to give times of 6.3 seconds, 12.6 seconds or 25.2 seconds. Moreover, there may be a need to store the Initial Sequence of Samples (captured at installation) for the valve opening and for the valve closing. A number of recent Sequence of Samples for valve opening and for valve closing may also need to be stored. Thus, the Initial and most recent Sequence of Samples may be stored in Non-Volatile memory, which may require about 4 times 4000 or 16000 bytes of Non-Volatile memory. To achieve such a non-volatile memory storage, the EEPROM for non-volatile storage may be increased to a 32K x 8 EEPROM.

In addition, some Network Cards may have less than 1K of RAM so transferring all this data over to the Network Card may have to be done in fragmented messages (small pieces such as 6-8 bytes at a time), where each piece may be individually identified, for example, by a 2 byte fragment address. A similar technique may further be used to transfer this data over the network, as each network protocol also has a limit to the amount of data that can be sent in one message. Thus, for example, in the DeviceNet network card a typical message consists of a CAN Header of 19 bit, followed

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by, a Data Field of up to 64 bits (8 byte), followed by a CAN Trailer of 25 bits. There is a minimum Interframe Space time of 3 bits. This would be 19 + 64 + 25 + 3 or 111 bits for one fragment (six bytes) of the Sequence of Samples. At a rate of 125 kbps this would take 888 uSec. To send the entire 4000 byte Sequence of Samples would require 667 DeviceNet messages. If this were the only device on the network and it could continually broadcast these messages this could take 667 X 888 uSec or 0.592 seconds for the 4000 bytes. Because there are also messages to the device, not just from the device, and because the device would likely need to send status information, not just Sample data, this time may increase significantly and could be doubled. If there are 64 devices on a network and each were sending data this time could be 64 X 2 X 0.592 or 75.8 seconds. As this amount of time may be unacceptable in some applications, other steps may be added to the process to further reduce this time. For example, one may lower the number of samples taken in each Sequence of Samples, compress the data, and/or process some of the data locally, on the motherboard. For these reasons, the valve controller according to the preferred embodiments may be configured with hardware and software robust enough to allow for all three cases.

Wireless technology may be used in combination with a valve controller having the specific valve operative arrangements and knowledge based valve performance discussed above. For example, each of the features for protection with respect to the valve operative arrangements and knowledge based valve performance may be individually protected for use with a short-range wireless protocol, and a communication method via the Internet. Combining the knowledge based valve performance methods with remote communications via the Internet may provide various opportunities to protect new methods of maintenance of valves at a location remote from the location of a maintenance staff. For example, a method of maintaining the operative performance of two valves may be performed. The method includes, for example, evaluating the operative conditions of two valves with a single valve controller; communicating the operative conditions of the two valves to a remote location via an Internet communication link; and changing operative commands of the valve controller via an Internet communication link.

Systems that utilize features on the valve controller may be protected. For example, a system of piping including a first pipe, a second pipe proximate the first pipe,

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a valve disposed between the first pipe and the second pipe, a valve actuator that operates the valve, and a valve controller that operates the valve actuator, the valve controller including a housing having a single supply path that feeds two separate pilot paths, the two separate pilot paths having a common exhaust path may be protected by the valve controller. The operative performance of the system may likewise be protected. Further details of the system may be added to specify the various uses of the valve controller. For example, piping to the controller could be defined and protection of written materials specifying the valve controller and its use may also be protected on a system wide basis.

Based on the foregoing, valve controller 10 may include a manifold assembly 20 including a manifold with integral coils and spools. The manifold assembly may further include a manifold having a single supply path, two pilot paths, and single exhaust path. The manifold may be a monolithic member or a two-piece member. For example, a two-piece manifold may include a base and a cover. The cover can define paths within the base. Thus, the manifold assembly may use a cover to define pneumatic operative paths of the valve controller. Moreover, the valve controller may have a manifold assembly that uses the same fasteners to secure the cover to the base of a housing. The manifold may also include one or more sensors. The sensors may monitor airflow through the manifold and signal other mechanical or electronic components. The valve controller may have a housing with a single pneumatic supply path, two separate pilot paths, a single exhaust path, and an individual pressure sensor for each path. In one embodiment, two of the sensors may be differential pressure sensors. The valve controller may also have valve position indicator or beacon (position indicator) located between separate chambers for mechanical and electronic components. The size of the beacon (position indicator) being selected to allow for viewing from a remote location. The beacon (position indicator) can operate via a non-contact position sensor. Moreover, the valve controller may provide for different operative arrangements. The valve controller may have a single pneumatic supply port that allows for two operational control signals. The two operational control signals may provide a first command signal and a second command signal to a single valve. The first command signal may be a discrete command signal. The second command signal may be a modulating command signal. The valve controller may be integrated with an actuator, the valve controller having a single pneumatic supply port that allows for two operational control signals. The valve

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controller may be used to operate a valve with two different command signals from a single pneumatic supply port. The valve controller may be used in a method of operating an integrated actuator with two different command signals from a single pneumatic supply port. The valve controller may have a single pneumatic supply port that allows for two operational control signals. The two operation control signals may provide a discrete command signal to a first valve and a separate discrete command signal to a second valve. The valve controller may be integrated with an actuator, the valve controller having a single pneumatic supply port that allows for two separate and identical operational control signals. The valve controller may be configured to provide a method of controlling fail-safe operation of two valves with a single pneumatic supply port

While the present invention has been disclosed with reference to certain preferred embodiments, numerous modifications, alterations, and changes to the described embodiments are possible without departing from the sphere and scope of the present invention, as defined in the appended claims. Accordingly, it is intended that the present invention not be limited to the described embodiments, but that it have the full scope defined by the language of the following claims, and equivalents thereof.

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What is claimed is:

1. A valve control apparatus comprising:

an enclosure defining a first chamber and a second chamber, the first and second chambers being spaced from each other along a longitudinal axis;

an indicator proximate the first and second chambers, the indicator having a visual symbol that identifies an operational state of at least one valve;

an operating media distribution system disposed in the first chamber, the operating media distribution system including:

an operating media supply passage;

an operating media exhaust passage;

at least three operating media transmission passages; and

a plurality of valves in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least three operating media transmission passages;

an electronic control unit disposed in the second chamber, the electronic control unit operates at least one of the plurality of valves to control operating media flow in the operating media distribution system; and

a plurality of connection ports that communicate with the operating media supply passage, the operating media exhaust passage, and the at least three operating media transmission passages.

2. The apparatus of claim 1, further comprising:

at least one sensor disposed in the enclosure, the sensor evaluates the operating media distribution system and provides information to the electronic control unit about at least one operating condition in at least one of the passages.

3. A piping system comprising:

a first pipe;

a first process valve connected to the first pipe;

a first actuator operating the first process valve; and

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a device controlling the first actuator, the device including:

an enclosure defining a first chamber and a second chamber, the first and second chambers being spaced from each other along a longitudinal axis;

an indicator proximate the first and second chambers, the indicator having a visual symbol that identifies an operational state of at least one valve;

an operating media distribution system disposed in the first chamber, the operating media distribution system including:

an operating media supply passage;

an operating media exhaust passage;

at least three operating media transmission passages; and

a plurality of valves in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least three operating media transmission passages; and

an electronic control unit disposed in the second chamber, the electronic control unit operates at least one of the plurality of valves to control operating media flow in the operating media distribution system.

4. A valve control apparatus comprising:

an enclosure;

an operating media distribution system disposed in the enclosure, the operating media distribution system including:

an operating media supply passage;

an operating media exhaust passage;

at least two operating media transmission passages; and

a valve in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least two operating media transmission passages;

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an electronic control unit disposed in the enclosure, the electronic control unit operates the valve to control operating media flow in the operating media distribution system;

at least one sensor disposed in the enclosure, the sensor evaluates the operating media distribution system and provides information to the electronic control unit about at least one operating condition in at least one of the passages; and

a plurality of connection ports that communicate with the operating media supply passage, the operating media exhaust passage, and the at least two operating media transmission passages.

5. The apparatus of claim 4, wherein the enclosure comprises first and second chambers, and the first chamber is spaced along a longitudinal axis from the second chamber.

6. The apparatus of claim 5, further comprising:

an indicator proximate the first and second chambers, the indicator having a visual symbol that identifies an operational state of at least one valve.

7. A piping system comprising:

a first pipe;

a first process valve connected to the first pipe;

a first actuator operating the first process valve; and

a device controlling the first actuator, the device including:

an enclosure;

an operating media distribution system disposed in the enclosure, the operating media distribution system including:

an operating media supply passage;

an operating media exhaust passage;

at least two operating media transmission passages; and

a valve in fluid communication with the operating media supply passage, the operating media exhaust

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passage, and the at least two operating media transmission passages;

an electronic control unit disposed in the enclosure, the electronic control unit operates the valve to control operating media flow in the operating media distribution system; and

at least one sensor disposed in the enclosure, the sensor evaluates the operating media distribution system and provides information to the electronic control unit about at least one operating condition in at least one of the passages.

8. A valve control apparatus for at least one process valve having a maximum exterior package dimension, the apparatus comprising:

an enclosure disposed entirely between first and second parallel planes, the first and second parallel planes being spaced apart a distance less than or equal to the exterior package dimension;

an indicator proximate the enclosure, the indicator includes a visual symbol that identifies an operational state of the at least one process valve, and the visual symbol is visible from above the first plane and from below the second plane;

an operating media distribution system disposed in the enclosure;

an electronic control unit disposed in the enclosure;

at least one sensor disposed in the enclosure, the at least one sensor evaluates the operating media distribution system and provides the electronic control unit information about at least one operating condition in the operating media distribution system; and

a plurality of connection ports that communicate with the operating media distribution system.

9. The apparatus of claim 8, wherein the distance between the first and second parallel planes is less than or equal to three inches.

10. The apparatus of claim 8, wherein the enclosure comprises first and second chambers, and the first chamber is spaced along a longitudinal axis from the second chamber.

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11. The apparatus of claim 8, wherein the operating media distribution system comprises:

an operating media supply passage;

an operating media exhaust passage;

at least two operating media transmission passages; and

a valve in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least two operating media transmission passages.

12. The apparatus of claim 8, wherein the electronic control unit controls media flow in the operating media distribution system to operate the at least one process valve.

13. An apparatus for distributing an operating media, the apparatus comprising:

a manifold defining:

an operating media supply passage;

an operating media exhaust passage;

a first operating media transmission passage;

a second operating media transmission passage;

a third operating media transmission passage; and

a fourth operating media transmission passage;

means for directing the operating media from the operating media supply passage to the first and third operating media transmission passages, and

means for directing the operating media to the operating media exhaust passage from the second and fourth operating media transmission passages.

14. The apparatus of claim 13, further comprising:

means for directing the operating media from the operating media supply to the second and fourth operating media transmission passages; and

means for directing the operating media to the operating media exhaust passage from the first and third operating media transmission passages.

15. The apparatus of claim 14, further comprising:

an electronic control unit;

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means for evaluating operating media pressure in each of the passages and for providing information to the electronic control unit about the operating media pressure in each of the passages.

16. The apparatus of claim 14, further comprising:

means for evaluating valve position and for providing valve position data to the control unit.

17. The apparatus of claim 16, further comprising:

means for monitoring valve performance and for developing at least one diagnostic performance attribute profile.

18. The apparatus of claim 17, wherein the at least one diagnostic performance attribute profile is selected from the group consisting essentially of a Commissioned Torque Profile and a Maintenance Torque Profile.

19. The apparatus of claim 17, further comprising:

means for fault monitoring valve performance by comparing the at least one diagnostic performance attribute profile with stored valve data.

20. The apparatus of claim 19, further comprising,

means for calculating an average probability of valve failure; and

means for predicting valve failure by comparing the average probability of valve failure with stored valve data.

21. A piping system comprising:

a first pipe;

a first process valve proximate the first pipe;

a first actuator operating the first process valve; and

an operating media distribution system controlling the first actuator, the operating media distribution system includes a manifold defining:

an operating media supply passage introducing operating media into the operating media distribution system from outside the housing;

an operating media exhaust passage discharging operating media from the operating media distribution system to outside the housing, and

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at least four operating media transmission passages in fluid communication with the operating media supply and exhaust passages, and a minimum of two of the at least four operating media transmission passages are in fluid communication with the first actuator.

22. The system of claim 21, wherein a minimum of two of the four operating media transmission passages are in fluid communication with a second actuator.

23. The system of claim 22, further comprising:

a second process valve being operated by the second actuator.

24. The system of claim 23, further comprising:

a second pipe proximate the second process valve.

25. The system of claim 21, wherein the operating media distribution system includes a plurality of valves in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least four operating media transmission passages.

26. The system of claim 25, further comprising:

an electronic control unit operating the plurality of valves to control operating media flow in the operating media distribution system;

at least one sensor evaluating the operating media distribution system and providing information to the electronic control unit about at least one operating condition in at least one of the passages; and

a plurality of connection ports that communicate with the operating media supply passage, the operating media exhaust passage, and the at least four operating media transmission passages.

27. The system of claim 21, wherein the manifold is disposed entirely between first and second parallel planes, the first and second parallel planes being spaced apart a distance less than or equal to three inches.

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28. An apparatus for distributing an operating media, the apparatus comprising:

an enclosure that includes upper and lower surfaces respectively defining first and second parallel planes, the enclosure is located entirely within a distance between the first and second planes;

an indicator proximate the enclosure, the indicator includes a visual symbol that identifies an operational state of the at least one process valve, and the visual symbol is visible from above the first plane and from below the second plane;

an operating media distribution system disposed in the enclosure; and

a plurality of connection ports that communicate with the operating media distribution system.

29. The apparatus of claim 28, wherein the distance between the first and second planes is less than or equal to three inches.

30. The apparatus of claim 28, wherein the enclosure comprises first and second chambers, and the first chamber is spaced along a longitudinal axis from the second chamber.

31. The apparatus of claim 28, wherein the operating media distribution system comprises:

an operating media supply passage;

an operating media exhaust passage;

at least two operating media transmission passages; and

a valve in fluid communication with the operating media supply passage, the operating media exhaust passage, and the at least two operating media transmission passages.

32. The apparatus of claim 31, further comprising:

an electronic control unit operating the valve to control operating media flow in the operating media distribution system;

at least one sensor evaluating the operating media distribution system and providing information to the electronic control unit about at least one operating condition in at least one of the passages.

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33. A method of distributing operating media, the method comprising:

introducing an operating media supply to a manifold;

allotting within the manifold the operating media supply to at least four operating media transmission passages;

transporting to a first actuator operating media from a first minimum of two of the at least four operating media transmission passages; and

collecting in an operating media exhaust passage exiting the manifold operating medium from a minimum of two of the at least four transmission passages.

34. The method of claim 33, further comprising:

transporting to a second actuator operating media from a second minimum of two of the at least four operating media transmission passages.

35. The method of claim 33, wherein the introducing comprises connecting the operating media supply to an operating media supply passage of the manifold.

36. The method of claim 35, wherein the allotting comprises connecting the operating media supply passage to at least one of a first operating media transmission passage, a second operating media transmission passage, a third operating media transmission passage, and a fourth operating media transmission passage.

37. The method of claim 36, wherein the wherein the allotting comprises connecting the operating media supply passage to the first and third operating media transmission passages.

38. The method of claim 33, wherein the operating media comprises air.

39. The method of claim 33, wherein the manifold is disposed entirely between first and second parallel planes, the first and second parallel planes being spaced apart a distance less than or equal to three inches.

40. A method of distributing operating media comprising:

connecting an operating media supply to a manifold, the manifold defining an operating media supply passage, an operating media exhaust passage, a first operating media transmission passage, a second operating media transmission passage, a third

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operating media transmission passage, and a fourth operating media transmission passage;

directing operating media from the operating media supply to the first and third operating media outlet passages; and

directing operating media from the second and fourth operating media outlet passages to the operating media exhaust passage.

41. The method of claim 40, wherein the operating media comprises air.

42. A manifold apparatus for distributing operating media, the apparatus comprising:

a first member defining:

an operating media supply cavity;

an operating media exhaust cavity;

at least four operating media transmission cavities in communication with the operating media supply cavity and the operating media exhaust cavity; and

a surface communicating a flow of operating media flow between a minimum of two of the at least four operating media transmission cavities.

43. The apparatus of claim 42, further comprising:

a second member defining at least one surface that cooperates with the first member to contain and transport operating media between a minimum of two of the at least four operating media transmission cavities.

44. A manifold apparatus for distributing operating media, that apparatus comprising:

a first member having a plurality of cavities for transporting operating media, the plurality of cavities including an operating media supply cavity, and

a second member defining a surface that cooperates with the first member to contain and transport operating media between at least two cavities.

45. The apparatus of any of claims 43 and 44, wherein the at least one surface comprises an interior surface that defines a recess, the recess cooperates with the first member to form a chamber in fluid communication with at least two cavities.

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46. The apparatus of claim 45, wherein the at least one surface defines a plurality of recesses that cooperate with the first member to form a plurality of chambers.

47. The apparatus of any of claims 42 and 46, wherein the second member comprises a manifold cover.

48. The apparatus of any of claims 42 and 44, further comprising a plurality of external ports that connect to the operating media supply cavity, the operating media exhaust cavity, and the first, second, third and fourth operating media transmission cavities.

49. The apparatus of claims 48, further comprising:

a first operating media distribution valve in fluid communication with the operating media supply cavity, the first and second operating media transmission cavities, and the operating media exhaust cavity, the first operating media distribution valve including:

a first configuration connecting the operating media supply cavity with the first operating media transmission cavity and connecting the second operating media transmission cavity with the operating media exhaust cavity; and

a second configuration connecting the operating media supply cavity with the second operating media transmission cavity and connecting the first operating media transmission cavity with the operating media exhaust cavity; and

a second operating media distribution valve in fluid communication with the operating media supply cavity, the third and fourth operating media transmission cavities, and the operating media exhaust cavity, the second operating media distribution valve including:

a third configuration connecting the operating media supply cavity with the third operating media transmission cavity and connecting the fourth operating media transmission cavity with the operating media exhaust cavity; and

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a fourth configuration connecting the operating media supply cavity with the fourth operating media transmission cavity and connecting the third operating media transmission cavity with the operating media exhaust cavity

50. The apparatus of claim 49, further comprising:

a first operational mode including the first configuration of the first operating media distribution valve and the third configuration of the second operating media distribution valve.

51. The apparatus of claim 49, further comprising:

a second operational mode including the second configuration of the first operating media distribution valve and the fourth configuration of the second operating media distribution valve.

52. The apparatus of claim 49, further comprising:

a third operational mode that includes occluding one of the plurality of connection ports corresponding to one of the first, second, third and fourth operating media transmission passages.

53. The apparatus of claim 49, further comprising:

an enclosure defining a first chamber, the first and second members being disposed in the first chamber, the enclosure is disposed entirely between first and second parallel planes, and the first and second parallel planes being spaced apart a distance less than or equal to three inches.

54. The apparatus of claim 48, wherein the plurality of external ports are disposed in a third member proximate the first member.

55. A system controlling two process valves, the system comprising:

a manifold defining a member that defines an operating media supply cavity, an operating media exhaust cavity, and at least four operating media transmission cavities in communication with the operating media supply cavity and the operating media exhaust cavity;

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a surface communicating a flow of operating media between a minimum of two of the at least four operating media transmission cavities;

a first process valve actuator including:

a first operating media port connected to the first operating media transmission cavity, and

a second operating media port connected to the second operating media transmission cavity; and

a second process valve actuator including:

a third operating media port connected to the third operating media transmission cavity, and

a fourth operating media port connected to the fourth operating media transmission cavity.

56. A system controlling two process valves, the system comprising:

a manifold defining first and second members, the first member having a plurality of cavities for transporting operating media, the plurality of cavities including an operating media supply cavity, and the second member defining a surface that cooperates with the first member to contain and transport operating media between at least two cavities;

a first operating media distribution valve in fluid communication with the operating media supply cavity, the first and second operating media transmission cavities, and the operating media exhaust cavity, the first operating media distribution valve including:

a first configuration connecting the operating media supply cavity with the first operating media transmission cavity and connecting the second operating media transmission cavity with the operating media exhaust cavity; and

a second configuration connecting the operating media supply cavity with the second operating media transmission cavity and connecting the first operating media transmission cavity with the operating media exhaust cavity;

a second operating media distribution valve in fluid communication with the operating media supply cavity, the third and fourth operating media transmission

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cavities, and the operating media exhaust cavity, the second operating media distribution valve including:

a third configuration connecting the operating media supply cavity with the third operating media transmission cavity and connecting the fourth operating media transmission cavity with the operating media exhaust cavity; and

a fourth configuration connecting the operating media supply cavity with the fourth operating media transmission cavity and connecting the third operating media transmission cavity with the operating media exhaust cavity;

a first process valve actuator including:

a first operating media port connected to the first operating media transmission cavity, and

a second operating media port connected to the second operating media transmission cavity; and

a second process valve actuator including:

a third operating media port connected to the third operating media transmission cavity, and

a fourth operating media port connected to the fourth operating media transmission cavity.

57. The system of any of claims 55 and 56, further comprising:

an electronic control unit controlling the first process valve actuator by operating the first operating media distribution valve and controlling the second process valve actuator by operating the second operating media distribution valve.

58. The system of claim 57, wherein the electronic control unit operates the first and second operating media distribution valves to select the first operational mode.

59. The system of claim 57, wherein the electronic control unit operates the first and second operating media distribution valves to select the second operational mode.

60. A piping system comprising:

a first pipe;

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a first process valve connected to the first pipe;

a first actuator operating the first process valve; and

a device controlling the first actuator, the device including:

a manifold defining a member that defines an operating media supply cavity, an operating media exhaust cavity, and at least four operating media transmission cavities in communication with the operating media supply cavity and the operating media exhaust cavity;

a surface communicating a flow of operating media flow between a minimum of two of the at least four operating media transmission cavities;

a first process valve actuator including:

a first operating media port connected to the first operating media transmission cavity, and

a second operating media port connected to the second operating media transmission cavity; and

a second process valve actuator including:

a third operating media port connected to the third operating media transmission cavity, and

a fourth operating media port connected to the fourth operating media transmission cavity.

61. A piping system comprising:

a first pipe;

a first process valve connected to the first pipe;

a first actuator operating the first process valve; and

a device for controlling the first actuator, the device including:

a manifold defining first and second members, the first member having a plurality of cavities for transporting operating media, the plurality of cavities including an operating media supply cavity, and the second member defining a surface that cooperates with the first member to contain and transport operating media between at least two cavities;

a first operating media distribution valve in fluid communication with the operating media supply cavity, the first and second operating

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media transmission cavities, and the operating media exhaust cavity, the first operating media distribution valve including:

a first configuration connecting the operating media supply cavity with the first operating media transmission cavity and connecting the second operating media transmission cavity with the operating media exhaust cavity; and

a second configuration connecting the operating media supply cavity with the second operating media transmission cavity and connecting the first operating media transmission cavity with the operating media exhaust cavity;

a second operating media distribution valve in fluid communication with the operating media supply cavity, the third and fourth operating media transmission cavities, and the operating media exhaust cavity, the second operating media distribution valve including:

a third configuration connecting the operating media supply cavity with the third operating media transmission cavity and connecting the fourth operating media transmission cavity with the operating media exhaust cavity; and

a fourth configuration connecting the operating media supply cavity with the fourth operating media transmission cavity and connecting the third operating media transmission cavity with the operating media exhaust cavity;

a first process valve actuator including:

a first operating media port connected to the first operating media transmission cavity, and

a second operating media port connected to the second operating media transmission cavity; and

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a second process valve actuator including:

a third operating media port connected to the third operating media transmission cavity, and

a fourth operating media port connected to the fourth operating media transmission cavity.

62. A method of method of maintaining operative performance of first and second valves, the method comprising:

evaluating with a single valve controller operative conditions of the first and second valves;

communicating the operative conditions of the first and second valves to a remote location via an internet communication link; and

changing operative commands of the single valve controller via the internet communication link.

63. The method of claim 62, further comprising:

operating the first and second valves with the single valve controller, the single valve controller including an operating media distribution system including a third valve in communication with an operating media supply passage, an operating media exhaust passage, and at least four operating media transmission passages.

64. The valve controller of claim 63, wherein the operating comprises an electronic control unit proximate the operating media distribution system and operating the third valve to control operating media flow in the operating media distribution system.

65. The valve controller of claim 64, further comprising:

evaluating the air distribution system with a plurality of sensors and providing the electronic control unit information about at least one operating condition in each of the passages.

66. The apparatus of any of claims 4, 8 and 28, wherein the enclosure comprises at least one cover that provides access to the operating media distribution system.

67. The apparatus of claim 66, wherein the at least one cover is secured to the enclosure by at least one fastening element.

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68. The apparatus of claim 67, wherein the enclosure has at least one fastening element attachment site, and the at least one fastening element cooperates with the at least one fastening element attachment site to secure the at least one cover to the enclosure.

69. The apparatus of any of claims 1, 5, 10 and 30, wherein the enclosure comprises at least one cover providing access to the first and second chambers.

70. The apparatus of claim 69, wherein the at least one cover is secured to the enclosure by at least one fastening element.

71. The apparatus of claim 70, wherein the enclosure has at least one fastening element attachment site, and the at least one fastening element cooperates with the at least one fastening element attachment site to secure the at least one cover to the enclosure.

72. The apparatus of claim 69, wherein the at least one cover comprises first and second covers, the first cover provides access to only the first chamber and the second cover provides access to only the second chamber.

73. The apparatus of any of claims 1 and 6, wherein the enclosure is disposed entirely between first and second parallel planes, the first and second parallel planes being spaced apart a distance less than or equal to three inches.

74. The apparatus of claim 73, wherein the visual symbol is visible from above the first plane and is visible from below the second plane.

75. The apparatus of any of claims 1, 5, 10 and 30, wherein the enclosure comprises:

a first wall including first and second segments that define portions of the first chamber, a projection along the longitudinal axis of the first segment has a first length transverse to the longitudinal axis, and a projection along the longitudinal axis of the second segment has a second length transverse to the longitudinal axis, the second length being greater than the first length; and

a second wall including third and fourth segments that define portions of the second chamber, a projection along the longitudinal axis of the third segment has a third

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length transverse to the longitudinal axis, and a projection along the longitudinal axis of the fourth segment has a fourth length transverse to the longitudinal axis, the fourth length being greater than the third length.

76. The apparatus of claim 75, wherein the first segment is proximate to the second wall, the second segment is distal to the second wall, the third segment is proximate to the first wall, the fourth segment is distal to the first wall, and the second segment of the first wall and the fourth segment of the second wall are parallel.

77. The apparatus of any of claims 1, 6, 8 and 28, wherein the indicator comprises:

a first member defining an interior space; and

a second member disposed within the interior space, the second member including the visual symbol that identifies the operational state of the at least one valve.

78. The apparatus of claim 77, wherein the second member oscillates with respect to the first member.

79. The apparatus of any of claims 1, 4, 11, 26, 31 and 44, wherein the operating media transmission passages comprise first, second, third and fourth operating media transmission passages and the operating media distribution system includes a manifold assembly comprising:

a first operating media distribution valve in fluid communication with the operating media supply passage, the first and second operating media transmission passages, and the operating media exhaust passage, the first operating media distribution valve including:

a first configuration connecting the operating media supply passage with the first operating media transmission passage and connecting the second operating media transmission passage with the operating media exhaust passage; and

a second configuration connecting the operating media supply passage with the second operating media transmission passage and connecting the first operating media transmission passage with the operating media exhaust passage; and

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a second operating media distribution valve in fluid communication with the operating media supply passage, the third and fourth operating media transmission passages, and the operating media exhaust passage, the second operating media distribution valve including:

a third configuration connecting the operating media supply passage with the third operating media transmission passage and connecting the fourth operating media transmission passage with the operating media exhaust passage; and

a fourth configuration connecting the operating media supply passage with the fourth operating media transmission passage and connecting the third operating media transmission passage with the operating media exhaust passage.

80. The apparatus of claim 79, wherein the manifold assembly consists of a single operating media exhaust passage.

81. The apparatus of claim 79, wherein the manifold assembly comprises a monolithic manifold defining:

a first outer surface portion including first, second, third and fourth openings, the first opening being in fluid communication with the operating media supply passage, the second opening being in fluid communication with the operating media exhaust passage, the third opening being in fluid communication with the first operating media transmission passage, and the fourth opening being in fluid communication with the second operating media transmission passage; and

a second outer surface portion including fifth, sixth, seventh and eighth openings, the fifth opening being in fluid communication with the operating media supply passage, the sixth opening being in fluid communication with the operating media exhaust passage, the seventh opening being in fluid communication with the third operating media transmission passage, and the eighth opening being in fluid communication with the fourth operating media transmission passage.

82. The apparatus of claim 79, wherein the manifold assembly comprises first and second manifold parts.

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83. The apparatus of claim 82, wherein the manifold assembly comprises at least one fastener commonly securing together the first manifold part, the second manifold part, and the enclosure.

84. The apparatus of claim 79, wherein the manifold assembly comprises a cover defining at least one operating media path.

85. The apparatus of claim 79, further comprising:

a first operational mode including the first configuration of the first operating media distribution valve and the third configuration of the second operating media distribution valve.

86. The apparatus of claim 85, wherein the electronic control unit operates the first and second operating media distribution valves to select the first operational mode.

87. The apparatus of claim 85, further comprising:

a second operational mode including the second configuration of the first operating media distribution valve and the fourth configuration of the second operating media distribution valve.

88. The apparatus of claim 87, wherein the electronic control unit operates the first and second operating media distribution valves to select the second operational mode.

89. The apparatus of claim 87, further comprising:

a third operational mode that includes occluding one of the plurality of connection ports corresponding to one of the first, second, third and fourth operating media transmission passages.

90. The apparatus of claim 79, wherein the first and second operating media distribution valves comprise spool valves.

91. The method of any of claims 37 and 40, further comprising:

directing operating media from the operating media supply passage to the second and fourth operating media transmission passages: and

directing operating media from the first and third operating media transmission passages to the operating media exhaust passage.

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92. The apparatus of any of claims 2, 4, 11, 26 and 32, wherein the at least one sensor comprises a plurality of sensors that evaluate at least one operating condition in at least one of the passages.

93. The apparatus of claim 92, wherein the plurality of sensors evaluate the operating media distribution system and provide information to the electronic control unit about at least one operating condition in each of the passages.

94. The apparatus of claim 92, wherein the plurality of sensors evaluate operating media pressure.

95. The apparatus of claim 92, wherein at least one of the plurality of sensors comprises a differential pressure sensor.

96. The apparatus of claim 92, wherein the indicator comprises a position sensor that evaluates valve position and provides valve position data to the electronic control unit.

97. The apparatus of claim 92, wherein the electronic control unit monitors valve performance and develops at least one diagnostic profile.

98. The apparatus of claim 97, wherein the at least one diagnostic profile is selected from the group consisting of Insufficient Line Pressure to Guarantee Correct Operation, Supply Pressure Failure, and Valve Shaft Bent.

99. The apparatus of claim 97, wherein the at least one diagnostic profile is selected from the group consisting of Valve Not Achieving Full Stroke, Backlash Detection, and Torque Demand of Valve Approaching Actuator Limit.

100. The apparatus of claim 97, wherein the at least one diagnostic profile is selected from the group consisting of Valve Seating/Break-out Torque Monitoring, Torque Limit Exceeded, and Close-on Torque.

101. The apparatus of claim 97, wherein the at least one diagnostic profile is selected from the group consisting of Shaft Broken, Valve Exercise, Valve Packing Torque, Line Filter and Silencer Conditions, and Solenoid Spool Sticking.

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102. The method of any of claims 36 and 40, further comprising:
sensing operating media pressure in each of the passages; and
evaluating in a control unit information about the operating media pressure in each of the passages.

103. The method of claim 102, further comprising:
sensing a valve operative position; and
evaluating in the electronic control unit information about the valve operative position.

104. The method of claim 103, further comprising:
developing a valve diagnostic performance attribute profile.

105. The method of claim 104, further comprising:
developing a Commissioned Torque Profile.

106. The method of claim 104, further comprising:
developing a Maintenance Torque Profile.

107. The method of claim 104, further comprising:
monitoring valve performance fault by comparing the valve diagnostic performance attribute profile with stored valve data.

108. The method of claim 107, further comprising:
indicating operating media pressure is insufficient to guarantee opening of the valve.

109. The method of claim 107, further comprising:
indicating Insufficient Line Pressure to Guarantee Correct Operation.

110. The method of claim 107, further comprising:
indicating Supply Pressure Failure.

111. The method of claim 107, further comprising:
indicating Valve Not Achieving Full Stroke.

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112. The method of claim 107, further comprising:
indicating Backlash Detection.

113. The method of claim 107, further comprising:
indicating Torque Demand of Valve Approaching Actuator Limit.

114. The method of claim 107, further comprising:
monitoring Valve Seating/Break-out Torque.

115. The method of claim 107, further comprising:
indicating Torque Limit Exceeded.

116. The method of claim 107, further comprising:
indicating Close-on Torque.

117. The method of claim 107, further comprising:
indicating Shaft Broken.

118. The method of claim 107, further comprising:
indicating Line Filter and Silencer Conditions.

119. The method of claim 107, further comprising:
indicating Solenoid Spool Sticking.

120. The method of claim 107, further comprising:
indicating Valve Exercise.

121. The method of claim 107, further comprising:
indicating Valve Packing Torque.

122. The method of claim 107, further comprising:
calculating average probability of failure on demand; and
predicting valve failure by comparing the calculated average probability of failure with stored valve data.

123. The apparatus of any of claims 1, 4, 8, 26 and 28, wherein the electronic control unit comprises at least one printed circuit board.

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124. The apparatus of claim 123, wherein the electronic control unit comprises a microprocessor.

125. The apparatus of any of claims 123 to 124, wherein the electronic control unit comprises a liquid crystal display.

126. The apparatus of any of claims 123 to 125, wherein the electronic control unit comprises an analog input.

127. The apparatus of any of claims 123 to 126, wherein the electronic control unit comprises an analog output.

128. The apparatus of any of claims 123 to 127, wherein the electronic control unit comprises a discrete output.

129. The apparatus of any of claims 123 to 128, wherein the electronic control unit comprises a discrete input.

130. The apparatus of any of claims 123 to 129, wherein the electronic control unit comprises a communications port.

131. The apparatus of any of claims 123 to 130, wherein the electronic control unit comprises a Flash memory.

132. The apparatus of any of claims 123 to 131, wherein the electronic control unit comprises a Data memory.

133. The apparatus of any of claims 123 to 132, wherein the electronic control unit comprises a Non-volatile memory.

134. The apparatus of any of claims 123 to 133, wherein the electronic control unit comprises a Discrete Output driver.

135. The apparatus of any of claims 123 to 134, wherein the electronic control unit comprises an Inter-processor communication circuitry.

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Page 364

136. The apparatus of any of claims 123 to 135, wherein the electronic control unit comprises a power supply.

137. The apparatus of any of claims 123 to 136, wherein the electronic control unit comprises a plug in network card.

138. The apparatus of any of claims 123 to 137, wherein the electronic control unit comprises a radio module interfacing with a peer-to-peer wireless area network.

139. The apparatus of any of claims 1, 4, 8, 21 and 28, wherein the operating media distribution system distributes an operating media comprising air.

140. The apparatus of claim 139, wherein the operating media in the operating media supply passage comprises the air having a pressure of about 40 to 120 pounds per square inch.

141. The apparatus of claim 139, wherein the operating media in the operating media supply passage comprises the air having a pressure of about 15 to 45 pounds per square inch.

142. The apparatus of claim 139, wherein the operating media in the operating media supply passage comprises the air having a pressure of less than about 120 pounds per square inch.

143. The apparatus of claim 142, wherein the pressure of the air in the operating media supply passage is less than about 40 pounds per square inch.

144. The apparatus of claim 139, wherein the operating media in the operating media supply passage comprises the air having a temperature of about –40 to 180 degrees Fahrenheit.

145. The apparatus of claim 139, wherein the operating media in the operating media supply passage comprises the air having a flow rate of about 5 standard cubic feet per minute at about 40 pounds per square inch to about 100 standard cubic feet per minute at about 120 pounds per square inch.

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146. The system of any of claims 3, 7, 60 and 61, further comprising:
a second process valve; and
a second actuator operating the second process valve;
wherein the device controls the first and second actuators.

147. The system of claim 146, further comprising:
a second pipe connected to the first process valve.

148. An operating media distributor comprising:
a first operating media distribution valve in fluid communication with an operating media supply passage, first and second operating media transmission passages, and an operating media exhaust passage, the first operating media distribution valve including:
a first configuration connecting the operating media supply passage with the first operating media transmission passage and connecting the second operating media transmission passage with the operating media exhaust passage; and
a second configuration connecting the operating media supply passage with the second operating media transmission passage and connecting the first operating media transmission passage with the operating media exhaust passage; and
a second operating media distribution valve in fluid communication with the operating media supply passage, third and fourth operating media transmission passages, and the operating media exhaust passage, the second operating media distribution valve including:
a third configuration connecting the operating media supply passage with the third operating media transmission passage and connecting the fourth operating media transmission passage with the operating media exhaust passage; and
a fourth configuration connecting the operating media supply passage with the fourth operating media transmission passage and connecting the third operating media transmission passage with the operating media exhaust passage.

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149. The distributor of claim 148, further comprising:

a first operational mode including the first configuration of the first operating media distribution valve and the third configuration of the second operating media distribution valve.

150. The distributor of claim 149, further comprising:

a second operational mode including the second configuration of the first operating media distribution valve and the fourth configuration of the second operating media distribution valve.

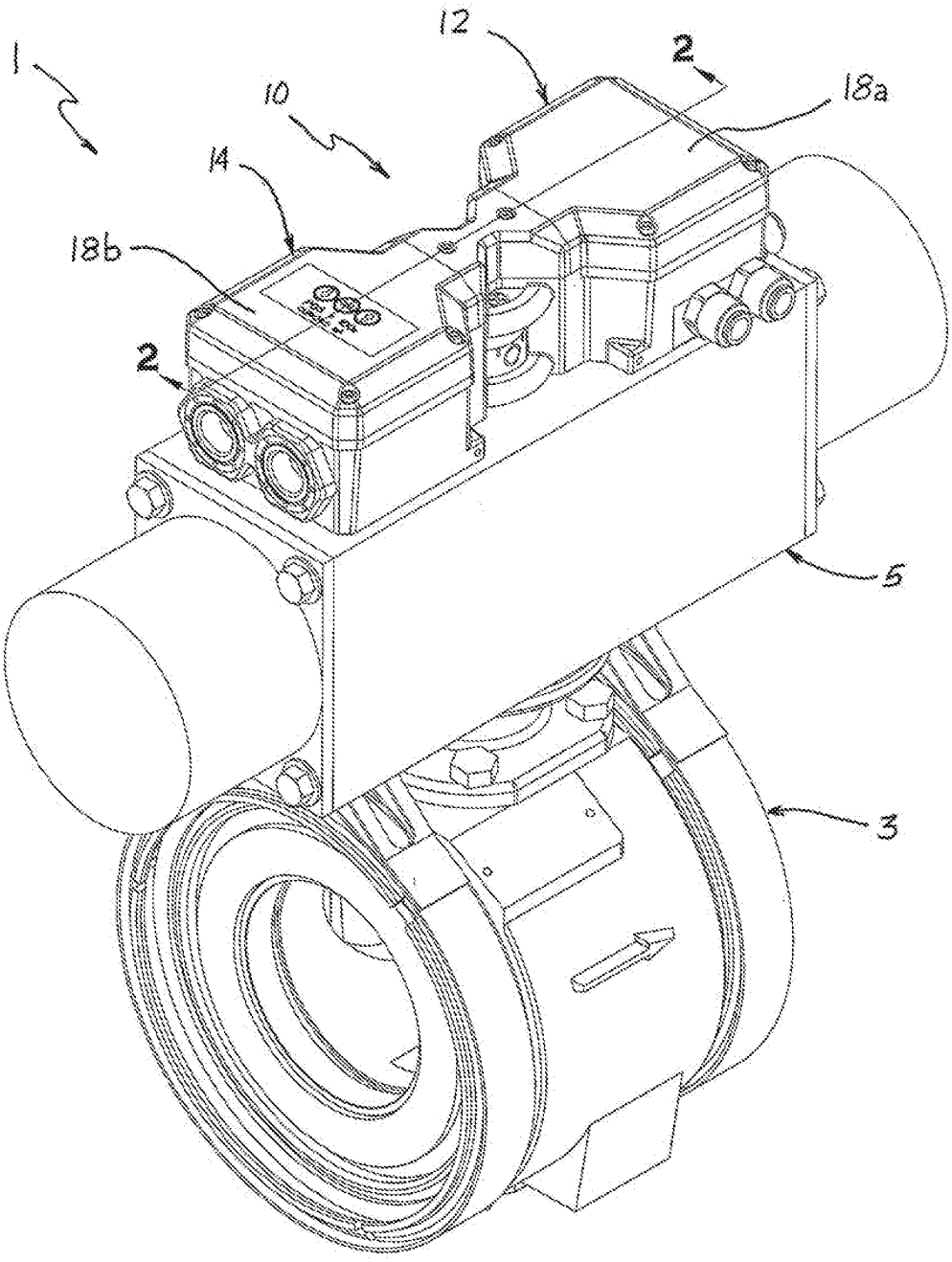
151. The distributor of claim 150, further comprising:

a third operational mode that includes occluding one of the plurality of connection ports corresponding to one of the first, second, third and fourth operating media transmission passages.

152. The subject of any of the preceding claims, wherein the operating media comprises compressed air.

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FIG. 1A



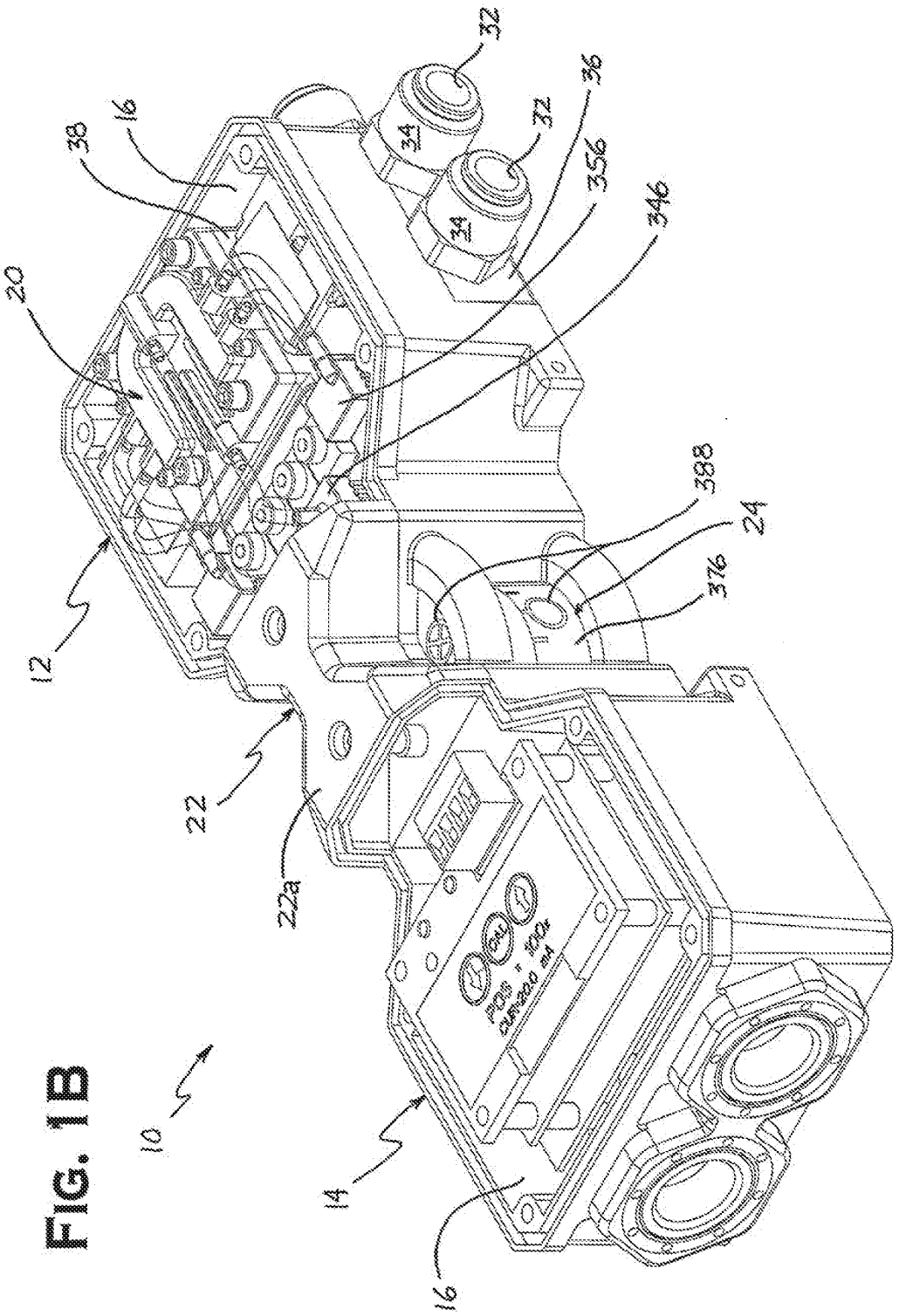


FIG. 1B

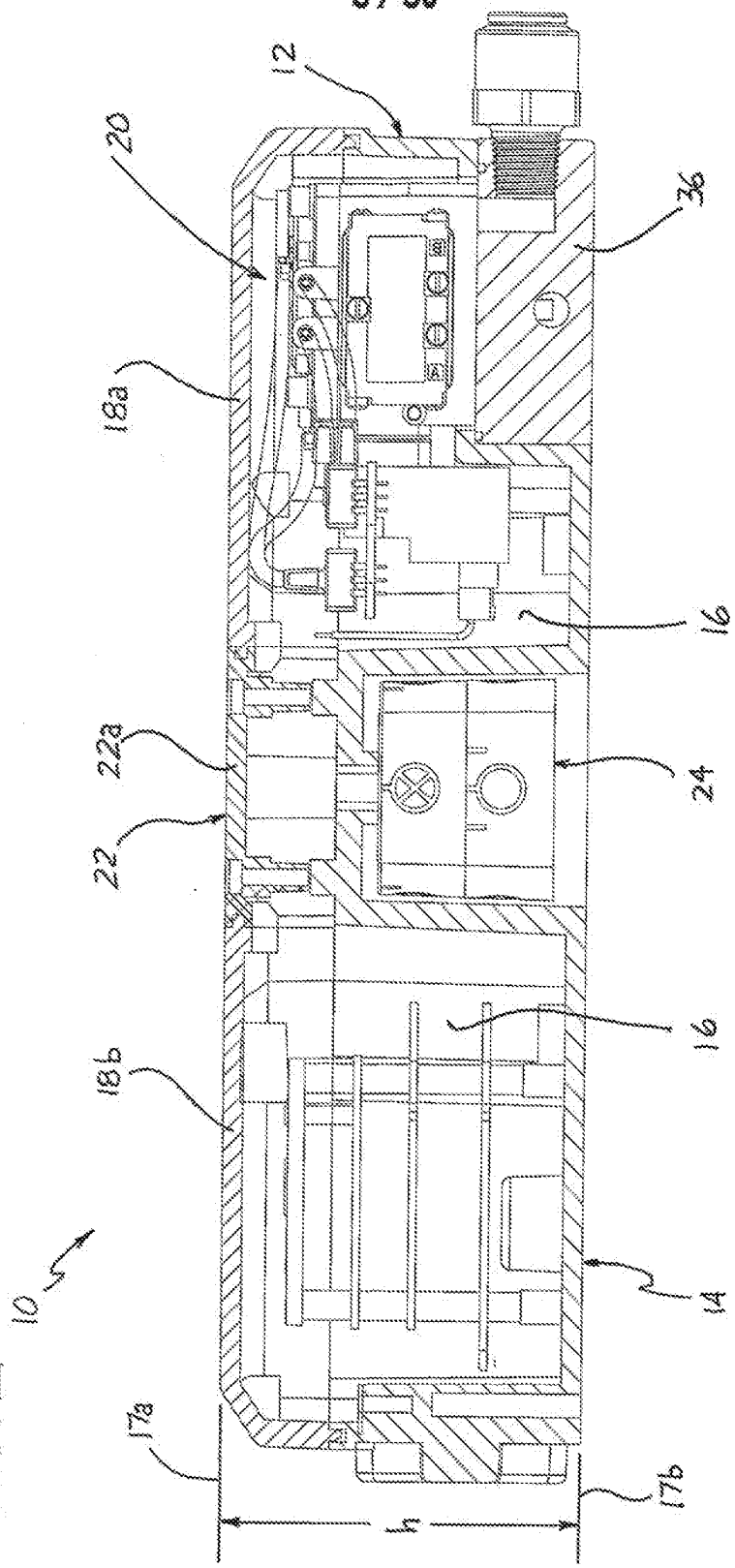


FIG. 2

FIG. 3A

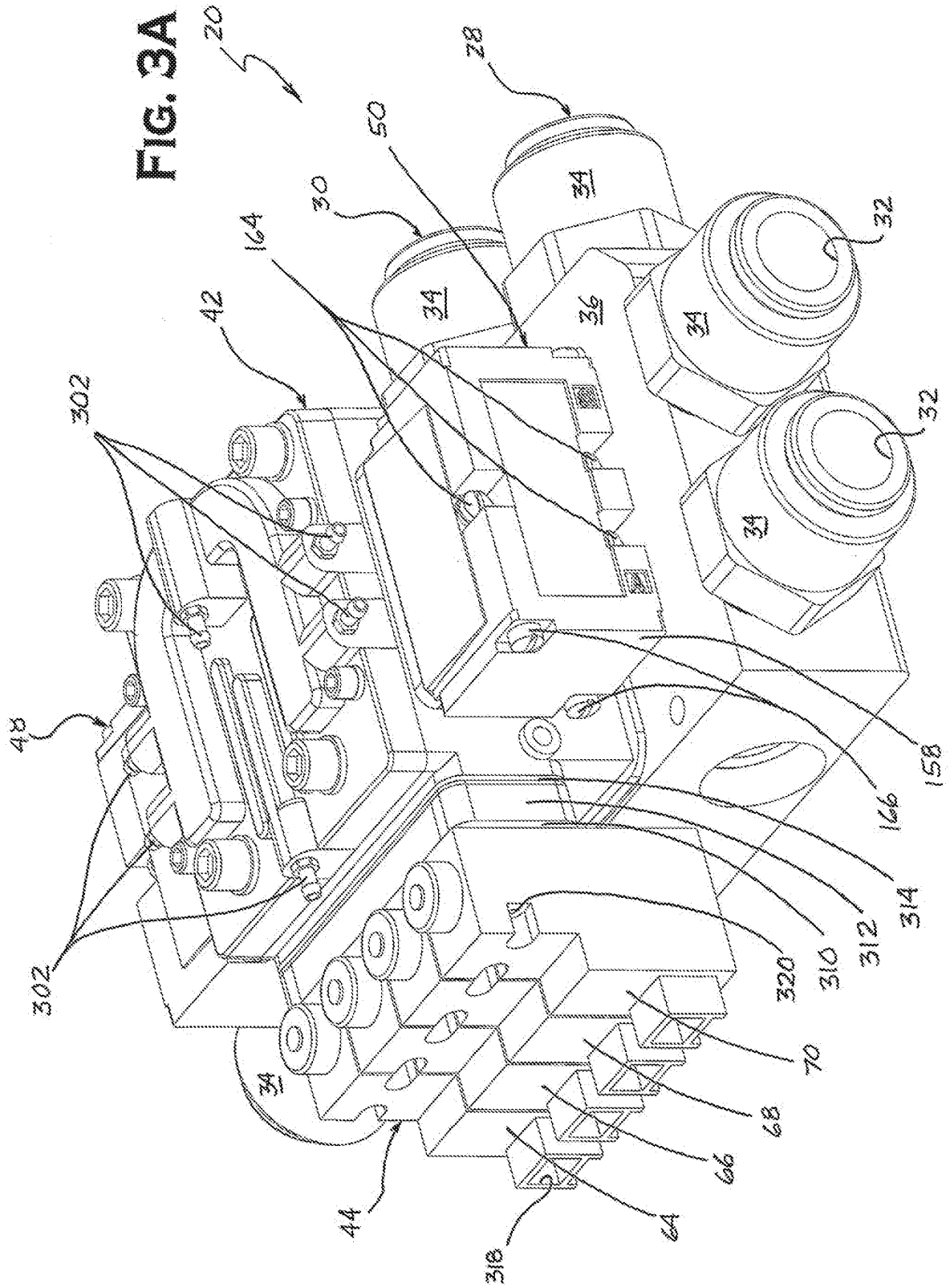

20
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164
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302
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36
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44
318

FIG. 3B

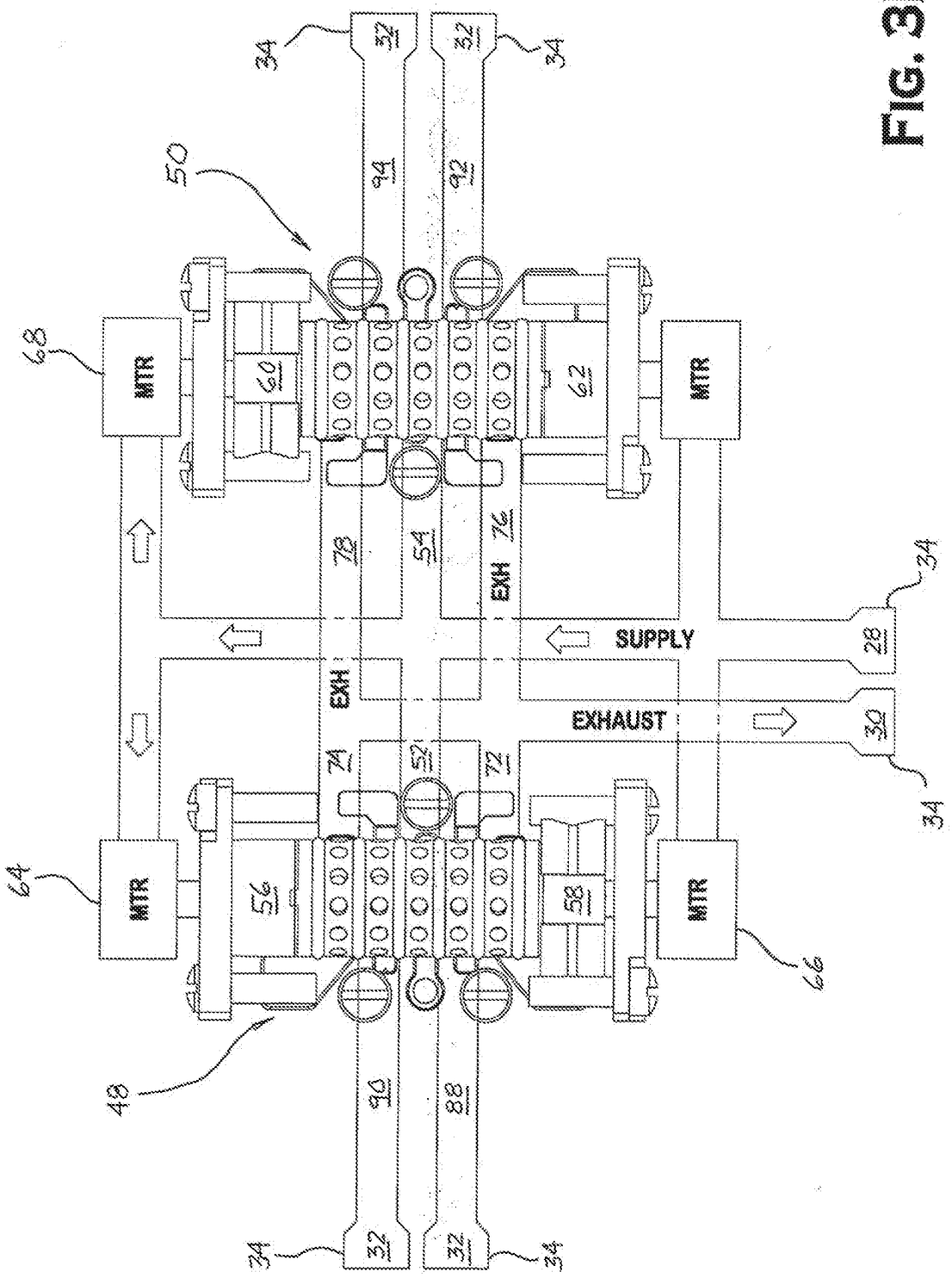

34
32
32
34
50
94
92
68
MTR
60
62
MTR
78
54
74
EXH
SUPPLY
34
28
EXH
EXHAUST
30
34
76
52
72
64
MTR
56
58
MTR
66
48
90
88
34
32
32
34

FIG. 4B

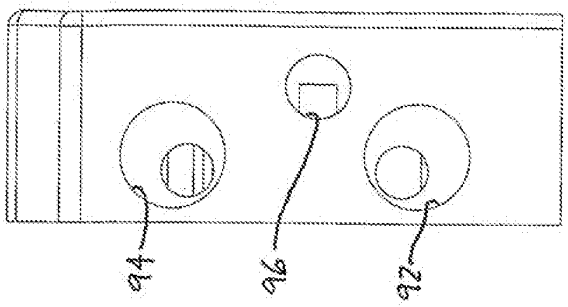


FIG. 4C

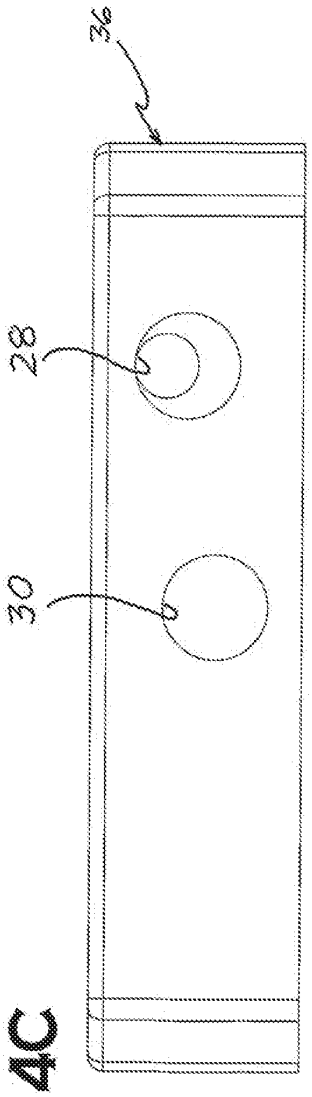


FIG. 4A

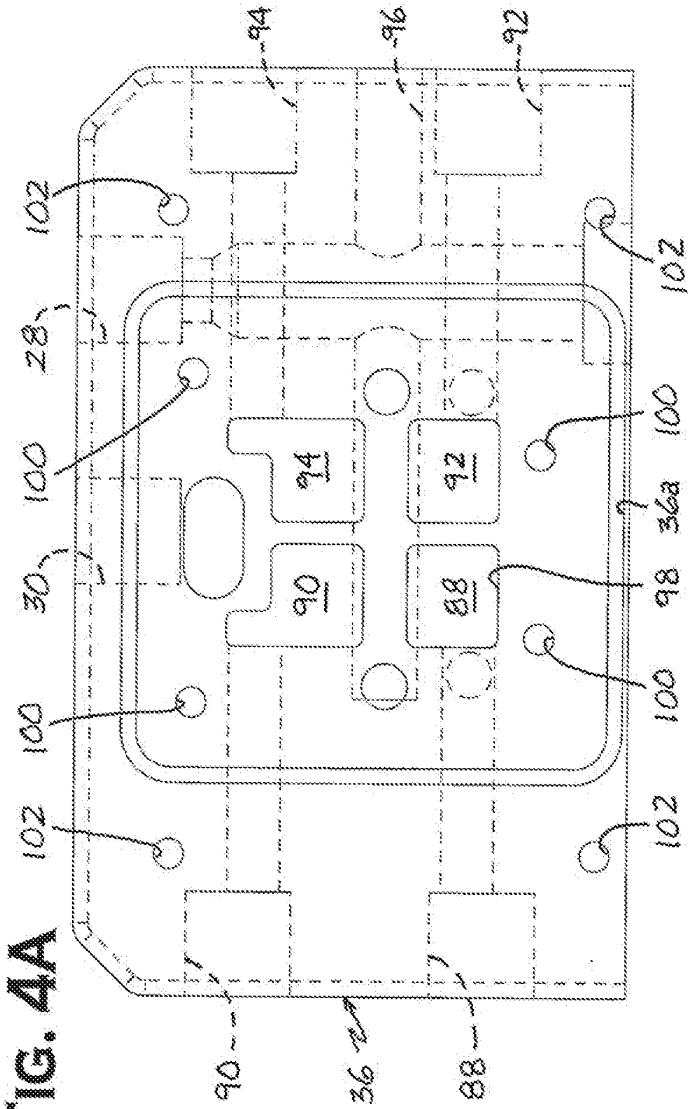


FIG. 4E

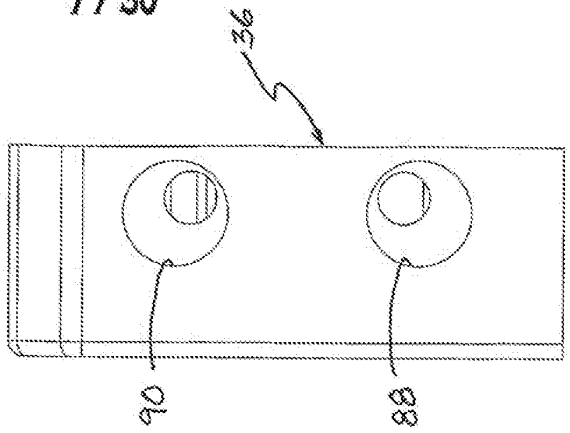
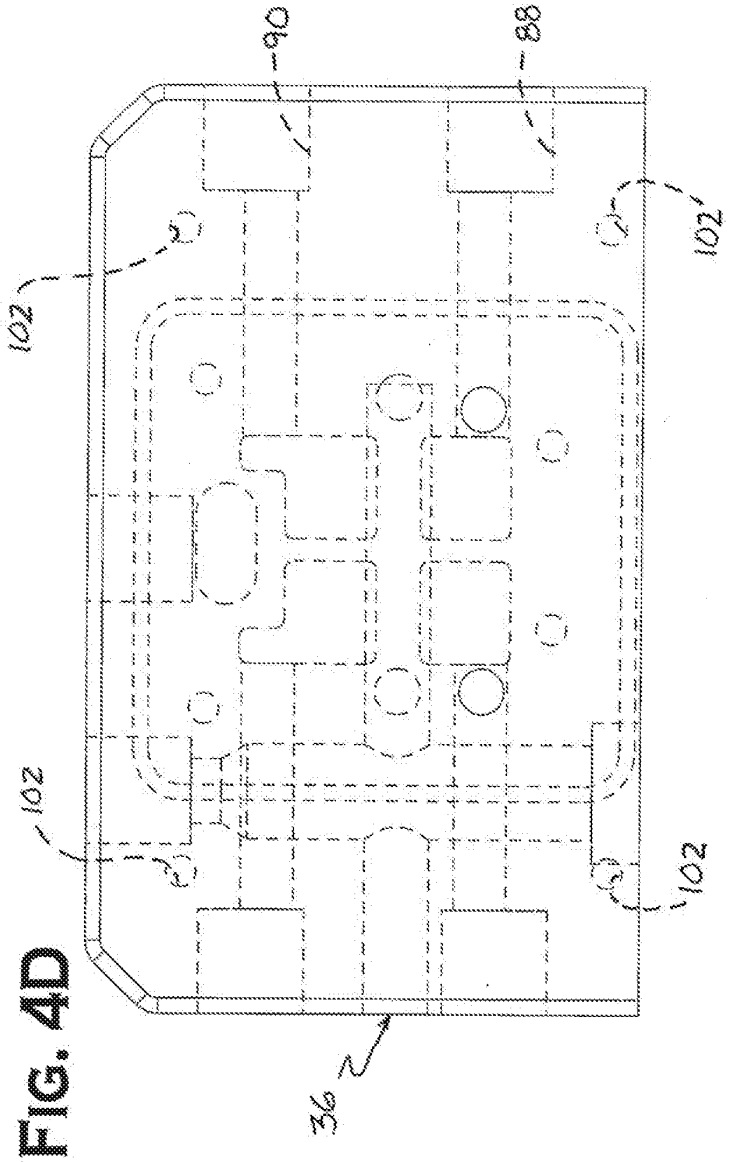


FIG. 4D



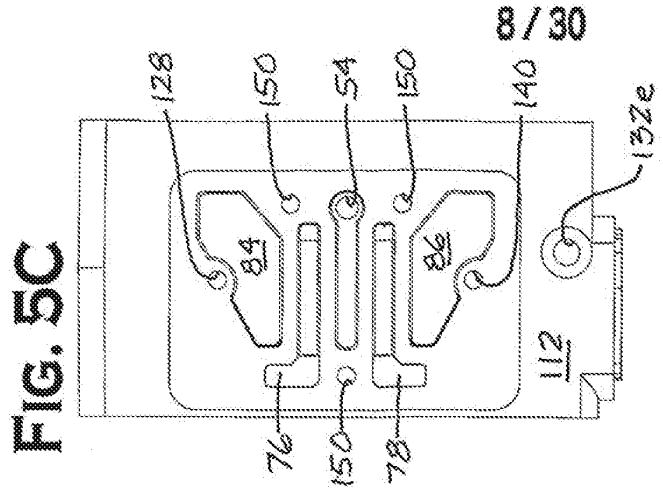


FIG. 5C

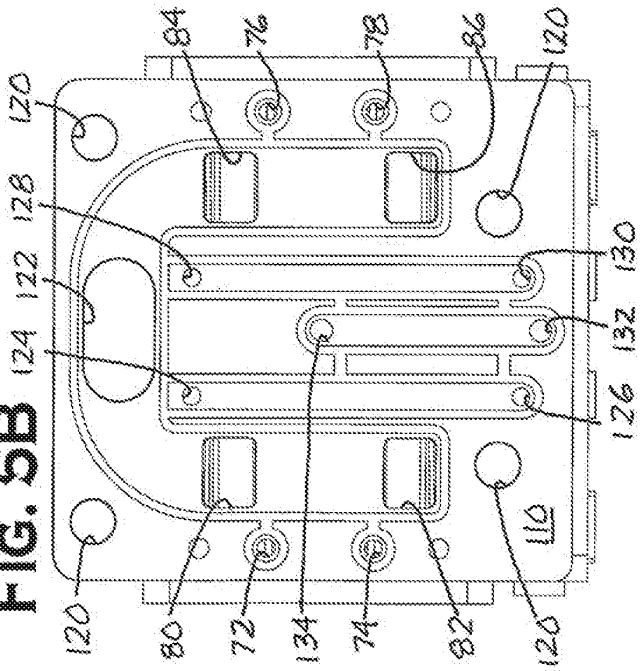


FIG. 5B

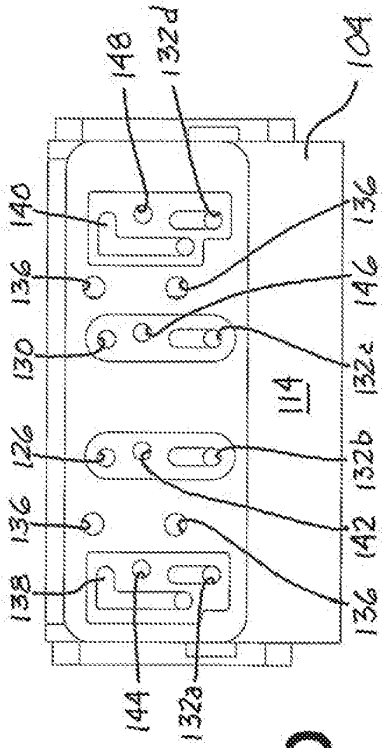


FIG. 5D

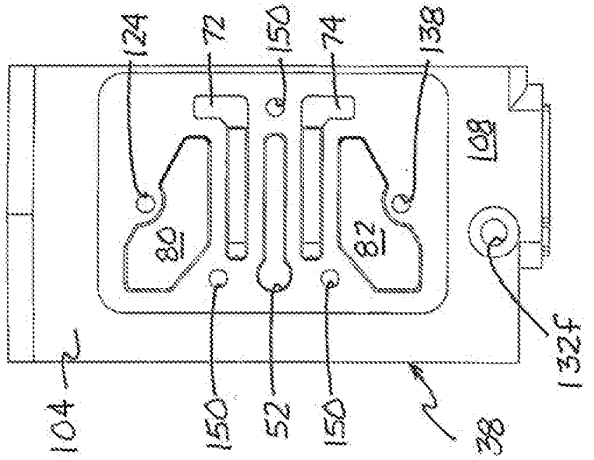


FIG. 5A

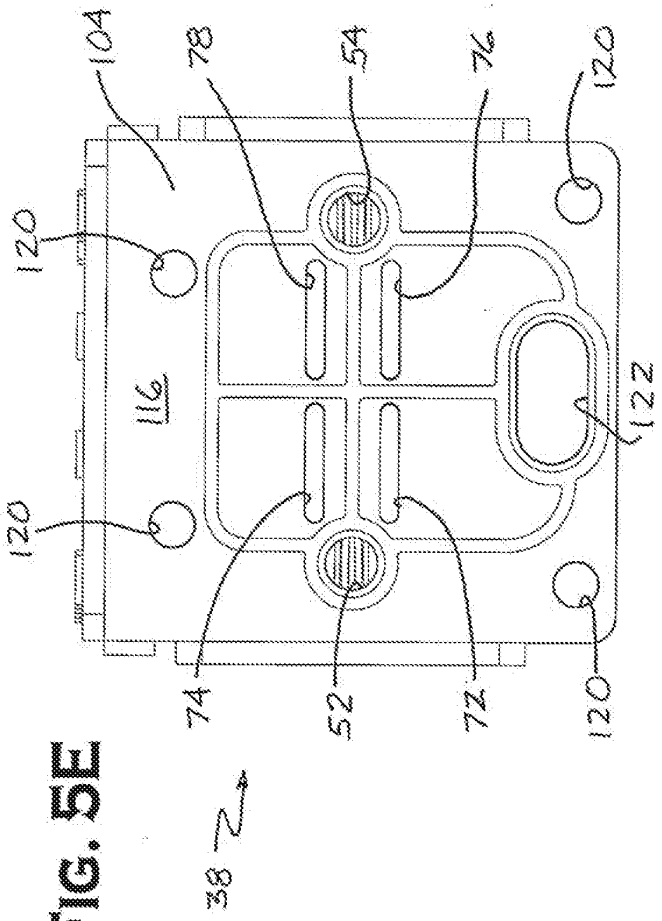


FIG. 5E

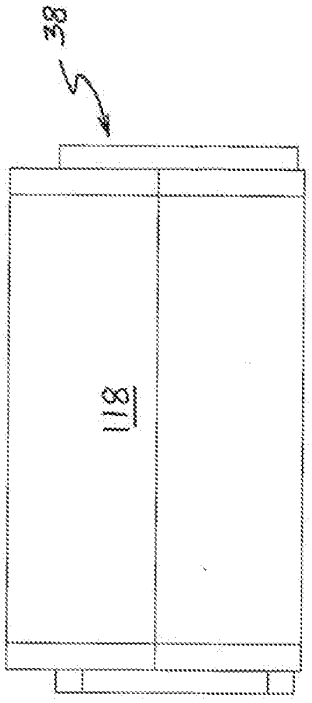


FIG. 5F

FIG. 6

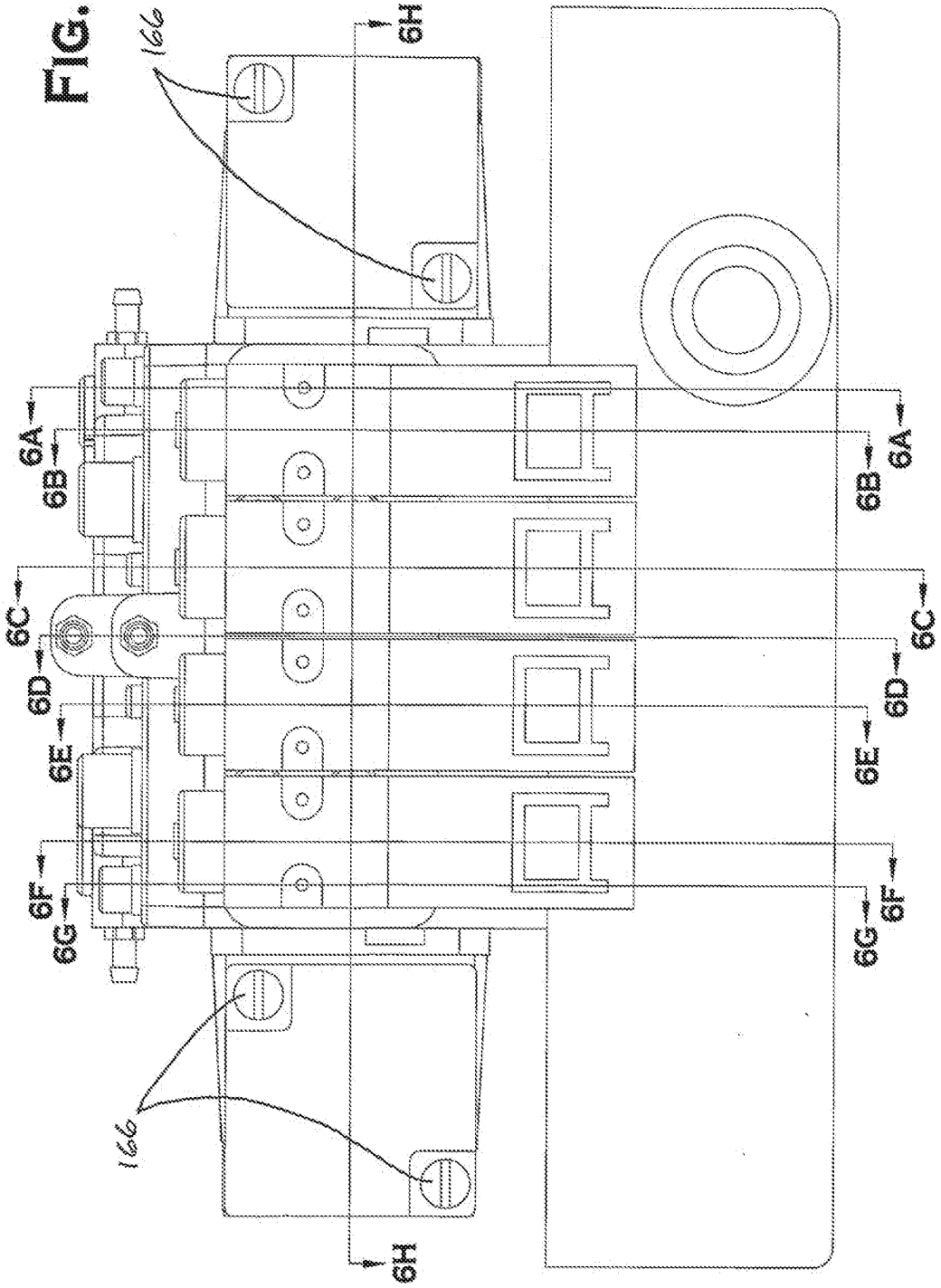


FIG. 6A

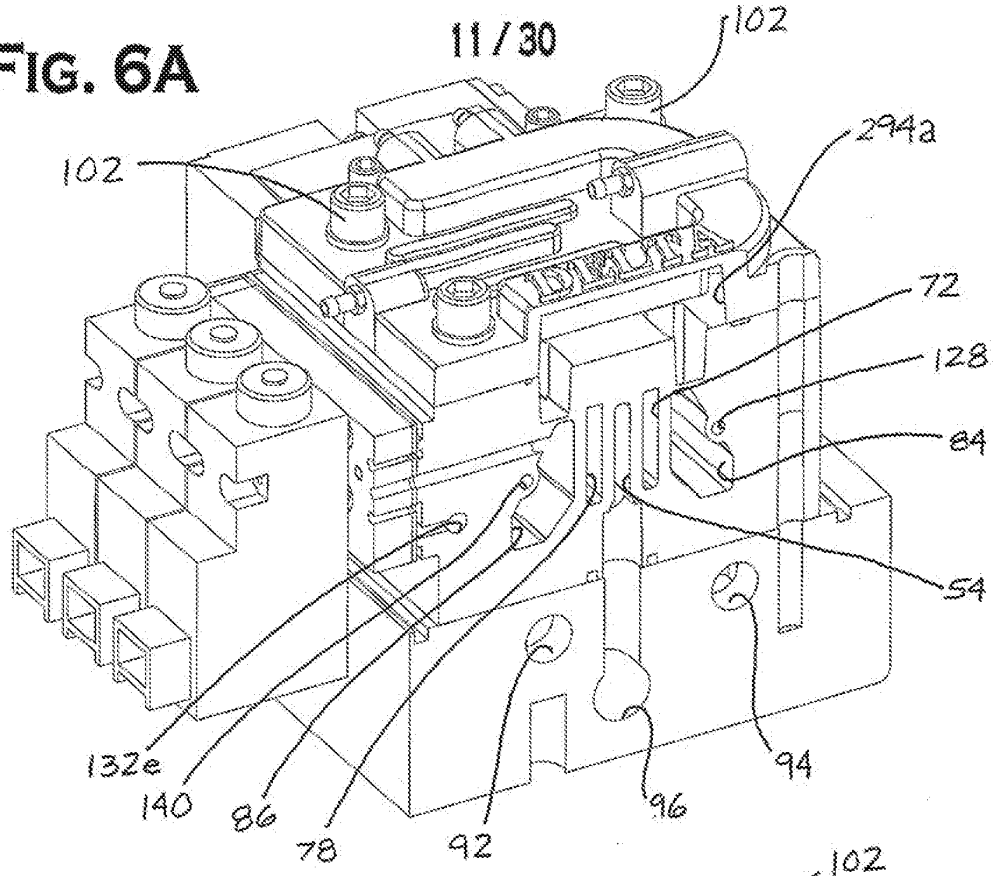

102
102
294a
72
128
84
54
132e
140
86
78
92
96
94

FIG. 6B

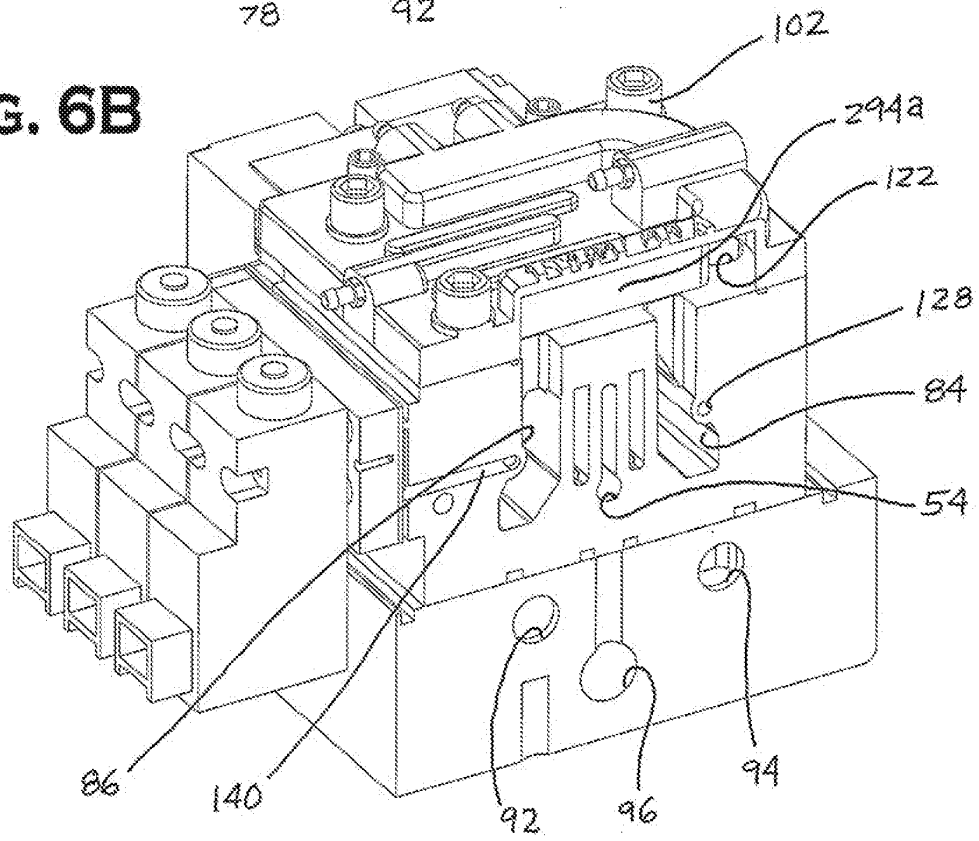

102
294a
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86
140
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96
94

FIG. 6C

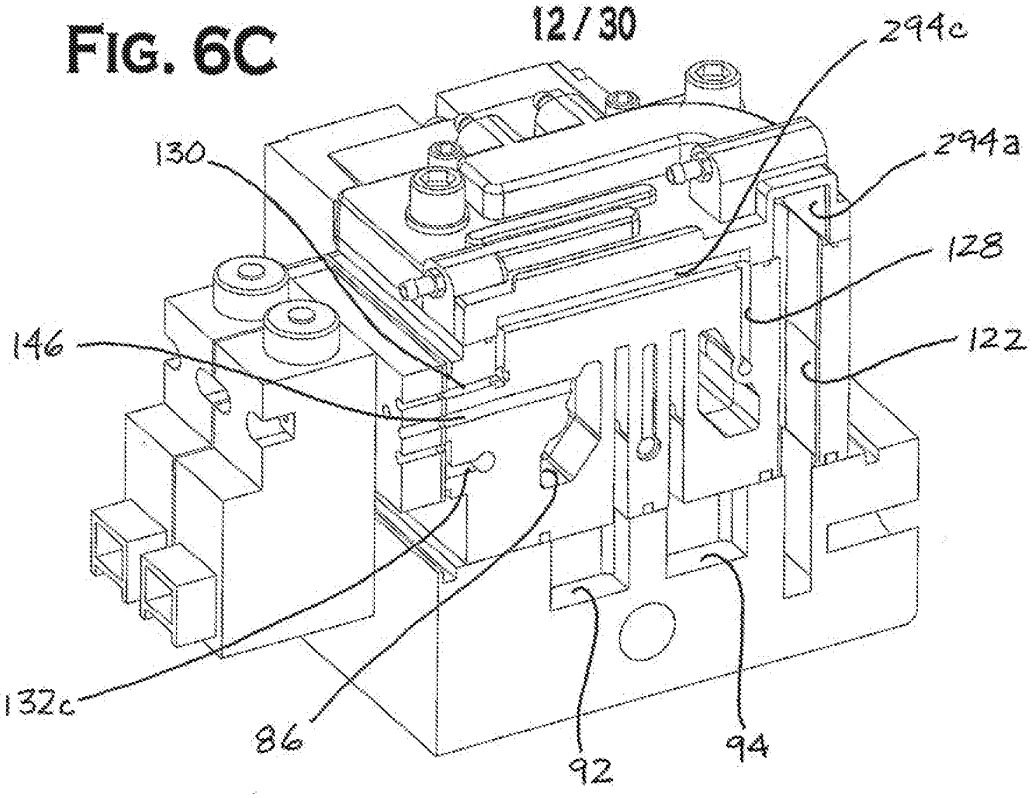

294c
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294a
128
146
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132c
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92
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FIG. 6D

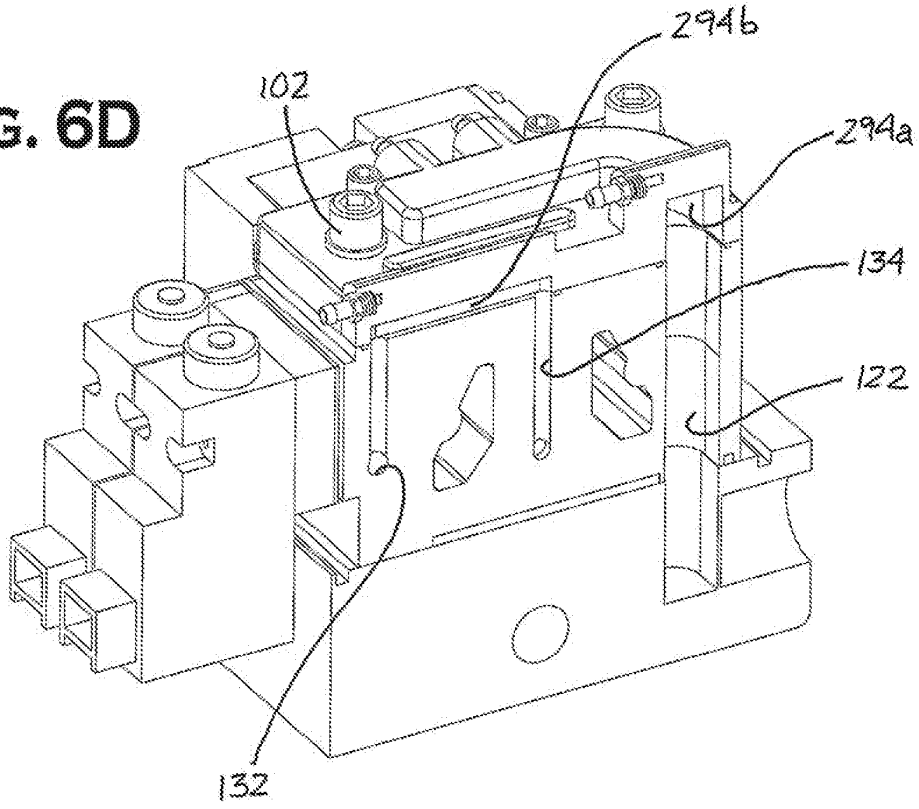

294b
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294a
134
122
132

FIG. 6E

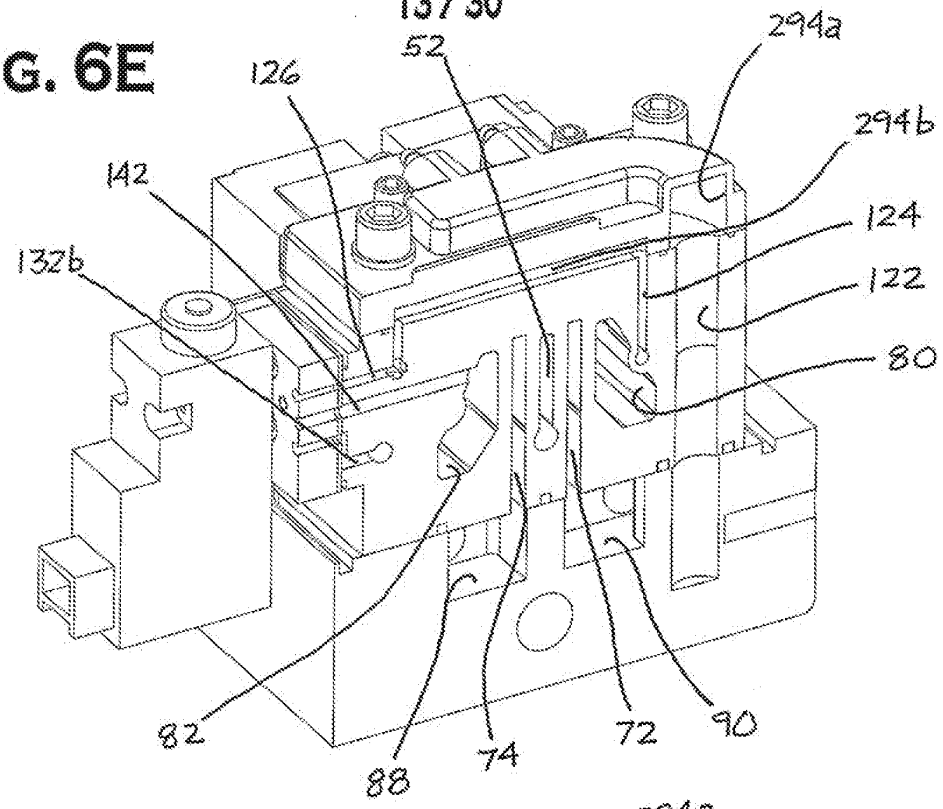

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126
294a
294b
142
124
132b
122
80
82
88
74
72
90

FIG. 6F

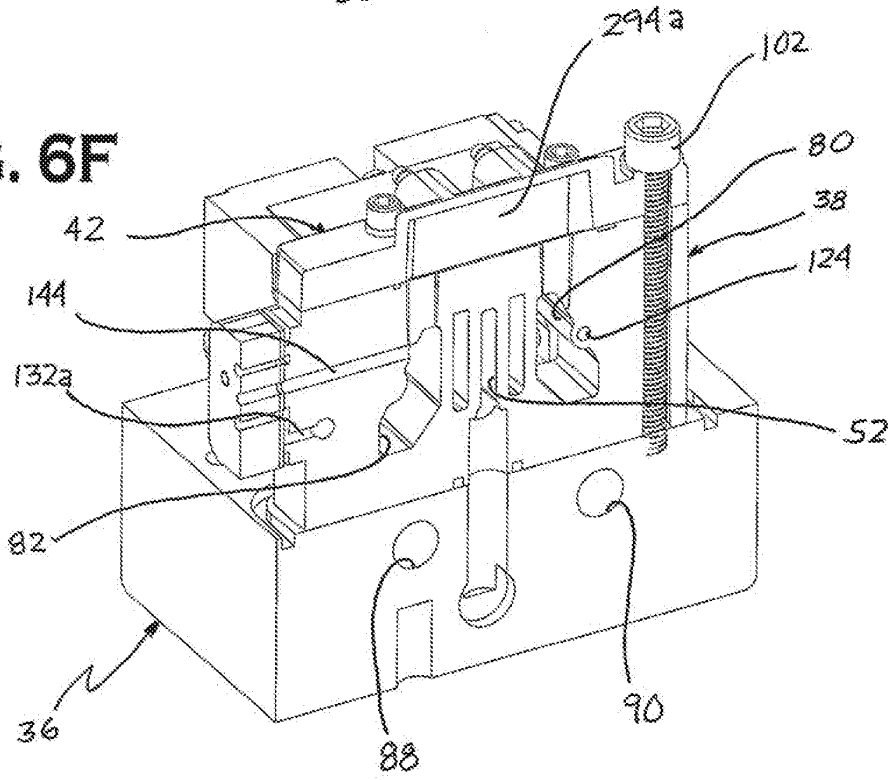
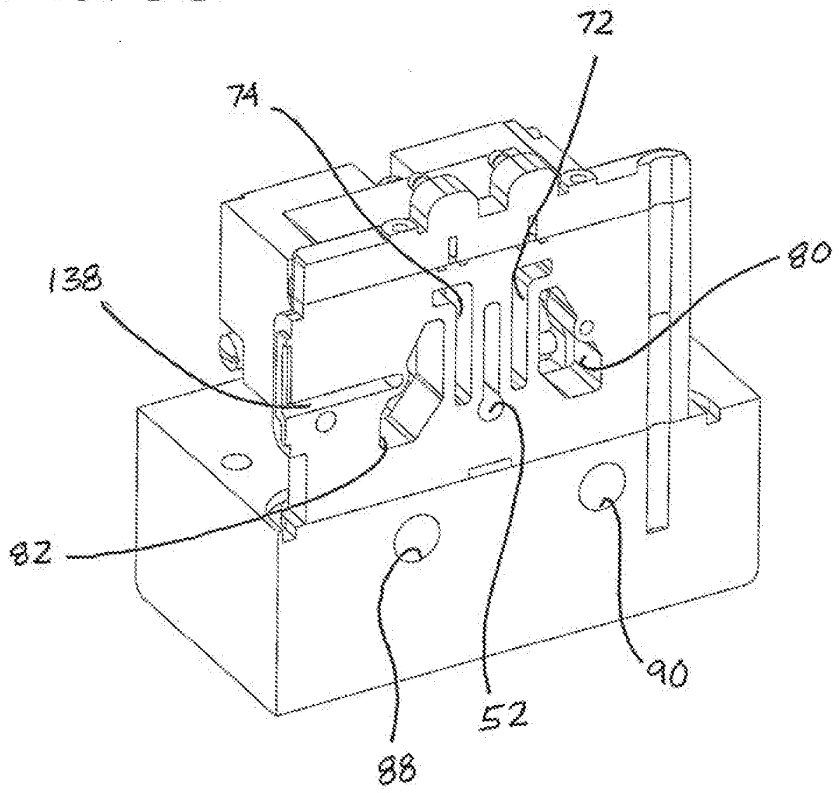

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132a
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36
88
90

FIG. 6G



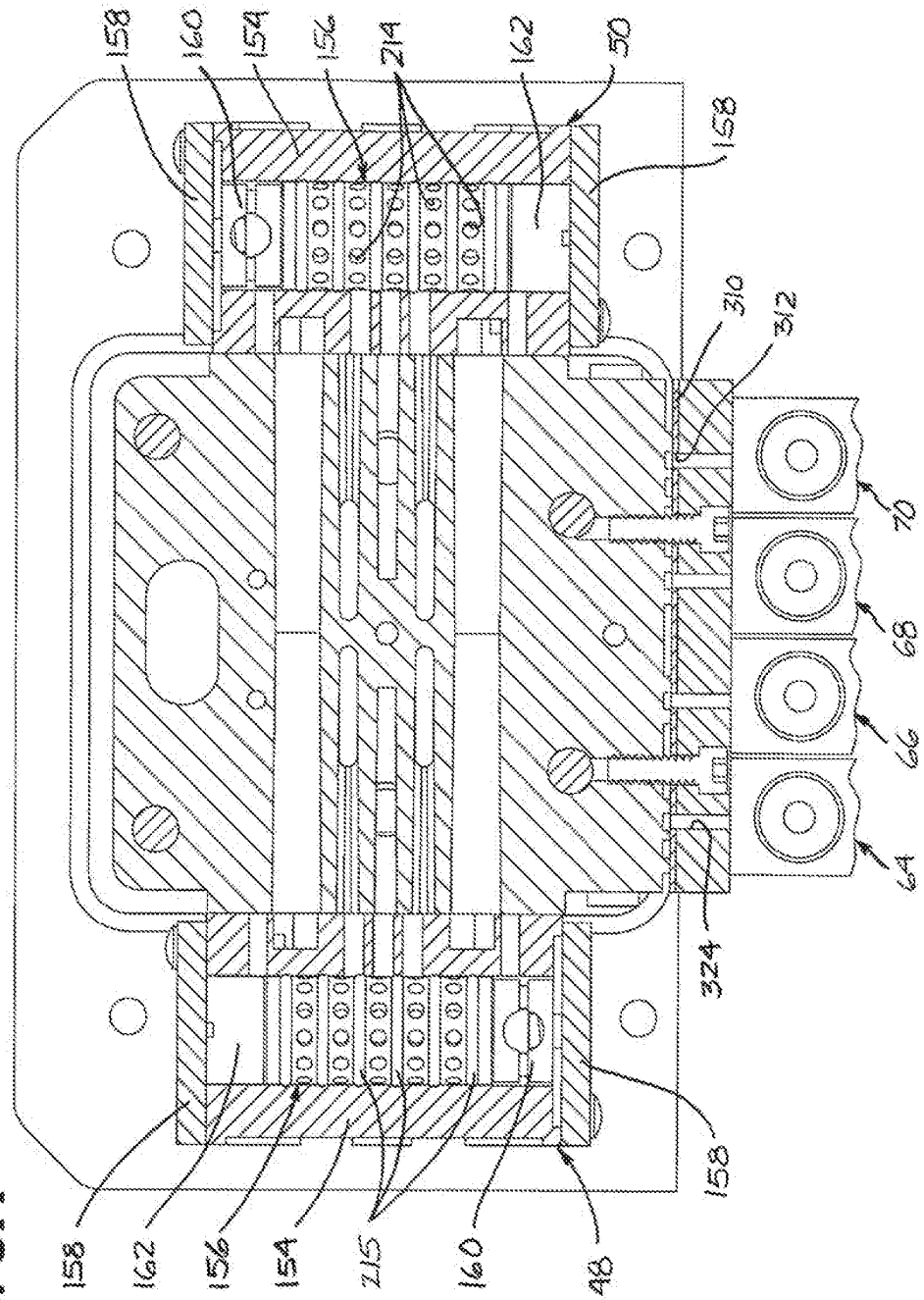

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214
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48

FIG. 6H

FIG. 7A

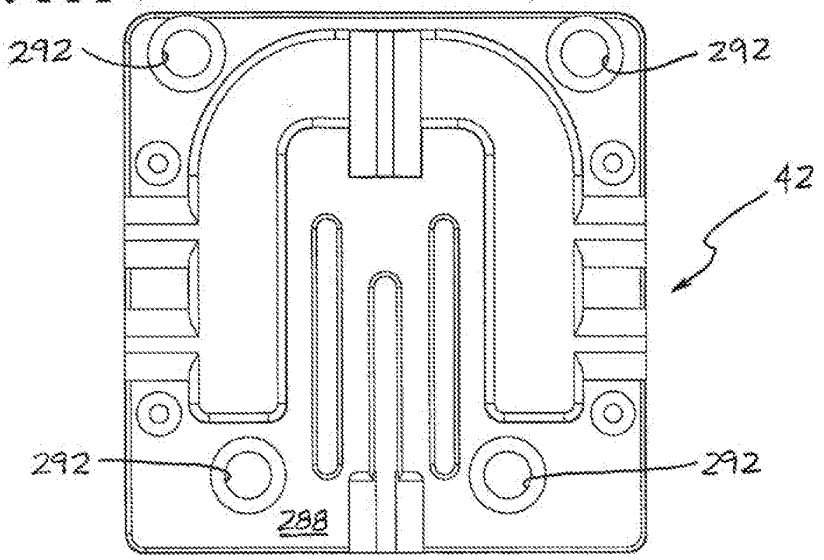


FIG. 7B

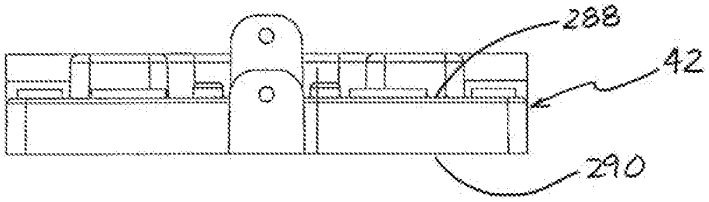


FIG. 7C

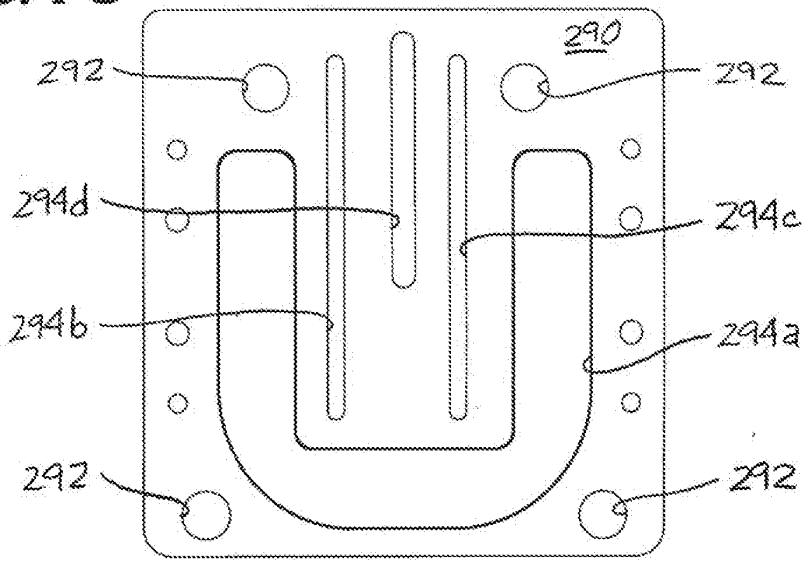


FIG. 8

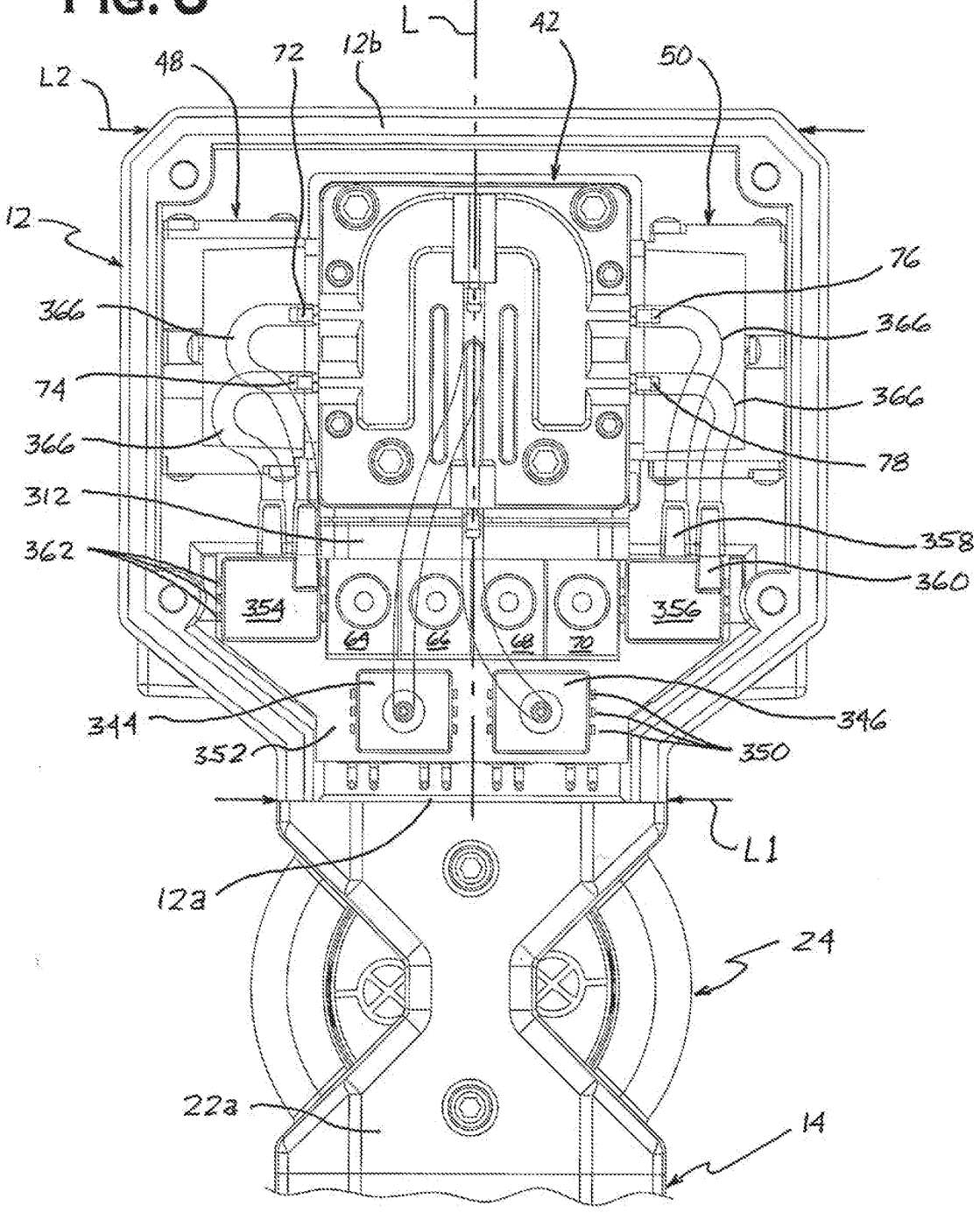
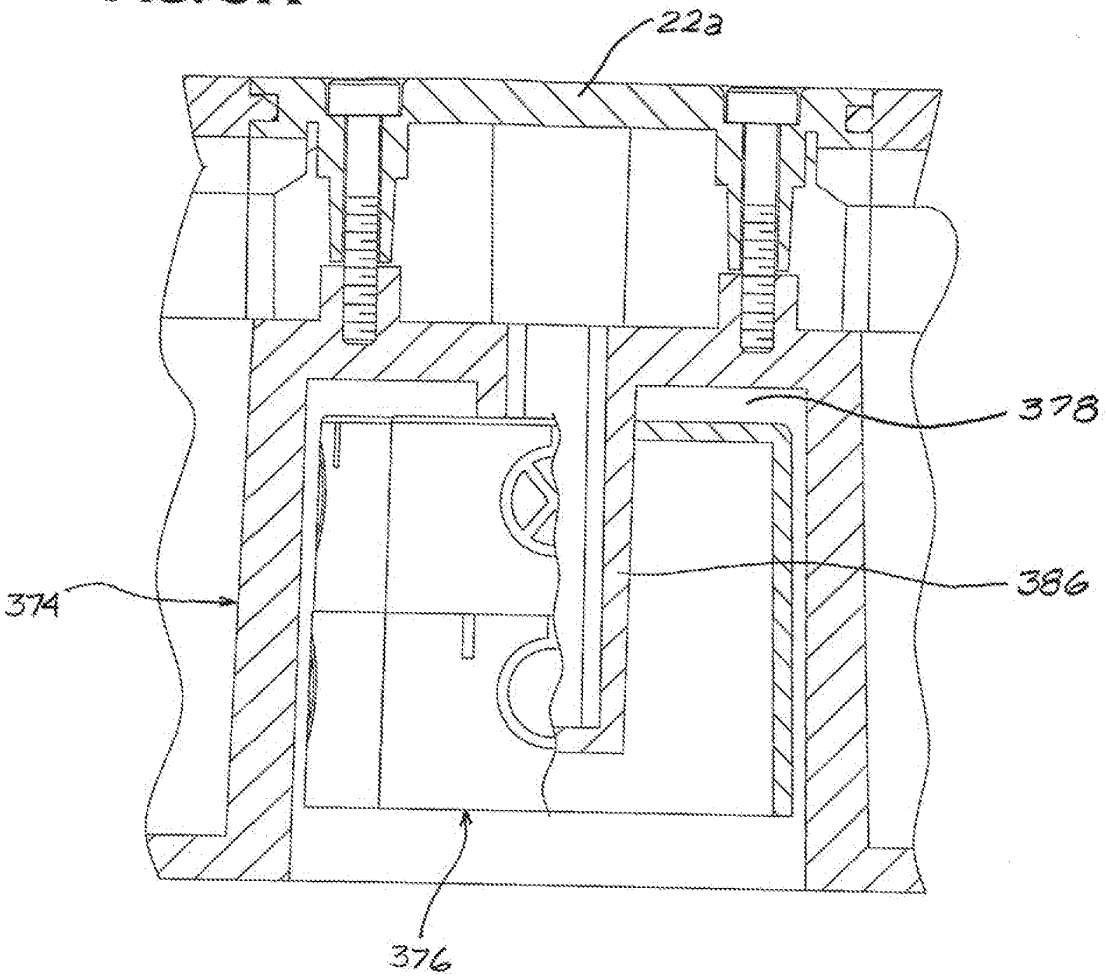

L
42
48
72
12b
50
L2
12
76
366
366
74
366
366
78
312
358
362
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64
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68
70
344
346
352
350
L1
12a
24
22a
14

FIG. 9A



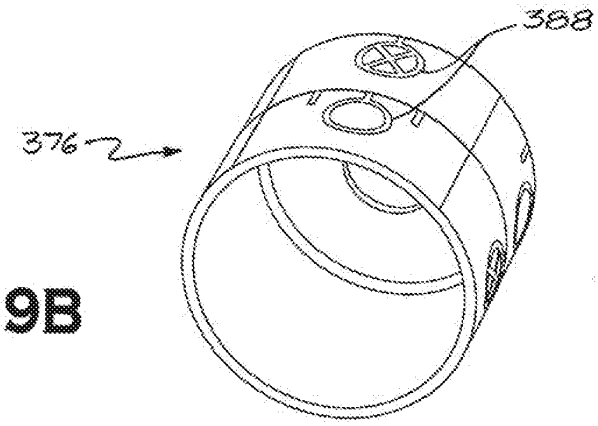


FIG. 9B

FIG. 10A

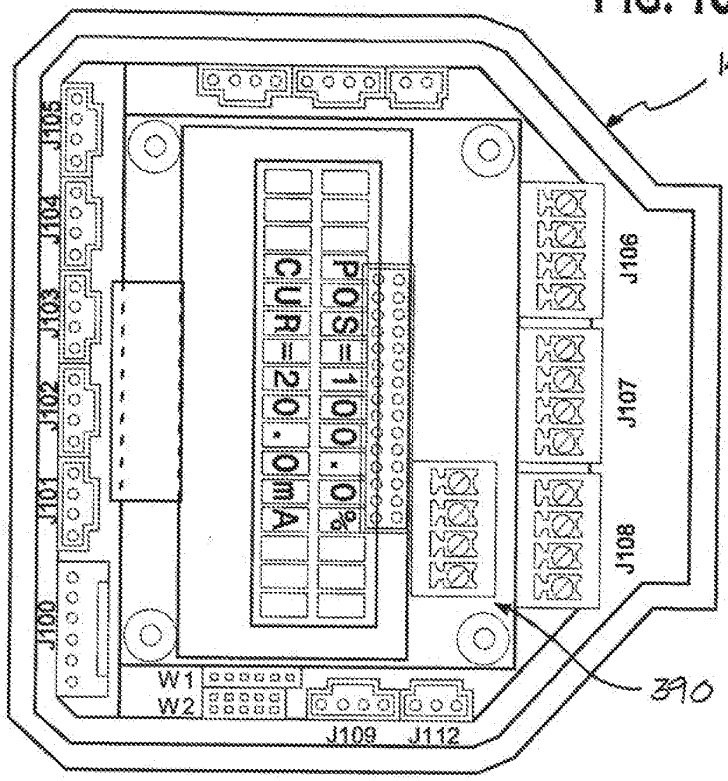
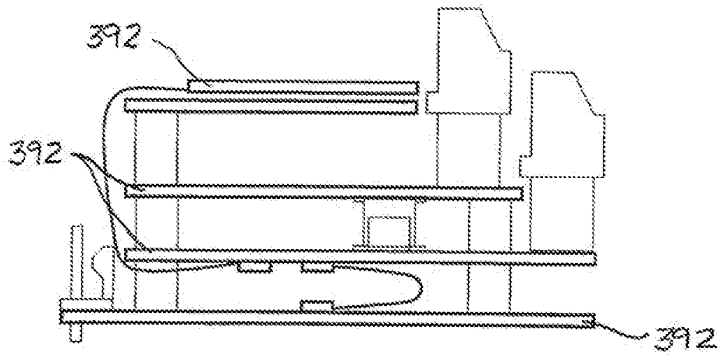


FIG. 10B



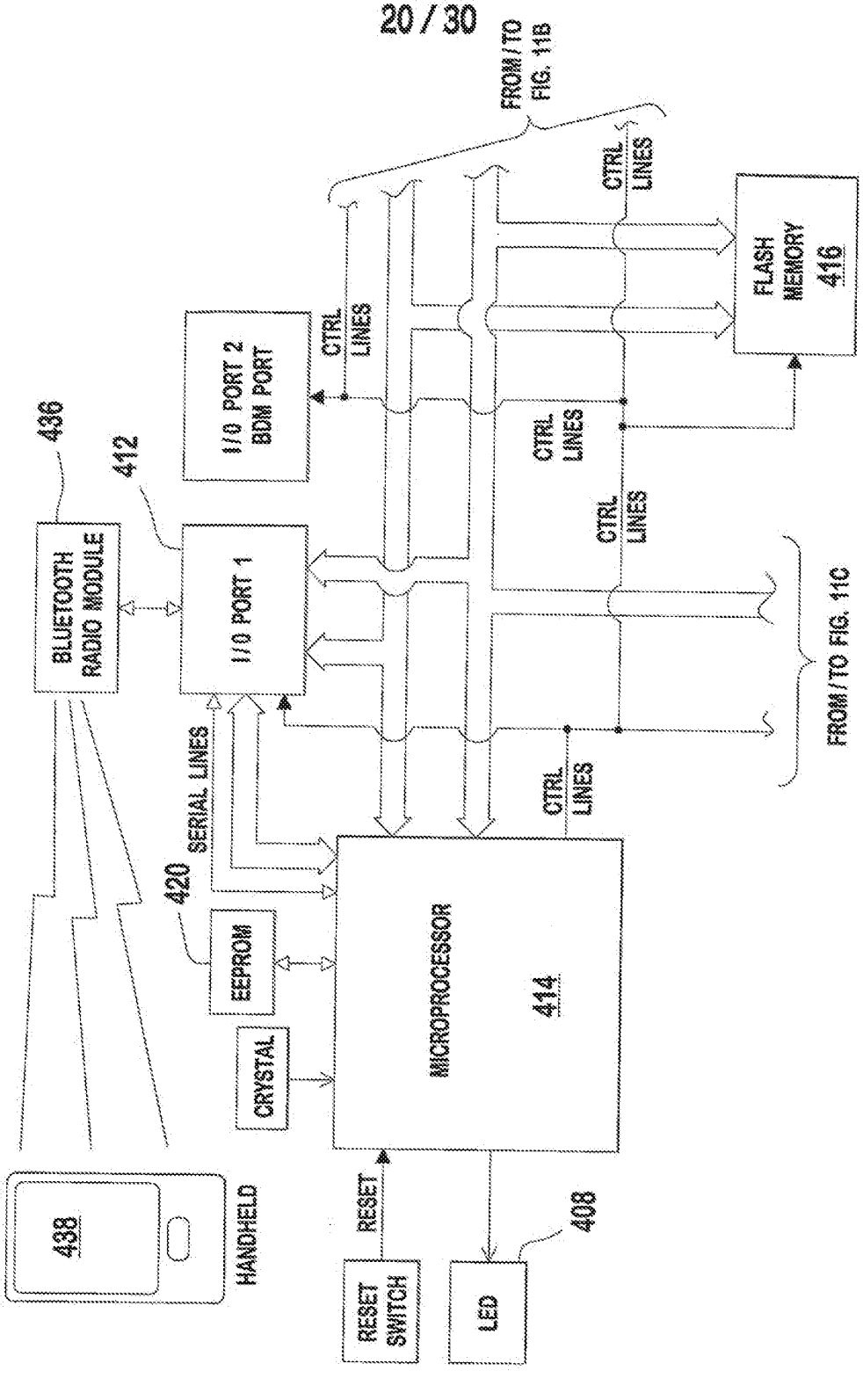
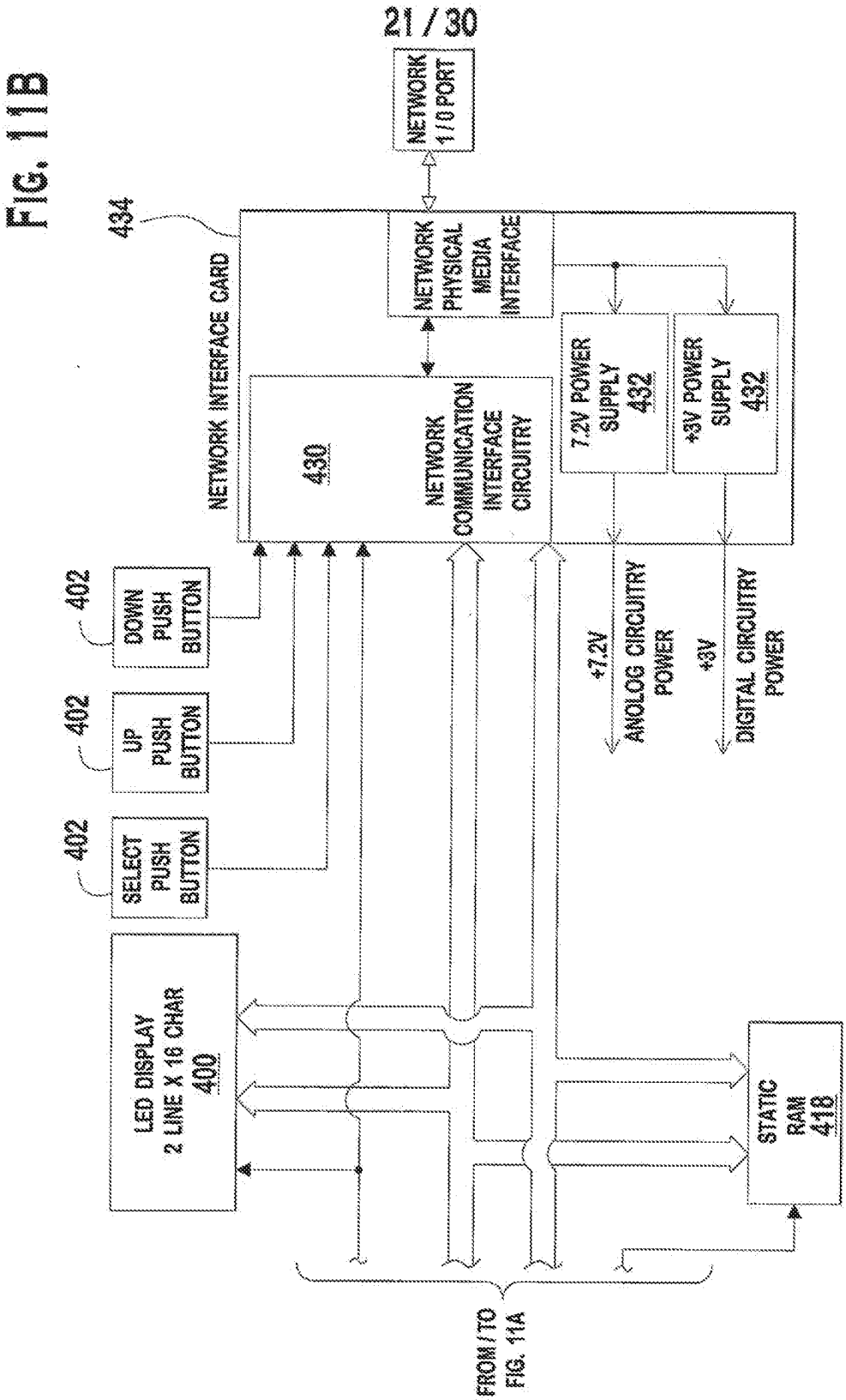

FROM / TO FIG. 11B
CTRL LINES
FLASH MEMORY 416
I/O PORT 2 BDM PORT
CTRL LINES
436
412
BLUETOOTH RADIO MODULE
I/O PORT 1
CTRL LINES
CTRL LINES
FROM / TO FIG. 11C
SERIAL LINES
CTRL LINES
420
EEPROM
CRYSTAL
MICROPROCESSOR 414
438
HANDHELD
RESET
RESET SWITCH
LED
408

FIG. 11A

FIG. 11B


NETWORK I/O PORT
434
NETWORK INTERFACE CARD
NETWORK PHYSICAL MEDIA INTERFACE
430
NETWORK COMMUNICATION INTERFACE CIRCUITRY
7.2V POWER SUPPLY 432
+3V POWER SUPPLY 432
402
DOWN PUSH BUTTON
402
UP PUSH BUTTON
402
SELECT PUSH BUTTON
+7.2V ANOLOG CIRCUITRY POWER
+3V DIGITAL CIRCUITRY POWER
LED DISPLAY 2 LINE X 16 CHAR 400
STATIC RAM 418
FROM / TO FIG. 11A

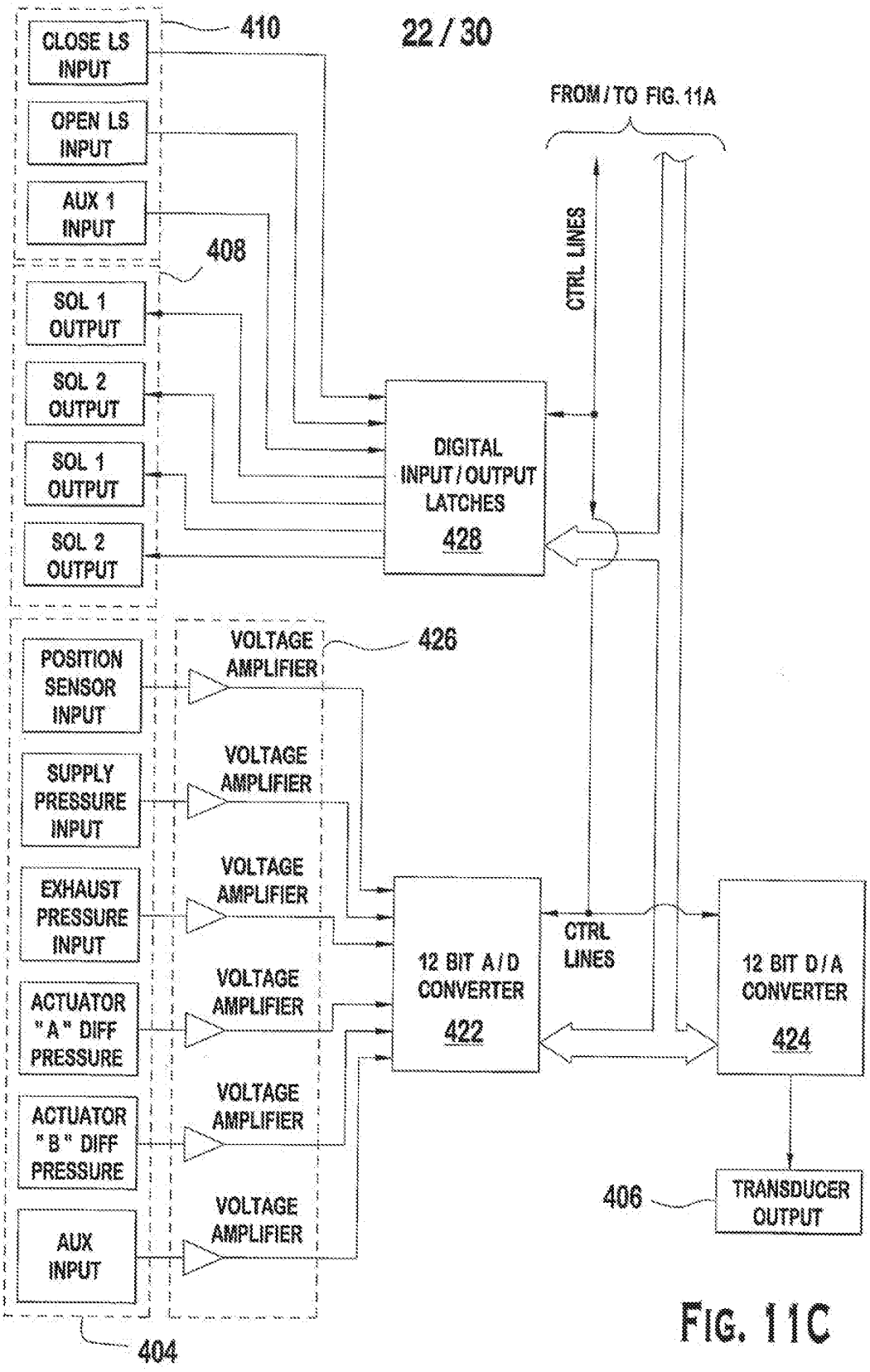

410
CLOSE LS INPUT
OPEN LS INPUT
AUX 1 INPUT
408
SOL 1 OUTPUT
SOL 2 OUTPUT
SOL 1 OUTPUT
SOL 2 OUTPUT
FROM / TO FIG. 11A
CTRL LINES
DIGITAL INPUT / OUTPUT LATCHES
428
426
VOLTAGE AMPLIFIER
POSITION SENSOR INPUT
SUPPLY PRESSURE INPUT
EXHAUST PRESSURE INPUT
ACTUATOR "A" DIFF PRESSURE
ACTUATOR "B" DIFF PRESSURE
AUX INPUT
12 BIT A / D CONVERTER
422
CTRL LINES
12 BIT D / A CONVERTER
424
406
TRANSDUCER OUTPUT
404

FIG. 11C

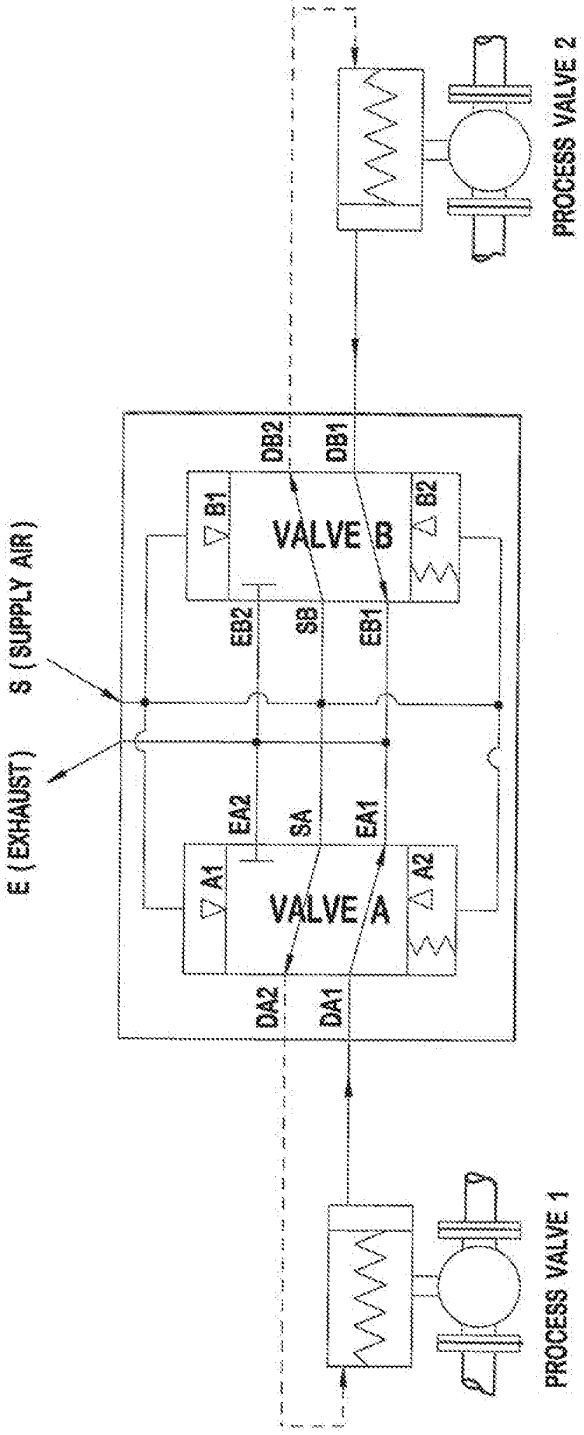
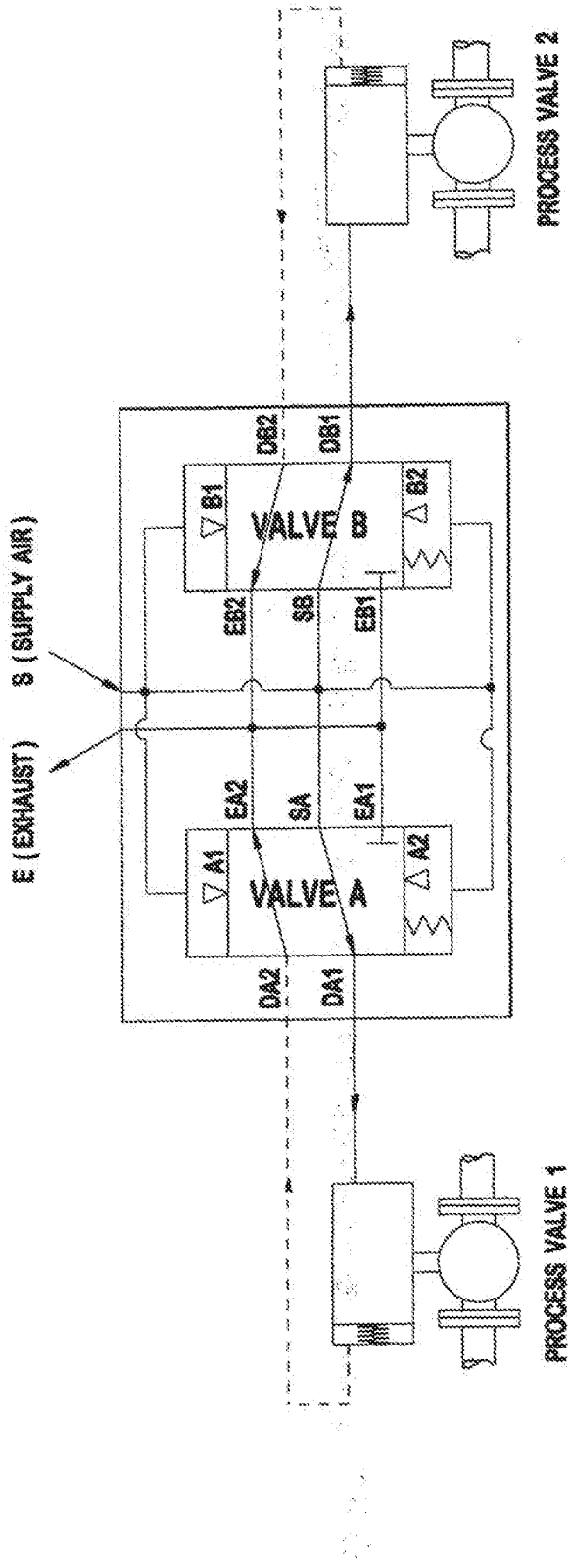
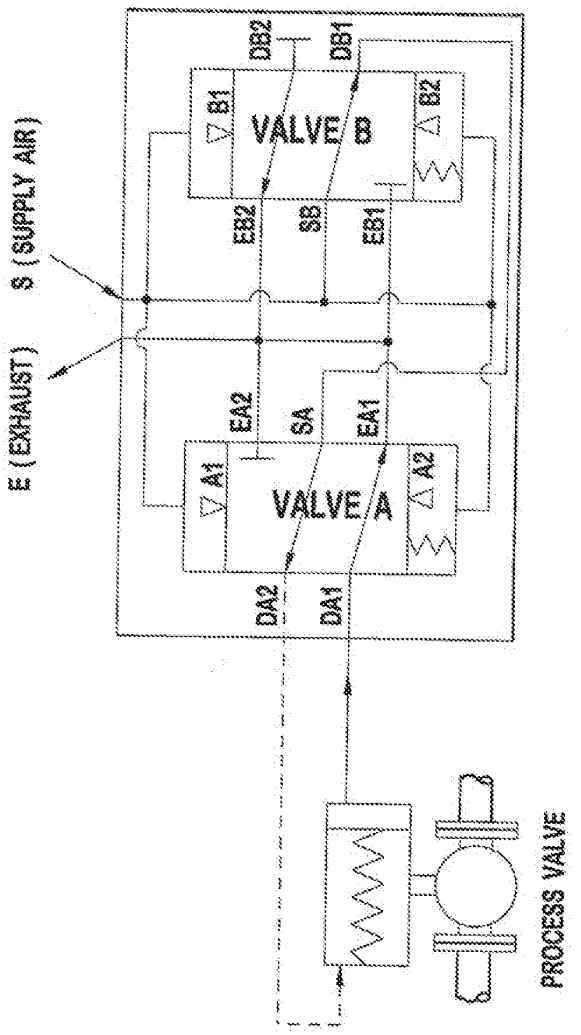

PROCESS VALVE 2
PROCESS VALVE 1
VALVE B
VALVE A
B1
B2
A1
A2
DB2
DB1
DA2
DA1
EB2
EB1
EA2
EA1
SB
SA
S (SUPPLY AIR)
E (EXHAUST)
PROCESS VALVES IN ZERO POSITION
VALVE A DE-ENERGIZED, VALVE B DE-ENERGIZED

FIG. 12A



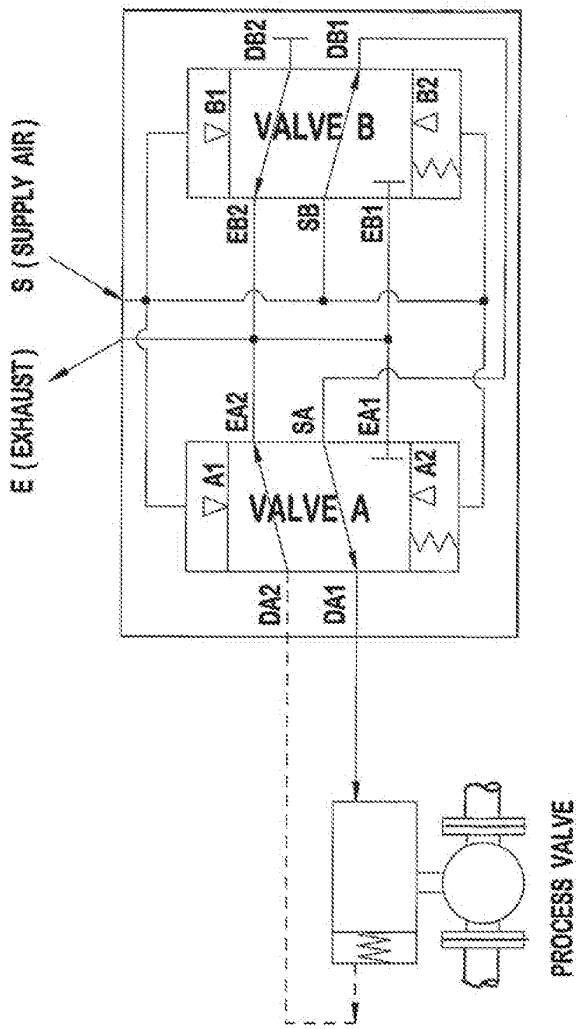
PROCESS VALVES IN SPAN POSITION
VALVE A ENERGIZED, VALVE B ENERGIZED

FIG. 12B



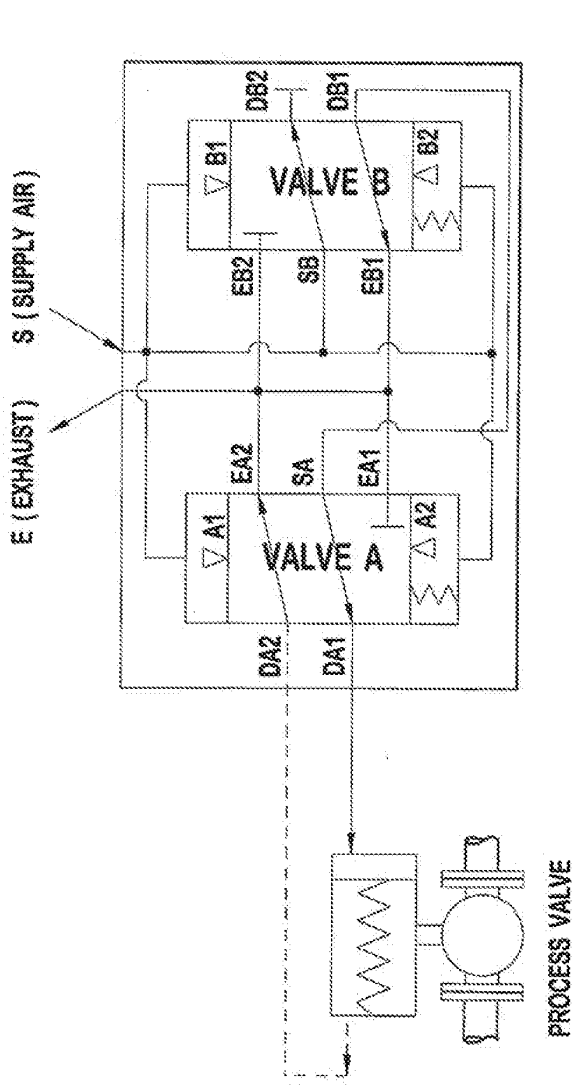
PROCESS VALVE IN ZERO POSITION
VALVE A DE - ENERGIZED , VALVE B ENERGIZED

FIG. 13A



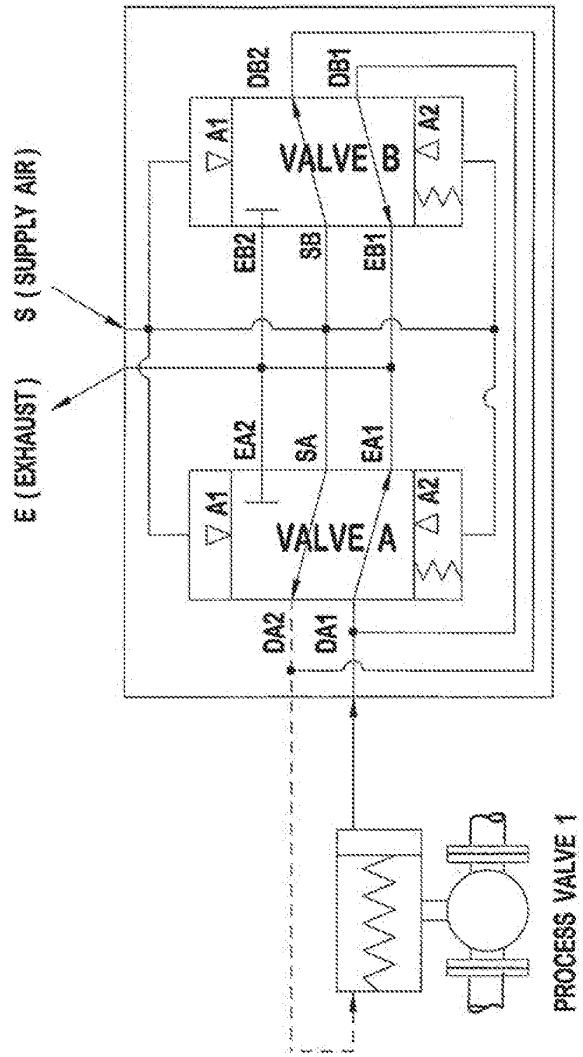
PROCESS VALVE IN SPAN POSITION
VALVE A ENERGIZED, VALVE B ENERGIZED

FIG. 13B



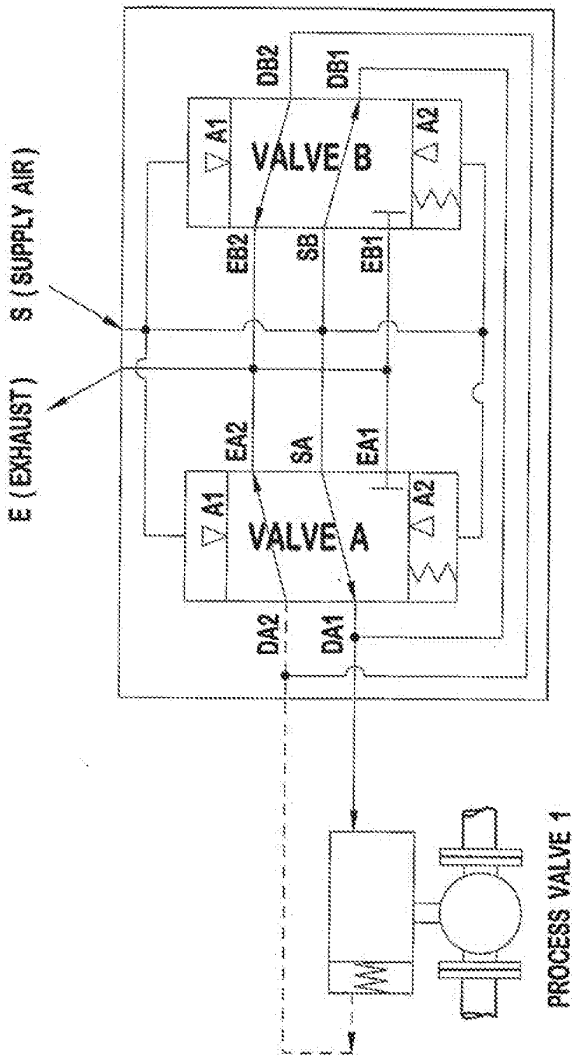
ESD / PARTIAL STROKE STATE
VALVE A ENERGIZED, VALVE B DE-ENERGIZED

FIG. 13C



PROCESS VALVES IN ZERO POSITION
VALVE A DE-ENERGIZED, VALVE B DE-ENERGIZED

FIG. 14A



PROCESS VALVES IN SPAN POSITION
VALVE A ENERGIZED, VALVE B ENERGIZED

FIG. 14B

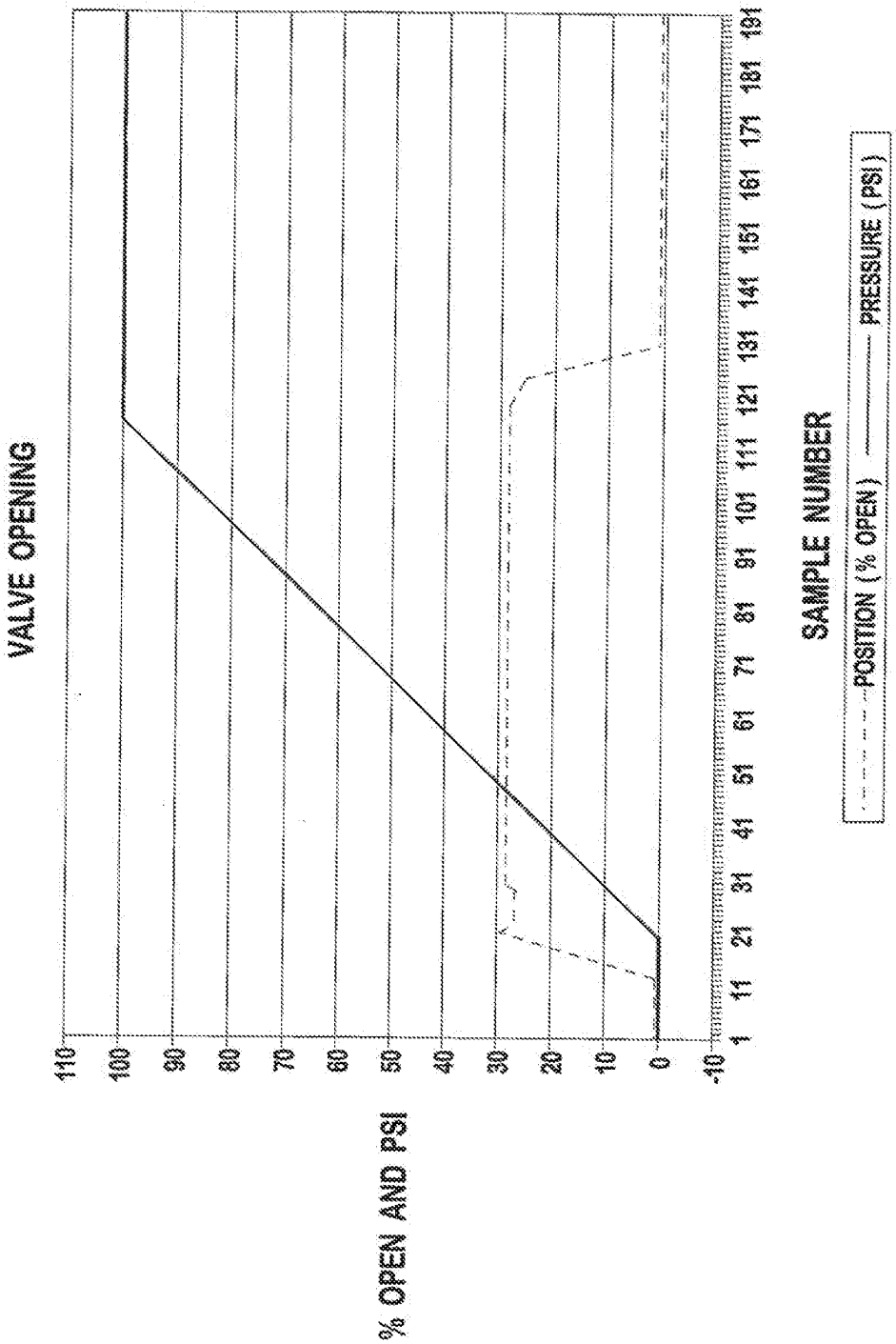

VALVE OPENING
% OPEN AND PSI
110
100
90
80
70
60
50
40
30
20
10
0
-10
1 11 21 31 41 51 61 71 81 91 101 111 121 131 141 151 161 171 181 191
SAMPLE NUMBER
POSITION (% OPEN)
PRESSURE (PSI)

FIG. 15

INTERNATIONAL SEARCH REPORT

International appli[illegible] No.
PCT/US04/11566

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7). : C07D 471/04; A61K 31/519
US CL. : 544/279; 514/264.11
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)
U.S. : 544/279; 514/264.11

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Fused Pyrimidines, Part Four

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	VICTORY, P. et al, New synthesis of pyrido[2,3-d]pyrimidines. V. Dehydrogenation of dihydropyridonic acid ring in 5- or 6-alkyl-substituted systems Afinidad, 1989, Vol. 46, No. 420, pages 107-13.	1-13
A	SCHOFFSTALL, A.M., Synthesis of 5,6-Dihydropyrido[2,3-d]pyrimidine derivatives directly from acyclic precursors	1-13

☐ 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 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
16 March 2005 (16.03.2005)	06 JUN 2005
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. (703) 305-3230	Authorized officer Thomas C. Mackenzie, Ph.D. Telephone No. (703) 308-1235

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/115

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

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

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

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

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

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

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: parts of claims 1-13

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(2)) (January 2004)

BOX III. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This application contains the following inventions or groups of inventions, which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) parts of 1-13, drawn to 2-amino-pyrido[2,3-d]pyrimidine-4,7(3H,8H)-dione compounds and compositions.

Group II, claim(s) parts of 1-13, drawn to 5-amino-thiazolo[4,5-d]pyrimidine-2,7(3H,6H)-dione compounds and compositions.

Group III, claim(s) parts of 1-13, drawn to 2-amino-3H-pyrrolo[2,3-d]pyrimidin-4(7H)-one compounds and compositions.

Group IV, claim(s) parts of 1-13, drawn to 2-amino-3H-pyrrolo[3,2-d]pyrimidin-4(5H)-one compounds and compositions.

Group V, claim(s) 14-32, drawn to nucleic acid compounds, compositions, and method of use.

Group VI, claim(s) 33-51, drawn to a second use of the nucleic acid compounds.

Group VII, claim(s) 52-63, drawn to treatment of viral infections with any IMPDH inhibitor.

Group VIII, claim(s) 64-82, drawn to treatment of cancer with any IMPDH inhibitor.

Group IX, claim(s) 83-100, drawn to treatment of autoimmune diseases with any IMPDH inhibitor.

Group X, claim(s) 101-111, drawn to treatment of tropical diseases with any IMPDH inhibitor.

Group XI, claim(s) 112 and 113, drawn to a second treatment of cancer.

Group XII, claim(s) 114 and 115, drawn to a second treatment of viral infection.

Group XIII, claim(s) 116 and 117, drawn to a second treatment of Autoimmune Diseases.

Group XIV, claim(s) 118, drawn to a treatment of Crohn's disease.

The inventions listed as Groups I-V do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the technical features of claim 1 are the four heterocyclic cores represented by the four different formulas. The technical feature of claim 14 is a nucleic acid, not present in claim 1.

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KLX - Exhibit No. 1011
Page 400

The inventions listed as Groups V and VI do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Applicants may have a single use of the compounds of claim 14 searched, not the two distinct uses they claim.

The inventions listed as Groups VII-XIV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: these claims do not require the compounds of claim 1 are drawn to separate uses of the IMPDH inhibitors.

Electronic Acknowledgement Receipt

EFS ID:	27117914
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
Filer Authorized By:	Jessie D. Herrera
Attorney Docket Number:	SAFO/0012USPC01
Receipt Date:	04-OCT-2016
Filing Date:	12-SEP-2016
Time Stamp:	15:09:23
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)	SAFO_0012USPC01_IDS.PDF	1037181 6bb6a6e46a0c18e183da69929e4491941a6ca814	no	10

Warnings:

Information:					
2	Foreign Reference	EP0647770A2.PDF	1219309 d72c72f79bebb53c419251ca09769a9fb1c27d0a	no	28
Warnings:					
Information:					
3	Foreign Reference	GB2391880.PDF	3368840 4361dbfa2e9a2ad20f0254747db2a6fbb4017b92	no	91
Warnings:					
Information:					
4	Foreign Reference	JP07042856.PDF	377335 d45b5b6ec976986b2aed1f76e0b1a59cd215ad93	no	7
Warnings:					
Information:					
5	Foreign Reference	WO0165061.PDF	1504234 f513d0a956b48d47d4e8ec6c6a345e76805bb855	no	31
Warnings:					
Information:					
6	Foreign Reference	WO0225612A1.PDF	851450 b88f51eab433f0cc6b4d3515e8de32a0b40a1140	no	26
Warnings:					
Information:					
7	Foreign Reference	WO2005097792.PDF	15342301 6afbc2c48242623ffa103150a7df2fed4f74e827	no	101
Warnings:					
Information:					
8	Non Patent Literature	ROTOWINK_INDICATORS.PDF	114564 78513be74fc1617108ab3095bf9e53c95401d69b	no	2
Warnings:					
Information:					

9	Non Patent Literature	VERSA_SERIE_SB_VALVES_BULLETIN.PDF	1446828 938c9c15f31ba394fbc5fbc83309579ac7aa4c73	no	8
Warnings:					
Information:					
			Total Files Size (in bytes):	25262042	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/262,642	09/12/2016	David LYMBEROPOULOS	FETI/0012USPC01

CONFIRMATION NO. 6248

26290
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

FORMALITIES LETTER

OC000000085962287

Date Mailed: 09/23/2016

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
- The application search fee must be submitted.
- The application examination fee must be submitted.
- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.
  The surcharge is due for any one of:
  - late submission of the basic filing fee, search fee, or examination fee,
  - late submission of inventor's oath or declaration,
  - filing an application that does not contain at least one claim on filing, or
  - submission of an application filed by reference to a previously filed application.

SUMMARY OF FEES DUE:

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. No entity status discount is in effect. If applicant is qualified for small entity status, a written assertion of small entity status must be submitted to establish small entity status. (See 37 CFR 1.27). If applicant is qualified for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- $ **280** basic filing fee.
- $ **140** surcharge.
- $ **600** search fee.
- $ **720** examination fee.
- $(**0**) previous unapplied payment amount.
- $ **1740** TOTAL FEE BALANCE DUE.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  David LYMBEROPOULOS
  Benjamin R. MATTHEWS

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web, including a copy of this Notice and selecting the document description "Applicant response to Pre-Exam Formalities Notice". https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/tnguyen/

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Page 406

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/262,642

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	18 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*				x 420 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1600

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/262,642	09/12/2016	3753	0.00	FETI/0012USPC01	18	2

CONFIRMATION NO. 6248

26290
PATTERSON & SHERIDAN, L.L.P.
24 Greenway Plaza, Suite 1600
Houston, TX 77046

FILING RECEIPT



Date Mailed: 09/23/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

David LYMBEROPOULOS, Houston, TX;
Benjamin R. MATTHEWS, Missouri City, TX;

Applicant(s)

SAFOCO, INC., Houston, TX;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/480,704 05/25/2012 PAT 9441453
which claims benefit of 61/551,319 10/25/2011

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 09/21/2016

KLX Energy Services LLC v. Safoco, Inc.
KLX - Exhibit No. 1011
Page 408

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/262,642**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
Title

SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

Preliminary Class

137

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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UNITED STATES PATENT APPLICATION FOR:

SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

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SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. Patent Application Serial No. 13/480,704, filed May 25, 2012, which claims benefit of U.S. Provisional Patent Application Serial No. 61/551,319, filed October 25, 2011 and is a continuation-in-part of co-pending U.S. Patent Application Serial No. 13/195,662, filed August 1, 2011, which claims benefit of U.S. Provisional Patent Application Serial No. 61/370,721, filed August 4, 2010, and U.S. Provisional Patent Application Serial No. 61/415,238, filed November 18, 2010, the disclosures of which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Embodiments of the invention relate to a wellhead control system for oil and gas wells. In particular, embodiments of the invention relate to systems and methods of an emergency shut down control system for surface and subsurface safety valves. Embodiments of the invention further relate to systems and methods of a relief valve control system.

Description of the Related Art

[0003] A wellhead system may be used to control the flow of fluids recovered from an oil and gas well in a safe and efficient manner. The wellhead system may include a variety of flow control devices, such as valves, which are operable direct fluid flow through a tubing system connected to the wellhead system. Fluids can be directed downstream of the wellhead system via the tubing system for further processing and/or storage.

[0004] The wellhead system may include surface and subsurface safety valves that are connected to the tubing system and are operable to shut off fluid flow

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through the tubing system in the event of an emergency in the well or at a location downstream of the wellhead system. Prior art safety valves are generally in fluid communication with the tubing system, and utilize the fluids therein for operation. For example, the pressure in the tubing system may be directly tied into the safety valves to actuate the valves into an open position, thereby allowing fluid flow through the system. In the event of an emergency, such as a rupture in the tubing system downstream of the safety valve or a drop in pressure in the well, as the pressure in the tubing system drops, so does the pressure in the safety valves. The safety valves are configured to move into a closed position after the pressure therein falls below a minimum pressure, thereby closing fluid flow through the tubing system and shutting in the wellhead system. Some safety valves may also be equipped with relief valves that are operable to block pressure from entering the valve and exhaust the pressure in the valve, thereby allowing the valve to move into a closed position.

[0005] There are numerous drawbacks to the prior art safety valve systems. One drawback includes the reliance of the safety valves on fluid pressure in the tubing system. These safety valves cannot be unilaterally operated as desired. Another drawback includes regular, manual maintenance of the safety valves to ensure that they are fully operational. Another drawback includes the potential pollution to the environment when fluid in the safety valves are exhausted into the atmosphere.

[0006] In some wellbore operations, such as when conducting a fracking operation, a high volume pressurized fluid is pumped to a manifold, which directs the fluid to one or more wells for fracturing the formation below. In the event that flow through the flow or fluid lines to the manifold and/or in the wells experience an interruption or become plugged, the highly pressurized fluid volume can cause catastrophic failure of the fluid lines, the wells, and any other equipment surrounding the wellsite, which can even potentially harm workers at the wellsite. Conventional relief valve systems are inefficient at detecting a failure, have slow response times, and/or are only one-time use, which require complete replacement in the event of operation.

[0007] Therefore, there is a need for a new and improved safety control valve system that is self reliant, can be remotely operated and monitored real-time, and can automatically shut in and/or relieve a wellhead system in the event of an emergency or when desired.

SUMMARY OF THE INVENTION

[0008] In one embodiment, a control system for controlling a safety valve attached to a flow line at a wellsite is provided. The control system includes a housing. The control system further includes a controller assembly disposed within the housing. The controller assembly is configured to receive a signal from a transducer connected to the flow line, wherein the signal corresponds to a measured physical property. Further, the control system includes a valve assembly disposed within the housing and in communication with the controller assembly. The control system further includes a compressor assembly disposed within the housing and in communication with the controller assembly. Additionally, the control system includes a power source disposed within the housing. The power source is configured to supply power to the controller assembly, the valve assembly, and the compressor assembly. The controller assembly is operable to cause the compressor assembly to supply pneumatic fluid to the safety valve to actuate the safety valve to an open position, wherein the controller assembly is operable to cause the valve assembly to actuate the safety valve to a closed position.

[0009] In one embodiment, a method for controlling a safety valve attached to a flow line at a wellsite is provided. The method includes the step of positioning a control system adjacent the safety valve. The control system has a controller assembly, a compressor assembly, and a power source disposed within a housing of the control system. The method further includes the step of supplying pneumatic fluid from the compressor assembly to the safety valve to open the safety valve. The method also includes the step of receiving a signal in the controller assembly corresponding to a sensed physical property in the flow line. Additionally, the method

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includes the step of closing the safety valve in response to a comparison of the sensed physical property to a pre-set condition.

[0010] In one embodiment, a control system for controlling a safety valve attached to a flow line at a wellsite may comprise a controller assembly configured to receive a signal from a transducer connected to the flow line, wherein the signal corresponds to a measured physical property; a valve assembly in communication with the controller assembly; and a fluid drive assembly in communication with the controller assembly, wherein the controller assembly is operable to actuate the fluid drive assembly to supply fluid to the safety valve to actuate the safety valve to a first position, and wherein the controller assembly is operable to actuate the valve assembly to actuate the safety valve to a second position.

[0011] In one embodiment, a method for controlling a safety valve attached to a flow line at a wellsite may comprise providing a control system for positioning adjacent to the safety valve, wherein the control system includes a housing, a controller assembly, a fluid drive assembly, and a valve assembly; supplying fluid to the safety valve using the fluid drive assembly to actuate the safety valve into a first position; monitoring a physical property in the flow line using the controller assembly; and actuating the valve assembly using the controller assembly to actuate the safety valve into a second position based upon a comparison of the monitored physical property to a predetermined condition.

[0012] In one embodiment, a method for controlling a safety valve attached to a flow line at a wellsite may comprise providing a remotely operable control system for positioning adjacent to the safety valve; actuating the safety valve into a closed position using the control system; monitoring fluid pressure in the flow line using a transducer in communication with the control system while maintaining the safety valve in the closed position; and actuating the safety valve into an open position using the control system when the monitored fluid pressure reaches or exceeds a predetermined fluid pressure to relieve fluid pressure in the flow line.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that the manner in which the above recited features of the invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0014] Figure 1 illustrates a wellhead control system according to one embodiment.

[0015] Figure 2 illustrates a safety valve control system according to one embodiment.

[0016] Figure 3 illustrates a surface safety valve according to one embodiment.

[0017] Figure 4 is a sectional view of a gate valve, an actuator, a mechanical override, and a safe mode indicator.

[0018] Figure 5 is a sectional view of the gate valve in an open position after a manual operation of the mechanical override.

[0019] Figure 6 is a sectional view of the gate valve in the open position after an automatic operation of the actuator and with the safe mode indicator indicating that the gate valve is operating in a safe mode.

[0020] Figure 7 is a sectional view of the gate valve in the open position after the automatic operation of the actuator, the mechanical override having been partially actuated, and the safe mode indicator indicating that the gate valve is not operating in the safe mode.

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[0021] Figure 8 is a cross-sectional view of the mechanical override along section line 8-8 in Figure 4.

[0022] Figure 9 is a sectional view of the gate valve in an open position after an automatic operation of the actuator.

[0023] Figures 10A-10H and 11-11D illustrate a valve assembly according to one embodiment.

[0024] Figure 12 is a sectional view of a valve in a fail-safe opened position.

[0025] Figure 13 illustrates a safety valve control system according to one embodiment.

[0026] Figure 14 illustrates a well control system according to one embodiment.

[0027] Figure 15 illustrates the well control system according to one embodiment.

DETAILED DESCRIPTION

[0028] Figure 1 illustrates a wellhead control system 100 of an oil/gas well according to one embodiment. The wellhead control system 100 is configured to control the recovery of fluids, such as hydrocarbons, from a reservoir through a primary wellbore 105. The wellhead control system 100 includes a tree 110 having a series of valve and flow control devices, a surface safety valve 120 in communication with the tree 100 via tubing 115, and a subsurface safety valve 130 in communication with the tree 100 via tubing 125. The subsurface safety valve 130 may also be in communication with a well production flow line 145 used to recover oil and/or gas from the oil/gas well. The surface safety valve 120 may also be in communication with a surface production flow line 135 used to direct any recovered fluids to one or more locations downstream of the wellhead control system 100 for further processing and/or storage. In one embodiment, the safety valves 120, 130 may include pneumatically or hydraulically actuated valves. In one embodiment, the safety valves 120, 130 may include pneumatic valves that are operated using hydraulic fluid. Each

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of the safety valves 120, 130 may include a self contained emergency shut down ("ESD") control system, identified as items 200, 300, and 700, respectively, that (1) may be operable to automatically close the safety valves 120, 130; (2) may be operable to be continuously monitored and/or operated (opened and closed) in real-time from a remote location; and (3) may be operable to verify at all times the operating condition/characteristics of the safety valves 120, 130, and various other components of the control system.

[0029] The ESD control systems 200, 300 may be "self-contained," which means that they do not depend on any external pneumatic, hydraulic, mechanical, or electrical sources for their operation to shut down the oil/gas well. For example, if there is a rupture of a production flow line downstream from the surface safety valve 120, and/or if there is a loss of well pressure at the subsurface safety valve 130, the ESD control systems 200, 300 are operable to effectively close the safety valves 120, 130, thereby shutting in the oil/gas well, and alert the appropriate personnel that a shut-in has occurred without the assistance of any additional external pneumatic, hydraulic, mechanical, or electrical power sources. All of the operating fluids and mechanisms necessary to operate the safety valves 120, 130 are maintained within the ESD control systems 200, 300 so that there is no pollution of the environment, and so that any fluids and/or gases from the oil/gas well may be effectively contained therein without any additional external dependencies.

[0030] Figure 2 illustrates the ESD control system 200 according to one embodiment. Embodiments of the ESD control system 200 described herein are equally applicable to the ESD control system 300 (and vice versa). The ESD control system 200 may include a housing 210 for supporting a controller assembly 220, a power source 230, a pump assembly 240, a fluid reservoir 250, a valve assembly 260, and a solar panel assembly 270. The ESD control system 200 may also include one or more transducers/devices 280, 282, 284, 286, and 288 for monitoring and/or measuring one or more physical properties (further described below). In embodiment, the ESD control system 200 may be configured to control one or more

valves, such as flow control valves or choke valves, that are in communication with the flow lines of the valves 120, 130 to control fluid flow through the wellhead control system 100

[0031] The housing 210 may include any structural support member, such as an explosion-proof container, for protecting the components stored therein from damage and environmental elements. Appropriate ventilation of the housing 210 may be provided by ventilation holes and/or an independent solar powered fan mounted in or through the housing 210. The housing 210 may further include an access panel or door for ease of access to the housing's interior, and may be configured for attachment to the tree 110 or the respective surface and subsurface safety valve 120, 130. One or more manifold assembles 212, 214, 216 may be provided on the housing 210 for fluid and/or electrical connections between the housing 210 (and the components within the housing 210) and the safety valves 120, 130, the solar panel assembly 270, and the transducer 280. In one embodiment, the manifold assembly 216 includes a solar converting charger device. In one embodiment, the structural components of the ESD control systems 200, 300, to the extent possible, may be made from stainless steel.

[0032] The controller assembly 220 may be disposed in the housing 210 and may include a microprocessor unit 222, a display screen 224, and a keypad 226. In one embodiment, the controller assembly 220 may be weather-proof, and may be intrinsically safe to provide power as necessary to one or more components of the ESD control systems 200, 300. In one embodiment, the controller assembly 220 may be positioned external to and/or adjacent to the housing 210. The microprocessor unit 222 may include a programmable logic controller, including a supervisory control and data acquisition system (SCADA) that is in communication with the one or more transducers/devices 280, 282, 284, 286, and 288, as well as the pump and valve assemblies 240, 260. The microprocessor unit 222 may include a current regulator to provide low current transmission between the controller assembly 220 and the various components of the control system. A watchdog sensor 228 may be used to

monitor the operation of the microprocessor unit 222 and provide an alarm in the event of a failure. The controller assembly 220 may be operable to send and receive signals with a computer system 150 (such as a desktop computer, laptop computer, or personal digital assistant (PDA)) at a remote location from the wellhead control system 100. In one embodiment, the signals may be sent and/or received between the controller assembly 220 and the computer system 150 via wired and/or wireless telemetry means, including but not limited to electrical wires, fiber optical cables, radio frequency, infrared, microwave, satellite, and/or laser light communication. In this manner, the ESD control systems 200, 300, 700 can be monitored and operated remotely from one or more locations on-site or off-site relative to the wellhead control system 100. In one embodiment, the ESD control systems 200, 300, 700 may be configured for manual and/or remote operation on-site at the wellhead control system 100. In one embodiment, the controller assembly 220 may be programmed with one or more trigger points, such as upstream and/or downstream high and/or lower pressure points, that will automatically trigger operation of the ESD control system 200, 700 upon sensing a pressure outside of the trigger point ranges. In one embodiment, the controller assembly 220 may be configured with a “master/slave” polling protocol or a “master/master” polling protocol as known in the art to retrieve and communicate information regarding the ESD control system 200, 700 as desired.

[0033] In one embodiment, the controller assembly 220 may be in communication with a pressure transducer 280 that is connected to the surface production flow line 135 as illustrated in Figure 1. The pressure transducer 280 can measure the pressure in the flow line 135 and communicate a signal corresponding to the measured pressure to the controller assembly 220. The pressure transducer 280 can be connected at various other locations within the wellhead control system 100, such as at the tree 110 or the tubing 115, 125. In one embodiment, the transducer 280 can be used to measure fluid flow rate or detect hydrogen sulfide. In one embodiment, one or more transducers 280 may be used to measure and/or detect additional well characteristics at the wellhead control system 100 and communicate the measured/detected well characteristics to the controller assembly 220 via a signal

corresponding to the measurement or detection for comparison to one or more predetermined conditions.

[0034] Regarding the pressure transducer 280, the signal may be recorded and/or communicated to the computer system 150 via the controller assembly 220 to provide real-time monitoring of the pressure in the flow line 135. The measured pressure may be displayed on the display screen 224 and/or on a display screen of the computer system 150. In response to the measured pressure, the controller assembly 220 may be configured to operate the respective safety valve 120, 130 to which it is connected. For example, the controller assembly 220 may be used to direct the pump assembly 240 and the valve assembly 260 to supply fluid from the fluid reservoir 250 to the surface safety valve 120 to open the valve. Upon receiving the signal from the controller assembly 220, the valve assembly 260 may be configured to open a circuit defined by lines 211, 213, 215 between the surface safety valve 120 and the fluid reservoir 250 to allow the pump assembly 240 to direct pressurized fluid from the fluid reservoir 250 to the surface safety valve 120, thereby opening the surface safety valve 120. The surface safety valve 120 may be maintained in the open position while the pressure transducer 280 continuously monitors the pressure in the flow line 135. The controller assembly 220 may be programmed to close the surface safety valve 120 upon receiving a signal from the pressure transducer 280 that corresponds to a pressure measurement that is greater than or less than a predetermined condition, such as a pre-set pressure range. The pre-set pressure range may be input into the controller assembly 220 by manual entry using the keypad 226 and the display screen 224. The pre-set pressure range may also be input into the controller assembly 220 remotely from the computer system 150. When the signal is received from the pressure transducer 280 that the pressure in the flow line 135 falls outside of the pre-set pressure range stored in the microprocessor unit 222, the controller assembly 220 may automatically direct the valve assembly 260 and/or the pump assembly 240 to return the fluid from the surface safety valve 120 to the fluid reservoir 250. Upon receiving the signal from the controller assembly 220, the valve assembly 260 may be configured to open a circuit

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defined by lines 211, 217 between the surface safety valve 120 and the fluid reservoir 250 to allow the pressurized fluid to dump into the fluid reservoir 250, thereby closing the surface safety valve 120. In one embodiment, a closing pressure generated by the surface safety valve 120 may be used to force the fluid into the fluid reservoir 250. Continuous real-time monitoring of the pressure in the flow line 135 may be used to verify that the surface safety valve 120 has been closed.

[0035] The ESD control systems 200, 300, 700 may be adjusted at anytime and can be configured to shut in the wellhead control system 100 at anytime manually and/or remotely. In particular, the microprocessor unit 222 can be programmed with one or more pre-set conditions, manually using the display screen 224 and keypad 226 and/or remotely via the computer system 150. The pre-set conditions may be changed at anytime. And when a signal is received from one or more of the various transducers/devices and/or the computer system 150 that conflicts with the pre-set conditions when compared, the controller assembly 220 may be operable to automatically close the safety valve 120, 130 to which it is connected. The controller assembly 220 may be operable when the signal is above the pre-set condition or when the signal is below the pre-set condition. Continuous real-time monitoring of the ESD control systems 200, 300, 700 may be used to verify the operating condition/characteristics of the wellhead control system 100 components at all times.

[0036] In one embodiment, the ESD control systems 200, 300, 700 may communicate an auditory, visual, or other similar type of sensory signal that the wellhead control system 100 has been shut in. In one embodiment, the controller assembly 220 may send a signal to the computer system 150 that can be converted into an alarm to alert an operator of the shut-in. In one embodiment, the controller assembly 220 may send a signal to trigger an indication device 282, such as an auditory and/or visual alarm disposed interior or exterior of the housing 120, to alert an operator within close proximity of the wellhead control system 100 of the shut-in.

[0037] In one embodiment, the ESD control systems 200, 300, 700 may include an emergency shutdown device 284 manually and/or remotely operable to

automatically give an alarm and send a signal to the controller assembly 220 to shut in the wellhead control system 100. In one embodiment, the ESD control systems 200, 300, 700 may include a fire device 286 that senses heat, and automatically gives an alarm and shuts in the wellhead control system 100 via the controller assembly 220 when the measured heat exceeds a certain temperature. In one embodiment, the ESD control systems 200, 300, 700 may include an anti-intrusion device 288 that when activated automatically gives an alarm and shuts in the wellhead control system 100 via the controller assembly 220, for example when a theft is attempted or the control system sustains some type of structural damage. In one embodiment, one or more of the transducers 282, 284, 286, 288 may be used to detect hydrogen sulfide (H2S), other gases and vapors, and/or the level of fluid in one or more storage tanks that are in fluid communication with the valves 120, 130. Each of the devices 284, 286, 288 may be continuously monitored real-time using the controller assembly 220 via the computer system 150 to verify operating conditions/characteristics of the wellhead control system 100.

[0038] Power may be provided to the controller assembly 220 and the pump assembly 240 from the power source 230. The power source 230 may be operable to provide a low current (amp) stream to the controller assembly 220 and/or the pump assembly 240. In one embodiment, the power source 230 may include an intrinsically-safe battery, such as a 12 or 24 volt, direct current, explosion-proof power supply. In one embodiment, the power source 230 may include a watchdog sensor 232 to communicate to the computer system 150 via the controller assembly 220 a failure of the power source. The watchdog sensor 232 may also give an auditory or visual alarm to alert an operator onsite that the power source 230 is low and/or dead. The controller assembly 220 may be configured to automatically shut in the wellhead control system 100 upon receiving a signal from the sensor 232. In one embodiment, the power source 230 may be a (re-chargeable) power supply that is supported by the solar panel assembly 270. The solar panel assembly 270 may include one or more solar panels 272 connected to the exterior of the housing 210 to consume light energy from the sun to generate electricity. The solar panels 272 may

be connected to the exterior of a housing 730 in the ESD control system 700. An intrinsically safe voltage controller 274 may deliver electrical current at an appropriate voltage, 12 or 24 volts for example, to the power source 230, which in turn supplies power to the controller assembly 220 and/or pump assembly 240. In one embodiment, the solar panel assembly 270 may be configured to provide enough power to the ESD control systems 200, 300, 700 to open and close the safety valves 120, 130 ten or more times from about two hours of sunlight per day.

[0039] In one embodiment, the pump (or fluid drive) assembly 240 may include an intrinsically safe motor 242 and a pump 244, which may each be located in the explosion-proof housing 210. The pump 244 may include a rotary piston pump with about a 100 to 10,000 psi range. The pump assembly 240 may pump pneumatic and/or hydraulic fluid from the fluid reservoir 250 to actuate the safety valve 120, 130 to which it is connected.

[0040] In one embodiment, the fluid reservoir 250 may be configured to store an amount of operating fluid sufficient to actuate the safety valve 120, 130 to which it is connected. The operating fluid may include air, water, propylene glycol, and other valve operating fluids known in the art. In one embodiment, the fluid reservoir 250 may include a level gauge 252, such as a sight glass, to indicate the level of fluid in the fluid reservoir 250. The fluid reservoir may also include a level sensor 252 that is in communication with the controller assembly 220 and is operable to monitor in real-time the level of fluid in the fluid reservoir 250. In the event that the level of fluid falls below a pre-set limit, due to evaporation of the fluid for example, the level sensor 252 may provide an alarm to alert an operator on-site at the wellhead control system 100 and/or at the remote location via the controller assembly 220 and the computer system 150. The controller assembly 220 may automatically shut in the wellhead control system 100 upon receiving a signal from the level sensor 252.

[0041] In one embodiment, the valve assembly 260 may include one or more (intrinsically safe) valves 262 to control and direct communication between the pump assembly 240, the fluid reservoir 250, and the safety valve 120, 130 to which it is

connected. The one or more valves 262 may include solenoid valves, shuttle valves, and/or any other type of valves operable to open and close the fluid circuits between the pump assembly 240, the fluid reservoir 250, and the safety valve 120, 130 to which it is connected. The valve assembly 260 may include an internal relief valve and/or circuit to rapidly expel the fluid from the safety valves 120, 130 to the fluid reservoir 250 to ensure quick closure of the safety valves 120, 130. The valve assembly 260 may include one or more gauges, such as pressure gauge 264, which can be visually inspected to monitor the pressure in the valve assembly 260 flow lines. In one embodiment, the pressure gauge 264 may be configured to shut off the pump assembly 240 when the pressure in the actuator of the safety valves 120, 130 reaches a pre-determined pressure setting. The one or more valves 262 may be controlled by the controller assembly 220 as described above.

[0042] In one embodiment, the display screen 224 and/or one or more gauges may be mounted through a front panel of the housing 210, 730 to indicate pressure within the various valves and lines in fluid communication with the ESD control systems 200, 300, 700 and the wellhead control system 100.

[0043] Figure 3 illustrates a surface safety valve 120 according to one embodiment. The surface safety valve 120 may include a valve actuator 122 for moving a gate valve 124 between an open and closed position. Pressurized fluid from the fluid reservoir 250 of the ESD control system 200 or pressurized fluid from the ESD control system 700 may be supplied to a chamber 123 of the valve actuator 122 via tubing 201 to open the gate valve 124. A biasing member 127, such as a spring disposed within the valve actuator 122 may be used to close the gate valve 124 when the force of the biasing member exceeds the fluid pressure in the valve actuator chamber 123. The valve actuator 122 may also include a top shaft 126 that can be used to manually actuate the valve actuator 122 by rotation of a hand wheel 128 to open and close the gate valve 124. The top shaft 126 may also be used as a visual indication to determine whether the gate valve 120 is in an open or closed position. For example, when the top shaft 126 is fully extended outward from the

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upper end of the valve actuator 122, the gate valve 124 may be in a closed position, and when the top shaft 126 is retracted into the upper end of the valve actuator 122, the gate valve 124 may be in an open position.

[0044] In one embodiment, the ESD control systems 200, 300, 700 may include a position indication assembly 290 that is operable to indicate whether the surface safety valve 120 is in an open or closed position, including any partial open/closed position therebetween, based on the location of the top shaft 126. As illustrated in Figure 3, when the top shaft 126 is in a fully extended position, the surface safety valve 120 is in the closed position. As the surface safety valve 120 begins to open and is moved either manually or automatically to the open position, the top shaft 126 will retract into the upper end of the valve actuator 122. The position indication assembly 290 may include one or more sensors 292 operable to sense the extension and retraction of the top shaft 126. The sensors 292 may communicate a signal to the controller assembly 220 corresponding to the measured position, which may then send a signal to the computer system 150 and display the measured position on a display screen. In this manner, an operator can continuously monitor and verify the position of the surface safety valve 120 at all times. The position indication assembly 290 can also be used to verify that the surface safety valve 120 is closed in the event that one of the other ESD control system 200, 700 components initiated a shut-in of the wellhead control system 100. In one embodiment, the sensors 292 may include magnetic sensors operable to sense a magnetic material of the top shaft 126. For example, one or more sensors 292 may be positioned at various locations along the longitudinal stroke of the top shaft 160 during opening and closing of the gate valve 124. When the top shaft 160 is fully extended, all of the sensors 292 may sense the magnetic material of the shaft, thereby indicating that the gate valve 124 is closed. However, when the top shaft 160 is fully retracted, only the sensors 292 closest to the upper end of the valve actuator 122 may sense the magnetic material of the shaft, thereby indicating that the gate valve 124 is open. In one embodiment, the sensors 292 may include other types of position sensors known in the art to monitor and measure the position of the top shaft 126.

[0045] In one embodiment, the ESD control system 200, 300, 700 can be used to partially stroke the safety valves 120, 130. In one embodiment, the controller assembly 220 may be configured to direct the pump assembly 240 and valve assembly 260 to supply an amount of operating fluid to the safety valves 120, 130 to partially open the safety valves. In one embodiment, the controller assembly 220 may be configured to direct the pump assembly 240 and valve assembly 260 to return an amount of operating fluid from the safety valves 120, 130 to partially close the safety valves. The controller assembly 220 may be programmed to automatically conduct a partial stroke of the safety valves 120, 130 after a pre-set amount of time or other condition. The controller assembly 220 may be manually and/or remotely operable to conduct a partial stroking of the safety valve to which it is connected when desired. The sensors 292 of the position indication assembly 290 can be used to monitor and verify the partial stroke of the safety valves 120, 130, based on the position of the top shaft 126. The partial stroking of the safety valves 120, 130 can assist in preventing/removing build-up of debris within the valves from the fluids flowing therethrough, which can potentially prevent complete opening and/or closing of the valves when necessary.

[0046] In one embodiment, the ESD control systems 200, 300, 700 may be configured to perform a specific sequential opening and closing of the safety valves 120, 130 when starting up or shutting in the wellhead control system 100. In one embodiment, either ESD control system 200, 300, 700 may initiate closure or opening of the surface safety valve first 120, and then closure or opening of the subsurface safety valve 130. In one embodiment, either ESD control system 200, 300, 700 may initiate closure or opening of the subsurface safety valve first 130, and then closure or opening of the surface safety valve 120. In one embodiment, if one of the ESD control system 200, 700 components initiates a shut-in, the controller assembly 220 may automatically send a signal to the computer system 150, which may then automatically send a signal to the controller assembly of the ESD system 300 to initiate closing of the subsurface safety valve 130. After closure of the subsurface safety valve 130 is verified by the ESD control system 300 via the

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computer system 150, another signal may be sent to the ESD control system 200, 700 to then initiate closing of the surface safety valve 120. The reverse process may be performed beginning with the ESD control system 300 if closure of the surface safety valve 120 is required prior to closure of the subsurface safety valve 130.

[0047] In one embodiment, a method for controlling a wellhead control system having a plurality of valves, including a surface safety valve and a subsurface safety valve, may include producing power with solar panel assembly and delivering the produced power to a controller assembly and to a pump assembly that supplies operating fluid to the valves, the control assembly operable to monitor a variety of conditions in an oil/gas well and at the wellhead control system. The controller assembly may be used to control the operation of the pump assembly and the valves manually, remotely, automatically, and/or in response to one or more pre-set conditions programmed in the controller assembly. The solar panel assembly may provide to a power source or directly to a pump assembly to operate a motor of the pump assembly, which in turn operates a pump of the pump assembly. The motor may be controlled by the controller assembly. The controller assembly may include a microprocessor and its related apparatuses, circuits, devices, switches, etc. The power produced by the solar panel assembly may be stored in a power source, such as in one or more battery apparatuses for use on demand. The use and flow of the stored power may be controlled and/or monitored by the controller assembly. The pump assembly may supply operating fluid (hydraulic and/or pneumatic) at a low or high pressure to operate either of both of the safety valves as directed by the controller assembly. The pre-set condition may include a fluid flow parameter, a flow line condition, an alarm, an emergency condition, and/or an intrusion of the components of the wellhead control system, including the valves and the controller assembly.

[0048] The voltages of power from the solar panel assembly may be controlled with a voltage controller having a sensor provide an alert signal, an alarm signal, and/or a shut-off signal if a pre-set voltage is exceeded or is not provided. One or

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more sensors may be provided to sense an amount and/or pressure of available operating fluid in any or all of the flow lines used and/or in a fluid reservoir, the sensor(s) providing a signal to indicate fluid volume and/or fluid pressure to the controller assembly. In response to the signal, the controller assembly may operate one or more of the valves and/or shut in the wellhead control system. The controller assembly may signal other devices, such as the pump assembly or a valve assembly to increase fluid pressure and/or fluid amount in some or all of the flow lines. A sensor may signal the controller assembly when a fire is detected and provide a fire alarm. The controller assembly may provide a fire alarm signal to a remote location and/or operate the valves to shut in the wellhead control system. The signals of alarm, intrusion, etc. may be provided at the immediate area of the wellhead control system and to a remote location via known transmission methods.

[0049] The controller assembly may be operable to monitor the various components of the wellhead control system and employing intrinsically safe components. A single controller assembly may be operable to control a surface safety valve, a subsurface safety valve, as well as one or more additional valves in communication with the wellhead control system. The controller assembly may be operable to control the subsurface safety valve with an electric submersible pump. The controller assembly may be operable to remotely shut in the wellhead control system using switches interconnected therewith, telephone, radio, SCADA, DCS and/or satellite signals. One or more sensors may be use to detect dangerous gases in the oil/gas well and/or at the wellhead control system and producing an alarm signal in response. A thermoelectric generator may be used instead of or in addition to a solar panel assembly. The pre-set condition(s) may include one or more of the following: the presence of fire or dangerous gases, intrusion by unwanted humans or animals, vandalism, damage, or destruction of equipment used in the wellhead control system, or too low to too high fluid pressures, fluid volumes, power amperages, or power voltages. In one embodiment, that various components of the control system may be weather proof and “intrinsically safe,” i.e. that they require

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vastly reduced power levels and therefore minimize the risk of sparks and explosions, e.g. less than 100 milliamps.

[0050] Figure 4 is a sectional view of a mechanical override 400, an actuator 401, a gate valve 402, and a safe mode indicator 403. The actuator 401 couples to a valve body 404 of the gate valve 402. A bonnet assembly can provide an interface between the gate valve 402 and the actuator 401. During an automatic operation of the gate valve 402, hydraulic or pneumatic pressure enters a chamber 406 of the actuator 401 defined by a cover 408 of the actuator 401 and a diaphragm 410 positioned over an operator member 412. The operator member 412 moves in response to the hydraulic or pneumatic pressure within the chamber 406 and against a biasing force supplied by a spring 418. A valve stem 414 coupled to a sliding gate 416 of the gate valve 402 moves in response to the movement of the operator member 412. In this manner, the automatic operation of the actuator 401 moves the sliding gate 416 of the gate valve 402 between a closed position shown in Figure 4 and an open position as shown in Figure 6.

[0051] In one embodiment, the actuator 401 may be selected from the pneumatic and hydraulic actuators described in detail in U.S. Patent No. 6,450,477 which is herein incorporated by reference in its entirety. The actuator 401 may be selected from any other actuator known in the industry for moving the sliding gate 416 of the gate valve 402 between the open and closed positions by automatic operation.

[0052] When using the automatic operation of the actuator 401, the biasing force of the spring 418 is configured to act as a fail-safe mechanism. When the pressure in the actuator 401 is removed, inadvertently or otherwise, the spring 418 will move the gate valve 402 into a fail-safe closed position illustrated in Figure 4 or a fail-safe opened position illustrated in Figure 12. Although the mechanical override 400 may provide an additional means to actuate the gate valve 402 in the event of a failure, such as a loss of pressure, it may also override the fail-safe mechanism. The mechanical override 400 may prevent the spring 418 from moving the gate valve 402 into the fail-safe closed position or the fail-safe opened position. The gate valve 402

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is operating in a safe mode when the fail-safe mechanism has not been overridden by the mechanical override and is not prevented or inhibited from moving into the fail-safe closed position or the fail-safe opened position. Therefore, the safe mode indicator 403 is configured to provide a signal, such as a visual indication, communicating to a valve operator that the valve is or is not operating in the safe mode. The signal from the safe mode indicator 403 may also communicate that (1) the valve will move to the fail-safe closed position or the fail-safe opened position in the event of a pressure loss in the actuator, (2) the valve has been automatically actuated into the open position, and/or (3) the mechanical override will not disable or interfere with the fail-safe mechanism.

[0053] As illustrated in Figure 4, the mechanical override 400 is connected to the actuator 401 to provide a manual operation for moving the sliding gate 416 between open and closed positions. The mechanical override 400 includes a top shaft 460, a lever for manual rotation of the top shaft 460, such as a handwheel 500, a housing 450 having a longitudinal bore therethrough, a drive sleeve 504 rotationally locked to the housing 450, and a top seal cartridge 550. The housing 450 passes through an aperture 452 in the cover 408 of the actuator 401. A shoulder 454 formed by a portion of the housing 450 with an increased outer diameter provides a stop for positioning the housing 450 in the aperture 452 of the cover 408. The housing 450 may be secured to the cover 408 by any known means such as a thread or by welding.

[0054] The housing 450 includes an upper bore 509, an inner shoulder 511, a top bore 510, and a bottom bore 512. The inner shoulder 511 is disposed below the upper bore 509, the top bore 510 is disposed below the inner shoulder 511, and the bottom bore 512 is disposed below the top bore 510. The bottom bore 512 has an inner diameter greater than the top bore 510. A tapered shoulder 515 is located at the interface between the top bore 510 and the bottom bore 512.

[0055] The top seal cartridge 550 is disposed in the upper bore 509 and can be removed for replacement as a single unit without disassembling the actuator 401 or

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the mechanical override 400. The top seal cartridge 550 is preferably formed of a plastic-like material such as Delrin and is held in place by at least one retainer ring 552 which is preferably stainless steel. Accessibility to the retainer ring 552 without disassembly of the actuator 401 permits removal of the retainer ring 552 from the top of the housing 450, thereby allowing removal and replacement of the top seal cartridge 550. The top seal cartridge 550 contains dual reciprocating top shaft seals 556 and dual static seals 558 to ensure seal integrity and long life. The top seal cartridge 550 incorporates rod wiper 554 to keep a shaft sealing region therebelow clean of dirt, grease, and other contaminants for longer life of the top shaft seals 556. The rod wiper 554 is preferably made from Molythane 90. These and other seals may be T-seals or other substantially elastomeric seals, such as O-ring seals.

[0056] The top shaft 460 extends through the longitudinal bore of the housing 450, the top seal cartridge 550, and the drive sleeve 504. The inner diameter of the inner shoulder 511 is greater than the outer diameter of the top shaft 460, but smaller than the outer diameter of the drive sleeve 504. The inner shoulder 511 permits axial movement of the top shaft 460 therethrough while providing a backstop for the drive sleeve 504. The top shaft 460 may also include a shoulder configured to engage an upper shoulder of the drive sleeve 504 to prevent removal of the top shaft 460 from the upper end of the drive sleeve 504.

[0057] The drive sleeve 504 is disposed in the housing 450 and is movable within the top bore 510 and the bottom bore 512. The drive sleeve 504 includes a threaded bore 516 that corresponds with a drive thread 514 on an outside surface of the top shaft 460. In one embodiment, the drive thread 514 is an Acme thread capable of functioning under loads and includes a small number of threads per inch, such as five, in order to decrease the work required to manually operate the actuator 401. The drive thread 514 permits unassisted rotation of the top shaft 460 with the handwheel 500. The threaded engagement permits relative axial movement between the top shaft 460 and the drive sleeve 504 within the housing 450. The outer diameter of the upper portion of the drive sleeve 504 is substantially the same

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as the inner diameter of the top bore 510 of the housing 450. One or more seals 518, such as o-rings, are provided on the outer diameter of the upper portion of the drive sleeve 504 to form a sealed engagement with the top bore 510 of the housing 450. One or more seals 519, such as o-rings, are provided on the inner diameter of the upper portion of the drive sleeve 504 to form a sealed engagement with the top shaft 460.

[0058] In one embodiment, the lower end of the drive sleeve 504 is configured to move axially relative to the bottom bore 512 of the housing 450 while being rotationally locked relative to the housing 450. Any known rotational locking assembly that prevents rotation of the drive sleeve 504 while permitting the drive sleeve 504 (and the top shaft 460) to move axially within the housing 450 during the automatic operation of the actuator 401 may be used. Figure 8 illustrates a new rotational locking assembly by showing one embodiment of a cross-section at sectional line 8-8 in Figure 4. Figure 8 illustrates the outer diameter of the lower end of the drive sleeve 504 having an oval shape that corresponds to an oval shape of the inner diameter of the housing 450. The oval shaped diameters provide a physical interference that rotationally locks the drive sleeve 504 to the housing 450 without inhibiting axial movement of the drive sleeve 504 relative to the housing 450. The outer diameter of the drive sleeve 504 and the bore of the housing 450 may be formed in a number of ways known by one of ordinary skill in the art to prevent relative rotational movement while permitting relative axial movement. In one embodiment, the lower portion of the drive sleeve 504 may have one or more splines that extend into one or more corresponding longitudinal grooves formed in the bottom bore 512 of the housing 450 to permit relative axial movement but prevent relative rotational movement. In one embodiment, the lower portion of the drive sleeve 504 may be keyed to the bottom bore 512 with a pin that extends through corresponding longitudinal grooves in the drive sleeve 504 and the bottom bore 512.

[0059] A coupling assembly 458 prevents longitudinal separation between a retaining nut 462 secured to the operator member 412 and the top shaft 460 while

isolating rotational movement of the top shaft 460 from the actuator 401 and the gate valve 402. The coupling assembly 458 includes a female coupler 464 and ball bearings 468. The lower end of the top shaft 460 rotates around the upper end of the retaining nut 462 and against the ball bearings 468. A bottom shoulder 472 on the top shaft 460 is secured against the ball bearings 468, which are positioned on the upper end of the retaining nut 462, by the female coupler 464. The female coupler 464 is connected to the upper end of the retaining nut 462 and includes an upper shoulder that engages the bottom shoulder 472 of the top shaft 460 to prevent separation of the shaft from the retaining nut 462 and thus the actuator 401 and the gate valve 402. The top shaft 460 freely rotates relative to the retaining nut 462 and eliminates the transmission of torque to the valve stem 414, the sliding gate 416, and/or components of the actuator 401 when using the mechanical override 400.

[0060] Embodiments of the invention do not require the coupling assembly connecting the top shaft 460 with the operator member 412. The top shaft 460 of the mechanical override 400 may contact and apply force directly to a portion of the actuator 401, such as the retaining nut 462 or the operator member 412 depending on the type of actuator used. For example, the end of the top shaft 460 may directly contact the upper end of the retaining nut 462. The solid retaining nut 462 may include a separate locking device to prevent the retaining nut 462 from unthreading from the operator member 412 since the top shaft 460 rotates during the manual operation of the mechanical override 400. Alternatively, other known rotation isolation means may be provided to prevent transference of the rotation of the top shaft 460 to other components within the actuator 401 and the gate valve 402.

[0061] Referring to Figure 6, a chamber 610 is formed within the housing 450 between the top seal cartridge 550 and the drive sleeve 504. The chamber 610 is sealed at an upper end by the engagement between the top seal cartridge 550, the upper bore 509, and the top shaft 460, and at a lower end by the engagement between the drive sleeve 504, the top bore 510, and the top shaft 460. Fluid communication may be established between the chamber 610 and the actuator 401

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when the drive sleeve 504 is moved into the bottom bore 512, as shown in Figure 6. In particular, the seals 518 of the drive sleeve 504 are moved across the tapered shoulder 515 into the bottom bore 512, thereby releasing the sealed engagement with the top bore 510. When the drive sleeve 504 is located in the bottom bore 512 and fluid communication is established between the chamber 610 and the actuator 401, the gate valve 402 is operating in the safe mode. When the gate valve 402 is operating in the safe mode, the valve may be moved to the fail-safe closed position (shown in Figure 4) or the fail-safe opened position (shown in Figure 12) by the fail-safe mechanism without interference from the mechanical override 400.

[0062] The safe mode indicator 403 communicates to a valve operator when the valve is operating in the safe mode. The safe mode indicator 403 includes an indication device 600, such as a sensor, that is connected to the housing 450. The indication device 600 is in fluid communication with the chamber 610 via an orifice 615 located through the housing 450. The pressure in the chamber 610 may be used to actuate the indication device 600 to communicate a signal to the valve operator.

[0063] In one embodiment, when the chamber 610 is at a first pressure, the indication device 600 may communicate a first signal to the valve operator to indicate that the valve is not operating in the safe mode. When the chamber 610 is at a second pressure that is different than the first pressure, the indication device 600 may communicate a second signal that is different than the first signal to the valve operator to indicate that the valve is operating in the safe mode. The pressure in the chamber 610 may be the pressure directed into the actuator 401 when fluid communication is established between the chamber 610 and the actuator 401, as shown in Figure 6. The pressure in the chamber 610 is communicated to the indication device 600 through the orifice 615 to actuate the indication device 600. In one embodiment, the first and/or second pressures may be in a range from about 0 PSI to about 80 PSI, 150 PSI, or greater. In one embodiment, the first and/or second

signals may be a visual indication, such as a colored light or marker, an auditory indication, and any other type of signal known to one of ordinary skill.

[0064] In one embodiment, the indication device 600 may be any commercial sensor, such as a pressure sensor, that can be used to indicate a pressure change in the chamber 610. In one embodiment, the indication device 600 may be a Rotowink Indicator, commercially available through Norgen Ltd. The Rotowink Indicator is a spring-loaded device actuated by air pressure for use in visual monitoring of pneumatic or fluidic circuits. The device uses two contrasting colors (e.g. black, red, yellow, green) on a rotating ball that can be viewed from any angle to indicate the presence or absence of pressure.

[0065] The operation of the invention illustrated in Figures 4, 5, 6, 7, 12 will now be described. Figure 4 illustrates the gate valve 402 in the fail-safe closed position. The spring 418 provides a force configured to bias the valve stem 414, the operator member 412, the top shaft 460, and the drive sleeve 504 in an upward direction, thereby positioning the sliding gate 416 in the closed position. Seating of the sliding gate 416 in the closed position limits the upward axial movement of the top shaft 460 and the drive sleeve 504. The mechanical override 400 is in an un-actuated position and does not interfere with the closing of the gate valve 402. The bias of the spring 418 raises the top shaft 460 to an extended position providing a visual indication that the gate valve 402 is in the closed position. The safe mode indicator 403 may provide a first visual indication that the gate valve 402 is not automatically actuated into the operating safe mode and/or the chamber 610 is not pressurized or has experienced a pressure change.

[0066] Figure 12 illustrates the gate valve 402 in the fail-safe opened position. The spring 418 provides a force configured to bias the valve stem 414, the operator member 412, the top shaft 460, and the drive sleeve 504 in an upward direction, thereby positioning the sliding gate 416 in the opened position. Seating of the sliding gate 416 in the opened position limits the upward axial movement of the top shaft 460 and the drive sleeve 504. The mechanical override 400 is in an un-actuated

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position and does not interfere with the opening of the gate valve 402. The bias of the spring 418 raises the top shaft 460 to an extended position providing a visual indication that the gate valve 402 is in the opened position. The safe mode indicator 403 may provide a first visual indication that the gate valve 402 is not automatically actuated into the operating safe mode and/or the chamber 610 is not pressurized or has experienced a pressure change.

[0067] Figure 5 illustrates the gate valve 402 in an open position after a manual operation of the actuator 401 using the mechanical override 400. To move the sliding gate 416 to the open position using the mechanical override 400, the valve operator manually turns the handwheel 500 to provide rotation to the top shaft 460. Rotation of the handwheel 500 rotates the top shaft 460 to advance the top shaft 460 through the drive sleeve 504 across the length of the drive thread 514. As the top shaft 460 rotates, the top shaft 460 advances through the drive sleeve 504 until the upper portion of the drive thread 514 is located at the lower portion of the threaded bore 516 of the drive sleeve 504. During the manual operation, the inner shoulder 511 provides the backstop that prevents the drive sleeve 504 from moving relative to the housing 450. The manual rotation of the handwheel 500 mechanically advances the top shaft 460 through the housing 450 to either directly or indirectly axially move the valve stem 414 to place the gate valve 402 in the open position. The top shaft 460 is mechanically driven against the bias of the spring 418, thereby compressing the spring 418. The top shaft 460 lowers during the manual operation to a retracted position and provides a visual indication that the gate valve 402 is in the open position. The valve operator may also check the safe mode indicator 403 to determine whether the gate valve 402 is operating in the safe mode. The pressure in the chamber 610 should not have significantly changed between the operation of the gate valve 402 from the fail-safe closed position, shown in Figure 4, to the open position by manual operation, shown in Figure 5. Thus, the safe mode indicator 403 communicates the same first visual indication to the valve operator, which has not changed by the mechanical operation of the gate valve 402. The safe mode indicator 403 may therefore indicate that the gate valve 402 is not operating in the safe mode,

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has not been automatically actuated, has been actuated (at least partially) using the mechanical override 400, and/or may be prevented from moving into the fail-safe closed position or the fail-safe opened position.

[0068] Figure 6 illustrates the gate valve 402 in the open position after an automatic operation of the actuator 401. Pressure is directed into the chamber 406 of the actuator 401 to overcome the bias of spring 418 and advance the top shaft 460, the drive sleeve 504, the operator member 412, and the valve stem 414 in a downward direction to position the sliding gate 416 into the open position. The top shaft 460 and the drive sleeve 504 are moved together axially within the bore of the housing 450 until the seals 518 on the drive sleeve 504 are moved across the tapered shoulder 515 and into the bottom bore 512. Fluid communication is established between the chamber 610 and the chamber 406. The pressure in the chamber 406 is communicated to the indication device 600 via the orifice 615, thereby actuating the indication device 600. The pressure change in the chamber 610 actuates the safe mode indicator 403 to communicate a second visual indication that is different than the first visual indication. Since the top shaft 460 also lowers during the automatic operation to the retracted position and provides a visual indication that the gate valve 402 is in the open position, the valve operator may use the safe mode indicator 403 to determine whether the gate valve 402 is operating in the safe mode. The second visual indication may therefore indicate that the gate valve 402 is operating in the safe mode, has not been mechanically actuated, has been automatically actuated, and/or will move into the fail-safe closed position or the fail-safe opened position upon release of pressure in the actuator 401. When operating in the safe mode, the upper end of the drive sleeve 504 is located at least a distance X from the inner shoulder 511 of the housing 450. In this position, the mechanical override 400 will not disable or interfere with the fail safe mechanism. When the pressure in the actuator 401 is released, the drive sleeve 504 is located a sufficient distance from the inner shoulder 511 so as not to limit upward axial movement of the top shaft 460 and thus the valve stem 414 and the sliding gate 416.

In this manner, the sliding gate 416 may move into the fail-safe closed position or the fail-safe opened position.

[0069] Figure 7 illustrates the gate valve 402 in an open position after an automatic operation of the actuator 401 and a partial operation of the mechanical override 400. Before and/or after automatic actuation of the gate valve 402, the mechanical override 400 may be actuated at least partially, inadvertently or otherwise. If the handwheel 500 has been rotated one or more times, the top shaft 460 and the drive sleeve 504 will move relative to each other in an offset position illustrated in Figure 7. When in the offset position and if the valve is automatically actuated, then the upper end of the drive sleeve 504 may be positioned a distance Y from the inner shoulder 511, which would prevent the gate valve 402 from moving to the fail-safe closed position or the fail-safe opened position. In one embodiment, the distance Y may be any distance that is less than the distance X identified in Figure 6. When the pressure in the actuator 401 is released, the upper end of the drive sleeve 504 would backstop on the inner shoulder 511 before the sliding gate 416 closes, and limit the upward axial movement necessary to move the sliding gate 416 into the fail-safe closed position or the fail-safe opened position. Depending on the amount of offset between the drive sleeve 504 and the top shaft 460, the sliding gate 416 may be located in a partially open/closed position. Also, when in the gate valve 402 is automatically actuated and the drive sleeve 504 is located the distance Y from the inner shoulder 511, the chamber 610 remains isolated from fluid communication with the chamber 406 by the seals 518 and 519. Any slight actuation of the mechanical override 400 may offset the top shaft 460 and the drive sleeve 504 enough to prevent the seals 518 from moving across the tapered shoulder 515 during automatic actuation.

[0070] Since the top shaft 460 may still visually indicate that the valve 402 is in the open position in Figure 7, the valve operator may also check the safe mode indicator 403 to determine whether the gate valve 402 is operating in the safe mode. The pressure in the chamber 610 should not have significantly changed since it is isolated

from the chamber 406 by the seals 518 and 519. Thus, the safe mode indicator 403 communicates the same first visual indication to the valve operator, which has not changed by the automatic actuation of the gate valve 402. The safe mode indicator 403 may therefore indicate that the gate valve 402 is not operating in the safe mode, has been actuated (at least partially) using the mechanical override 400, and/or may be prevented from moving into the fail-safe closed position or the fail-safe opened position. While the actuator 401 is pressurized, the valve operator may rotate the handwheel 500 to advance the drive sleeve 504 into the bottom bore 512 until the gate valve 402 is operating in the safe mode. The valve operator may rotate the handwheel 500 until the safe mode indicator 403 changes from the first visual indication to the second visual indication, e.g. when fluid communication is established between the chamber 406 and the chamber 610, to ensure that the gate valve 402 is operating in the safe mode. Alternatively, the valve operator may release the pressure in the actuator 401 to permit the drive sleeve 504 to backstop against the inner shoulder 511, and then rotate the handwheel 500 to move the mechanical override 400 into the un-actuated position so that the top shaft 460 and the drive sleeve 504 are not in an offset position as described above. The actuator 401 may be re-actuated automatically so that the safe mode indicator 403 indicates that the valve is operating in the safe mode.

[0071] Figure 9 illustrates the gate valve 402 in an open position after an automatic operation of the actuator 401 according to one embodiment. The gate valve 402, the actuator 401, and the mechanical override 400 illustrated in Figure 9 may each include the embodiments described above with respect to Figures 4-8. Figure 9 further illustrates a bore 462 disposed through the top shaft 460, a check valve 464 disposed in a lower end of the top shaft 460 and in communication with the bore 462, and a retaining member 466 coupled to the top shaft 460 to support the check valve 464 in the lower end of the top shaft 460. In one embodiment, the bore 462 may be disposed through the top shaft 460 in any manner known by one of ordinary skill in the art to allow fluid communication between the chamber 610 and the chamber 406. In one embodiment, the check valve 464 may be any type of valve

known by one of ordinary skill in the art, such as a one-way valve, that is operable to control the flow of fluid through the bore 462 in either direction. In one embodiment, the retaining member 466 may be any type of member known by one of ordinary skill in the art, such as a retainer ring, that is operable to maintain the check valve 462 in engagement with the top shaft 460 and/or the bore 462. The top shaft 460 illustrated in Figure 9 may be used in any of the embodiments described with respect to Figure 4-8.

[0072] In operation, the bore 462 may be configured to relieve any fluid pressure that is located in the chamber 610, which may cause a pressure lock and prevent the fail-safe mechanism from closing the gate valve 402. For example, when the gate valve 402 is operating in the safe mode as illustrated in Figure 9, the chamber 610 is in fluid communication with the chamber 406 of the actuator 401 and is filled with pressurized fluid. As the pressure in the chamber 406 is reduced, the spring 418 begins to move the gate valve 402 into the closed position, as illustrated in Figure 4, and the chamber 610 is sealed upon engagement of the seals 518 with the inner surface of the top bore 510. Any fluid that may be retained in the chamber 610 is relieved through the bore 462 into the chamber 460. In one embodiment, the fluid may be forced through the bore 462 and the check valve 464 under its own pressure and/or as it is pressurized as the volume of the chamber 610 is reduced by movement of the drive sleeve 504 toward the shoulder 511 via the spring 418. The check valve 464 may allow fluid to flow from the upper end of the top shaft 460, through the bore 462 and into the chamber 406, and prevent fluid from flowing into the bore 462 and thus into the chamber 610 from the lower end of the top shaft 460. In one embodiment, the top shaft 460 may include one or more ports 468 located adjacent to the outlet of the check valve 464 to assist with venting fluid pressure into the chamber 406. In one embodiment, one or more seals 519 may be situated between the top shaft 460 and the drive member 504 to prevent any unintended leak paths from communicating fluid to the bore 462 during operation of the gate valve 402.

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[0073] In one embodiment, the ESD Control Systems 200, 300, 700 described herein with respect to Figures 1-3 and 13 may be used in combination with the mechanical override 400, the actuator 401, the gate valve 402, and/or the safe mode indicator 403 as described herein with respect to Figures 4-9. In one embodiment, the pressure transducer 280 illustrated in Figure 2 can be connected to the housing 450, similar to the indication device 600 illustrated in Figures 6, 7, and 9. The pressure transducer 280 may be operable to measure the pressure in the chamber 610 via the orifice 615 and send a signal to the controller assembly 220 corresponding to the measured pressure. The controller assembly 220 may then send a signal to the computer system 150 via wired or wireless telemetry for monitoring and display of the measured pressure in real time. In this manner, the ESD control systems 200, 300, 700 can be used to remotely monitor and verify whether the gate valve 402 is operating in the safe mode as described above.

[0074] Figures 10A-10H and 11-11D illustrate a valve assembly 1000 according to one embodiment. Figures 10A-10H illustrate a top perspective view, a left side view, a bottom perspective view, a front view, a top view, a right side view, a bottom view, and a rear view, respectively, of the valve assembly 1000. Figure 11 illustrates a top view of the valve assembly 1000, and Figures 11A-11D illustrate cross sectional views A-A, B-B, C-C, and D-D, respectively, of the valve assembly 1000. The valve assembly 1000 may be used as the valve assembly 260 described above. The valve assembly 1000 includes a first body portion 1010, a second body portion 1015, a first seat 1020, and a second seat 1030. The first and second body portions 1010, 1015 may be formed from a single piece of material, or may include two separate pieces of material that are connected together. The first and/or second seats 1020, 1030 may be removably secured to the first body portion 1010 for accessing a gate 1055 that is movably disposed in the first body portion 1010 to control fluid communication therethrough. The first and second body portions 1010, 1015 may be provided with one or more mounting holes 1011, 1012, 1013 for securing the valve assembly 1000 within the housing 210 and/or to one or more components of the ESD control systems 200, 300. The first body portion 1010 may include a first fluid inlet 1040 for

receiving fluid from the pump assembly 240. The first fluid inlet 1040 may include a fluid path 1041 disposed through the first body portion 1010 from a first end to a second end, adjacent to the first seat 1020. Second and third fluid inlets 1042, 1045 (the third fluid inlet 1045 being disposed through the first seat 1020) may optionally be provided to receive fluid from the pump assembly 240. As illustrated, the optional second and third fluid inlets 1042, 1045 are plugged with one or more sealing members, but include fluid paths that are in communication with the fluid path 1041 of the first fluid inlet 1040. The first body portion 1010 may also include a first fluid outlet 1050 for directing fluid to the actuator of the surface and/or subsurface safety valves 120, 130 to actuate the valves. The first fluid outlet 1050 may also include a fluid path 1051 disposed through the first body portion 1010 from a first end to a second end, adjacent to the second seat 1030. The first body portion 1010 may further include a fluid path 1052 that extends from the first seat 1020 to the second seat 1030 to provide fluid communication between the first fluid inlet 1040 and the first fluid outlet 1050. The gate 1055 may be disposed in the fluid path 1052 between the first and second seats 1020, 1030 to control fluid communication between the first fluid inlet 1040, the first fluid outlet 1050, and a first relief outlet 1060 of the second seat 1030 as described below. One or more machining holes 1051, 1052 (illustrated as being plugged) may be formed in the first body portion 1010 to form the fluid paths disposed through the body as described herein.

[0075] During operation, fluid may flow through at least one of the fluid inlets 1040, 1042, 1045 past the gate 1055 that is disposed within the fluid path 1052 of the first body portion 1010 between the first and second seats 1020, 1030, and then through the fluid outlet 1050. While fluid is flowing through the valve assembly 1000 to the actuators of the valves 120 and/or 130, the pressure in the first body portion 1010 forces the gate 1055 to seal off communication with the first relief outlet 1060. The first relief outlet 1060 provides fluid communication to the fluid reservoir 250, to dump the fluid in the first body portion 1010 and the valve actuators when desired during operation. A second relief outlet 1070 may also be provided to quickly release fluid from the first body portion 1010 and the valve actuators. The second relief outlet

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1070 may include a fluid path 1071 that intersects the fluid path 1041 of the first fluid inlet 1040, but which includes an in-line relief valve to release fluid from the fluid paths to the fluid reservoir 250 in the event that the pressure in the first body portion 1010 exceeds a pre-determined pressure. A pressure switch port 1019 may be disposed through the first body portion 1010 that intersects the fluid path 1051 of the first fluid outlet 1050. The pressure switch port 1019 may be used as a means to communicate the pressure in the first body portion 1010 to one or more sensors/transducers that are in communication with the ESD control systems 200, 300 and/or the controller assemblies 220, 320. Using the pressure measured by the sensors/transducers via the pressure switch port 1019, the controller assemblies 220, 320 may selectively control, e.g. turn on and off, the pump assemblies 240, 340 to actuate the valves 120, 130 as described herein.

[0076] The second body portion 1015 may include a fluid control outlet 1090 that directs flow from the fluid path 1041 of the first fluid inlet 1040 via a fluid path 1091 to a control valve assembly, such as a solenoid valve assembly. The solenoid valve assembly may also be in communication with the controller assemblies 220, 320 to control operation (e.g. open and close) of the valve assembly 1000 to thereby control actuation of the valves 120, 130 as desired. The second body portion 1015 may further include a second fluid control outlet 1080 to release fluid from the fluid paths in the second body portion 1015 via a fluid path 1081 and the control valve assembly to the fluid reservoir 250. When the control valve assembly is actuated to dump fluid pressure to the fluid reservoir 250, the pressure release in the fluid path 1041 of the first fluid inlet 1040 and the back pressure in the fluid path 1051 of the first fluid outlet 1050 may move the gate 1055 to a position within the first body portion 1010 where the fluid in the first body portion 1010 and the valve actuators is quickly released to the fluid reservoir 250 via the first relief outlet 1060, the second relief outlet 1070, and/or the second fluid control outlet 1080. In this manner, the valve assembly 1000 may be selectively used to supply and maintain fluid in one or more valve actuators of the valves 120, 130, and to selectively release and dump fluid from the valve actuators to the fluid reservoir 250.

[0077] Figure 13 illustrates the ESD control system 700 according to one embodiment. Embodiments of the ESD control system 700 described herein may be applicable to the ESD control system 300. For convenience, the components in the ESD control system 700 that are similar to the components in the ESD control system 200 will be labeled with the same number indicator. The ESD control system 200 may include the housing 730 for supporting the controller assembly 220, the power source 230, a compressor (or fluid drive) assembly 740, a check valve 715, a pressure switch 710, a filter/dryer assembly 705, and the solar panel assembly 270. In one embodiment, the controller assembly 220 and/or any of the other components may be disposed external to and/or adjacent to the housing 730.

[0078] The ESD control system 700 may be "self-contained" or "stand-alone unit," which means that the ESD control system 700 does not depend on any external pneumatic, hydraulic, mechanical, or electrical sources for its operation to shut down the oil/gas well. In other words, the power source 230, the compressor assembly 740 and other components are within the housing 730 and thus the ESD control unit 700 is an integral portable unit. For example, if there is a rupture of a production flow line downstream from the surface safety valve 120, and/or if there is a loss of well pressure at the subsurface safety valve 130, the ESD control system 700 is operable to effectively close the safety valves 120, 130, thereby shutting in the oil/gas well, and alert the appropriate personnel that a shut-in has occurred without the assistance of any additional external power sources, such as external compressors or motors.

[0079] The ESD control system 700 may also include one or more transducers/devices 280, 282, 284, 286, and 288 for monitoring and/or measuring one or more physical properties as described herein. The ESD control system 700 may be configured to control one or more valves, such as flow control valves or choke valves that are in communication with the flow lines of the valves 120, 130 to control fluid flow through the wellhead control system 100. The ESD control system 700 may also include a quick dump valve 725 in line 211. The quick dump valve 725

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is a manual valve that is configured to exhaust pneumatic fluid to an area outside of the housing 730. Additionally, the check valve 715 may be located in the line 211. The check valve 715 is a valve that allows fluid flow in one direction, from the compressor assembly 744 to the valve 120, and restricts fluid flow in the opposite direction.

[0080] The housing 730 may include any structural support member, such as an explosion-proof container, for protecting the components stored therein from damage and environmental elements. Appropriate ventilation of the housing 730 may be provided by ventilation holes and/or an independent solar powered fan mounted in or through the housing 730. The housing 730 may further include an access panel or door for ease of access to the housing's interior, and may be configured for attachment to the tree 110 or the respective surface and subsurface safety valve 120, 130. In one embodiment, the structural components of the ESD control system 700, to the extent possible, may be made from stainless steel. The controller assembly 220 may be disposed in the housing 730 and may include a microprocessor unit 222, a display screen 224, and a keypad 226. In one embodiment, the controller assembly 220 may be weather-proof, and may be intrinsically safe to provide power as necessary to one or more components of the ESD control system 700. The microprocessor unit 222 may include a programmable logic controller, including a supervisory control and data acquisition system (SCADA) that is in communication with the one or more transducers/devices 280, 282, 284, 286, and 288, as well as the compressor assembly 740 and valve assemblies 710, 720.

[0081] In one embodiment, the compressor assembly 740 may include an intrinsically safe motor 742 and a compressor 744, which may each be located in the explosion-proof housing 730. As set forth herein, the compressor assembly 740 may supply pneumatic fluid from a location outside the housing 730 to actuate the safety valve 120, 130 to which it is connected. The pneumatic fluid may be ambient fluid, such as air, outside the housing 730. In one embodiment, the compressor assembly 740 may have multiple compressors and/or motors in parallel.

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[0082] In one embodiment, the pneumatic fluid may be supplied from an optional reservoir 735 located outside of the housing 730. The reservoir 735 may be connected to the filter/dryer assembly 705 for supplying fluid to the compressor assembly 740. The reservoir may also be connected to the valve assembly 720 and/or valve 725 for receiving fluid exhausted from the system. The reservoir 735 may include a level gauge, such as a sight glass, to indicate the level of fluid in the reservoir 735. The reservoir 735 may also include a level sensor that is in communication with the controller assembly 220 and is operable to monitor in real-time the level of fluid in the reservoir 735. In the event that the level of fluid falls below a predetermined limit (e.g. pre-set limit), due to evaporation of the fluid for example, the level sensor may provide an alarm to alert an operator on-site at the wellhead control system 100 and/or at the remote location via the controller assembly 220 and the computer system 150. The controller assembly 220 may automatically shut in the wellhead control system 100 upon receiving a signal from the level sensor.

[0083] As set forth herein, the signal from the pressure transducer 280 may be recorded and/or communicated to the computer system 150 via the controller assembly 220 to provide real-time monitoring of the pressure in the flow line 135. The measured pressure may be displayed on the display screen 224 and/or on a display screen of the computer system 150. In response to the comparison of the measured pressure to one or more predetermined conditions, the controller assembly 220 may be configured to operate the respective safety valve 120, 130 to which it is connected. For example, the controller assembly 220 may be used to direct the compressor assembly 740 to supply pneumatic fluid, such as ambient air, to the surface safety valve 120 to open the valve. Upon receiving the signal from the controller assembly 220, the valve assembly 720 may be configured to open a circuit defined by lines 211, 215 between the surface safety valve 120 and the filter/dryer assembly 705 to allow the compressor assembly 740 to direct fluid from the fluid entering the filter/dryer assembly 705 to the surface safety valve 120, thereby opening the surface safety valve 120. The surface safety valve 120 may be

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maintained in the open position while the pressure transducer 280 continuously monitors the pressure in the flow line 135. The controller assembly 220 may be programmed to close the surface safety valve 120 upon receiving a signal from the pressure transducer 280 that corresponds to a pressure measurement that is greater than or less than a pre-set pressure range. The pre-set pressure range may be input into the controller assembly 220 by manual entry using the keypad 226 and the display screen 224. The pre-set pressure range may also be input into the controller assembly 220 remotely from the computer system 150. When the signal is received from the pressure transducer 280 that the pressure in the flow line 135 falls outside of the pre-set pressure range stored in the microprocessor unit 222, the controller assembly 220 may automatically direct the compressor assembly 740 to stop supplying pressurized fluid to the surface safety valve 120 and/or allowing the valve assembly 720 to exhaust the pneumatic fluid, thereby closing the surface safety valve 120. Continuous real-time monitoring of the pressure in the flow line 135 may be used to verify that the surface safety valve 120 has been closed.

[0084] Power may be provided to the controller assembly 220 and the compressor assembly 740 from the power source 230. The power source 230 may be operable to provide a low current (amp) stream to the controller assembly 220 and/or the compressor assembly 740. The controller assembly 220 is configured to control the pressure switch 710, which can be visually inspected to monitor the pressure in the line 211. In one embodiment, the pressure switch 710 may be configured to shut off the compressor assembly 740 when the pressure in the actuator of the safety valves 120, 130 reaches a predetermined pressure setting.

[0085] Figure 14 illustrates a well control system 800 at a wellsite for conducting a wellbore operation, such as a fracturing operation. The well control system 800 may be configured with one or more of the control systems 200, 300, 700 as described herein. The well control system 800 includes a fluid supply 810, such as a reservoir or tank, or a vehicle comprising a storage tank for storing fluid. A pump 820, or other fluid drive assembly, is provided for pumping fluid from the fluid supply 810 to a well.

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In particular, fluid from the fluid supply 810 is pumped through flow or fluid line 811 to a manifold 830, which directs the pressurized fluid to one or more wellheads 840, 841, 842, 843 via fluid lines 831, 832, 833, 834, respectively. As illustrated, the wellhead 840 may control the pressurized fluid flow into a well 850 that intersects a formation 860 for conducting a fracturing operation as conventionally known in the art.

[0086] A fluid line 812 is in fluid communication with the fluid line 811 at a location downstream of the pump 820. The fluid line 812 may also be in fluid communication with the fluid supply 810 or with any other fluid reservoir type assembly. The safety valve 120 is in-line with the fluid line 812 for controlling fluid flow from the fluid line 811 to the fluid supply 810. The safety valve 120 may be configured as a fail-safe open relief valve or a fail-safe close safety valve, and is operable using one or more of the control systems 200, 300, 700. The safety valve 120 is operable using a pneumatic/hydraulic working fluid, which may be supplied from a fluid reservoir internal or external of the control systems 200, 300, 700 (as described herein) and/or from the fluid supply 812 directly or via one of the fluid lines. The transducer 280, such as a pressure transducer, measures the pressure in the fluid line 812 and communicates the measured characteristic to the controller assemblies of the control systems 200, 300, 700, which compare the measured characteristic to one or more predetermined conditions. The computer system 150 enables remote monitoring, control and operation of the safety valve 120 using the control systems 200, 300, 700 as described herein.

[0087] In one embodiment, one or more fluid lines 812 may be provided for fluid communication between fluid lines 811, 831, 832, 833, 834 (including the manifold and/or wellheads) and the fluid supply 810 or other fluid reservoir. In one embodiment one or more safety valves 120 and/or control systems 200, 300, 700 may provided in-line with one or more of the fluid lines 811, 831, 832, 833, 834 (including the manifold and/or wellheads). In one embodiment, one or more transducers 280 may be provided for measuring physical properties (e.g. pressure,

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temperature, flow rate, flow volume, etc.) of one or more of the fluid lines 811, 831, 832, 833, 834 (including the manifold and/or wellheads).

[0088] In operation, the pump 820 may be actuated to pump fluid from the fluid supply 810 to the manifold 830 via fluid line 811. The safety valve 120 may be actuated into a closed position using a working fluid as directed by the control systems 200, 300, 700 to prevent or substantially restrict fluid flow through fluid line 812. The pressurized fluid may therefore be directed from the manifold 830 to the wellheads 840, 841 842, 843 via fluid lines 831, 832, 833, 834 for conducting a fracturing operation, such as in well formation 860. The safety valve 120 may be continuously monitored remotely using the computer system 150. The transducer 280 may also continuously monitor and measure physical properties, such as fluid pressure, in fluid line 811 and communicate the measured physical properties to the control system 200, 300, 700 for comparing to one or more predetermined conditions. In the event that the pressure in the fluid line 811 exceeds a predetermined condition (as programmed into the controller assembly of the control system), the control system is operable to release the working fluid from maintaining the safety valve 120 in the closed position, and the safety valve 120 is operable to automatically move into the open position (such as by spring 418 or other biasing member) to relieve the pressure in the fluid line 811 and dump the pressurized fluid back into the fluid supply 810 or other reservoir via fluid line 812. The well control system 800 is therefore operable to prevent over pressurization or other conditions of the fluid lines 811, 831, 832, 833, 834 (including the manifold and/or wellheads) that can lead to failure.

[0089] After any remedial operations necessary to remove any restriction to flow to the wellheads, the control system 200, 300, 700 may be operable to actuate the safety valve 120 into the closed position to continue with one or more wellbore operations. Advantages of the well control system 800 include the ability to relieve high fluid volume, flow, and pressure quickly, efficiently, and repeatedly to prevent failure of the wellbore system. Additional advantages include the ability to remotely monitor and control the system 800.

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[0090] In one embodiment, the control system 200, 300, 700 may be configured to actuate the safety valve 120 at a predetermined condition, such as a set pressure, which is below the rated working pressure of one or more of the fluid lines, manifolds, and/or wellheads. In the event that the pressure in the fluid lines reach or exceed the predetermined set pressure (as measured by the transducer 280), the control system 200, 300, 700 will actuate the safety valve 120 into the open position to relieve the excessive fluid pressure. In one embodiment, the control system 200, 300, 700 may be configured with a predetermined condition, such as a reset pressure. For example, in the event of actuation of the safety valve 120 due to a failure, the control system 200, 300, 700 may prevent operation of the safety valve 120 back into the closed position until the transducer 280 measures the predetermined reset pressure in the fluid lines.

[0091] In one embodiment, the control system 200, 300, 700 may be configured to actuate the safety valve 120 in anticipation of a failure. For example, the control system 200, 300, 700 may include an electronic wave generator for generating a wave signal that corresponds to fluid flow volume, rate, pressure, etc., and which is monitored by the controller assembly for any changes or fluctuations that indicate a failure at one or more points in the well control system 800. In the event of an indication of failure, the control system 200, 300, 700 can operate the safety valve 120 for actuation into the open position.

[0092] In one embodiment, the control system 200, 300, 700 can monitor, track, and record the operation of the safety valve 120 and/or the transducer 280 measurements. In one embodiment, the control system 200, 300, 700 may be configured with one or more mechanical and/or electrical overrides for independent, manual, or direct operation of the safety valve 120. In one embodiment, a transducer 280 may be coupled to the safety valve 120 to monitor the working pressure within the valve actuator, which can help determine life of the valve, force required to actuate, and whether maintenance is required.

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[0093] In one embodiment, the control system 200, 300, 700 may be configured to trigger or actuate one or more alarms or alerts (audio/visual) to indicate a potential or actual failure; that the safety valve 120 has been actuated; and/or one or more other conditions have been detected, such as H2S (or other harmful gases), fire, and/or damage to the control system. In one embodiment, the alarms or alerts may be communicated through the computer system 150. In one embodiment, the control system 200, 300, 700 may be configured to prevent remote operation in the event that the safety valve 120 has been actuated, and may require manual re-setting of the system.

[0094] In one embodiment, the control system 200, 300, 700 may include a geographical positioning system for tracking the location of the control system and the safety valves, which may be displayed, monitored, and tracked using the computer system 100. In one embodiment, the control system 200, 300, 700 may store information related to a particular wellbore operation, including maintenance and operational history, employee contact information, and/or status of the safety valve. In one embodiment, the control system 200, 300, 700 may be configured to open and/or close the safety valve 120 within a predetermined time frame. In one embodiment, the control system 200, 300, 700 may be configured to actuate the safety valve 120 at one or more predetermined time intervals.

[0095] Figure 15 illustrates the well control system 800 according to one embodiment. The well control system 800 includes a gate valve 402 and a valve actuator 401, the operations of which are described above with respect to at least Figures 4-12. A pilot valve 870 (or other functionally similar type of mechanical, electrical, and/or hydraulic sensor) may be coupled to the valve actuator 401, and may be operable to control fluid communication between the valve actuator 401 and a fluid reservoir 875 via fluid line 872. A pump 876 may be provided to pump actuator fluid from the reservoir 875 to the valve actuator 401 to actuate the valve 402 into the closed position.

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[0096] Upon actuation of the pilot valve 870, the actuator fluid may be released from the valve actuator 401 back to the reservoir 875, such that the valve 402 may be automatically biased into the open position. The pilot valve 870 may be actuated by fluid pressure via fluid line 871, which is in communication with fluid line 811. In the event that fluid pressure directed to the wellheads 840-843 exceeds a predetermined amount, the fluid pressure will actuate the pilot valve 870 (via fluid line 871) to release the actuator fluid from the valve actuator 401 to the reservoir 875 (via fluid line 872), and thereby automatically bias the valve 402 into the fail safe open position to release the excessive fluid pressure back to the fluid supply 810 (via fluid line 812) as described above.

[0097] In one embodiment, the pilot valve 870 may operate as a check valve or one-way valve when in an un-actuated or first position, to allow actuator fluid to be pumped into the valve actuator 401 while preventing actuator fluid flow out of the valve actuator 401. When the pilot valve 870 is in an actuated or second position, actuator fluid may flow out of the valve actuator 401 to the reservoir 875. The pilot valve 870 may monitor and be in communication with the fluid pressure in any one of the flow lines 811 and 830-834. In one embodiment, the actuator fluid may be forced into the reservoir 875 by the biasing member 418 acting on the operating member 412 as described above.

[0098] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

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Claims:

1. A control system for controlling fluid flow through a flow line at a wellsite, the control system comprising:

a fluid supply;

a first fluid line in fluid communication with the fluid supply;

a pump in fluid communication with the first fluid line and configured to pump fluid from the fluid supply to one or more wellheads through the first fluid line;

a second fluid line in fluid communication with the first fluid line at a location downstream of the pump and configured to return fluid from the first fluid line to the fluid supply;

a safety valve in-line with the second fluid line and in a closed positon to close fluid flow through the second fluid line;

a valve actuator configured to actuate the safety valve from the closed position to an open position to open fluid flow through the second fluid line;

an electronic controller assembly programmed with a predetermined condition and configured to receive a signal from a transducer connected to the first fluid line, wherein the signal corresponds to a measured physical property;

a valve assembly in communication with the controller assembly; and

a fluid drive assembly in communication with the controller assembly, wherein the controller assembly is operable to actuate the fluid drive assembly to supply fluid to the valve actuator to move the safety valve into the closed position, and wherein the controller assembly is operable to actuate the valve assembly in response to a comparison of the measured physical property to the predetermined condition to release the fluid from the valve actuator to move the safety valve into the open position and thereby open fluid flow through the second fluid line to return fluid in the first fluid line back to the fluid supply.

2. The system of claim 1, further comprising a housing for supporting the controller assembly, the valve assembly, and the fluid drive assembly.

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3. The system of claim 2, wherein the fluid supplied to the valve actuator by the fluid drive assembly is supplied from a reservoir disposed outside of the housing.

4. The system of claim 1, wherein the fluid drive assembly is a compressor and the fluid supplied to the valve actuator by the fluid drive assembly is a pneumatic fluid.

5. The system of claim 1, wherein the fluid drive assembly is a pump and the fluid supplied to the valve actuator by the fluid drive assembly is a hydraulic fluid.

6. The system of claim 1, further comprising a power source for supplying power to the controller assembly, the valve assembly, and the fluid drive assembly.

7. The system of claim 1, further comprising a housing for supporting the fluid drive assembly, and a filter attached to the housing for filtering fluid entering the housing by the fluid drive assembly.

8. The system of claim 1, wherein the fluid supplied to the valve actuator by the fluid drive assembly is ambient air.

9. The system of claim 1, wherein the controller assembly is operable to communicate a signal corresponding to the measured physical property to a remote computer system.

10. The system of claim 1, wherein the controller assembly is a programmable logic controller.

11. A method for controlling fluid flow through a flow line at a wellsite, the method comprising:

providing a control system comprising:

a fluid supply;

a first fluid line in fluid communication with the fluid supply;

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a pump in fluid communication with the first fluid line and configured to pump fluid from the fluid supply to one or more wellheads through the first fluid line;

a second fluid line in fluid communication with the first fluid line at a location downstream of the pump and configured to return fluid from the first fluid line to the fluid supply;

a safety valve in-line with the second fluid line;

a valve actuator configured to actuate the safety valve;

a housing;

an electronic controller assembly;

a fluid drive assembly; and

a valve assembly;

supplying fluid to the valve actuator using the fluid drive assembly to actuate the valve actuator to move the safety valve into a closed position;

maintaining the safety valve in the closed position to close fluid flow through the second fluid line;

monitoring a physical property in the first fluid line using the controller assembly; and

actuating the valve assembly using the controller assembly to release the fluid from the valve actuator to move the safety valve into an open position and thereby open fluid flow through the second fluid line based upon a comparison of the monitored physical property to a predetermined condition to return fluid from the first fluid line back to the fluid supply.

12. The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a pneumatic fluid disposed external to the housing, and further comprising filtering the pneumatic fluid as it enters the housing by the fluid drive assembly.

13. The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a hydraulic fluid disposed in a reservoir within the housing that is in fluid communication with the fluid drive assembly.

14. The method of claim 12, further comprising measuring the physical property using a transducer configured to communicate a signal corresponding to the measured physical property to the controller assembly.

15. The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a pneumatic fluid, and wherein the fluid drive assembly is a compressor.

16. The method of claim 12, wherein the fluid supplied to the valve actuator by the fluid drive assembly is a hydraulic fluid, and wherein the fluid drive assembly is a pump.

17. The method of claim 12, further comprising communicating a signal from the controller assembly to a remote computer system, wherein the signal corresponds to an operational characteristic of the safety valve.

18. The method of claim 12, further comprising actuating the safety valve by communicating a signal from a remote computer system to the controller assembly.

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ABSTRACT OF THE DISCLOSURE

A safety valve control system may include a remotely operable control assembly, a first transducer, a valve assembly, and a compressor assembly in communication with the control assembly. The control assembly is operable to actuate the pump and valve assemblies to supply fluid to actuate the safety valve into open and closed positions, in response to one or more signals received from the first transducer. A method of operation may include maintaining the safety valve in an open or closed position while sensing a physical property with the control system; communicating a signal corresponding to the sensed physical property to the control system; and automatically closing or opening the safety valve in response to a comparison of the sensed physical property to a pre-set condition.

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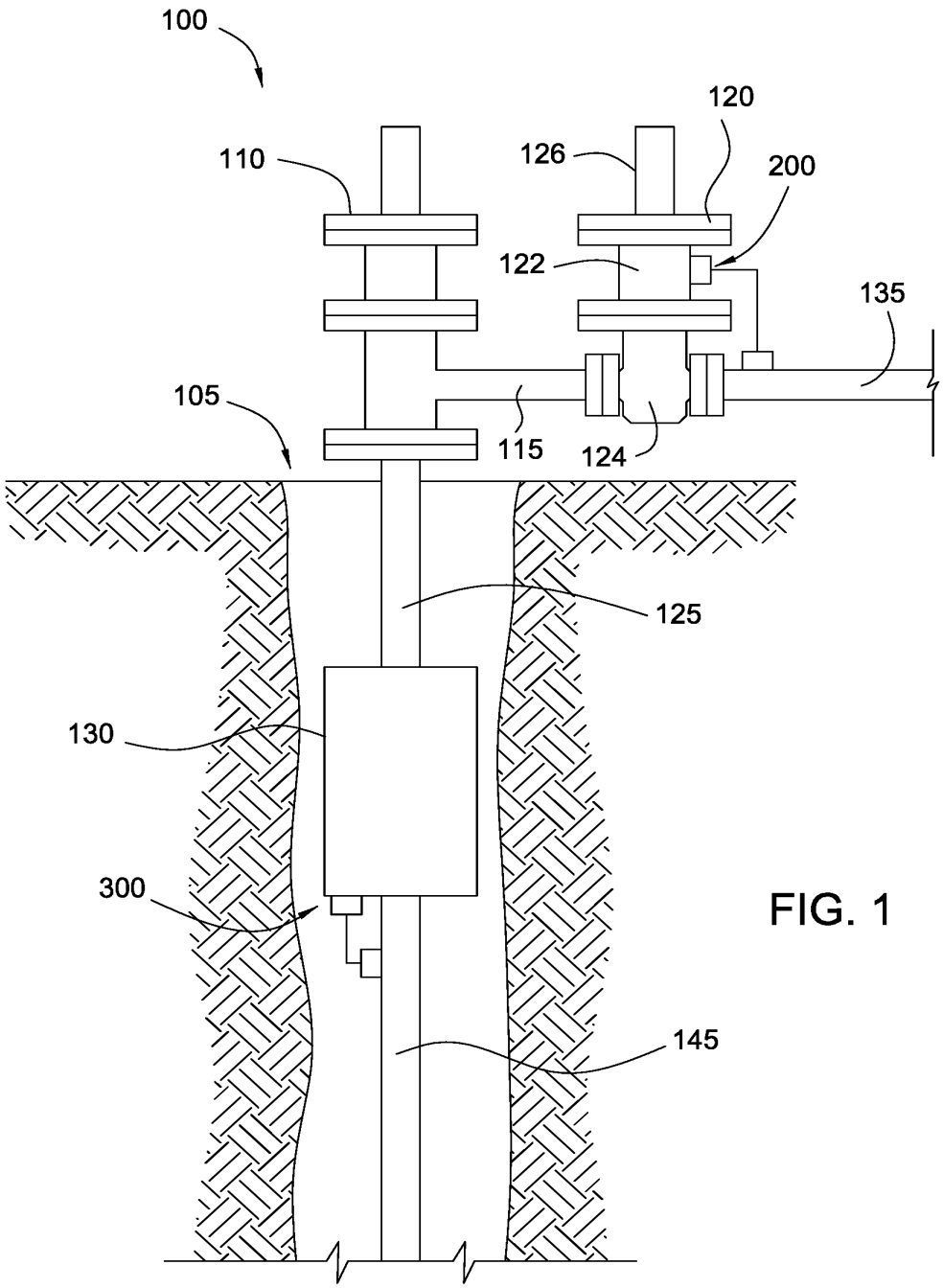


FIG. 1

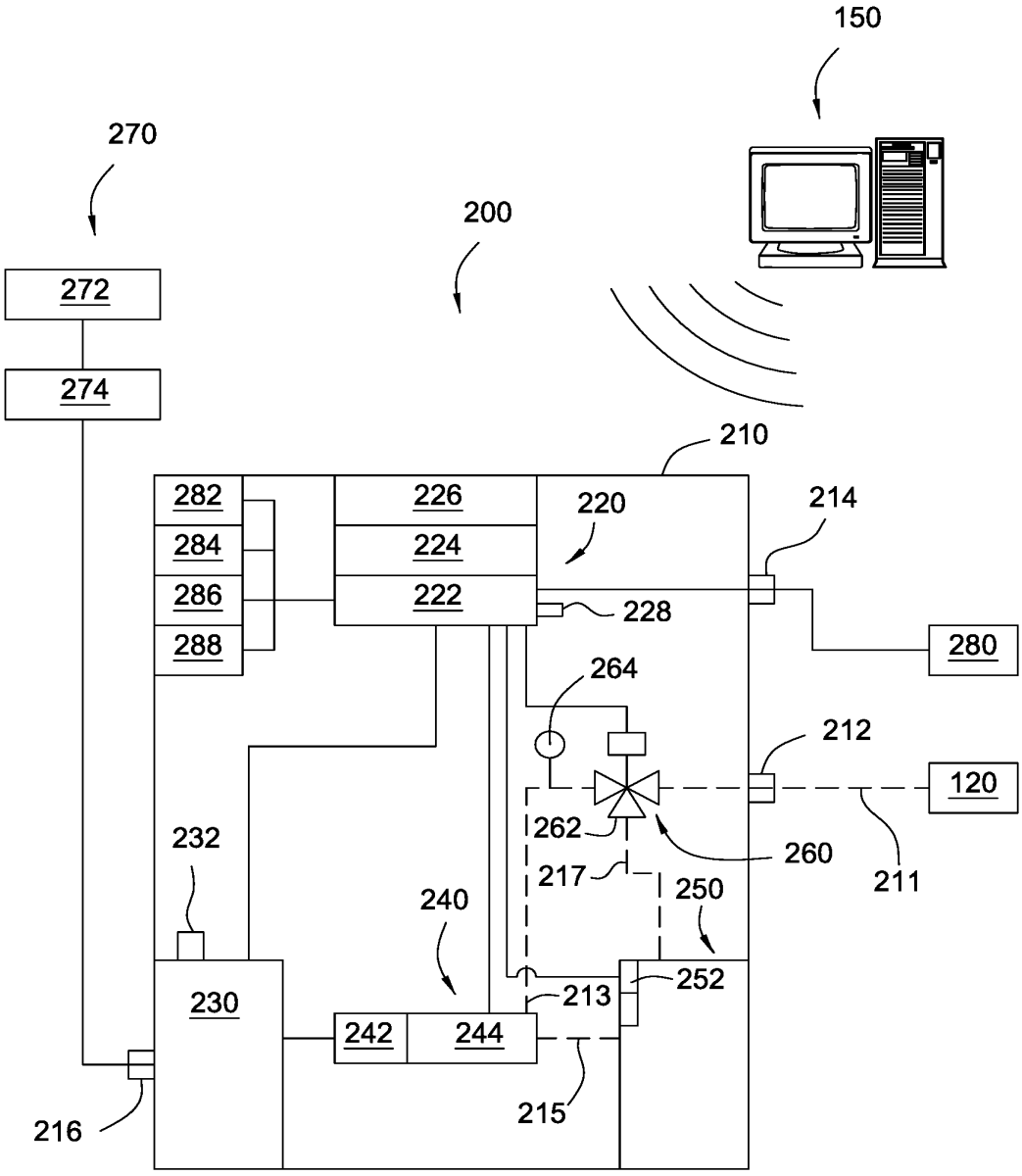

150
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200
272
274
210
282
284
286
288
226
224
222
220
214
228
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216

FIG. 2

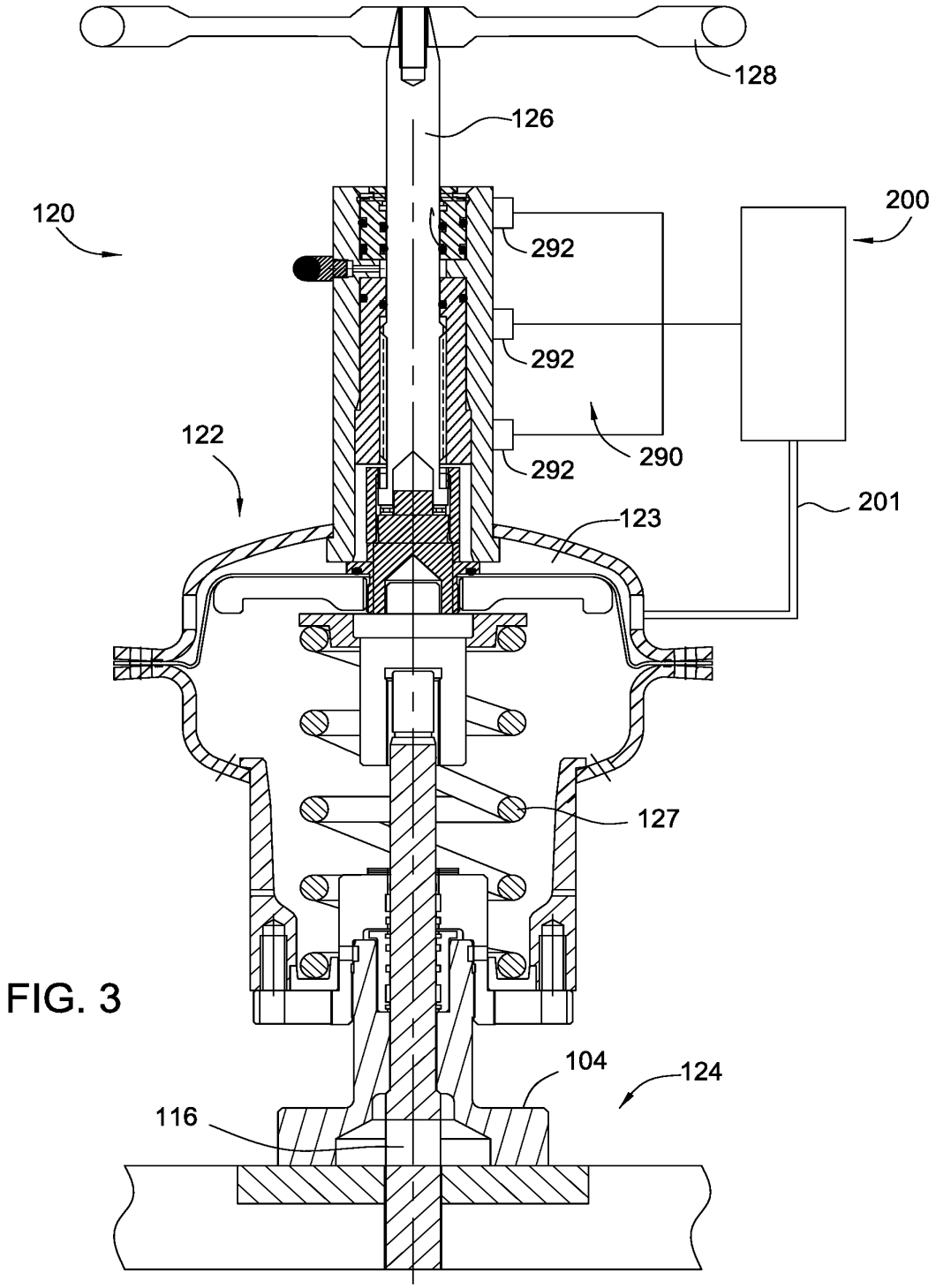


FIG. 3

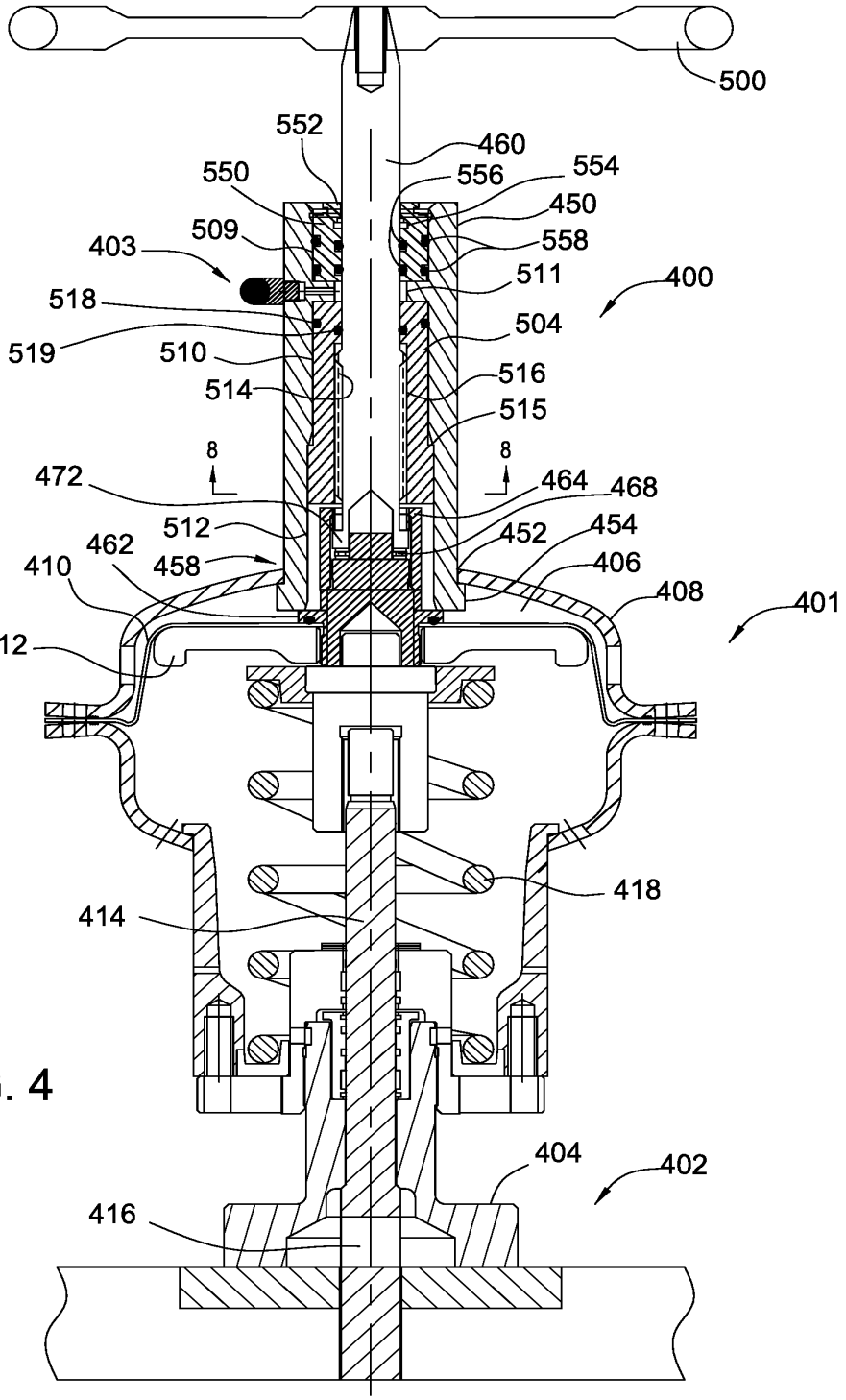

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FIG. 4

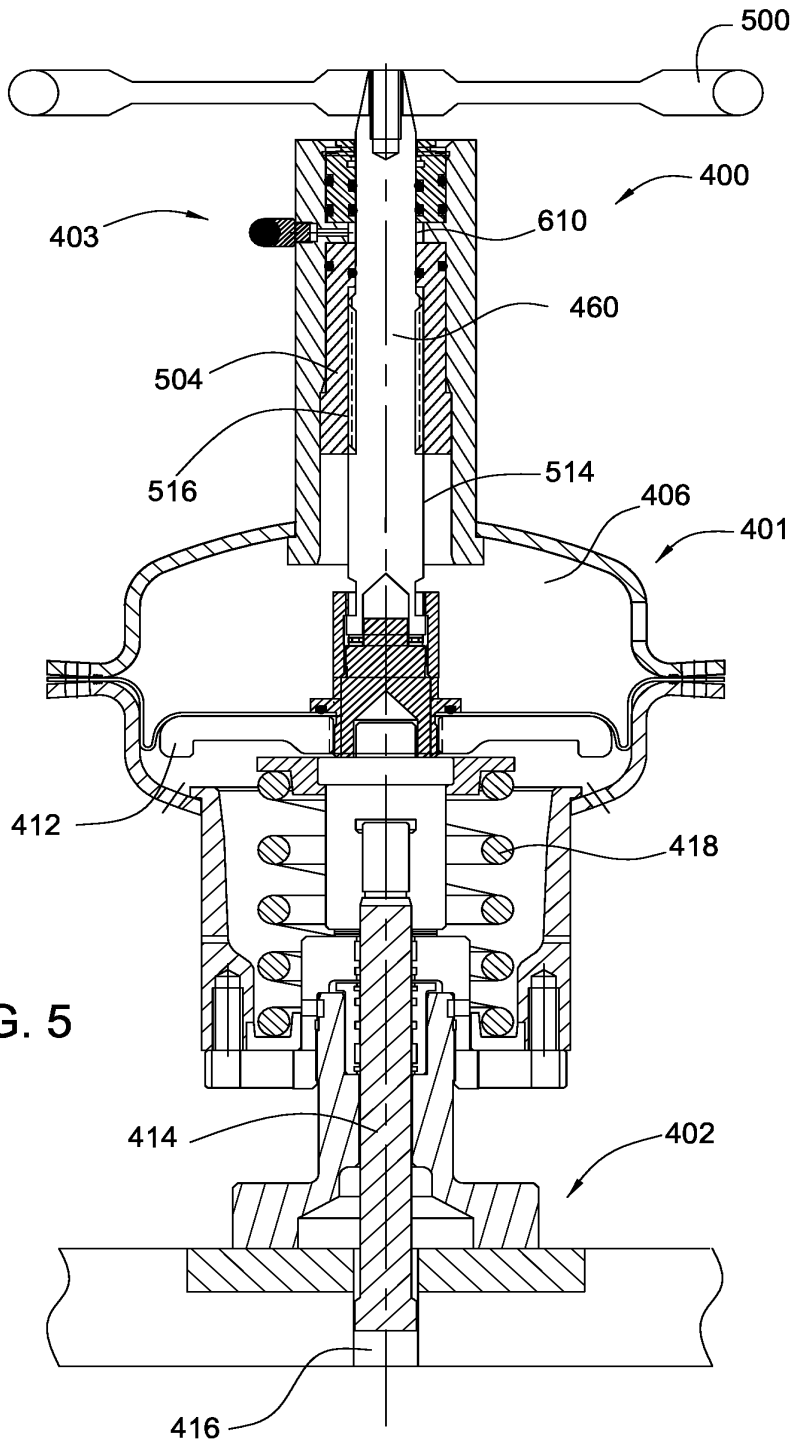


FIG. 5

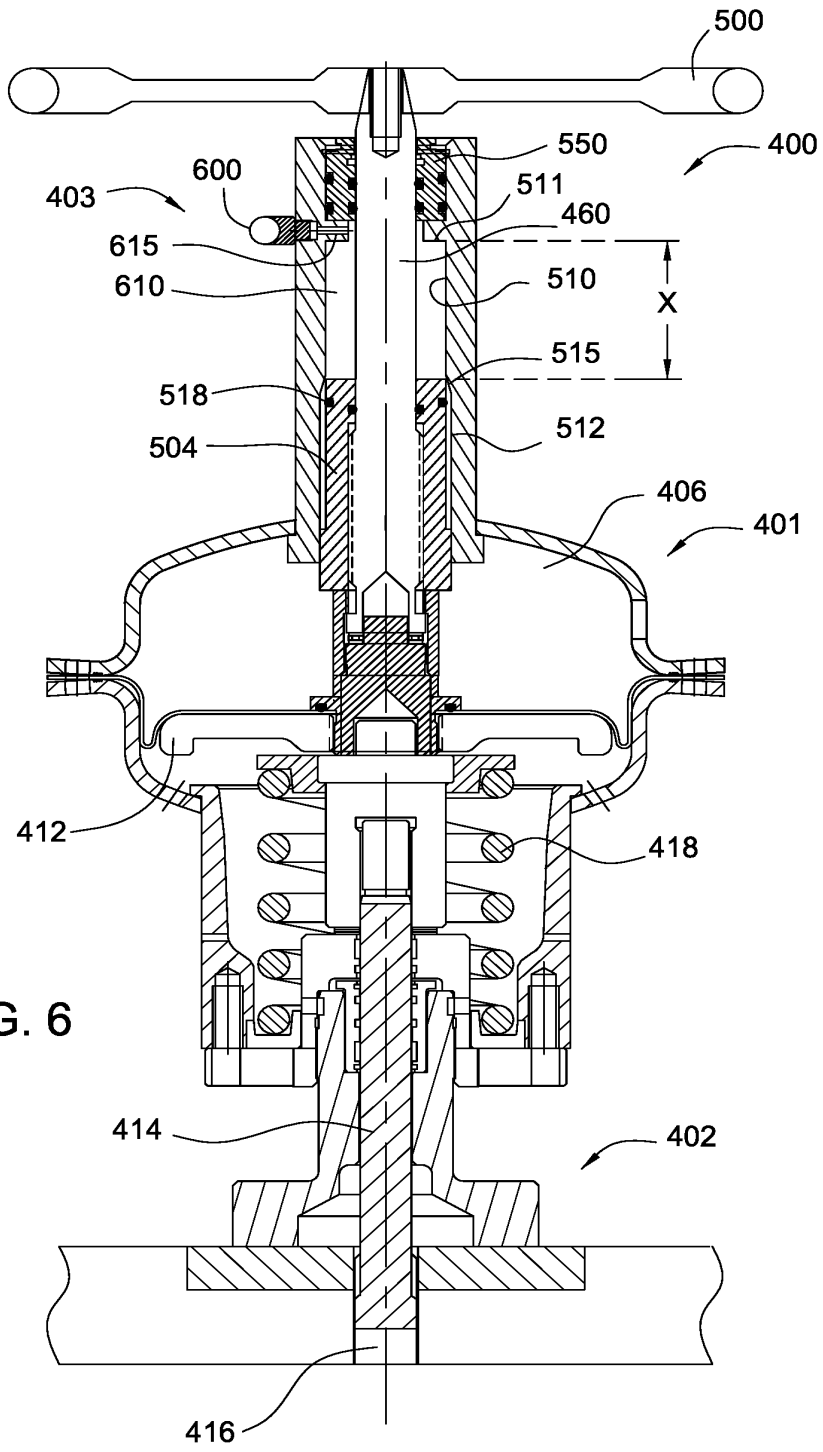

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FIG. 6

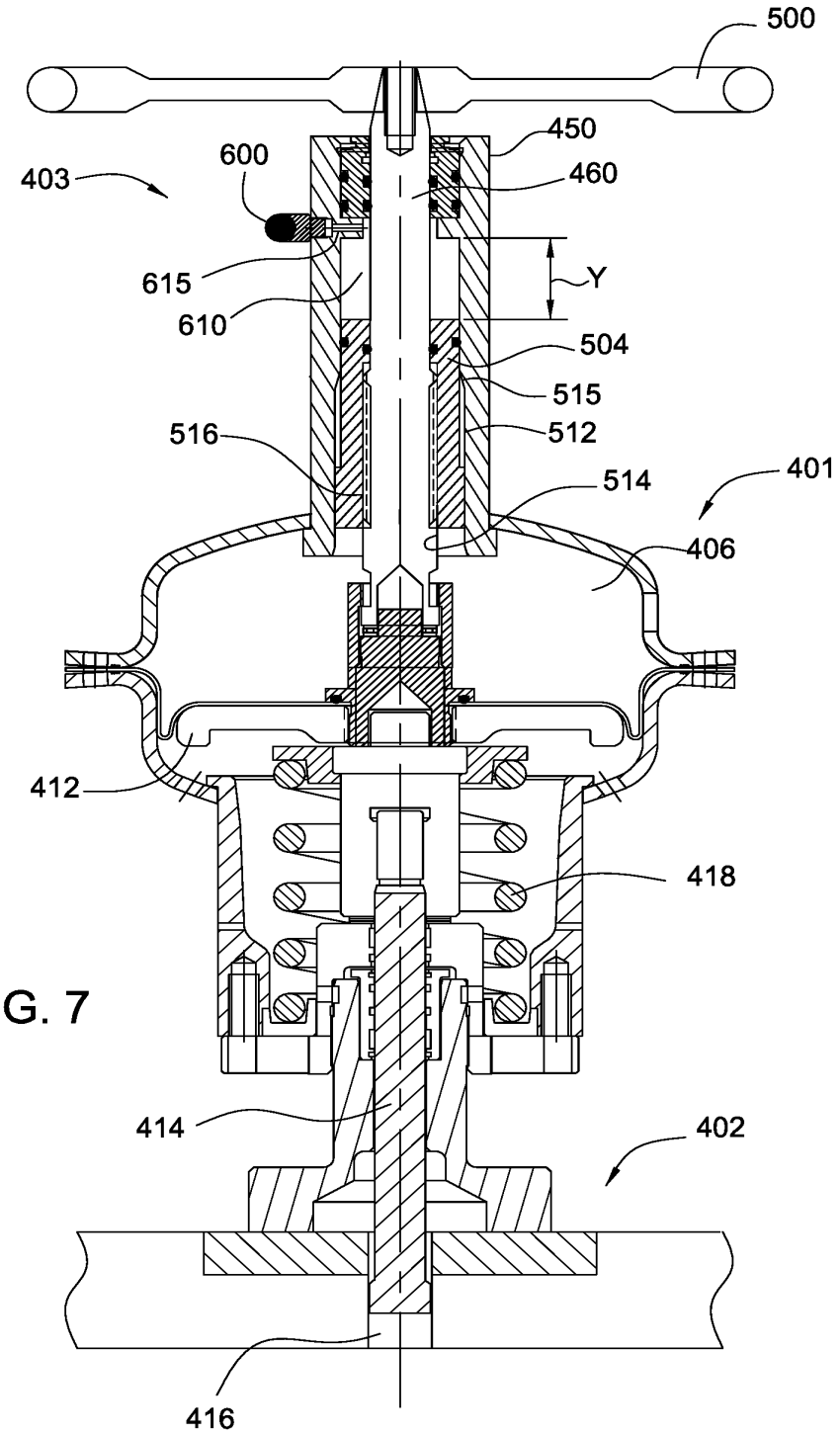

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FIG. 7

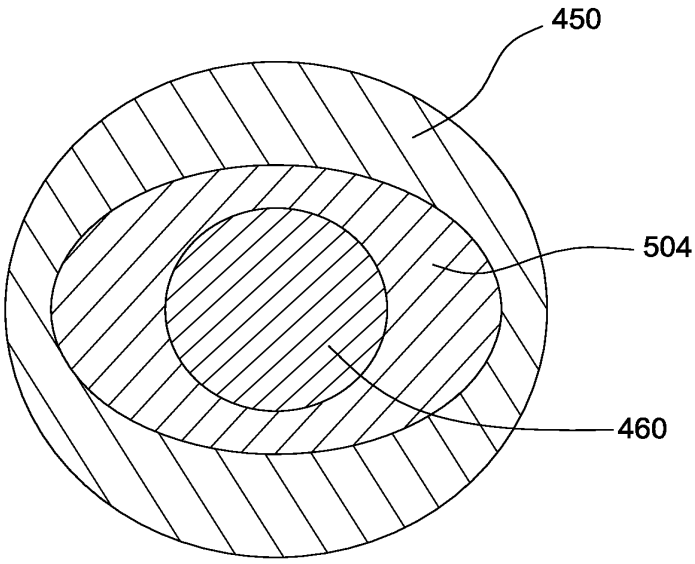


FIG. 8

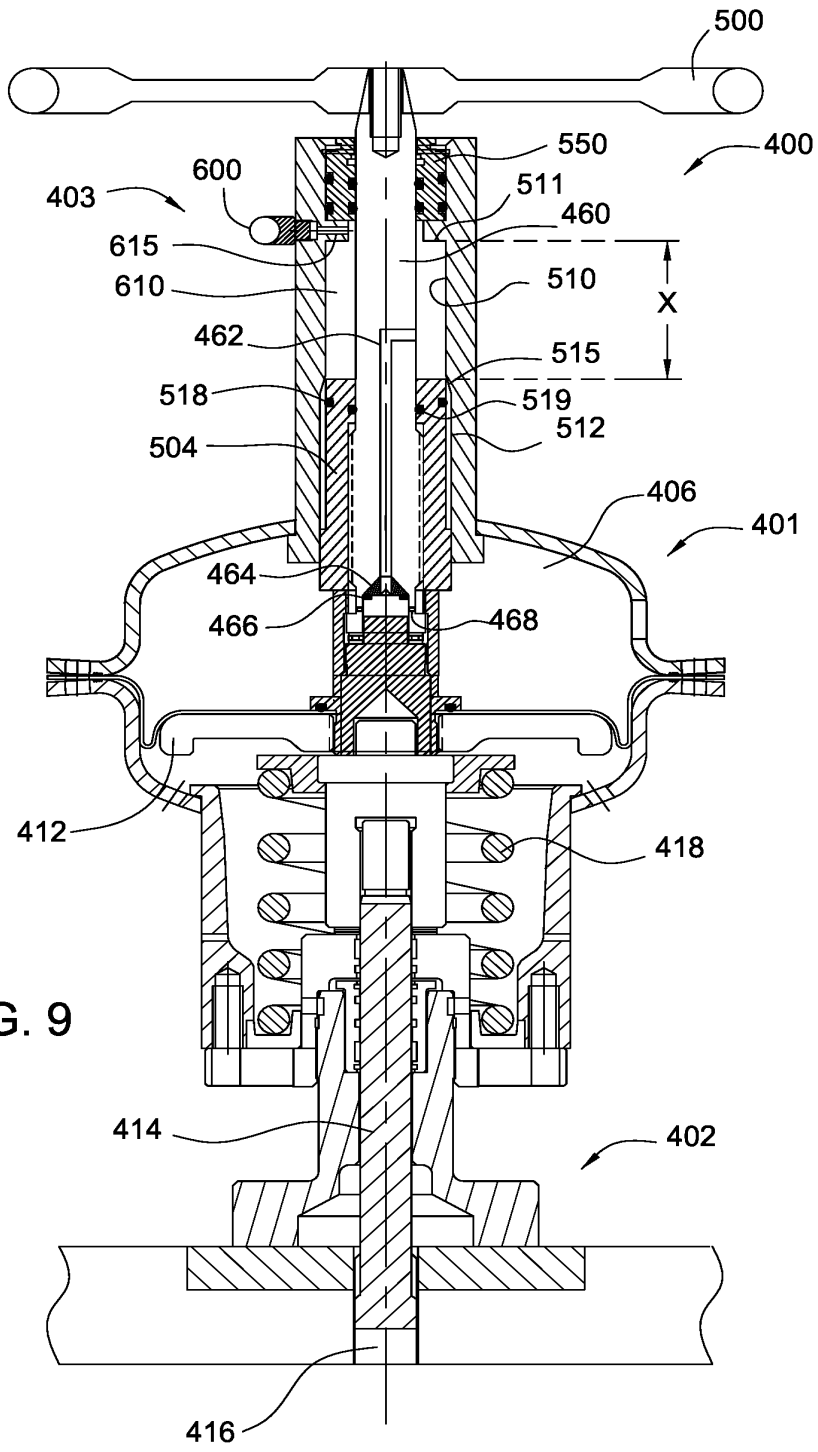

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FIG. 9

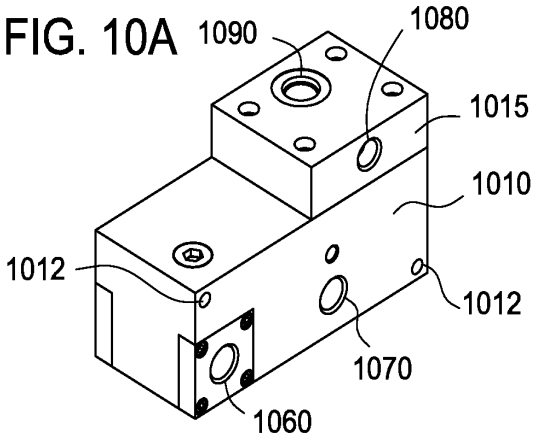


FIG. 10A

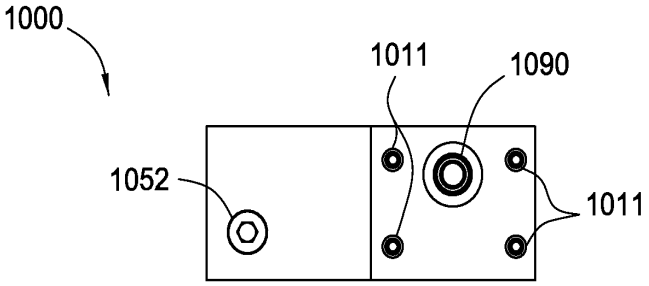


FIG. 10E

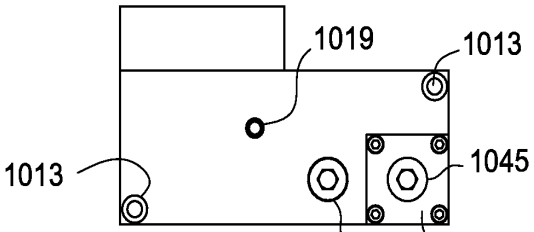


FIG. 10B

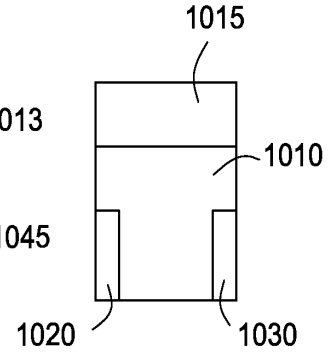


FIG. 10D

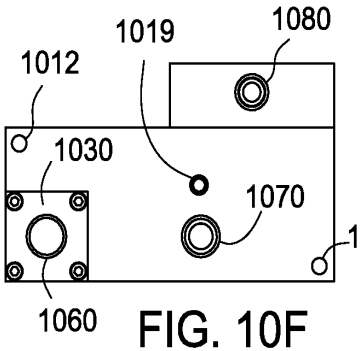


FIG. 10F

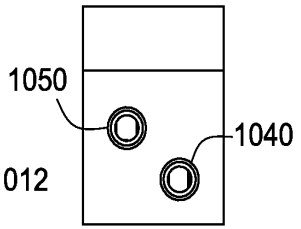


FIG. 10H

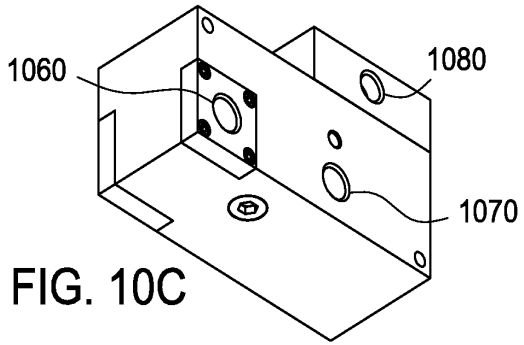


FIG. 10C

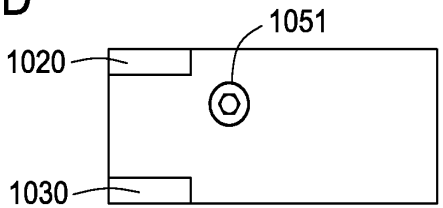
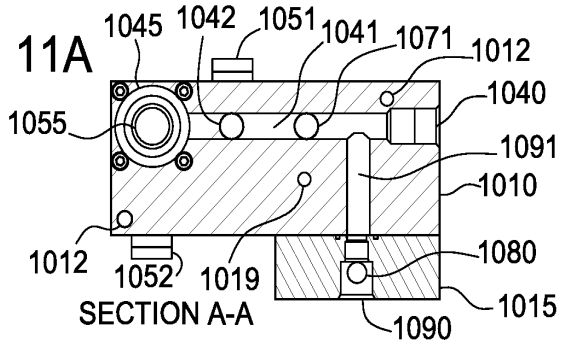


FIG. 10G

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FIG. 11A



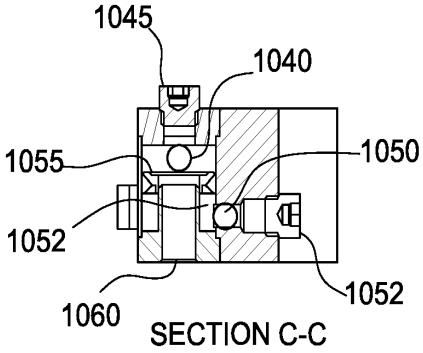
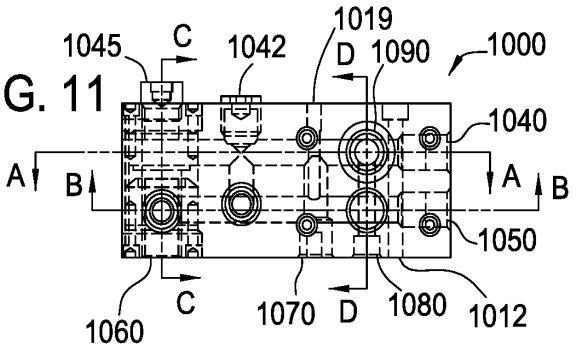


FIG. 11C

FIG. 11



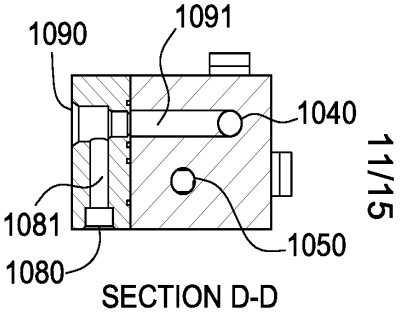


FIG. 11D

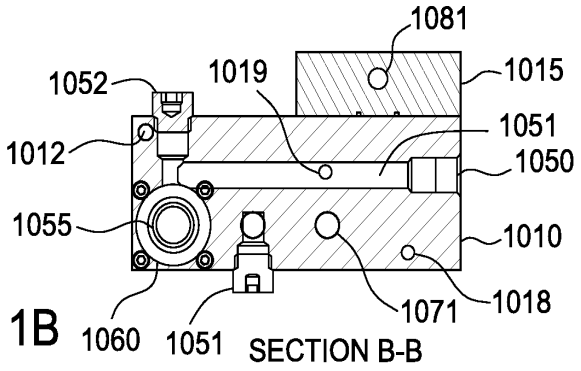


FIG. 11B

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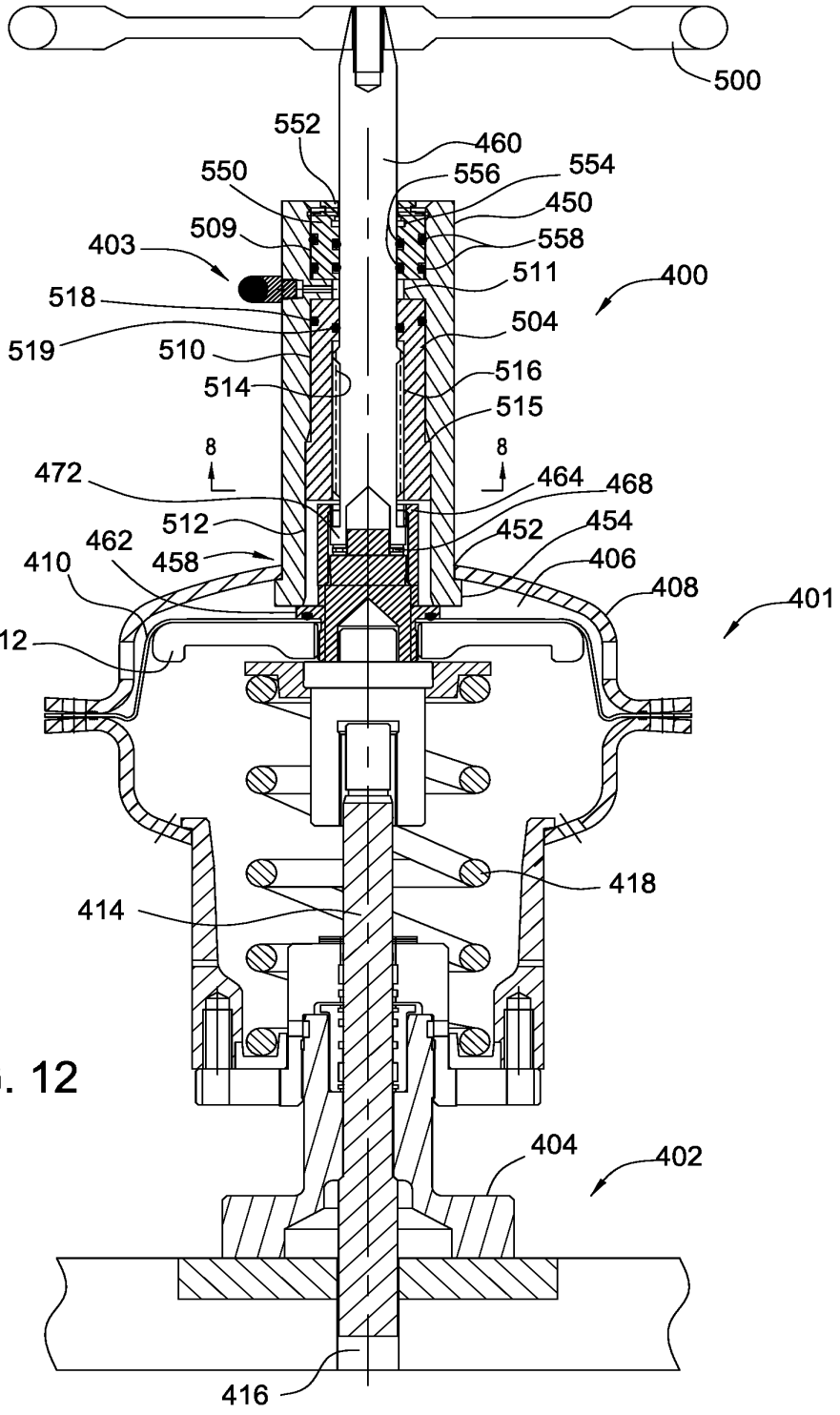

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FIG. 12

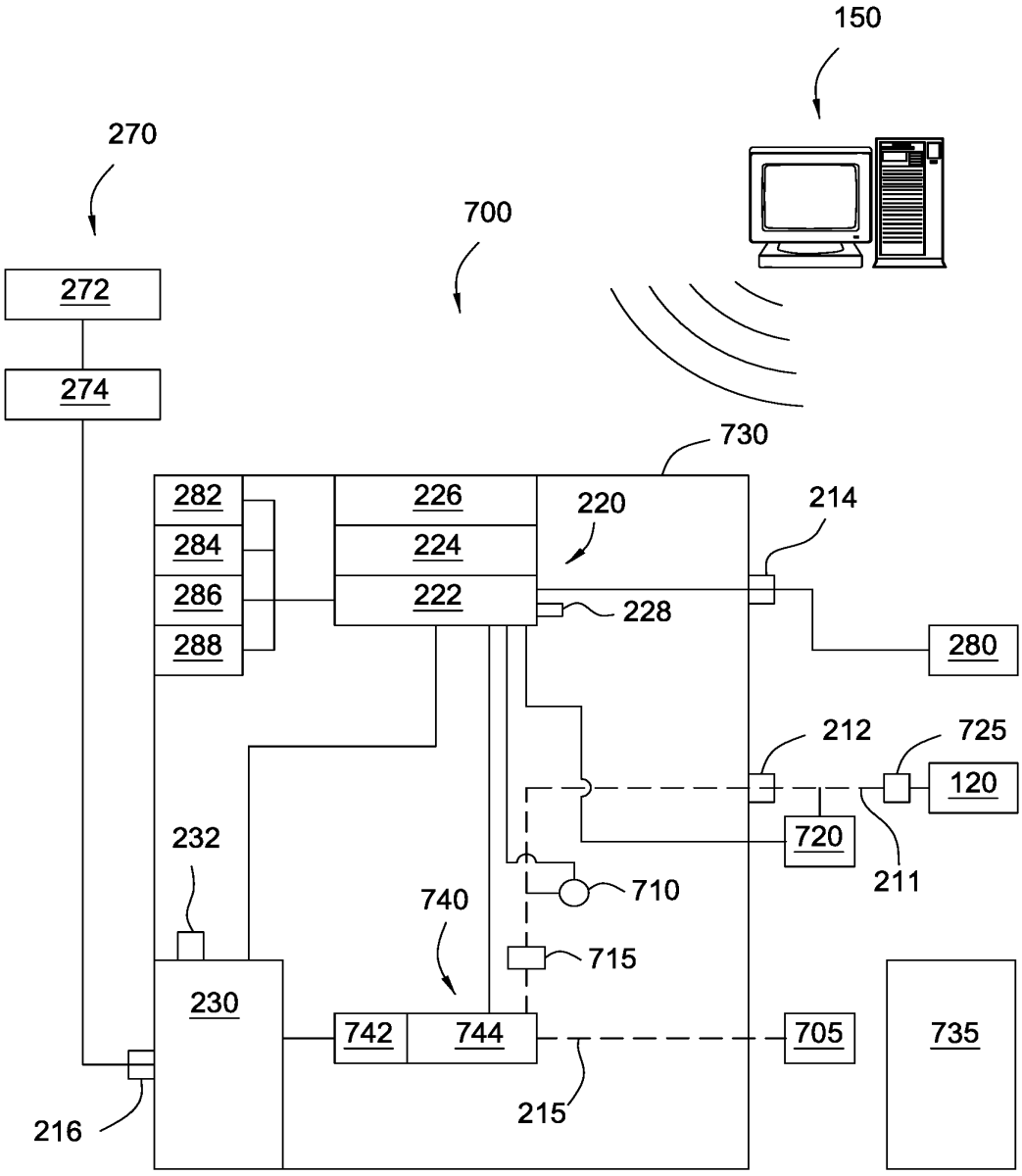

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FIG. 13

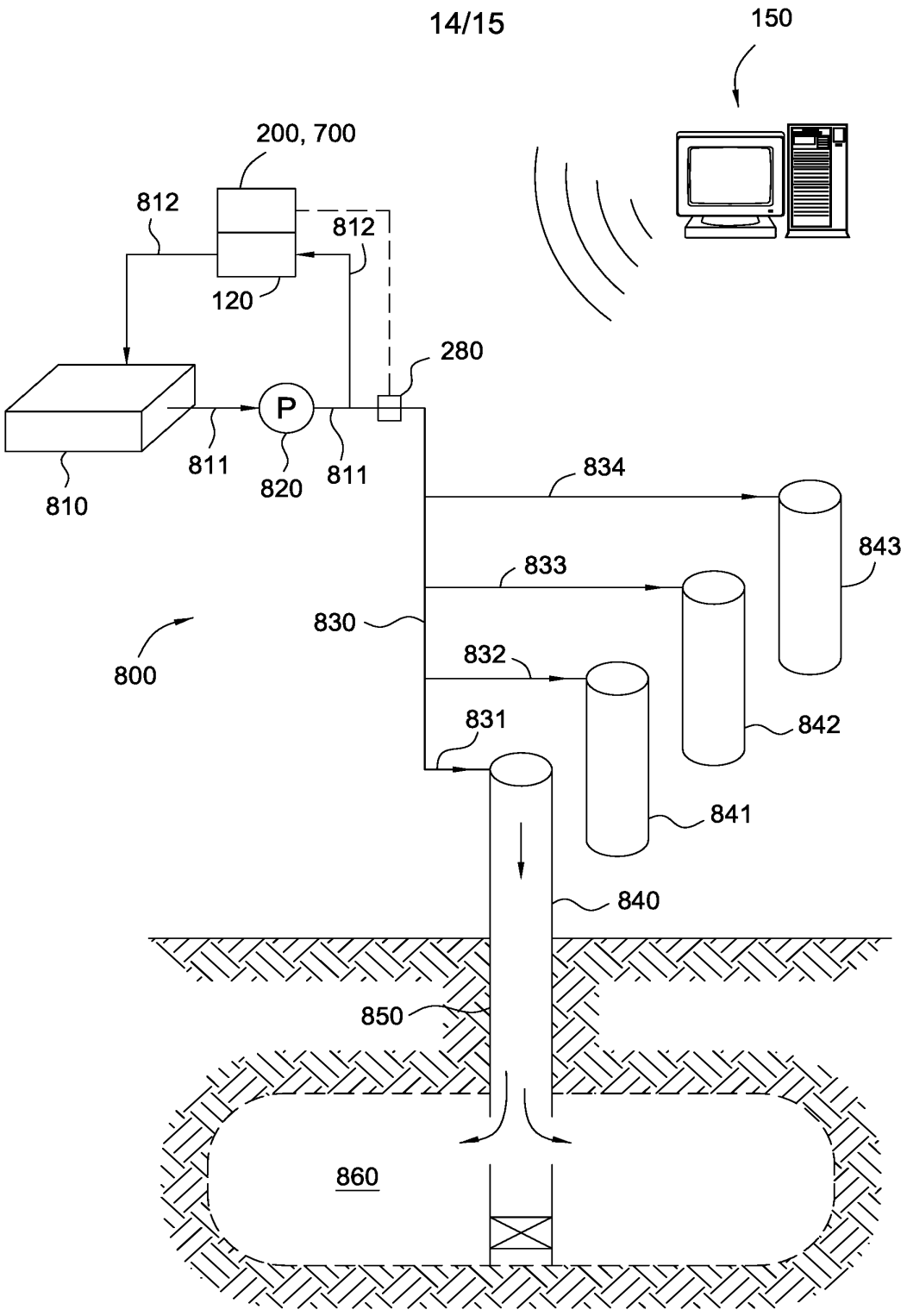

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FIG. 14

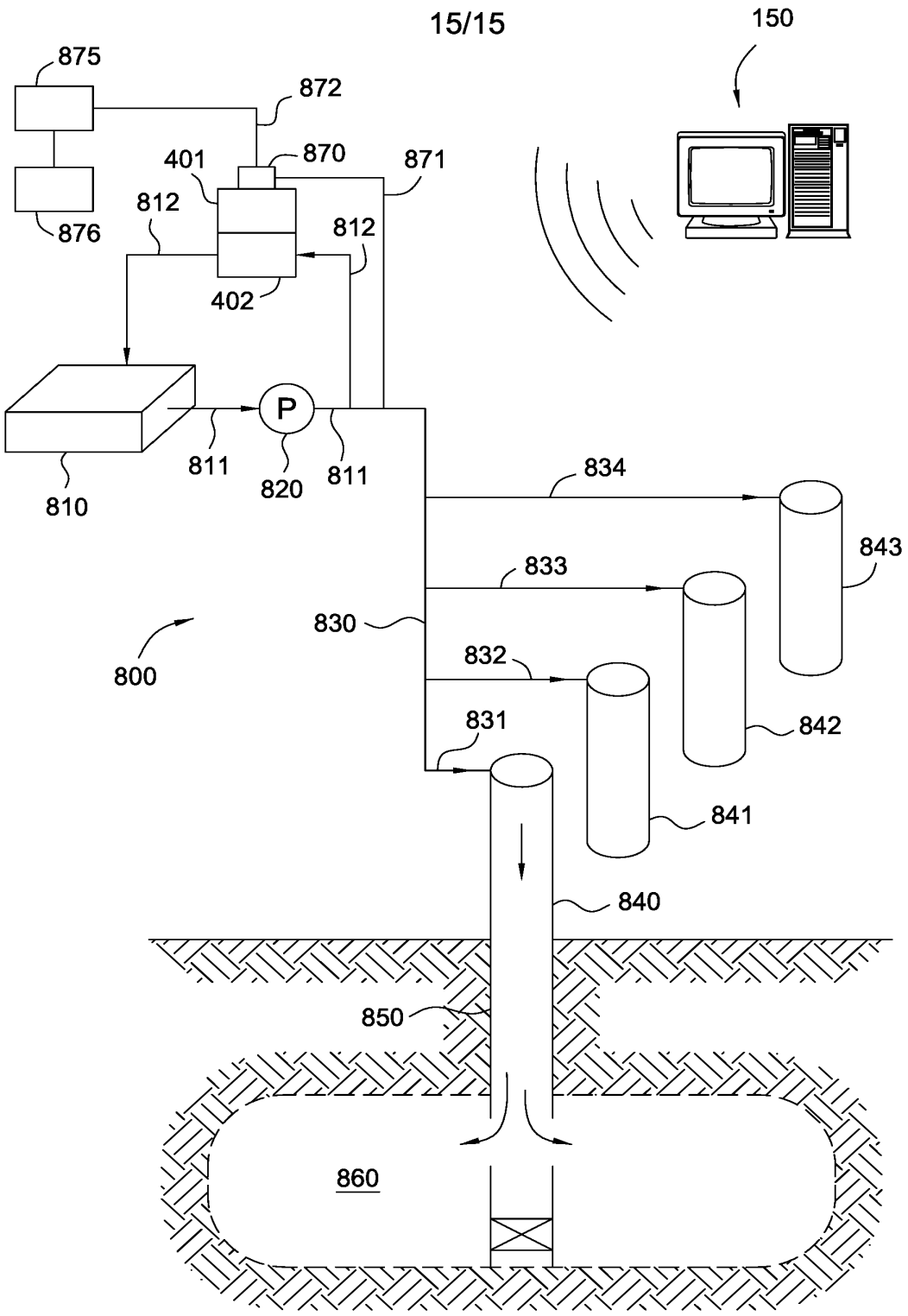

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FIG. 15

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
Mr.	David		LYMBEROPOULOS	

Residence Information (Select One) ● US Residency Non US Residency Active US Military Service

City	Houston	State/Province	TX	Country of Residence	US

Mailing Address of Inventor:

Address 1	8310 North Tahoe Drive		
Address 2			
City	Houston	State/Province	TX
Postal Code	77040	Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
Mr.	Benjamin	R.	MATTHEWS	

Residence Information (Select One) ◉ US Residency Non US Residency Active US Military Service

City	Missouri City	State/Province	TX	Country of Residence	US

Mailing Address of Inventor:

Address 1	3522 Rolling Green Lane		
Address 2			
City	Missouri City	State/Province	TX
Postal Code	77459	Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	26290		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE		
Attorney Docket Number	FETI/0012USPC01	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	15	**Suggested Figure for Publication (if any)**	13

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	26290		

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	13/480704	2012-05-25
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13/480704	Claims benefit of provisional	61/551319	2011-10-25
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
61/551319	Continuation of	13/195662	2011-08-01
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13/195662	Claims benefit of provisional	61/415238	2010-11-18
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13/195662	Claims benefit of provisional	61/370721	2010-08-04
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.			Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Remove

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

● Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	SAFOCO, INC.		
Mailing Address Information For Applicant:			
Address 1	11421-A TODD ROAD		
Address 2			
City	Houston	**State/Province**	TX
Country	US	Postal Code	77055
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	FETI/0012USPC01
	Application Number	
Title of Invention	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

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If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
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NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Jessie D. Herrera/			Date (YYYY-MM-DD)	2016-09-12
First Name	Jessie D.	Last Name	Herrera	Registration Number	63,799

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

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Electronic Acknowledgement Receipt

EFS ID:	26897626
Application Number:	15262642
International Application Number:	
Confirmation Number:	6248
Title of Invention:	SAFETY VALVE CONTROL SYSTEM AND METHOD OF USE
First Named Inventor/Applicant Name:	David LYMBEROPOULOS
Customer Number:	26290
Filer:	Jessie D. Herrera/Stephanie Dominguez
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Time Stamp:	15:49:01
Application Type:	Utility under 35 USC 111(a)

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Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Application.pdf	166550 f2c792b62bbd5fd7a11d132e9b1d5383bee99fea	yes	48

	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Specification		1	43	
	Claims		44	47	
	Abstract		48	48	
Warnings:					
Information:					
2	Drawings-only black and white line drawings	Drawings.pdf	473556 419872a2082bcf6ab0f975175ffdf884fca02d96	no	15
Warnings:					
Information:					
3	Application Data Sheet	ADS.pdf	1823322 8e03d4700de92f807ba81347282027 82ad8e8eca	no	9
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		Total Files Size (in bytes):	2463428		

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

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If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

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