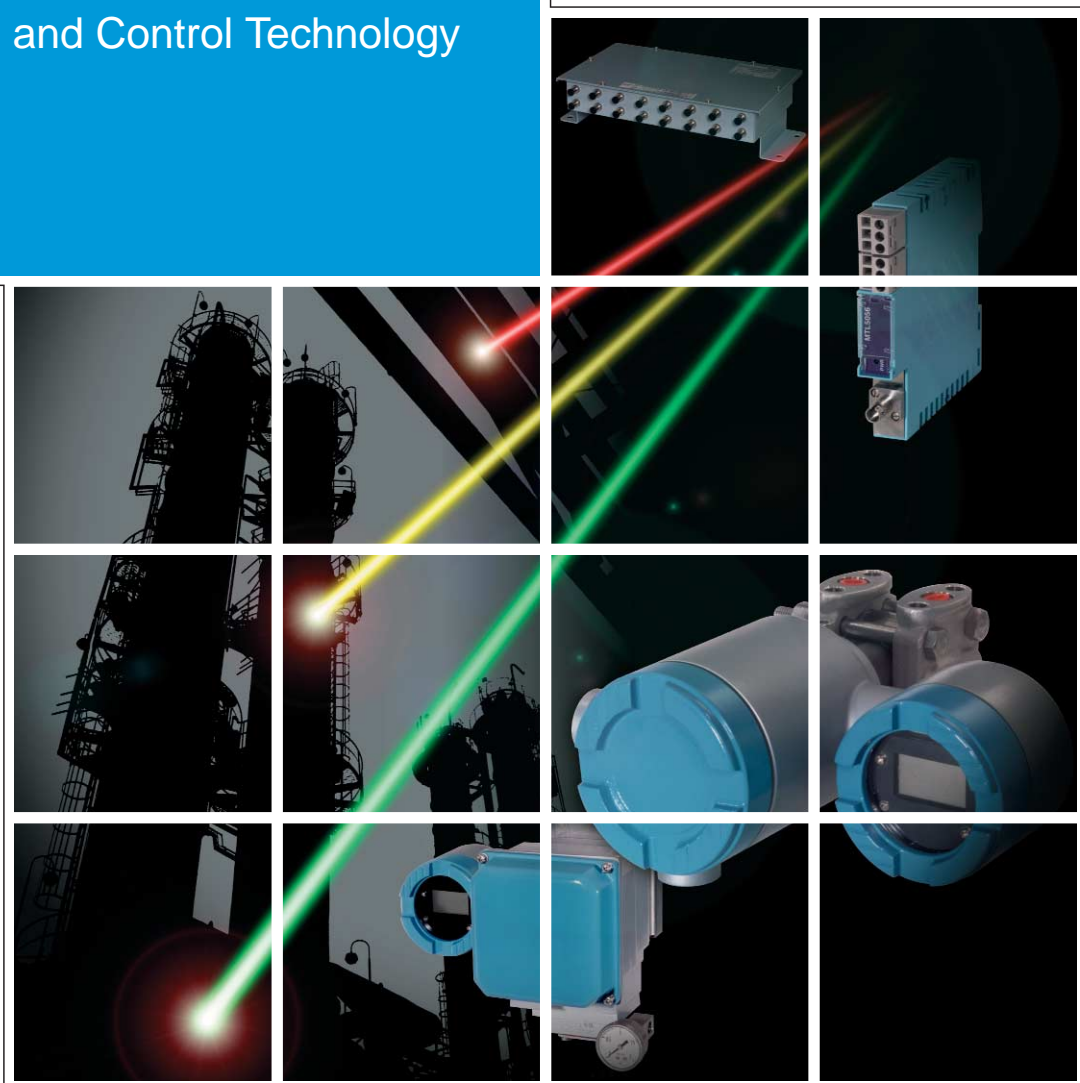


FUJI ELECTRIC REVIEW



1998 VOL.44

Instrumentation and Control Technology



By Integrating Development, Production and Sales,
FUJI ELECTRIC INSTRUMENTS
Begins Operation

Under the policy of "Customer First",
Fuji Electric Instruments (FIC) has
strengthened its organization.

Fuji Electric's Instruments Division has been integrated
with development, production, and sales to offer
quick and reliable solutions for customer needs.

Experts at Fuji Electric Instruments are creating solutions
for the future.

FIC



Electronic transmitter



Electromagnetic
flowmeter



Ultrasonic flowmeter



Microjet recorder



Temperature controller



Gas analyzer

FUJI ELECTRIC REVIEW

Instrumentation and Control Technology

2

1998 VOL.44

CONTENTS

The Trend of Instrumentation and Control Technology	34
Development of Optical Fieldbus Systems	39
Open Integrated Instrumentation and Control System "FOCUS"	45
New Technologies for Measuring Instruments	52
An Instrumentation and Control system for Incineration Plants and a Plant Simulator	58
Super-High Resolution Vision System "FAY-1000"	63

Cover Photo:

The modernization of on-site systems with various distributed measuring instruments has lagged compared with central monitoring and control systems.

Fuji Electric has contributed to this drive toward modernization by working for international standards since the inception of the fieldbus. Standards proposed by Fuji Electric for the optical fieldbus were approved and issued as the IEC international standards in November 1995.

Due to transmission by optical fibers, the fiber-optical fieldbus has advantages such as noise immunity, lighting immunity, and intrinsic safety in addition to the fundamental advantages of fieldbus.

The cover photo shows the new on-site fieldbus environment, a combination of optical fieldbus devices, an optical star coupler, and an electrical-optical fieldbus converter.

The Trend of Instrumentation and Control Technology

Takeya Fukumoto

1. Introduction

From a marketing point of view, although the high exchange rate of the yen has been rectified and industrial output has recovered, equipment investment for the private sector demands includes few new constructions for expansion of production. It is mostly comprised of intensive equipment arrangements to develop competitive power in price as well as for the extension, conversion, and replacement of rationalization.

The price of industrial products greatly dropped between 1993 and 1995. Also, Japan's output of industrial instruments fell from 1991, as shown in Fig. 1, and bottomed out during these two years. Annual growth of about 3% is expected in the future.

The world's process automation systems (PAS)

centering around distributed control systems (DCS), with an output of about 800 billion yen in 1996.

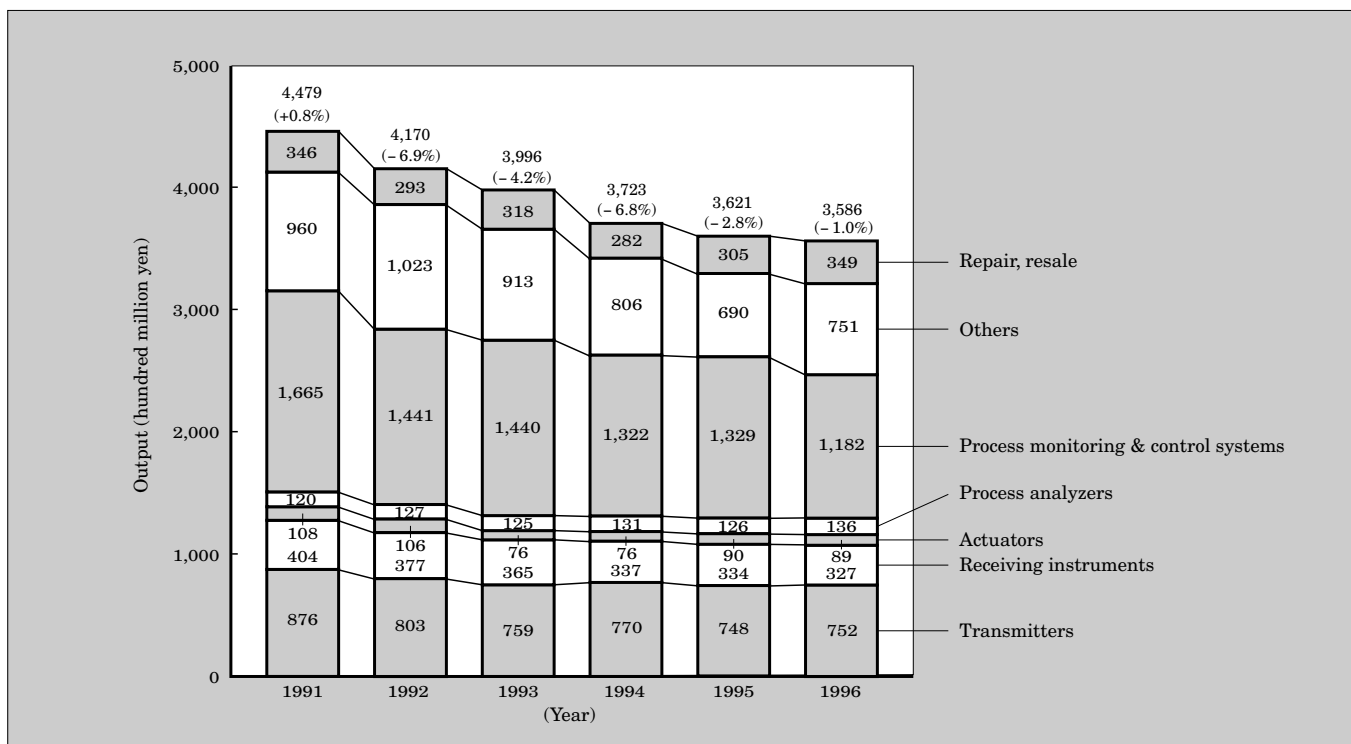
On the other hand, the world's major industrial instrument manufacturers are promoting innovative technical development and developing strategies to integrate enterprises by mergers and acquisitions (M&A).

This paper reviews the current trends in the world and Japan and describes Fuji Electric's plan for developing information and control systems and measuring instruments.

2. Trends of Information and Control Technology and the Market

Recently, the integration of control and information has been regarded with more importance and it is

Fig.1 Change of output of industrial instruments
(Source: Japan Electric Instrument Industries Association, Annual Report 1997-7)



necessary to consider for information and control systems.

2.1 Key elements in technical innovation and system configuration

The key elements in technical innovation are open networks, open databases, and multimedia having personal computers (PC) as the core. A conceptual diagram of the trends in technology and the market is shown in Fig. 2.

2.1.1 Wide use of PCs and Windows NT^{*1}

The technical innovation of PCs has accelerated and new products improving cost performance are announced every several months. Moreover, due to the abundance of package software with advanced functions produced from the open development environment, the use of PCs has rapidly increased not only for information processing in office automation (OA) but also on a personal level.

Due to the improvements in PC hardware efficiency and reliability and in Windows NT real-time operation and reliability, PCs have been applied in process automation (PA) and factory automation (FA) as well as in OA.

Windows NT has been replacing many companies' own operating systems (OS) and UNIX^{*2} as the OS for human communication interfaces (HCI) in the world of information and control systems. In the future, when compatibility with system scales and performance requirements is verified, the system domain for Windows NT will spread widely.

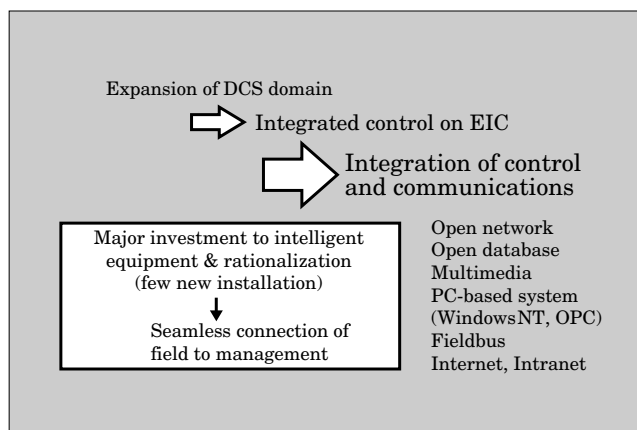
2.1.2 Promotion of open networks

Network for information and control systems are classified into three stages: information, control and

*1 Windows NT: A registered trademark of Microsoft Corp., USA

*2 UNIX: A registered trademark in the USA and other countries and is licensed by X/Open Company Ltd.

Fig.2 Conceptual diagram of trends in technology and the market



field networks. An open information network has already been achieved. Worldwide standardization and business partnerships are being strategically promoted to attain open networks for the other two stages.

(1) Application of the intranet to information networks

In order to connect plant information to the management system or carry out management not under the control of regional restrictions, the intranet is now able to allow easy access to information on business management, maintenance, and data analysis. This will have a positive affect on data acquisition by the management and engineering support for operators.

(2) Open field networks

The Fieldbus Foundation has two kinds of fieldbuses; the low-speed fieldbus for PA instrumentation signals (H1) and the high-speed fieldbus for connecting controllers or remote PIO to controller (H2). With regard to the H1, several companies' products based on the final specifications were extensively displayed and mutually connected at INTERMAC '97. In 1998, several manufacturers scheduled to market their products.

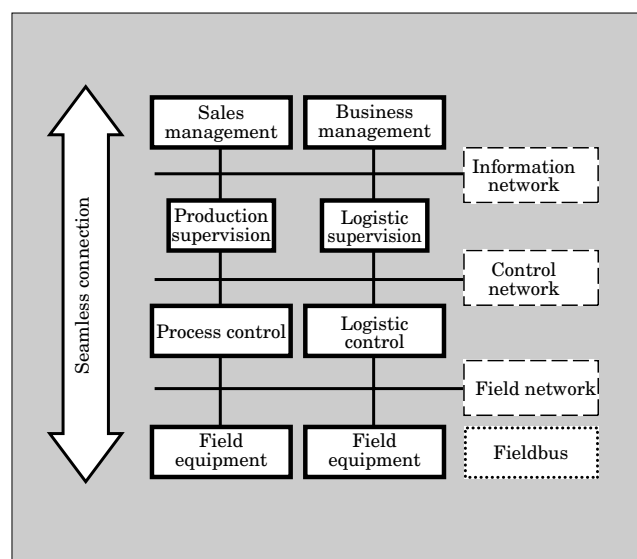
Open fieldbuses will give users the advantages of (1) open multi-vendor systems, (2) remote calibration and changing of the setting constant, (3) high accuracy measurement, and (4) transmission of status signals.

2.1.3 Seamless connection of the field to management

Sales, production, and distribution are closely connected in the manufacturing industry, and timely data transmission from each division is required by the other divisions. Formerly, each division worked out its own systems and many efforts were made to connect information between the divisions.

In contrast, information between divisions will be

Fig.3 Conceptual diagram of seamless connection of field to management



directly connected in the future by an open network, just as if they were structured as system. This will result in a system in which the direct connection of sales, production, and distribution allows exact judgment and prompt policy determination.

A conceptual diagrams for the seamless connection of the field to management is shown in Fig. 3.

2.2 Technical domain of the next generation system

Fuji Electric's next generation system aims at seamless connection of the field to management by expanding the range of information communication

Fig.4 Technical domain of the next-generation system

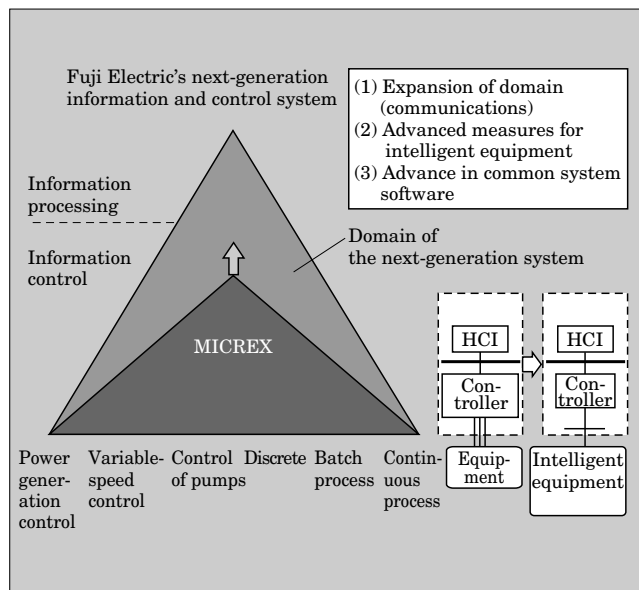
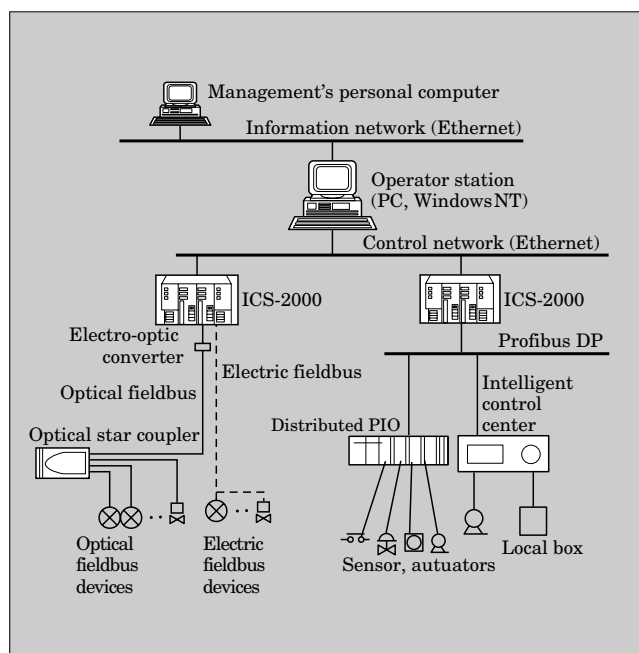


Fig.5 FOCUS open EIC-integrated system



functions.

On the other hand, by developing the fieldbus, Fuji Electric promotes open interfacing systems with intelligent sensors and drivers. As a result, part of the controller functions will be included in the sender and driver. In the control systems, the weight of the sensors and drivers will be increased, and the function and position of the controllers will be greatly changed.

By developing open system software, Fuji Electric can quickly take measures to meet any situation. A conceptual illustration is shown in Fig. 4.

2.3 Fuji Electric's information and control systems

Fuji Electric has supplied many systems with the electric, instrumentation, and computer control (EIC) integrated system MICREX-IX. Furthermore, we have developed the advanced information and control system MICREX-AX as an upper level type of the MICREX-IX that uses an open local area network (LAN) (TCP/IP, conforming to FDDI) and multimedia, enhancing the information processing function.

In October 1996, Fuji Electric marketed the PC-based open integrated control system FOCUS for medium and small systems. This system is based on Windows NT and uses Ethernet^{*3} for the information and control networks. Recently, the system has been developed to meet the fieldbus as a field network, further contributing to an open network. In addition, the system can be connected to an intelligent control center through the Profibus. These features combined with an ICS-2000 advanced EI-integrated controller, compose an open EIC-integrated system that incorporates the specifications of the next-generation system. This system is shown in Fig. 5.

3. Trends of Measuring Instruments

From the viewpoint of instrument manufacturers' output, the long stagnation of private demands and the problem of exchange rates forced many enterprises into restructuring, and the instrumentation industry has finally attained a stable period with a hopeful future.

In the instrumentation industry during this period, the prices of process instruments dropped by 20 to 30%. This resulted in pressure on the management of instrumentation suppliers and a wave of inevitable worldwide reorganizations through M&A. Under these circumstances, a reduced products cost was not enough. Seeking further improvement in efficiency, Fuji Electric established the specialty instrumentation supplier/Fuji Electric Instruments Co., Ltd., an enterprise which will quickly adapt to market changes and respond to customer requirements.

*3 Ethernet : A registered trademark of Xerox Corp., USA

3.1 Field instruments

Fuji Electric's production and sales of instruments have gone worldwide. After having launched a manufacturing and sales company in China, Fuji Electric established Fuji Electric France S.A. in 1995 and Thermax-Fuji Electric Ltd. in India in 1996.

Differential pressure transmitters are internationally produced and are supplied only by a limited number of manufacturers. Therefore, Fuji Electric intends to promote development not only for regular components but also for needs that include peripheral components. In the meantime, Fuji Electric's products are ranked at the top level in the world in every respect regarding function, performance, and price. They are highly rated by many users.

Recently, level meters were added to comply with the sanitary specifications for the pharmaceutical and food industries and the small diameter flange specification for differential pressure flow meters for the oil and petrochemical industries and for general-purpose use. This completed the product line meeting customer needs.

Fuji Electric considers ultrasonic flow meters to be important basic measuring components in the future in addition to pressure or differential pressure transmitters. Demand is expected to greatly increase. Following the sale of portable ultrasonic flow meters in 1995, we carried out overall improvement of the fixed installation ultrasonic flow meters and improved measuring accuracy and response characteristics as well as greatly reduced the effect of bubbles in the fluid. In addition, they were reduced in size and weight and supplemented with the functions of multi-path measurement and multi-pipe application, which resulted in advanced functions and performance.

Sanitary specifications, underwater types, and explosion-proof types have been added to complete the line of electromagnetic flow meters.

Fuji Electric has recently developed commercial fiber-optic fieldbus instruments.

A topic of the technology is that Fuji Electric has newly developed an optical star coupler, the key component, and applied it to the H1 level fiber-optic fieldbus system. With the cooperation of Chiyoda Corporation, it is currently under field trial in the Shell pilot plant in the Netherlands. It is expected to greatly contribute to safe operation in hazardous areas and regions that suffer heavily from lightning.

3.2 Panel instruments

In the field of panel instruments (controllers, indicators, and recorders), Fuji Electric has marketed new temperature controllers and recorders. The high, middle, and economy-class temperature controller series were completed earlier, but ten years have passed since the economy class was marketed, so an overall model change has been undertaken to reduce costs and

improve the functions.

The new series has the following advantages for easy and useful application:

- (1) Addition of a small front size of 48×24 mm (a first in Japan) that improves compatibility with small machines
- (2) Addition of a waterproof front face increases environmental endurance
- (3) Specification of 24V AC and 24V DC
- (4) The fuzzy control function as standard for the whole series reduces overshoot and improves disturbance immunity

Other temperature controllers have been marketed. These have the same construction as the existing function models for position control and communication for the PLC.

These temperature controllers are suitable for medium and small machines that are mainly controlled sequentially and also require temperature control at several points. The advantage is that two independent loops can be controlled with one module and a fuzzy control function is also installed.

With regard to recorders, a new type has been added to the ink jet recorder series that Fuji Electric has consistently developed.

Chart recorders are rapidly becoming daily necessities. Someday, high-class types will replace the simple types, and hybrid recorders will occupy the market.

The new type based on the concept of economical, analog-like hybrid recorders is characterized by simple recording and digital printing and meets the current requirements.

3.3 Analyzers

Fuji Electric's analyzers are mainly used for processes and the environment. The major types are infrared and oxygen analyzers.

Japanese market for process analyzers has remained the same these past several years, but the environmental analyzers changed the downward trend beginning in 1993 to an upward one in 1996.

Recently, the market is growing for analyzers used in the reduction of dioxin generated by incineration plants. The Western nations promote the tightening of control over exhaust gas from stationary sources and automobiles. Pacific Rim countries have begun to as well, and an increase in demand should follow.

Under these circumstances, Fuji Electric has improved analyzers for environmental measurement and has supplied a number of CO/O₂ analyzers to measure dioxin in incineration plants as well as flue gas analyzers for boilers.

As for water quality analyzers, to meet requirements for safe and good tasting water, Fuji Electric has developed new products in anticipation of the future. Acute toxicant monitors utilizing biotechnology, optics-applied floc sensors, chemistry-applied triha-

lomethane analyzers, optics and chemistry-applied supply water quality monitors (color and turbidity analyzers) are characteristic products developed by combining biotechnology, chemistry, and optics to our own sensor technology. Also, a highly sensitive turbidimeter was developed based on measuring technology using scattered laser to count particles in ultrapure water for semiconductor processing. This turbidimeter can measure low turbidity of 0.001mg/L and count particles of 0.5 μ m or more and can precisely perform turbidity control of outlet water from the filter basin of a water purification plant in accordance with the tentative guidelines issued by the Ministry of Health and Welfare as countermeasures against

cryptosporidium in the water supply.

4. Conclusion

Recent information and control systems and measuring instruments have been reviewed. Global industries will overcome the borderless price competition by rationalizing technology, production, and control as well as by speedy management. Utilization of superior information and control systems is indispensable in reinforcing competitive power. With our advanced technology, Fuji Electric will make efforts to offer instruments and information and control systems meeting customer needs.



Development of Optical Fieldbus Systems

Noboru Kanzaki
Takeou Matsudaira
Takumi Gunji

1. Introduction

In the areas of such fundamental materials as oil and chemical fields, the search for world-wide innovation and high added value products has risen year by year, driven by intense international competition.

As a result, highly functional flexible and inexpensive systems have become expected through the use of open technologies such as instrumentation control and information systems. Fieldbus system is expected as one of the solution to these issues.

Fuji Electric has aggressively developed open systems in the field of instrumentation control and promoted the establishment of international standards. Optical fieldbus physical layer specification was decided as IEC international standard in November 1996.

To establish a international standard for fieldbus systems, the Fieldbus Foundation was founded in September 1994 and has more than 100 enterprises world-wide. As a director of the Fieldbus Foundation, from the beginning Fuji Electric has been working on certain specifications, hardware development, promoting increased usage, and public relations.

The Fieldbus Foundation tested the communication protocol for a low-speed fieldbus and completed final specifications in January and June 1996 respectively in the USA. Fuji Electric has started the fiber optic fieldbus working group, and now the results of the working was finalized as final specification in the Fieldbus Foundation.

This paper describes the specifications and features of Fuji Electric's fieldbus system that satisfies both the IEC standard and specifications of the Fieldbus Foundation.

2. Outline and Configuration of the Optical Fieldbus System

2.1 Outline of the optical fieldbus system

The fieldbus replaces the conventional analog current signal (4 to 20 mA) with digital communication that connects each field device and control device that make up an instrumentation and control system. The

optical fieldbus uses optical fibers to transfer the fieldbus signal, and therefore has excellent transfer characteristics such as anti-noise and stable operation.

The standard physical layer of the optical fieldbus has been introduced in IEC 1158-2 Optical Medium (clause 15 to 18) and the host layer has been introduced in the Fieldbus Foundation specifications (same as for the electric fieldbus).

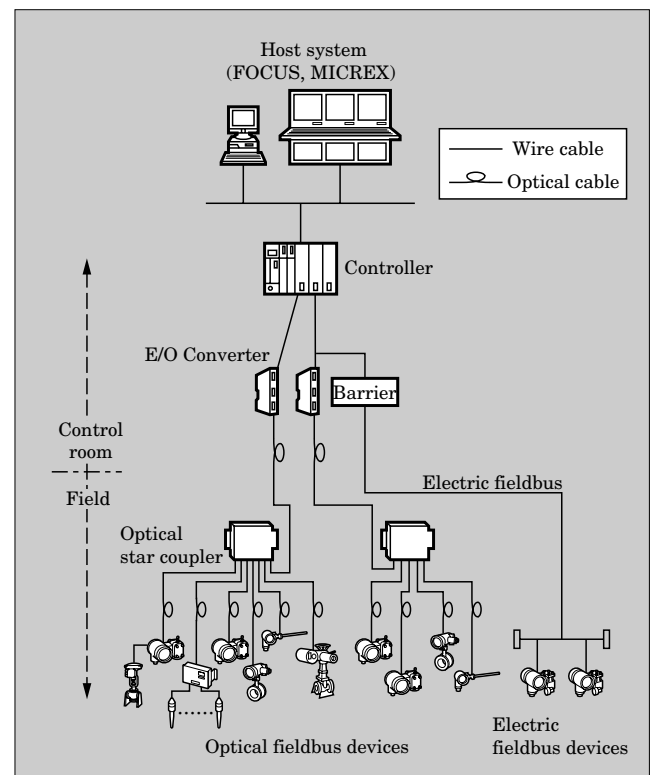
2.2 Configuration of the optical fieldbus system

The optical fieldbus system is composed of 4 main devices: field devices such as a sensor and actuator, an optical star coupler, an E/O converter and a host system. These are connected to an optical fiber or electric cable. Figure 1 shows the system configuration.

2.2.1 Field devices

Field device of the optical fieldbus include optical

Fig.1 Configuration of optical fieldbus system



parts known as “optical units” in addition to ordinary sensors and actuators.

An optical unit has a monolithic construction and consists of an LED, a photo diode and an optical connector for transferring and detecting receipt of the optical signal. Bidirectional communication is possible with one optical fiber.

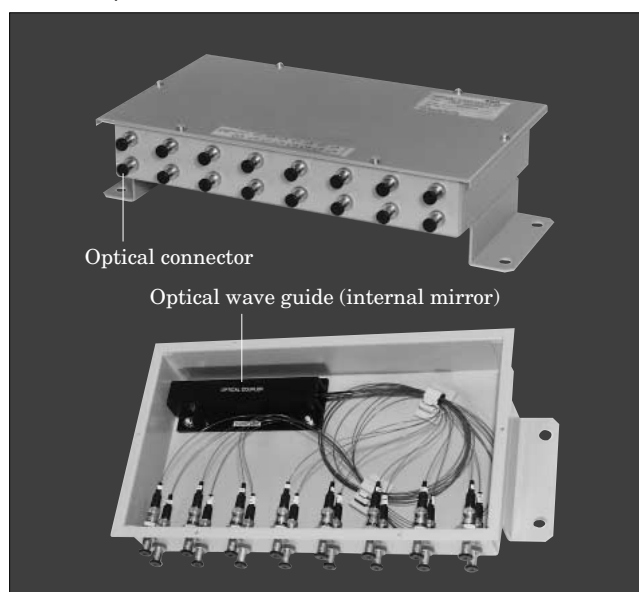
Most of the power sources for field devices are built-in lithium batteries. As a result, since a external power line is unnecessary for each device, the field devices are insulated.

2.2.2 Optical star coupler

An optical star coupler is an optical device used in the field without power. The role of the optical star coupler is to transfer multi-channelled signals from each device to the host device through one optical fiber, and on the other hand, to distribute signals from the host device to the field devices. Figure 2 shows the external and internal construction of the optical star coupler.

The optical star coupler has 16 optical connectors

Fig.2 External and internal construction of the optical star coupler



and it can connect a maximum of 16 field or host devices. The optical signals input from each optical connector are reflected by the internal mirror and then are output from all the optical connectors.

2.2.3 Electro/Optical fieldbus converter

The E/O fieldbus converter mutually converts electric and optical signals of the fieldbus. The external view is shown in Fig. 3.

Power is supplied to the converter together with an electric fieldbus signal. The converter is mounted in the control room with the host device and acts as an interface between the field device and the host. The converter has been developed by Fuji Electric and MTL (Measurement Technology Limited) which is a barrier manufacturer in the UK.

2.2.4 Host device

The host device is a distributed control system (DCS) or a personal computer. An interface unit for transferring and detecting the fieldbus signal is mounted on the host device. The host device is common to both electrical and optical signals from the field device.

2.2.5 Optical fiber cable

In addition to the required transfer characteristics and economics for practical applications, it is also important that the optical fiber for the optical fieldbus have a large diameter for easy handling and easy assembling of the connector in the field.

As a result, the fiber and the connector use two

Fig.3 External view of E/O fieldbus converter

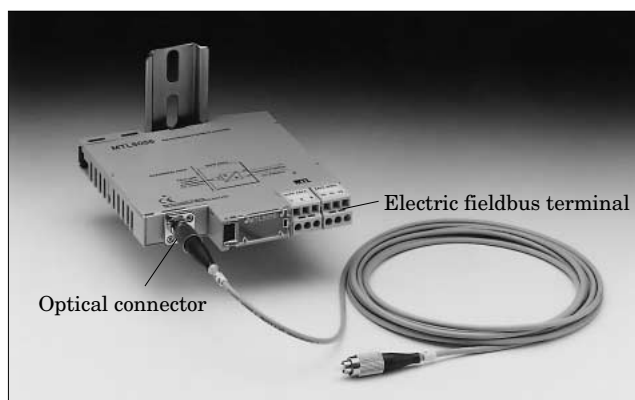
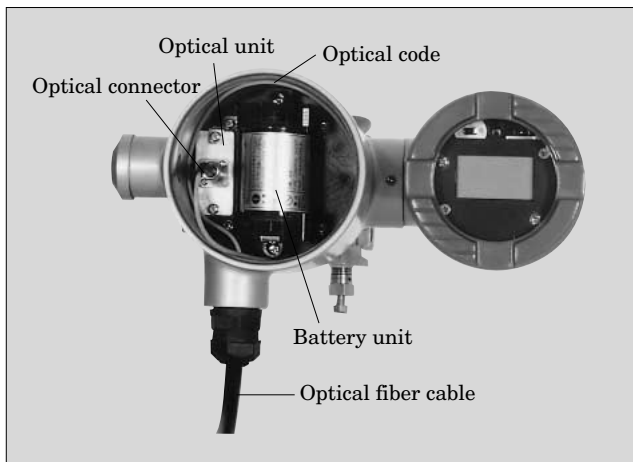


Table 1 Optical fiber cable for optical fieldbus

Optical fiber		Optical loss and transmission distance	Assembly ease of optical connector	Use and remarks
Type	Core/cladding			
Silicate optical fiber	50/125μm	Optical loss : low Transmission distance : long ↑↓	Difficult ↑↓ Easy	○ Computer communications ○ LAN, PLC communications for control system
Silicate optical fiber	62.5/125μm			Utilized for optical fieldbus (optical loss of 4dB/km at max. distance of 1.2km)
Silicate optical fiber	100/140μm			Introduced for optical fieldbus (optical loss of 6dB/km at max. distance of 0.7km)
Plastic cladding fiber (PCF)	200/230μm	Optical loss : high Transmission distance : short		
Optical connector : FC connector or ST connector Cable type : optical cord assembly type				

Fig.4 Example connection of optical fiber



types of silicate and plastic cladding as shown in Table 1, and two types of FC and ST connectors.

The fiber has an optical cord assembly type construction and is connected to an optical connector in the terminal box of the field device. Figure 4 shows a connection diagram of the optical fiber.

3. Features of the Optical Fieldbus

The optical fieldbus system has optical transmission features in addition to features of the fieldbus.

3.1 Digital communication

The fieldbus is the infrastructure technology of an instrument control system which is able to connect to and communicate with field devices as a DCS (distributed control system) host device. The fieldbus is expected to realize various intelligent functions which are impossible to achieve with the conventional 4 to 20 mA analog communication.

Communication among the field devices enables signal detection and control operations that will make possible the realization of field distributed control and a high-level device maintenance function.

3.2 Multi-drop connection

The conventional 4 to 20 mA analog communication requires a pair of cables for each field device, due to a point-to-point connection structure between the field and host devices.

Because multiple field devices can be connected with one bus, the fieldbus has the advantage of eliminating the signal cable and making the wiring more efficient. The topology (connection configuration) is based on the bus configuration and can also incorporate tree or split type configurations for the electric fieldbus.

3.3 Excellent transfer characteristics

In order to transfer the digital communication properly, the fieldbus uses software techniques such as

error control to prevent noise or distortion of the signal waveform. Since the signal transmission medium for the electric fieldbus is wire, there is no method to completely eliminate external electromagnetic noise.

However, a suitable cable has been selected and the cable route has been designed to reduce the noise. Because it uses optical signal transmission, the optical fieldbus is not affected by external noise.

3.4 Resistance to lightning

Since the electric fieldbus is connected to multiple field devices on every bus, damage by lightning is considered more serious than with analog transmission. In addition to connecting a lightning arrester as before, the type and number of connecting devices for each bus are limited in the system design stage.

On the other hand, many devices of the optical fieldbus are electrically insulated and well protected against lightning.

3.5 Intrinsic safety

To satisfy the intrinsic safety (IS) of the electric fieldbus, one barrier is connected to each bus.

Although the fieldbus standard specifies that a maximum of 32 devices can be connected to each bus, that number is limited due to the limited input current. Moreover, the state of actual connections must be estimated to decide whether to satisfy the IS. Therefore, the number of devices that can be connected to the fieldbus depends on the manufactures and types of devices.

When using optical devices, no limitation is imposed on the number of connectable devices, recognition that each device satisfies IS. Most of the devices are able to satisfy IS without barriers, as they are activated by internal batteries with no external power supplies.

3.6 Duplexed transfer line

In the case of the optical fieldbus, it is possible to duplicate the optical cable trunk line (optical cable between the optical star coupler and control rooms) and the host device by using two channels of the optical star coupler connector. The connection of multiple fieldbus devices is an economical advantage that is compatible with improved reliability.

Figure 5 shows the construction of a duplex optical fieldbus system.

4. Development and Features of the Optical Fieldbus

4.1 Development

A summary and specifications of the fieldbus being developed are listed below.

4.1.1 Pressure and differential pressure transmitter

The gauge which measures various fluids is a fine precision, electrostatic capacitance type and is a differ-

ential pressure transmitter (Fig. 6).

The transmission protocol is based on the Fieldbus Foundation Standard, and on the function block that realizes interoperability between devices.

The gauge is designed for low power consumption by using a power management controller which controls each device by regulating the power supply and supply clock.

(1) Configuration

The device consists of a sensing unit for pressure measurement, an amplifier unit for signal processing and communication of the pressure output, an optical unit for transferring and detecting the optical signal, a display unit for pressure, and a power unit for stabilizing the power source. These are all driven by a built-in lithium battery (Fig. 7).

(2) Specifications

- (a) Accuracy rating: $\pm 0.1\%$
- (b) Ambient temperature: -30 to $+70^{\circ}\text{C}$
- (c) Power source:
built-in lithium battery (1 battery)

Fig.5 Configuration of optical fieldbus duplexed system

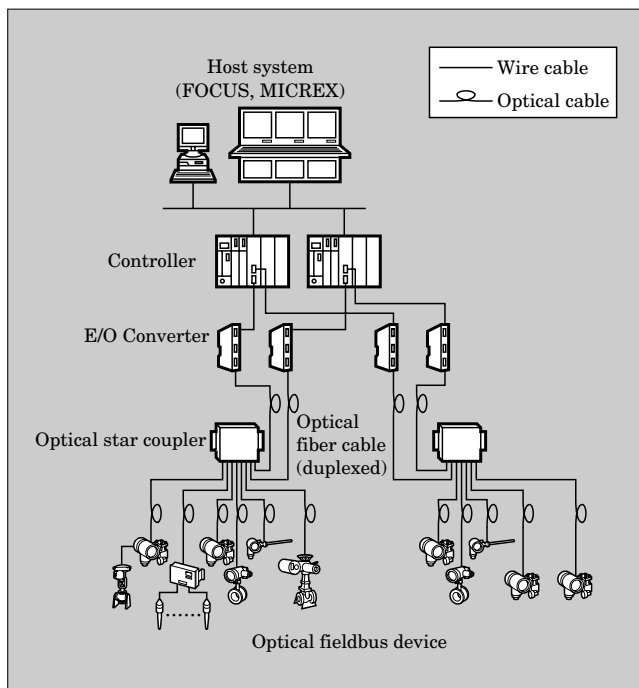


Fig.6 Exterior of pressure transmitter



(d) Measuring range:

- gauge pressure; 1.6 to 50,000 kPa
- differential pressure; 0.1 to 3,000 kPa

(e) Explosion-proof: intrinsic safety

4.1.2 Temperature converter and multi-point temperature converter

The temperature converter (for 1 point) and multi-point converter (for max. 8 points) connect to an optical fieldbus system which detects signals from 1 or a maximum of 8 measuring points by a thermocouple or resistance bulb sensor. An external view of the multi-point temperature converter is shown in Fig. 8.

The multi-point temperature converter has a diagnostic function that detects sensor disconnections and processes alarms for the function block. The multi-point temperature converter multiplexes temperature data of a maximum of 8 points and is able to transfer that data through a single optical fiber to the host.

(1) Configuration

The input signal is detected by a standard AI function block (Fieldbus Foundation Standard) after conversion by the high precision A-D converter in the built-in microprocessor. Single point and multi-point

Fig.7 Internal configuration of optical fieldbus transmitter

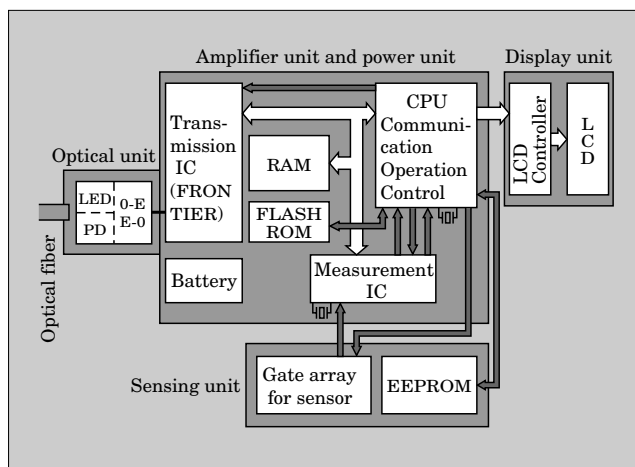
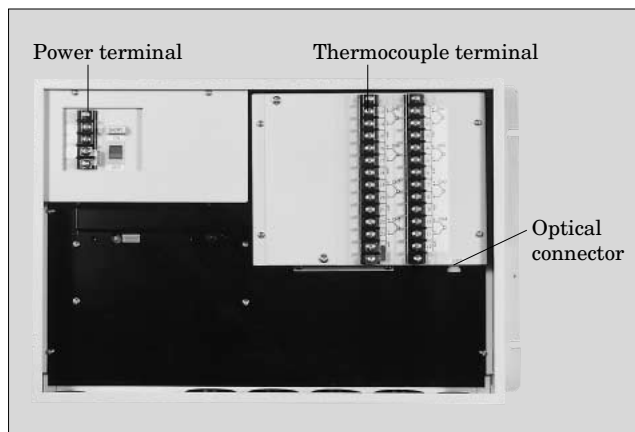


Fig.8 Configuration of multi-point temperature converter



temperature conversion is powered by a built-in battery and an external power source respectively.

(2) Specifications

- (a) Power source:
 - single point temperature converter;
 - built-in lithium battery (1 battery)
 - multi-point temperature converter;
 - 24VDC, 100/115/220VAC
- (b) Measuring range: -200 to $+1,200^{\circ}\text{C}$
- (c) Applied sensor:
 - thermocouple or resistance bulb
- (d) Explosion-proof: intrinsic safety

4.1.3 Optical-pneumatic converter

The converter drives a diaphragm type control

valve pneumatically (20 to 100 kPa) in response to the indicator input through the optical fieldbus (Fig. 9).

As the converter needs no external power source, it is able to realize the IS structure by itself and has a burn out function if the input fails and a function to read back the output.

(1) Configuration

The converter is composed of a control unit for communication and control, an electric-pneumatic pressure converter unit that pneumatically converts the output and a feedback sensor to measure the output pressure. All of these units can be driven by the internal lithium battery.

(2) Specifications

- (a) Pneumatic output: 20 to 100 kPa
- (b) Power source: built-in lithium battery (1 or 2 batteries)
- (c) Explosion-proof: intrinsic safety

4.1.4 Optical signal repeater

In the case of long transfer distance between the field device and receiving unit, the repeater is used as an optical amplifier.

In addition to improving distorted signals, the repeater sends out an amplified optical signal with standard intensity (-40dBm to $+13.5\text{ dBm}$) that decreases due to the long transmission length.

(1) Configuration

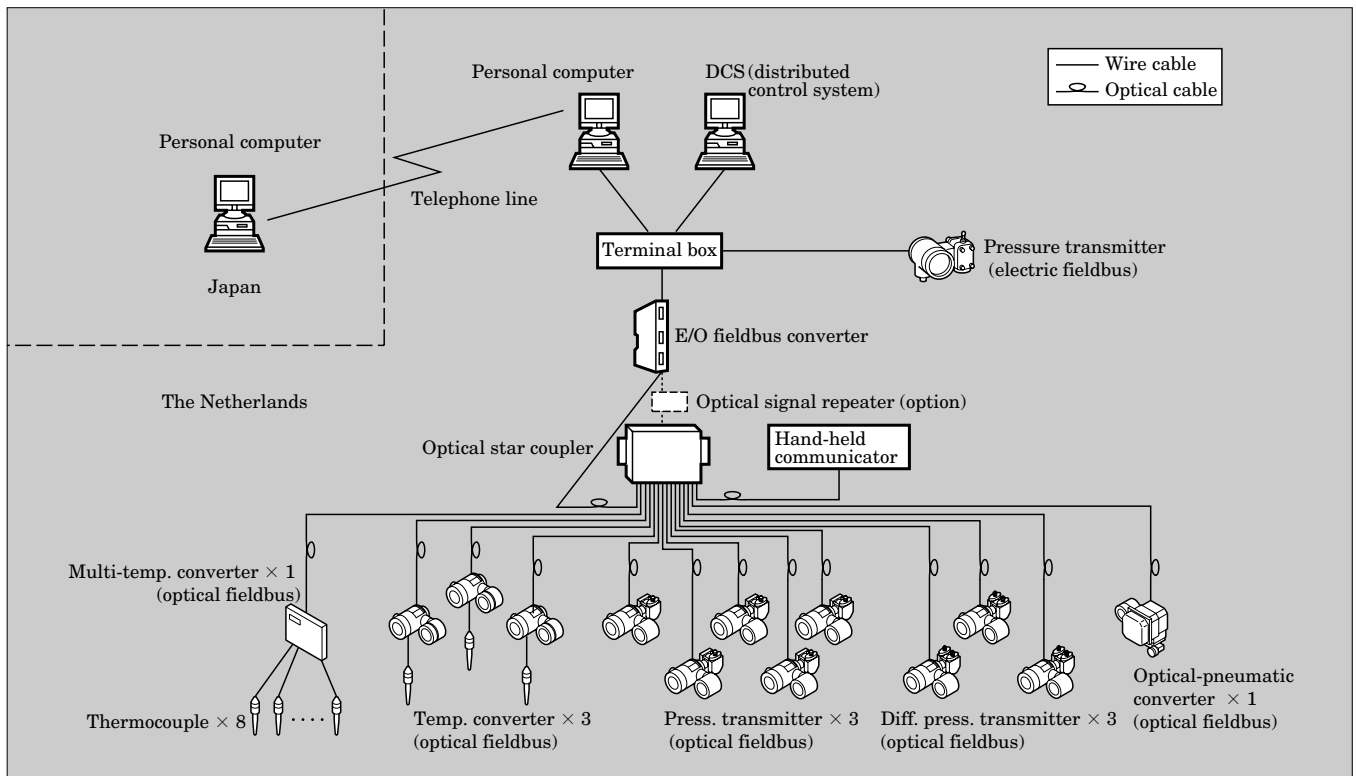
The optical signal repeater is composed of following three functional parts.

- (a) An O/E converter that converts optical signal input to an electric signal

Fig.9 Exterior of optical-pneumatic converter



Fig.10 Configuration of field demonstration test system



- (b) A logic circuit that improves the quality of converted electric signal.
- (c) An E/O converter that converts the output signal back to an optical signal
- (2) Specifications
 - (a) Input and output signal:
optical fieldbus digital signal
 - (b) Transfer distance:
Max. 7km between fieldbus and host device
 - (c) Power source: 24 VDC (20 to 30 VDC)
 - (d) Ambient temperature: -10 to +50°C
 - (e) Explosion-proof: intrinsic safety

4.2 Future developments

The devices introduced in this paper are fundamental for plant construction and will be arranged into a product series. A signal converter to convert the conventional signal (4 to 20mA, 1 to 5V) to optical fieldbus signals and a HHC (hand held communicator) will be considered in future products.

Future goals include developing an optimal maintenance tool to operate these functions completely, to accumulate the know how and maintenance for communication analysis, and to "build-up" the operator. Promoting the wide use of the fieldbus is one means to achieve the quick and practical use of these functions.

5. Field Trial for the Optical Fieldbus

At present, plans are progressing for a field trial of the optical fieldbus with Chiyoda Corporation and Shell, a major oil company, at SRTCA (Shell Research

and Technology Center in Amsterdam, Shell International Oil Products B.V.). Figure 10 shows the construction of the evaluation system. The ease of setting up field devices, optical cable characteristics, system functionality and reliability, and practical applications for users will be evaluated more thoroughly from October 1997 to June 1998.

6. Conclusion

This paper describes features of the configuration and specifications developed for the optical fieldbus system.

Fuji Electric presented the fieldbus at the ISA TECH/97 exhibition in the USA in October 1997 and at INTERMAC/97 in Japan. The practical field test of the optical fieldbus system is the last stage before production. Fuji Electric will continue to develop the fieldbus for practical applications.

References:

- (1) IEC 1158-2, Fieldbus Standard for Use in Industrial Control Systems-Part2: Physical Layer Specification and Service Definition, paragraphs 15-18, (1993).
- (2) N. Tsuji, N. Kanzaki and S. Kuroiwa: An Advanced Optical Fieldbus Instrument System Using 16×16 Reflection Type Optical Star Coupler and Low-Powered Transmitter, ISA/95 Advanced Instrumentation and Control Vol. 50, Part 2 p. 755-764 (1995).
- (3) InTech: Fuji Develops Optical Fieldbus System, Feed-forward p. 11 (Dec/1997).



Open Integrated Instrumentation and Control System “FOCUS”

Yoshinori Inoue
Yutaka Yoshida

1. Introduction

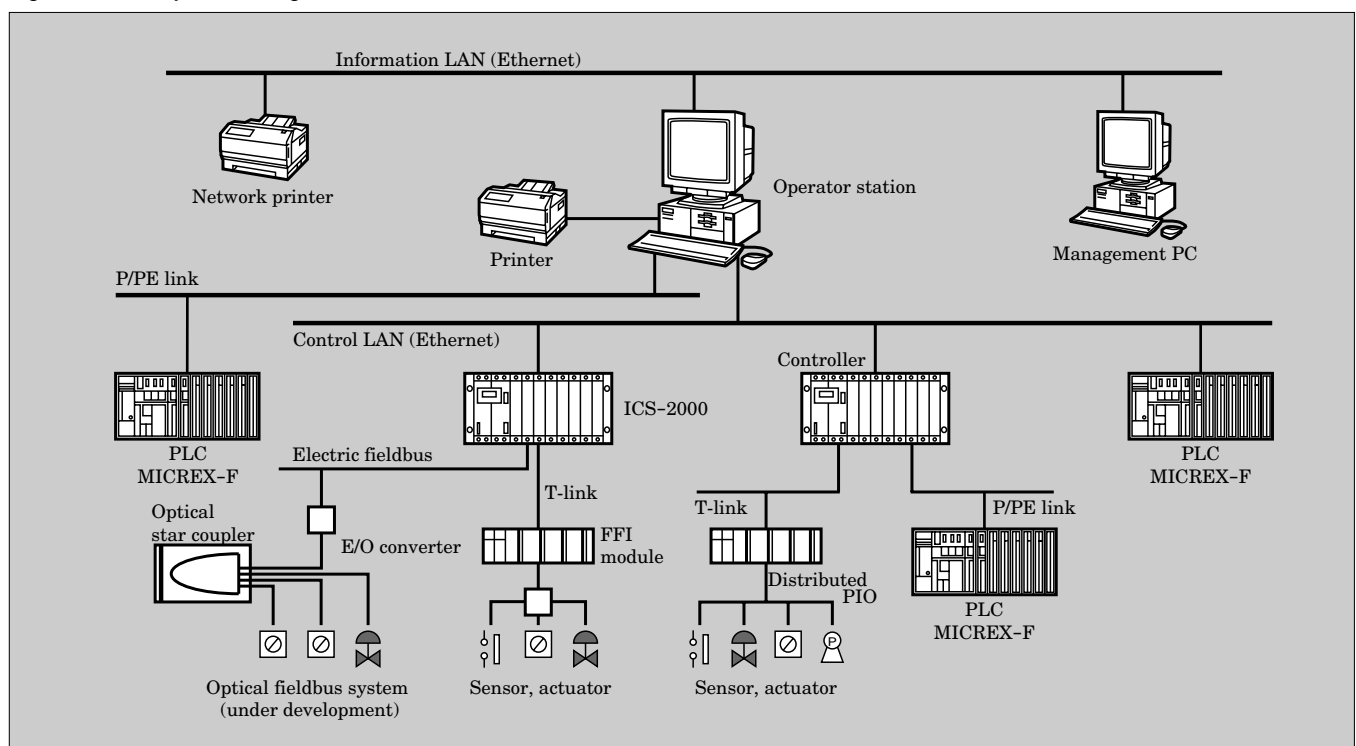
Recently, there have been many advances in plant supervisory control systems. These objective plants are integrated with physical systems, and are constructed to minimize input, the internal flow of substances, and the required energy to obtain the maximum output. Supervisory control systems are required to manage such plants for effective operation and to achieve maximum productivity with a minimum number of operators. Prediction and estimation prior to the commencement of the phenomena and operation based on the operator's knowledge must be tied to the production of excellent results.

For this purpose, the information level must be upgraded to a higher level than conventional plant supervisory control equipment. Furthermore, the system must be constructed at a reasonable price.

Harmony between the scheduling and manufacturing systems as well as the utilization of general-purpose products provides the solution. The role of the vendor is to closely connect people with workplace information and the world inside the computer. At present, owing to the improvement of functions and performance of the personal computer (PC), the utilization of PCs has been spreading rapidly from office to manufacturing workshop environments. Graphical human interfaces that are highly expressive and open information and communication functions have become readily available in the field of instrumentation and control. The introduction of advanced systems has become easy even in spite of the severe economical situation and low investment in equipment.

Development of new control system configurations that utilize PCs is also in demand. The range of applications must not only include small-scale systems

Fig.1 FOCUS system configuration



but also systems of any size. In the following, the open integrated instrumentation and control system “FOCUS” (Fuji Open Control Universal System) developed based on the concepts of “right sizing” and “right selection” is described.

2. Configuration and Features of the System

2.1 Configuration of the system

Various systems can be configured by combining PC related open components and controllers.

- (1) A configuration of the system is shown in Fig. 1. Systems can be configured from a minimum of one operator station with one controller to a maximum of six operator stations with eight controllers. The operator stations and controllers are connected by the control LAN (Local Area Network) (Ethernet^{*1}). The DCS (Distributed Control System) controller ICS-2000 and programmable controller (PLC) MICREX-F are connected on the same Ethernet and are able to share the control functions. The MICREX-F can be connected to the P/PE link.

The information LAN (Ethernet) enables data links with other systems and allows integration with manufacturing, logistics and maintenance systems. Furthermore, connecting a network printer to the information LAN enables one printer to be shared among multiple operator stations.

- (2) A client server system can be configured with FOCUS at its core. The server and controllers are connected by the control LAN, and the server singularly controls the application program and process data. Multiple client operator stations are connected by the server and information LAN. The application program with singular control enables the supervision and operation of different facilities by multiply operators using the singular control data.
- (3) The remote connection configuration of an operator station is shown in Fig. 2. The local operator stations and remote operator stations are connected by telephone or ISDN lines. The same operation and supervision that are possible onsite can also be performed at a remote office. The supervision of image display from the site monitoring terminal camera as well as the supervision and operation onsite by the terminals are possible using remote connection, mobile computing and wireless techniques.

2.2 Operator stations

- (1) An IBM PC/AT^{*2} compatible PC is used as the operator station. Windows NT^{*3}, having an excellent user interface and high reliability is utilized as the OS (Operating System). FA PCs can be utilized in systems requiring higher reliability. FA PCs are able to withstand

the environment and have been designed for continuous 24-hour operation.

- (2) Input devices can be selected based on system requirements and consist of the following: standard keyboard, mouse, touch panel and application keyboard.
- (3) Console desks are provided so that installation can be performed in a conventional control room without any feeling of disorder.
- (4) Reflecting the experience of DCS, easy to use displays are installed for supervision and operation. The list of supervision and operation displays is shown in Table 1. Display examples are shown in Figs. 3 and 4. The plant display is

-
- *1 Ethernet : A registered trademark of Xerox Corp., USA
 *2 PC/AT : A trademark of International Business Machines Corp., USA
 *3 Windows NT : A registered trademark of Microsoft Corp., USA
-

Fig.2 Remote connection to an operator station

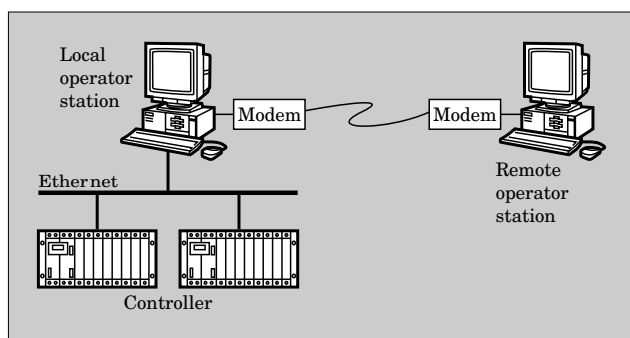


Table 1 List of supervision and operational panels

Plant panel	512 points × 100 pages	Graphic display for piping or electrical diagram of the plant
Group panel	8 tags × 384 pages	Group display for max. 8 instrument modules
Loop panel	1 tag × 2,304 pages	Detail display for each instrument module
Alarm panel	20 points/display page (scroll display 2,000 points)	Alarm message indicating the time of occurrence
Historical message panel	20 points × 100 pages	Historical operation message
Annunciator panel	32 points × 16 pages	Annunciation window display
System condition panel	1 page	System condition display
Trend panel	8 pens × 64 pages	Analog trend display
Logging panel	Daily reports: 20 types Monthly reports: 20 types Annual reports: 20 types	Logging data display

prepared by InTouch^{*4} (an operation and supervision software package of Wonderware Corp.). Instrumentation symbols and parts such as pumps and valves are provided in the software, allowing the efficient preparation of displays. The format for logging data can be created with EXCEL^{*5}. As a result, the processing and graphing of data is easy to implement, and the logging

of data is a visual process.

2.3 Controllers

The ICS-2000 EI (Electric Instrumentation) integrated controller, which is common with Fuji Electric's DCS MICREX-IX series, and the MICREX-F programmable controller can be used. The most suitable model

*4 InTouch : A trademark of Wonderware Corp., USA
 *5 EXCEL : A product name of Microsoft Corp., USA

Fig.3 Example of FOCUS plant display

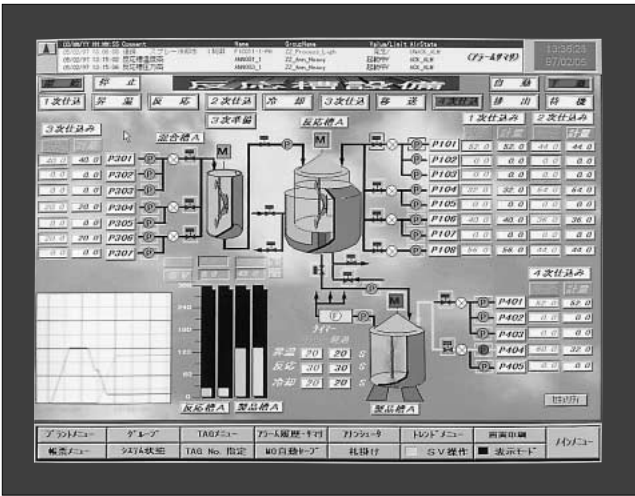
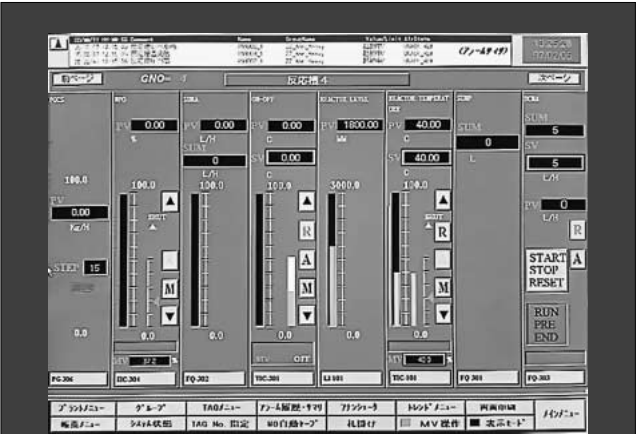


Table 2 ICS-2000 control function specifications

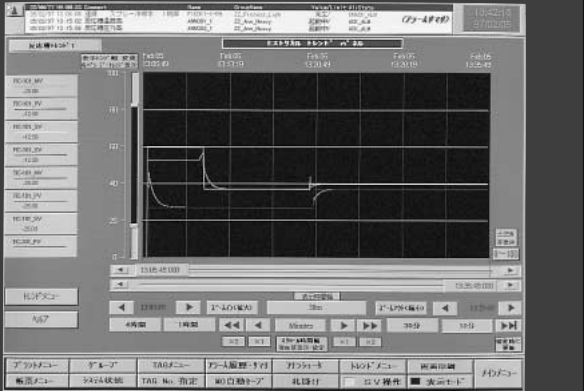
Instrumentation and control	Instrumentation module	288 modules PID controller (position/velocity type), ratio setter, ON/OFF controller, alarm indicator monitor, manual loader, etc.
	Sequence table	64 sequence table
Task management	No. of tasks	5 level, 100
	Interrupt	1ms/10ms, periodic, event
	No. of subroutine	480
Processing speed	Instruction execution time	0.125μs (sequential calculation)
	Calculation period for the instrumentation module	Min. 60ms
	Calculation period for the time chart module	200ms × n times
Memory capacity	Program	256k words
	Data	128k words
No. of I/O points		Max. digital: 8,704 points analog: 2,048 points
Programming method		Ladder, function block, SFC, decision table, instrument loop, time chart
Data type		Bit, word, double word, floating point

Fig.4 Example of FOCUS standard display



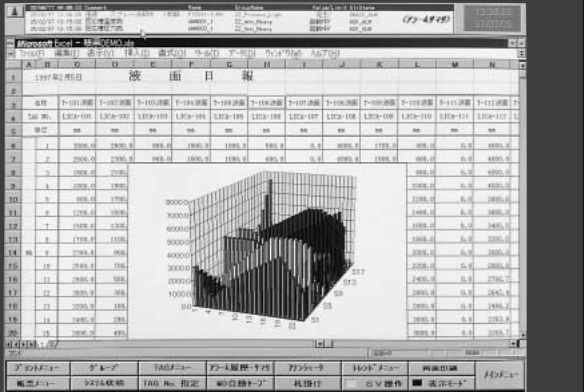
Group panel

8 instrumentation modules introduced from tag menu panel are simultaneously monitored and operated.



Trend panel

Analog trend display with various time scales and measurement ranges.



Data logging panel

Each daily, monthly and annual report is displayed with an EXCEL sheet. Manual input is also available.

can be selected depending on the requirements. Furthermore, the supervision and operation of both ICS-2000 and MICREX-F can be conducted from the same display. Feedback can be controlled by the MICREX-F, and in this case, the instrumentation symbols for both the ICS-2000 and the MICREX-F can be indicated in the same display.

2.3.1 ICS-2000 EI integrated controller

Specifications of the ICS-2000's control functions are shown in Table 2, and its features are described below.

- (1) This controller is common to the MICREX-IX, and is able to execute EI integrated control and fuzzy control that organically combines high-speed sequential control and regulatory control similar to conventional DCS, even in a PC instrumentation system.
- (2) Since this module structure is able to withstand the environment, it does not have to be installed in a custom locker.
- (3) The individual type PIOs (IPUs) are connected by the field LAN (T link). IPU's have a module structure of one point unit and can be installed at distributed sites. The FFI (fiber-optic field instrumentation system) can be connected. Optical field bus compatibility is currently under development.

2.3.2 MICREX-F programmable controller

A system that mainly executes sequence control can be configured at minimum cost. PID control is possible by the PID module or the single loop controller with a T link connection. Furthermore, a software module is provided to perform PID control by software.

2.4 Peripheral devices

Since commercially available peripheral devices for PCs can be used, a system can be configured at a low price as described below.

- (1) Printers, such as a color ink jet printer for alarm printing and a laser printer for data log printing, can be used selectively.
- (2) A CD-ROM (compact disc read only memory) device for the rapid installation of software packages and an MO (magneto-optical) disk device for backing-up and saving the application program and trend data can be used.
- (3) Voiced annunciation can be output from the sound board of the PC.
- (4) Monitoring of the site is possible by capturing the video display via the video capture board.

2.5 Redundancy

Reliability can be improved through utilizing redundancy for the components that configure the system, depending on the application as described below.

- (1) Operator stations are provided in parallel. Even if one station is down, supervision and operation can be continued by another station.
- (2) The ICS 2000 controller is duplicated according to

the required shelf. This system, in which two MPUs execute identical control independently of each other, is called the warm standby system. Data is copied from the operating MPU to the standby MPU at all times, and control is continued by the standby MPU if the operating MPU is down.

- (3) The Ethernet cable can be a duplex cable.
- (4) The T link cable can be a duplex cable.
- (5) The PIO for each I/O module unit can be duplex.

2.6 Engineering

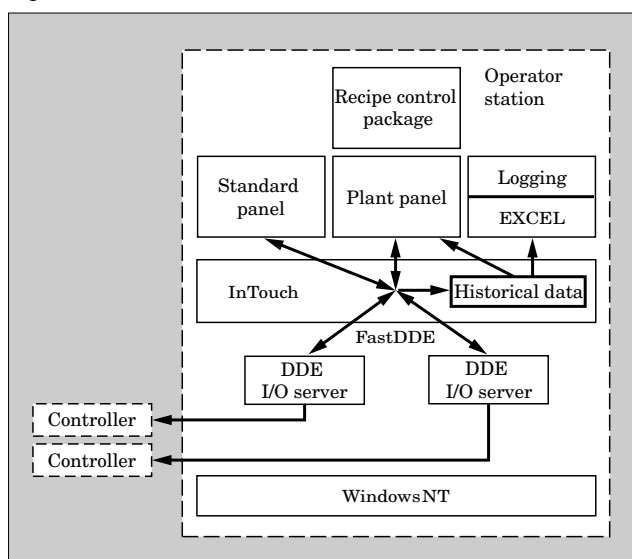
- (1) An intuitive display can be drawn easily on the plant supervision display using graphical animation with InTouch.
- (2) Data display and setting, as well as the variation of shapes and colors depending on the data can be performed without programming.
- (3) The controller program can be created and tested on a PC.
- (4) Programming with various data types such as ladder diagrams, function blocks, SFCs (sequence flow charts), instrumentation loop diagrams, time charts, etc. are possible.
- (5) The defined tags are developed for the tag database of the operator station to increase engineering efficiency.

3. Software Structure

The software structure of the operator station is shown in Fig. 5.

The DDE I/O server executes the transfer of data with controllers. The DDE I/O server uses DDE (Dynamic Data Exchange) to interface with the data. DDE is a transmission protocol developed by Microsoft Corp. to enable the mutual transfer of data between

Fig.5 Software structure



applications running in the Windows^{*6} environment. The transfer of data is possible not only with InTouch but also with other software packages, so it is easy to link data. With InTouch, the DDE I/O server transfers data by Fast DDE, a high-speed DDE.

Data transfer via the Ethernet is possible with the DDE interface. This is an easy means to link data with other systems such as management PCs. Also, a client server system can easily be configured by interfacing DDE through the network.

Various DDE I/O servers are commercially available, and can be connected to PLCs made by other manufacturers.

The standard and plant panels are supported by InTouch, and data can be displayed and set by the tag name without the need to specify the controller address.

Regarding data logging, a macro process in the EXCEL sheet format captures historical data to display and print process data, calculated values and graphs.

4. Examples of System Applications

FOCUS is being introduced into various fields such as chemical, food, pharmaceutical, cosmetic, steel, boiler, incinerator, etc. The motive for these applications is in the features of FOCUS, that is the application of a platform having an open environment to HCI (human communication interface), the use of a controller fitted to system requirements, engineering that is easy to operate, economical merit, short delivery time, and high reliability that is selectable depend-

ing on the application.

Since being introduced, this system has received favorable reviews from users. Several application examples are described below.

4.1 Small-scale EIC systems

The construction of large-scale plants has been decreasing while the construction of mid or small-scale plants, as well as partial modifications, has been increasing in the present market. In the past, small-scale EI control systems were integrated using a DCS such as the MICREX-IX series.

With the introduction of FOCUS, advanced control systems can be realized at a lower cost. The easy to use graphical interface and powerful data management enable highly reliable and safe operation to be guaranteed. System configuration examples using the DCS controller and the PLC MICREX-F are shown in Fig. 6 and Fig. 7 respectively.

In both systems, several hundred PIOs are connected to one controller and high-speed calculation and control is performed. Operation guidance, supervision and operation of the utility, and supervision and operation of the plant are carried out on two sets of HCI. Furthermore, logging of the daily report, monthly report, quarterly report and annual report, and logging of the various control data and the test report are documented based on performance calculations of the plant. Logged data is output by connecting a laser printer for OA (office automation) to the printer port of the information LAN or a PC. The hard copy is output using a general-purpose ink jet printer.

*6 Windows: A registered trademark of Microsoft Corp., USA

Fig.6 Configuration example of a FOCUS small-scale EIC system (DCS controller)

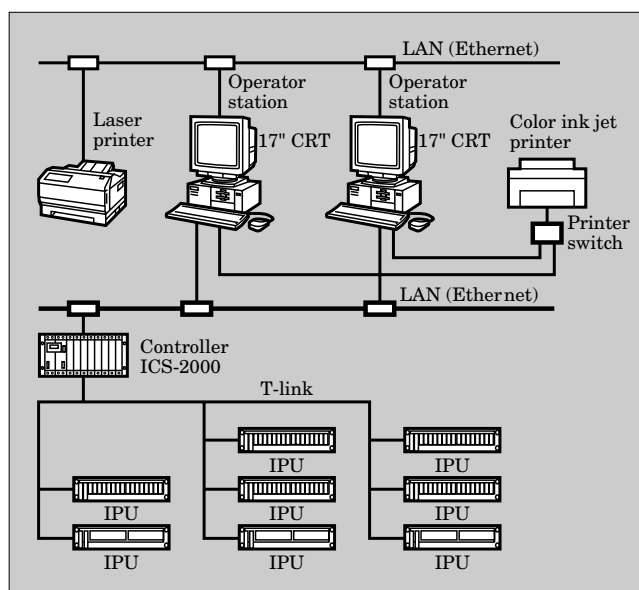


Fig.7 Configuration example of a FOCUS small-scale EIC system (using PLC)

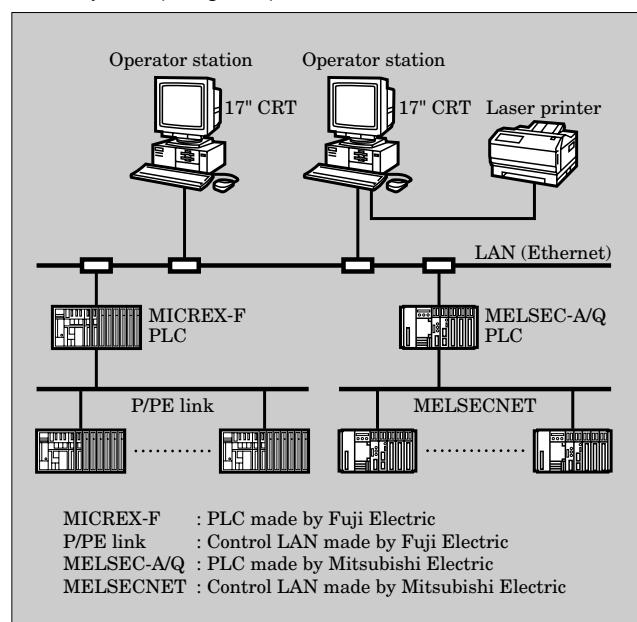


Fig.8 Configuration example of a FOCUS client server system

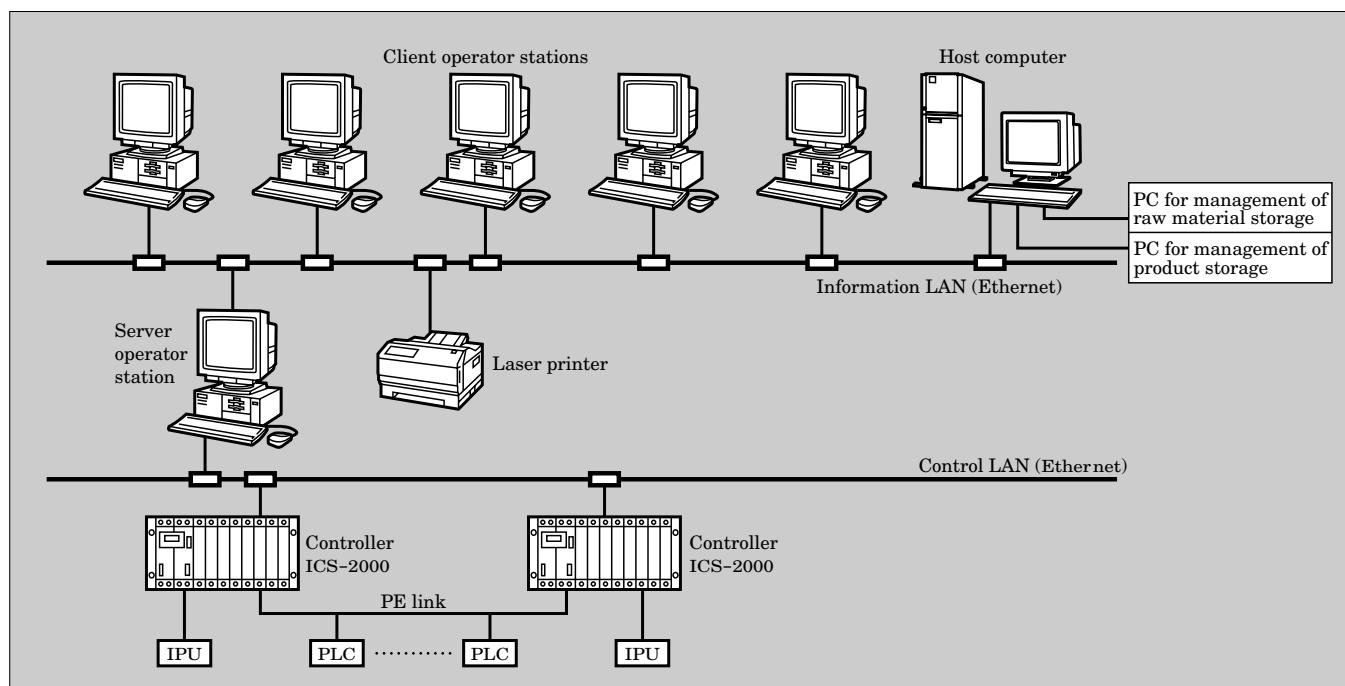
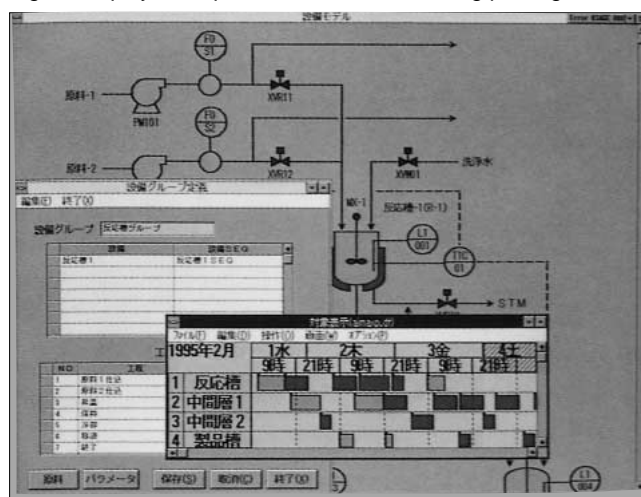


Fig.9 Display example of the batch scheduling package



4.2 Client server system

Since production in chemical, food, pharmaceutical and cosmetics plants varies in product type and quantity, production control information and recipe control information must be transferred to the plant supervisory control equipment so as to ensure that smooth production is continued. Also, the recipe control information must be scheduled suitably based on the production situation.

Figure 8 shows an example of a production control and manufacturing control system configured with the FOCUS client server system.

The on-site process information is singularly controlled by the PC server. Supervision and operation are conducted from the client via graphic display,

group display, annunciator display, historical message display, etc.

The product scheduling system and manufacturing control system, including the raw materials warehouse and products warehouse, are connected by the information LAN. Instructions from the product scheduling system are transferred to the manufacturing control PC server and are then transformed into process instruction values by the AI batch scheduling package and the recipe control package (FLEX-BATCH) integrated into this server. Thus, smooth production is carried out.

Figure 9 shows an example of the batch scheduling display.

The AI batch scheduling package has the following features.

- (1) High-speed scheduling is possible according to the manufacturing order.
- (2) Simulation based on actual result data is possible with the Gantt chart.
- (3) Scheduling close to the actual operation is possible by considering the actual manufacturing results obtained by the link with the FLEX-BATCH.
- (4) An estimation of the trends for each lot can be obtained.
- (5) Optimized recipe data can be automatically prepared for every lot.
- (6) Intelligent alarm output is possible.

By applying these features, the following user benefits can be obtained.

- (1) A shift to operation that matches the delivery time and the manufacturing capability
- (2) Cost reduction by means of equalizing manpower

and utility loads

- (3) Real time, dynamic investigation of the effect on product schedule and actual results due to unexpected accidents
- (4) Singular control of manufacturing information and engineering information

5. Conclusion

The fundamental systems and application examples of FOCUS have been described. FOCUS combines the open techniques related to PCs and the successful DCS techniques to provide a solution for various

control systems. Fuji Electric offers a system that allows the synthetic integration of various control systems and computing by the end users.

Fuji Electric will endeavor for further improvements by applying novel techniques such as OPC (OLE for process control : the communication standard between the control application, field equipment and office application), clusters (a system in which multiple computers, connected via a network, process information while linked to distribute the load and allow substitution in the event of a malfunction), and the Internet to extend the application range, improve reliability and integrate unrestricted systems.



New Technologies for Measuring Instruments

Masayoshi Nakano

1. Introduction

Fuji Electric's measuring instruments have a history of 50 years. During this time, Fuji Electric has developed new technologies and offered new products to lead the industry. Recently in the field of measuring instruments, in addition to improvements in performance and functionality, the following features are being requested: compatibility with various applications, low added installation and maintenance costs, and measures for dealing with environmental problems including the requirements of ISO 14000.

Under these circumstances, Fuji Electric has been developing new unique products for various product groups, based on the following principal concepts.

- (1) To supply products that are well timed to meet the needs of the market timely
- (2) To develop distinctive products by means of evolutionary and unique technology
- (3) To propose a product line for international markets

New specifications have been added to Fuji Electric's field instrument transmitters, which are widely accepted internationally. These new features include a sanitary model, required especially in the food and medical industries, and a small flange model required for level meters in the petroleum and petrochemical industries and also for general use. The total system cost for these products has been revised.

Among the different types of flowmeters, demand for ultrasonic flowmeters is especially expected to increase. Fuji Electric has developed a fixed installation model in addition to the portable model. To satisfy diversified customer's needs, the measuring precision and response characteristics have been improved, as well as performance and functionality, including multi-path and multi-pipe measurement. The electromagnetic flowmeter will be applied to various fields including the water treatment, food processing and petrochemical industries. To support these areas, Fuji's product line has been enriched by developing, in addition to the wafer and flange models, new models such as the sanitary, explosion-proof and surface mount models.

In the field of receiving instruments, Fuji Electric's economical temperature controller has undergone a model change. The new model achieves the following improvements.

- A fuzzy logic control function is attached to improve and extend functionality.
- A smaller front size has been adopted corresponding to the recent smaller size of cubicles and machines.
- The PXZ series, compliant with the NEMA4 waterproof standard, has been developed for the food processing field.

In the recorder market, at the same time as functions are advancing and becoming more varied, user needs remain strong for more economical, and easy to use models. Fuji Electric has developed the "Microjet Recorder-E" series, an industrial-use hybrid recorder that is economical and can be used in the same manner as an analog recorder. This series has been added to the family of inkjet recorders that are able to record and print clearly with high quality, a continuing effort by Fuji Electric.

The market for analyzer devices has become active as these devices are used as a means to reduce the dioxins generated in an incineration plant or are used in relation with ISO 14000. In response, Fuji Electric has developed a new infrared gas analyzer. Its small module construction enables the measurement of a maximum of five components simultaneously by a single unit and is suitable for measuring concentrations of many kinds of gases, including exhaust gas.

This paper will describe details of the above mentioned types of measuring instruments.

2. Field Instruments

2.1 FCX-A series of small flange type transmitters

In recent years, there has been strong customer demand for reduced installation and maintenance costs of devices that measure pressure, flow and fluid levels. To reduce costs, small flange type transmitters, have been mounted directly on small equipment, making instrumentation possible that does not use impulse piping. To meet such requirements of the

Fig.1 Small flange remote seal type differential pressure transmitter



N68-420-7

Table 1 Specifications of the FCX-A small flange transmitter

Item	Group	Level trans-mitter	Remote seal type	
			Differential press. transmitter	Pressure transmitter
Flange sizes			$\frac{1}{2}$ B, $\frac{3}{4}$ B, $1\frac{1}{2}$ B, 2B	
Flange rating			JIS 10, 20, 30K ANSI/JPI 150, 300LB	JIS 10, 20, 30, 63K ANSI/JPI 150, 300, 600LB
Measuring span			3 to 130 kPa 12.5 to 500 kPa	0.05 to 3 MPa 0.25 to 10 MPa
Material of the wetted parts			316L stainless steel, Hastelloy	
Capillary length			1.5, 3, 5 (m)	
Ambient temperature			- 15 to +65 °C	
Liquid temperature			- 40 to +120 °C	
Rated accuracy			0.25%	
Temperature effect (zero drift)			$\pm 1\%$ / 55°C (Measuring span: larger than half of the maximal span)	

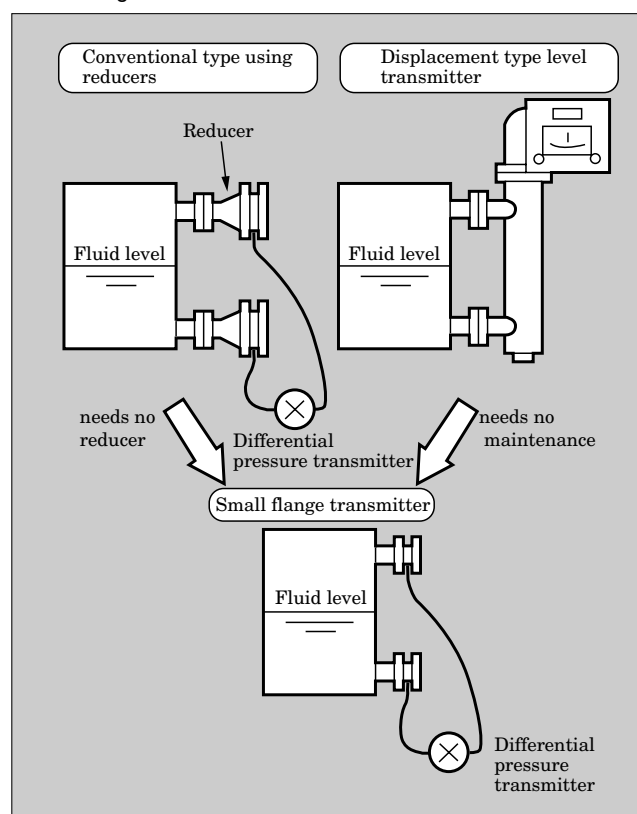
customer, Fuji Electric has developed transmitters with smaller flanges ($1\frac{1}{2}$ B, 2B, $\frac{1}{2}$ B, and $\frac{3}{4}$ B), although most of the conventional flange mount type transmitters have flanges of 3B or 4B.

The following items have either been solved technically or have evolved with the product development.

- (1) By simply changing conventional wetted parts to smaller flange sizes, the highly linear operating range of the seal diaphragm would become too small to be used. Therefore, construction of the wetted part has been optimized, to maintain the necessary linear operating range.
- (2) The wetted part has been constructed such that commercially available gaskets can be used.
- (3) $1\frac{1}{2}$ B and 2B are standard flange sizes. Adapters are applied for smaller size flanges. The application of adapters also enables compatibility with various processes having other dimensions.

Figure 1 shows the external view of the remote seal

Fig.2 Example of fluid level measurement using the small flange transmitter



type differential pressure transmitter, the most commonly used model among small flange type transmitters.

2.1.1 Specifications

The specifications of FCX-A, the small flange type transmitter, are shown in Table 1. Corresponding to such various applications as direct mounting on small equipment or the replacement of impulse pipes, many flange sizes are available.

2.1.2 Example of fluid level measurement using a small flange type transmitter

An example of fluid level measurement using a small flange transmitter is shown in Fig. 2. $1\frac{1}{2}$ B and 2B flanges are generally applied to small tanks. To mount a transmitter having 3B flanges to such small tanks, it was necessary to use a reducer for the connection. However, the newly developed small flange transmitter can be mounted using no reducer, thereby eliminating the reducer cost. To measure fluid levels in a small tank, the displacement type level transmitter has been generally used. The displacement type level transmitter requires regular maintenance because it has a mechanically sliding part. By replacing the installed displacement type level transmitter with the small flange remote seal type, such regular maintenance required for the displacement type transmitter as disassembling and cleaning becomes unnecessary, resulting in reductions of those corresponding costs.

Fig.3 New ultrasonic flowmeter



Table 2 Specifications of the new ultrasonic flowmeter

Item	Specification
Applicable pipe dia.	13 to 6,000 mm (according to the type of sensor used)
Measuring path	Max. 4 measuring paths (according to the type of transmitter used)
Measurable fluid	Homogenous fluid with a turbidity < 10,000mg/L
Measuring range	0 to 0.3 ... 32m/s
Accuracy rating	±1.0% of the rate
Power source	100 to 240 V AC ±10%, 50/60Hz
Input/output signals	4 to 20 mA DC, Integrated output, Input/output status, each 1 point
Indicator display	16 columns × 2 rows, LCD with backlight

2.2 New ultrasonic flowmeter

Following the introduction of the “Portaflow-X” portable type ultrasonic flowmeter in 1995, a new fixed installation type flowmeter has been developed. This new type of flowmeter is summarized below.

2.2.1 Features

(1) Small size and lightweight

Adoption of state-of-art electronics and digital signal processing has reduced the size and mass of the transducer to half that of our conventional products.

(2) Improved anti-bubble characteristics

The application of digital signal processing has improved the anti-bubble characteristics to more than 10 times higher than that of our conventional products.

(3) Excellent temperature characteristics

Excellent temperature characteristics are realized by real-time measurement of the propagation path of the ultrasonic waves and the speed of sound in the liquid to be measured, and by compensating for the affects of liquid temperature and pressure.

(4) A wide variety of products

Fuji Electric has developed 2 types of transducers, a standard type having a single path with a single function and a high performance type capable of multi-

Fig.4 New electromagnetic flowmeter



Table 3 Specifications of the new electromagnetic flowmeter

Item	Specification
Applicable pipe dia.	2.5A to 300A
Electrode material	316L stainless steel, Tantalum, Hastelloy, Platinum, Iridium
Lining material	Teflon (PFA mold), Polyurethane rubber
Measurable fluid	Conductive fluid with a conductivity > 3μS/cm
Measuring range	0 to 0.1 ... 15m/s
Rated accuracy	±0.5% of the rate
Power source	100 to 240V AC ±10%, 50/60 Hz.
Input/output signals	4 to 20 mA DC, Integrated output, Input/output status, each 1 point
Indicator display	16 columns × 2 rows, LCD with backlight

Fig.5 Temperature controller PXZ series



path or multi-pipe measurement.

2.2.2 Specifications

Table 2 shows the main specifications of the new ultrasonic flowmeter of Fig. 3.

2.3 New electromagnetic flowmeter

The new developments in electromagnetic flowmeters have entirely revised this product series. A summary is listed below.

2.3.1 Features

(1) Varied products line

In addition to the wafer type and flange type, the

sanitary type, explosion-proof type and surface mount type have been added to the product line.

(2) Optimized magnetic field design

An optimized magnetic field design minimizes the effect on measurements due to the flow velocity distribution and material composition of adjacent pipes.

(3) Safety for water condensation and submersion

The integrated electronics housing and the terminal box of separate type detectors have two airtight chambers that protect against water condensation and submersion.

(4) Class 3 (JIS) grounding is possible with the explosion-proof type

The housing construction is separated by insulation and a built-in barrier to reduce the cost of class 3 (JIS) grounding for the explosion-proof type flowmeter (patent for new practical design).

2.3.2 Specifications

Table 3 shows main specifications of the new electromagnetic flowmeter of Fig. 4.

3. Receiving Instruments

3.1 PXZ series of temperature controllers

In recent years, temperature controllers have progressed from relatively simple temperature control up to the area conventionally known as process control. Temperature controllers are classified as economic, medium and high performance types. As the application area of the temperature controller widens, greater functionality is required of the controller, including the economic type. Recognizing this tendency in the temperature controller market, Fuji Electric has completely reengineered the economical temperature controller. Specifically, based on the following principals, new models have been introduced for all types including PYZ, which has been the most important model of the Z series temperature controller, PYV and PYW. (See Fig. 5.)

- (1) To enrich functionality and expand the models, while maintaining continuity with conventional models
- (2) To equip all models with fuzzy logic control to prevent overshoot
- (3) To realize easy operability
- (4) To acquire UL, CE-marking and NEMA4X (waterproof standard) certification

Specific developments of the above principle are described below.

3.1.1 Features

(1) Function enrichment and model expansion

(a) Installation of a ramp soak function

For temperature control, sometimes simple program control is desired rather than an exclusive program controller, as has been applied conventionally. This can be achieved at a relatively low price by enriching the functionality.

(b) Model expansion

Adding the PXV3 model, having front dimensions of 48×24 (mm), to the series, has enabled the reduction in size of the control equipment panel, making the entire control equipment more compact. Further, all models have been made compatible with a 24V power source, enabling the use of equipment for which a lower voltage power source is desired.

(2) Fuzzy logic control function as standard equipment

By equipping economical models with the fuzzy logic control function, which has already been well accepted by the market, overshoot has been drastically reduced.

(3) Easy operability

As the functionality of temperature control increases, negative effects have also appeared, such as a drastically increased number of parameters that hinder operability. To prevent this effect, “display” or “non-display” can be selected for each parameter. This provision has dramatically reduced the complexity of operation by selecting “non-display” for unnecessary parameters.

(4) NEMA4X, UL, and CE-marking certification

Approval for such important foreign standards as UL and CE marks has already been obtained. Recently, approval for the waterproof standard, NEMA4X, has been acquired, greatly expanding the applicable fields of the instruments.

3.2 Recorder

Market size of the industrial strip chart recorder is estimated to be approximately 13 billion yen in Japan and 40 billion yen world-wide. In the last few years, this figure has tended to decrease slightly. The recorder has developed, supported also by the advance of technology, from a simple tool for recording to become an important component of the plant operation system. However, currently it is being replaced by PC based control and monitoring systems, which have been driven by recent developments in personal computers and also by the wide spread use of helpful software. Simple operability of the recorder function is desired more than complicated functions.

Fuji Electric's industrial type recorder has a history of approximately 40 years. Especially noteworthy is the “Microjet Recorder”(trade name) which we developed and then introduced to the market in 1991. The Microjet Recorder attracted the attention of users and suppliers of measuring instruments throughout the world. Today, because the inkjet method is superior in several aspects that are difficult for other recording methods to realize, the inkjet method is used widely in many applications including printers for personal computers, plotters for CAD, and industrial printing systems. The inkjet method is a suitable recording technology for multi-point, multi-color and high speed

recording, and because it directly records on chart paper, it can record data clearly and with high quality. The inkjet printing mechanism has a very simple construction and can record and print all types of data using only a single ink cartridge. High-speed ink ejection makes it possible to trace many continuous records with solid lines, the same as with a convention-

Fig.6 Microjet Recorder-E



Table 4 Specifications of the Microjet Recorder-E

Item		Specification
Input system	Recording points	1 or 2 continuous, 6 dotting
	Input signals	12 kinds of thermo-coupling, RTD Pt100, JPt100 DC voltage $\pm 50\text{mV}$ to $\pm 50\text{V}$ DC current 4 to 20mA 10 to 50mA
Recording system	Recording method	Inkjet method
	Recording cycle	Continuous type: 2 to 40 s Dotting type: 30 s
	Paper feed speed	10, 20, 24, 30, 50, 120, 200, 300, 400, 1,000, 1,200, 1,500 (mm/h)
	Chart paper	Z fold 15.08m
	Digital printing	Periodic printing, Scale printing, Channel No. printing, Alarm printing, Burnout printing
	Recording color	1 continuous: violet 2 continuous: channel 1 red, channel 2 blue 6 dots: channel 1 orange, channel 2 green, channel 3 violet, channel 4 red, channel 5 black, channel 6 blue
Digital display		LED, 7 segments \times 6 columns
Display accuracy		$\pm(0.3\% + 1 \text{ digit})$ (per recording range)
Recording accuracy		Display accuracy $\pm 0.2\%$ (per recording range)
Alarm relay output (option)		1 continuous: 2 points, 2 continuous: 4 points 6 dots: 6 points
External control input (option)		Selection of chart speed (including recording start and stop)
Power source		85 to 132 V AC, 180 to 264 V AC
Case construction		Plastic mold
External dimensions, mass		Continuous type: 144 \times 144 \times 175 mm, ca 1.2 kg Dotting type: 144 \times 144 \times 197 mm, ca 1.5 kg

al pen recorder. This small recorder realizes multi-pen recording easily by using only a single cartridge, making it possible to trace several records on the same time axis without relative pen offsets. The above features have made the inkjet method the most important recording technology. Fuji Electric has continuously developed this unique inkjet technology and is pursuing additional developments to meet the market needs of the future.

Fuji electric has now introduced a new model, the "Microjet Recorder-E", to the market (Fig. 6, Table 4). The Microjet Recorder-E is an industrial use hybrid recorder that utilizes inkjet recording technology and is also economical. Since the introduction of the hybrid recorder, every recorder manufacturer has been pursuing higher and a greater number of functions. This has undoubtedly brought much convenience to users. However, on the other hand, we regret not having paid enough attention to the market, where users request conventional models that are economical and easily to use.

The Microjet Recorder-E, based on the concept of providing an economical and easy to use hybrid recorder, has been developed to meet just such requests of the users.

Main features of the Microjet Recorder-E are listed below.

- (1) The Microjet Recorder-E is a conventional analog recorder, that incorporates the hybrid function, and the inkjet method is utilized as in conventional recorders. Therefore, the the Microjet Recorder-E can easily perform not only clear recording, but also various kinds of digital printing.
- (2) Before delivery, various recorder parameters shall have already been set as specified by the user. There is no need for the user to perform complicated start up procedures.
- (3) By utilizing a plastic mold case, this recorder is ultra lightweight, an epoch-making achievement for this class. The Microjet Recorder-E is optimal for mounting in machines and equipment.

4. Analyzer

4.1 Infrared gas analyzer

The infrared gas analyzer is an instrument for measuring gas concentrations utilizing the correlation between the specific infrared wave length that is absorbed by each kind of gas and the rate of absorption proportional to the gas concentration. Infrared gas analyzers are used widely in many areas, including atmosphere control in industrial furnaces or measurement of environmental pollutant components in combustion exhaust gas. Recently, the number of components to be measured at one measuring point have increased according to intensified regulations for environmental protection. Accordingly, the analyzer has been increasing its measuring components. On the

Fig.7 Infrared gas analyzer



Table 5 Specifications of the new infrared gas analyzer

Item	Specification
Measurable components	CO, CO ₂ , NO, SO ₂ , CH ₄ , etc.
Min. measuring range	0 to 100 ppm (CO ₂ : 0 to 50 ppm, CH ₄ : 0 to 500 ppm)
Repeatability	±0.5%FS
Output signal	0 to 1V DC or 4 to 20mA DC
Concentration display	LCD (320 × 240 dots)
Optional functions	Automatic calibration O ₂ concentration display, O ₂ correction output Mean value output for 1 h or 4 h H/L alarm contact output, Range ID contact output, etc.
External dimensions	435 (W) × 177 (H) × 400 (D) mm
Mass	Approx. 20kg

other hand, requirements for smaller instruments have also increased due to lack of installation space.

Fuji Electric, long since an industry leader in the areas of infrared gas analyzers and developing new products for the world, has now developed a new model of the infrared gas analyzer having a smaller size and more components to satisfy the above requirements (Fig. 7). A summary is presented below.

4.1.1 Composition

The infrared gas analyzer consists of an analyzing

unit (optical unit) and a signal processing/displaying unit. Analyzer sensitivity increases with a higher temperature (brightness) of the infrared light source that forms the analyzing unit and a longer optical path in the cell in which gas to be measured is conducted. The analyzing unit of the new analyzer is reduced to 1/10 in volume of Fuji's conventional model by means of the following measures: utilization of a newly developed small and bright light source constructed from a new fine ceramic, utilization of a miniaturized multi-reflectional cell which is constructed from precisely machined parts such that alignment of the optical axis is unnecessary, and utilization of a highly sensitive mass flow sensor.

4.1.2 Performance and specifications

The miniaturized analyzing unit is designed as a module containing a preamplifier that is 70 mm wide, 150 mm high and 300 mm long. A maximum of 3 modules can be mounted on a 19 inch rack type case that is 435 mm wide, 177 mm high and 400 mm long. A maximum of two components can be measured by each module and a maximum of 5 components can be measured by an analyzer simultaneously. It is also possible, with a signal input from an external oxygen sensor, to display the oxygen concentration and to compute the output value, corrected for the measured gas concentration, at standard O₂ concentration.

Dramatic downsizing of the analyzing unit has made downsizing of the entire analyzing unit possible, increased portability, as well as enabled flexible design for a variety of applications. Fuji Electric will continue to expand the application area of this analyzing unit.

5. Conclusion

New Fuji Electric technology and products for measuring instruments has been introduced above. We are convinced that each product, having several advantages due to their unique technology, will be able to meet the needs of domestic and overseas users and to contribute to the world market.

Fuji Electric will continue to develop excellent technology and products to meet future user needs.



An Instrumentation and Control system for Incineration Plants and a Plant Simulator

Kazuhiko Nakaya

1. Introduction

Responding to various needs due to increased waste, environmental requirements and energy problems, incineration plants have advanced to become highly functional, composite and large-scale facilities. To operate these plants safely and efficiently, a distributed control system (DCS) has been aggressively implemented.

The rapid advance in automation of plant control requires operators to quickly respond to non-steady-state operations and plant malfunctions. Therefore,

the task of operator training has recently become an important topic.

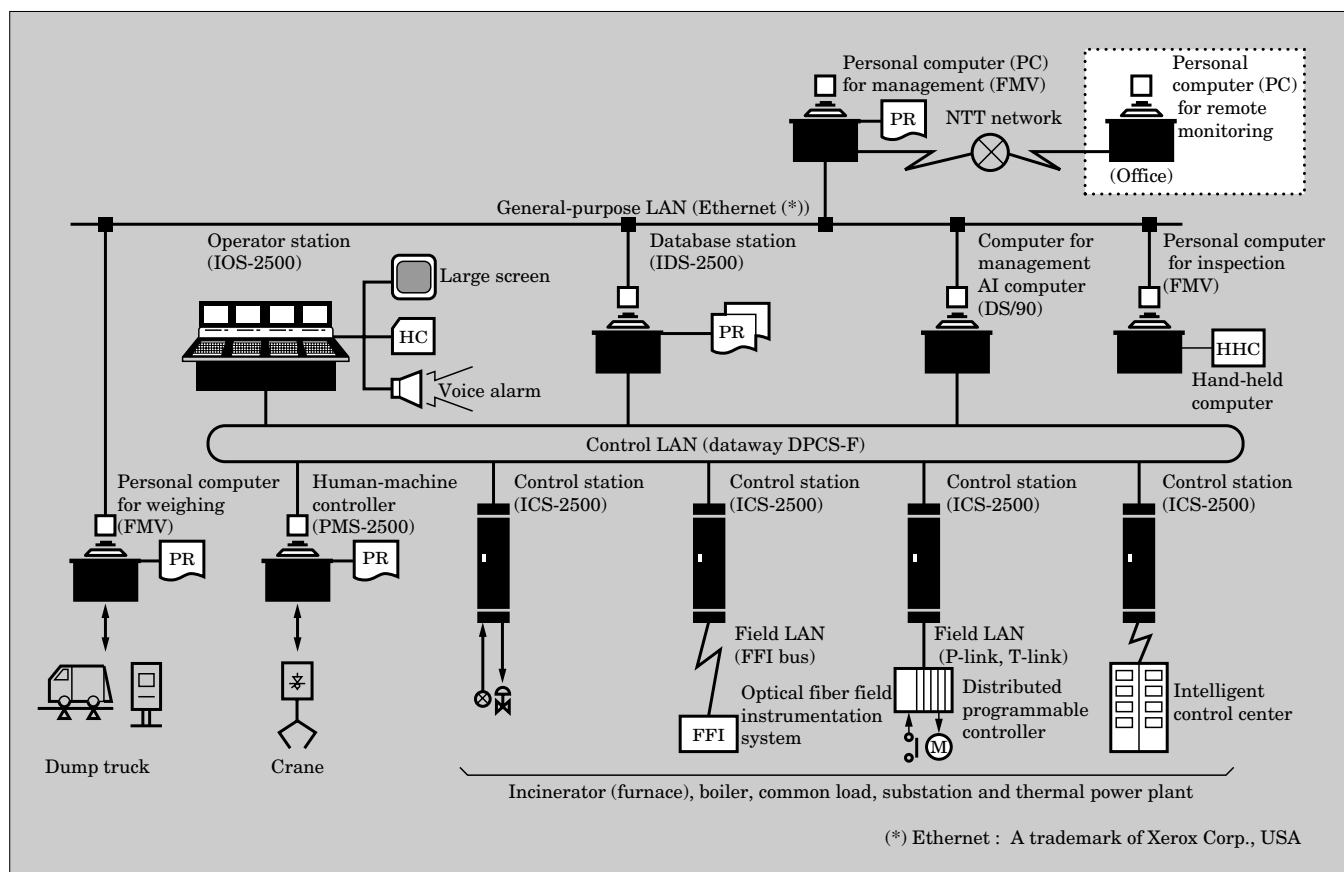
This paper describes the IICS (incinerator instrumentation and control system) and the associated plant simulator that Fuji Electric has recently developed.

2. Recent Incinerator Instrumentation and Control System

2.1 System configuration

As shown in Fig. 1, the IICS (incinerator instru-

Fig.1 IICS system configuration



mentation and control system) is constructed as an integrated system with the controllers of the MICREX-IX series: the IOS-2500 operator station for human-interface, the IDS-2500 data base station for unified management of the plant data, the ICS-2500 control stations for control of instrumentation, the control LAN (local area network) of the dataway DPCS-F, etc. The PMS-2500, capable of stand-alone monitoring, operation, control, and printing, is applied to monitor and control onsite equipment such as cranes and is also connected to the dataway. In addition, to make an integrated system, the computer for management is connected to the control LAN and general-purpose LAN to control plant data and the personal computer for weighing.

2.2 Features of the IICS

The features of the IICS are as follows:

(1) EIC integration

To safely and efficiently operate and control a large-scale and composite factory, this system is capable of monitoring and controlling information concerning electricity (E), instrumentation (I) and computers (C) on the same CRT display, thus forming an EIC-integrated system.

(2) Enhancement of the network

The network consists of three hierarchical layers: the general-purpose LAN, the control LAN, and the field LAN, which perform data communication in each layer and between the layers. This network is a high-speed horizontal and vertical data communication system.

Combined with EIC integration, these features are most useful for automating and integrating control throughout the entire factory.

(3) Enhancement of operation control support system

To reduce the burden of operators, maintenance personnel or factory managers, this system can add the following operation and control support systems.

(a) Preventive maintenance, equipment diagnosis and operation support system

Utilizing AI (artificial intelligence) technology, this system forecasts the occurrence of equipment or process malfunctions, signals a warning output, and performs preventive maintenance of the machines and equipment.

Moreover, the system provides operation support guidance to operators for analysis of the tripping process, probable cause assumption, progress forecast, influence forecast, etc.

(b) Control system for inventory and equipment ledger

This system uses a general-purpose personal computer to control and readily retrieve spare parts and expendable supplies, the detailed specifications of machines and equipment, their inspection history and their parts replacement history.

(c) Inspection data processing system

Using a hand-held terminal to perform onsite inspection before start up of the incinerator and regular periodic site maintenance, this system simplifies inspections and prevents oversight in inspections and mistakes in procedures. The system also connects online with the DCS to link the inspection data.

(d) Remote monitoring system

The system can use a remote terminal to monitor various data (alarm, measurement values, trends, and log data) of the incineration plant via a public communication line, determine the operating situation and any malfunctions (RAS information), and then receive remote maintenance service through the maintenance contract with the DCS manufacturer.

3. Plant Simulator

3.1 Overview of the plant simulator

This plant simulator is a system that simulates the plant operation.

This system provides a means for educating beginner operators, caused by a shortage of skilled engineers, and helps operators acquire skills through an efficient learning plan. This system not only simulates the dynamic performance and behavior of processes, but also improves and maintains knowledge and skill for implementing appropriate measures against accidents or failures that cannot be experienced during normal operation. This system has two kinds of models, the learner model and the plant model. The learner model helps identify the cause of mistakes by a trainee and determines the level of his understanding. The plant model consists of a dynamic performance model, a piping system model, and an equipment model. In addition, the system provides for a learning plan according to the training purpose and the level of understanding of the trainee.

3.2 Role of the plant simulator

(1) Support for cause analysis when a malfunction occurs

When a malfunction occurs, the plant simulator reproduces historical trend data and provides analysis support.

(2) Support for training of plant operation

The plant simulator not only simulates the dynamic performance of the process but also generates a pseudo-malfunction to help the operator determine the behavior of the plant. In this manner, the operator is trained to restore operation after a malfunction.

(3) Support for monitoring and operation by the operator

Based on the amount of manipulation by the operator, the plant simulator uses the plant model to simulate possible behavior. Thus, it supports monitor-

ing and operation by the operator.

3.3 Hardware and software configuration of the plant simulator

The trainee uses the plant simulator in an environment that provides the feeling of being connected to

Fig.2 Hardware configuration of the plant simulator

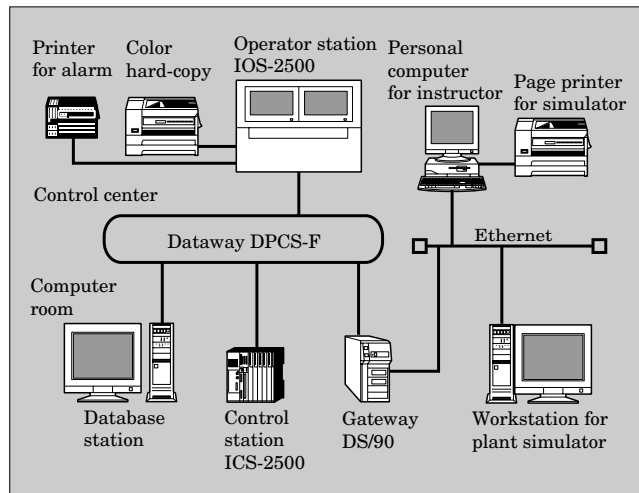
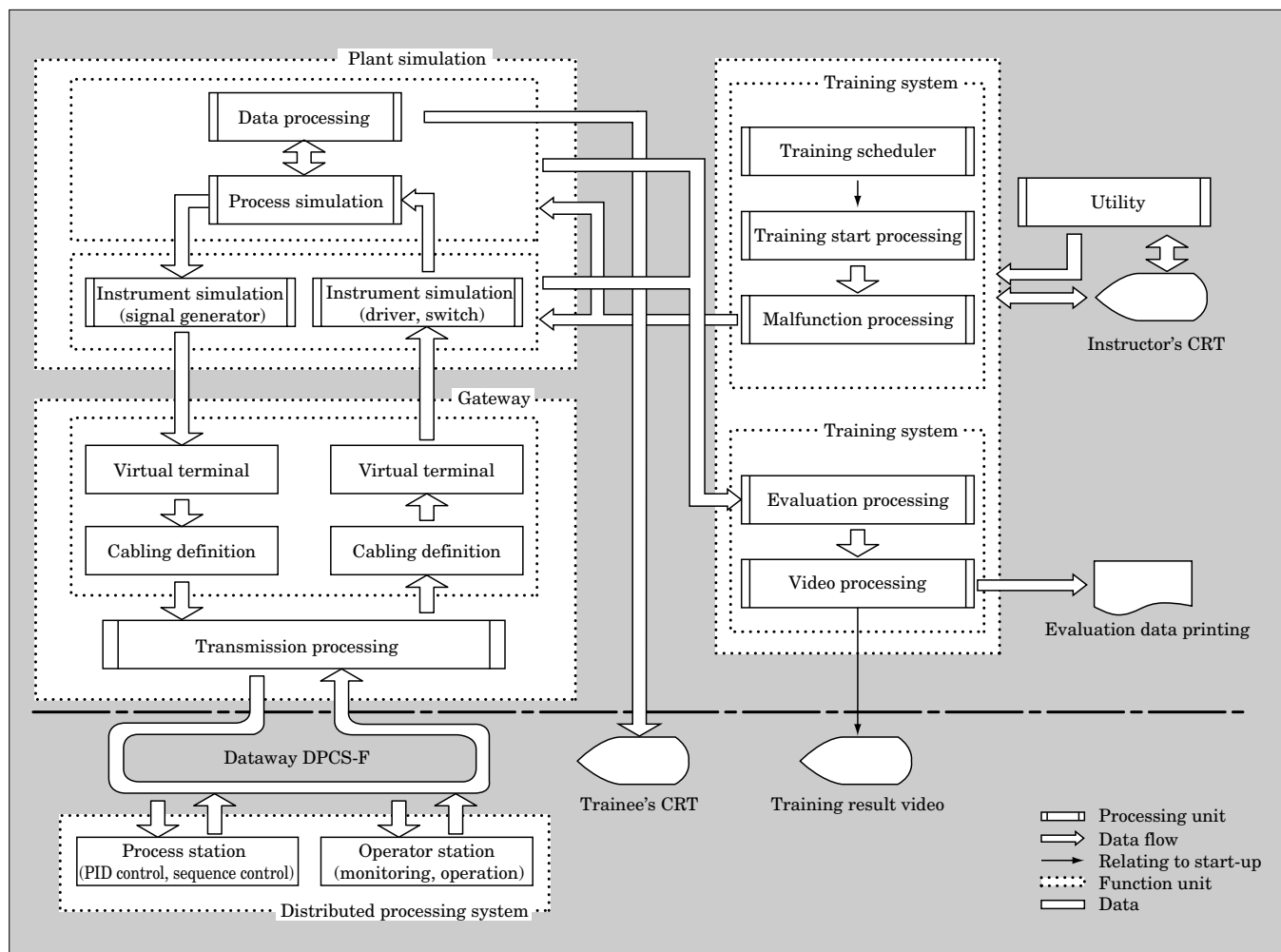


Fig.3 Software configuration of the plant simulator



the actual DCS. The trainee controls the plant from the DCS screen in the same manner as actual operation. The object plant is simulated as a plant model in the computer, and the trainee is trained as if he were controlling the actual plant.

Additionally, the plant simulator has a terminal for the instructor to control and evaluate the training. Figure 2 shows the hardware configuration and Fig. 3 shows the software configuration.

3.4 Contents of training

The playback function of the plant simulator permits the operator to repeat past training. This makes it possible to confirm improvements in operation technique or to intensively practice certain operations that require skill.

The items for operation training are as follows.

(1) Training for steady-state operation

The following items are examples of training in response to malfunctions in steady-state operation.

- (a) High boiler drum pressure
- (b) High concentration of exhaust gas NO_x
- (c) High or low quantity of steam generated
- (d) Hopper bridge

- (e) Commercial electric power bridge
 - (2) Training for serious malfunctions
- The following items are listed as training for emergency and serious malfunctions that halt plant operation.

- (a) Trip of the steam turbine
 - (b) Trip of the gas turbine
 - (c) Trip of the blower
 - (d) Trip of the induced draft fan
 - (e) Trip of the commercial electric power
 - (3) Training for non-steady-state operation
- This training includes monitoring and operation for automatic start-up and shut-down of the plant as well as operation in response to congestion.
- (a) Boiler start-up and shut-down
 - (b) Incinerator start-up and shut-down
 - (c) Steam turbine start-up and shut-down
 - (d) Gas turbine start-up and shut-down

3.5 Control function of the simulation

This function combines a plant model with a real plant training simulator system. The plant model is constructed with the program SimuLink^{*1} that runs on MATLAB^{*2}, a numerical calculation and control analysis program, to model and simulate a dynamic system.

Construction of the plant model with MATLAB is described below.

To use a plant model constructed by MATLAB with the simulator, a source code generator program RTW (real-time workshop that runs on MATLAB) produces the C source code.

MATLAB constructs the plant model and produces the C source code for the simulator.

- (1) MATLAB extracts variable names used by the plant model and generates the block name table. This block name table links the variables of the plant model with those of the simulator.
- (2) The C source code generated by MATLAB can be activated with Windows NT^{*3}.

This plant simulator system executes items (1) and (2) above.

3.6 Control function for training

This control function performs operation and settings by the instructor.

3.6.1 Operation by instructors

- (1) Operation function for training

The time span, that is the progress speed of the simulator, can be selected for training from 1/10 to 10 times the actual speed. The state of the training model is changed with operation buttons for start, stop,

pause, restart, and playback. In addition, the operation function can perform training by generating malfunctions via manual operation from the instructor instead of a standard training scenario.

- (2) Instructor's name control function

This control function selects and adds instructor's names, and also keeps track of the related trainee's names.

- (3) Trainee's name control function

This control function selects and adds trainee's names and also keeps track of related training results, evaluations, and scenarios.

- (4) Plant model control function

A file name which the actual system can use and control is selected and specified as the model for the plant simulator.

- (5) Training scenario control function

This control function sets the training scenario for each model and can sequentially generate malfunctions corresponding to each training item. The control function also keeps track of the names of the training scenario and selects and executes the training scenario.

The instructor can also generate malfunctions and execute training by selecting only the initial state, instead of using the training scenario.

- (6) Malfunction control function

This control function displays a list of malfunctions for the selected plant model and training scenario, and also adds or deletes the malfunctions. (These are additions or deletions to the training scenario, not the plant model.)

- (7) Initial state control function

This control function selects an initial state for each plant model and training scenario. This function obtains data for the initial state by using the spot saving function after starting the plant model and establishing a stable state.

- (8) Trend display function

This display function displays the trend graph of process variables showing the operation of this simulator and operation variables that the trainee manipulates.

3.6.2 Operation by trainees

The trainee is basically trained according to the training scenario that the instructor has planned. Training results are evaluated at the end of training by comparison of the trainee's changes in parameters during training with operation of the model after training.

- (1) Training operation setting

In training which uses DCS, the amount of operations is set the same as for DCS.

For stand-alone use, a simple screen set by the personal computer or a screen simulating the DCS is used.

- (2) Trend display function

This display function displays the trend graph of process variables showing the operation of this simula-

*1 MATLAB: A registered trademark of The Math Works. Inc., USA

*2 SimuLink: A registered trademark of The Math Works. Inc., USA

*3 Windows NT: A registered trademark of Microsoft Corp., USA

tor and operation variables that the trainee manipulates.

3.7 Support function for training evaluation

This function supports training evaluation by the instructor.

3.7.1 Operation of instructors

(1) Evaluation function for detecting malfunctions

This function extracts the time from generation of a malfunction to detection as an evaluation index and evaluates the training results for detecting malfunctions.

(2) Extraction function for model operation

This function extracts the model operations that the instructor performs for each training scenario. Training results are evaluated by calculating the deviation in the amount and timing of operations by the trainee from those of the model operations by the instructor.

(3) Evaluation function for process behavior

This function sets the variation tolerance for each process variable. The training results are evaluated by measuring the frequencies that exceed the variation tolerance, as an evaluation index. Minimum and maximum values of the measured variations are also displayed.

(4) Advice regarding the training results

This function provides a format for advice based on the training results. This advice consists of an objective evaluation of above items (1) through (3) and comments that the instructor enters.

(5) Generating a training scenario

The function extracts the mistakes made by the trainee from the training history to create a training scenario.

3.7.2 Operation by the trainee

(1) Display function for evaluation of operation training

This function evaluates and displays the results of operation training by the trainee.

4. Conclusion

Created as a mathematical model of a plant, the plant simulator uses computer simulation to realize various training not possible in a real plant. The author wishes that the plant simulator introduced in this paper will evolve to different instrumentation and control systems. Fuji Electric will continue to propose optimal and viable systems amiable to both man and the environment.



Super-High Resolution Vision System “FAY-1000”

Kazuhiko Fukuda

1. Introduction

Accompanying the development of various highly technological materials, electronics and printing techniques advancing towards super-high precision and density, demands are progressively increasing for precisely automated visual inspections in their manufacturing processes. Despite these demands, inspections of printed patterns, sheet surfaces and semiconductors, in which defects on rather large surfaces should be inspected in full detail, have not been put into practice. This is, because conventional vision systems for general use could not meet them. In addition, as for uneven and rounded surface parts inspections, practical use has been restricted since conventional area-sensor CCD (charge coupled device) camera systems were not capable of handling them.

The last inspections in the manufacturing processes of these high density and high precision parts or rounded surface parts have now been automated but still partially rely on personal visual inspections. However, as their mounting density and processing precision increase in the future, the personal visual inspection of finished products will be practically impossible. Realizing a highly precise and automated visual inspection with digital image processing technology is now indispensable.

The major topics of the super-high resolution vision system encompass the following fields:

- (1) Printed food vessel surface inspection
Printed external surface inspections of cans, resin cups, Styrofoam cups, etc.
- (2) Sheet surface inspection
Inspections of plain or printed continuous sheets including paper, aluminum, film and steel.
- (3) Semiconductor inspection
Super-fine defect inspections in the manufacturing processes of IC wafers, TAB (tape automated bonding), lead frames, etc.
- (4) Flat panel display inspection
Surface defect inspections of flat panel display including liquid crystal panels, and plasma display panels.
- (5) Cylindrical parts inspection

Fine surface defect inspections of cylindrical parts including drums.

In response to the above topics, Fuji Electric developed the FAY-1000 super-high resolution and high-speed vision system combining a super-high resolution line-sensor CCD camera with original gray-scale image processing technology and pattern matching technology. An overview of these technologies is described below.

2. Merits of the FAY-1000 Super-High Resolution Vision System

2.1 Super-high resolution

Although there are high resolution appearance inspection systems for FA (factory automation), an area-sensor CCD camera with 512×480 pixels is presently used as the image processing system. But to fulfill the needs of recent super-fine inspections, approximately 200 times the conventional pixel resolution is required.

For realizing such super-high resolution, the FAY-1000 is based on image processing with the high resolution line-sensor camera.

Line-sensor cameras of 4,096 pixels/line, 2,048 pixels/line and 6,000 to 8,000 pixels/line are respectively selected for standard, super high-speed and high sensitivity, and super-high resolution, respectively.

In addition, it is also possible to connect with area-sensor cameras of $1,024 \times 1,024$ pixels or $2,048 \times 2,048$ pixels.

2.2 Unique gray-scale image processing technology

With the 2-dimensional space image processing technology which Fuji Electric has been developing for some time, such defects as faint uneven spots, stringy scratches, dents, and stains can be inspected despite the fact that the FAY-1000 is a line-sensor image processing system.

2.3 Dynamic programming based pattern matching technology

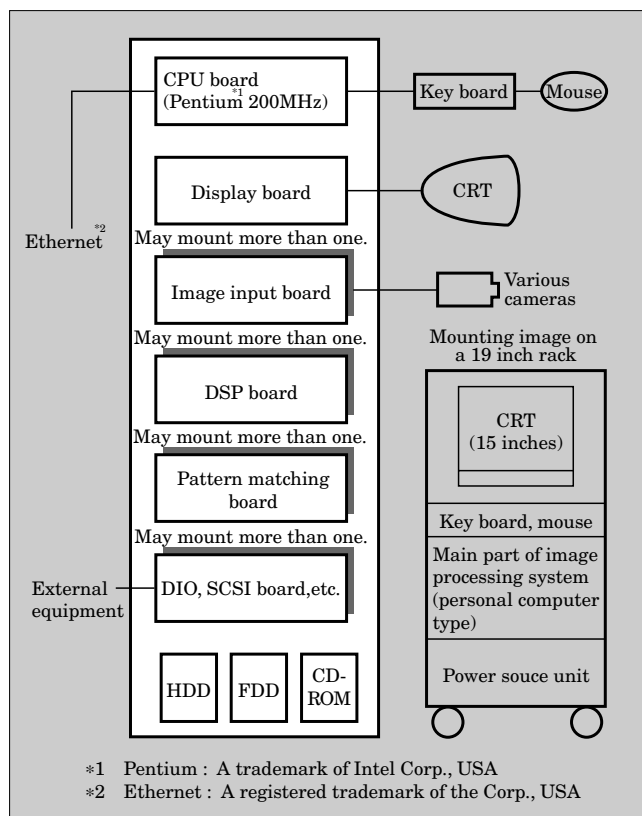
On inspection of large and flat surface patterns, there often appears significant stretching/contracting,

bending or shifting of patterns that existed originally on the parts or were generated when conveying the parts. Many of the conventional image processing systems were not capable of handling this. For the FAY-1000, the dynamic programming based pattern matching technology, which automatically calibrates the above stretching/contracting, bending or shifting of patterns, has been developed. This constitutes a first in this industry, in addition to the gray-scale judgment function with a normalized image co-relation method.

Fig.1 Appearance of the FAY-1000



Fig.2 Basic system structure of the FAY-1000



2.4 Compatibility with personal computers

Recent needs for visual inspections are closely related to information processing technology. This need includes not only the inspections but also network construction of the upper and lower processes, co-operation with quality control systems, and data base systematizing of inspection results. By adopting a personal computer (Windows 95^{*1}, Windows NT^{*2}), the

*1 Windows 95 : A trademark of Microsoft Corp., USA

*2 Windows NT : A trademark of Microsoft Corp., USA

Table 1 Basic functions of the FAY-1000

Item	Function	
Camera portion	Monochrome line-sensor camera	Super high-speed and high-sensitivity type: 2,048 pixels Standard type: 4,096 pixels Super high-resolution type: 6,000 to 8,000 pixels
	Color line-sensor camera	RGB full color type: 2,048 × 3 pixels
	Area camera	Wide monochrome area type: 2,048 × 2,048 pixels
	Number of cameras	Maximum: 2 (expandable)
Image processing controller portion	Processing image size	Horizontal direction: 2,000 to 8,000 pixels × Vertical direction: 2,000 to 6,000 pixels in standard
	Gray level	256 levels (8 bits/pixel)
	Standard image registration	Correct sample input method (with an average of N pieces)
	Position/orientation calibration	Calibration functions of position in X, Y direction and of rotation
	Pre-processing functions	Image enhancement/smoothing/differentiation etc.
	Timing of taking images in	With external encoder
	Speed variation calibration	Follows conveyed parts and speed variation
	Position search function	Possible to search position in specified patterns
	Gray level transformation function	Calibration with look-up table
	Judgment functions	Area judgment, pattern matching judgment, shape judgment, etc.
	Judgment objects	Attached foreign substans, stain, broken/attached patterns, pinhole, broken/distored character, color unevenness, color tone defect, position shifting
	Judgment area setting	Setting with rectangular, circular or polygonal shapes
	Judgment criteria setting	Possible to set judgment criteria with AND/OR
	Monitoring	Indication of taken-in images, indication of positions judged as defective
	Defects judgment processing	Possible to sum up every kind of defect and possible to save defective images
	Adjustment	Automatic adjusting functions of camera sensitivity/noise level

FAY-1000 can offer an integrated system directly linked to the production process lines.

3. Specifications of the FAY-1000

3.1 Appearance of the FAY-1000

Figure 1 shows the FAY-1000. When compared to the conventional video-sensors of the Fuji Electric's FAY series (FAY-400/600), the FAY-1000 has a rack mount construction that allows use in rack-based system applications.

3.2 Basic functions of the FAY-1000

Figure 2 shows the basic system structure of the FAY-1000, and its basic functions are listed in Table 1.

4. Specifications and Application Examples of the FAY-1000 for Every Application Field

The basic specifications of the FAY-1000 for every typical application field will be introduced below.

4.1 Inspection of the external surface of the printed food vessel

The main inspection objects of the external surface

Fig.3 System structure of the inspection system for the printed food vessel's external surface

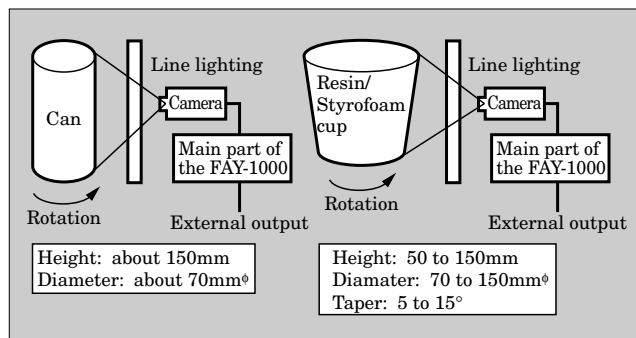


Table 2 Typical inspection items of the printed food vessel's external surface inspection

Inspection item	Inspection precision/specification
No print	None of the printed articles exist (refer to the limit sample)
Ink stain	0.5 to 2.0mm \square
Ink splash	0.5 to 2.0mm \square
Broken/blurred defect	0.5 to 2.0mm \square
Distorted/blotted defect	0.5 to 2.0mm \square
Stringy scratch	0.5 to 2.0mm \square
Misdirected shifting	Gap or overlap owing to misalignment of printing plates
Color tone defect	Deepness or faintness of color tone (refer to the limit sample)
Ink shading defect	Deepness or faintness of ink (refer to the limit sample)
Printed position shifting	Within ± 0.5 mm of printed position in vertical direction

of the printed food vessel.

- Type 1: Cans (beer, juice, coffee, etc.)
- Type 2: Resin cups (yogurt, ice cream, etc.)
- Type 3: Styrofoam cups (Chinese noodles, wheat flour noodles, etc.)

This inspection field lags behind in practical use because of a requirement for high-speed processing and a variety of complicated printed patterns. For performing various kinds of external surface inspection of food vessels, the FAY-1000 is installed with a high-speed scanning function of printed rounded surfaces by the line-sensor CCD camera and a DP (dynamic programming) based pattern matching function for inspection, regardless of stretching/contracting, shifting or bending of the printed patterns.

(1) System structure

Figure 3 illustrates the structure of the inspection system of the printed food vessel's external surface.

(2) Inspection items

The inspection items differ depending on the inspected parts but are roughly summarized in Table 2.

(3) Conditions of conveyed parts

The parts conveyor is driven in tact, and the maximum speed allowed is 450 pieces/min. Rotation speed of the parts up to a maximum of 2,000r/min is allowed.

Rotation speed within $\pm 1\%$ and inclination within 1mm are desirable as conditions of the conveyed parts but they may differ according to the required detection precision.

(4) Indication of detection results

Many options are provided for the user. The basic functions are as follows:

(a) Indication of judgment results

The results of quality judgment are relayed externally through the programmable controllers.

(b) Indication of the total number and defects number

For every inspection item, the numbers are relayed externally with time information (day, hour, minute and second).

(c) Saving defective images

Image data judged as defective are automatically stored in an inside image memory. In the standard type, the memory can save up to 30 images and is optionally expandable. Furthermore, after the inspection, it is possible to transfer the image data to MO (magneto-optical) disks for off-line preservation and analysis.

Figure 4 shows a displayed screen in an application example of the inspection of the food vessel's external surface.

4.2 Inspection of the sheet surface

This is the inspection for surface defects of continuously conveyed parts in sheet form, such as rolled paper, film and copper plate.

The inspection objects are as follows:

- Type 1: Rolled paper (plain or with printed patterns)
- Type 2: Film (transparent or with printed patterns)
- Type 3: Rolled metal sheets (copper, brass, steel aluminum, etc.)

There are already many examples of sheet surface inspections in use but until now, they have been mostly for judging spot defects on one line.

For detecting faint gray level uneven spots, stringy scratches or line-shaped defects, the FAY-1000 first extends the image taken in through the line-sensor CCD camera to 2-dimensional image data [for exam-

Fig.4 Displayed screen in application example of food vessel's external surface inspection

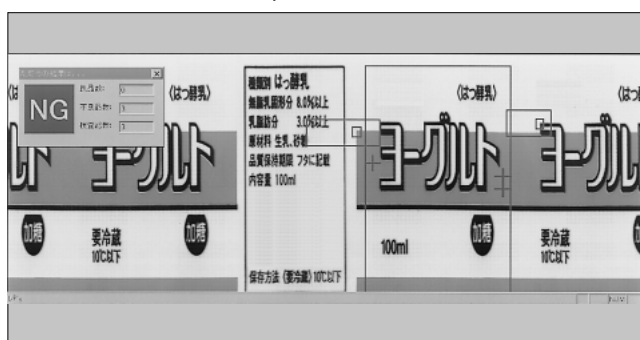


Fig.5 System structure of the sheet surface inspection system

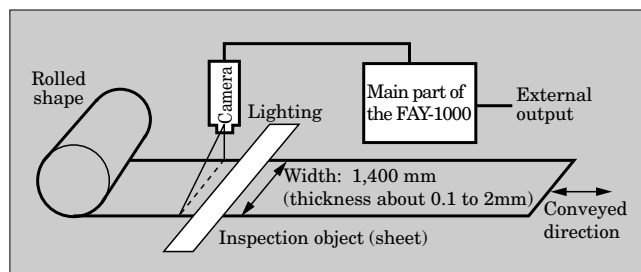


Table 3 Typical inspection items of the sheet surface inspection system

Inspection item	Inspection precision/specification
Spot defect	Black spot: 0.3 to 0.5mm [□] White spot: 0.3 to 0.5mm [□]
Hole defect	0.3 to 0.5mm [□]
Line-shaped defect	Blackish: over 0.3 × 3 (mm) Whitish: over 0.3 × 3 (mm)
Stringy scratch defect	Over 0.3 × 3 (mm) of stringy scratch defects owing to twisted paper in both conveyed and cross-wise directions
Gray level spot defect	Faint stain: 3.0 to 30mm ^φ (Yellow color on white ground: over 30mm ^φ) Blurred defects: 3.0 to 30mm ^φ
Shading defect	Deep or faint overall
Torn defect on sheet edge	About 3 to 30mm of torn part with 3mm width (on both edges)

ple, 4,096 × 4,096 pixels]. Then, they are processed with Fuji Electric's original 2-dimensional gray-scale processing algorithm. Thus, the above-mentioned defects can be inspected.

(1) System structure

Figure 5 illustrates the sheet surface inspection system.

(2) Inspection items

The inspection items of the sheet surface inspection system differ depending on the inspected parts. They are roughly summarized in Table 3.

(3) Conditions of conveyed parts

The parts conveyor is driven continuously and a maximum speed of up to 400 to 700m/min is allowed.

Winding motion within ±10mm and up-and-down motion within ±1 mm are desirable as conditions of the conveyed parts but they differ according to the re-

Fig.6 Displayed screen in an application example of the sheet surface inspection

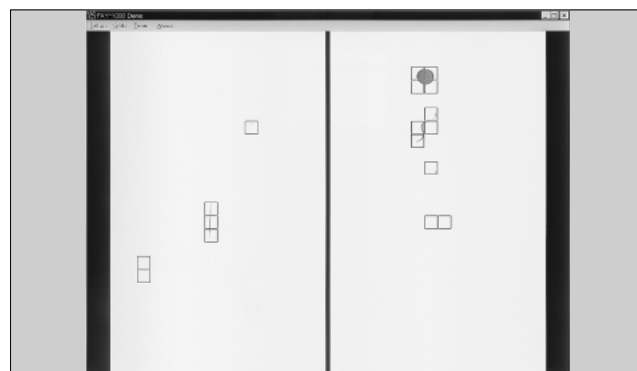
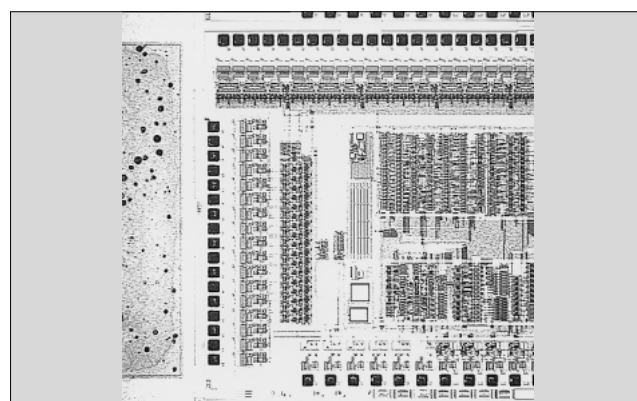


Table 4 Typical inspection items of the semiconductor inspection

Inspection item	Inspection precision
Attached foreign substance	5 to 10μm, respectively
Pattern defect	
Pattern width defect	
Electrode shape defect	
Defective distance between pins	
Defective gap between patterns	

Fig.7 Example of the IC wafer appearance inspection



quired detection precision.

(4) Defect detection and classifying system

The defective parts are classified into large, medium or small sizes and into a deep or a faint gray level, if necessary.

(5) Indication of detection results

Many options are provided for the user. The basic functions are as follows:

(a) Indication of judgment results

① Lengthwise direction (conveyed direction)

The defective positions are output with the value in mm. This is calculated from the encoder's counted value after onset (maximum 256mm).

② Crosswise direction (width direction)

The 2 to 4 defective positions per camera are output with the value in mm.

(b) Indication of the total number and defects number

For every inspection item, the numbers are relayed externally with time information (day, hour, minute and second).

(c) Saving defective images

Image data judged as defective are automatically stored in the inside image memory. In the standard type, the memory can save up to 100 images and is optionally expandable. Furthermore, after the inspection, it is possible to

transfer the image data to MO disks for off line preservation and analysis.

Figure 6 shows a display screen in an application example of the sheet surface inspection.

4.3 Inspection of semiconductors

The inspection objects in the semiconductor field are as follows:

- Type 1: IC wafer (plain or with printed patterns)
- Type 2: BGA/PGA (ball grid array/pin grid array) patterns
- Type 3: Lead frame

The typical inspection items are listed in Table 4, and Fig. 7 shows an example of the IC wafer visual inspection.

4.4 Inspection of flat panel displays

The inspection objects of the flat panel displays are as follows:

- Type 1: Glass plate for liquid crystal panel
- Type 2: Complete liquid crystal panel (back lighting inspection)

Table 5 Typical inspection items of the panel display inspection system

Inspection item	Inspection precision/specification
Spot defect	Black spot: 0.3 to 0.5mm [□] White spot: 0.3 to 0.5mm [□]
Hole defect	0.3 to 0.5mm [□]
Line-shaped defect	Blackish: over 0.3 × 3 (mm) Whitish: over 0.3 × 3 (mm)
Gray level spot defect	Faint stain: 3.0 to 30mm ^φ Blurred defects: 3.0 to 30mm ^φ
Shading defect	Deep or faint overall

Fig.8 Appearance of the organic photoconductor drum inspection system



Table 6 Inspection items of the organic photoconductor drum inspection system

Defect items in appearance			Shapes in appearance	Standard	Image defect	
					PPC	Printer
Internal defect	Black defect	Black spot	Deeply painted part in spot shape (surrounding part becomes faint)	None or $a \leq \phi$	White spot	Black spot or faint relief in white
		Black stringy scratch	Deeply painted part in line shape	None or $b \leq 1$	White stringy scratch	Black stringy scratch
	White defect	White spot	Faintly painted part in circular shape	None or $c \leq \phi$	Black spot	White spot
		White stringy scratch	Faintly printed part in line shape	None or $d \leq 1$	Black stringy scratch	White stringy scratch
	Uneven painting	Uneven color defect	Deeply painted part in irregular shape	Refer to limit sample	Irregular-shaped part relieved in white	Irregular-shaped part with faint density
		Stain	Faintly painted part in irregular shape	Refer to limit sample	Irregular-shaped part relieved in white	Irregular-shaped part faintly relieved in white
Surface defect	Attached foreign substance	Attached foreign substance	Appears as uneven surface or color shade	None	Black spot or relief in white (irregular shape)	Black spot or relief in white (irregular shape)
		Scratch	Appears as uneven surface	None or $e \leq \phi$		

- Type 3: Colored filter
- Type 4: Plasma display panel

The inspection items of the flat panel display inspection system differ depending on the inspected parts but are roughly summarized in Table 5.

4.5 Inspection of cylindrical parts

The inspection objects of the cylindrical parts are

Fig.9 Processed results example of the organic photoconductor drum inspection (in detection of spot defects)

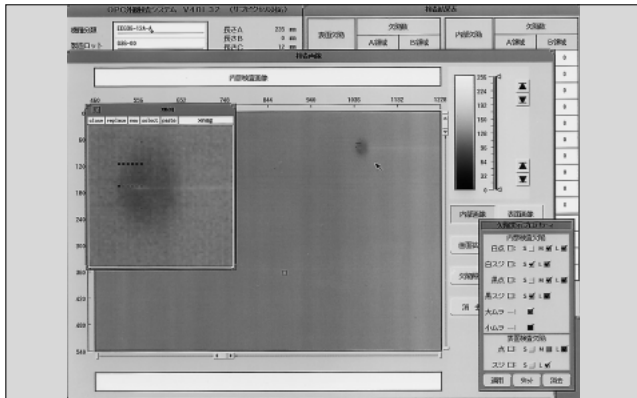


Fig.10 Processed results example of the organic photoconductor drum inspection (in detection of gray level non-uniformity defects)

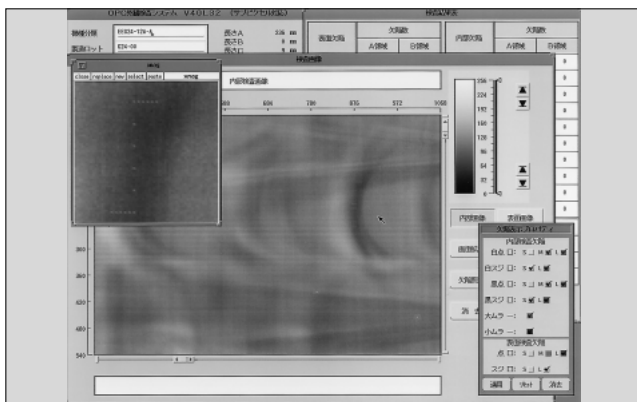
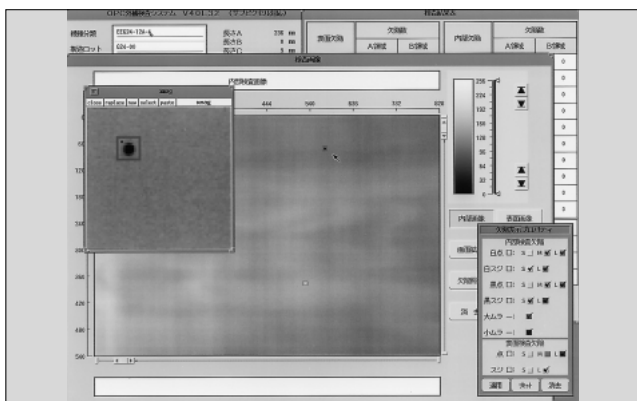


Fig.11 Processed results example of the organic photoconductor drum inspection (in detection of spot defects in uneven painting)



as follows:

- Type 1: Drum (organic photoconductor drum, etc.)
- Type 2: Metal rod (copper, brass, steel, etc.)
- Type 3: Cylindrical vessel (packing vessel, etc.)

The organic photoconductor drum inspection system mentioned here is an application example of the cylindrical parts inspection. Figure 8 shows the organic photoconductor drum inspection system. The inspection items of the system are listed in Table 6. Furthermore, some examples of processed results of the organic photoconductor drum inspection are shown in Figs. 9, 10 and 11.

5. Application Form of the FAY-1000

(1) Application software

The FAY-1000 is an engine for offering a dedicated system specified for every kind of use. The system is supplied to the user in the form of the FAY-1000, and supplemented with application software. For the typical applications described in Chapter 4, a sufficient number of packaged programs is planned so that the software will be developed more quickly.

(2) Parts conveyer mechanism

Similar to the application software, the FAY-1000 requires the most suitable conveyer mechanism for every application. For typical applications, like software, standardization of the mechanism is planned to shorten the development terms of the respective conveyer mechanism. However, engineering must be based on arrangements with the user since the mechanism must be well-matched to the user's process line.

6. Conclusion

The FAY-1000 super-high resolution vision system is used for precise visual inspections of parts of higher density. These include the external surfaces of printed food vessels, sheets, semiconductors, flat panel displays, and cylindrical parts. Several application examples and a technical overview are described.

For performing those highly precise visual inspections, development of image recognition technology which allows flexible judgment adapted to the surface characteristics, and visual inspection technology which holds a resolution of sub-micron level are required as future developments. Fuji Electric will promote further development of the precise visual inspection technology and make efforts for further expansion of this technology. This includes the progress to a 3-dimensional surface inspection and development of a sensing technique having an active relationship between sensor and lighting and a sensing technique in a laser beam area.

Global Network



● : Overseas Representative Offices ◆ : Overseas Manufacturing Bases

AMERICA

■ FUJI ELECTRIC CORP. OF AMERICA

● Head Office

Park 80 West Plaza II, Saddle Brook, NJ07663, U.S.A.

TEL : (201) 712-0555 FAX : (201) 368-8258

■ FUJI ELECTRIC DO BRASIL INDUSTRIA E COMERCIO LTDA.

Rua Guajajaras, 1707, Barro Preto,
CEP 30180-101 Belo Horizonte, M. G., BRASIL

TEL : (031) 291-5161 FAX : (031) 291-8185

EU

■ FUJI ELECTRIC CO., LTD.

Erlangen Representative Office, Sieboldstr. 3, D-91052
Erlangen, F.R. GERMANY

TEL : (09131) 729613, 729630 FAX : (09131) 28831

■ FUJI ELECTRIC GmbH

Lyoner Str. 26,
D-60528 Frankfurt am Main, F.R. GERMANY

TEL : (069) 6690290 FAX : (069) 6661020

■ FUJI ELECTRIC CO., LTD.

London Representative Office, Commonwealth House, 2 Chalkhill
Road, Hammersmith, London W6 8DW, U.K.

TEL : (0181) 233-1166 FAX : (0181) 233-1160

■ FUJI ELECTRIC (U.K.) LTD.

London Representative Office, Commonwealth House, 2 Chalkhill
Road, Hammersmith, London W6 8DW, U.K.

TEL : (0181) 233-1130 FAX : (0181) 233-1140

ASIA

■ FUJI ELECTRIC CO., LTD.

Beijing Representative Office, Suite 3603, China World Tower,
China World Trade Center No. 1, Jian Guo Men Wai Avenue,
Beijing 100004, THE PEOPLE'S REPUBLIC OF CHINA

TEL : (010) 6505-1263, 1264 FAX : (010) 6505-1851

■ FUJI ELECTRIC CO., LTD.

Hangzhou Representative Office, #402 Heng He Bldg.,
23-2 Huan Cheng Dong Lu Hangzhou City, Zhejiang Province,
THE PEOPLE'S REPUBLIC OF CHINA

TEL : (0571) 704-5454 FAX : (0571) 704-3089

■ SUZHOU LANLIAN-FUJI INSTRUMENTS CO., LTD.

Songlin Economic & Technical Development
Zone, Wujiang City, Jiangsu Province 215200,
THE PEOPLE'S REPUBLIC OF CHINA

TEL : (05223) 41-1594 FAX : (05223) 41-1654

■ FUJI ELECTRIC TECHNOLOGY AND SERVICE (SHENZHEN) CO., LTD.

No. 44 Dongjiao Street., Zhongxing Rd., Shenzhen City,
Guangdong Province 518014,
THE PEOPLE'S REPUBLIC OF CHINA

TEL : (0755) 220-2745 FAX : (0755) 220-2745

■ FUJI ELECTRIC CO., LTD.

Taipei Representative Office, 5th Fl.,
Taiwan Fertilizer Bldg., No. 90, Nanking E Rd.,
Sec.2 Taipei, TAIWAN

TEL : (02) 561-1255, 1256 FAX : (02) 561-0528

■ FUJI/GE (TAIWAN) CO., LTD.

12F, No.70, Cheng Teh N. Rd., Sec.1, Taipei, TAIWAN

TEL : (02) 556-0716, 9061 FAX : (02) 556-0717

■ FUJI ELECTRIC (ASIA) CO., LTD.

10th Fl., West Wing Tsimshatsui Centre, 66 Mody Rd.,
Tsimshatsui East Kowloon, HONG KONG

TEL : 2311-8282 FAX : 2312-0566

■ FUJI ELECTRIC KOREA CO., LTD.

16th Fl. Shinsong Bldg. 25-4 Youido-Dong,
Yongdungpo-Gu, Seoul, 150-010, KOREA

TEL : (02)780-5011 FAX : (02)783-1707

■ FUJI ELECTRIC CO., LTD.

Bangkok Representative Office, Room No.1202, 12th Fl.
Two Pacific Place

142 Sukhumvit Rd. Bangkok 10110, THAILAND

TEL : (02) 653-2020, 2021 FAX : (02) 653-2022

■ P. T. BUKAKA FUJI ELECTRIC

Plaza Bapindo, Menara I, 24th Fl. Jl. Jendral Sudirman Kav,
54-55 Jakarta 12190, INDONESIA

TEL : (021) 5266716~7 FAX : (021) 5266718

■ FUJI ELECTRIC CO., LTD.

Singapore Representative Office, 401 Commonwealth Drive,
#04-05 Hawpar Technocentre, Singapore 149598, SINGAPORE

TEL : 479-5531 FAX : 479-5210

■ FUJI ELECTRIC SINGAPORE PRIVATE LTD.

401 Commonwealth Drive, #04-05 Hawpar Technocentre,
Singapore 149598, SINGAPORE

TEL : 479-5531 FAX : 479-5210

■ FUJI/GE PRIVATE LTD.

171, Chin Swee Rd., #12-01/04 San Center,
Singapore 169877, SINGAPORE

TEL : 533-0010 FAX : 533-0021

■ HOEI ELECTRONICS (S) PRIVATE LTD.

No.5 Pereira Road, #02-04, Asiawide Industrial Building,
Singapore 368025, SINGAPORE

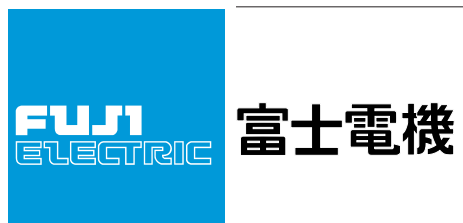
TEL : 285-3238 FAX : 285-7317

■ GE/FUJI ELECTRIC CO., LTD.

Nicolaou Pentadromos Centre, Office 908,
Block A, P. O. Box 123, Limassol 205, CYPRUS

TEL : 5-362580 FAX : 5-365174

Fuji Electric, the Pioneer in Energy and Electronics



Printed on recycled paper