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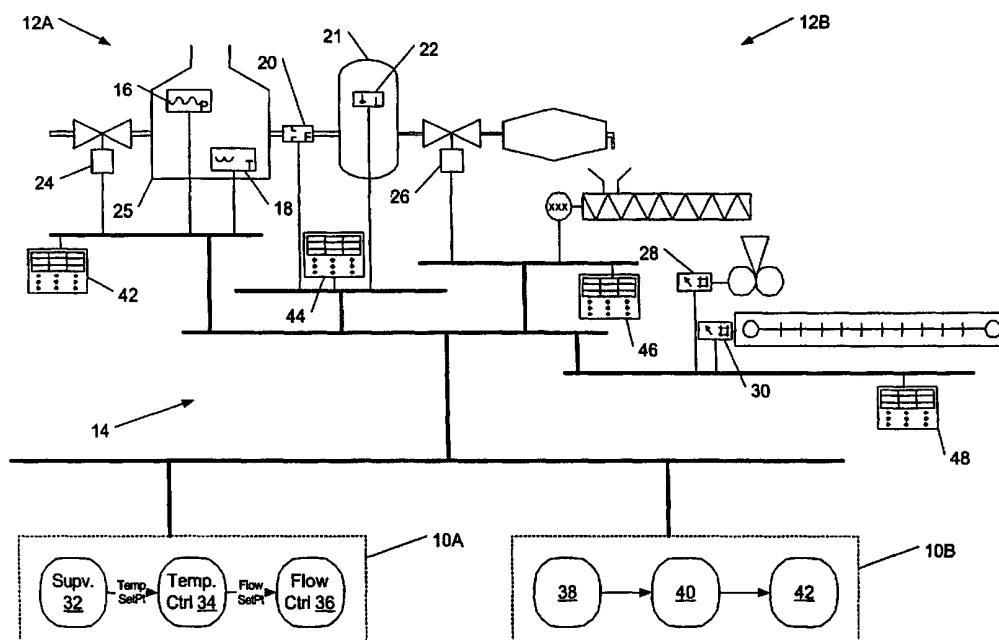
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(54) Title: PROCESS CONTROL SYSTEM WITH AUTOMATIC FAULT-AVOIDANCE



(57) Abstract: A control system incorporates components that automatically switch information sources in response to actual or potential degradation of information generated by them. Thus, a control system has first (10A) and second (10B) control components that generate first and second "source" signals, respectively, representing substantially identical or related process control variables. A third control component, which normally processes the first source signal, responds to actual or potential degradation of that signal for processing the second source signal in lieu of the first.



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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.*

## PROCESS CONTROL SYSTEM WITH AUTOMATIC FAULT-AVOIDANCE

**Background of the Invention**

The invention pertains to control and, more particularly, to methods and apparatus for avoidance of faults in process and other control systems.

The terms "control" and "control systems" refer to the control of a device or system by monitoring one or more of its characteristics. This is used to insure that output, processing, quality and/or efficiency remain within desired parameters over the course of time. In many control systems, digital data processing or other automated apparatus monitor the device or system in question and automatically adjust its operational parameters. In other control systems, such apparatus monitor the device or system and display alarms or other indicia of its characteristics, leaving responsibility for adjustment to the operator.

Control is used in a number of fields. Process control, for example, is typically employed in the manufacturing sector for process, repetitive and discrete manufactures, though, it also has wide application in electric and other service industries. Environmental control finds application in residential, commercial, institutional and industrial settings, where temperature and other environmental factors must be properly maintained. Control is also used in articles of manufacture, from toasters to aircraft, to monitor and control device operation.

Reliability is among the key requirements of any control system. A controlled manufacturing process, for example, that occasionally produces a bad batch is wholly unacceptable for many purposes. Given the expense of manufacturing individual process control components that achieve satisfactory levels of reliability, designers have turned to redundancy. This typically involves using two or more control elements in place of one. The duplicated units can be sensors, actuators, controllers or other components in the control hierarchy.

Thus, for example, U.S. Patent 4,347,563 discloses an industrial control system in which redundant processing units serve as bus masters "of the moment," monitoring status information generated by primary processing units. If a redundant unit detects that a primary has gone faulty while executing an applications program, the redundant unit loads that program and takes over the primary's function. A shortcoming of these and many other prior art redundancy schemes is their imposition of undue computational or hardware overhead. U.S. Patent 4,058,975, for example, has the disadvantage of requiring a computer to continually compare the outputs of multiple temperature sensors monitoring a gas turbine.

Implementing such solutions can be difficult in some situations and impossible in others. The latter may prove true if the control elements or configuration do not support communications or processing necessary to implement the necessary redundancy protocols.

The self-validating sensors described in U.S. Patents 5,570,300 and 5,774,378 (assigned to the assignee hereof and the teachings of which are incorporated herein by reference) represent a significant advance in the art. Such sensors provide not only estimates of control variables (e.g., pressure or temperature) being monitored, but also information about the uncertainty and reliability of those estimates. Thus, for example, a sensor can generate a validated measurement signal (VMV) representing a best estimate of a control variable being monitored, a validated uncertainty signal (VU) identifying the uncertainty in VMV, a status signal (MV) indicating the status of VMV (e.g., "clear," "blurred," "dazzled," "blind,"), and a device status signal indicating a status of the sensor itself.

Notwithstanding the advent of self-validating sensors, still more flexible mechanisms for avoiding fault are desired. This is increasingly so as the art shifts to control architectures that permit the "hot" insertion or replacement of control elements.

An object of this invention is to provide improved methods and apparatus for control and, more particularly, improved such methods and apparatus that provide for avoidance of detected faults.

A further object of the invention is to provide such methods and apparatus as facilitate maintaining continuous operation of a process, environmental, industrial or other control system in the face of actual or potential degradation of a sensor or other control element.

A still further object of the invention is to provide such methods and apparatus for use with self-validating control elements and particularly, for example, with self-validating sensors.

## Summary of the Invention

The foregoing are among the objects attained by the invention which provides, in one aspect, a control system with components that respond to actual or potential faults, e.g., in sensors or other field devices, by automatically switching to other sources of desired control or process variables.

Thus, in one aspect, the invention provides a control system with first and second control components that generate first and second "source" signals, respectively, representing substantially identical or related process control variables. A third control component, which normally processes the first source signal, responds to actual or potential degradation of that signal (or the control component that generated it) for processing the second source signal in lieu of the first.

By way of example, a process control system according to this aspect of the invention can have a first sensor that generates a temperature reading of a reactor vessel and a second sensor that generates a pressure reading of that same vessel. A control processor can be arranged to process the reading generated by the first sensor, e.g., as part of a temperature control loop. In response to indications of actual or potential degradation of the first sensor, the control processor can process readings from the second sensor, e.g., in lieu of those from the first.

Further aspects of the invention provide a control system as described above in which the first control component (e.g., the first sensor in the above example) generates a confidence signal indicative of actual or potential degradation of the first sensor. Where the first component is a self-validating sensor, that confidence can be a measurement value (MV) status signal and/or a device status signal, both as described above. The third control component (e.g., the control processor in the example) can identify actual or potential degradation of the first control component from that confidence signal.

Still further aspects of the invention provide a control system as described above in which the second control component (e.g., the second sensor in the example) generates a signal identifying

the control variable (e.g., temperature or pressure) output by it. The second component can transmit that signal, e.g., to a distributed registry, for storage. The third control component can retrieve the identifier signal from the registry in the event of actual or potential degradation of the first source signal, thus, permitting identification of the second source signal as a potential substitute for the first.

Yet still further aspects of the invention provide a control system as described above in which the control components and/or registry are coupled via bus, a network and other communications media, by way of non-limiting example, compatible with any of Foundation Fieldbus, Profibus, DeviceNet™, InterBus™ and Modbus® standards, among others.

Other aspects of the invention provide process, environment, industrial control systems and methods in accord with the foregoing.

These and still other aspects of the invention are evident in the drawings and in the description that follows.

**Brief Description of the Drawings**

A more complete understanding of the invention may be attained by reference to the drawings, in which:

Figure 1 depicts a digital data processing system of the type with which apparatus and methods according to the invention may be practiced;

Figure 2 illustrates controlled processes, along with a fault-avoidance process control system according to the invention for controlling them; and

Figure 3 is a flowchart depicting operation of a fault-avoidance process control system according to the invention.



### Detailed Description of the Illustrated Embodiment

Figure 1 depicts a digital data processing system of the type with which apparatus and methods according to the invention may be practiced. The system includes one or more controllers 10A, 10B or other digital data processors that monitor and/or control one or more manufacturing, industrial or other processes 12A, 12B. The illustrated controllers 10A, 10B represent hardware or software processes executing on workstations, microprocessors, embedded processors, "smart" field devices, or other digital data processing apparatus of the types commercially available in the marketplace, constructed and operated in accord with the teachings herein to achieve fault-avoidance in process control.

Workstation 11 represents a personal computer, mainframe computer or other digital data processing device that can be used, e.g., by an operator, to monitor and/or administer controllers 10A, 10B. While workstation 11 can be independent of the other devices shown in the drawing, it can alternatively incorporate functionality of controllers 10A, 10B. Conversely, monitoring and/or administrative functionality of workstation 11 can be contained in microprocessors, embedded processors, controllers, "smart" field devices that serve other functions in the control system.

Network 14 provides a communications medium for the transfer of data and control information among components of the control system, including, controllers 10A, 10B, workstation 11, blocks 32 - 42, and field devices. Though illustrated to represent a LAN, WAN, or global network (Internet), those skilled in the art will appreciate that element 14 may comprise a bus or other communications medium through which information may be transferred. In preferred embodiments, at least portions of the network 14 comprise buses compatible with industry standards such as, by non-limiting example, Foundation Fieldbus, Profibus, DeviceNet™, InterBus™ and/or Modbus®.

Figure 2 illustrates in greater detail processes 12A, 12B and a control system according to the invention for controlling them. In the illustration, exemplary process 12A is a manufacturing process including conventional processing equipment, such as by way of non-limiting example

conveyors, aeration tanks, and so forth. Control of the process 12A is effected through flow sensors, pressure sensors, temperature sensors, level sensors, valves, recorders, positioners, or other sensors or actuators operating with outputs and inputs in the range of 4 - 20 mA or 1 - 5 V dc, or otherwise, per proprietary or industry protocol (collectively, "field devices"). In the illustrated embodiment, these include valve 24 that governs the rate of fluid flow to a reactor vessel 25, whose temperature and pressure are monitored by sensors 16, 18. These also include flow sensor 20 that monitors the outflow of vessel 25 to tank 21. In a preferred embodiment, one or more of the sensors are "smart" field devices, i.e., sensors or actuators that include embedded processors, microprocessors or other digital data processing capacity, operating in accord with the teachings herein.

Whether of the "smart" variety or otherwise, one or more of the sensors 16, 18, 20 can be of the self-validating variety that output estimates of measured process variables (e.g., pressure, temperature, flow, respectively), along with information about the uncertainty and reliability of those estimates. Preferred self-validating sensors include, by way of non-limiting example, those taught in incorporated-by-reference U.S. Patents 5,570,300 and 5,774,378. Such sensors generate a validated measurement signal (VMV) representing a best estimate of a process variable being monitored, a validated uncertainty signal (VU) identifying the uncertainty in VMV, a status signal (MV) indicating the status of VMV (e.g., "clear," "blurred," "dazzled," "blind,"), and a device status signal indicating a status of the sensor itself.

Monitoring and control of processes 12A, 12B is further effected through controllers 10A, 10B that are coupled to field devices 16 - 30, as well as to one another, via network 14. The controllers execute control strategies in the conventional manner known in the art as modified in accord with the teachings herein.

To this end, the controllers 10A, 10B comprise blocks and/or other executable software components (collectively, "blocks") 32 - 42 that model field devices, processing apparatus and other aspects of the controlled process 12A and that monitor and/or control the states and interactions therebetween, e.g., via execution of control algorithms (or portions thereof) or

otherwise. In the illustrated embodiment, blocks 32 - 42 comprise blocks of the type utilized in the I/A Series<sup>®</sup> systems marketed by the assignee hereof and/or objects of the type disclosed in co-pending commonly assigned patent applications 60/139,071, filed June 11, 1999, entitled "Omnibus and Web Control," 60/144,693, filed July 20, 1999, entitled "Omnibus and Web Control," 60/146,406, filed July 29, 1999, entitled "Bi-Directional Entities for Maintaining Block Parameters and Status in a Process Control System," and 60/149,276, filed August 17, 1999, entitled "Methods and Apparatus for Process Control (AutoArchitecture)," the teachings of all of which are incorporated herein by reference. The blocks 32 - 42 may represent other software and/or hardware components capable of executing on or in connection with controllers 10A, 10B. For example, the blocks may be various types of function blocks, or the like, as defined and executed within the aforementioned Foundation Fieldbus, Profibus, DeviceNet<sup>™</sup>, InterBus<sup>™</sup> and Modbus<sup>®</sup> or other industry standards.

Blocks 32 - 42 operate in the conventional manner known in the art, as modified in accord with the teachings herein for fault avoidance. Thus, for example, controller 10A includes supervisor 32, temperature controller 34 and flow controller 36, each of which may include further blocks (not shown). Supervisor component 32 initiates process control functions, including activation and execution of blocks 34, 36. Block 32 also generates a temperature supervisory set point, e.g., based on operator input. Block 34 is a temperature controller that utilizes a proportional-integral-derivative (PID) or other control algorithm to generate a flow set point based on the temperature set point from the supervisor object 32 and on temperature readings from sensor 18. Block 36 serves as a flow controller that, too, utilizes a PID or other control algorithm to set a flow level, e.g., for valve 24, based on the flow set point from block 34 and on flow readings from sensor 20.

In process control terminology, supervisor 32 is referred to as a "source" for temperature controller 34 and, more accurately, for the temperature set point parameter used by controller 34. Temperature sensor 18 is also a source for controller 34. The flow controller 36, conversely, is referred to as a "sink" for temperature controller 34 and, more accurately, for the flow set point parameter generated by it. Like terminology can be applied to the other elements and parameters

that are sources (i.e., suppliers) or sinks (i.e., consumers) of information produced within the system.

The illustrated apparatus includes one or more registries 42 - 48 to maintain information about the field devices 16 - 32. These can be contained in memory or other data stores within workstation 11, within the processors 10A, 10B, within smart field devices 16 - 32, within stand-alone storage devices (as illustrated), or otherwise. Where more than one registry is provided, they can be distributed among domains and, indeed, among the field devices themselves. The registries can be implemented as pointers, symbols, objects, variables, vectors, tables, records, databases, files, or other data structures or stores. They can be implemented as stand-alone entities or, for example, within other system components such as function blocks, or the like, as defined and executed within the aforementioned Foundation Fieldbus, Profibus, DeviceNet™, InterBus™ and Modbus® or other industry standards.

The registries maintain information about the control or process variables monitored by sensor-type field devices. Thus, for example, entries in registry 42 can indicate that sensor 16 monitors the pressure of vessel 25 and that sensor 18 monitors the temperature of that vessel. Registry 44, by way of further example, can indicate that sensor 20 monitors flow in the conduit between vessel 25 and tank 21. The registries can also maintain information about process variables governed by actuator-type sensors. Other information can be maintained in the registries, as well, for example identifiers of sources and/or sinks of each of the elements in the process control system.

In the illustrated embodiment, each process control component 32 - 42 maintains, e.g., in its own dedicated store or in a registry, identities of the process variables supplied to it by the "sources." Identities and other information regarding the sources can be maintained as well. Thus, for example, temperature controller 34 maintains an internal store indicating that one of its sources, sensor 18, supplies the temperature of vessel 25.

Figure 3 is a flowchart depicting how the process control system of Figure 2 provides for fault-avoidance. In steps 50 - 52, each field device "registers" with the system upon "hot" insertion, installation or commencement of operation. In the illustrated embodiment, registration is performed by sensor-type field devices, e.g., pressure, temperature and flow sensors 16 - 20, and entails generating an identifier indicating which process variable is monitored by each sensor. Thus, for example, sensor 16 generates an identifier signal indicating that it monitors the pressure of vessel 25, while sensor 18 generates a signal indicating that it monitors the temperature of that vessel. These identifier signals are stored in registry 42, or elsewhere, as discussed above.

The identifier signal generated by the field device can be based, for example, on information stored in the sensor, or otherwise supplied to the system, e.g., by a field technician prior to (or concurrent with) insertion. Alternatively, by way of further non-limiting example, it can be based on keys, tags or other physical indicia installed on or in the field device.

In step 54, controllers 10A, 10B commence operation, monitoring and/or controlling operation of processes 12A, 12B.

In step 56, each component 32 - 42 (Fig. 2) monitors its sources to identify actual or potential degradation of the information supplied by them. Where the sources are self-validating field devices, as described above, the recipient component (or sink) utilizes the above-described status signals as means of determining actual or potential fault. In this regard, for example, temperature controller 34 can identify as faulty a source (e.g., sensor 18) generating an MV signal of "blurred," "dazzled," "blind."

For sources that are not self-validating, the recipient process control components, i.e., blocks 32 - 42, can monitor process variables, statistically or otherwise, to identify actual or potential degradation. Still other elements resident in the controllers and/or in the control system (e.g., other field devices) can monitor sources and notify recipients of actual or potential degradation. The detection of fault by recipient components or other elements can be based on

principles paralleling those discussed in incorporated-by-reference U.S. Patents 5,570,300 and 5,774,378, or otherwise.

In step 58, processing continues in the normal course unless an actual or potential fault is detected in a source (e.g., temperature sensor 18). Upon detection of such a fault, the recipient component (e.g., temperature controller 34) seeks a replacement source. Step 60. Alternatively, another component or element in the system (e.g., supervisor component 32) seeks a replacement on behalf of the recipient.

In either event, the replacement is identified via a search of registries 42 - 48 for a source that provides an identical or related process variable to that identified as actually or potentially faulty. Thus, for example, in the event readings from temperature sensor 18 are detected as actually or potentially faulty, readings from another temperature sensor (not shown) on the same vessel 25 could be identified for use as replacements.

In the illustrated embodiment, pressure sensor 16 is deemed to provide a "related" process variable, since the temperature of the contents vessel 25 can be determined with acceptable accuracy from its pressure.

In still further embodiments, replacement readings are taken from sensors or other process control components that measure (or otherwise generate) an identical or related process variable but that normally output another process variable. Examples of this include multimeasurement sensors, e.g., a flow sensor 20 implemented as a CFT10 Series I/A Series<sup>®</sup> mass flow transmitter of the type commercially available from the assignee hereof. Though such a sensor typically outputs a flow reading, it measures temperature (along with other flow-related variables) in order to normalize the flow reading. Upon determining that temperature readings from sensor 18 are actually or potentially faulty, temperature controller 34 can utilize the temperature readings generated by mass flow sensor 20 as replacements. This is likewise true of (i) multimeasurement sensors that measure or otherwise generate "related" process variables, such as pressure in the above example, and (ii)

blocks and other process components that generate identical or related process variables by way of calculations performed during execution of a control algorithm or otherwise.

If no replacement source is found (step 62), the operator is notified. Step 64. System operation may nonetheless continue, depending on the nature of the fault.

If a replacement source is found (step 66), its outputs are coupled to the inputs of the recipient component. The manner in which this is accomplished varies in accord with the specific nature of source/sink coupling in controller 10A. For example, if each component (e.g., temperature controller 34) maintains pointers to its sources (e.g., temperature sensor 18), replacement is effected by substituting a pointer to the replacement element (e.g., pressure sensor 16) for that of the actually or potentially faulty element (e.g., temperature sensor 18). Alternatively, if source information is coded into component via a configurator (not shown), such a configurator may be employed to impart sufficient information to effect replacement. In the event that the replacement source does not provide identical information to that provided by the actually or potentially fault source, the recipient executes appropriate conversions (e.g., pressure-to-temperature conversions) and/or compensates for differences in uncertainty or accuracy, e.g., using alternate control algorithms in order to insure proper operation.

Once a source, previously detected as actually or potentially faulty, resumes normal operation (e.g., as a result of physical repair or replacement by a technician or as a result of termination of a transient fault condition), it can be coupled back into the system -- thus, in effect, replacing its replacement. For example, a repaired source can register with the system upon being brought on-line and, in the process, send a local or system-wide notification, e.g., over medium 14 or portions thereof. Recipients or sinks of information generated by the repaired source can recouple with it, as described above. Such recoupling can be predicated, for example, on a comparison of tolerances, accuracy or other operational parameters of the repaired source and the replacement that had been substituted for it on detection of the original fault condition.

Described above are methods and apparatus achieving the desired objects. Those skilled in the art will appreciate that the embodiments described herein and shown in the drawings are examples of the invention and that other embodiments incorporating one or more of the mechanisms and techniques herein, or equivalents thereof, fall within the scope of the invention.

Thus, for example, further embodiments of the invention provide environmental control systems utilizing apparatus and methods like those herein to monitor and/or control heating, ventilation, cooling, and other environmental factors. Yet still further embodiments of the invention provide industrial control systems, manufacturing control systems, or the like, that also utilize apparatus and methods like those herein to monitor and/or control respective industrial, manufacturing or other processes.

In view of the foregoing, what is claimed is:



1. A control system comprising  
  
a first set comprising plural control components, each control component generating a source signal representative of control variable, an identifier signal identifying that control variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,  
  
a second set comprising at least one control component that processes a selected source signal and that responds to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,  
  
wherein the first and second sets have any of zero, one or more control components in common.
2. A control system according to claim 1, wherein at least the control component that generates the selected source signal is self-validating.
3. A control system according to claim 2, wherein the self-validating control component generates the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of the control component.
4. A control system according to claim 1, comprising one or more registries that are coupled to the control components in the first and second sets for storing the identifier signals.
5. A control system according to claim 4, comprising a plurality of distributed registries.
6. A control system according to claim 1, wherein the control components of the first and second sets are coupled by any of a bus, a network and other communications media.

7. A control system according to claim 6, wherein the control components of the first and second sets are coupled by communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
  
8. A control system comprising
  - a first set comprising plural control components, each control component generating a source signal representative of control variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,
  
  - one or more registries that store identifier signals, each identifying a control variable and any of a control signal or control component corresponding thereto,
  
  - a second set comprising at least one control component that processes a selected source signal and that responds to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,
  
  - wherein the first and second sets have any of zero, one or more control components in common,
  
  - wherein the registries, the control components of the first set and the control components of the second set are coupled by communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
  
9. A process control system comprising

a first set comprising plural process control components, each process control component generating a source signal representative of process variable, an identifier signal identifying that process variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,

a second set comprising at least one process control component that processes a selected source signal and that responds to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,

wherein the first and second sets have any of zero, one or more process control components in common.

10. A process control system according to claim 9, wherein at least the process control component that generates the selected source signal is a self-validating process control component.
11. A process control system according to claim 10, wherein the self-validating process control component generates the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of the process control component.
12. A process control system according to claim 9, comprising one or more registries that are coupled to the process control components in the first and second sets for storing the identifier signals.
13. A process control system according to claim 12, wherein the registries are distributed.

14. A process control system according to claim 9, wherein the process control components of the first and second sets are coupled by any of a bus, a network and other communications media.
15. A process control system according to claim 14, wherein the process control components of the first and second sets are coupled by communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
16. A process control system comprising  
  
a first set comprising plural process control components, each process control component generating a source signal representative of process variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,  
  
one or more registries that store identifier signals, each identifying a process variable and any of a control signal or process control component corresponding thereto,  
  
a second set comprising at least one process control component that processes a selected source signal and that responds to any of actual and potential degradation of that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,  
  
wherein the first and second sets have any of zero, one or more process control components in common,  
  
wherein the registries, the process control components of the first set and the process control components of the second set are coupled by communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.

17. A method of operating a control system, comprising

generating, with each control component in a first set of plural control components, a source signal representative of a control variable and confidence signals indicative of any of actual and potential degradation of that source signal,

storing, in one or more registries, one or more identifier signals that identify control variables and any of control signals and control component corresponding thereto,

with a control component of a second set that comprises at least one control component, processing a selected source signal and responding to any of actual and potential degradation that selected source signal by (i) identifying from the identifier signals in the registries an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,

wherein the first and second sets have any of zero, one or more control components in common,

transferring information among any of the registries and the control components via a communications medium operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.

18. A method of operating a process control system, comprising

generating, with each process control component in a first set of plural process control components, a source signal representative of process variable, an identifier signal identifying that process variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,

with a process control component in a second set comprising at least one process control component, processing a selected source signal and responding to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,

wherein the first and second sets have any of zero, one or more process control components in common.

19. A method according to claim 18, wherein at least the process control component that generates the selected source signal is a self-validating process control component.
20. A method according to claim 19, comprising generating, with the self-validating process control component, the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of the self-validating process control component.
21. A method according to claim 18, comprising storing the identifier signals in one or more registries.
22. A method according to claim 21, wherein the registries are distributed about the process control system.
23. A method according to claim 18, comprising transferring information among any of the process control components via any of a bus, a network and other communications media.
24. A method according to claim 23, comprising transferring information among any of the process control components via communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.

25. A method of operating a process control system comprising
- generating, with each process control component in a first set of plural process control components, a source signal representative of process variable and a confidence signal indicative of any of actual and potential degradation of that source signal,
- storing identifier signals in one or more registries, each identifying a process variable and any of a control signal or process control component corresponding thereto,
- with a process control component in second set comprising at least one process control component, processing a selected source signal and responding to any of actual and potential degradation of that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,
- transferring information among any of the registries and the control components via a communications medium operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard,
- wherein the first and second sets have any of zero, one or more process control components in common.
26. A control system comprising
- a first control component generating a first source signal,
- a second control component generating a second source signal,

the first and second source signals representing any of substantially identical control variables and related control variables,

a third control component that is in at least selective communication with the first control component and the second control component,

the third control component processing the first source signal and responding to any of actual and potential degradation of that signal by processing the second source signal in lieu of the first source signal.

27. A control system according to claim 26, wherein the first control component generates a confidence signal indicative of any of actual and potential degradation of the first source signal.
28. A control system according to claim 27, wherein the first control component is self-validating.
29. A control system according to claim 27, wherein the first source signal is a measurement.
30. A control system according to claim 29, wherein the first control component is self-validating sensor.
31. A control system according to claim 27, wherein the second control component generates an identifier signal identifying a control variable represented by the second source signal.
32. A control system according to claim 31, wherein the third control component processes the second source signal in lieu of the first source signal in response to a confidence signal indicative of any of actual and potential degradation of the first control signal and in response to an identifier signal identifying the second source signal as representative of a



control variable that is any of substantially identical to and related to a control variable represented by the first source signal.

33. A control system according to claim 31, comprising a registry that stores the identifier signal.
34. A control system according to claim 33, wherein the third control component obtains the identifier signal from the registry.
35. A process control system comprising
- a first process control component generating a first source signal,
- a second process control component generating a second source signal,
- the first and second source signals being representative of any of substantially identical and related process variables,
- a third process control component that is in at least selective communication with the first process control component and the second process control component,
- the third process control component processing the first source signal and responding to any of actual and potential degradation of that signal by processing the second source signal in lieu of the first source signal.
36. A process control system according to claim 35, wherein the first process control component generates a confidence signal indicative of any of actual and potential degradation of the first source signal.
37. A process control system according to claim 36, wherein the first process control component is self-validating.

38. A process control system according to claim 36, wherein the first source signal is a measurement.
39. A process control system according to claim 38, wherein the first process control component is self-validating sensor.
40. A process control system according to claim 36, wherein the second process control component generates an identifier signal identifying the process variable represented by the second source signal.
41. A process control system according to claim 40, wherein the third process control component processes the second source signal in lieu of the first source signal in response to a confidence signal indicative of any of actual and potential degradation of the first control signal and in response to an identifier signal identifying the second source signal as representing a process variable that is any of substantially identical or related to the process variable represented by the first control signal.
42. A process control system according to claim 40, comprising a registry that stores the identifier signal.
43. A process control system according to claim 42, wherein the third process control component obtains the identifier signal from the registry.
44. A process control system comprising  
  
a first field device generating a first source signal,  
  
a second field device generating a second source signal,

the first and second source signals being representative of any of substantially identical and related process variables,

a process control component in communication with the first field device and the second field device,

the process control component processing the first source signal and responding to any of actual and potential degradation of that signal by processing the second source signal in lieu of the first source signal.

45. A process control system according to claim 44, wherein the process control component is a controller.
46. A process control system according to claim 44, wherein the process control component is coupled with any of the first field device and the second field device by any of a bus, a network and other communications media.
47. A process control system according to claim 46, wherein process control component is coupled with any of the first field device and the second field device by communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
48. A process control system according to claim 44, wherein the first source signal and the second source signal represent a characteristic of a same process element and a same process control component.
49. A process control system according to claim 48, wherein the first source signal and the second source signal represent related characteristics of any of a same process element and a same process control component.

50. A process control system according to claim 49, wherein the first field device generates a confidence signal indicative of any of actual and potential degradation of the first source signal.
51. A process control system according to claim 50, wherein the first field device is self-validating.
52. A process control system according to claim 50, wherein the first source signal is a measurement.
53. A process control system according to claim 52, wherein the first field device is self-validating sensor.
54. A process control system according to claim 50, wherein the second field device generates an identifier signal identifying the process variable represented by the second source signal.
55. A process control system according to claim 54, wherein the process control component processes the second source signal in lieu of the first source signal in response to a confidence signal indicative of any of actual and potential degradation of the first control signal and in response to an identifier signal identifying the second source signal as representing a process variable that is any of substantially identical or related to the process variable represented by the first control signal.
56. A process control system according to claim 54, comprising a registry that stores the identifier signal.
57. A process control system according to claim 56, wherein the process control component obtains the identifier signal from the registry.
58. A method of operating a control system, comprising the steps of

generating, with a first control component, a first source signal,

generating, with a second control component, a second source signal,

the first and second source signals being representative of any of substantially identical and related process variables,

with a third control component processing, processing the first source signal and responding to any of actual and potential degradation of that signal by processing the second source signal in lieu of the first source signal.

59. A method of operating a control system according to claim 58, comprising the step of generating, with the first control component, a confidence signal indicative of any of actual and potential degradation of the first source signal.
60. A method of operating a control system according to claim 59, wherein the first control component is self-validating.
61. A method of operating a control system according to claim 59, comprising the step of generating the first source signal as a measurement.
62. A method of operating a control system according to claim 61, wherein the first control component is self-validating sensor.
63. A method of operating a control system according to claim 59, comprising the step of generating, with the second control component, an identifier signal identifying the control variable represented by the second source signal.
64. A method of operating a control system according to claim 63, comprising the step of

responding to a confidence signal indicative of any of actual and potential degradation of the first control signal and to an identifier signal identifying the control variable represented by the second source signal as any of substantially identical and related to the control variable represented by the first source signal,

by processing, with the third control component, the second source signal in lieu of the first source signal.

65. A method of operating a control system according to claim 63, comprising the step of storing the identifier signal in a registry.
66. A method of operating a control system according to claim 65, comprising the step of using the third control component to obtain the identifier signal from the registry.
67. A method of operating a process control system, comprising the steps of
- generating, with a first process control component, a first source signal,
- generating, with a second process control component, a second source signal,
- the first and second source signals being representative of any of substantially identical and related process variables,
- with a third process control component, processing the first source signal and responding to any of actual and potential degradation that signal by processing the second source signal in lieu of the first source signal.
68. A method of operating a process control system according to claim 67, comprising the step of generating, with the first process control component, a confidence signal indicative of any of actual and potential degradation the first source signal.

69. A method of operating a process control system according to claim 68, wherein the first process control component is self-validating.
70. A method of operating a process control system according to claim 68, comprising the step of generating the first source signal as a measurement.
71. A method of operating a process control system according to claim 70, wherein the first process control component is self-validating sensor.
72. A method of operating a process control system according to claim 68, comprising the step of generating, with the second process control component, an identifier signal identifying the process variable represented by the second source signal.
73. A method of operating a process control system according to claim 72, wherein the third process control component processes the second source signal in lieu of the first source signal in response to a confidence signal indicative of any of actual and potential degradation the first control signal and to an identifier signal identifying the second source signal as representing a process variable that is any of substantially identical and related to the process variable represented by the first source signal.
74. A method of operating a process control system according to claim 72, comprising the step of storing the identifier signal in a registry.
75. A method of operating a process control system according to claim 74, wherein the third process control component obtains the identifier signal from the registry.
76. A method of operating a process control system comprising  
generating, with a first field device, a first source signal,

generating, with a second field device, a second source signal,

the first and second source signals being representative of any of substantially identical and related process variables,

with a process control component, processing the first source signal and responding to any of actual and potential degradation that signal by processing the second source signal in lieu of the first source signal.

77. A method of operating a process control system according to claim 76, wherein the process control component is a controller.
78. A method of operating a process control system according to claim 76, comprising communicating between the process control component and any of the first field device and the second field device by way of any of a bus, a network and other communications media.
79. A method of operating a process control system according to claim 78, comprising communicating between the process control component and any of the first field device and the second field device by communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
80. A method of operating a process control system according to claim 76, wherein the first and second source signals represent like characteristics of any of a same process element and a same process control component.
81. A method of operating a process control system according to claim 80, wherein the first and second control signals represent related characteristic of any of a same process element and a same process control component.



82. A method of operating a process control system according to claim 81, comprising generating with the first field device a confidence signal indicative of any of actual and potential degradation the first source signal.
83. A method of operating a process control system according to claim 82, wherein the first field device is self-validating.
84. A method of operating a process control system according to claim 82, comprising the step of generating the first source signal as a measurement.
85. A method of operating a process control system according to claim 84, wherein the first field device is self-validating sensor.
86. A method of operating a process control system according to claim 82, comprising generating with the second field device an identifier signal identifying the process variable represented by the second source signal.
87. A method of operating a process control system according to claim 86, comprising responding to a confidence signal indicative of any of actual and potential degradation the first control signal and to an identifier signal identifying the second source signal as representing a control variable that is any of substantially identical to and related to the control variable represented by the first source signal,
- by processing, with the process control component, the second source signal in lieu of the first source signal.
88. A method of operating a process control system according to claim 86, comprising the step of storing the identifier signal in a registry.

89. A method of operating a process control system according to claim 88, comprising the step of using the process control component to obtain the identifier signal from the registry.
90. A control system comprising
- a plurality of field devices, each generating a source signal representative of a control variable, an identifier signal identifying that control variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,
- at least one block that processes a selected source signal and that responds to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,
- wherein the field devices and blocks are coupled by any of a bus, a network and other communications media.
91. A control system according to claim 90, wherein the block executes within a field device.
92. A control system according to claim 90, wherein the field devices comprise any of a flow sensor, pressure sensor, temperature sensor, level sensor, valve, recorder, positioner, other sensor, and other actuator.
93. A control system according to claim 90, wherein at least one field device is self-validating.
94. A control system according to claim 93, wherein the self-validating field device generates the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of that self-validating field device.

95. A control system according to claim 90, comprising one or more registries that store the identifier signals.
96. A control system according to claim 95, comprising a plurality of distributed registries.
97. A control system according to claim 90, wherein the communications media is operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
98. A process control system comprising
- a plurality of field devices, each generating a source signal representative of a control variable, an identifier signal identifying that control variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,
- wherein the field devices comprise any of flow sensors, pressure sensors, temperature sensors, level sensors, valves, recorders, positioners, other sensors and other actuators,
- one or more registries that store the identifier signals,
- at least one process control block that processes a selected source signal and that responds to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,
- wherein the field devices, registries and control blocks are coupled by a network comprising one or more buses operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.

99. A process control system according to claim 98, wherein any of a process control block and a registry are resident within a field device.
100. A process control system according to claim 98, wherein at least one field device is self-validating.
101. A process control system according to claim 98, wherein the self-validating field device generates the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of that self-validating field device.
102. A process control system according to claim 101, comprising plural registries that are distributed within the process control system.
103. A method of operating a control system comprising
- generating, with each field device in a set of plural field devices, a source signal representative of a control variable, an identifier signal identifying that control variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,
- with at least one block, processing a selected source signal and responding to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,
- wherein the field devices and blocks are coupled by any of a bus, a network and other communications media.
104. A method of operating a control system according to claim 103, comprising executing the block within a field device.

105. A method of operating a control system according to claim 103, wherein the field devices comprise any of a flow sensor, pressure sensor, temperature sensor, level sensor, valve, recorder, positioner, other sensor and other actuator.
106. A method of operating a control system according to claim 103, wherein at least one field device is self-validating.
107. A method of operating a control system according to claim 106, comprising generating, with the self-validating field device, the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of that self-validating field device.
108. A method of operating a control system according to claim 103, comprising storing the identifier signals in one or more registries.
109. A method of operating a control system according to claim 103, comprising storing the identifier signal in plural registries that are distributed about the control system.
110. A method of operating a control system according to claim 103, comprising transferring information among the field devices and blocks with a communications media operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.
111. A method of operating a process control system comprising  
  
generating, with each field device in a set of plural field devices, a source signal representative of a control variable, an identifier signal identifying that control variable, and a confidence signal indicative of any of actual and potential degradation of that source signal,

wherein the field devices comprise any of flow sensors, pressure sensors, temperature sensors, level sensors, valves, recorders, positioners, other sensors and other actuators,

one or more registries that store the identifier signals,

with at least one block, processing a selected source signal and responding to any of actual and potential degradation that source signal by (i) identifying from the identifier signals an alternate source signal, and (ii) processing that alternate source signal in lieu of the selected source signal,

transferring information among the field devices, registries and control blocks via a communications medium comprising one or more buses operable in accord with any of a Foundation Fieldbus standard, a Profibus standard, a DeviceNet™ standard, an InterBus™ standard and a Modbus® standard.

112. A method of operating a process control system according to claim 111, comprising the step of executing a process control block within a field device.
113. A method of operating a process control system according to claim 111, wherein at least one field device is self-validating.
114. A method of operating a process control system according to claim 111, comprising generating, with the self-validating field device, the confidence signal to be representative of any of a status of a value represented by the corresponding source signal and a status of that self-validating field device.
115. A method of operating a process control system according to claim 114, comprising plural registries that are distributed within the process control system.

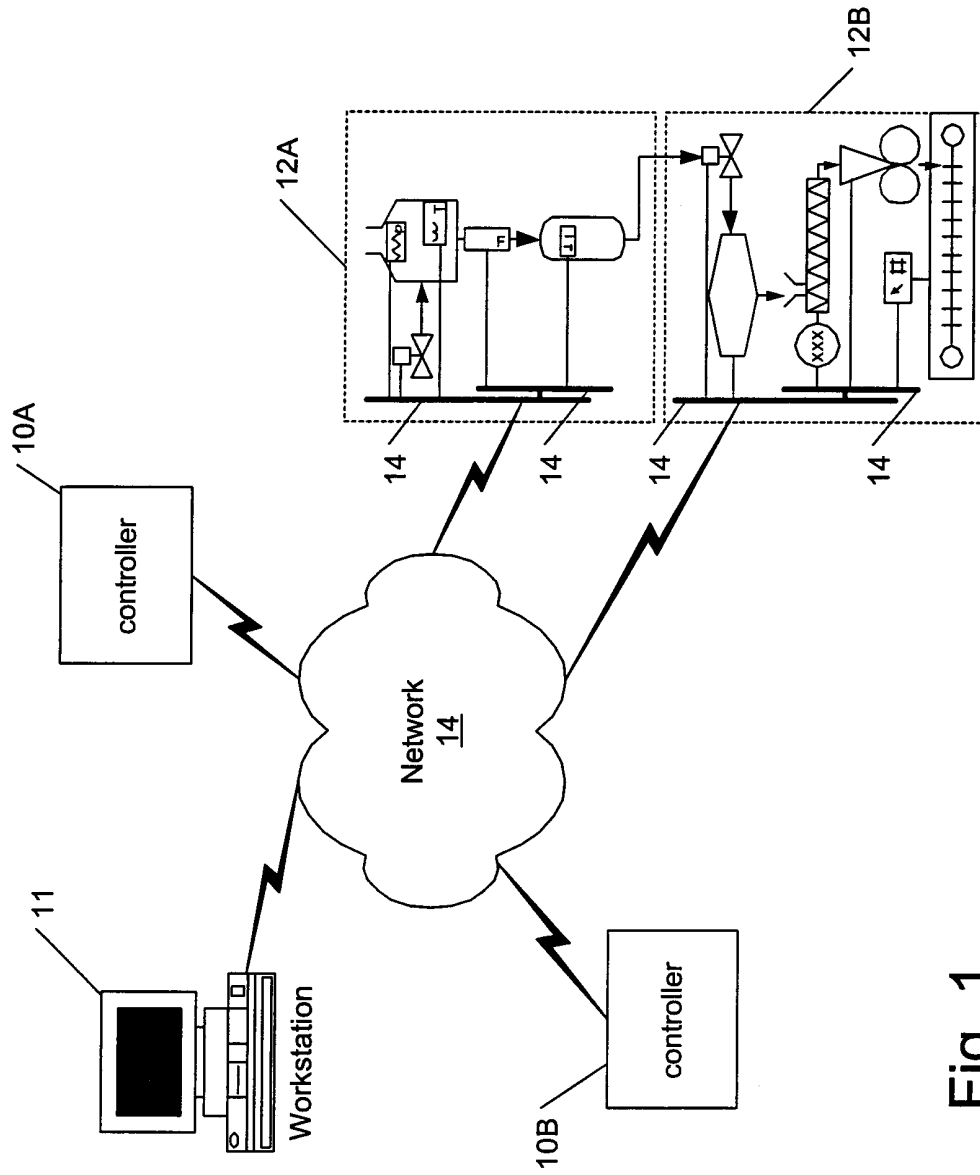


Fig. 1

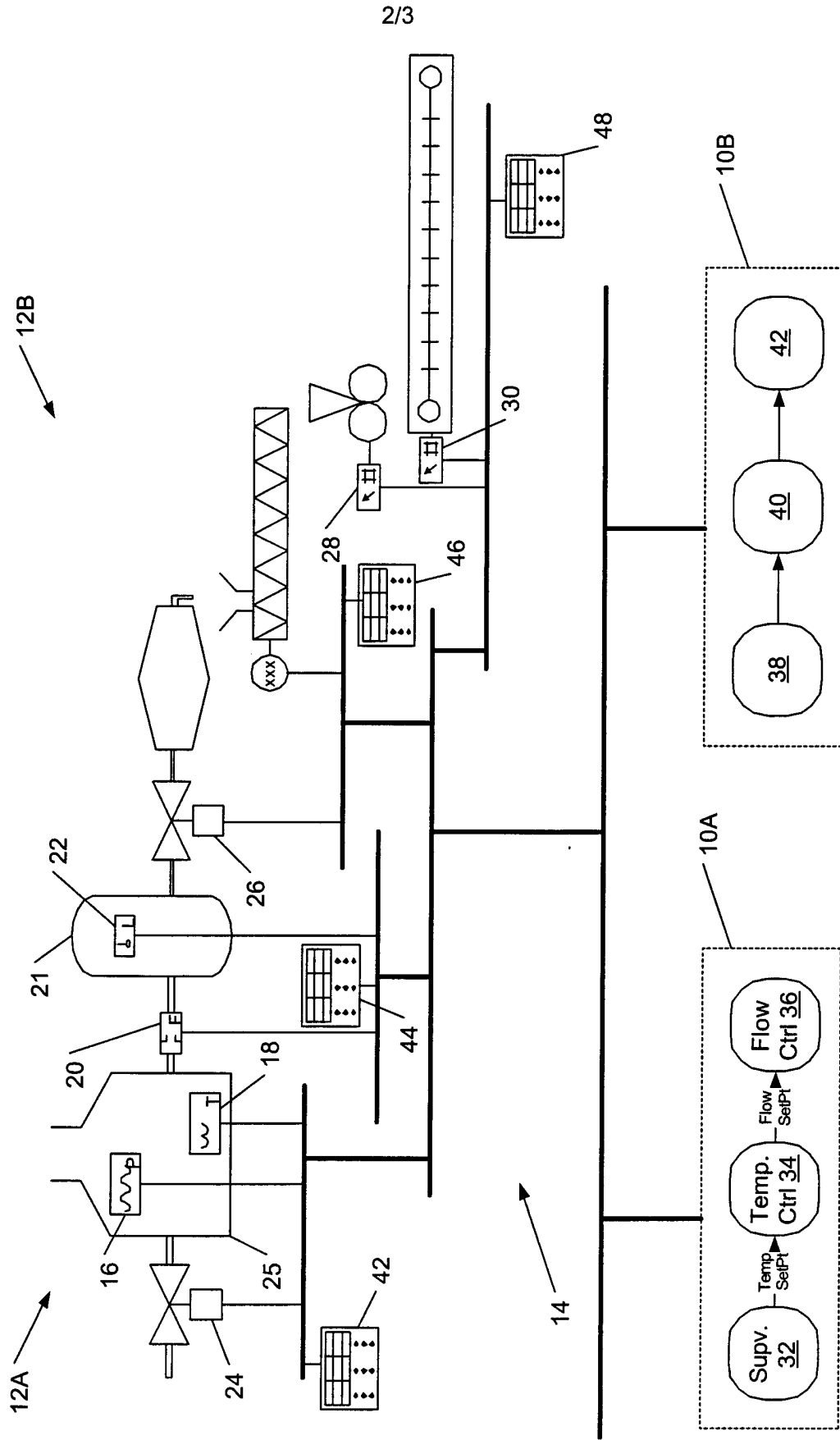


Fig. 2



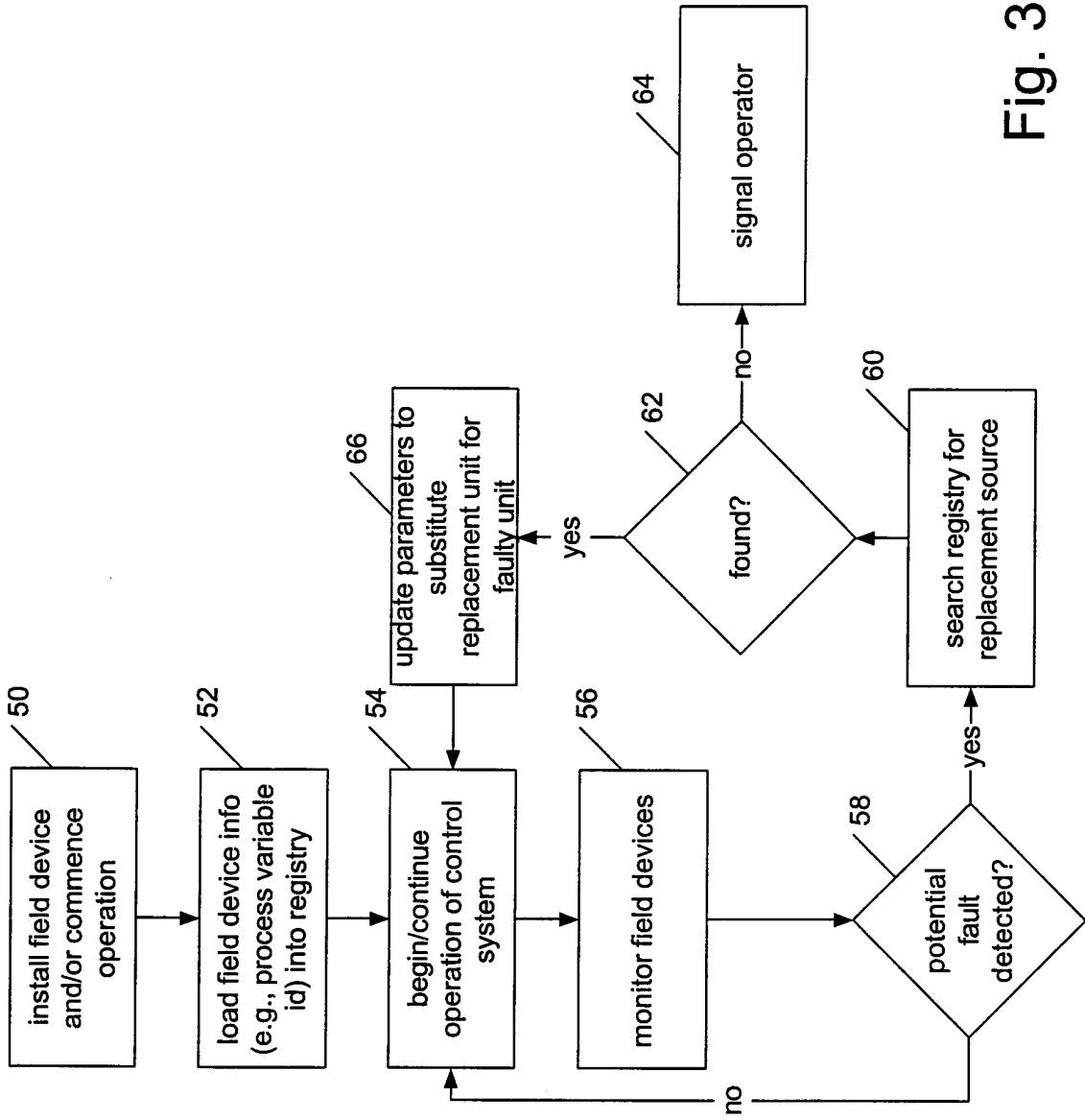


Fig. 3

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US00/32814**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : G05B 15/02, 11/01, 13/02

US CL : 700/11, 21, 28, 32

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. : 700/11, 21, 28, 32

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

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

East and West

search terms: reactor, control system, sensor, backup, redundant

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,491,625 A (PRESSNALL et al) 13 February 1996, col. 1, line 7 - col. 2, line 20	1-115
X	US 5,428,769 A (GLASER et al) 27 June 1995, col. 1, line 7 - col. 2, line 50.	1-115
Y	US 5,586,156 A (GAUBATZ) 17 December 1996, col. 1, line 23 - col. 2, line 2.	1-115
Y,P	US 6,049,578 A (SENECHAL et al) 11 April 2000, col. 1, line 23 - col. 2, line 51.	1-115
Y,P	US 6,070,250 A (YEAGER et al) 30 May 2000, col. 1, line 6 - col. 2, line 30.	1-115
A	US 5,715,178 A (SCAROLA et al), 3 February 1998, col. 1, lines 17-58.	1-115

 Further documents are listed in the continuation of Box C.
  See patent family annex.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier document published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

08 FEBRUARY 2001

Date of mailing of the international search report

05 MAR 2001

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/32814

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,774,378 A (YANG), 30 June 1998, col. 1, lines 11-20.	2-3, 10-11, 19-20, 28-30, 37-39, 51-53, 60-62, 69-71, 83-85, 93-94, 100, 106-107, 113
A	US 5,570,300 A (HENRY et al), 29 October 1996, col. 1, line 18 - col. 2, line 6.	1-115
A	US 5,864,773 A (BARNA et al), 26 January 1999, col. 1, line 18 - col. 2, line 8.	1-115