UDC 681.2.084:531.787

DEVELOPMENT OF NEW-GENERATION TRANSMITTERS FCX SERIES

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1. FOREWORD

Ten years have passed since development of the FC transmitter was started in 1978. During this time, the number of FC transmitters manufactured and sold has increased seven times and they have been delivered all around the world. Grouped by export area, the number becomes progressively larger in Europe, Asia, and North America order. Supported by an overwhelming export quantity, the FC transmitter has steadily increased its share. However, because of the drop of price competitive power due to the high value of the yen, much is expected from the development of new products. The new FCX transmitters were developed and simultaneously placed on sale as transmitters which meet these expectations and can more than amply counter the next generation of transmitters of competitors from the standpoints of price, power, performance, functions, etc.

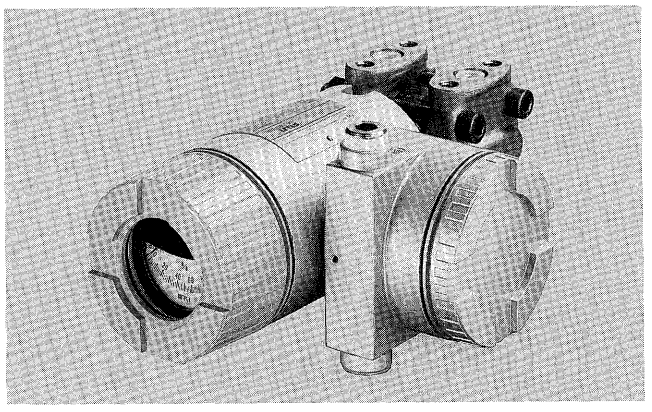
2. OVERVIEW OF NEW GENERATION TRANSMITTERS

The FCX transmitters developed this time are roughly classified into two types. One type are high performance analog output transmitters and the other are digital transmitters.

The high performance analog output transmitters use a newly developed miniature silicon sensor at the sensor, which is the heart of the transmitter. To amply extract the sensor characteristics, the sensor used a new construction (advanced floating cell) which advanced the floating cell construction acclaimed with the FC transmitter still farther. Advanced compensation operation by microprocessor had become possible even for measurement technology which detects pressure by capacitance. This improved accuracy and reduced the affects of static pressure and over-range, and made other substantial improvements in performance.

The digital transmitters can perform digital transmission in both directions. They have a function which performs remote maintenance easily by means of this communication function.

Fig. 1 Exterior view of FCX transmitter



The sensor of the digital transmitters is common with that of the analog output transmitters. The digital transmitters are further classified into three subgroups by microelectronics. One subgroup are smart transmitters, the second subgroup are FFI transmitters, and the third subgroup are field bus compatible transmitters.

FCX transmitter family

- High performance analog output transmitter
- Digital transmitter
  - Smart transmitter
  - FFI transmitter
  - Field bus compatible transmitter (under development)

3. FEATURES

FCX transmitters are a series of differential pressure gauges pressure, and absolute pressure which can meter a wide range of pressures from 10 mmH_2O to 500 kg/cm^2. A differential pressure type flowmeter is also available. Level meters, remote seal meters, and many other models are available corresponding to the process interface.

Approvals as intrinsic safty and explosionproof are pending in Japan, America, and the major countries of Europe. Use in explosive atmospheres and other hazardous location is possible.

They also have a convenient construction which allows modification of the direction of the field indicator at verti-

cal piping and horizontal piping.

The detector of the FCX family is common to all models. Interchangeability is its biggest feature. This has made it possible to store all the sensor correction data in a nonvolatile memory built into the detector.

The main features of the FCX transmitter family are introduced below.

3.1 High performance analog output transmitter

This is a two-wire 4 to 20 mA output transmitter. It has the features described below. Big features not found with competing FCX transmitters is the ability to add the option of (4) and the extreme ease by which it can be upgraded to a smart transmitter.

(1) High accuracy 0.1%
An accuracy of 0.1% is guaranteed without affecting elevation, suppression, and range changes.

(2) Improved temperature characteristic by advanced compensation operation
Zero drift 0.25% URL/55°C
Span shift 0.25%/55°C
These are double those of the old model.

(3) Improved static pressure effect
Zero drift 0.1%/100 kg/cm^2

(4) Upgrading to a smart transmitter possible by adding a communication unit

(5) Digital indicator, as well as analog indicator, can be installed as the field indicator.

3.2 Digital transmitter

3.2.1 Smart transmitter

This is a device with a digital signal for remote maintenance superimposed on a 4 to 20 mA standard signal. It is designed for more advanced functions and higher accuracy.

(1) Wide rangeability 100:1
(2) High accuracy 0.1% (See the table.)
(3) Remote device setting, monitoring, and diagnosis possible by remote communication function.

The analog output transmitter are convertible to the smart one by adding a communication unit.

3.2.2 FFI transmitter

This device uses an optical fiber cable for signal transmission at the outside wiring and is designed to be intelligent by means of low power micro-electronics operated by a built-in lithium battery.

It has the following features:

(1) Intrinsically safe property by optical fiber
Intrinsically safe specification by transmitter alone.

(2) Optical fiber transmission is not affected by noises and lightning surges and improves environment resistance.

(3) High accuracy achieved by digitalization of measurement operation, correction operation, and output signal.

(4) Remote setting, monitoring, and diagnosis of devices by remote communication function.

3.2.3 Field bus compatible transmitter

A digital serial type transmission bus which connects a distributed control system and programmable controllers and field transmitters, actuators, etc. is called a field bus. International standardization of the field bus is performed by a special committee of the IEC and deliberations on basic items are expected to end by the beginning of 1990. The features of the field bus compatible transmitter are:

(1) Digital transmission improves data accuracy and reliability.

(2) Bus structure reduces wiring man-hours.

(3) Remote maintenance function

4. MEASUREMENT PRINCIPLE

A micro capacitance silicon sensor differentially detects pressure and converts it to capacitances C_1 and C_2. To obtain a signal proportional to pressure, C_1-C_2/C_1+C_2 operation must be performed. The capacitance detection circuit used this time is shown in *Fig. 2*. This circuit is designed to minimize the analog circuit part, and consists mainly of a drift-less digital circuit.

Charging is performed by capacitor C_1 and resistor R_1 of the detector and flip-flop Q_1 is operated by C-MOS threshold voltage V_{TH}. When Q_1 operates, a fixed pulse of the time constant of R_3C_3 is output. C_1 is discharged during this period. When the time at which this charging and discharging is performed n times is measured by a timer, its value becomes the following equation:

$$T_1 = nR_1C_1 \log e \frac{V_{CC}}{V_{CC}-V_{TH}} + (n-1)R_3C_3 \log e \frac{V_{CC}}{V_{CC}-V_{TH}} \quad \cdots\cdots\cdots (1)$$

Similarly,

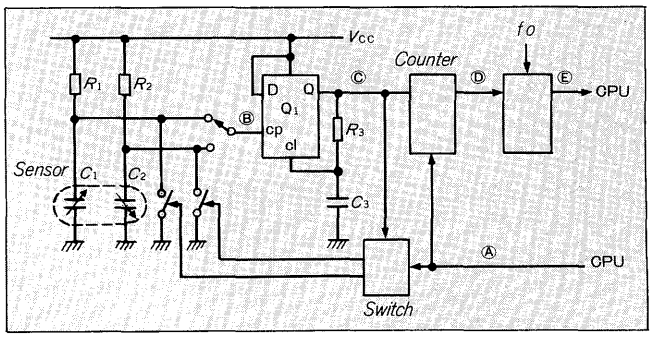
$$T_2 = nR_2C_2 \log e \frac{V_{CC}}{V_{CC}-V_{TH}} + (n-1)R_3C_3 \log e \frac{V_{CC}}{V_{CC}-V_{TH}} \quad \cdots\cdots\cdots (2)$$

Here, when $R_1=R_2$, $T_C=2(n-1)R_3C_3 \log e\, V_{CC}/V_{CC}-V_{TH}$ and the following operation is performed by CPU, the value proportional to pressure is obtained.

$$\frac{T_1-T_2}{T_1+T_2-T_C} = \frac{C_1-C_2}{C_1+C_2} = \frac{\Delta d}{d} \quad \cdots\cdots\cdots\cdots (3)$$

With the CPU, advanced correction is performed for

Fig. 2 Capacitance detector



the linearity and temperature characteristic and the expected high performance is obtained.

5. CONSTRUCTION

The internal construction of the FCX transmitter is shown in *Fig. 3*. A newly developed micro capacitance silicon sensor is used as the sensor which accurately converts pressure to electric signal.

5.1 Sensor

An exterior view of the sensor and its construction are shown in *Fig. 4* and *Fig. 5*, respectively.

A pair of fixed electrodes are arranged opposite the measurement diaphragm (moving electrode) at the center of the sensor. Displacement of the diaphragm is detected as a differential capacitance change.

The FCX sensor is miniaturized and has 1/50 the volume and 1/100 the weight of the old sensor.

The voltage input to the sensor is converted to a displacement proportional to pressure by a measurement diaphragm made of single crystal silicon and is accurately detected as a differential capacitance change.

The features of the newly developed sensor are:

(1) Improved accuracy and linearity

The mechanical characteristics of single crystal silicon, especially, its very low elastic hysteresis, were used to the maximum to improve accuracy and linearity substantially. The displacement of the diaphragm was brought near the displacement of an ideally balanced flat plate by making the measurement diaphragm a center disk with grooves. An accuracy of 0.1% and maximum linearity of 0.05% were realized by means of this.

(2) Low cost

Substantial material cost reduction and batch mass production by wafer process were made possible by micro construction and micro machining techniques.

(3) Temperature characteristic improvement

Because the coefficient of thermal expansion and the modulus of longitudinal elasticity temperature change of the single crystal making up the sensor are very small, a sensor whose characteristics are changed by the ambient temperature with difficulty could be obtained.

Fig. 3 Interior construction of FCX transmitter

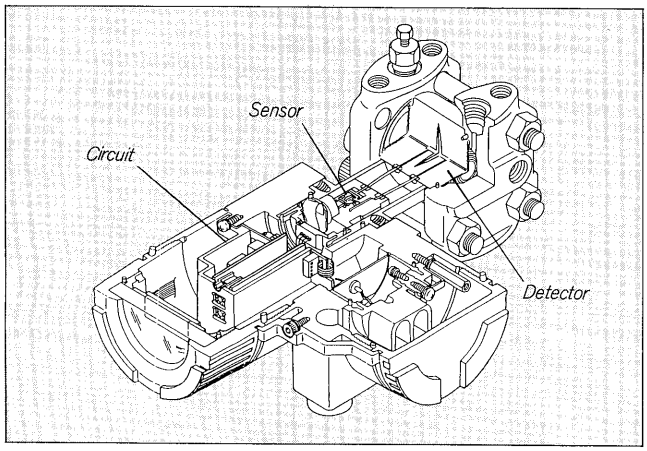


Fig. 4 Exterior view of FCX sensor

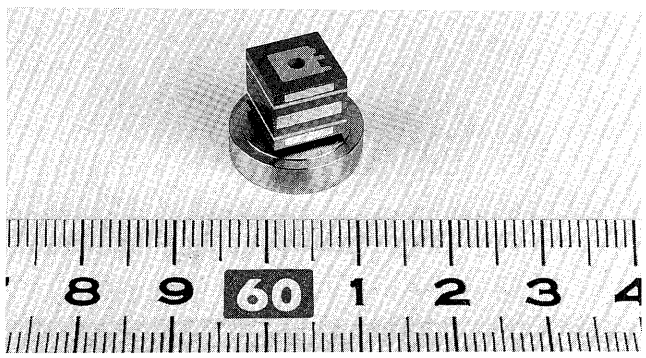
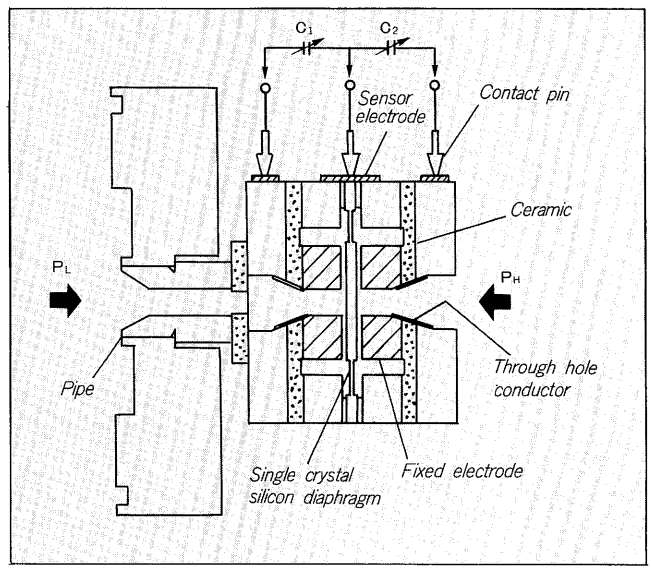


Fig. 5 FCX sensor construction

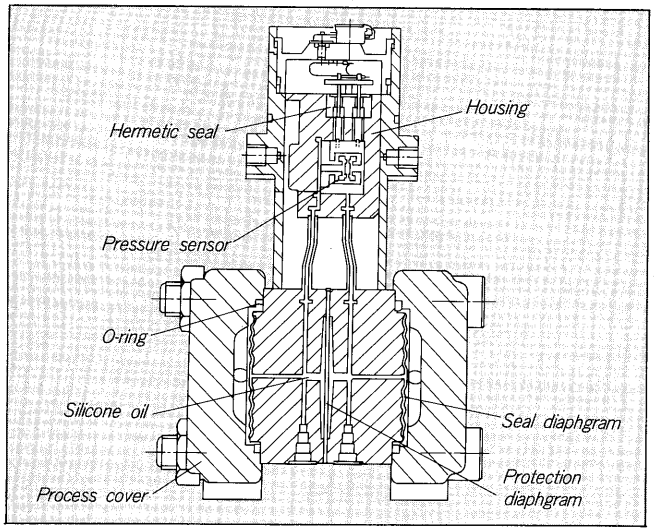


5.2 Detector

The construction of the detector is shown in *Fig. 6*. This construction is an advanced version of Fuji Electric's acclaimed floating cell construction. The action of the protection diaphragm at the center and the seal diaphragm at both sides protect against over-range input. The input pressure is transmitted simultaneously to the protection diaphragm and sensor. When the pressure reaches a specified pressure over the sensor measurement limit, the seal diaphragms contact the opposing back-up plate and a higher pressure is not transmitted to the detector. Therefore, an over-range pressure above a specified value is interrupted completely by the action above and the sensor is protected.

The sensor is floating in the housing and the inside and outside of the sensor are filled with an incompressible fluid. When static pressure acted, the inside and outside of the sensor becomes the same pressure and the static pressure has almost no affect on its characteristics. The sensor is supported by a thin insulation pipe at the housing

Fig. 6 FCX detector construction

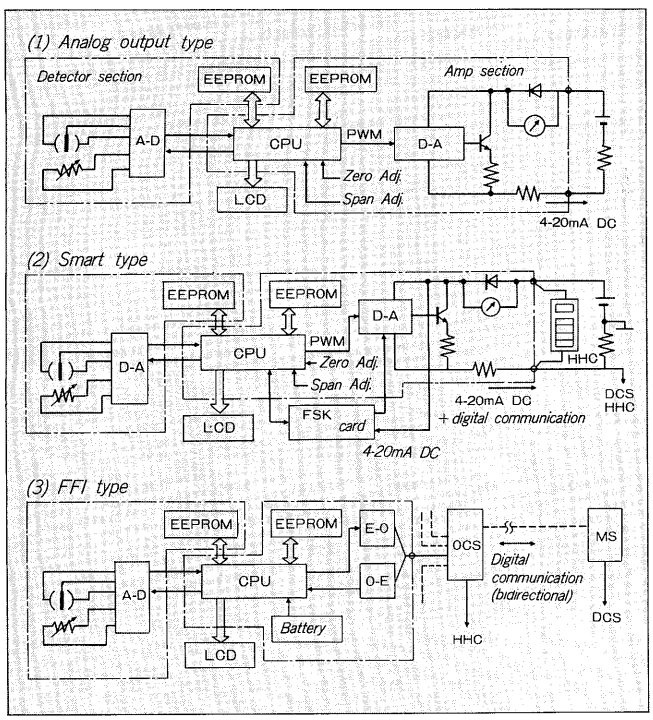


and is mechanically and electrically separated and insulated. This construction is extremely strong against high temperature, heat shock, high pressure, and electric noise.

6. FCX FAMILY CIRCUIT CONFIGURATION

The circuit configuration of the FCX family is shown in *Fig. 7*. An A/D converter and nonvolatile memory, which stores the sensor correction data, are located at the pressure sensor and temperature sensor detection section. This part is common to each family. The amp section consists of an operation processing unit made up of a CPU and nonvolatile memory and a power supply circuit and D/A converter.

Fig. 7 FCX family circuit configuration



The difference between the high precision analog output circuit and smart circuit is whether or not there is a communication unit (FSK card) The basic parts are identical.

7. SPECIFICATIONS

The high precision analog output transmitter specifications table is shown in *Table 1* and the main specifications of the smart transmitter are shown in *Table 2*.

8. CHARACTERISTICS

Typical characteristics of a 6400 mmH_2O measurement range high precision analog output transmitter are shown in *Fig. 8* to *Fig. 11*.

The conversion characteristic is within the accuracy rating of 0.1% even when range change is performed up to 1/10. As for the static pressure and over pressure effects, the zero and span shift amount is held to a very small value by the advanced floating construction. At the temperature characteristic, the zero and span shift were reduced substantially by high-order digital correction. The linearity

Fig. 8 FCX transmitter accuracy

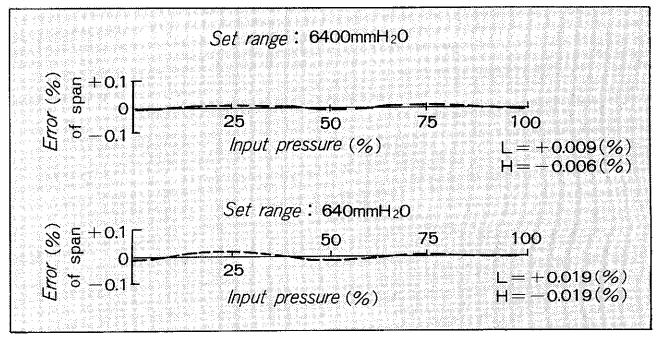


Fig. 9 FCX transmitter static pressure effect

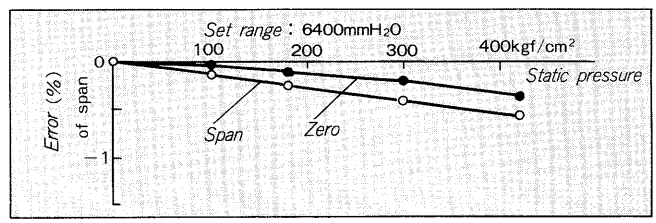


Fig. 10 FCX transmitter over pressure effect

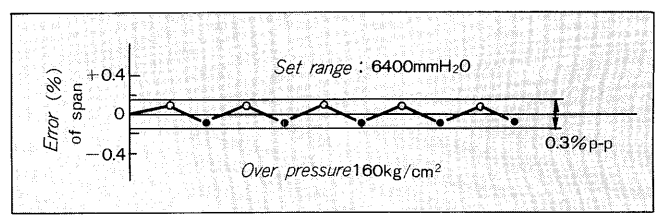


Table 1 FCX analog output transmitter specifications

Specification \ Type	Differential pressure			Flow			Level	Gauge pressure	Absolute pressure
	Low range	Middle range	High range	Low range	Middle range	High range			
Ranges	2 models 0...100 mmH_2O 0...600 mmH_2O	3 models 0...3200 mmH_2O 0...6400 mmH_2O 0...1.3 kg/cm^2	2 models 0...5 kg/cm^2 0...30 kg/cm^2 0...20 kg/cm^2	2 models 0...100 mmH_2O 0...600 mmH_2O	3 models 0...3200 mmH_2O 0...6400 mmH_2O 0...1.3 kg/cm^2	2 models 0...5 kg/cm^2 0...30 kg/cm^2	4 models 0...3200 mmH_2O 0...6400 mmH_2O 0...1.3 kg/cm^2 0...5 kg/cm^2	5 models 0...0.64 kg/cm^2 0...5 kg/cm^2 0...30 kg/cm^2 0...100 kg/cm^2 0...500 kg/cm^2	4 models 0...0.16 kg/cm^2 0...1.3 kg/cm^2 0...5 kg/cm^2 0...30 kg/cm^2
Accuracy rating at calibrated span	0.1%						0.2% ** (0.1%)	0.1%	0.2%
	Accuracy guaranteed on all measurement ranges without linear adjustment								
Linearity	0.05%						0.1% ** (0.05%)	0.05%	0.1%
Temperature effect (at max span) — Zero	0.5%/55°C	0.25%/55°C	*1.5%/55°C		*0.7%/55°C		** 0.8 (0.5)%/55°C	0.25%/55°C	0.5%/55°C
Temperature effect (at max span) — Total	0.8%/55°C	0.5%/55°C					** 1.5 (0.8)%/55°C	0.5%/55°C	0.8%/55°C
Static pressure effect — Zero (At max span)	0.2%/10 kg/cm^2 0.2%/32 kg/cm^2	0.1%100 kg/cm^2	*0.5%/10 kg/cm^2 *0.5%/32 kg/cm^2		*0.25%/100 kg/cm^2		0.2%/Flange rating	–	
Static pressure effect — Span	0.2%/32 kg/cm^2	0.2%/100 kg/cm^2	0.2%/32 kg/cm^2		0.2%/100 kg/cm^2		0.2%/Flange rating		
Over pressure effect (at max span)	0.3%/10 kg/cm^2 0.3%/32 kg/cm^2	0.3 0.3%/160kg/cm^2 0.6%/420kg/cm^2	*0.75%/10 kg/cm^2 *0.75%/32 kg/cm^2		*0.75%/160kg/cm^2 *1.5%/420kg/cm^2		0.3%/Flange rating	0.2%/Overrange limit R	
Output, power supply	DC4-20 mA, DC11-45V								
Zero devation/suppression	(–) 100% to (+) 100% of Upper Range Limit							–1 kg/cm^2	
Rangeability	10:1								
Electrical damping	0, 0.3, 1.2, 4.8, 19.2 sec. switchable								
Temperature limit — Detector	–40 to 120°C							–40 to 100°C	–40 to 85°C
Temperature limit — Amp	–40 to 85°C								
Pressure rating	32kg/cm^2	160, 420kg/cm^2	32kg/cm^2		160, 420kg/cm^2		Flange rating	–	
Over range-limit	Up to working pressure							0.64-30 kg/cm^2 300% of URL 100, 500 kg/cm^2 150% of URL	5kg/cm^2 ~ or 300% URL
Classification of enclosure	IEC IP67, NEMA 4X								
Explosion proof	FM, CSA, JIS, PTB, BASEEFA (EExds IIC T6)								
Intrinsic safety	FM, CSA, JIS, PTB, BASEEFA (EExia IIC T6)								
Wetted part material	SUS316, hastelloy-C, monel, tantalum, O-ring (viton, teflon)								
Process connection	RC 1/4, NPT 1/4						ANSI JIS, etc.	RC 1/4, NPT 1/4	
Weight	5kg						–	3.7kg	4.0kg
Options	Remodel, field indicator (analog: LCD), mount, oval flange, side vent/drain valve, arrester, stainless amp housing								

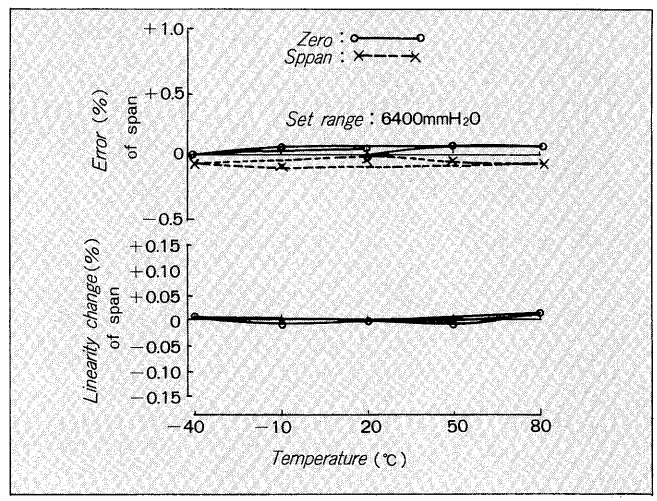
* At flow output 20%
** Option
*** Static pressure 420kg/cm^2 only

Table 2 Main specifications of smart transmitter

Specification		Contents
Functions	External adjustment function	Zero and span one push adjustment from outside of amp case
	Smart functions	• Tag No. • Zero and span setting/adjustment • Damping • Linear/Linear/$\sqrt{}$ • Forward/reverse operation switching • Type, material, range information • Self-diagnosis • Constant current output
Performance	Turndown ratio	100:1
	Accuracy rating	±0.1% However, setting range 0.1 x URL or less is ±[0.05+0.05 0.1x URL/SPAN]%
HHC (Hand Held Communicator specifications	Display	LCD 16 digits x 4 lines
	Power supply	Storage battery
	Explosionproof	Intrinsically safe explosionproof
	Option	Printer

change by temperature is a very small 0.05% over the entire temperature range.

Fig. 11 FCX transmitter temperature characteristics



9. CONCLUSION

The FCX transmitters were developed on Fuji Electric's accumulated industrial instruments technology and experience, and amply reflect consideration of the demands received from many domestic and foreign users regarding the FC transmitter.

We are confident that it will meet the expectations of users as a device which introduces a new generation of field instruments.