

# TREND OF WATER AND SEWAGE WORKS SENSORS

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## I. FOREWORD

Sensor technology has been substantially effected by the noticeable advances made in computer data processing technology, including the latest microcomputers. That is, because the processing capacity of these computers has increased tremendously, processing of the necessary data has become easy, and the performance of a series of control systems (see *Fig. 1*) consisting of "sensors", "data processing, and "operation" is primarily determined by the data detection capability of the sensors which form the contact point with the control objective.

On the other hand, movement to solve the energy saving, resources conservation, environment and pollution, and other social problems by controlling the at the optimum conditions with control system technology is advancing in all fields and, in this case, the performance of the sensor is of the upmost technical importance. From this background, a lot is expected of sensor technology and it is considered to be a field which will show amazing development in the future.

Fuji Electric is putting all its strength into the sensor technology on which systems are based. Several of the flow, pressure, level, and water quality meters and other new sensors developed for water and sewage works are introduced in this special issue.

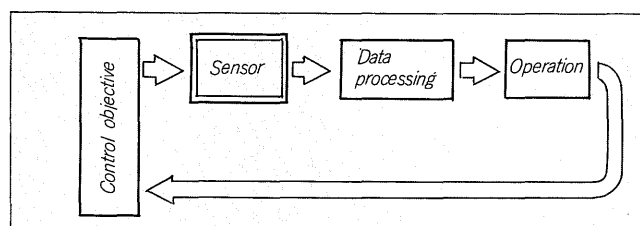
## II. FUJI ELECTRIC SENSOR TECHNOLOGY

As already mentioned, sensors are needed in an extremely wide range of fields and the sensed objectives are also extremely diverse. To meet these needs, diverse and advanced element technology is demanded.

Fuji Electric has a wide technological base as a consolidated electric machinery manufacturer, and is directing its efforts toward meeting these needs through the use of this technological base.

Measuring technology centered about process measuring sensors is one technology making up its nucleus. We have many achievements in temperature, pressure, flow,

*Fig. 1* Control system composition



component analysis, and other measuring technologies.

These sensors have a wide range of applications from general measuring to ultrasonic stress, correlation technology, infrared ray, radiation, etc. The ultrasonic flowmeter, level meter, FC series pressure sensor, electric magnetic flowmeter, various water quality meters, gas analyzer, radiation thickness gauge, and other sensors and measuring instruments are developed by means of this.

Electrostatic capacitance detection or magnetic detection technology seen in general electric machinery proximity switches, temperature detection technology in electric motor overheating protectors, and other detection technologies are also important fields.

On the other hand, in the electronics technology field there is video sensor technology which links optical sensor technology pattern recognition technology and image technology, and various kinds of agricultural and marine products selection equipment and pharmaceuticals automatic appearance inspection equipment are being developed.

Besides, in the research and development field, a distributed gauge pressure sensor, zirconia alkalinity sensor, catalytic combustion type gas sensor, solid alkali film applied blood analysis sensor, water quality sensor, light applied field or magnetic field sensor and other new sensors are being developed on thin film technology, catalyst technology, biology application technology, light application technology, etc.

*Table 1* lists the sensor and measuring technologies of Fuji Electric by element. This table shows that a wide range of technology is supported and that various kinds of sensors are being developed as described above.

Table 1. Sensor technology of Fuji Electric

Element technology	Sensor, measuring instruments	Main fields of application
Light application technology	Unscattered infrared ray gas analyzer (SO <sub>2</sub> , NO, CO, CO <sub>2</sub> , HC, water vapor, anesthesia gas) Light emitting oxygen analyzer Scattered light type turbidity meter Ultraviolet ray organic turbidity meter Infrared ray film thickness meter Optical fiber applied sensor Video sensor Laser posture controller	Plant Environment and pollution Medicine and pharmaceuticals Air conditioning Forestry and fisheries Sewage treatment Prevention and safety Civil engineering and architecture Polymer film measurement Research
Semiconductor technology	Silicon diffusion gauge Pressure sensor Silicon radiation detector Silicon strain gauge Optical sensor	Car electronics Plant Radiation monitoring Public welfare
Catalyst technology	Catalytic combustion type gas sensor Catalyst applied unscattered infrared ray Gas analyzer (NO <sub>x</sub> , NH <sub>3</sub> , micro CO)	Public welfare Plant Environment and pollution
Electro-chemistry application technology	Glass electrode pH meter Dissolved oxygen meter Residual chlorine meter	Waterworks, Sewage works
Biology, micro-organism application technology	Immobilized enzyme electrode sensor (Blood glucose, uric acid, amylase) Respiro meter	Medicine Sewage treatment
Ceramics application technology	Zirconia oxygen sensor	Combustion control
Ultrasonic wave application technology	Flow sensor Level sensor Flaw detector	Waterworks and Sewage treatment, Atomic power Plant Inspection, Predictive maintenance
Radiation	Various radiation sensors Thickness gauge Densimeter	Radiation monitoring Plant
Correlation technology	Particle flowmeter	Plant
Electro-magnetism and static electricity application technology	RF oscillation type proximity sensor Magnetic type proximity sensor Vibration sensor Electrostatic capacitance type pressure sensor Electrostatic capacitance type level sensor	Plant Prevention and safety
Others	Various temperature sensors (Thermocouple, platinum resistor, thermistor) Various moisture sensors (Lithiumchloride type, polymer film type) Magnetic type alkalinity meter Heat conduction gas analyzer	Plant Public welfare Environment and pollution

III. PORTABLE ULTRASONIC FLOWMETER

The recent advances made in ultrasonic wave application technology has led to the development and practicalization of the ultrasonic flowmeter as a general normal temperature flowmeter.

Funi Electric has already delivered 700 units of ultrasonic flowmeters which have been used it in water and sewage works and industrial water measuring. Since the ultrasonic flowmeter can measure flow from the outside wall of piping, it does not hinder the flow or cause a pressure loss and also has simple maintenance and inspection and other superior features and its usefulness is widely recognized and a wider range of applications is demanded. Moreover, an an open channel flow meter combining an ultrasonic flow rate meter and ultrasonic level meter, etc. are also being practicalized.

The portable type “Portaflow” which displays the special feature of the ultrasonic flowmeter that allows flow measurement from the outside wall of the pipe has been developed. The Portaflow is being applied to service water management by pipeline flow measurement, leakage investigation, invading water investigation, and other water and sewage works applications.

(1) Temporarily metering at a pipe which is not equipped

Fig. 2 Portaflow detection section mounting

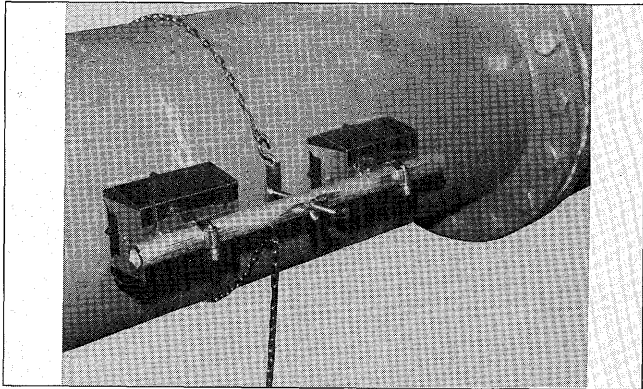


Fig. 3 Portaflow exterior view

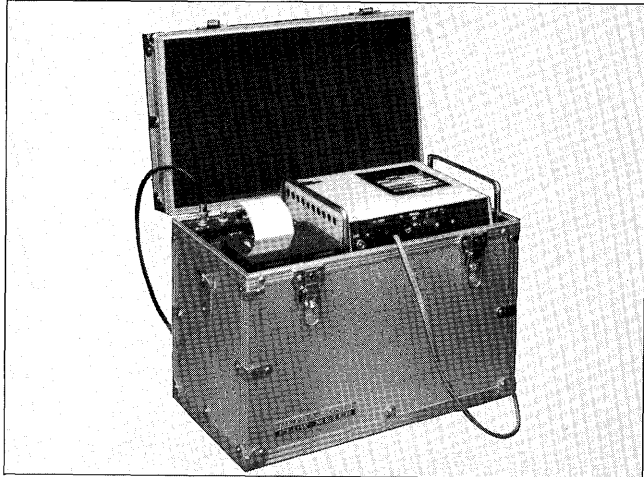


Table 2. Portable specifications

Measurable fluid	Clean water, sewage, sea water, waste liquid, oil, solvent, etc.			
Pipe diameter	25 ~ 3,000 mm			
Measurable flow velocity range	-16 ~ 0 ~ +16 m/s			
Power supply	AC100V 50/60 Hz 12V or 24V DC also usable by attaching an adapter.			
Case structure weight	Main unit (aluminum case): Approx. 13 kg Accessories (attache case): Approx. 7 kg			
Indication	Instantaneous flow rate, integrated flow rate, flow direction, receiving wave fault, self-diagnosis			
Recording	Instantaneous flow rate and integrated flow rate via digital printer			
Analog output	4 to 20 mA DC or 1 to 5V DC			
Ambient temperature/humidity	-10 to 45°C, 90% RH max.			
External dimensions (D × W × H)	Main unit (aluminum trunk): 315 × 414 × 244 (mm) Accessories (attache case): 360 × 450 × 90 (mm)			
Accuracy	Digital indication	Pipe diameter	At flow velocity 1 m/sec or larger	At flow velocity less than 1 m/sec
		φ1,000 or larger	±1% of indicated value ±1 digit	±0.01 m/s of indicated value ±1 digit
		Less than φ1,000	±1.5% of indicated value ±digit	±0.015 m/s of indicated value ±1 digit
	Analog output	Pipe diameter	At flow velocity 1 m/sec full scale or larger	At flow velocity 0.3 m/sec full scale or less
φ1,000 or larger Less than φ1,000		±1% of full scale ±1.5% of full scale	±3% of full scale ±5% of full scale	
Accessories	Detector, connection cable, wire rope, silicon compound, test piece, printing paper, waterproof cover, tools, etc.			

with a flowmeter.

- (2) Existing flowmeter checking and repair period maintenance.
- (3) Pump and valve characteristics approval and opening, etc. parameters flow conversion.
- (4) Inlet and outlet flow difference measurement with one Portaflow.
- (5) Measurement of inclined flow by two measuring line system.

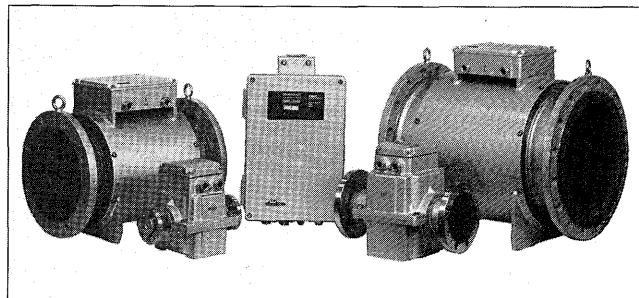
etc. are interesting usage examples of this Portaflow in which the new concept of carrying the flowmeter is realized.

Refinements to utilize the detection section mounting construction from small diameter to large diameter and other features of the Portaflow are being made.

#### IV. NEW TYPE MAGNETIC FLOWMETER

Fuji Electric has delivered many various other magnetic flowmeters to various plants. An advanced functions converter with built-in microcomputer has been developed for higher precision flow measurement and improved reliability

Fig. 4 New type electro-magnetic flowmeter



and widening of its applicable fields has been realized.

Its main features are the following three points:

- (1) High precision and excellent zero point stability. Measurement accuracy is  $\pm 0.5\%$  (velocity 1 to 10m/sFS).
- (2) Ease of use much improved Digital setting, self-diagnosis, and self-calibration are standard.
- (3) Wide range of options permit advanced functions.

Besides integrating pulse output, automatic multiplex range switching, forward/reverse switching, and operation of two detectors with one converter are possible.

#### V. FC SERIES PRESSURE AND DIFFERENTIAL PRESSURE SENSORS

FC series transmitters are industrial instruments for the measurement of flow, level, specific weight, and other fluid process quantities. Basically, they are based on the differential pressure sensor and currently use the electrostatic capacitance system that is the mainstream of differential pressure measurement.

Since they were placed on the market, over 10,000 units have been delivered inside and outside Japan and their reliability and performance are highly acclaimed.

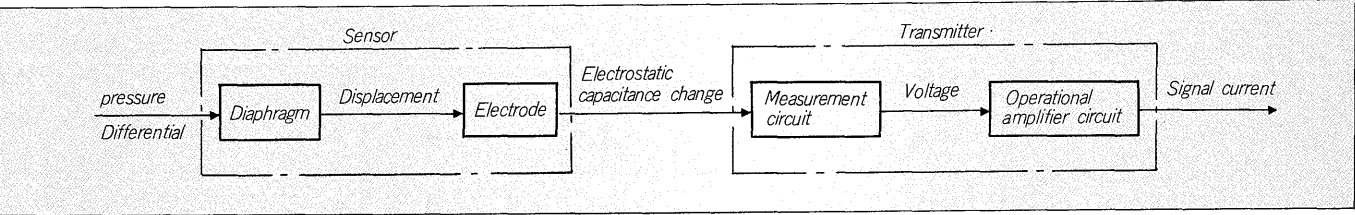
FC Series transmitters consist of abundant types of nine types and approximately 40 models. Furthermore, high accuracy is guaranteed over a wide measurement range from 10 mmH<sub>2</sub>O to 500kg/cm<sup>2</sup> for all models.

The principles of operation are shown in the block in Fig. 6. The measuring diaphragm is displaced by the measurement of differential pressure, an electrostatic capacitance

Fig. 5 FC series transmitters



Fig. 6 FC series transmitter principles



change is obtained, this change is measured and calculated and transmitted.

VI. INSERTION TYPE LIQUID LEVEL TRANSMITTER (MODEL FQK)

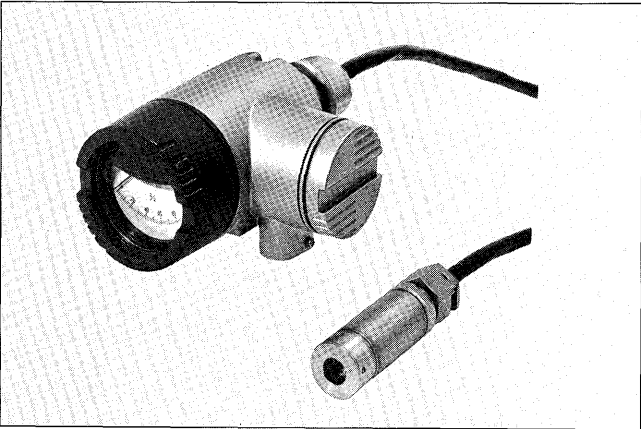
The Model FQK liquid level transmitter using a silicon pressure sensing diaphragm is shown in Fig. 7. This liquid level transmitter is the so-called insertion type in which the sensor and transmitter are separated and are connected by a cable and the sensor is suspended directly into the measured liquid.

Simpler installation and setting work easier than that of other types is one feature of the insertion type liquid level transmitter. Moreover, since this insertion type liquid level transmitter uses a silicon pressure sensitive diaphragm, the sensor is small and light weight, it can be easily used even for water level measurement of underground water by means of a deep well, and in a wider range of other applications than conventional types. Especially, it is perfect for water level measurement of water and sewage works, agricultural and industrial water, river water, underground water, etc. Its main specifications are shown in Table 3.

The principles and construction of the sensor are shown in Fig. 8.

The change in pressure caused by liquid level change acts on the pressure receiving seal diaphragm and is sent to the silicon pressure sensitive diaphragm through the sealed in liquid, and is detected as a change in the diffused molded gauge resistance at the surface of the pressure sensing diaphragm.

Fig. 7 Insertion type liquid level transmitter



The surface of the silicon pressure sensitive diaphragm, lead wire, etc. are completely sealed from the outside air and measured liquid and is an extremely high reliability construction.

The back of the silicon pressure sensing diaphragm is

Table 3 Specifications of insertion type liquid level transmitter Model FQK

Measurement range	0~3, 5, 10, 20, 30mH <sub>2</sub> O
Ouput	DC4~20mA
Supply power	DC24V DC24V 2-wire
Load resistance	550Ω
Wetted parts material	Pressure receiving diaphragm: SUS316L Other wetted parts: SUS304 Cable: PVC covered
Measurement liquid temperature	0~30°C
Ambient temperature	-20~60°C
Sensor dimensions	φ43mm x 160mm
Sensor weight	Approx 0.8kg
Arrester	Fuji Zett lamp built-in
Accessories specifications	On-site indicator Sensor stand (for setting at bottom of water)
Allowable error	±0.5%

Fig. 8 Water quality analyzer for water treatment plant

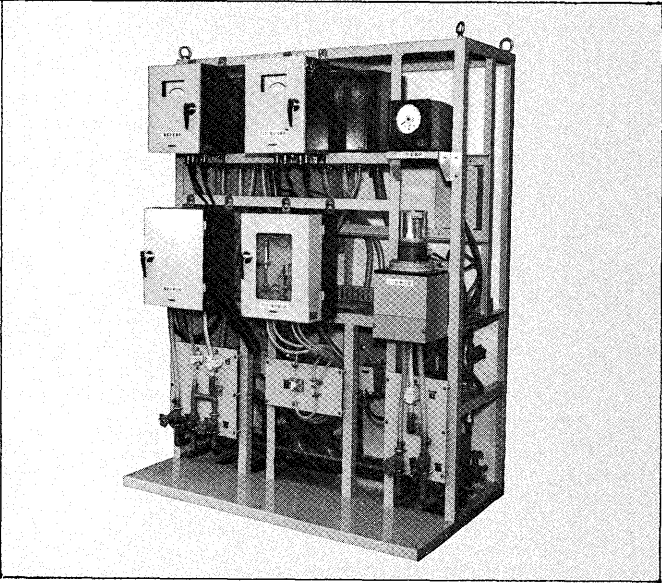


Table 1 Sensors of Fuji Electric

Item	Measurement principle	Measurement objective	Measurement range, etc.
Gas analyzer	Infra-red ray absorption type	CO, CO <sub>2</sub> , SO <sub>2</sub> , CmHn CCl <sub>4</sub> , NO, NH <sub>3</sub> , N <sub>2</sub> O, halogen, H <sub>2</sub> O, etc.	From 0 to 2ppm to 0 to 100% (by model and measurement com-component)
	Heat transmission type	CO <sub>2</sub> , H <sub>2</sub> , He, SF <sub>6</sub> , Ar, etc.	For % order measurement
	Magnetic presser type	O <sub>2</sub>	0 to 2% or 0 to 100%
	Magnetic wind type	O <sub>2</sub>	0 to 10% or 0 to 100%
	Zirconia solid electrolytic application	O <sub>2</sub>	0 to 5% or 0 to 21%
	Chemical luminescence type (yellow phosphor)	O <sub>2</sub>	0 to 20ppm or 0 to 10ppm
	Ultraviolet absorption type	O <sub>2</sub>	0 to 2mg/l or 0 to 40mg/l
	Lithiumchloride application	Moisture	-10~ +60°C Dew Point
	Glass electrode type	pH	pH0 to 14 or 4~10
Water quality analyzer	Scattered light type	Turbidity	0 to 2ppm or 0 to 1000ppm
	Neutralizing titration type	Alkalinity	0 to 50ppm (CaCO <sub>3</sub> ) or 0 to 100ppm (CaCO <sub>3</sub> )
	Conductivity type	Conductivity (total water quality index)	0 to 1μs or 0 to 5,000μs
	Electrolysis reduction (Two systems: with reagent and without reagent)	Residual chlorine	0 to 1ppm or 0 to 6ppm
	Ultraviolet ray absorption type	Organic turbidity	Light absorption 0 to 0.5 or 0 to 1.0
	Galvanic type	Dissolved oxygem	0 to 5ppm or 0 to 15ppm
	Reflected scattered light type	Turbidity	500ppm to 5000ppm or 500ppm to 1000ppm
	Respiration speed meter	Activated sludge respiration speed and respiration activity	Respiration speed 0 to 50mgO <sub>2</sub> /1 hour Respiration activity 0 to 50mgO <sub>2</sub> /g at MLSS

atmosphere conductive by an air cable and is not unaffected by change in the atmospheric pressure.

## VII. ANALYZERS

Fuji Electric gas analyzer have a 30 year history and are continuing to play a leading role. Even today, efforts are being made in developing new technology on this background and new products which lead the world are being produced. Recently, advance to overseas has been taken up positively.

On the other hand, water quality analyzers have grown substantially in recent years in connection with orders received by Fuji Electric for water treatment plants. Currently, positive research and development are being conducted for still newer needs.

The Fuji Electric analyzers currently being sold classified by principle are listed in Table 4.

### 7.1 Water and sewage water quality meters

In filtration plants with the supply of cheap and abundant clean water suitable for drinking to general users, the raw water from rivers, lakes, etc. containing turbid matter and bacteria is cleaned to water which conform to water quality standards of the level specified by the water-works law by passing it through sedimentation, filtering, and detoxification basic treatment processes.

For appropriate operation of the cleaning process of water, the water quality conditions are at each stage of the process are measured and grasped, and various chemicals are added to improve the treatment result as needed. At filtration plants for this purpose, analysis and measurement are performed for various water quality items and automatic measurement of the basic and most important of these is planned.

Fuji Electric supplies the automatic water quality analyzers listed in Table 4 which are practically demanded from current water filtration plants and has a corresponding record of achievements. To obtain suitable measured values with water quality analyzers, the pumped up detection water must be adjusted to a state suitable for measurement through debubbling, suspended matter removal, flow adjustment, and other preprocessing operation and sent to the analyzer itself. Fig. 6 is an example in which Fuji Electric water quality analyzers are added as part of preprocessing.

In sewage treatment plants, after the remove of large suspended matter in the general home, factory, and office drainage, the organic matter is removed and cleaned by using the absorption and dissolution action of microorganisms. Therefore, the facility called the aeration tank which aids the growth of the microorganisms by blowing air into the mixing water of microorganism and drainage is an important facility of the sewage treatment plant. Fuji Electric supplies the dissolved oxygen meter, respiro meter, and turbidity meter as the density of the microorganism

organic matter mixture listed in *Table 1* and the ultraviolet ray organic turbidity meter to be described later for monitoring of the cleaning effect as measuring instruments for grasping the state of this facility and for suitable operation.

### 7.2 Ultraviolet ray type organic turbidity meter

The ultraviolet absorption of the organic matter in waste water is effective as one organic turbidity index and it is known that the correlation with COD (chemical oxygen demand) is especially good. Compared to the conventional COD meter, TOC meter, etc., the organic turbidity meter that uses this principle has such advantages as:

- (1) Designed for continuous measurement.
- (2) Low price.
- (3) No chemicals used and power consumption is low so running cost is low.
- (4) No picking of water, a fixed quantity, chemical reaction, and other delicate parts so maintenance is easy.

Moreover, because manual analysis COD of JIS which is the standard for water quality turbidity restriction has good correlation for a wide range of waste water, it has been steadily becoming fixed as the center of water quality total control from 1981.

### 7.3 Ozone oxidation COD analyzer

Many COD, TOD (total oxygen demand) and other

conventional water quality turbidity analyzers have been developed for indoor analysis.

Therefore, the continuous water quality turbidity analyzer which automates these analysis methods is disadvantageous as on line measurement apparatus because it consumes a large amount of reagent or maintenance is difficult, etc.

To solve this problem, Fuji Electric has developed the ozone oxidation COD analyzer. This method oxidizes the turbid matter in the waste water by means of ozone and makes the amount of oxygen consumed by this oxidation the water quality turbidity index. This corresponds to the chemical oxygen demand amount when ozone is used as the oxidant and can be called COD ( $O_3$ ).

Because the measured value not only has a high correlation relationship with conventional COD, but the ozone oxidation rate is also high, this system is a superior water quality evaluation method.

Furthermore, with the continuous analyzer using this system there is no danger of trouble due to contamination of the sensor and clogging of the sampling system which frequently occur with conventional water quality analyzers and amply meets the demands of an online water quality meter.

XX

## TOPICS

### INSTRUMENTATION OF BANGKOK WATER SUPPLY SYSTEM

Fuji Electric delivered instrumentation systems to Bangkok Khen Filtration Plant of Metropolitan Water Works Authority of Thailand and three distribution pumping stations, and radio telemeter system between the filtration plant and distribution pumping stations in 1982. These systems are contributing to improve the water supply control level by centrally controlling the statuses of the pumping stations and filtration plant at the control center.

