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- (71) **Applicant:** NUMATICS, INCORPORATED [US/US];
46280 Dylan Drive, Novi, MI 48377 (US).
- (72) **Inventors:** DE CAROLIS, Enrico; 2440 Selkirk Court,
Oakland Township, MI 48306 (US). ESKEW, John, F.;
17416 N. 24th Drive, Phoenix, AZ 85023 (US). WELLS,
Gregory, A.; 12229 N. 60th Lane, Glendale, AZ 85304
(US).
- (74) **Agent:** PERMUT, Steven, L.; Reising Ethington P.C.,
755 W. Big Beaver Road, Suite 1850, Troy, MI 48084
(US).

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- (54) **Title:** A VALVE MANIFOLD SERIALLY MOUNTED TO A DISTRIBUTED CONTROL SYSTEM ASSEMBLY

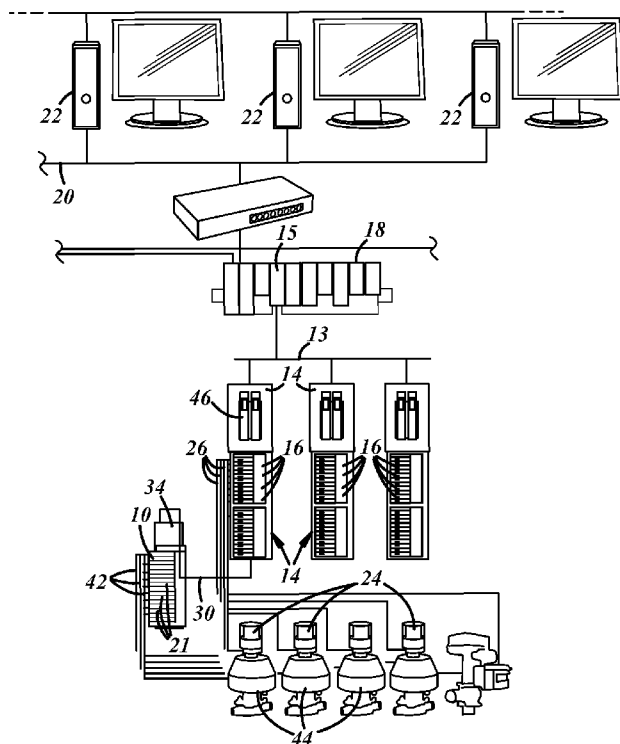


FIG. 2

(57) **Abstract:** A control system has an I/O bank with a communication module controlling a plurality of Input/Output modules operably connected to its communication backplane and a valve manifold having a communication module serially connected to the backplane of the I/O bank. The I/O bank with a plurality of Input/Output modules is constructed to be connected to a plurality of field sensors or loads. The valve manifold with a plurality of solenoid valves is constructed to be pneumatically connected to a plurality of field devices.

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A VALVE MANIFOLD SERIALLY MOUNTED TO A DISTRIBUTED CONTROL SYSTEM ASSEMBLY

5 TECHNICAL FIELD

The field of this invention relates to an electrical bus system that has a solenoid valve manifold that is serially connected to a distributed control system via a distribution I/O system.

10 BACKGROUND OF THE DISCLOSURE

Industrial automation uses many control devices. One useful control device is a solenoid valve manifold, often simply referred to as a valve manifold, that houses a plurality of electrically actuated solenoid valves. The solenoid valves control the direction of hydraulic or pneumatic flow for actuating other downstream field devices, for example process valves. These valve manifolds have communication modules that often mount adjacent the solenoid valve stations, and connect to various fieldbus networks.

These fieldbus networks have become commonplace in automation control.

20 The fieldbus network provides remote control over the valve stations. Typical fieldbus networks may use EtherNet/IP™, FIPIO™, Interbus-S™, ControlNet™, DeviceNet™ or other proprietary or open network protocols. The valve manifold is connected to a fieldbus network usually mastered by a remote programmable logic controller (PLC), industrial personal computer (IPC), and/or distributed

25 control system (DCS). As used herein, the term distributed control system (DCS) is generic in nature and also includes PLCs and IPCs.

It is also common to have side by side network architecture as illustrated in Figure 1, i.e., a fieldbus 11 that is connected to the valve manifold is parallel to another fieldbus network 13 with respect to a DCS 18. The DCS 18 may be a commercially available DeltaV™ DCS. A bank of Input/Output modules (I/O bank) 14, that uses a proprietary Ethernet connection as an example, is connected remotely from the DCS 18 to ethernet master unit 15 in the DCS 18. The I/O bank may be a commercially available CHARM™ I/O bank 14 connected to a plurality of field devices, i.e. sensors 24 that send back signals for various parameters sensed at process valves 44 or loads that may include valves. The I/O bank 14 can receive signals from the sensors and relays the signals in the fieldbus network 13 to the DCS 18. Valve manifolds 10 are connected to a master unit 12 in DCS 18. Valve manifold 10 is pneumatically operably connected to the plurality of process valves 44. The valve manifold 10 is connected in parallel to the DCS 18 relative to the I/O bank 14 via a different network 11, e.g. Profibus-DP. Both master unit 12 and ethernet network master 15 are controlled by DCS 18. In this fashion, the valve manifold and I/O bank work in parallel, side by side, using their own respective fieldbus networks 11 and 13 and respective protocols.

This standard prior art system uses one protocol network for controlling the valves, but uses another network to verify valve positions and other parameters via sensors. The use of two networks to coordinate the valves and sensors adds a level of undesirable complexity.

Coordination of valve and I/O control can be achieved by connecting each valve manifold station through a CHARM I/O module, each module having with its own microprocessor. This connection method, however, is expensive and labor intensive by the need to wire a separate CHARM I/O module with its own

microprocessor to each solenoid valve of each valve station on the manifold.

What is needed is a more expeditious arrangement where the valve manifold is connected to the I/O bank 14 and logically becomes an integral part of the I/O bank as if the valves were physically part of the I/O bank such that the DCS can control the valve manifold and I/O bank as if they were one unit, using the I/O bank's existing backplane protocol and also allowing the DCS to decode diagnostic information available via the valve manifold's communication module for the valves and manifold system.

SUMMARY OF THE DISCLOSURE

In accordance with one aspect of the invention, a control system has a distributed control system (DCS) connected to an I/O bank that has a communication module. A plurality of input-output modules of the I/O bank are operably connected to and mastered by the remote I/O bank's communication module for control of its I/O modules. A valve manifold having a manifold communication module for controlling a plurality of valve stations is also operably connected to the I/O bank using the same protocol of the I/O bank. Preferably, the I/O modules and manifold communication modules are connected to the communication module through a backplane of the I/O bank. The I/O bank is constructed to be connected to a plurality of field sensors and/or loads. The valve manifold is constructed to be pneumatically connected to a plurality of field devices. The field device may be process valves and the field sensors may be appropriate for sensing various parameters, e.g. process valve position, pressure flow, temperature at the process valves or in the process system.

Preferably, the I/O bank and valve manifold are housed in a single cabinet. Preferably, the valve manifold has pneumatic fittings extending through a wall of the cabinet.

In an alternate embodiment, the I/O bank and the valve manifold are housed in separate cabinets. A cable for providing communication and power extends from the I/O bank in one cabinet to the valve manifold in the other cabinet. Preferably, the valve manifold has pneumatic fittings extending through a wall of the other cabinet.

According to another aspect of the invention, a control system has a

communication module operably connected to an I/O bank with a plurality of Input/Output modules. A valve manifold has a manifold communication module operably connected to a plurality of valve stations and serially connected to the backplane of the communication module of the I/O bank using the same protocol as the backplane. The Input/Output modules are constructed to be connected to a plurality of field sensors and/or loads. The valve manifold is constructed to be pneumatically connected to a plurality of field devices. The I/O bank and the valve manifold are housed in a single cabinet.

In accordance with another aspect of the invention, a control system has a DCS connected to an I/O bank with a plurality of Input/Output modules operably connected to a communication backplane mastered by the I/O bank's communication module for controlling the plurality of its Input/Output modules. A valve manifold having a manifold communication module for controlling a plurality of valve stations is operably connectable to a plurality of field devices preferably through a pneumatic connection. The manifold communication module is serially connected to the I/O bank's communication backplane through a single communication cable. A second redundant cable for safety may also be connected.

The Input/Output modules of the I/O bank are constructed to be connected to a plurality of field sensors and/or loads.

Preferably, each Input/Output module of the I/O bank has a microprocessor therein. The manifold communication module has a microprocessor programmed to emulate a plurality of microprocessors of the Input/Output modules connected to the communication backplane of the I/O bank.

In one embodiment, the manifold communication module has power supplied from the I/O backplane through a cable. The cable also preferably

provides communication.

In one embodiment, a redundant cable also supplies redundant power and redundant communication.

In accordance with another aspect of the invention, a second communication
5 module may be installed on the same network with the I/O bank and its backplane.
The valve manifold communication module is connected to the second
communication module and is constructed to emulate a plurality of Input/Output
module microprocessors and control a plurality of valves.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference now is made to the accompanying drawings in which:

Figure 1 is a schematic chart of a prior art control system with a DCS which communicates in parallel to a valve manifold and an I/O bank using two separate
5 fieldbus networks;

Figure 2 is a schematic chart showing a valve manifold serially connected to an I/O bank which is in turn connected to a DCS via a communication network in accordance with an embodiment of the invention;

Figure 3 is a fragmented and enlarged schematic showing the I/O bank and
10 the valve manifold connected in series as shown in Figure 2 with redundant backplane communication;

Figure 4 is a plan view showing the I/O bank and the valve manifold connected in series and both housed in a single cabinet housing;

Figure 5 is an alternate embodiment where the valve manifold and the I/O
15 bank are connected in series and mounted in separate proximately located cabinets; and

Figure 6 is an alternate embodiment where the valve manifold and the I/O bank are mounted in separate remote cabinets where the valve manifold is serially connected to a remote I/O bank without any Input/Output cards.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Figure 2, a control network 20 has a plurality of work stations 22 connected to a DCS 18. The DCS may be a commercially available DELTAV™ system from Emerson Process Management. The DCS 18 is in turn connected through its network 13 to one or more I/O banks 14 containing individual Input/Output modules 16. A suitable bank of I/Os may be the commercially available CHARM™ I/O bank from Emerson Process Management. These I/O banks 14 may be remotely positioned from the DCS 18.

Many of the individual I/O modules 16 in the bank may be connected to field sensors 24 through cables 26 for receiving information from the field sensors 24. In addition, a valve manifold 10 may also be connected to the I/O bank 14. Preferably, as illustrated in Figure 3, the connection is made by extending a cable 30 that integrates both power and communication from a backplane 32 of the I/O bank 14 to the communication fitting 33 of a communication module 34 of the valve manifold 10. More specifically, the power and communication cable 30 extends from the fitting 33 of the valve manifold 10 to a column extender 36 that connects the backplane 32 of the I/O bank 14. A redundant integrated power and communication cable 38 is also installed to fitting 40 in case cable 30 fails. In certain commercially available embodiments, the cable 30 only provides communication and cable 38 only provides power.

The valve manifold 10 has its plurality of valve stations 21 attached to pneumatic fittings 45 that are connected to a plurality of pneumatic tubes 42 as shown in Figure 2 which in turn are operably connected to field devices 44 for example process valves. As shown in Figure 3, cables 30 and 38 extend from the

I/O bank 14 to the valve manifold 10 and the pneumatic tubes 42 extend from the valve manifold 10 to the field devices 44 in Figure 2. The field sensors 24 may be operably connected to the field devices 44 for sensing one or more parameters, e.g. process valve position, pressure at the field devices 44 and are connected through
5 cables 26 directly back to the I/O bank 14 bypassing the valve manifold 10 and its communication module 34. The field sensor may also sense other parameters, such as temperature and flow rate at other locations in the process system remote from the field devices.

The I/O bank 14 may have a communication module 46 connected to a DCS
10 18 for control and communication with the I/O modules 16 via backplane 32 as shown in Figure 3. A redundant communication module 46B may be mounted adjacent module 46 for safety and redundancy. The redundant communication module 46B may be on a redundant network 53 as more clearly shown in Figure 4. The advantage of the using the CHARM™ system is that each individual
15 replaceable card 16 for each I/O can be fitted into the housing 48 as shown in Figure 3 to commission the I/Os 16 to either an input or an output position without changes to the hard wiring in its housing 48 or base plate 49, i.e. it performs electronic marshalling for all the signals coming in or emanating from the I/O modules 16 of bank 14.

20 By having the manifold communication module 34 connected to the backplane 32 of the I/O bank 14, the valve manifold 10 is directly in communication with the communication module 46 of the I/O bank 14 and, therefore, seamlessly controlled by the DCS 18. In other words, the valve manifold has a communication module which translates the serial backplane protocol of the
25 I/O bank, so the DCS 18 can seamlessly control the valve manifold.

By using the same protocols in both the manifold communication module 34 of the valve manifold 10 and the backplane communication of I/O bank 14, the valve manifold 10 may "piggyback" onto the I/O bank 14 and enhance the functionality of the I/O bank 14 by adding valve capabilities to the I/O bank. The single microprocessor of the manifold communication module 34 emulates multiple Input/Output module 16 microprocessors and thus, the communication module 46 reads the signals from the manifold communication module 34 as if they were signals from the different Input/Output modules 16. While it is known that an IC chip with a CPU on it is called a microprocessor, a single IC chip may also include I/O pins, RAM, ROM and other components. These single IC chips are commonly called microcontrollers. Microprocessors, as used herein, include IC chips now commonly referred to as microcontrollers.

Furthermore, the piggybacking of the valve manifold onto the I/O bank eliminates the need for additional dedicated networks for solenoid valve manifolds. There is no further need for a second fieldbus network, e.g., DeviceNet/Profibus-DP/AS-Interface, etc. and, thus, the number of fieldbus networks is reduced for the entire control system in Figure 2.

The wiring is also reduced by providing only a single network cable 13 connecting the field junction box, i.e. the communication module 34 back to the distributed control system 18 for both the I/O bank 14 and the solenoid valve manifold 10.

A single connection to the I/O bank 14 from the DCS 18 allows for a tightly integrated solution with no need for additional software configuration tools. Both the I/O bank 14 and valve manifold 10 provide a single point for a user to control of products, documentation and diagnostics. All the configuration work can be done

via the DCS 18.

The diagnostics of the valve manifold are available via the DCS. The valves in the valve manifold are sensed by the DCS and are available with the same distributed control system diagnostics application that is used for other field devices
5 connected to the I/O bank or to the DCS.

Figures 4 and 5 illustrate different cabinet configurations for the use of the I/O bank 14 and valve manifold 10 shown in Figure 2 and 3. Figure 4 illustrates a typical installation of a single cabinet 50 housing both the I/O bank 14 and the valve manifold 10. The cables 30 and 38 extend from a column extender 36 at the I/O
10 bank 14 and connect to the communication module 34 of the valve manifold 10. In this illustrated embodiment, the pneumatics fittings 45 of the valve manifold 10 extend out of a side 52 of the cabinet 50.

Figure 5 illustrates the I/O bank 14 mounted in cabinet 50 while the valve manifold 10 is mounted in a separate second cabinet 54. The cabinets 50 and 54 are
15 mounted a short enough distance from each other to allow the cables 30 and 38 to extend from the column extender 36 and out of the cabinet 50 to cabinet 54 where it is connected to the communication module 34 for the valve manifold 10. The pneumatic fittings 45 extend out of side 56 of the cabinet 54. This embodiment is preferred when the pneumatic system is remote from the cabinet 50.

20 Figure 6 illustrates separate cabinets 50 and 54 where the cabinets are mounted a farther distance with respect to each other than the cabinets shown in Figure 5. In this embodiment, the I/O bank 14 is mounted in cabinet 50 and the valve manifold 10 is mounted in the second cabinet 54. Power is separately supplied to the second cabinet 54 (not shown). Communication is supplied via
25 network 13 to a second communication module 46A without I/O modules 16 that is

mounted in cabinet 54. The second communication module 46A is also mounted to connect to network 13 of DCS 18. A redundant communication module 46C may be mounted adjacent a second communication module 46A and connected to redundant network 53 for meeting safety protocols. The power and communication
5 cables 30 and 38 extend from the I/O bank backplane 32 to connect communication modules 46 and 46A to the communication module 34 of the valve manifold 10 for controlling the valve manifold 10. The pneumatic fittings 45 extend out of side wall 56.

As shown in Figure 6, a communication module 46 need not be connected
10 to any Input/Output module 16, but the advantage of using the I/O bank backplane to serially connect to valve manifold 10 via communication module 34 still provides the advantage of using a single network 13 for both the I/O units and manifold valves and eliminating a separate network 11.

Other variations and modifications are possible without departing from the
15 scope and spirit of the present invention as defined by the appended claims.

CLAIMS

The embodiments in which an exclusive property or privilege is claimed are defined as follows:

- 5 1. A control system comprising:
a distributed control system connected to an I/O bank;
said I/O bank operable has a communication module controlling a plurality
of Input/Output modules operably connected to the communication module;
a valve manifold with a manifold communication module for controlling a
10 plurality of valve stations serially connected to the communication module of the
I/O bank and using the same protocol and operably connectable to a plurality of
field devices;
the I/O bank constructed to be connected to a plurality of field sensors or
loads; and
15 said valve manifold being constructed to be pneumatically connected to a
plurality of field devices.
2. A control system as defined in claim 1 further comprising:
said I/O bank with a plurality of Input/Output modules and said valve
20 manifold being housed in a cabinet.
3. A control system as defined in claim 2 further comprising:
said valve manifold having pneumatic outlets extending through a wall of
said cabinet.

4. A control system as defined in claim 1 further comprising:
said I/O bank with a plurality of Input/Output modules and said valve manifold being housed in separate cabinets; and
a cable for providing communication and power extending from the I/O
5 bank in one cabinet to the valve manifold in said other cabinet.
5. A control system as defined in claim 4 further comprising:
said valve manifold having pneumatic outlets extending through a wall of
said other cabinet.
- 10
6. A control system as defined in claim 1 further comprising:
said I/O bank with a plurality of Input/Output modules and said valve manifold being housed in separate cabinets; and
a cable for providing communication and power extending from the I/O
15 bank in one cabinet to the valve manifold in said other cabinet.
7. A control system as defined in claim 1 further comprising:
said I/O bank having a backplane that operably connects to said plurality of
Input/Output modules, said communication module and said manifold
20 communication manifold.
8. A control system comprising:
a communication module having an I/O bank with a plurality of
Input/Output modules;
25 a valve manifold having a manifold communication module serially

connected to the communication backplane of the I/O bank using the same protocol as the communication backplane for controlling a plurality of valve stations;

said I/O bank with plurality of Input/Output modules constructed to be connected to a plurality of field sensors or loads;

5 said valve manifold being constructed to be pneumatically connected to a plurality of field devices; and

said I/O bank and said valve manifold being housed in a cabinet.

9. A control system as defined in claim 8 further comprising:

10 said valve manifold having pneumatic outlets extending through a wall of said cabinet.

10. A control system comprising:

a distributed control system connected to an I/O bank;

15 said I/O bank having a communication module controlling a plurality of Input/Output modules operably connected to its communication backplane;

a valve manifold with a manifold communication module for controlling a plurality of valve stations operably connectable to a plurality of field devices having its manifold communication module serially connected to the communication

20 backplane of the I/O bank through a single cable or through a second cable for redundant communication;

the Input/Output modules of said I/O bank with a plurality of Input/Output modules constructed to be connected to a plurality of field sensors or loads; and

25 said valve manifold being constructed to be pneumatically connected to a plurality of field devices.

11. A control system as defined in claim 10 further comprising:
each Input/Output module of said I/O bank having a microprocessor therein;
and

5 said manifold communication module having a microprocessor constructed
to emulate a plurality of said microprocessors of each Input/Output module therein
and connected to the I/O bank's communication backplane and controlling said
plurality of field devices.

10 12. A control system as defined in claim 11 further comprising:
said manifold communication module having power supplied from said
backplane of said I/O bank through said single cable.

13. A control system as defined in claim 12 further comprising:
15 said second cable also connected to supply redundant power from said
backplane.

14. A control system as defined in claim 12 further comprising:
said bank of Input/Output modules and said valve manifold being housed in
20 separate cabinets; and
said single cable extending from the I/O bank in one cabinet to the valve
manifold in said other cabinet.

15. A control system comprising:
25 a distributed control system operably connected to a communication module

for an I/O bank having no Input/Output modules attached thereto;

a valve manifold with a manifold communication module for controlling a plurality of valve stations operably connectable to a plurality of field devices having its manifold communication module serially connected to said communication

5 module through a communication cable; and

said valve manifold being constructed to be pneumatically connected to a plurality of field devices.

16. A control system as defined in claim 15 further comprising:

10 said manifold communication module connected via a communication backplane of said I/O bank without Input/Output modules to said communication module.

15

The embodiments in which an exclusive property or privilege is claimed are defined as follows:

- 5 1. A control system comprising:
a distributed control system connected to an I/O bank;
said I/O bank has a communication module controlling a plurality of
Input/Output modules operably connected to the communication module;
a valve manifold with a manifold communication module for controlling a
10 plurality of valve stations serially connected to the communication module of the I/O
bank and using the same protocol and operably connectable to a plurality of field
devices;
the I/O bank constructed to be connected to a plurality of field sensors or loads;
said valve manifold being constructed to be pneumatically connected to a
15 plurality of field devices; and
at least one of said I/O bank with a plurality of Input/Output modules and said
valve manifold being housed in a cabinet.

2. A control system as defined in claim 1 further comprising:
20 said I/O bank with a plurality of Input/Output modules and said valve manifold
being housed in a cabinet.

3. A control system as defined in claim 2 further comprising:
said valve manifold having pneumatic outlets extending through a wall of said
25 cabinet.

4. A control system as defined in claim 1 further comprising:
said I/O bank with a plurality of Input/Output modules and said valve manifold
being housed in separate cabinets; and
5 a cable for providing communication and power extending from the I/O bank in
one cabinet to the valve manifold in said other cabinet.

5. A control system as defined in claim 4 further comprising:
said valve manifold having pneumatic outlets extending through a wall of said
10 other cabinet.

6. A control system as defined in claim 1 further comprising:
said I/O bank with a plurality of Input/Output modules and said valve manifold
being housed in separate cabinets; and
15 a cable for providing communication and power extending from the I/O bank in
one cabinet to the valve manifold in said other cabinet.

7. A control system as defined in claim 1 further comprising:
said I/O bank having a backplane that operably connects to said plurality of
20 Input/Output modules, said communication module and said manifold communication
module.

8. A control system comprising:
a communication module having an I/O bank with a plurality of Input/Output
25 modules;

a valve manifold having a manifold communication module serially connected to the communication backplane of the I/O bank using the same protocol as the communication backplane for controlling a plurality of valve stations;

said I/O bank with plurality of Input/Output modules constructed to be connected
5 to a plurality of field sensors or loads;

said valve manifold being constructed to be pneumatically connected to a plurality of field devices; and

said I/O bank and said valve manifold being housed in a cabinet.

10 9. A control system as defined in claim 8 further comprising:
said valve manifold having pneumatic outlets extending through a wall of said cabinet.

10. A control system comprising:
15 a distributed control system connected to an I/O bank;
said I/O bank having a communication module controlling a plurality of Input/Output modules operably connected to its communication backplane;
a valve manifold with a manifold communication module for controlling a plurality of valve stations operably connectable to a plurality of field devices having its
20 manifold communication module serially connected to the communication backplane of the I/O bank through a single cable or through a second cable for redundant communication;

the Input/Output modules of said I/O bank with a plurality of Input/Output modules constructed to be connected to a plurality of field sensors or loads; and
25 said valve manifold being constructed to be pneumatically connected to a

plurality of field devices.

11. A control system as defined in claim 10 further comprising:
each Input/Output module of said I/O bank having a microprocessor therein; and
5 said manifold communication module having a microprocessor constructed to
emulate a plurality of said microprocessors of each Input/Output module therein and
connected to the I/O bank's communication backplane and controlling said plurality of
field devices.

10 12. A control system as defined in claim 11 further comprising:
said manifold communication module having power supplied from said
backplane of said I/O bank through said single cable.

13. A control system as defined in claim 12 further comprising:
15 said second cable also connected to supply redundant power from said
backplane.

14. A control system as defined in claim 12 further comprising:
said bank of Input/Output modules and said valve manifold being housed in
20 separate cabinets; and
said single cable extending from the I/O bank in one cabinet to the valve
manifold in said other cabinet.

15. A control system comprising:
25 a distributed control system operably connected to a communication module for

an I/O bank having no Input/Output modules attached thereto;

a valve manifold with a manifold communication module for controlling a plurality of valve stations operably connectable to a plurality of field devices having its manifold communication module serially connected to said communication module

5 through a communication cable; and

said valve manifold being constructed to be pneumatically connected to a plurality of field devices.

16. A control system as defined in claim 15 further comprising:

10 said manifold communication module connected via a communication backplane of said I/O bank without Input/Output modules to said communication module.

AMENDED CLAIMS STATEMENT

Applicants submit the following informal comments in response to the International Search Report and Written Opinion mailed 28 December 2015. Claim 1 of the present application as filed has been indicated not to be novel or contain an inventive step under Article 33(2) and (3).

Claim 1

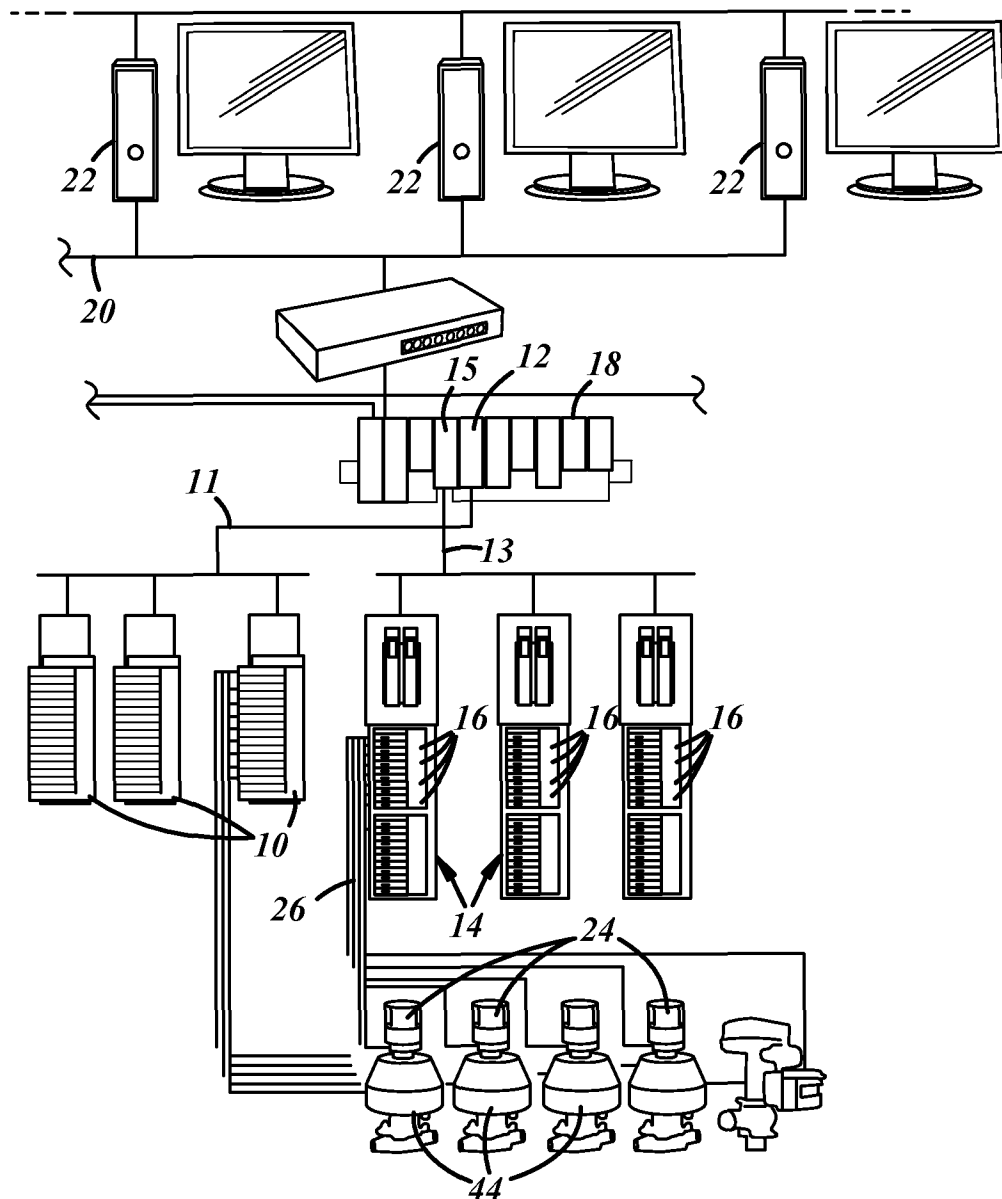
It is asserted in the Written Opinion that the U.S. Patent 7,753,740 to Carolis (sic) (see certificate of correction which shows "DeCarolis") discloses a control system having a distributed control system with a controller that is connected to an I/O bank.

Applicant's invention as defined in claim 1, as amended is clarified to state that at least one of said I/O bank and said valve manifold is housed in a cabinet. It is respectfully contended that the DeCarolis reference does not disclose any cabinet that houses the I/O bank or the valve manifold and thus does not render the claim 1 as amended as lacking novelty or lacking an inventive step.

Claim 7

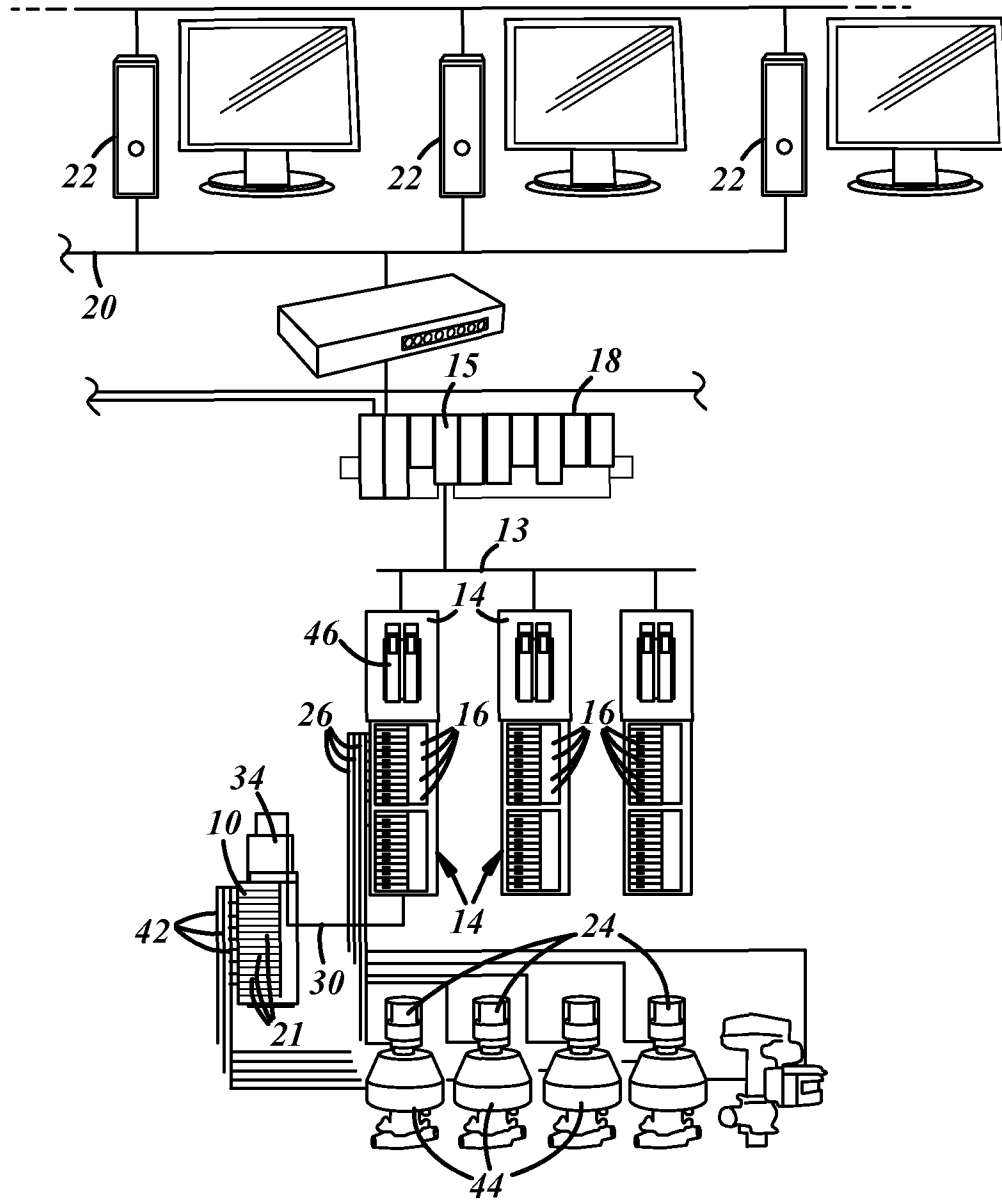
Claim 7 has been amended to correct a clerical error. The correct term “manifold communication module” is clearly supported in the Specification on Page 4, Lines 9-11 and Page 9, Lines 20-21.

It therefore is believed and respectfully submitted that all claims 1-16 now meet the novelty, inventive step and industrial applicability requirements of the PCT.



(Prior Art)

FIG. 1

**FIG. 2**

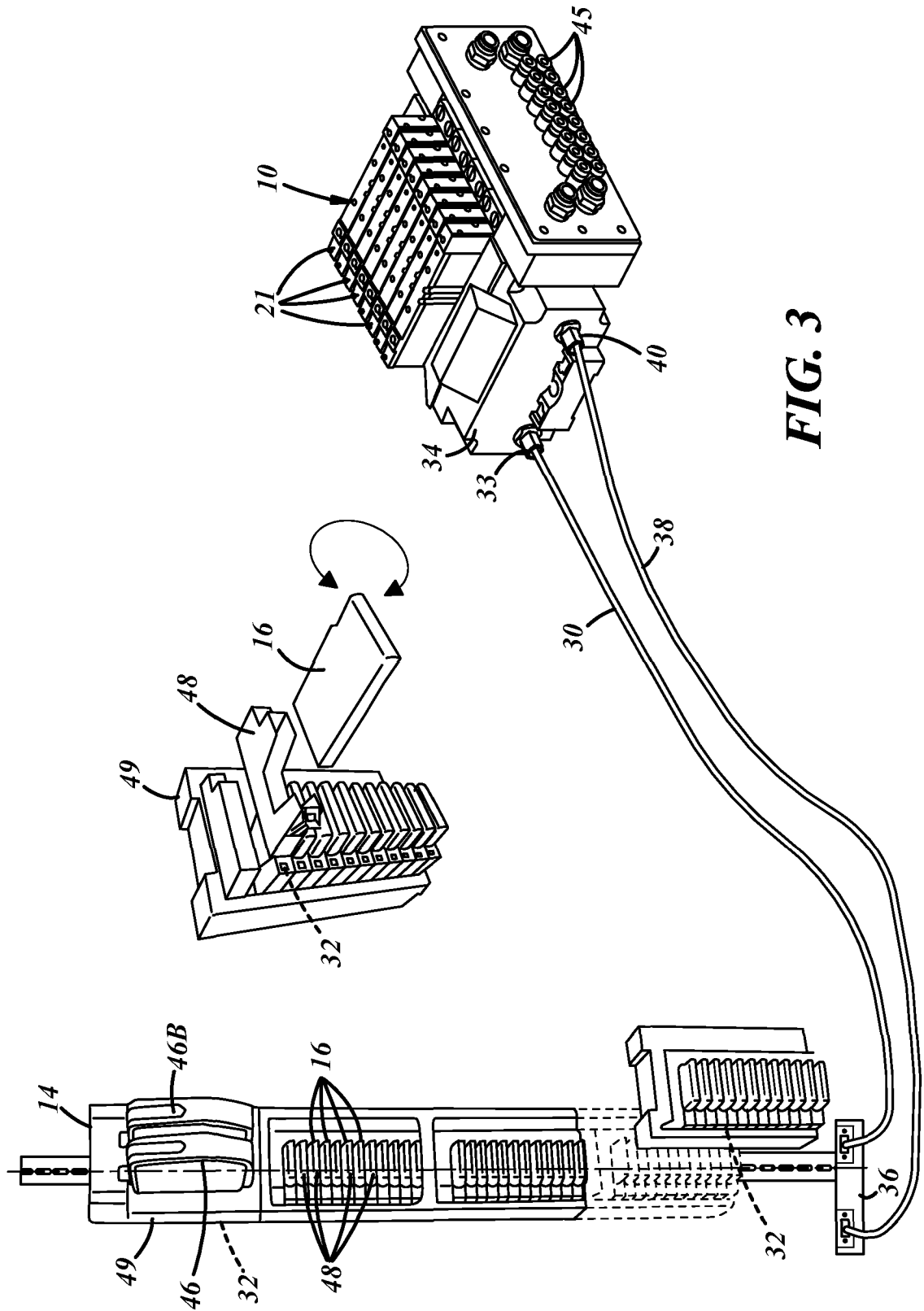


FIG. 3

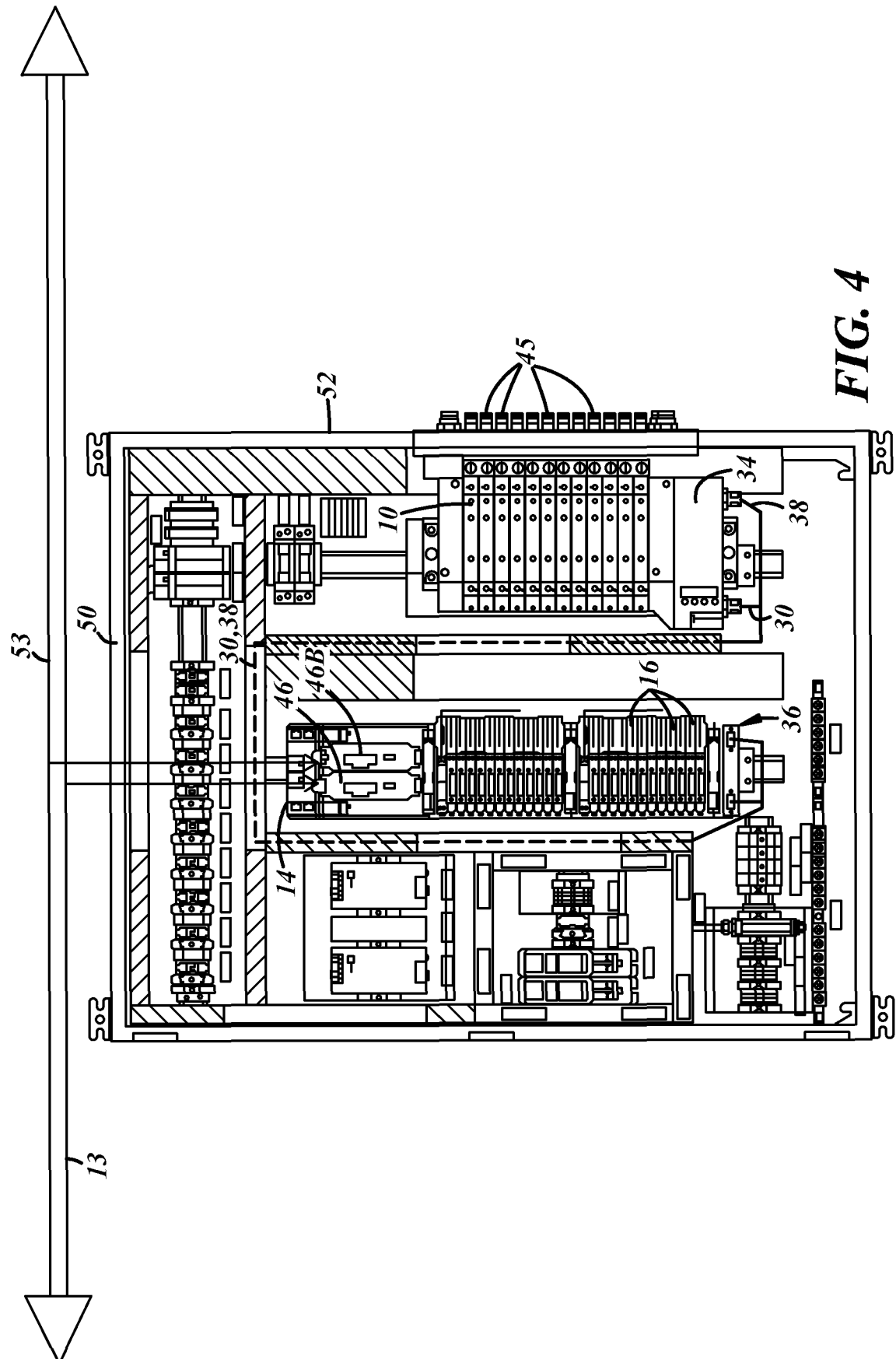


FIG. 4

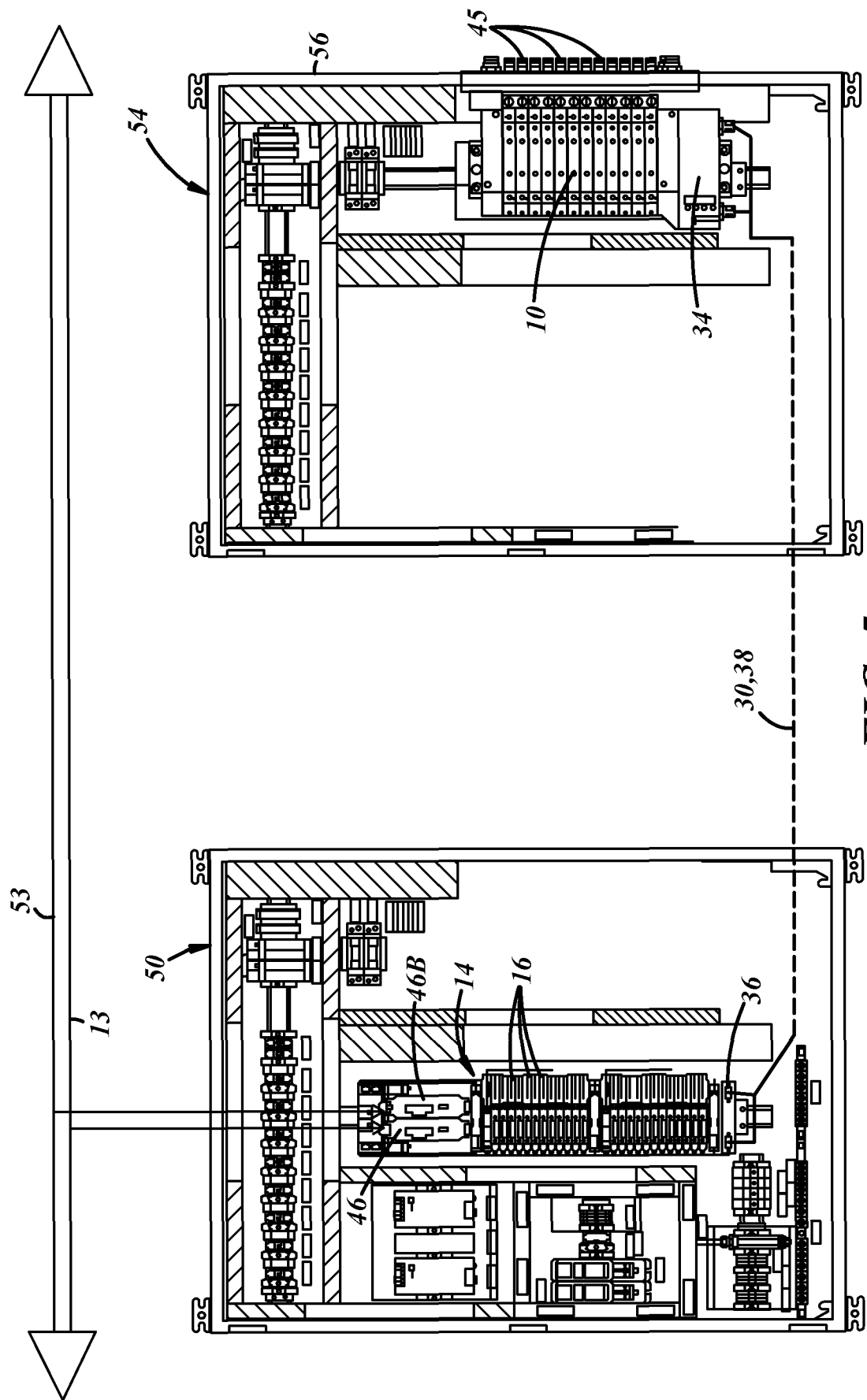


FIG. 5

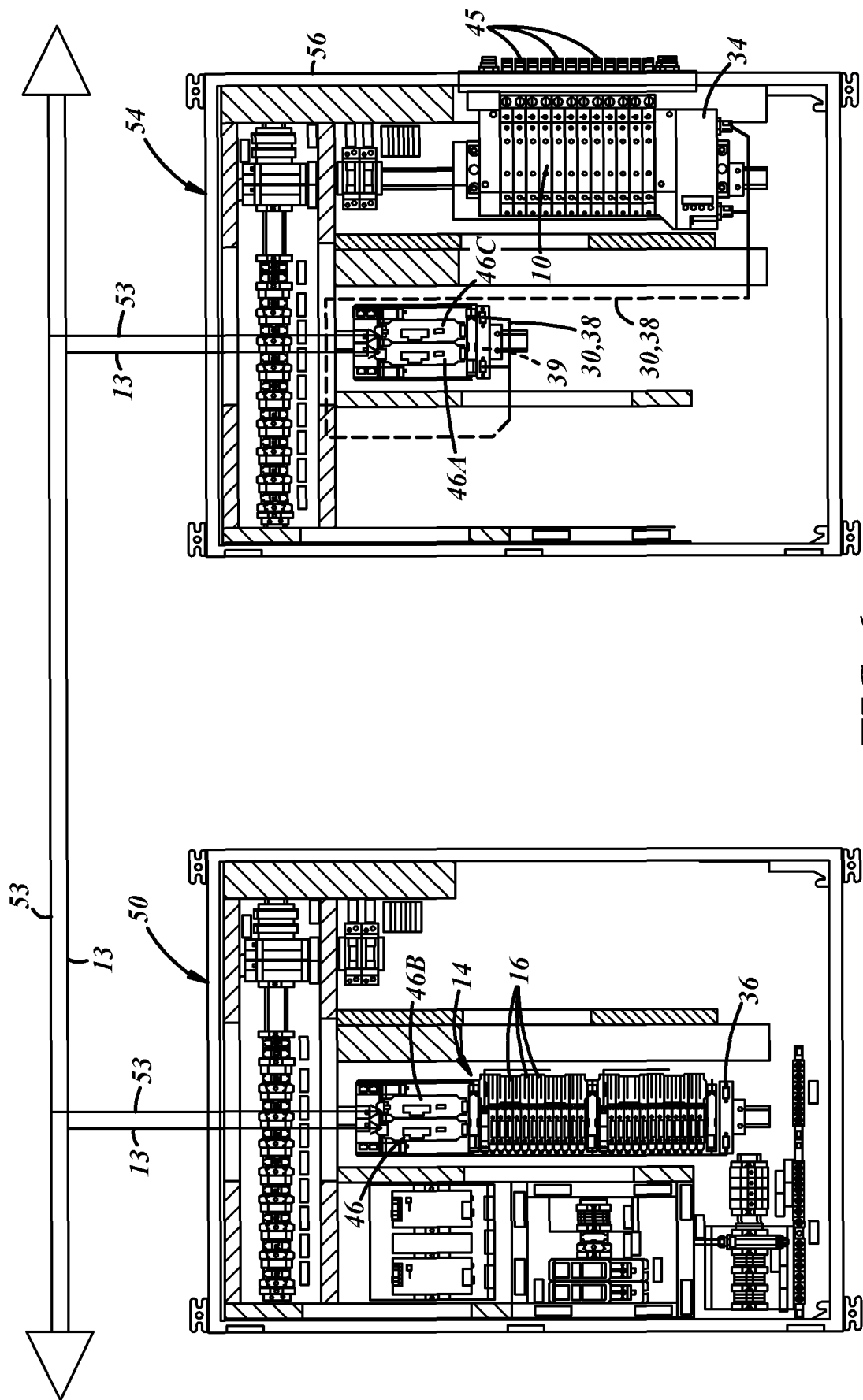


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2015/054701

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H05K 7/14 (2015.01)

CPC - H05K 7/1477 (2015.11)

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)

IPC(8) - G05B 19/048, 19/05; G05D 7/00; H01R 9/22; H04L 12/28, 29/12; H05K 7/02, 7/10, 7/14 (2015.01)
USPC - 137/884; 340/855.1; 439/717; 700/1, 3, 79, 83, 282; 710/110

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

CPC - G05B 19/0428; H01R 9/2408; H04L 12/40006; H05K 7/1472, 7/1475, 7/1477 (2015.11) (keyword delimited)

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

Orbit, Google Patents, Google Scholar, Google.

Search terms used: pneumatic, control, valve, manifold, sensor, bank, protocol, cable, cabinet, distributed, communication, module, network, tube, fitting, field, serially, connected

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7,753,740 B2 (CAROLIS et al) 13 July 2010 (13.07.2010) entire document	1
A	US 2009/0088874 A1 (ARCEO et al) 02 April 2009 (02.04.2009) entire document	1-16
A	US 8,219,253 B2 (ARBTER et al) 10 July 2012 (10.07.2012) entire document	1-16
A	US 7,182,102 B2 (KARCHER) 27 February 2007 (27.02.2007) entire document	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

29 November 2015

Date of mailing of the international search report

28 DEC 2015

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Blaine Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774