Feature Article

Product and Technology Development by STEC

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Abstract

The root of STEC Inc. is Standard Technology Co., Ltd. that was founded in 1974 to unify the calibration of pollution measuring instruments. Since its founding, STEC has grown with gas and liquid flow measurement and control as its core technology. The company enjoys a worldwide reputation for excellent performance and reliability of its mass flow controllers, especially those created for the semiconductor industry. This article introduces STEC's products and technologies up to the present as well as the leading-edge trend for mass flow controllers.

1 Founding of Standard Technology

STEC was founded as "Standard Technology Co., Ltd." on January 19, 1974. At that time, pollution control was a significant problem all over Japan.

In order to stem the environmental destruction that was the dark side of Japan's rapid economic growth, the Japanese government has tightened the regulations for air pollution and water pollution control since the so-called "pollution diet" in 1970. On the other hand, the government sped up the development of environment measuring instruments that were to be the basis of the regulations.

In 1972, the Ministry of International Trade and Industry (MITI) at the time specified "concentration meters for pollution measurement" as the enforcement standard for the measurement law, and decided to develop a "standard gas generator for pollution meter calibration" as a new project run by the Japan Society for the Promotion of Machine Industry. Manufacturing of these "concentration meters for pollution measurement" was commissioned to HORIBA, which had developed its own standard gas calibration technology that used the capillary flow-rate ratio mixing method (Fig.1).

In the early 1970 s, gas analyzers were calibrated based on gas chromatography measurements of a cylinder of calibration gas. However, this method had drawbacks because the true values were not clear and variations with time were large. HORIBA had adopted the calibration of standard gas concentration by the capillary flow-rate ratio mixing method since the commercialization of infrared gas analyzers, and analyzers inspected and shipped using this technology had received very favorable acceptance from customers. This excellent reputation led to the commission of the development of the SGGS-1 standard gas generator for pollution meter calibration, (Fig.2), which may be called a meter standard in Japan's gas concentration measurement.

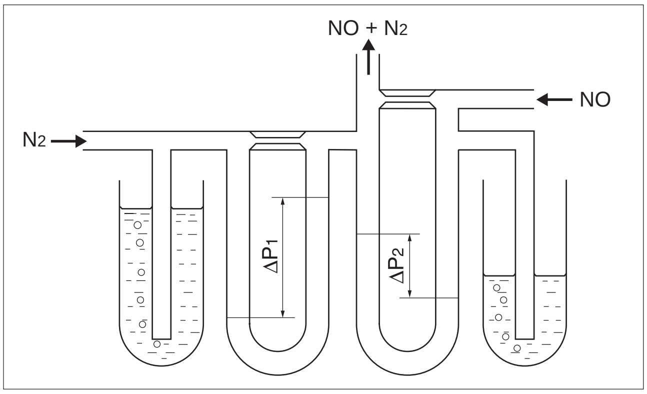

Fig.1 Capillary Flow-rate Ratio Mixing Method

Fig.2 SGGS-1 Standard Gas Generator for Pollution Meter Calibration

The MITI subsequently sounded out HORIBA on releasing its “capillary flow-rate ratio mixing method” standard gas generation technology to the public for the development of Japan’s environmental administration. Masao Horiba, President at the time, readily agreed to this proposal saying, “Though we may lose our precious edge, I feel highly honored because our technology was officially recognized.” He at the same time founded the Standard Technology Co., Ltd. together with manufacturers of measuring devices and standard gases on January 19, 1974, implementing his idea that this project must combine the forces of the measuring instrument industry.

2 Conversion from Capillary Flow-rate Control to Mass Flow Control

Since its foundation, Standard Technology has released many products that use the capillary flow-rate ratio mixing method, such as the SGGU series (compact standard gas generation system) and the SGD series (standard gas divider), which were adopted by municipalities and a wide variety of industries including automotive, catalyst, and chemical manufacturers.

However, in step with the development of electronics, a wave of electronics came to the standard gas generator, and the capillary flow-rate ratio mixing method, which was based on mechanical principles, was not suited to converting the detection and control of gas flow-rate into electrical signals.

At that time, a mass flow controller (MFC) had been developed in the U.S. as a flow-rate controlling element that employed electrical signals, and its incorporation into the standard gas generation system was immediately tried. However, the 1-2 % mixing precision required for the standard gas generation system required that the MFC maintain a high precision over its full scale at ± 0.5 %, which the then commercially available MFC could not provide. Therefore, we started to develop a high-precision MFC for standard gas generation systems.

3 Birth of STEC, Semiconductor Specialist

Although the development of the new MFC at first was planned for incorporation into a standard gas generation system, it was discovered through market research on fluid flow-rate measurement and control that there were great needs in the semiconductor industry. As a result of introducing prototypes to semiconductor device manufacturers, one company rated them as being superior in accuracy, reproducibility, and linearity. Based on these outcomes, the first mass flow controller, SEC-L/LU (Fig.3), came to the world.

Fig.3 STEC’s First Mass Flow Controller, the SEC-L/LU

This MFC used a thermal-type flow-rate control valve and laminar flow elements for the bypass. As the flow-rate ratio between the sensor and the bypass is less variable, this MFC became well-regarded especially for its linearity. From about this time, our full-scale challenge to the semiconductor market began.

From around 1980, when we entered the semiconductor market, we grew steadily, achieving sales of one billion yen in 1984. In the same year, on the occasion of the anniversary of the founding, the company name was changed from “Standard Technology” to “STEC,” which was derived from the initial letters of “S” for “Standard,” and “TEC” for “technology.”

4 Ultraclean Technology

As a flow-rate control element, the MFC has a significant and indispensable role in the semiconductor process. In step with finer and multilayer semiconductor devices, process gases are becoming more and more purified and diversified, requiring the MFC to be ultraclean : corrosion resistant and dust free.

The SEC-4000 series (Fig.4) is the world's first ultraclean MFC developed to meet such a requirement. It has the features shown below. Fig.5 shows the internal structure of the SEC-4000 series.

(1) High-speed Response

The SEC-4000 series realized ultra-high-speed response with the piezo element, which was used in the valve actuator for the first time in the world. Additionally, the piezo element's large driving force allowed the valve to have a diaphragm structure, which made it possible to make the MFC ultraclean. The piezo element used at that time was made of the same piezoelectric material as that of a pyroelectric infrared sensor manufactured by HORIBA.

Fig.4 SEC-4000 Series

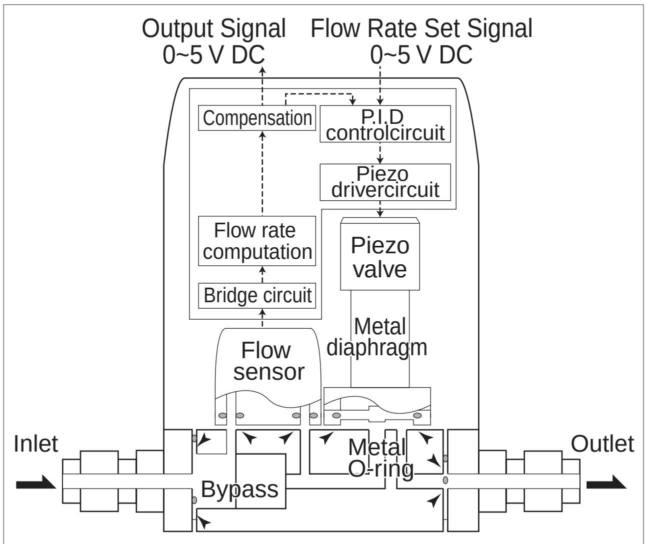

Fig.5 Internal Structure of SEC-4000 Series

(2) Leak Free

The MFC must be air-tight to prevent the entry of impurities into the gas system and the leakage of hazardous gases into workspaces. In the SEC-4000 series, hollow stainless steel is used as a sealant, reducing the leak rate of helium gas to lower than 1×10^{-11} Pa·m^3/s.

(3) Particle Free

Particles are an important factor that influences the production yield of semiconductor devices. The flow-rate control valve in the MFC has a drive part, which can produce particles. STEC realized a particle-free structure by achieving submicron or smaller metal diaphragm surface roughness, perfectly eliminating sliding parts through the control of clearances between orifice surfaces, and using no screws.

(4) Outgassing

To provide high-purity gas, it is critical to minimize adsorption and desorption of gas constituents, especially water. In the SEC-4000 series, all the gas-contacting parts are made of metal, reducing the adsorption and desorption and making outgassing by baking easier.

(5) Minimization of Dead Volume

If there is dead volume where gas resides inside the MFC, there is a possibility that purging and exhaustion from the gas line will take time and impurities will remain. We minimized such dead volume with a diaphragm-type control valve driven by a piezo actuator.

(6) Downsizing

Because of limitations in available installation space, minimal size is desirable for a gas supply system. In the SEC-7300 series, the sizes of all parts have been reduced, realizing a considerably short face-to-face distance of 106 mm.

5 World's Leading Liquid Controller Manufacturer

STEC has established a firm position in the semiconductor market, and is seeking to be the world's leading liquid controller manufacturer with constant efforts for upgrading the quality and range of our technologies and products and through global business activities.

5.1 Integrated Gas Panel and Modularization

In regards to hardware, there is a strong demand for gas supply systems that are smaller and easy to maintain. Conventionally, the possibility of reducing hardware size was rather limited because each component was connected with pipes. Against this backdrop, we developed the SEC-G100, an MFC that is applicable to an integrated gas panel. Designed with the latest 3-D CAD technology, the SEC-G100, measuring 39 mm per side, is one of the world's smallest. Additionally, specifications of the SEC-G100's mounting parts have been standardized so that it can be surface-mounted on one integrated gas panel together with other components such as filters and valves. Fig.6 shows an example of integrated gas panels.

STEC expanded the concept of the integrated gas panel to develop the SEC-Z70D series, a gas flow module that integrates a flow-rate control device, pressure sensor, regulator, filter, and temperature sensor in one device. This hybrid gas panel answers the customers' requirements for total cost reduction and reduced size of the system.

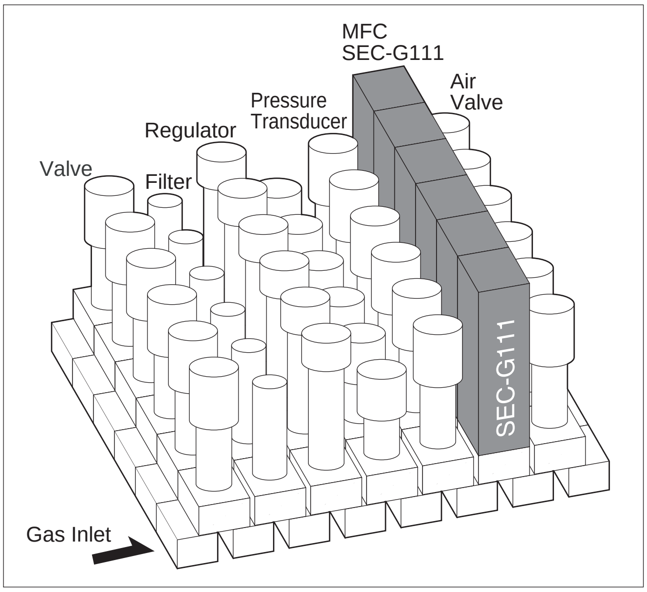

Fig.6 Integrated Gas Panel

5.2 Expansion to Liquid Vaporization and Supply System

In step with the sophistication and diversification of the semiconductor process, various thin-film forming technologies have been developed. In particular, the chemical-vapor deposition (CVD) method is widely used as a thin-film forming method that provides good step coverage and high throughput. CVD requires an MFC that can vaporize and accurately inject various liquids into chambers. Various liquid sources are used during the semiconductor manufacturing process. Among insulation films, there is TEOS, which representative is SiO_2 film, and those films added with TEB/TEPO as dopants are called BPSG films.

To respond to the recent sophistication of semiconductor devices, high permittivity materials began to be used for capacitors and gate films. On the other hand, low permittivity materials like Aurora (R) and TMS are also studied for reduction of wiring capacity, and copper-based source materials that have lower resistance than conventional aluminum began to be used.

Vaporizers are necessary to supply these liquid sources to semiconductor manufacturing equipment, and STEC developed a heated-type liquid source controller (LSC) combining liquid tank heating and high-temperature mass flow control. Because this system is simple and has an edge in cost, further reduction in size and standardization are being sought.

Additionally, for measuring the flow-rates of liquid material itself, STEC commercialized in 1988 the world's first liquid mass flow meter cooled by a Peltier device, the LF series, and then added a liquid mass flow controller including a control valve, the LV series. In 1990, we released the TL series, which is a liquid vaporization and supply system consisting of a liquid MFC combined with a vaporizer. This series measures and controls the flow-rate of liquid phase material, and vaporizes and supplies the whole quantity. It is called a direct injection system (Fig.7).

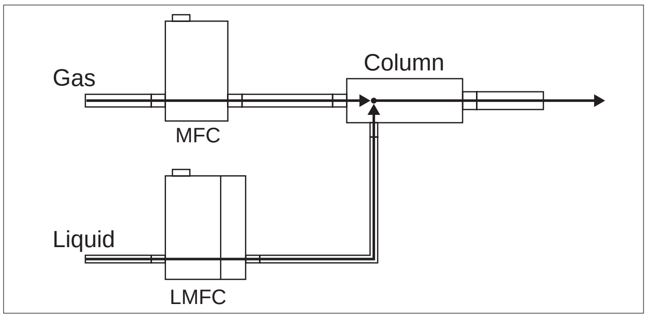

Fig.7 Direct Injection

The direct injection system was further developed into the VC series (Fig.8), a liquid vaporization and supply system applicable to single wafer-type semiconductor manufacturing equipment. In response to the requirement for micro flow-rate control (smaller than 0.001 ml/min) of difficult high-boiling point and corrosive materials, we produced compact systems through the combination with a liquid MFM or a high-temperature supporting MFM. Our product line also offers a comprehensive liquid vaporization and supply system that includes components from a liquid material tank to a chamber.

Fig.8 Liquid Vaporization and Supply System, VC Series

5.3 Digitalization

In 1990, STEC successfully commercialized the world's first digital MFC (DMFC) equipped with a CPU, the SEC-F1 series. Digital design facilitated the improvement of flow-rate control accuracy, multiple calibration curve control (i.e., flow-rate control of gasses with different characteristics by one MFC), and high-speed response over the whole control range. The SEC-F700 series additionally has a function to detect anomalies in the gas supply system from the change in flow-rate control status and a central alarm function, and made the usefulness of digital MFCs widely recognized.

STEC has also commercialized application software for the DMFC such as software to monitor and automatically store control status for more intelligent failure prediction and root cause analysis and software that facilitates the change of calibration gas types and flow-rate values. STEC is placing emphasis also on the development of such software.

5.4 Promotion of Reading Scale (RS), Multi Gas (MG) and Multi Range (MR)

One of the indexes that indicate the performance of the MFC is flow-rate accuracy. The control accuracy of the MFC had conventionally been evaluated by the accuracy against full scale (full scale accuracy), but the accuracy against a set value (reading scale accuracy) is now in common use to achieve more strict control. Also, to allow one MFC to handle more than one type of gas and a wide range of flow-rates (multi-gas and multi-range), STEC developed a new algorithm that is different from the conventional single-point conversion factor (CF: flow-rate ratio of actual gas to N_2 at the same sensor output), challenging the limit of the thermal sensor-type MFC. Furthermore, the recently developed continuous optimization PID control system permits several hundred millisecond response time over the whole flow range.

The MG/MR MFC can be configured by the customer; a customer simply inputs desired gas types and flow-rates using a PC without troubling about the CF. It makes it possible to greatly reduce the number of MFCs that must be installed for each gas type, allowing considerable reduction in inventories for our users: device and equipment manufacturers, as well as STEC. This type of MFC is now being shipped to equipment manufacturers in the U.S. as the SEC-Z300 series.

Table 1 shows the main specifications of the SEC-Z300 series.

Table 1 Main Specifications of SEC-Z300 Series

Model	SEC-Z302	SEC-Z303
Material in gas contact	SUS-316L	
Range of flow-rate	5 to 500 SCCM	1 to 10 SLM
Control valve	Piezo valve NC/NO	
Flow rate accuracy	±1 % R.S. (25 to 100 %) ±0.25 % F.S. (2 to 25 %)	
Response speed	1 second or less (T^{98})	
Flow rate setting output	Analog output : 0-5 VDC/0-100 % F.S. Digital output : RS485	
Standard function	Automatic close/quick start	

5.5 DeviceNet™ Communication

In semiconductor manufacturing plants, networking of all devices in the manufacturing line using a common protocol is promoted as a key strategy for improving productivity. DeviceNet™ is a communication protocol promoted by ODVA (Open DeviceNet Vendor Association, Inc.) as an open and global standard, and it is being introduced by device and equipment manufacturers inside and outside Japan.

STEC produced the SEC-Z10D series incorporating a DeviceNet™ communication feature into an existing high-performance digital MFC. The SEC-Z10D has passed various functional tests conducted by third parties such as the ODVA Conformance Test, the ODVA SEMI SIG Test, and the Texas A&M University Marathon Test, and its high performance and reliability have been confirmed. Fig.9 shows an example of a network using the SEC-Z10D DeviceNet™.

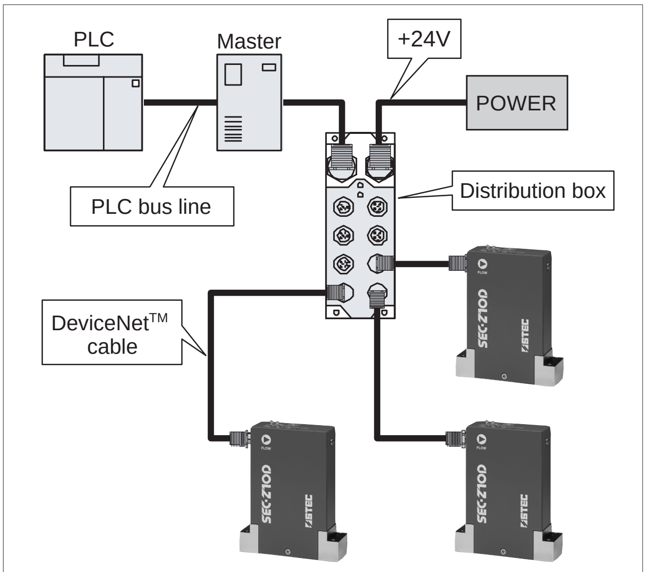

Fig.9 Example of Network using SEC-Z10D DeviceNet™

6 Our Future Direction

STEC has started working on the following new commitments aiming at further enhancing the quality and range of our technologies and products.

(1) Development and Application of Pressure Measurement and Control Technology

In addition to flow-rate control, STEC has already commercialized pressure control equipment including exhaust pressure controllers (UR series and EC series). We have also developed sonic-type MFCs and MFCs including a pressure sensor like the SEC-Z70D series (gas flow module). Pressure measurement and control technology and equipment are gaining more and more importance. Considering this technology will be one of key technologies in the future, STEC is fostering this technology and its practical applications with positive alliances.

(2) Residual Gas Analyzer (RGA)

We are now studying practical applications of an ultra-compact quadruple mass spectrometer to the chamber/gas-related system in semiconductor equipment. We expect that they will demonstrate excellent performance in periodic maintenance of chambers, which had conventionally been performed just by feel, and contamination control such as PVD, etcher, and ion implantation.

7 Conclusion

Since its founding, STEC has developed a wide variety of products based on the fluid measurement and control technology. In the recent global semiconductor market, we have earned a reputation as the best manufacturer of MFCs. However, it is still necessary to expand and apply our technologies and products developed in the semiconductor market to markets other than semiconductor, in order to strengthen our corporate structure to endure the great variability in the semiconductor market. We would like to further expand our unique products and technologies centering on the MFC, and on the other hand promote the amalgamation of technologies among HORIBA group affiliates to provide our customers with more sophisticated and better products and more speedy service.

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