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SENSORS FOR WATER TREATMENT AND TRAFFIC

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1. CURRENT SITUATION AND VIEW

The main sensors used in water, sewage, and other water treatment are shown in *Table 1*. When the sensors used in the ancillary facilities are included, it is no exaggeration to say that most kinds of sensors are used.

Flowmeters, from large diameter units which connect to the main pipes of water and sewage works to very small diameter units used in the chemical injection process, are widely used.

When compared to general process instrumentation, except for open channel flow meters, few restriction type flowmeters are used and the magnetic flowmeter and ultrasonic flowmeter are mainly used. These are also the sensors which are most advanced in skill by microcomputer and digital transmission.

Level meters are usually installed outdoors. Intrinsically nonconductive and high insulation resistance optical transmission type immersion type level meter with internal power supply to prevent lightning damage have gained attention.

The performance and serviceability of even water quality sensors are being improved by smart sensing and multi sensing with common sampling and pretreatment section.

In the roadway field, road sensors for assisting the safe, smooth flow of traffic, sensors for management cost saving and predictive maintenance and various other sensors are used. The main types are shown in *Table 2*.

In the railway field, besides sensors for assuring safe and reliable operation of railways as mass transit organizations and sensors for state supervision of individual equipment, the importance of sensors for state supervision of systems (sensing systems) for improving the feeding system and rolling stock installed equipment is increasing. Many sensors are used in preventive maintenance, in addition to current status management and operation applications. Optical sensors which are sensitive to infrared rays, natural light, and ultraviolet rays are used as quality measurement sensors as sludge water content meters, turbidity meter, clarity meters, and organic pollution density meters.

However, as a new trend, performing various sensing by video processing of video signals produced by infrared camera and color camera is being tried.

These sensors are raw water quality sensor (fish movement pattern), sedimentation pond floc sensor, activated sludge bulking sensor (filamentous bulking search), sludge melting furnace granule sensor, railway crossing obstruction sensor, and dense fog and rainfall sensor. Biowater quality sensor research is also flourishing.

The Fuji sensors actually used in water treatment and traffic are introduced below.

2. SENSORS USED IN WATERWORKS

(1) Overview

Waterworks instrumentation was introduced on a full scale in 1965 and has currently advanced to a consolidated digital instrumentation system centered about the computer and DCS. Initially, instrumentation equipment was mainly the air pressure and vacuum tube types. Today, it has changed to the electronic and digital types. Of course, electronic (especially the advance of the microprocessor) communication technology (optical communication) as technical needs have also had a large impact on the development of sensors used in waterworks. The sensor signal system has changed from the initial four-wire system (signal and power wired separately to the two-wire system. The signal level has also changed from the diverse signal levels (DC10 to 50mA, 0 to 10mV) of each company to an international standard unified signal (DC 4 to 20mA). Currently, development is advancing from analog to digital and from electric signal to optical signal and is aimed at a sensor which can connect directly to a high-level system network.

On the other hand, sensors which are especially important in waterworks instrumentation are water flow, water level, and water quality (pH, tubidity, alkalinity, electrical conduction). This group of sensors measures items which are pointers to waterworks facilities management and safe water production.

The items which are expected of waterworks sensors are:

(a) Easy maintenance and inspection (Especially shortening of the water quality meter inspection period)
(b) Induction and lightning resistance

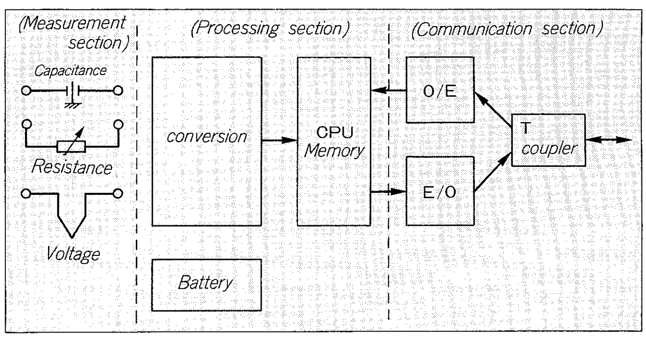
Table 1 Sensors used in water and sewage works

Measure-ment item	Kind of sensor	Example of use in water works	Example of use in sewage works
Electrical change	Voltage Current Power (amount) Frequency Insulation resist-ance Leakage current	Power receiving and distributing facility	Power receiving and distributing facility
Flow	Positive displace-ment flow meter Restriction flow-meter Ultrasonic flow-meter Magnetic flow-meter Vortex flowmeter	Chemical flow Open channel weir (raw water) Filtration flow Chemical flow, various flow measurement	Closed channel influent, aeration flow Initial setting influent flow, influent flow Chemical flow, various flow measurements Aeration
Water level or liquid level	Float level meter Water head level meter Ultrasonic level meter	River, pump well level Chemical tank liquid level Open channel level	Grit chamber, pump well level Level of various tanks Conveyance of water channel
Pressure, weight	Power, torque Distortion (impedance electrostatic capacitance) Differential pressure system	Pressure of various pipes Conveyer weight Chlorine weight (capacity)	Pressure of various pipes Conveyer weight Furnace internal pressure
Tempera-ture	Electrical resist-ance Thermoelectric effect	Water tempera-ture, coolant temperature, etc. Granule furnace, etc.	Water tempera-ture, coolant temperature, etc. Each part of sludge incinera-tor
Machine movement	Rotating speed Vibration	Pump, prime mover	Pump, prime mover
Density	Solid composition	Raw water, sedimentation water, purified water tubidity	Influent water, processing water SS, MLSS, sludge SS
	Fluid composition	Trehalose methane Ammonia meter Raw, water, purified water specific color pH meter used at each place Alkalinity Residual chlorine	Influent pH, etc. BOD, COD T-N, T-P Ammonia analyzer
	Gas analysis	O_3 Chlorine leakage	DO, respiration rate sensor SO_2, NO_X

Table 2 Expressway sensors

Measurement item	Kind of sensor	Example of sensor data use
Weather forecasting	Thermometer for road surface, air tempera-ture gauge Dew point thermometer Rain and snow gauge Visibility meter Back scattering visibility meter Road surface frost sensor Wind direction and speed meter Rainfall sensor	Traffic control Snow and ice counter-measures Information service
Tunnel measurement	CO gas analyzer View intensity instrument Wind direction and velocity meter Fire alarm sensor Illuminance meter	Tunnel ventilation measurement, control Firefighting facility control Emergency leading equipment Lighting facilities control
Traffic amount measurement	Vehicle sensor (Vehicle type traffic amount, time occupa-tion rate, average speed) Speed sensor	Traffic control Violation vehicles control Information service
Vehicle measurement	Vehicle sensor (vehicle type, number of axles, number of wheels) Vehicle scales, axle scales Vehicle height meter	Toll collection automation Violation vehicles control
Movement observation	Seismometer Displacement meter Acceleration meter Wind direction and velocity meter	Observation of the move-ment of bridges and earth Maintenance of bridges and roads Traffic control

Fig. 1 FFI sensor principle



(c) Satisfaction of the installation conditions (Resistant to chlorine gas, waterproof, immersion in water, and other adverse environments)
(d) Accuracy improvement (high accuracy flowmeter, improved water quality meter precision)
(e) Appearance of new sensors (ammonia analyzer, trehalose methane meter, etc.)

Currently, development to satisfy the above conditions is advancing, but only especially distinctive equipment is described.

(2) New sensors for waterworks: Optical fiber field in-

Fig. 2 Optical fiber field instrumentation system FFI composition

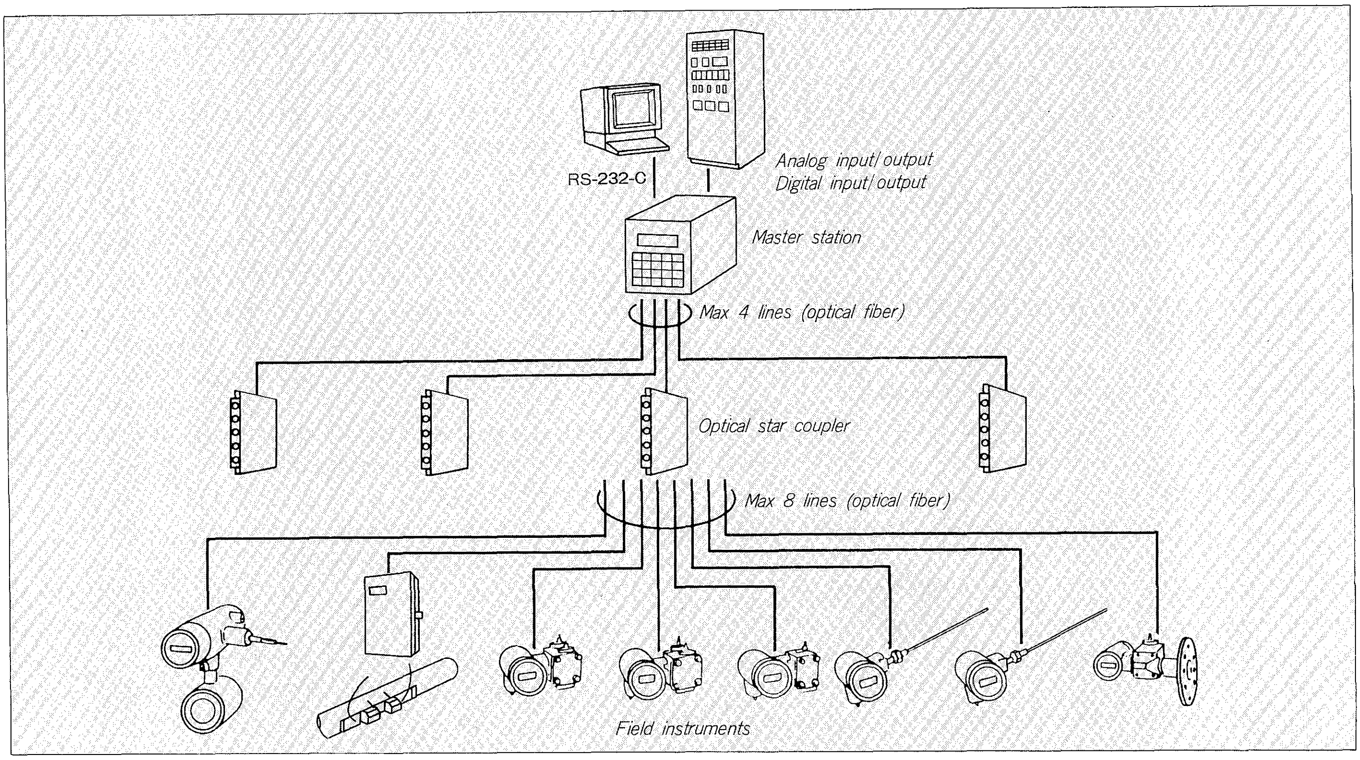


Table 3 Comparison of performance with conventional equipment

Item			Immersion type level meter	FFI immersion type level meter	
System Precision			±0.5%	±0.25%	Only conversion error of sensor by digitalization
Functions	Self-check function		None (performed manually in the field)	Circuit check and power check possible at the panel by internal microcomputer	
	Zero span setting		Set inside the field instrument	Possible at panel	
	Various compensation, operation		No (separate converter necessary)		
	Supply power		DC 24V or AC 100V	Effect of induction on power supply eliminated by using a built-in lithium battery (life 8 years max)	
Reliability	Noise resistance (transmitter)	Common mode	0.5%/50V, 1.0%/100V	Effect of noise essentially eliminated by using optical fiber. (Combined signal/power cable use possible)	
		Induction noise	0.15% change at output signal line 30A on/off		
		RF noise	1% change at output-ground 20kHz, voltage 3V		
	Surge resistance		Arrester must be installed to output signal line and power line	Surge not received	
	Explosion resistance		Pressure resistant, intrinsically safe explosionproof construction (one zener barrier/loop used)	Transmitter, thermometer: Built-in battery Installation in dangerous places possible.	

strumentation system (FFI)

Optical fiber field instrumentation (FFI) is a new intelligent sensor mounting a microprocessor at the optical fiber transmission and sensor section. It is a sensor which realizes the easy maintenance, lightning damage countermeasures, and high precision demanded by a waterworks.

The measurement section detects displacement by means of electrostatic capacitance and detects voltage directly, the same as the conventional system. What is distinctive is that the sensor contains a microprocessor (CPU), incoming and outgoing data can be sent freely by optical signal, and the sensor power supply is a lithium battery. This construction solves the following waterworks instrumentation problems.

Regarding maintenance and inspection, remote analysis (the sensor and circuit and power supply can be constantly monitored for abnormalities), remote sensing (zero/span calibration, damping time constant, etc.), and management data collation (remote collation of equipment type and model code) can be performed without patrolling but from one place by optical transmission (multiplex transmission). Since optical fiber cable transmission is used, the lightning problem is essentially solved.

The problems of conversion precision, etc. are eliminated and precision depends only on only the measurement section because everything after the measurement section can be digitalized. A comparison with the conventional type of immersion type level meter widely used at waterworks distribution ponds, etc. is shown in *Table 3.*

3. WATER QUALITY SENSORS USED IN SEWAGE TREATMENT

3.1 Water quality sensors for sewage treatment

Sewage treatment utilizes of microorganisms. Therefore, if the processing function of the microorganisms drops, the quality of the treated water worsens and leads to pollution of rivers, lakes, ocean, and other environmental water. Online water quality measurement in sewage treatment is indispensable for avoiding such a situation and is widely used for monitoring of influent and discharge water quality in treatment plant and control of treatment process.

The measurement items are water temperature, pH, turbidity, electric conductivity, BOD, DO, MLSS, sludge density, SVI, redisual chlorine, COD, nitrogen, phosphorus, ammonia, etc.

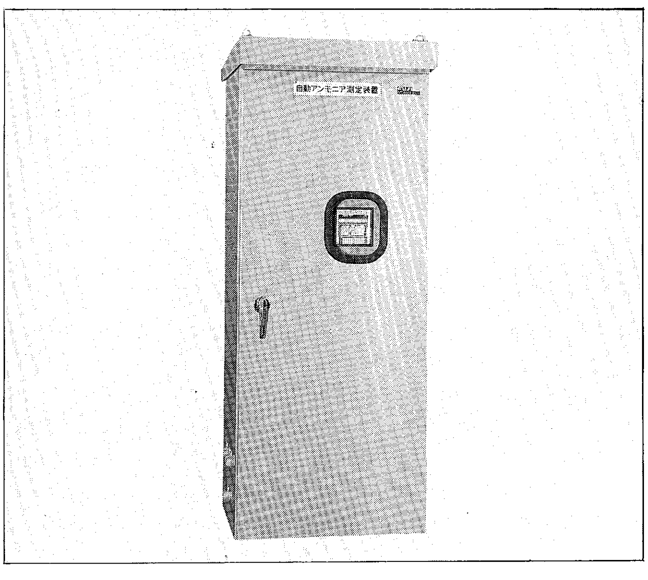
Generally, it is said of water quality sensors for sewage use that "the failure frequency is high and cleaning and adjustment period is short" due to contamination by the measured water, etc. Moreover, there are also sensors which require reagent and heat processing and these are more difficult to handle and more costly to run than other sensors.

Fuji Electric is putting its efforts into the development of a water quality meters which solve such problems. Five distinctive types are introduced below.

(1) Automatic total nitrogen measurement system

This system measures the total amount of nitrogen which exists in various forms in water. Total nitrogen measurement is made up of two stages: The first stage is pre-treatment which converts the nitrogen compounds existing in the form of ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, and organic nitrogen to nitrate nitrogen. And the second stage is quantification which finds the total amount of nitrogen by measuring this nitrate nitrogen. With the recommended method based on JIS, pre-treatment must be performed at normal temperature and normal pressure by using ozone, therefore the equipment is simplified and the measurement range extended.

Fig. 3 Ammonia analyzer



Quantification is the ultraviolet adsorption method which is the same as the recommended method.

Currently, a system which measures the three components, nitrite nitrogen, nitrate nitrogen, and total nitrogen, simultaneously by using ultraviolet rays of different wavelengths, is being developed.

(2) Automatic total phosphorus measurement system

The phosphorus compounds in water are converted to phosphate ion by oxidation or hydrolysis. With the recommended method based on JIS, the pre-treatment process, which converts the phosphorus compounds to phosphate ion is performed at high pressure and high temperature by adding potassium peroxidisulfate.

This system uses a method which performs oxidation by using ozone and heating. Quantification does not use a reductant like the recommended method, but uses constant potential electrolysis which measures the reduction current in the electrolysis cell. So this system reduces the unstable chemicals and simplifies the equipments.

(3) Ozone COD meter

"COD" is the amount of oxygen consumed when oxidants in water are oxidized and is used as an index of water pollution.

With the recommended method, oxidation is performed by means of potassium permanganate and other reagents and the oxygen consumption is found from the amount of reagent consumed. With the ozone COD meter, the sample is oxidized by ozone and the oxygen amount corresponding to that of consumed ozone is measured with an oxygen analyzer.

The features of this system are ① long-term stable measurement are possible because quantification is gas analysis and there is no contact with sample water. ② special reagent is unnecessary and running costs are low.

(4) Respiration rate meter

"Respiration rate" is the speed of oxygen consumption by microorganisms and is an effective index in finding the activity of microorganisms.

This equipment measures the respiration rate by measuring the difference of the concentration of the intake air and exhaust of an aeration and then calculating the respiration rate. Long-term stable measurements are possible, just like the ozone COD meter.

(5) Ammonia analyzer

The ammonia nitrogen in water (PH>11) is almost completely NH_3. And stirred in this condition the NH_3 is vaporized and becomes balanced between gas and liquid.

This analysis system uses this characteristic and measures the varporized NH_3 concentration by means of a membrane electrode. Since the electrode does not contact the liquid, long-term stable measurements are possible. Moreover, with this system, measurements are performed by adding two kinds of NH_3 references having different concentrations to the sample and calculating the ammonia concentration in the sample from the output of each. The fluctuations of temperature, etc. can be canceled by using this system.

4. SENSORS USED WITH EXPRESSWAYS

4.1 Expressways and sensors

At the end of 1987, the length of the nation's expressways reached 4280km. Moreover, the 4th national general development plan was presented and the scheduled routes of the national development main automotive roads, and other expressways has expanded from 7600km to 11,520km.

The importance of expressways is a matter of course, but at zones which are expanding annually, the importance of road operation, maintenance management, and service to expressway users aimed securing and improving their safety, pleasantness, and high speed properties is increasing steadily.

Of the sensors manufactured by Fuji Electric, two examples of expressway use sensors are introduced.

(1) Vehicle sensor for entrance automation

The Japan Highway Public Corporation is automating dispensing of expressway entrance tickets. In the past, the ticket was handed to the driver by a man in a booth. When automating this, a ticket dispensing position matched to the height of the driver's seat of the vehicle must be selected.

The newly developed vehicle sensor have vehicle entry detection and vehicle height detection functions and controls the automatic ticket vending machine by means of these signals. Vehicle entry detection is performed by separation count and number of axles for each entry vehicle by means of pressure sensitive rubber number of axles detector and a photoelectric vehicle separation detector. Vehicle height judgment has a function which sorts all vehicles into three kinds by photoswitch application and simultaneously sends an alarm to vehicles which exceed the height limit.

In 1987, a total of twelve units were delivered to the Douou expressway (Mikasa-Bibai) and Takamatsu, Matsuyama expressway (Zentsuji-Doi).

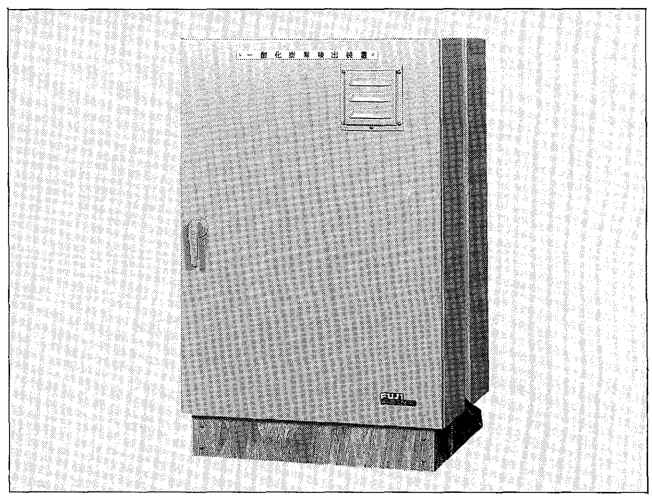
(2) Carbon monoxide sensor

The toxic matter exhausted with running of an automobile contains carbon monoxide and other gases and dust and other particles.

Generally, ventilation of road tunnels is performed with dust density as the index. As a result, these toxic matter are diluted to a low density which poses no problem.

Fig. 4 Vehicle sensor for entrance automation

Fig. 5 Carbon monoxide sensor



The carbon monoxide target density in road tunnels is 100ppm or less. This equipment is installed to monitor this.

The Fuji carbon monoxide sensor features high precision and maintenance-free operation by a unique infrared absorption measurement principle. Approximately 100 units were delivered to expressways up to 1987.

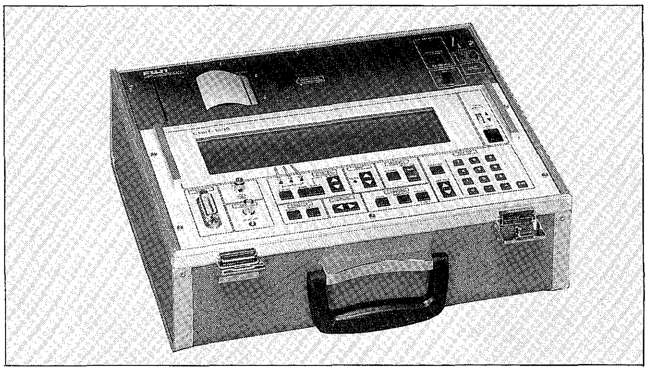
5. SENSORS USED BY RAILWAYS

Since the public characteristic of railways as mass transit organizations is high, high safety reliability and minimum maintenance are demanded. As one means of solving this, various sensors (including equipment that uses sensors) for control and trouble detection use or preventive maintenance use are necessary with fraction substation equipment and rolling stock equipment. Of the sensors used by railways, the comparatively new and distinctive units are introduced here.

(1) Insulation resistance supervising equipment under hot line (Hotmeg®)

Hotmeg is an equipment (measures and monitors

Fig. 6 Computer assisted BEARING inspection diagnosis tool CABIT-1000



insulation resistance by superimposing a 10Hz AC current into the main circuit) developed (1978) to measure and monitor the insulation resistance of low voltage distribution line, etc. under hot line in response to the demand for larger, more complex, and more reliable electric installations. Recently, it is combined with the microcontroller, etc. used in substation control. And compensation for earth capacity, sensor automatic switching, (all circuits or by feeder) and measured value recording, etc. are being performed to obtain higher sensitivity and precision.

(2) Remote temperature supervising, etc. in power management system

In power management system using a computer, besides supervisory control and other original tasks, the electric power equipment, are remotely supervised for preventive maintenance. Regarding the temperature and pressure of the equipment of substations and circuit breakers, the operation count, etc. are constantly grasped at the control station by means of various sensors and in addition to graph output as maintenance data, whether or not preventive maintenance is necessary is judged automatically and alarm output, etc. is performed.

(3) Computer assisted bearing inspection diagnosis tool (CABIT-1000)

This equipment was developed to detect abnormalities of rolling bearings with the rotary machine kept installing to the rolling stock. The bearing vibration is input by means of a piezo acceleration sensor and arithmetic processing and condition judgment are performed by microcomputer according to the type of bearing and the result is output in three ranks (OK, AG, NG). An exterior view of the CABIT-1000 is shown in Fig. 6.

(4) Monitor for rolling stock

Various monitors are installed to the rolling stock and the main circuit voltage, current, control information, etc. are input by various sensors and are arithmetically processed by a microprocessor and a preventative maintenance effect is achieved by grasping the timely change of the various devices or the cause of the abnormality is quickly and easily found if trouble should occur.

6. CONCLUSION

The development of industrial sensors using electronics, data processing technology, biotechnology, and other new technologies new materials is advancing. The ammonia biosensor using biotechnology and image sensing which graps conditions and performs state measurements by means of data processing technology, etc. are given. A solar sensor with a solar cell as the power supply for use in remote places where there is no power source has been practicalized already. We will put out efforts into the development of effective sensors for water treatment and traffic, including a sensor for Tricloromethane measurement to produce safe water.