

Process connection adapter for a meter calibration system

FIELD OF INVENTION

This invention pertains to systems that are used in calibrating meters for
5 purposes of assuring accuracy from the meter being calibrated. More specifically,
the system enables the calibration of volumetric flowmeters, mass flowmeters,
densitometers, and viscometers devoid of process connection.

PROBLEM

It is desirable to perform a calibration on all meters prior to use in order to
10 ensure accurate and reliable measurement data. The purpose of a meter
calibration effort is to ascertain a flow calibration factor that will be used as a
multiplier in correcting direct measurements from the meter under test. Coriolis
meters, orifice meters, and positive displacement meters are known in the art as
linear meters, i.e., the flow calibration factor is a constant with respect to flow rate.
15 Other meters, including magnetic flow and vortex types, are nonlinear meters
meaning that the flow calibration factor varies with respect to flow rate.

The calibration process typically is performed on a meter with process
connections already attached as per a customer order. The meter is inserted into
the calibration system having process connections that match those already
20 attached to the meter. After insertion into the calibration system, the calibration
process is performed. The most reliable calibration systems include gravimetric
standards or master meter transfer standards used as flow rate references during
the calibration process. The fluid used within the calibration system and the meter
under test has precisely known intrinsic and extrinsic fluid properties, e.g.,
25 temperature, density, viscosity, and volume. The meter under test performs flow
measurements on this fluid. These measurements are compared with the known
fluid properties or flow rate reference to ascertain or validate a flow calibration
factor or other calibration factors for the meter under test.

The problem with the above procedure is the requirement to have customer-
30 specific process connections attached to the meter prior to performing the
calibration. There are several drawbacks associated with this requirement.

One drawback is related to capital expenditure. In an effort to minimize
warehouse inventory, meter manufacturers defer the process connection
attachment step until a customer places an order. Furthermore, in an effort to

reduce customer delivery lead-time, meter manufacturers locate customer service facilities around the world as near as possible to customers. As a result, since the calibration step currently follows the process connection attachment step, expensive calibration system hardware must be replicated in several facilities

5 around the world.

Another drawback is the inability to test a meter for functional discrepancies immediately following meter assembly and prior to the meter proceeding through the process connection attach, calibration and shipping functions. With the current process, a discrepant meter would not be identified until it has completed its route
10 through the customer service facility. Identifying the discrepant meter at the end of the process results in extremely high scrap costs and a delay in delivery to the customer.

For the reasons given above, a need exists for a meter calibration system with sufficient accuracy that enables calibration of meters devoid of process
15 connections. Moreover, the system should be capable of calibrating both linear and nonlinear meters and should not reduce the current system's performance or capabilities.

SOLUTION

This invention overcomes the problems outlined above and advances the art
20 by providing methods and apparatus capable of calibrating meters devoid of process connections. The apparatus are a calibration system and process connection adapters, where the system is operable for calibrating both linear and nonlinear meters at multiple flow rates, and is suitable for use with both gravimetric and master meter standard references.

25 One embodiment of the present invention is a process connection adapter used to fluidly connect a calibration system with a test meter devoid of process connections. The process connection adapter is an apparatus composed of a system mating portion, an intermediate portion, and a meter mating portion. The system mating portion is designed to physically match a connection on the
30 calibration system. Typically this connection is in the form of a flange, sanitary fitting, union fitting, or some other type of sealing connection for piping. The intermediate portion transitions the flow area of the system mating portion to the flow area of the meter mating portion. The meter mating portion incorporates mechanical features to physically match a portion of the meter that would typically

have a process connection attached to it. Depending on the connection type used by the system, a sealing component may be required to ensure that the interfaces between the process connection adapters, the calibration system, and the test meter are leak-free. Such a component could be an O-ring or gasket seal. During meter installation into the calibration system, the process connection adapters can either be secured to each of its mating members through bolts or other fittings or simply compressed as an assembly between hydraulic or pneumatic actuators.

The order fulfillment process begins by receiving a meter, devoid of process connection, from the manufacturing facility. Next, process connection adapters are attached on each end of the meter to form a test assembly. The test assembly is then mounted in the test bed by placing a portion of the test assembly on support structures integrated in the calibration system. Once the test assembly is fixed into the support structures, hydraulic or pneumatic actuators compress the calibration system connectors against the process connection adapters. This compression capability enables quick and easy insertion and removal of the test assembly while also ensuring a leak-free fluid path. Once the test assembly is inserted into the calibration system, the meter signal cabling is attached to the controller and the calibration process is started.

The basic meter calibration system includes a mechanism for supplying fluid to use in flow calibration measurements, a flow and density measurement reference, a controller for automating the system in order to optimize the accuracy or sensitivity of the measurements, and, of course, a meter under test. The flow measurements are used to ascertain or validate a flow calibration factor for the meter under test. The same principles apply for mass flow rate, volumetric flow rate, density, or viscosity calibrations.

The fluid supply mechanism can provide any fluid type; e.g., a liquid reservoir and a pump; a multiphase fluid including multiple immiscible liquid phases and gas; an attachment to a pressurized water supply, such as plant process fluids, a city water supply, artesian well, or gravimetric system; or a pressurized gas supply, such as natural gas, air, or plant process gases. For most meter calibrations, a constant-pressure source of water is the preferred supply mechanism.

The meter is operably configured, as described above, to receive fluid from the fluid supply mechanism. The meter under test is positioned in the flow piping

between the fluid supply and either a scale, as in the case of a gravimetric system, or a master meter array as in a master meter system, described in U.S. Patent No. 6,360,579 issued to DeBoom et al.

5 Once the calibration process is started, the meter under test provides flow measurement signals to a supervisory CPU-based controller. The controller adjusts valves leading to the meter for the purpose of controlling flow through the meter within the range of optimal measurement sensitivity corresponding to relatively low uncertainty for the meter. The controller interprets these electrical signals as flow measurement data and calibrates the meter under test using a flow
10 calibration factor obtained from flow data.

The following sets forth aspects of the invention. One aspect of the invention comprises a meter calibration system configured to calibrate a meter devoid of process connections comprising a source for flowing a process material through the calibration system, a controller configured to process measurement
15 signals derived from the calibration system and the meter to derive calibration information and characterized by:

process connection adapters for connecting the meter under calibration to the calibration system.

20 Preferably, the process connection adapters are configured to emulate a process connection that may be subsequently attached to the meter.

Preferably, the process connection adapters are configured to emulate flange process connections.

Preferably, the process connection adapters are configured to emulate sanitary process connections.

25 Preferably, the meter calibration system comprises a master meter for supplying measurement signals to said controller for use in deriving said calibration information.

30 Preferably, the meter calibration system comprises a scale for supplying measurement signals to said controller for use in deriving said calibration information.

Preferably, the meter under test is a Coriolis meter.

Preferably, the meter calibration system includes a test unit comprising serially-connected meters under test.

Preferably, said process connection adapters are compressively held onto a meter inlet and outlet.

Preferably, said process connection adapters are integrated into the calibration system.

5 Preferably, the meter calibration system comprises means for ensuring a leak-free seal between the process connection adapter and the meter.

Preferably, the means for ensuring a leak-free seal between the process connection adapter and the meter is an O-ring.

10 Preferably, the meter calibration system comprises means for ensuring a leak-free seal between the process connection adapter and the calibration system.

Preferably, the means for ensuring a leak-free seal between the process connection adapter and the calibration system is an O-ring.

15 Another aspect of the invention comprises a method of calibrating a meter under test devoid of process connections, the method characterized by the steps of:

connecting a first process connection adapter to an input of said meter and a second process connection adapter to an output of said meter to form a series connection with said meter;

20 flowing serially through said first process connection adapter, said meter, and said second process connection adapter;

generating measurement signals in response to said flow; and

processing measurement signals to derive calibration information for the meter.

25 Preferably, the step of connecting process connection adapters includes the step of using process connection adapters that are configured to emulate a process connection that may be subsequently attached to the meter.

30 Preferably, the step of using process connection adapters that are configured to emulate a process connection that may be subsequently attached to the meter further includes the step of using process connection adapters that are configured to emulate flange process connections.

Preferably, the step of using process connection adapters that are configured to emulate a process connection that may be subsequently attached to the meter further includes the step of using process connection adapters that are configured to emulate sanitary process connections.

Preferably, the step of processing measurement signals includes the step of using measurement signals from a master meter to derive said calibration information.

5 Preferably, the step of processing measurement signals includes the step of using measurement signals from a scale to derive said calibration information.

Preferably, the method of calibrating a meter under test devoid of process connections includes the step of calibrating a Coriolis meter.

10 Preferably, method of calibrating a meter under test devoid of process connections includes the step of compressively holding said process connection adapters onto a meter input and output.

Preferably, the step of connecting process connection adapters includes the step of connecting the process connection adapters to a test unit comprising serially-connected meters under test.

BRIEF DESCRIPTION OF THE DRAWINGS

15 These and other advantages and features of the present invention may be better understood in connection with a reading of the following detailed description of one possible exemplary embodiment thereof taken in conjunction with the drawings in which:

20 FIG. 1 is a process schematic diagram showing the flow process for a meter calibration system according to the prior art;

FIG. 2 discloses a calibration installation according to an embodiment of the present invention;

FIG. 3 depicts a process connection adapter;

FIG. 4 depicts an additional process connection adapter;

25 FIG. 5 is a process schematic diagram showing the flow process for a meter calibration system according to the present invention;

FIG. 6 depicts a block schematic diagram of the flow process for a meter calibration system according to the present invention;

30 FIG. 7 depicts a block schematic diagram of the flow process for a meter calibration system according to another embodiment;

FIG. 8 discloses a process schematic diagram showing the calibration process.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed toward methods and apparatus used in calibrating meters devoid of process connections for the purposes of assuring measurement accuracy. The apparatus can include a flow calibration unit and associated adapters for connecting and calibrating meters without process connections. Many specific details of certain embodiments of the invention are set forth in the following description and in **FIGS. 1- 8** to provide a thorough understanding of such embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments and that they may be practiced without several of the details described in the following description.

FIG. 1 is a process schematic diagram showing a process **100** of how a meter is routed from production to shipment to a customer according to the prior art. Step **105** involves the production of a meter from component or piece parts. This production includes all assembly, welding and finishing processes up to but not including the attachment of process connections. After the meter has completed production, the meter is then shipped to a storage area in step **110** to await a customer order.

In step **115**, a customer orders a meter based on customer requirements, including flow rate, fluid type and line pressure. Based on the customer's requirements, an order is placed in manufacturing for a meter with a specific process connection attached. Various types of process connections exist, including flanges, union fittings, sanitary, etc.

Step **120** entails the connection of the process connections ordered by the customer. The meter and process connections are attached using either an automated or manual welding station.

After the meter has been built, it is calibrated as shown in step **125**. Depending on the meter type and size, a calibration facility requires between 2 and 3 calibration systems. Calibration units can cost as much as \$450,000 dollars and can take up as much as 800 sqft. Due to the cost and size of these systems, limiting the number of installations is desirable. Not only is the size and cost a consideration, but also calibration is a time-consuming process. The calibration process is subsequently described in further detail.

Once the meter has been calibrated, a quality check is performed in step **130**. Then, the meter is shipped to the customer as denoted by step **135**. The quality check involves, among other things, the meter's adherence to strict performance standards as well as its conformity to manufacturing standards. If, for any reason, the meter does not meet the quality standards, it is routed back to manufacturing for further disposition while a replacement meter is substituted for order fulfillment. Unfortunately, the labor and materials expended during the process connection attachment and calibration steps are wasted since the quality assurance check occurs at the end of all manufacturing steps.

10 Description of Figure 2

FIG. 2 discloses a calibration installation according to an embodiment of the present invention. A meter support **200** is comprised of a back support **202** and two side supports **204**. The back support **202** has attached to it guides **206** for enabling process connection supports **208** to be installed and adjusted, up or down, depending on the size and type of flow meter under test. Incorporated on the side supports are the process fluid inlet **210** and outlet **211** for conveying process fluid through the process connection adapters **216** and the test meter **220**.

Once the test meter **220** has the process connection adapters attached onto each end of the test meter **220**, the assembly is placed on process connection supports **208** and locked down with clamps **218**. The process fluid inlet **210** and outlet **211** are then pressed against the process connection adapters, thereby creating a leak-free fluid path.

Description of Figures 3 and 4

FIGS. 3 and 4 are exploded views of different types of process connection adapters that may be used to install a meter devoid of process connections into a calibration system. **FIG. 3** is a process connection adapter **300** that is designed to act as a mock flange connection. The process connection adapter **300** comprises a disc portion **305** with bolt holes **310** that may be used to connect to a mating flange on the calibration system. From the disc **305**, the adapter reduces in size to a neck portion **315** and truncates at the meter mating portion **320**. The meter mating portion **320** may further contain a sealing mechanism **325** (e.g. an O-ring) to ensure a leak-free seal between the test meter **220** and the process connection adapter **300**.

FIG. 4 is a process connection adapter **400** designed to act as a mock sanitary connection. The process connection adapter **400** comprises a disc portion **405** that interfaces with either the process fluid inlet **210** or outlet **211** of the calibration system piping. From the disc **405**, the adapter reduces to a meter mating portion **410**. The meter mating portion **410** may further contain a sealing mechanism **415** (e.g. an O-ring) to ensure a leak tight seal between the test meter **220** and the process connection adapter **400**.

Description of FIG. 5

FIG. 5 is a process schematic diagram showing a process **500** of how a meter is routed from production to shipment to a customer according to one possible exemplary embodiment of the invention. Step **505** involves the production of a meter from component or piece parts. This production includes all assembly, welding and finishing processes up to but not including the attachment of process connections.

After the meter has completed production, the meter is then calibrated as shown in step **510**. The calibration process differs for that in **FIG. 1** step **125** in that the meter is calibrated without process connections. Compared to the process in **FIG. 1**, this process enables completion of more steps prior to customization based on a customer's order. Once the meter has been calibrated, it is put through a battery of tests to verify its adherence to strict quality standards as denoted by step **515**. If the meter fails to pass any of the quality tests, it is routed back to meter production for further disposition. However, if the meter passes the quality test, it is forwarded to meter storage as depicted by step **520**. Due to the fact that all calibration and quality check procedures have been performed on the meter, the storage facility can be located in any part of the world. It is not necessary, as in the prior art process denoted by **FIG. 1**, for the storage facility to have costly calibration systems. It is only necessary that the facility have capabilities for attaching process connections, a relatively inexpensive capital investment and relatively less labor-intensive operation.

In step **525**, a customer orders a meter based on many criteria, including flow rate, fluid type and line pressure. Based on the customer's requirements, an order is placed in manufacturing for a meter with a specific type of process connection.

The meter type ordered by the customer is retrieved from storage and the process connection attachment is performed as shown in step **530**. The meter and process connections are attached using either an automated or manual welding station. As mentioned above, the relatively low cost of the welding stations enable
5 their use in many locations.

After the meter has the process connections attached, it is shipped to the customer as shown in step **535**. The benefit of the described process over the prior art is the ability to maintain meter inventories at multiple locations throughout the world while minimizing capital cost. This strategy improves the response time to a
10 customer's order by locating the customer specific operations close to the customer, while limiting the locations performing labor and capital-intensive operations such as manufacturing, calibration, and quality testing.

Description of Figure 6

As mentioned previously, the ability to calibrate meters early in the work-flow
15 process is beneficial because of the time and costs associated with a calibration system. One such system is a master meter calibration system of the present invention, as shown in **FIG. 6**. **FIG. 6** depicts a meter calibration system **600**. A reservoir **602** contains water or another liquid, which is pressurized in tubing **604** by the action of gravity and an optional pump **606**. An automated valve **608** may be
20 partially opened to permit a portion of the flow from pump **606** to bypass flow through system **600**. A first meter array **612** is positioned to receive liquid from tubing **604** under the pressure influence of pump **606**. The term "array" is used to denote a grouping of flow meters. A meter under test or test unit **614** is positioned between first meter array **612** and a second meter array **616**. The term "test unit" is
25 used here because a single meter may be tested or a plurality of similar meters may be connected in series for simultaneous calibration testing. The testing of meters in series significantly enhances the test process efficiency because flow measurement data from a single test perceived by first meter array **612** and second meter array **616** can be used to calibrate each meter in series within test unit **614**,
30 as opposed to having to run separate volumes through the arrays while testing each meter.

Test unit **614** receives liquid through tubular segment **618** and, in turn, passes this liquid to second meter array **616** through tubular segment **620**. A CPU-based controller **622** is in electrical contact with each of first meter array **612**, test

unit **614** and second meter array **616** through corresponding cables **624**, **626**, and **628**. Controller **622** is also in electrical contact with pump **606** and valve **608** through corresponding cables **630** and **632**. Tubing **634** provides a return of fluid from second meter array **616** to reservoir **602**.

5 A pressure indicating recorder **636** and a temperature indicating recorder **638** are mounted in tubular segment **618**, i.e., upstream of test unit **614**. A temperature indicating recorder **640** is mounted in tubular segment **620**, i.e., downstream of test unit **614**. These devices are in operable contact with controller **622** through cables **642**, **644**, and **646** for the receipt and transmission of signals.

10 The pressure indicating recorder **636**, temperature indicating recorder **638**, and temperature indicating recorder **640** provide data that is used according to conventional practices in obtaining density measurements from test unit **614** when it contains a Coriolis flowmeter. Pressure and temperature data from the positions shown for pressure indicating recorder **636**, temperature indicating recorder **638**,

15 and temperature indicating recorder **640**, are also required to perform volumetric measurements when the test unit **614** contains a volumetric flow meter, such as a positive displacement meter or orifice meter.

 In operation, the meter under test **614** has been newly manufactured or recently removed from a normal service position (not depicted in **FIG. 6**). Meter

20 under test **614** has just been installed into position contacting tubular segments **618** and **620** for calibration test purposes, and the portion of system **600** downstream of reservoir **602** has been bled of air and other gasses. Controller **622** actuates pump **606** to flow liquid from within reservoir **602** in series into first meter array **612**, meter under test **614** and second meter array **616**, which each perform simultaneous flow

25 measurements on the liquid. Controller **622** synchronizes these simultaneous measurements. The synchronous measurements avoid the possibility of obtaining flow measurements at different times where the flow measurements may be influenced by pressure surges or pulses from the action of pump **606**. Controller **622** operates, as described in greater detail below, to assure that respective meters

30 within second meter array **616** are operating at flow rates making it at least ninety-five percent certain that the uncertainty of measurements obtained from second meter array **616** are at least three times more accurate than the manufacturer's performance specification that is allocated to meter under test **614**.

Description of Figure 7

FIG. 7 depicts another form of the calibration system called a gravimetric scale system **700**. A reservoir **702** contains water or another liquid, which is pressurized in tubing **704** by the action of gravity and an optional pump **706**. An automated valve **708** may be partially opened to permit a portion of the flow from pump **706** to bypass flow through system **700**. A meter under test or test unit **714** is positioned between reservoir **702** and scale **716**. The term "test unit" is used here because a single meter may be tested or a plurality of similar meters may be connected in series for simultaneous calibration testing. The testing of meters in series significantly enhances the test process efficiency because flow measurement data from a single test can be used to calibrate each meter in series within test unit **714**.

Test unit **714** receives liquid through tubular segment **718** and, in turn, passes this liquid to a scale **716** through tubular segment **720**. A CPU-based controller **722** is in electrical contact with each of test unit **714** and scale **716** through corresponding cables **726**, and **728**. Controller **722** is also in electrical contact with pump **706** and valve **708** through corresponding cables **730** and **732**. Tubing **734** provides a return of fluid from scale **716** to reservoir **702**.

A pressure indicating recorder **736** and a temperature indicating recorder **738** are mounted in tubular segment **718**, i.e., upstream of test unit **714**. A temperature indicating recorder **740** is mounted in tubular segment **720**, i.e., downstream of test unit **714**. These devices are in operable contact with controller **722** through cables **742**, **744**, and **746** for the receipt and transmission of signals. The pressure indicating recorder **736**, temperature indicating recorder **738**, and temperature indicating recorder **740** provide data that is used according to conventional practices in obtaining density measurements from test unit **714** when it contains a Coriolis flowmeter. Pressure and temperature data from the positions shown for pressure indicating recorder **736**, temperature indicating recorder **738**, and temperature indicating recorder **740**, are also required to perform volumetric measurements when the test unit **714** contains a volumetric flow meter, such as a positive displacement meter or orifice meter.

In operation, the meter under test **714** has been newly manufactured or recently removed from a normal service position (not depicted in **FIG. 7**). Meter under test **714** is installed into position contacting tubular segments **718** and **720**

for calibration test purposes, and the portion of system **700** downstream of reservoir **702** has been bled of air and other gasses. Controller **722** activates pump **706** to flow liquid from within reservoir **702** in series into meter under test **714** and scale **716**, which each perform simultaneous measurements on the liquid.

5 Controller **722** synchronizes these simultaneous measurements.

Description of Figure 8

FIG. 8 depicts a schematic block process diagram showing a process **800** of meter calibration as described in step **510** from **FIG. 5**. The discussion of the steps of **FIG. 8** is framed in the context of reference numbers of the apparatus of **FIG. 6**.

10 Step **802** entails inserting a unit under test. This assembly typically includes inserting process connection adapters on to each end of the test unit **614** and compressing the process connection adapters between tubular segments **618** and **620**. Test unit **614** is typically held in place between tubular segments **618** and **620** by a hydraulic or pneumatic actuator.

15 Test unit **614** is normally filled with air after the unit under test has been properly installed in step **802**. A pressurized air source is used to blow liquid from the system, if needed, prior to determining an air density reference value from each individual meter in the test unit **614**, pursuant to step **804**.

20 According to step **806**, air is next bled from the system and water or another test fluid is introduced into the test unit **614**. The test fluid can be air, in which case air does not need to be bled from the system and step **806** can be skipped.

25 Controller **622** opens automated valves (not shown) and uses liquid from pump **606** to purge the test unit **614**. Alternatively, controller **622** can open valves for return of fill liquid to reservoir **602** if residual fluid and/or particles inside test unit **614** will not contaminate the fluid in the reservoir.

30 In step **808**, controller **622** activates pump **606** to flow water from reservoir **302** or permits fluid from another source to flow fluid through flow calibration system **600**. Controller **622** also determines the flow rate for the calibration test based upon operator input identifying the type or types of meters in the unit under test and a lookup table or database of appropriate test profile information for each meter. The operator can also input the test profile information to override or supplement test profile information in the database. Controller **622** then selectively opens and closes the automated valves to match the test profile.

Controller **622** is preferably configured to obtain simultaneous readings from each active meter in first meter array **612**, second meter array **616**, and the test unit **614**. This synchronization avoids the possibility that pressure surges through the system **600** could skew the measurement results if controller **622** polls the
5 respective meters at different times. This flow measurement data can be quickly obtained, e.g., seven measurement points can be obtained in two to three minutes.

In step **810**, the flow measurement data from second meter array **616** is used to calculate a flow calibration factor or calibration equation that is compatible with the type of meter under test in test unit **614**. The flow calibration factor
10 calculation is performed according to the manufacturer's specifications, and the manner of this calculation is preferably kept in the same database or lookup table that is used to identify the test profile in step **808**.

Step **812** entails additional flow measurement testing to verify performance of the meter under test using the flow calibration factor that was calculated in step
15 **810**. Controller **622** again synchronizes measurements from all of the active meters in flow calibration system **600**.

In step **814**, the controller **622** checks each measurement signal from steps **808** and **812** and compares the cumulative signals (e.g., representing total flow rate amounts from two meters in first meter array **612**) that are obtained from one array
20 at a single time against the cumulative signals from the other array at the same time. The comparison entails subtracting one signal from the other and determining whether the difference exceeds an uncertainty limit.

It is to be expressly understood that the claimed invention is not to be limited to the description of the preferred embodiment but encompasses other
25 modifications and alterations within the scope and spirit of the inventive concept. For example, the term "material" encompasses fluids, gases, liquids and any other element that can be made to flow through a meter.

CLAIMS

What is claimed is:

1. A meter calibration system (600) configured to calibrate a meter devoid of process connections (220) comprising a source (602) for flowing a process material through the calibration system, a controller (622) configured to process measurement signals derived from the calibration system and the meter to derive calibration information and characterized by:
5 process connection adapters (216) for connecting the meter under calibration to the calibration system.
10
2. The meter calibration system of claim 1 wherein the process connection adapters are configured to emulate a process connection that may be subsequently attached to the meter.
- 15 3. The meter calibration system of claim 2 wherein the process connection adapters (300) are configured to emulate flange process connections.
4. The meter calibration system of claim 2 wherein the process connection adapters (400) are configured to emulate sanitary process connections.
20
5. The meter calibration system of claim 1 further comprising a master meter (616) for supplying measurement signals to said controller (622) for use in deriving said calibration information.
- 25 6. The meter calibration system of claim 1 further comprising a scale (716) for supplying measurement signals to said controller (722) for use in deriving said calibration information.
7. The meter calibration system as set forth in claim 1 wherein the meter
30 under test is a Coriolis meter.
8. The meter calibration system as set forth in claim 1 including a test unit (614) comprising serially-connected meters under test.

9. The meter calibration system as set forth in claim 1 wherein said process connection adapters are compressively held onto a meter inlet and outlet.

5 10. The meter calibration system as set forth in claim 1 wherein said process connection adapters are integrated into the calibration system.

10 11. The meter calibration system as set forth in claim 1 further including means (325) for ensuring a leak-free seal between the process connection adapter and the meter.

12. The meter calibration system as set forth in claim 11 wherein the means (325) for ensuring a leak-free seal between the process connection adapter and the meter is an O-ring.

15 13. The meter calibration system as set forth in claim 1 further including means for ensuring a leak-free seal between the process connection adapter and the calibration system.

20 14. The meter calibration system as set forth in claim 13 wherein the means for ensuring a leak-free seal between the process connection adapter and the calibration system is an O-ring.

25 15. A method of calibrating a meter under test devoid of process connections, the method characterized by the steps of:
connecting a first process connection adapter to an input of said meter and a second process connection adapter to an output of said meter to form a series connection with said meter;
flowing serially through said first process connection adapter, said meter, and said second process connection adapter;
30 generating measurement signals in response to said flow; and
processing measurement signals to derive calibration information for the meter.

16. The method of claim 15 wherein the step of connecting process connection adapters includes the step of using process connection adapters that are configured to emulate a process connection that may be subsequently attached to the meter.

5

17. The method of claim 16 wherein the step of using process connection adapters that are configured to emulate a process connection that may be subsequently attached to the meter further includes the step of using process connection adapters that are configured to emulate flange process connections.

10

18. The method of claim 16 wherein the step of using process connection adapters that are configured to emulate a process connection that may be subsequently attached to the meter further includes the step of using process connection adapters that are configured to emulate sanitary process connections.

15

19. The method of claim 15 wherein the step of processing measurement signals includes the step of using measurement signals from a master meter to derive said calibration information.

20

20. The method of claim 15 wherein the step of processing measurement signals includes the step of using measurement signals from a scale to derive said calibration information.

25

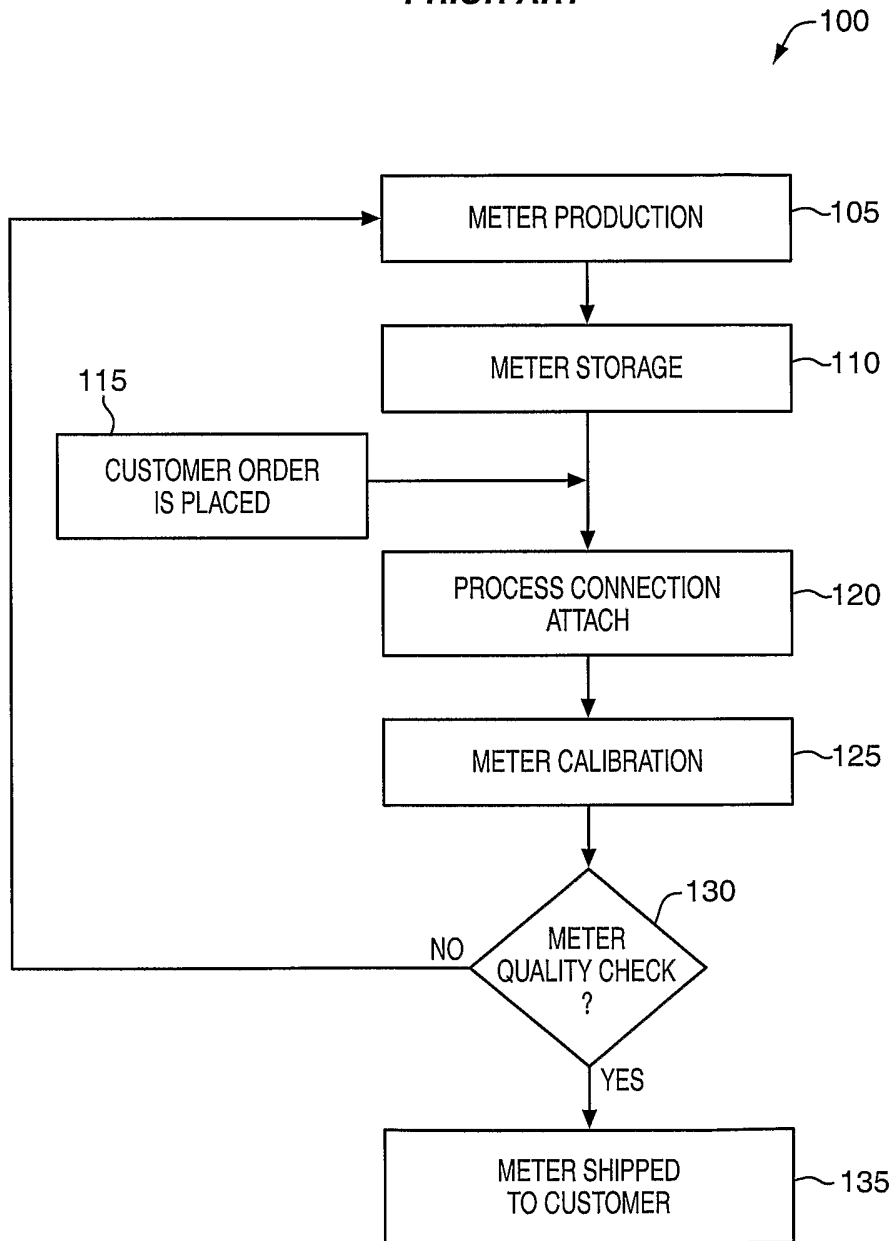
21. The method of claim 15 includes the step of calibrating a Coriolis meter.

22. The method of claim 15 further including the step of compressively holding said process connection adapters onto a meter input and output.

30

23. The method of claim 15 wherein the step of connecting process connection adapters includes the step of connecting the process connection adapters to a test unit comprising serially-connected meters under test.

FIG. 1
PRIOR ART



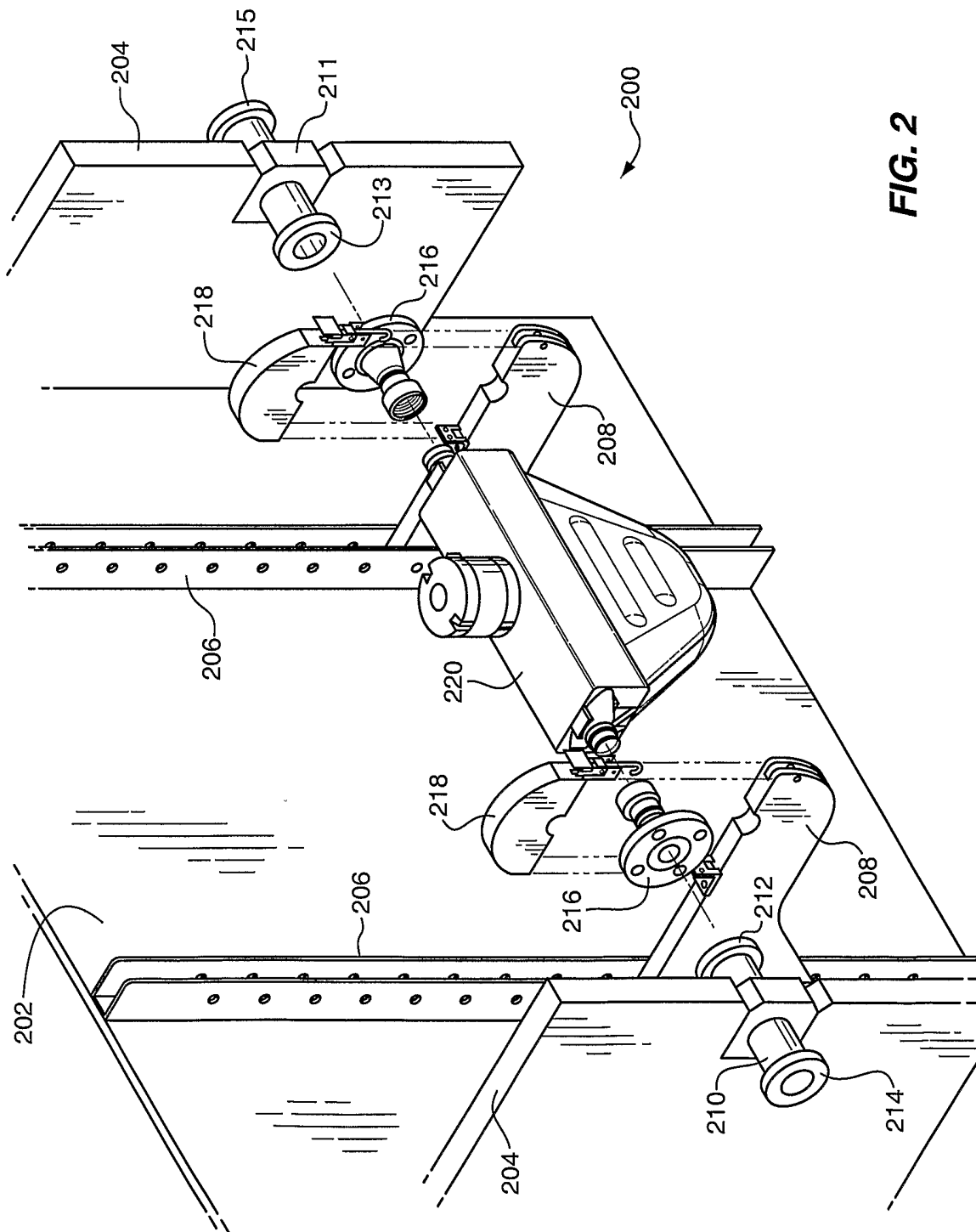


FIG. 2

FIG. 3

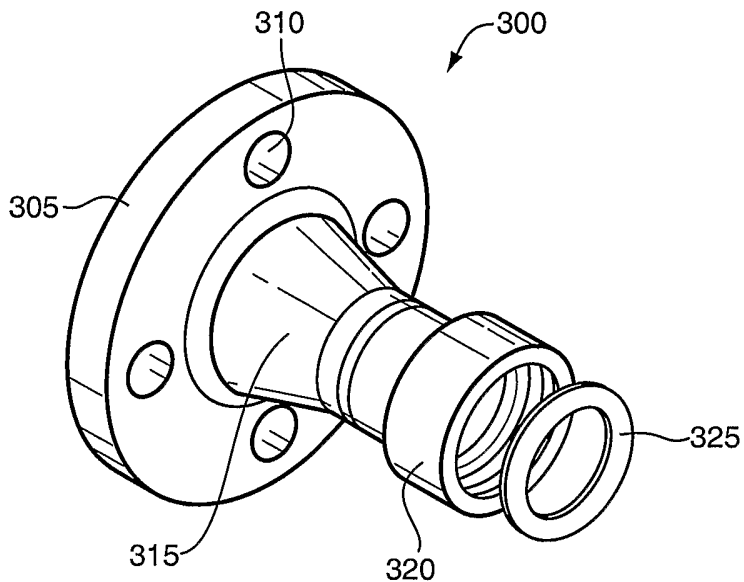


FIG. 4

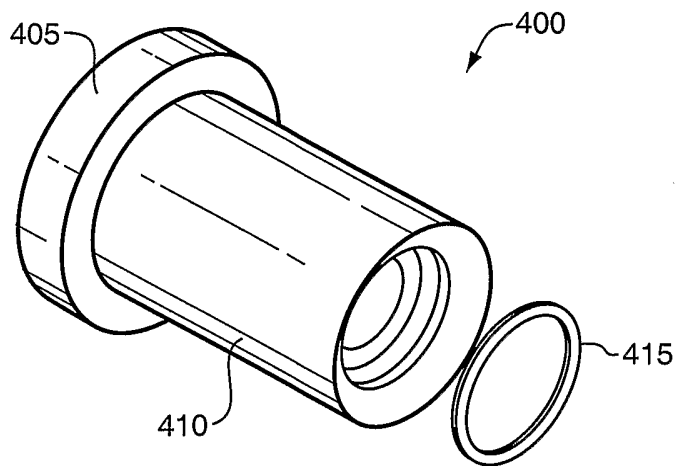
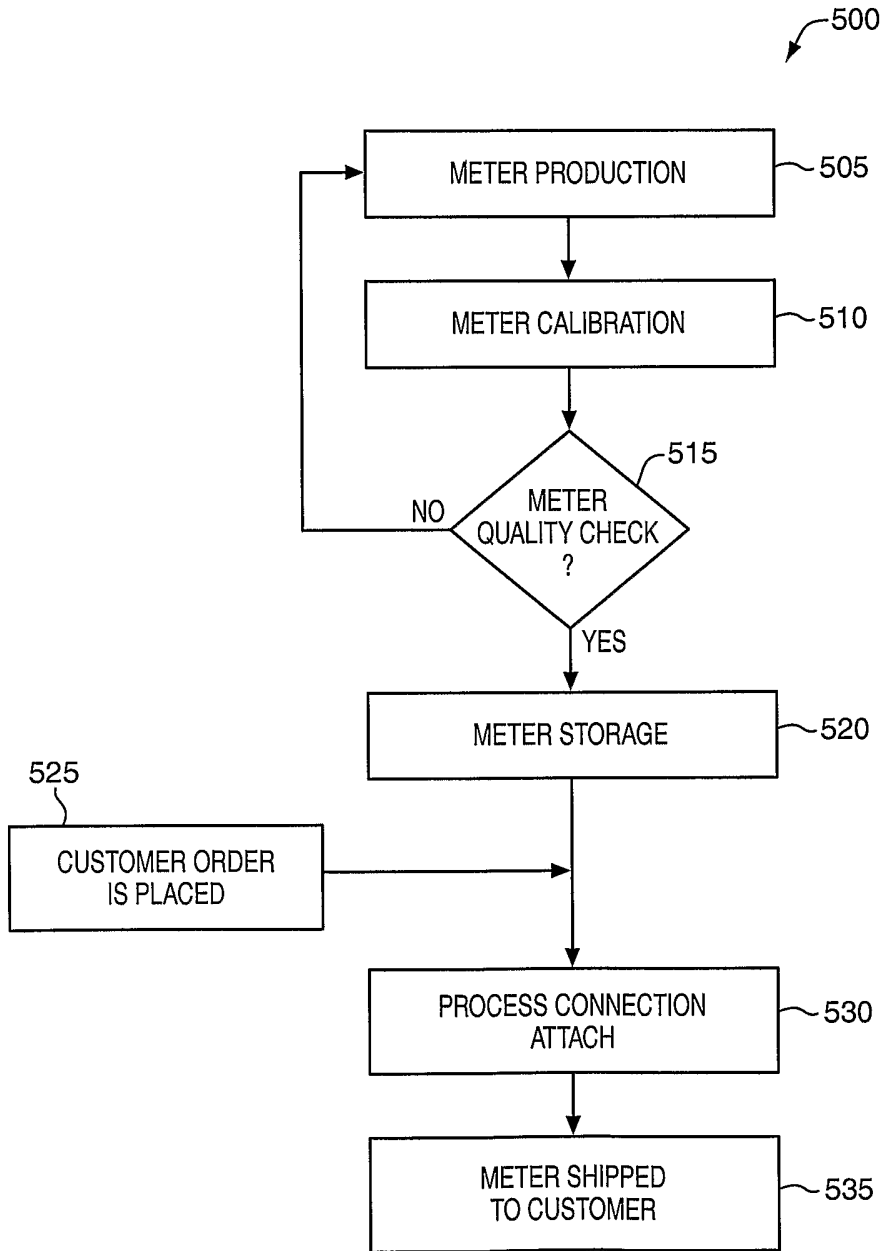


FIG. 5



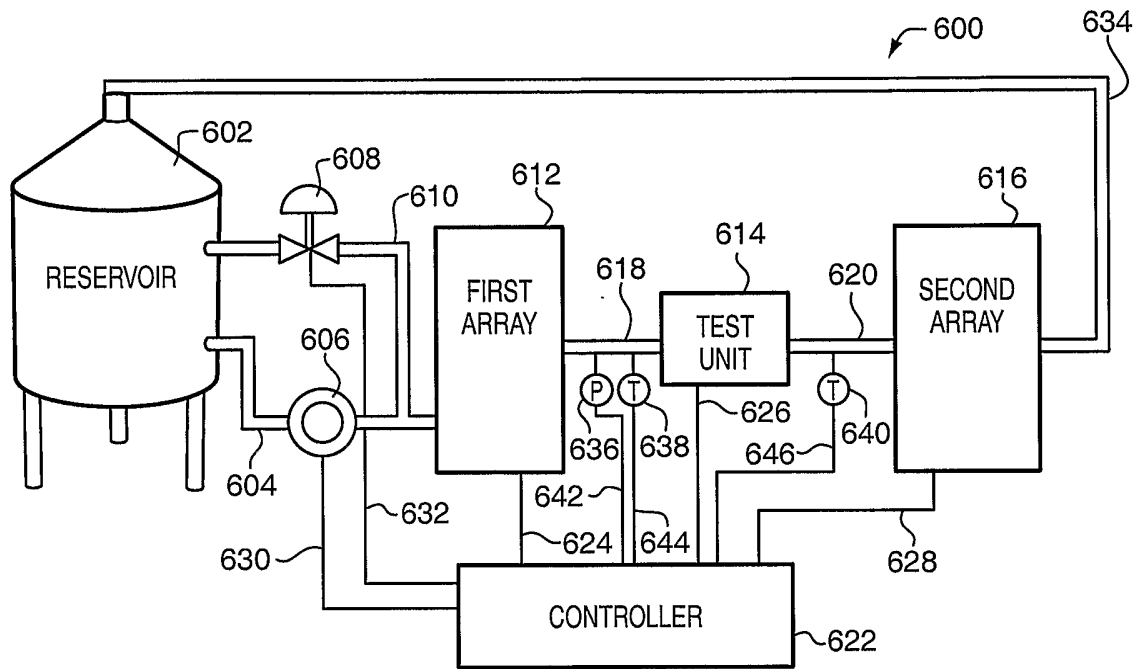


FIG. 6

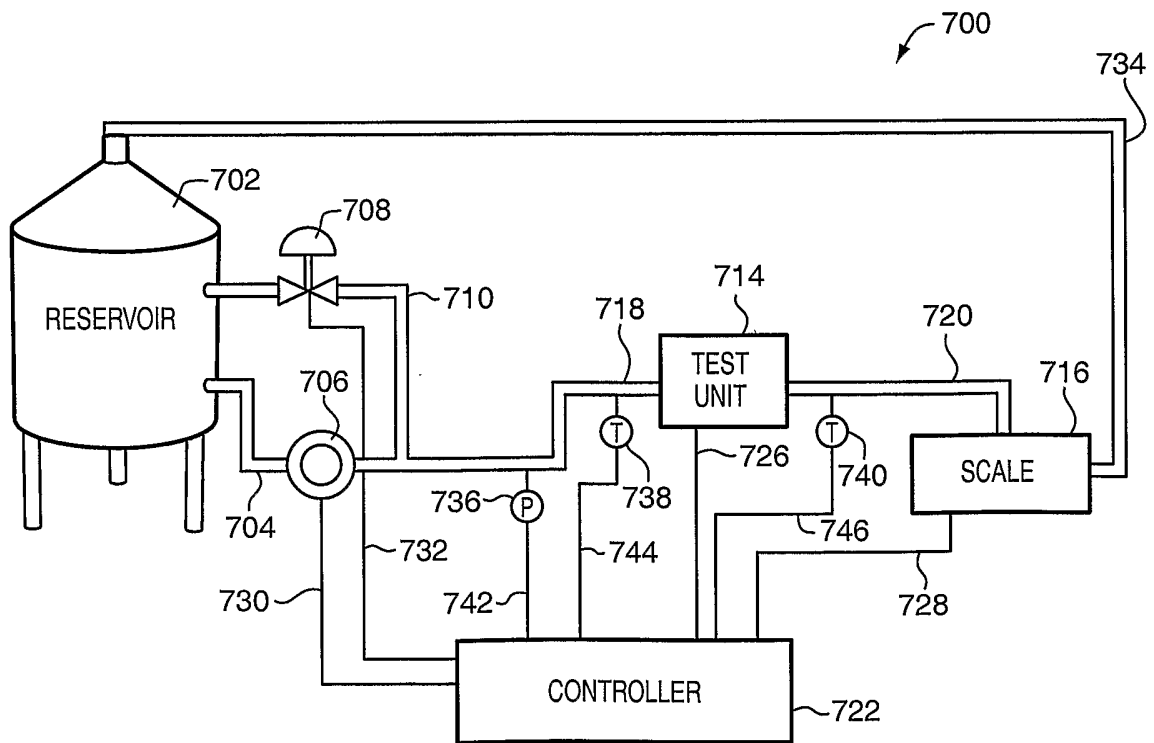
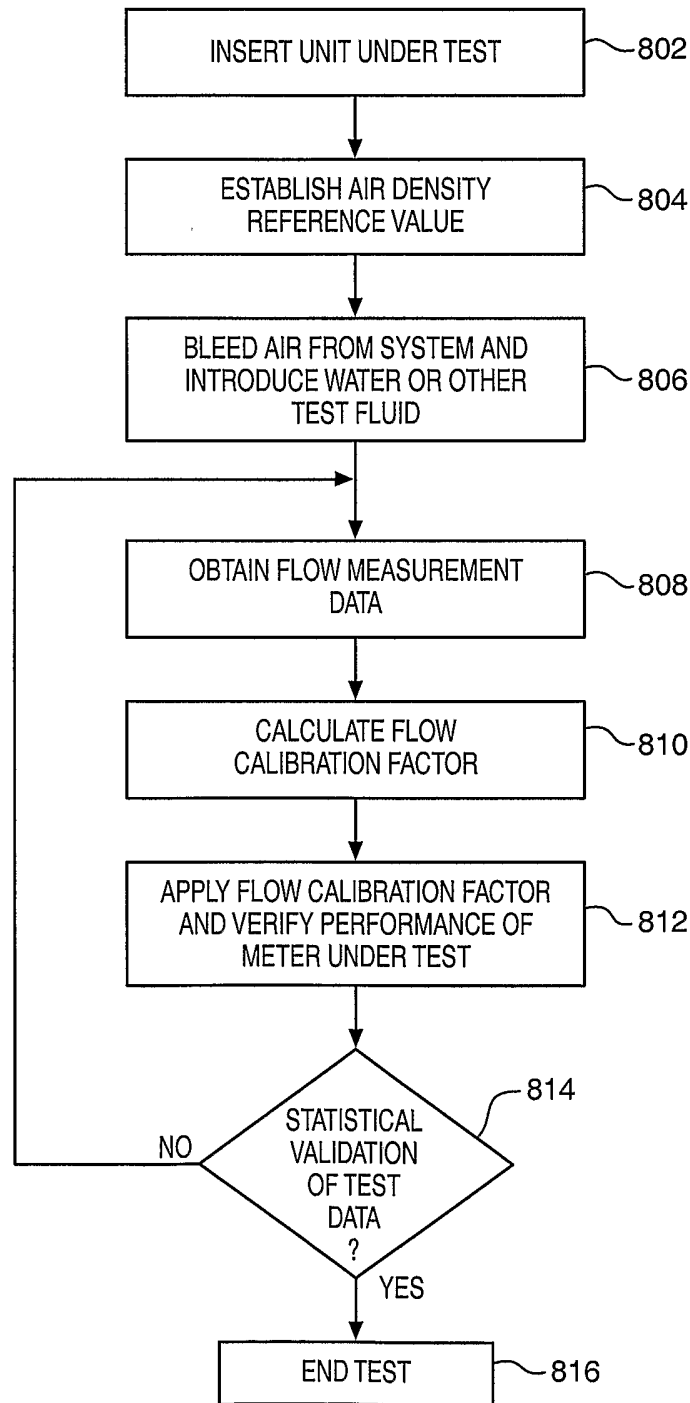


FIG. 7

FIG. 8

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 03/17051

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 G01F1/84 G01F25/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC 7 G01F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 360 579 B1 (GNIFFKE JULIE ET AL) 26 March 2002 (2002-03-26) cited in the application column 5, line 19 -column 8, line 10; figure 1 ---	1,5, 7-15,19, 21-23
Y	US 899 960 A (DORNIN T. B.) 29 September 1908 (1908-09-29) page 1, line 44 -page 2, line 57; figures 1-4 ---	1,5, 7-15,19, 21-23
A	US 2 631 451 A (FORD WILBUR E ET AL) 17 March 1953 (1953-03-17) column 2, line 26 -column 6, line 20; figures 1-5 --- -/--	1,6, 8-15,20, 22,23
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
° Special categories of cited documents :		
A document defining the general state of the art which is not considered to be of particular relevance *E* earlier document 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 10 September 2003		Date of mailing of the international search report 19/09/2003
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Roetsch, P

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	US 2 768 522 A (WARREN HENKE RUSSELL) 30 October 1956 (1956-10-30) column 1, line 46 -column 2, line 57; figures 1-5 -----	1,15

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