Fuji Electric's Measuring Instrument and Sensor Technology

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1. Introduction

Over 45 years have passed since Fuji Electric began manufacturing industrial measuring instruments. During this time period, Fuji has developed numerous products and thereby, as a private enterprise, has contributed to the advancement of process automation. This paper overviews the present technological trend, market situation and Fuji's industrial measuring instrument and sensor products.

2. Technological Trend of Measuring Instruments and Sensors

2.1 Flowmeter group

Flowmeters have one of the largest variety of measuring principles among industrial sensors. The principle structure has been diversified for optimum flow rate measurement based upon specific properties of the process fluid, the purpose of flow rate control, monitoring and commercial transaction, the piping conditions at the measuring point, etc.

The most popular flowmeters are differential pressure transmitters (about one third of flowmeters fall into this instrumental category) followed by electromagnetic flowmeters and area flowmeters. In recent years, the rapid increase in demand for Coriolis mass flowmeters has been drawing attention. This flowmeter is the only one capable of directly measuring mass flow rate. It is expected that with the progress of sensor and electronic technology, this flowmeter will be made smaller and lighter in weight and will secure a firm position among industrial instruments.

2.2 Panel instrument group

Supported by a strong demand for general purpose instrumentation and with the advancement of DCS, panel instrument technology has been steadily increasing.

Pen and wire-dot mechanisms remain as the most commonly employed writing technology for recorders. For laboratory use, demand for the high-speed thermal array head is increasing. However, it is the ink jet technology that deserves the most attention at present. This technology, first adopted in OA equipment, will surely penetrate the PA field in the future. Advances in applying electronic technology have resulted in upgraded functionality such as faster data processing, enriched calculating and communication functions, and use of memory cards.

DCS has been and will be dominant in process instrumentation. However, single loop controllers are still found in uses such as a back-up loader for DCS or in applications at small/medium-system plants which take advantage of their higher flexibility and lower system cost feature than DCS. Demand seems to be slightly increasing. The main control method of single loop controllers is still PID. Improvements to controllability have been made by introducting 2 degrees of freedom PIDs, a self-tuning function, AI technology, etc. In addition, the down-sizing of instruments using ASIC/SMT technology will be inevitable. It is thought that these instruments will become more responsive to field bus configuration in order to ensure maximum use merits.

2.3 Industrial analyzer group

Although major changes in the basic technology of industrial gas analyzers are not taking place, a bipolarization can be pointed out; one trend for multi-component measurement and multiple functions through upgrading the conventional technology, and the other for single-component measurement and single function through simplification. Multi-component measurement by FTIR for application to process and environmental measurement is expected to become a new technological trend. However, unlike conventional batch measurement used mainly in the laboratory, adequate reliability for enduring continuous measurement is required. Therefore, a final evaluation of this technology must be made in future. In addition to the conventional solid electrolyte sensor for O_2 measurement, those for CO_2, NO and SO_2 measurement have also been under research and development. Presently, such sensors are yet to be applicable in practice. Hence, a conclusion on this technology also remains to be made in the future.

2.4 Temperature controller group

The ratio of analog to digital types of temperature controllers is 1:5 (in Japan), showing predominance of the

digital type. In this field, digitalization often results in offering maximum user merits such as (1) realization of an auto tuning function, (2) full multi-input and (3) incorporation of communication functions. In particular, a new tendency to improving controllability by using fuzzy control or simplified 2 degrees of freedom PID control system is emerging, compelled by the need to suppress overshoot. Temperature controllers have come to be divided into two types, economy and high-grade. In case of the high-grade type, the sampling period is 0.1 to 0.2 second and accuracy is 0.1 to 0.2%. This performance is competitive with industrial measuring instruments. The high-grade type is currently being used in a wide area of applications in the process field.

2.5 Radiation sensor

Radiation sensors are used in area monitors, dust monitors, survey meters, personnel exposure monitors, etc. for measuring radiation concentration in the atomic energy industry and in civilian institutions such as universities and hospitals. It is also used in thickness gauges, and density meters for the industrial measurement.

For measuring radiation (α, β, γ, x-rays), the semiconductor method which has advanced remarkably in recent years, is used in addition to the conventional GM counter tube and scintillator. The semiconductor method allows ultra-miniaturization by utilizing the small size of a semiconductor element for personnel exposure monitoring. Also, it appears that area monitors and survey meters will advance toward enlarge the sensitive area and increase sensitivity of semiconductors themselves.

3. Market of Industrial Measuring Equipment

Figure 1 shows the production statistics (JEMIMA pro-

Fig. 1 Production statistics of individual industrial measuring instruments in Japan (JEMIMA statistics)

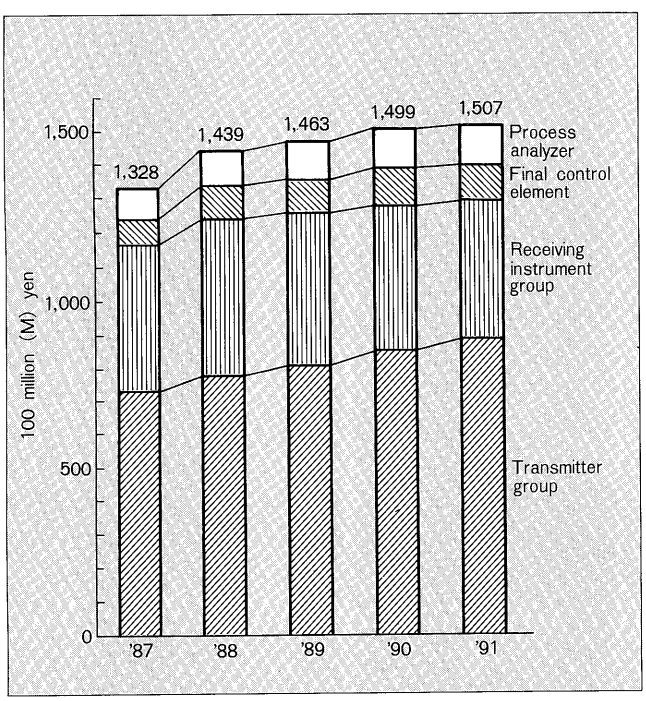


Fig. 3 Ordering statistics for each type of industry in fiscal '91 (JEMIMA statistics)

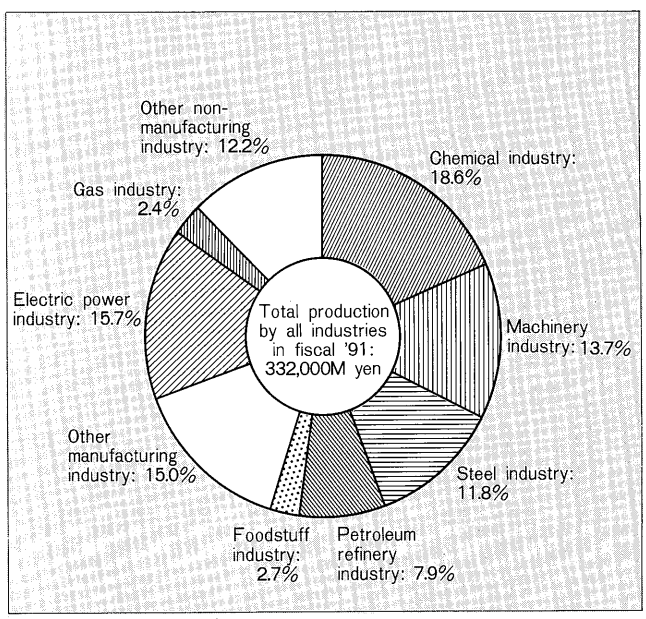


Fig. 2 Production amount of each kind of transmitter receiving instrument and process analyzer in fiscal 1991

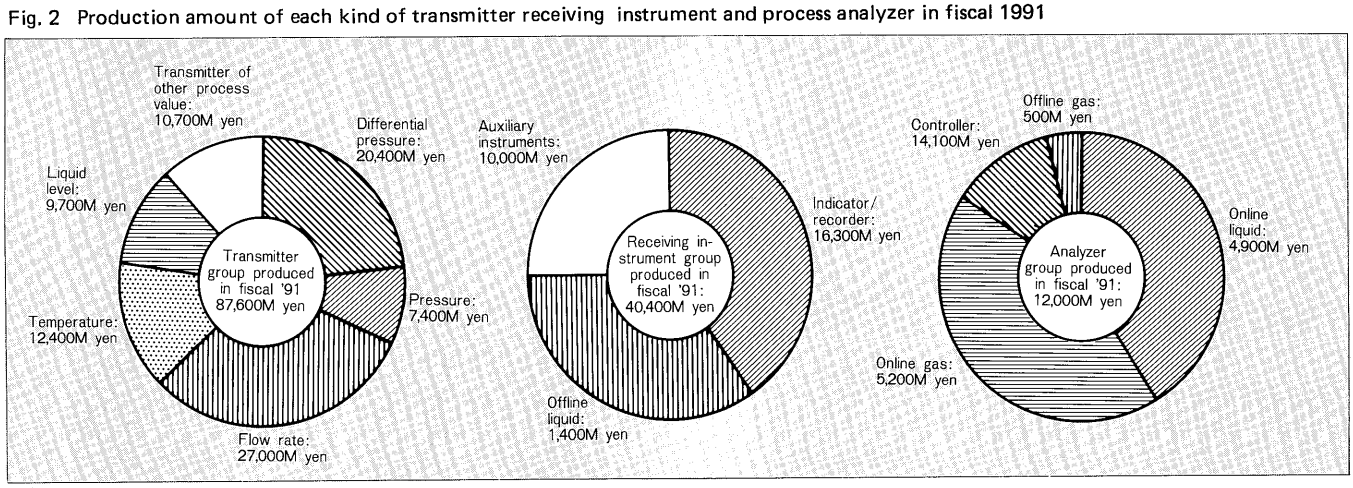


Table 1 Major Fuji sensor

Sensing object	Sensor/product name	Principle/elementary technology	Major specification/feature	Principle application
Pressure/differential pressure	• Pressure/differential pressure transmitter • Pressure sensor	• Capacitance • Piezoresistance effect of silicon	• Pressure: 0 to 64mm H_2O ...500kg/cm² • Differential pressure: 0 to 10mmH_2O...30kg/cm² • Pressure: 0 to 0.4...8kg/cm²	• PA and FA in general • Automobile and general industries
Flow rate	• Differential pressure type flowmeter • Electromagnetic flowmeter • Ultrasonic flowmeter • Karman vortex gas flowmeter	• Detection of differential pressure across orifice • Electromagnetic induction according to Faraday's law • Dependence of ultrasonic wave's propagation velocity on flow velocity • Detection of Karman vortex	• Diameter of pipe: 8mm at minimum • Electrically conductive fluid: 0 to 10m/s, Diameter of pipe: 2.5 to 2600mm • Liquid: −32 to +32m/s • Gas at normal temperature, Diameter of pipe: 25 to 100mm	• PA in general • PA in general • PA in general • General industries
Temperature	• Resistance bulb for temperature measurement • Thermocouple thermometer • Thermistor thermometer	• Change in electric resistance of platium • Electromotive force of thermocouple • Change in resistance of thermistor	• JIS-conformed Pt 100Ω • JIS-conformed J, E, K, R and PR thermocouples	• FA and PA in general • FA and PA in general • FA and PA in general
Humidity	• Zirconia high temperature humidity sensor	• Application of zirconia oxygen sensor	• 0 to 30, 100vol%, 600°C max.	• PA in general
Gas	• Paramagnetic oxygen analyzer • Thermal conductivity gas analyzer • Zirconia oxygen analyzer • Oxygen sensor • Trace oxygen analyzer • NDIR gas analyzer • Gas leak alarm unit	• Magnetic attraction of axygen gas • Hot wire cooling by gas • Oxygen electromotive force of zirconia solid electrolyte • Electrolytic current of zirconia solid electrolyte • Light emission from yellow phosphorus due to oxygen • Infrared absorption spectra of various gases • Catalytic combustion of combustible gas on catalyst	• 0 to 2...100vol% • For example, 0 to 10vol% CO_2 • 0 to 5...25vol%, 600°C max. • 0 to 25vol% • 0 to 2...10ppm • Various gases, 0 to a few ppm ...100vol% • LEL level of LPG and isobutane	• PA in general • PA in general • PA in general • Environmental control • PA in general • PA, environment, environmental pollution, research • In homes
Water quality	• Residual chlorine analyzer • Free chlorine analyzer • Turbidity analyzer • pH analyzer • Alkalinity analyzer • Conductivity analyzer • Water quality inspection robot • Ultraviolet-ray organic turbidity analyzer • Dissolved oxygen analyzer • Automatic total nitrogen analyzer • Ammonia analyzer • Mixed liquor suspended solid measuring instrument • Respiration speedmeter • Fine particle counter • Ultrafine particle counter	• Polarography with fixed platinum electrode • Polarography with fixed gold electrode • Measurement of scattered light from surface • Glass electrode • Neutralization titration with sulfuric acid • Direct insertion type AC bipolar electrode method • Full automation of preprocessing and measurement • Ultraviolet absorptiometry • Diaphragm galvanic electrode • Ozone oxidation and ultraviolet absorption measurement • Non-wetted ion electrode • Reflected/scattered light • Gas sampling with exhaust gas collector • Light shut-off method (LED) • He-Ne laser 90° scattered beam measurement • Semiconductor laser beam scanning type 90° scattered beam measurement • Argon laser beam scanning type 90° scattered beam measurement	• 0 to 1, 3, 5, 6mg/ℓ • 0 to 1, 2, 3mg/ℓ • 0 to 2...1000mg/ℓ • 0 to 8, 0 to 14, 2 to 12, 4 to 10pH • 0 to 50, 100mg/ℓ • 0 to 200, 500, 1000μs/cm • Fe, Cr^{6+} and other 14 constituents • Absorbance: 0 to 0.5, 0 to 1 • 0 to 5, 0 to 15mg/ℓ • 0 to 70mg/ℓ • 0.1 to 1...100mg/ℓ • 500 to 5000, 10000ppm • Respiratory speed and respiratory activity • 1 to 40μm, 0 to 2000 particles/mℓ • Detectable diameter of particles in pure water: 0.1μm at minimum • 0.15 to 10μm, 0 to 10^4 particles/mℓ, 6 minutes • 0.07 to 10μm, 0 to 10^4 particles/mℓ, 6 minutes	• Waterworks • Waterworks • Waterworks/sewerage, industrial waste water • PA, research in general • Waterworks • Waterworks/sewerage, industrial waste water • Waterworks • Sewerage, industrial waste water • Sewerage, industrial waste water • Sewerage, industrial waste water • Sewerage, industrial waste water • Sewerage, industrial waste water • Sewerage, industrial waste water • Pure water, foodstuff, medical supplies, etc. • Ultrapure water, foodstuff, medical supplies, etc.
General composition	• Fourier infrared spectro-photometer	• Visible and infrared ray absorption spectra	• Various gases, liquids and solids	• LA in general, quality control
Radiation	• Various types of radiation monitor and radiation survey meter	• Gas flow counter, GM counter tube, various scinillators, ionization box, silicon semiconductor detector, etc.	• Detection of α, β, γ, neutron and x-rays, various types from pocketable size to stationary type	• Nuclear installation, hospital, laboratory
Thickness	• β-ray thickness gauge • γ-ray thickness gauge • Infrared ray thickness gauge	• Absorptivity of β-ray • Absorptivity of γ-ray • Absorptivity of specific infrared ray	• 2 to 6000g/m² • 0 to 4...10mm • 10 to 2000μm	• Metal, paper, etc., PA in general • Metal, PA in general • Plastic film
Level	• Float type level meter • Immersion type level meter • Ultrasonic level meter • γ-ray level meter	• Detection of float position on liquid surface • Detection of water pressure with capacitance or resistance manometer • Reflection time of ultrasonic wave • Transmission and absorption of γ-ray	• Water level: 0 to 0.5...40m • Water level: 0 to 3...30m • Liquid/solid level: 0 to 3...30m • Liquid/solid level: 0 to 1...3m	• PA in general • PA in general • PA in general • PA in general

duction statistics covering 54 companies) of individual industrial measuring instruments manufactured in Japan from 1987 to 1991. The industry of industrial measuring instruments can be regarded as a mature one and has maintained a stable growth rate of 3.4% per year.

Figure 2 shows the production amount of each kind of transmitter, receiving instrument and process analyzer in fiscal 1991. The annual growth rate from 1987 to 1991 was 2.3% for transmitters, −1.7% for receiving instruments, 9.3% for final control elements and 7.2% for process analyzers. Receiving instruments alone resulted in minus growth. Receiving instruments are classified into indicators/recorders, controllers and auxiliary instruments. The minus growth of receiving instruments appears to have been caused by a decrease in demand for self-balancing recorders and overseas transfers of production sites.

Figure 3 showing JEMIMA's ordering statistics (in fiscal 1991) for each type of industry, may be used to determine fields of application.

The statistics include individual industrial measuring instruments and process monitoring/control systems. The ratio of ordering from manufacturing industries to that from non-manufacturing industries was 7:3. Among manufacturing industries, the chemical industry had the most orders, followed by machinery, steel and petroleum refinery industries. Among non-manufacturing industries, demand from the electric power industry was the largest.
(Note) JEMIMA stands for Japan Electric Measuring Instruments Manufacturers' Association.

4. Fuji's Measuring Instrument and Sensor Technology

Table 1 lists the major sensors used for industrial measurement.

4.1 Flowmeter group

Fuji's flowmeter group includes differential pressure flowmeters, electromagnetic flowmeters, ultrasonic flowmeters and Karman vortex flowmeters for mounting on a car.

Differential pressure flowmeters are used in a combination of primary devices such as an orifice, nozzle or venturi tube or an FCX series differential pressure transmitter. The FCX transmitters lead competitive products in terms of variety, performance and other specifications, and are recognized as the highest grade of this type of industrial equipment in the world. More recently, for the first time a transmitter having a hydrogen-resisting transmission function has been developed for application to the petroleum and petrochemistry industry.

New types of electromagnetic and ultrasonic flowmeters have been marketed last year. The electromagnetic flowmeter comes in two types: the model FMQ which has an integral design made of ceramic parts and provides smart function, and the models FMS and FMT of separation type.

Ultrasonic flowmeters are available as time delta series FLV/FLW. This series has employed an ABM (Anti Bubble Measurement) system which has a tenfold resistance to the formation of air bubbles when compared with the conventional method. The sensor is of the clamp-on type and may be mounted by one person. These ultrasonic flowmeters are far easier to use than the preceding types.

Fig. 4 FCX series differential pressure transmitter

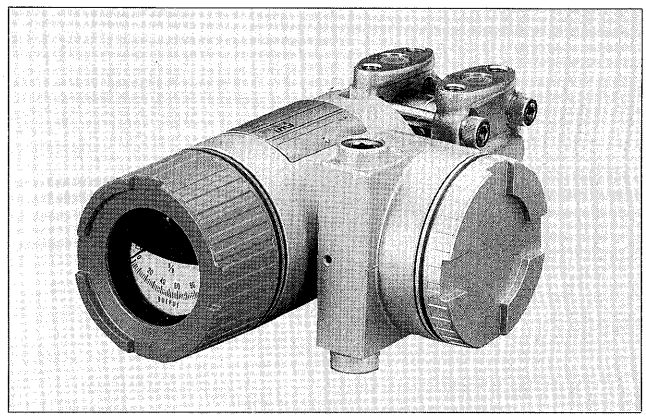
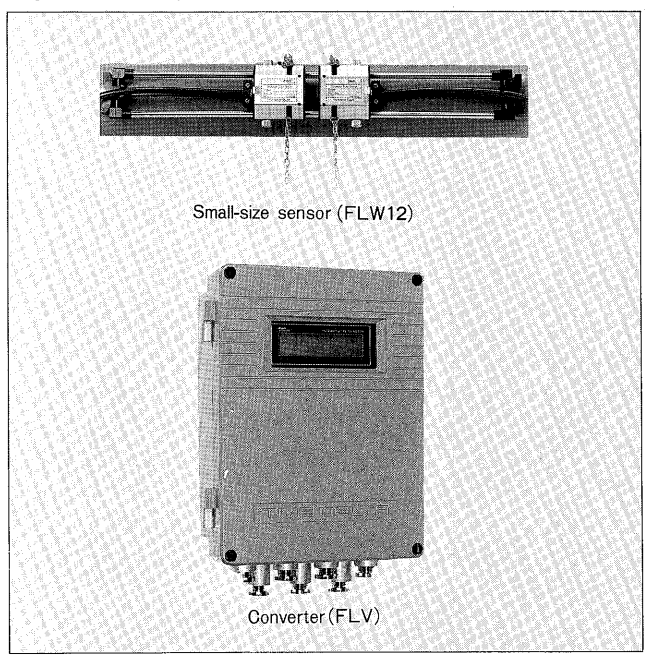


Fig. 5 Time Delta series ultrasonic flowmeter



4.2 Panel instrument group

Now that use of a microprocessor has become commonplace, the key to discriminating one recorder from others lies in writing technology. Since 1991. Fuji Electric has been marketing a microjet recorder based on the ink jet method, which has been established as an original merchandise-discriminating technology.

Ink jet writing technology is suited for multi-point, multi-color and quick recording. Because it directly records on paper, a clear and reliable result is obtainable, and tracing and printing can be carried out as desired with only one cartridge. As exemplified above, this technology is superior to other methods. Moreover, an ink refillable type head is

Fig. 6 Microjet recorder (180/100 mm)

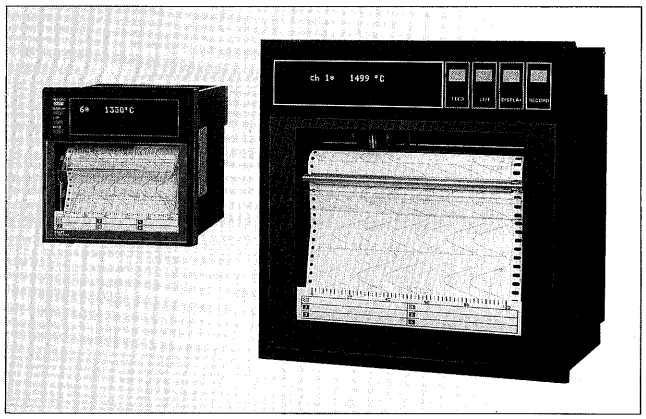
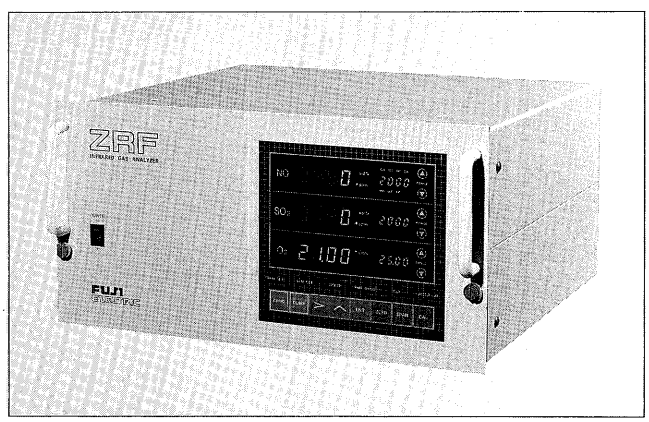


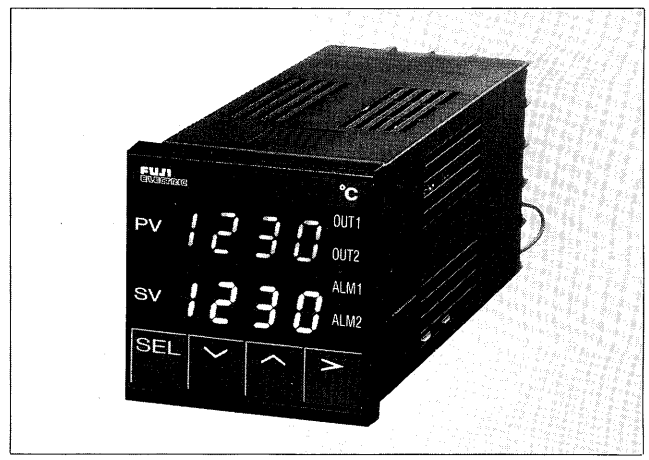
Fig. 7 Infrared gas analyzer (model ZRF for 3-component measurement)



under development in consideration of global environment protection. Fuji's writing technology has given rise to innovative products, namely the microjet recorder which features an industry-first 12 continuous traces, recording on the same time axis without pen offset, and 6-color trend output, character and scale printing.

Three series of digital controllers have been developed: CC-F series (high class), CC-S series (medium class) and CC-E (economy class). The CC-F series is the first digital controller developed in Japan. It has a number of features including the use of a plasma bar-graph in the display unit, the inheritance of analog feeling on front panel operation, easy configuration of PID and complicated functions using the built-in setting unit and an abundance of PIO points. The CC-F series is quite popular among users in every segment. The CC-S series has been developed as a strategic commodity for the overseas market. This series of controllers compose a product group aimed at the internationalization of merchandise development through functional expansion while surpassing the technology of the high-class CC-F type with the provision of a general-purpose communication interface (RS-422), a drip-proof front panel structure, configuration software which will run on an IBM

Fig. 8 Fuzzy temperature controller



personal computer and flexible power supply voltage (DC 24V, AC 100V, AC 220V).

4.3 Industrial analyzer group

Among the analyzers recently developed by Fuji, infrared gas analyzers (models ZRF and ZRG) are tailored for multiple components and multiple functions. A maximum of 3 components including oxygen are simultaneously measurable. In addition, various functions such as automatic calibration, oxygen correction and mean value calculation, which are externally in the conventional design, can be incorporated internally. An analyzing system can be constructed simply and economically from these models. The multi-channel zirconia oxygen analyzer (model ZRN) is a true multi-function type analyzer. With up to 9 direct insertion type detectors connected, multi-point measurement is carried out simultaneously. Mean value calculations are possible through combinations of desired detectors. This analyzer is particularly efficient for the combustion control of large-sized boilers.

4.4 Digital temperature controller group

There are three classes of digital temperature controllers: the PYZ·PYV/W series (economical type), the PYX series (medium-class controllers) and the PYH series (high-class controllers). The economical controllers PYZ·PYV/W give priority to cost reduction. However, this series has a variety of features including an auto tuning function, a freely selectable power supply, multiple inputs, simple operation and a drip-proof front face structure. The medium-class PYX series has just been put on sale this year (in May, 1993). This series offers a group of products intended for overshoot suppression and system integration through a communicating function with fuzzy control and many other functions comprised in 1/16 DIN. The high-class PYH series features a sampling period of 0.1 second, an input accuracy of 0.2%, incorporation of a communicating function, etc. This specification shows it is applicable not only to temperature measurement, but also to the measurement of pressure, flow rate, etc.

4.5 Radiation sensor

Fuji boasts a rich line-up of radiation sensors including a GM counter tube, scintillator, ionization box and semiconductor system, which are used for measurement of α, β, γ, x-rays, etc.

Fuji uses a semiconductor detector in the alarm function-provided pocket dosimeter REM MASTER-Q for personnel exposure monitoring, the area monitoring detector (NDM) for working environment measurement, etc., and the dust monitoring detector (NDT) for measuring the concentration of radiation in dust carried in air, etc.

The dust monitoring detector has a large area (equivalent to 50 mmϕ) and a structure facilitating transmission of β rays through the surface of this detector.

5. Afterword

It is predicted that demand for industrial measuring instruments will require higher functions, more intelligent features, down-sizing and open structure such as the field bus. With these goals, Fuji aims to offer customer-friendly control systems and components based on its instrumentation technology established through a half-century of experience.