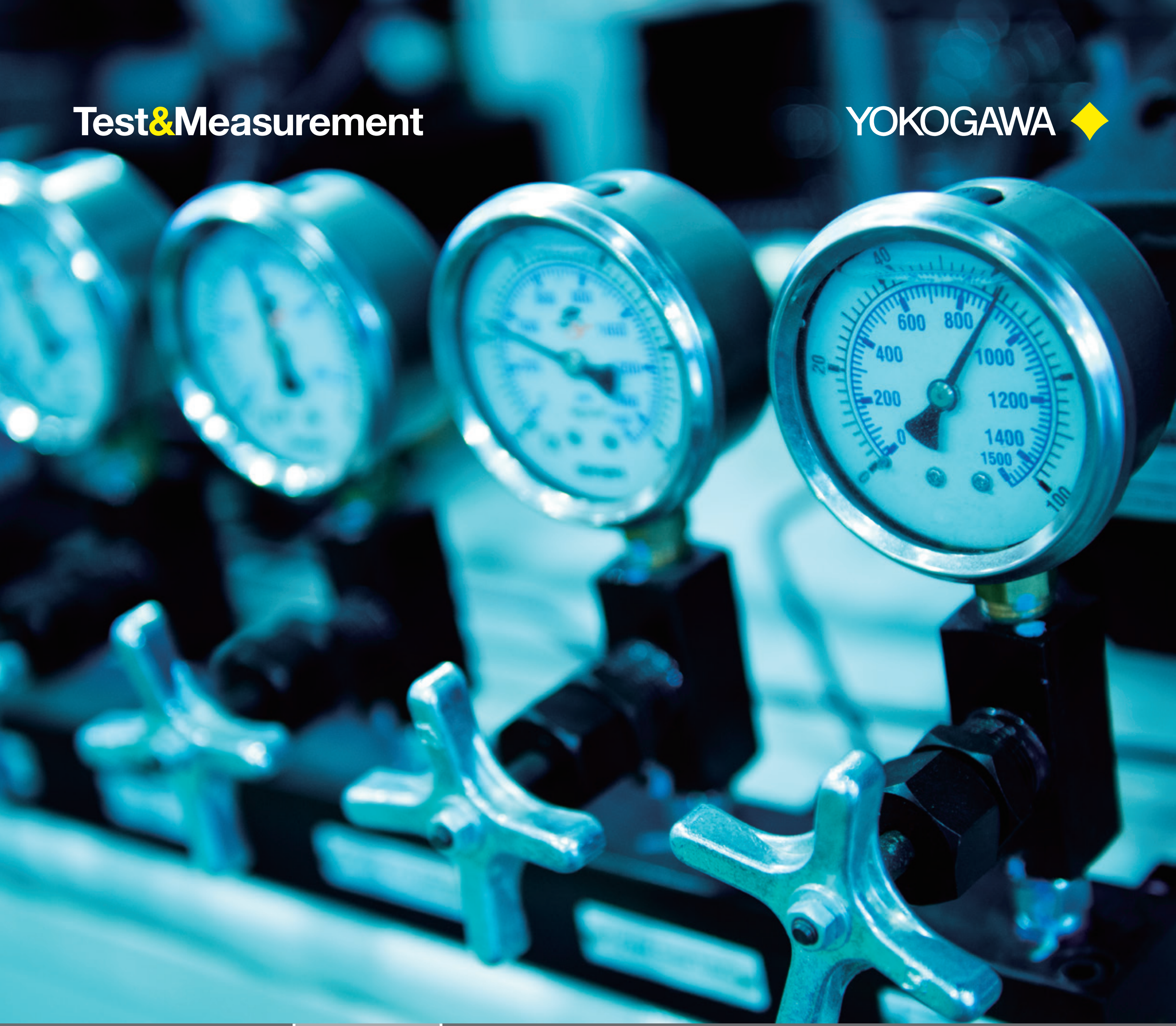
Test&Measurement

YOKOGAWA



Application Notes

—Pressure Measurement—

AN Pressure-Measurement-01EN

Silicon Resonant Sensor

Technology and Features of Silicon Resonant Sensor

A vibrator, formed using semiconductor process technology on a silicon wafer, is driven by a permanent magnet. When pressure is applied to the diaphragm chip, the vibrator is distorted, causing the resonant frequency to change.

1. The diaphragm that receives pressure is made of silicon single crystal with superior flexibility.

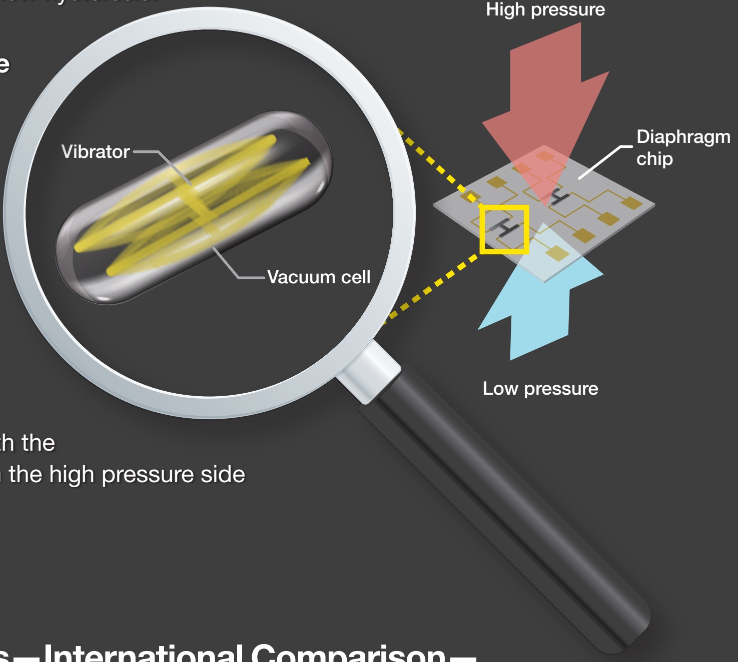
This provides highly repeatable measurements with low hysteresis.

2. The vibrators are placed in the vacuum cell on the diaphragm chip.

Pressure is derived from the difference between the two unique oscillation counts. The vibrators are not exposed to the open air, so the effect of external environment such as temperature and humidity is minimized.

3. Structure that receives pressure on both sides of the diaphragm chip

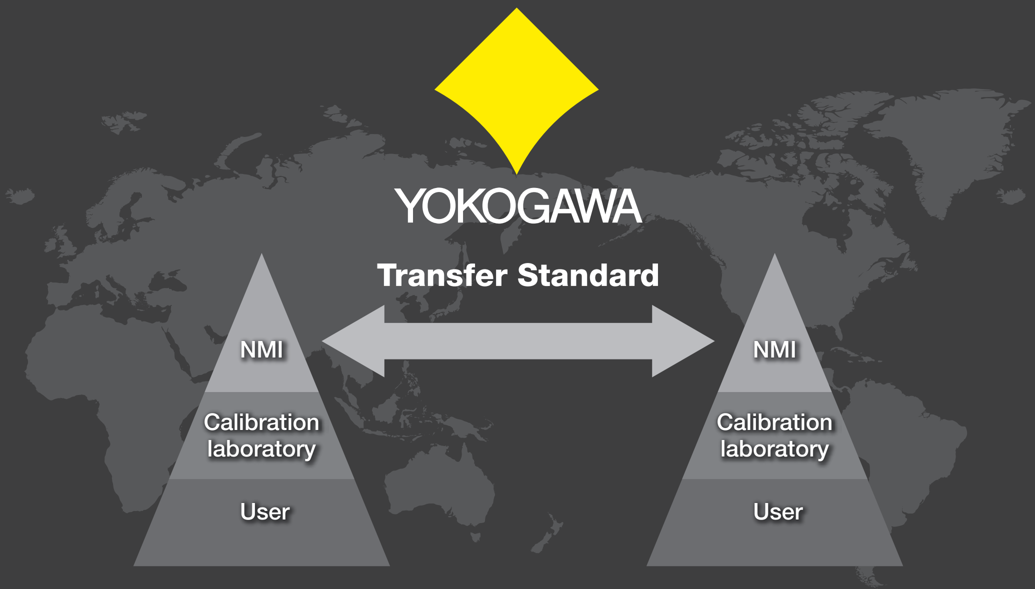
High precision measurement is achieved by directly measuring the differential pressure between two points with the differential pressure method, which receives pressure from the high pressure side and the low pressure side.



Initiatives for National Metrology Institutes—International Comparison—

The Yokogawa's pressure sensor and the MT series are adopted as a Transfer Standard for many CC-level and the regional-level (for example APMP) international comparisons of pressure standards based on the enhanced performance of digital pressure gauges and the evaluation result of long term stability.

*Transfer Standard: A standard used as a transfer equipment to compare standards.



Calibration Application

Pressure Calibration using Pressure Balance

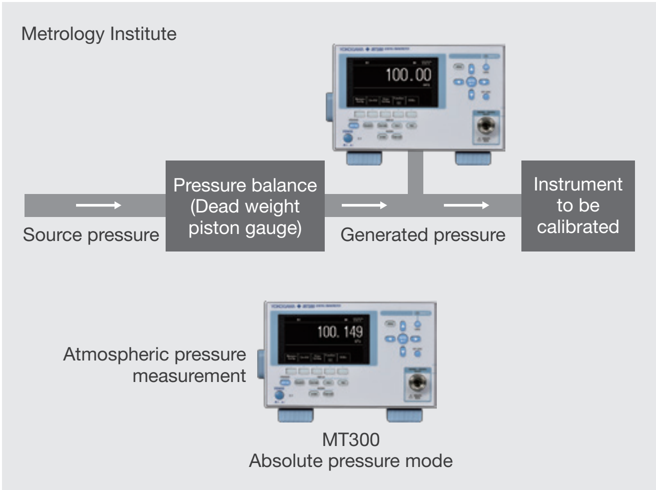
A pressure balance is used for pressure calibration requiring high calibration performance. It is a highly reliable instrument and widely used as a pressure standard by national metrology institutes and top-class calibration laboratories around the world.

Overview

When a pressure balance is used in calibration, connecting a manometer is necessary to confirm that the calibration values are generated correctly. Also, measurement of atmospheric pressure is required to confirm the effects of atmospheric pressure to the calibration results.

Key point

Highly accurate measurement of generated pressure leads to high calibration performance. Long-term stability of calibration equipment allows devices and environment to be maintained for a long-term period, which can uniformly provide the robustness of calibrated instruments in the same environment.



Shipping Inspection of Pressure Sensors

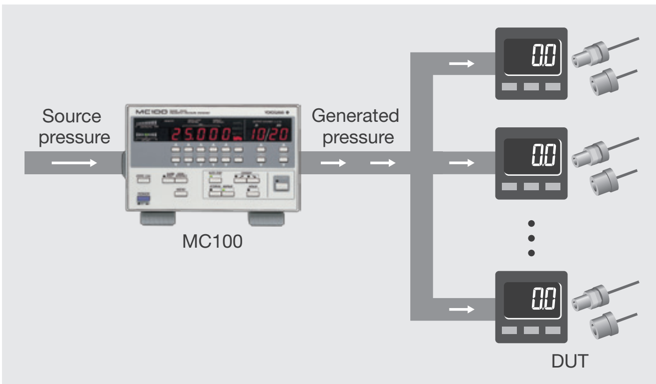
Pressure sensors installed in various devices such as automobiles, industrial equipment, and medical equipment have different characteristics -such as measurement range, accuracy, response, and hysteresis- depending on their measurement principle. This means that performance evaluation and shipping inspection based on their characteristics are required.

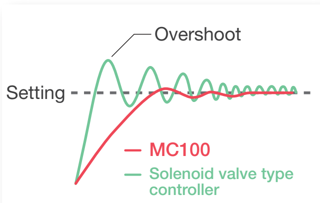
Overview

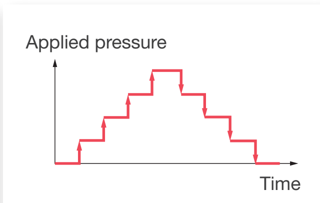
In the mass production of pressure sensors, it is important to shorten the production takt time. A pressure generator or pressure controller is used to apply a predetermined pressure to the pressure sensors under test and switch the pressure values at high speed.

Key point

The MC100 needle valve type pressure controller is effective in reducing takt time for inspecting sensors on mass production lines as its settling time required to reach a desired set pressure value is shorter than that of the solenoid valve type controller. The MC100 can generate a set pressure in steps, making it easy to test rising and falling pressures. It contributes to improved inspection efficiency.







FA Application

Precise Pressure Measurement for Calibrating Submersible Water Level Meters

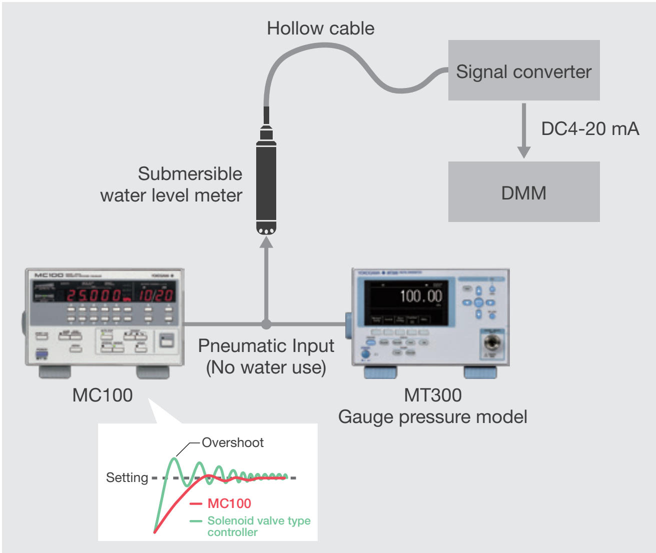
Among water level meters that monitor water levels in water and sewerage systems or rivers, submersible (pressure-type) water level meters measure liquid pressure associated with changes in water depth and convert it to water level. They are more accurate than ultrasonic water level meters and some deliver a guaranteed measurement accuracy of ±0.2%.

Overview

With a submersible (pressure-type) water level meter, the pressure value corresponding to a water level of 20 m is approximately 200 kPa. In performance testing of water level meters with an accuracy of ±0.2%, a pressure controller or digital manometer with generated pressures of 200 kPa or higher and accuracy of 0.1% or less is used.

Key point

In the performance evaluation of water level meters, applied pressure must transition smoothly to the set pressure without exceeding it in order to reduce the effect of hysteresis. Compared to a solenoid valve type controller, a pressure controller that controls pressure with a needle valve can settle at a set value without exceeding it, so the performance of a pressure sensor built into a water level meter can be evaluated correctly.



Flow Rate Characteristics Evaluation of Electro-Pneumatic Regulators

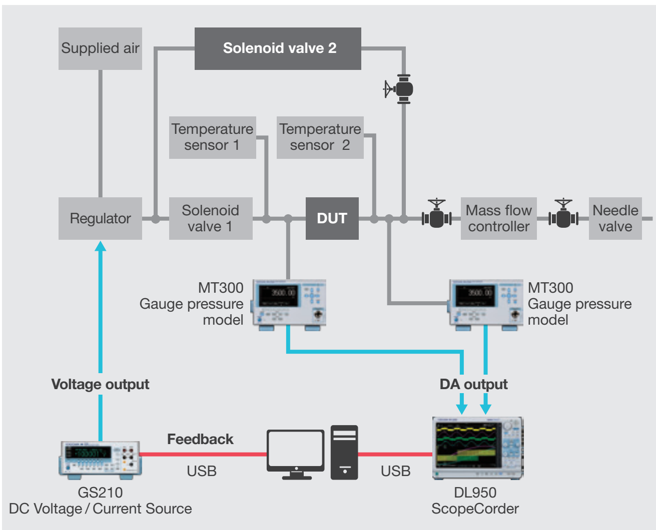
An electro-pneumatic regulator is a device that controls the pressure of liquid or gas supplied from an electric pump or compressor. It has a built-in pressure sensor and controls the solenoid valves by using feedback control to generate a set pressure. During the development phase of electro-pneumatic regulators, control signals and pressure levels must be accurately measured simultaneously to verify accurate pressure control.

Overview

The GS210 DC Voltage/Current Source outputs voltage to the electro-pneumatic regulator to control the generated pressure, and the MT300s test flow rate characteristics of the regulator under test. The MT300s output the measured pressure levels with the DA output function (16 Bit), and the data logger measures them at the same time.

Key point

YOKOGAWA can provide all the necessary measuring instruments for a system to evaluate flow rate characteristics, including a low-noise voltage generator to control an electro-pneumatic regulator, the MT300 to accurately measure output pressures, and a data logger to measure data in time series (DL950 ScopeCorder).



Differential Pressure (flow rate) Measurement in Performance Test of Small Compressors

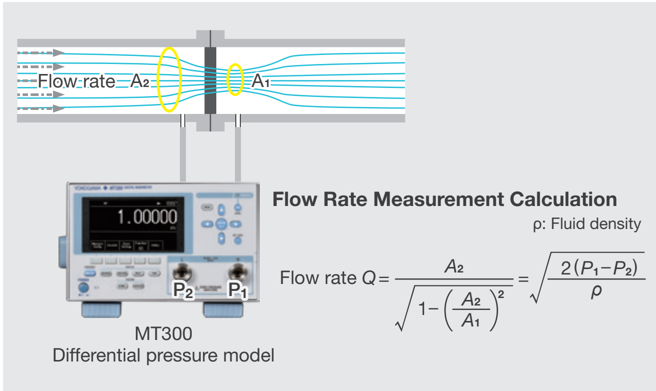
Performance tests of small compressors (positive displacement compressors) are conducted in accordance with ISO 1217. It is recommended that actual volume flow rate be measured by following the flow rate measurement method using pressure differential devices inserted in circular cross-section conduits as specified in ISO 5167.

Overview

ISO 5167 states that the flow rate of a fluid flowing through a circular conduit should be determined by measuring the static pressure difference between the upstream and downstream sides of the circular orifice plate.

Key point

The orifice hole diameter specified in ISO 5167 is 12.5 mm or larger. In low flow rate measurement, the differential pressure between the upstream and downstream sides is small, so a manometer capable of measuring minute differential pressure with high accuracy is required.



$$\text{Flow rate } Q = \frac{A_2}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}} \sqrt{\frac{2(P_1-P_2)}{\rho}}$$

Pressure Measurement in Development of High-Pressure Washers

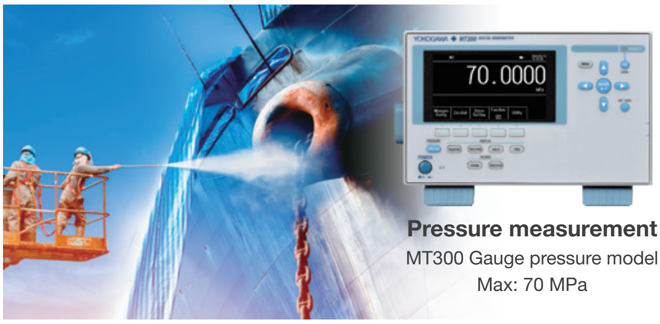
A high-pressure washer is a device that uses high-pressure water to remove dirt and grime. It has a built-in pump to increase water pressure. Pressure measurement in the development and shipping inspection of high-pressure washers is important to verify product safety, energy-saving effects, and performance.

Overview

The pressure reference value for high-pressure washers for household use is said to be 2.5 MPa-25 MPa. In their development and inspection, a digital manometer is used to measure whether the pressure is raised to a specified level. While measuring the pressure, various measurements, including power consumption measurement, are taken to determine product performance.

Key point

As high-pressure washers operate at high pressure, high safety requirements are specified for them in IEC 60335-2-79, which requires measurement of rated pressure and power with nozzles and hoses attached. The MT300 can measure pressures up to 70 MPa, which covers most pressure standards. A comprehensive evaluation of safety performance is possible by taking pressure measurements and making power measurements with the WT300E series Digital Power Meter or other devices.



Pressure measurement
MT300 Gauge pressure model
Max: 70 MPa

Power measurement
WT300E Series
Digital Power Meter

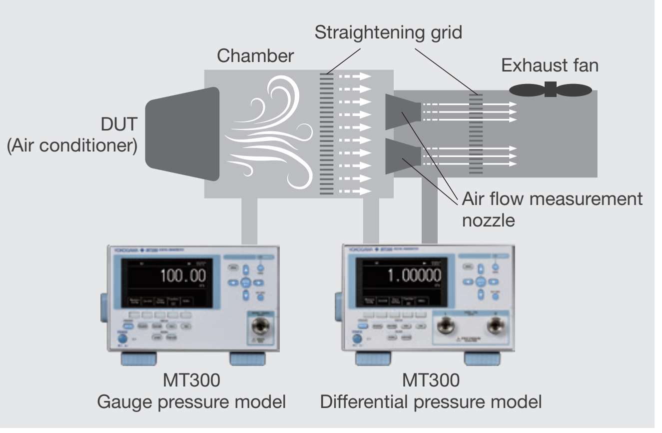
Life and Environmental Application

Evaluation of Air Conditioners

With economic growth in developing countries, the demand for air conditioners for buildings and vehicles is expanding globally. On the other hand, the widespread use of air conditioners has led to increased energy consumption and contributed to global warming, and so manufacturers are required to develop products that are energy-saving and energy-efficient and have high heating, cooling, and dehumidification capacities.

Overview

The cooling and heating performance of air conditioners is determined from the differential pressure of the air before and after it flows through an air flow measurement nozzle and the air temperature/humidity. The test method for air conditioners is specified in JIS C 9612, and manufacturers are required to strictly control the environment according to this standard and conduct evaluations.



Key point

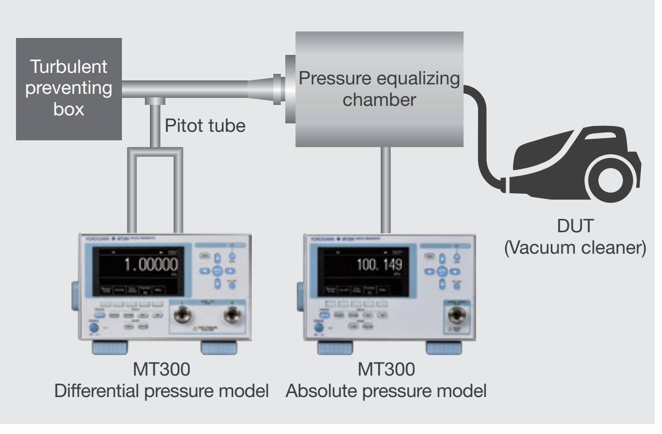
A standard-compliant environment can be created and the robustness of the air conditioner under test can be confirmed by using a single sensor to accurately measure the pressure difference of the air before and after it flows through the air flow measurement nozzle and rapidly checking the changes in the internal pressure of the chamber.

Suction Power Test of Vacuum Cleaners

Household vacuum cleaners are sold by domestic and foreign vacuum cleaner manufacturers and vary in performance. Suction power (suction work ratio) is an important factor in determining the performance of a vacuum cleaner and is one of the criteria that consumers use to make a purchase.

Overview

The suction power is calculated from the amount of intake air and the degree of vacuum in the pressure equalizing chamber. The amount of intake air can be obtained by measuring the differential pressure through a pitot tube, and the degree of vacuum can be obtained by measuring the absolute pressure. The testing of suction power (suction work ratio) requires a measuring instrument with fast response to confirm dynamic characteristics during suction. The test method is specified in JIS C 9108, and manufacturers are required to strictly control the environment according to this standard and conduct evaluations.



Key point

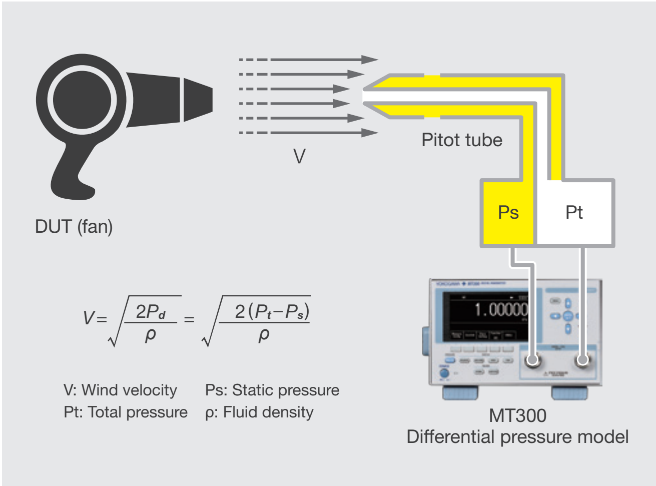
Highly accurate measurement of intake air amount is achieved by accurately measuring the minute differential pressure obtained through the pitot tube with a single sensor. An environment for measuring dynamic characteristics can be created in accordance with the standard's requirements by capturing pressure fluctuations in a pressure equalizing chamber at high speed.

Wind Velocity Measurement of Fans and Blowers

Fans and blowers are used in various fields for controlling airflow and temperature, ranging from everyday appliances such as dryers and air cleaners to large-scale industrial air conditioning control systems such as oxygen supply to iron-making furnaces. The performance of fans and blowers determines the performance of the products and equipment that use them, and is a very important factor in saving energy and improving efficiency in the production process.

Overview

The wind velocity of a fan or blower is calculated from the differential pressure between the two pressure measurement ports using a pitot tube. The test method for hair dryers is specified in JIS C 9613, and manufacturers are required to conduct evaluations in an environment compliant with this standard.



Key point

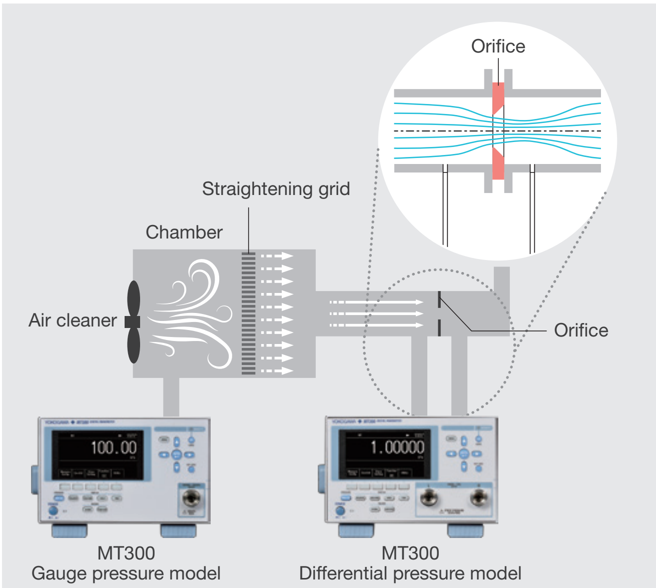
The MT300 uses a single sensor to measure the pressure difference between static pressure (Ps) and total pressure (Pt) obtained through the pitot tube with high accuracy, which provides highly accurate measurement of wind velocity. This helps to create a measurement environment that complies with the standard's requirements.

Air Flow Measurement of Air Cleaners

In recent years, the global market for air cleaners has been expanding due to concerns about health hazards caused by air pollution and the demand for prevention of hay-fever and viral infection. While filtering capacity is an important performance requirement for air cleaners, intake air amount, that is air flow rate, is also an important performance requirement for them to remove a large number of substances.

Overview

Air flow rate is calculated by measuring air density, orifice plate opening area, and differential pressure before and after the orifice plate. The evaluation test of air cleaners must be performed in an equilibrium state, a state in which internal and external pressures are equal. This requires simultaneous measurement of the internal and external pressures. The test method is specified in JIS C 9615, and manufacturers are required to conduct evaluations in an environment compliant with this standard.



Key point

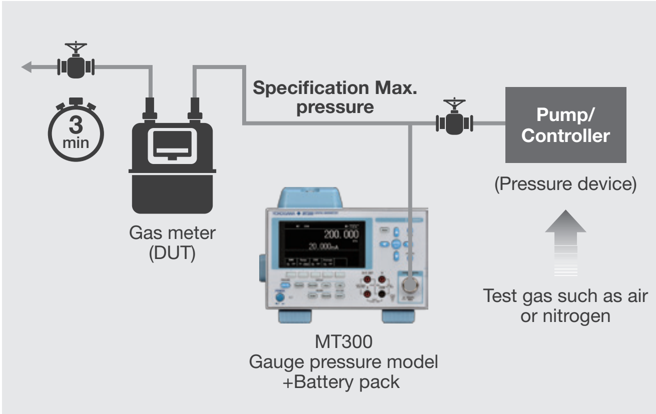
Highly accurate measurement of air flow rate can be achieved by measuring the minute pressure difference before and after the orifice plate with a single sensor. Monitoring the pressure inside the chamber while measuring the differential pressure before and after the orifice enables confirmation of the equilibrium state, which is required by the standard.

Gas Meter Leak Test

OIML R 137-1&2 specifies the requirements for gas meters that measure the volume of gas used as an energy source. The chapter on technical requirements states that "the case of a gas meter shall be gas-tight as specified according to national or international standards and requirements concerning safety and at least up to the maximum working pressure of the gas meter."

Overview

In a gas meter leak test, a pressure device and test gas are used to pressurize the gas meter under test to a specified level, the meter is sealed in that state, and pressure change (leak rate) is measured.



Key point

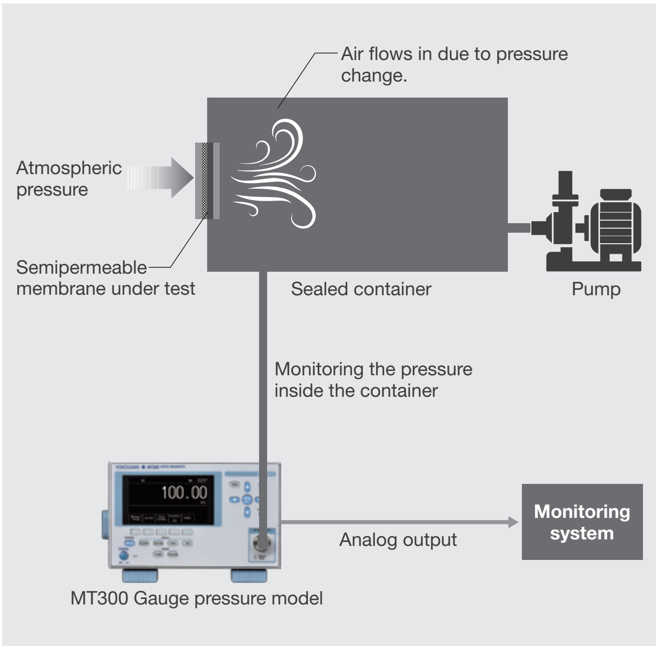
The MT300 has a 10 kPa range, enabling high-accuracy and high-resolution measurement of low pressure ranges required in gas meter evaluations. The MT300's leak test function monitors pressure changes from the start to the end of leak measurement and displays the leak rate for a certain time period, which contributes to increased operational efficiency.

Performance Testing of Semipermeable Membranes for Waterproof Cases

The recent wide spread use of wearable and mobile devices has increased the demand for equipment for outdoor use. As outdoor-use equipment is used in the rain or underwater, it needs to be waterproof. For waterproofing, semipermeable membrane materials that are impervious to water and have high air permeability to reduce the heat generated by devices are used. Performance testing of semipermeable membranes involves high-precision pressure measurement to determine the threshold of osmotic pressure.

Overview

In performance testing of semipermeable membranes, the difference between the atmospheric pressure and the pressure in a sealed container separated by a semipermeable membrane is measured. A pump is used to change the pressure in the container, and the osmotic pressure (threshold) is determined from the pressure change as the air permeates through the semipermeable membrane. Measuring instruments to confirm the osmotic pressure (threshold) require fast response to continuously monitor pressure changes as well as high accuracy and high resolution.



Key point

The MT300 has a 10 kPa range, which enables highly accurate measurement of minute pressure changes from negative pressure to near atmospheric pressure. Pressure fluctuations can also be monitored on the monitoring system with the MT300's high-speed measurement mode (optional) and analog output option.

Wind Velocity Measurement using a Pitot Tube for Wind Tunnel Test Device

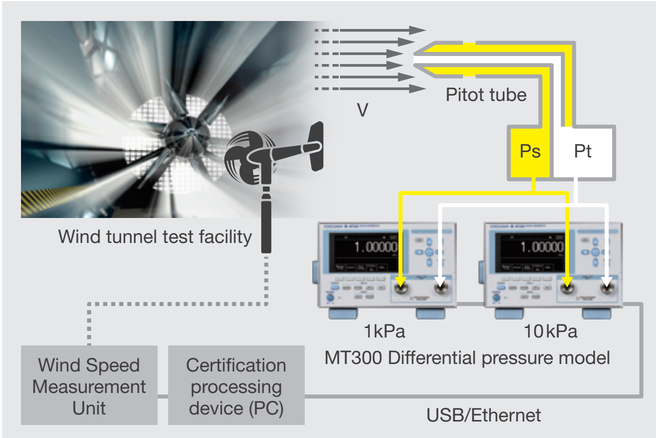
In the development and evaluation of automobiles and aircraft, a wind tunnel test is performed to evaluate aerodynamic characteristics. A wind tunnel test device must generate a reference airflow, and so highly accurate wind velocity measurement is needed to verify that an accurate airflow is generated.

Overview

A reference wind velocity that a wind tunnel test device generates can be determined by measuring the total pressure (Pt) and static pressure (Ps) obtained through a pitot tube using a highly accurate differential manometer. An anemometer, which is a meteorological instrument, is subject to comparative wind velocity testing at the time of certification, and the MT300 is used by public institutions to measure reference wind velocities.

Key point

The MT300 series offers a wide range of pressure ranges and can handle a variety of wind speeds. It provides high-precision pressure measurement, which enables highly accurate wind velocity measurement.



$$V=\sqrt{\frac{2P_d}{\rho}}=\sqrt{\frac{2(P_t-P_s)}{\rho}}$$

V: Wind velocity Ps: Static pressure
Pt: Total pressure ρ: Fluid density

Helmet Ventilation Test

Helmets for motorcycles, cars, and bicycles use the Venturi effect* to provide ventilation. The difference in pressure between the inside and outside of a helmet creates a flow of air through the inside, allowing the outside air to enter the helmet and inside air to exit.

*Venturi effect: Forcing a fluid through a narrower section of a pipe causes an increase in its velocity.

Overview

The ventilation properties induced by the Venturi effect can be evaluated by measuring the minute differential pressure between the inside and outside of a helmet with the MT300.

Key point

Unlike ordinary manometers, the MT300 differential pressure model can measure differential pressure with a single sensor, making it twice as accurate as ordinary manometers. The MT300 differential pressure model is ideal for applications that require minute differential pressure measurement, including testing the Venturi effect on helmets.

MT300
Differential pressure model



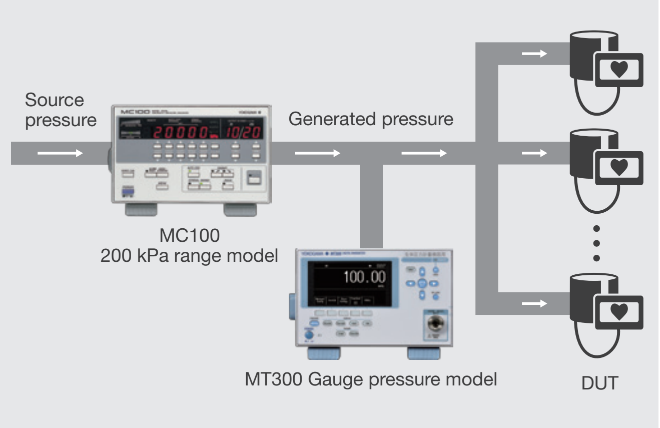

Medical Application

Shipping Inspection of Sphygmomanometers

Sphygmomanometers are medical devices that accurately measure pressures of 40 kPa (300 mmHg) and below. A pressure sensor built inside sphygmomanometers detects the pressure. The performance and functional requirements for sphygmomanometers are specified in IEC 80601-2-30, which also describes the required accuracy.

Overview

In manufacturing inspection, a stable pressure is applied to the sphygmomanometer under test with a pressure controller. The generated pressure is monitored using a high-precision manometer to obtain a reference pressure value, which is then compared with the pressure value of the pressure sensor built into that sphygmomanometer.



Key point

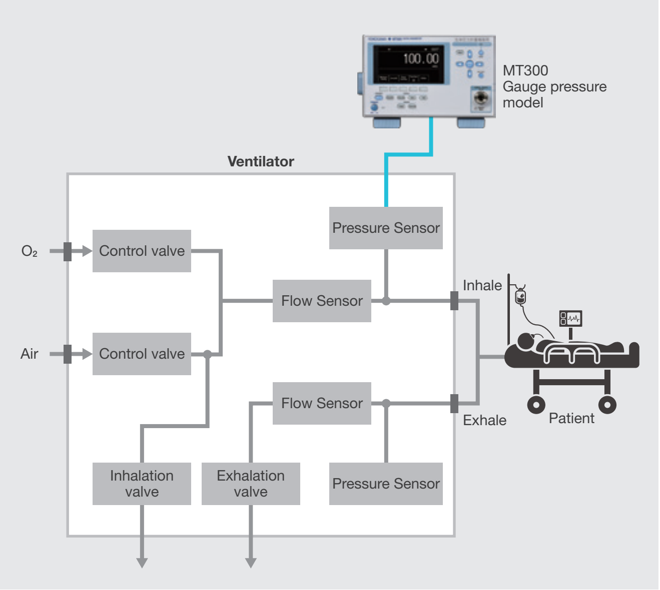
The MT300 can display measurements in units of mmHg, which sphygmomanometers use. It also provides the measurement range, accuracy, and resolution required for sphygmomanometers. Combined with the MC100, the MT300 enables automation of pressure generation and measurement, making production and operations more efficient.

Inspection of Internal Devices in Ventilators

A ventilator is a medical device used to assist getting air into and out of a patient's lungs and contains many pressure-related devices such as pressure sensors, on-off valves, compressors, and pumps. ISO 5369 requires measurement of expiratory flow rate and airway pressure, and specifies the required accuracy and other requirements.

Overview

Since the pressure sensor of a ventilator has a range of 10 kPa or less, which is a low pressure range among biological pressures, a reference standard must deliver high accuracy and resolution in low pressure ranges.



Key point

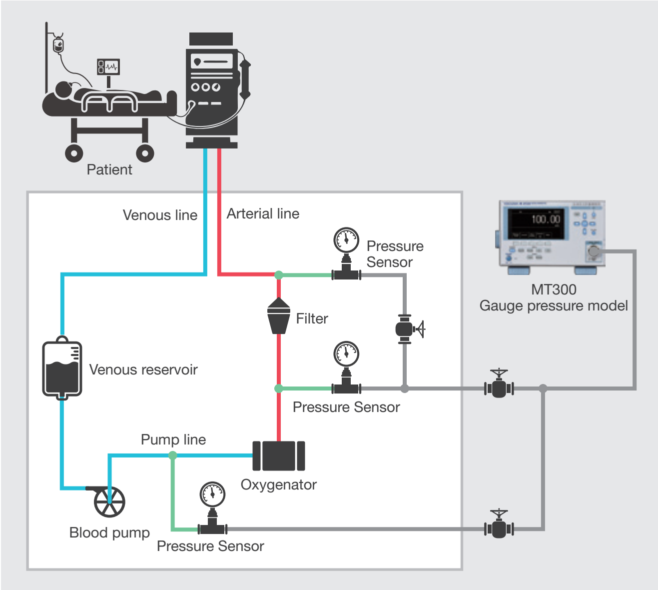
The MT300 can display measurements in units of cmH_2O, which ventilators and ventilator-related equipment use. Guaranteeing the accuracy of 0.01% of reading even in the low pressure range, the MT300 can be used for various testing applications of devices used for artificial ventilation, such as accuracy test of internal devices, functional test of on-off valves, and pressure test.

Inspection of Heart-Lung Machines

A heart-lung machine is a device that takes over the pumping function of the heart and the gas exchange function of the lungs for a period of time. The machine has multiple blood pumps and pressure sensors and monitors the sensors to adjust the pump's rotation speed. Because a heart-lung machine is a vital device, it requires strict maintenance. ISO 7199 specifies the test method for oxygenators of heart-lung machines and the accuracy requirement for measuring devices used for the testing.

Overview

Inspection of heart-lung machines requires testing of the pressure loss in the blood circuit and the pump's rotational performance. These parameters can be measured from the pressure sensors that are built in to detect clogging caused by thrombi or other conditions. To maintain the accuracy of these pressure sensors, comparison calibration is performed against a reference standard.



Key point

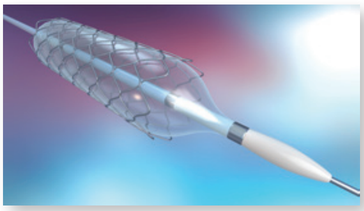
The MT300 is suitable as a reference standard for comparison calibration because it maintains a sufficient accuracy ratio to the accuracy of the built-in pressure sensors required by the standard.

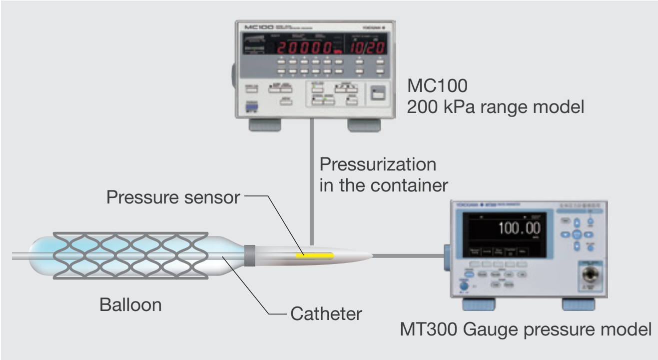
Inspection of Pressure Sensor Elements for Catheters

A balloon catheter has a pressure sensor incorporated into its tip to block blood flow and blood vessels and to measure arterial pressure and other parameters in vascular surgery. Since the pressure sensor is a critical component that detects conditions inside a patient's body, it is subjected to rigorous inspection.

Overview

In the inspection of these pressure sensors, a pressure controller is used to apply pressure inside a chamber to a specified level to create a condition that simulates the pressure inside the body. In this process, a comparison inspection is performed using the pressure sensor readings and a reference manometer.





Key point

The MT300 can display measurements in units of mmHg used for balloon catheters. It has a 200 kPa range and allows measurement from low pressure to pressure beyond 50 kPa, which is required for human body pressure. The MC100 makes it possible to pressurize the inside of a chamber to a specified level and to automate the inspections, improving operational efficiency.

Endoscope System Gas Pressure Measurement

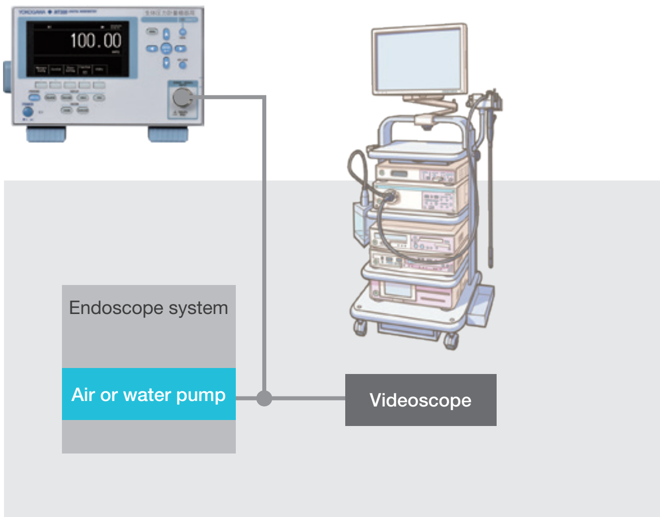
An endoscope system is designed to pump air or CO_2 into or out of a human body. The pumps and sensors used in the system must provide accurate pressure output and display to avoid placing an undue strain on the human body.

Overview

An endoscope system may be equipped with pressure sensors to detect pressures on the surface of body tissue and inside organs and to prevent the endoscope system from touching tissues or organs with excessive pressure. Since these are for the human body, they must deliver high accuracy and even higher-accurate pressure measurement is needed to evaluate them.

Key point

Offering high stability and measurement accuracy in the range of human body pressure, the MT300 can help maintain the functions and performance required for endoscopic systems. Because liquid can be used as a measuring medium, the MT300 can also be used to investigate the performance of water pumps.



Pressure Measurement for Maintaining and Controlling Indoor Clean Level and Negative Pressure

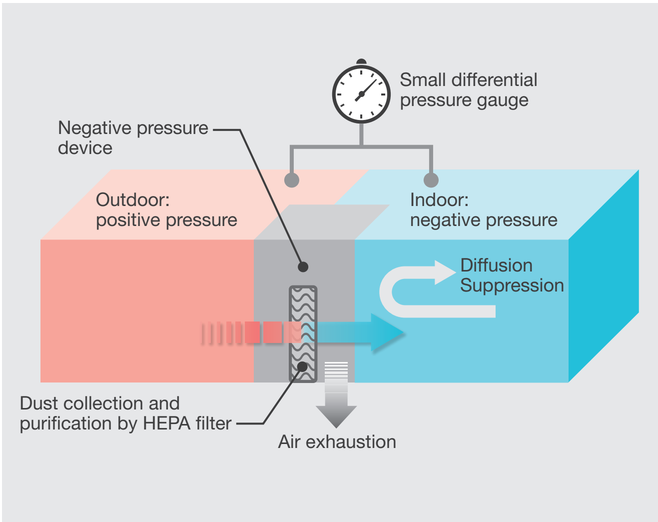
Many areas in a hospital need clean air, including infection control rooms, operating rooms, and ICUs. To achieve this, positive and negative air pressures are controlled. Air moves from higher pressure to lower pressure, so controlling the flow of air into a room prevents the spread of viruses. Positive pressure is used in cleanrooms to keep contaminants and undesired particles out of the room.

Overview

ISO 29463-1 requires performance testing of cleanroom air filters. The testing includes measurement of the pressure loss before and after the filter unit and the pressure loss of test filter media.

Key point

The differential pressure model of the MT300 can measure slight differential pressure with high accuracy and can be used to evaluate the performance of negative pressure devices equipped with HEPA filters for dust collection. The MT300 can be battery powered, giving it the portability to calibrate differential pressure gauges installed at various facilities. This makes periodic inspection and testing work much more efficient.



Automotive Application

Measurement of Pressure Loss in Coolant Flow Channels in Water-cooled Devices for EVs

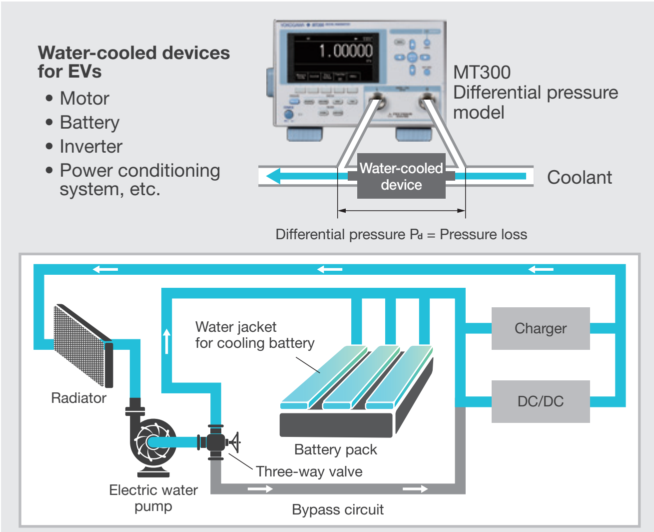
Electric vehicles (EVs) are equipped with many devices that require temperature control, such as motors, batteries, and power control units. Since each of these devices generates different amounts of heat and has a different optimum temperature, a single vehicle is usually equipped with multiple cooling devices. As the performance of EVs improves, cooling systems will become increasingly important.

Overview

In the development and design of water-cooled cooling systems that use coolant to remove heat from devices, it is essential to measure the pressure loss in a channel through which coolant flows to improve the efficiency and energy saving performance of cooling circuits.

Key point

A single MT300 differential pressure model can provide differential pressure measurement with a high accuracy of 0.01%. The MT300 differential pressure model has been used in many differential pressure measurement applications in the field of thermal management in EV development, including pressure loss measurement of radiators and electric water pumps.



EV Cooling System

P-Q Characteristics of Catalyst Support

Catalyst supports are used in automobiles to detoxify exhaust gases through a chemical reaction. The power and torque characteristics of an automobile are affected by exhaust resistance, so the P-Q characteristics of catalyst support need to be measured. As engine displacements continue to shrink and alternative fuels are developed, the performance of catalyst supports will need to be improved even more.

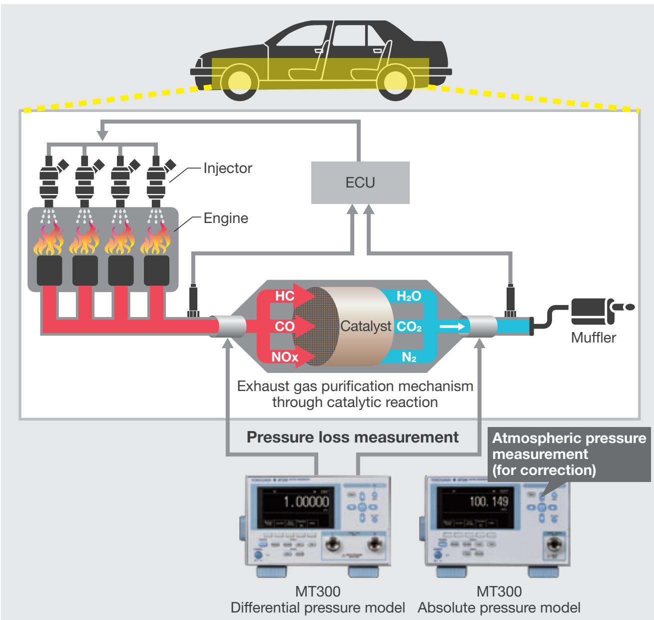
Overview

The following four measurements are required to measure P-Q characteristics to evaluate catalyst supports.

- Atmospheric pressure
- Pressure loss of the catalyst support under test
- Differential pressure of nozzles for flow rate
- Pressure inside the test equipment chamber

Key point

Measurement of P-Q characteristics is a requirement. P-Q characteristics represent the relationship between the flow rate Q [m³/s] and the pressure difference P [Pa] between the outlet and inlet at a certain rotation speed. However, if the measurement tolerances for pressure and flow rate are large, the characteristics cannot be plotted accurately when graphed. The MT300 can measure pressure and flow rate with a relative accuracy of 0.01%, making it ideal for accurate measurement of P-Q characteristics.



Pressure Measurement for Atmospheric Pressure Correction in Oxygen Sensor Production Lines

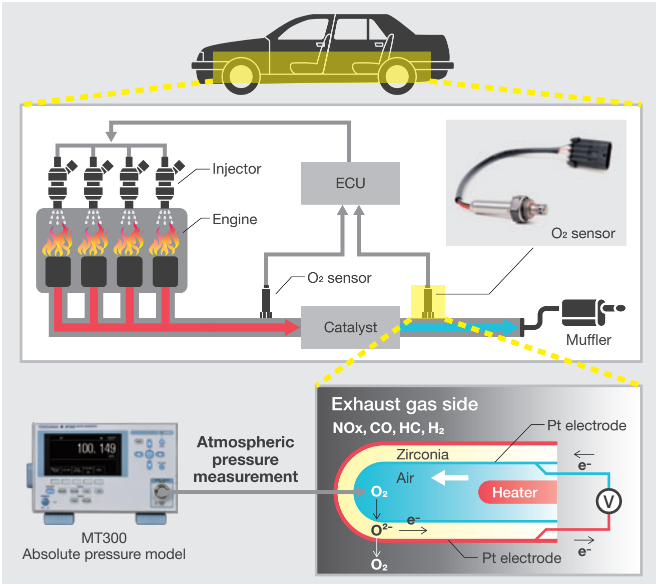
An oxygen sensor is a sensor that generates voltage according to the oxygen concentration in exhaust gas. Controlling fuel injection based on the oxygen sensor signal enables combustion near the theoretical air fuel ratio for cleaner exhaust gas. An oxygen sensor is also installed downstream of the catalyst to support self-diagnostic functions such as catalyst deterioration detection.

Overview

In the development and manufacture of oxygen and NOx sensors, a certain amount of oxygen is supplied to the sensors to detect oxygen concentration. Since, in measurement principle, the detection of oxygen concentration depends on atmospheric oxygen concentration and the atmospheric oxygen concentration depends on atmospheric pressure, highly accurate atmospheric pressure measurement is essential for the calculation of reference oxygen concentration.

Key point

For environmental measurement, the MT300 absolute pressure model is ideal for measuring and monitoring atmospheric pressure with high accuracy. ETHERNET, GP-IB, and D/A output are supported, enabling systemization of inspection that requires highly accurate atmospheric pressure measurement data on the production line.



Pressure Measurement of Automotive Turbochargers

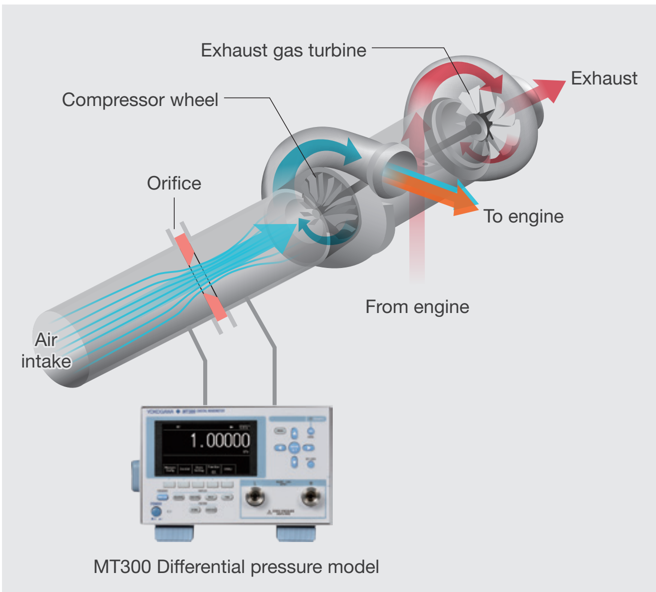
Turbochargers have been widely used on internal combustion engines in not only sports cars but also in regular passenger cars to downsize the engines. Recently, turbochargers that take air into an fuel cell as well as internal combustion engine for higher efficient power generation have been developed.

Overview

In the final inspection during the manufacturing of turbochargers installed in automobiles, simulated air is fed into the turbochargers for inspection. In this process, control of the flow rate of the fed air is extremely important. The flow rate is controlled by measuring pressure using an orifice.

Key point

When controlling the flow rate, it is necessary to accurately measure pressures of a few kPa. Compared to ordinary manometers, the MT300 differential pressure model can measure differential pressure with a single sensor, making it twice as accurate. The MT300 is used in the inspection line of turbochargers that requires accurate flow rate control.



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