

SERIES OF DIGITAL CONTROL SYSTEM FOR WATER AND SEWAGE EQUIPMENT

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I. INTRODUCTION

Control systems made in water and sewage equipment in the past have been advanced from analog instrumentation to the digital computer system, and have made a significant contribution to the maintenance and rationalization of water and sewage equipment.

However, the appearance of the microprocessor in recent years has brought about a revolution in instrumentation technology. That is, digital instrumentation and total control instrumentation systems. Man-machine devices typified by the microcomputer, microcontroller, digital calculator dataway systems, CRT display and data logger and other complex instrumentation have become more familiar. Thereafter, advances were made in the further completion and refinement of the system components and digital instrumentation systems have become better qualitatively and quantitatively. The appearance of the single loop controller is typical. Fuji Electric has completed the new teleperm FC Series as such a controller. A complete series of computer systems, digital instrument systems, transmission systems, and analog instrumentation systems are available and the total instrumentation control system has

been completed.

Thereupon, the construction of the perfect water and sewage system by combining skillfully combining these abundant instrumentation apparatus has become extremely important.

As we enter the decade of the 80s, the water and sewage world is faced with numerous problems. The needs for energy, resources the environment problem and instrumentation are becoming increasingly diverse. The so-called rural age has become an age of unique instrumentation to solve the problems of instrumentation and maintenance and management of small and medium scale waterworks. Offering a complete line-up of instrumentation systems that meet these expectations is extremely significant.

The Fuji Electric digital instrumentation system completely serialized for optimum system design of water and sewage systems is introduced and examples of its application are given.

II. DIGITAL CONTROL SYSTEM

The digital control system is grouped into a control system, transmission system, man-machine system, and data

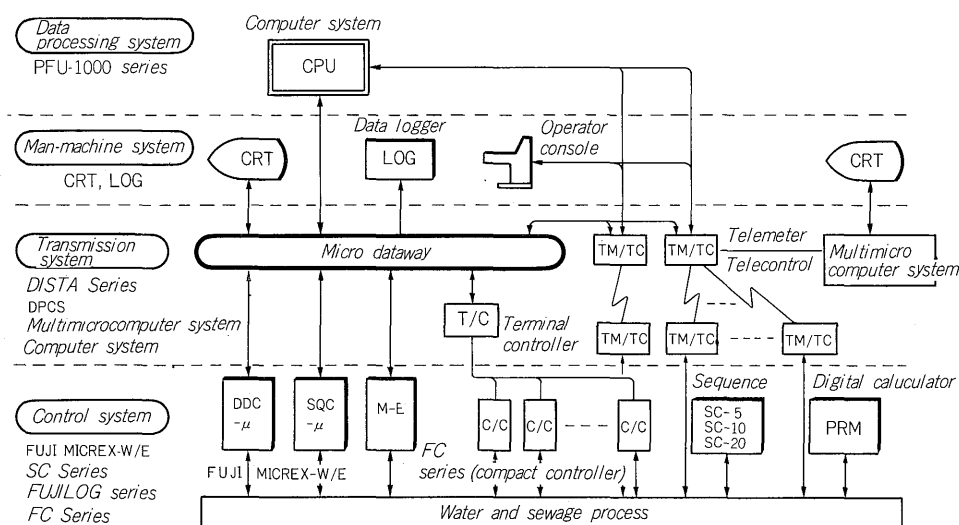


Fig. 1 Situation of digital control system

processing system. Each of these systems has been serialized and standardized. The system is designed to permit organic coupling between systems. Fig. 1 shows the situation of these systems.

The following outlines the digital control system.

1. Control system

The control system is situated at lowest level of all the systems and directly measures and controls the plant. Digitalization of control systems is based on the microprocessor, and the system has abundant functions ranging from a single loop controller to a multiloop controller. The Fuji Electric new teleperm FC Series, FUJI MICREX-W, FUJI MICREX-E, and sequence (SC Series) correspond to this.

1) The Fuji teleperm FC series compact controller

Fuji compact controller is a single loop controller. Its housing and front panel is similar to the analog controller, and it can be handled in the identical manner. The indicator has no mechanical parts and has a plasma bar graph display. (See Fig. 2.)

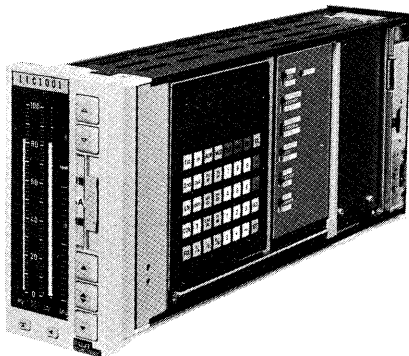


Fig. 2 Compact controller

The functions of the control loop are not only fixed value control, cascade control and ratio control, but also various sophisticated computations. Moreover, to secure loop reliability and couple to a higher level system, self-diagnosis and transmission programs are available. The specifications of the teleperm compact controller are shown in Table 1.

It is a most reliable microcomputer in the field of the plant control, so, it is used to chemical dosing controls, airtation flowcontrols, return sludge volume controls, which are important to water and sewage control system.

2) Teleperm digital calculator (PRM)

The teleperm digital calculator is compactly housed to permit up to 16 analog inputs, 8 analog outputs, and 64 digital inputs/outputs as the standards inputs/outputs and can perform complex calculation difficult with conventional analog instruments.

It is used as an open channel flow meter and calculator, chemical dosing rate calcuator, and compact data logger. (Table 2)

Table 1 Specifications of Teleperm compact controller

Type		Continuous output type controller (Type PMK) Intermittent output type controller (Type PML)
Input signals	Measured value	DC 1~5 V
	Externally set value	DC 1~5 V or pulse width input
	Auxiliary input	AI x 5, DI x 4
Output signal	Operating output	DC 4~20mA or pulse width output
	Auxiliary output	AO x 2, DO x 8
Indicator		Solid-state display
Setting unit		Constants, parameters setting and display, calculation wafer connection
Transmission function		Transmission to computer sytem
Control functions		Fixed value control, cascade control, variable gain control, ratio control, PID control with dead band, dead time compensation control
Calculation function		Linearize, temperature pressure compensation, multiplication and division, open/close calculation, addition and subtraction, selector, others
Alarm functions		Upper and lower limit alarm, faulty input check, change rate alarm, faulty output check, deviation alarm
Power requirement		DC 24 V

Table 2 Specifications of Teleperm digital calculator

Input signals	analog signals	DC 1~5 V 8 channels/card
	Digital signals	OV/no signal, 24V/signal, 16 channels/card
Output signals	Analog signals	DC 1~5 V, 4 channels/card
	Digital signal	Transistor output (open collector) 16 channels/card
Calculation functions		Addition, subtraction, multiplication, division, square root, average, function, comparison logic, bit handling, etc.
Accessory function		Measured value limiter, output limiter, dead time function, timer function

3) FUJI MICREX-W

The Fuji Micrex system consists of hardware and software. The hardware is grouped by function into a DDC micro (DDC-μW), sequence micro (SQC-μ), data logger (LOG-μ), CRT display (CRT-μ), operator console (POC-μW), etc. These hardwares are connected in a loop by a microdataway (DPCS-μ). The system is connected to a high level computer through an interface controller (IFC-μ) and constitutes a microcontroller supervisory and control system. The DDC-μW has a feedback control function and sequence control funciton. The feedback control function can

control up to 32 loops. The number of sequence steps is a standard 1000, but can be expanded up to 2000 as required.

The basic software for each device and packaged application software are available. The software has been simplified

Table 3 Specifications of FUJI MICREX control

Type			DDC-μW	SQC-μ
Application			32 loop DDC + sequence control	Medium speed sequence control Simple data calculation
DDC	Number of loops		32	
	Number of modules		64	
	Kinds of modules		14	
	Calculation period		1~8 sec	
	Input/output	AI	128	
PI		32		
AO/PO		32		
SQC	Program capacity		4k words	4k words
	Temporary storage capacity		256k words	64k words
	Calculation time		100 μs/sequence basic instruction	
	Input/output	Inter-rupt	—	4 points
		DI	Total 448 points	512 points
		DO		512 points
		PI	DDC input used	8 points
		PRC		4 points
		AI/AO		16 points
	Timer	0.1 sec	16 points	16 points
1 sec		48 points	48 points	
Transmission function			By DPCS line	

Table 4 Specifications of FUJI MICREX-E

Central processing unit	Item	Specification
	Control system	Microprogram system
	Instruction execution time	Logic operation 5.75μs Register operation 3.5μs Addition and subtraction 6.25μs
	Main memory	Elements Core or EPROM Wordlength 16 bits + 2 parity bits Capacity Basic 4k words Standard program 4k words Application program Max 28k words
	Timer/counter	Total 240 points
	Function modules	For user 128
	Dataway connection	Microdataway (DPCS)
	Remote input/output	Remote input/output unit Max 8
Input/output unit	Inputs/outputs	Input/output cards 16 cards/unit Inputs/outputs per card Digital inputs/outputs 16/card Analog inputs 8/card Analog outputs 2/card

through the use of an FIF(Fill in the Format) format and a POL (Problem Oriented Language). It is grouped into sedi-ment basin, filtering basin, chemical dosing, sludge, pump, and power receiving microcontroller system for water works and blower, pump, sludge dehydration, sludge incineration, and power receiving microcontroller system for sewage works. Each control system is formed by inserting these software at the DDC-μW. A self-diagnosis function is also provided to enhance reliability. (Table 3)

4) FUJI MICREX-E

The Fuji MICREX-E system is a Fuji MICREX system family centered around sequence control and permits fast and simple DDC control, printing, and other composite control.

Typical examples of its use in water and sewage equip-ment are pump control, filtering basin control, sludge removal control, blower control, graphic panel display, etc. (Table 4)

5) Sequence control equipment

The sequencer SC Series (Type SC) is stored program sequence control equipment and have logic calculation functions.

Program capacity is 1k word for the Type SC-5 that has sequence control of 100-200 relays as its objective and 4k words for the Type SC-20 that has 400-600 relays as its objective. (See Table 5).

An example of its use in water and sewage is filtering basin control. a syphon system at one basin has about 20 valves and about 100 relays are necessary for relay control.

Table 5 Specifications of SC series sequencers

Type	SC-5	SC-20
Program capacity	Core memory 1k word, (16 + 1) bits/word	Core memory 4k words, (16 + 1) bits/word
Basic in-struction words	4 kinds	8 kinds, other than the 4 instructions at the left
Inputs/outputs	Total inputs/outputs 191 Can be reduced and ex-panded in units of 16	Total inputs/outputs 511 (Maximum 767) Can be reduced and expanded in units of 16
Main functions	Small scale sequence control Timers (0.1 ~ 999 secs) Counters (1 ~ 999) Total 64 Internal memories 64 Self-diagnosis function	Medium scale sequence control Timers (0.1 ~ 999 secs) Counters (1 ~ 999) Total 94 Internal memories 512 Self-diagnosis function Input/output data power failure save function

2. Transmission system

1) Dataway system

Type MPCS dataway system for process computer sys-tems and Type DPCS-μ dataway system for microcomputer systems are available.

Table 6 Specifications of DISTA series

Type	DISTA-200	DISTA-220	DISTA-300	DISTA-400	DISTA-1000
Features	Small capacity supervision and control type	Road manhole installation type	Large capacity transmission type	Large capacity supervision and control type	High speed, high capacity, high performance type
Applications	Water intake facility supervision and control, Relay pumping station supervision and control, Distributing reservoir supervision and control	Distribution monitor Small pump station supervision and control, Distributing reservoir management	Distributing reservoir supervision, Pumping station supervision, Water-conveyance reservoir and distribution plant supervision	Relay pump station supervision and control Water intake pumping station supervision and control	Centralized supervision and control, Large pumping station supervision and control Large pipe network supervision and control
Master station: slave station	1 : 1, 1 : N	1 : 1, 1 : N	1 : 1	1 : 1, 1 : N	1 : 1, 1 : N
Transmission capacity	Measurement 8 point Supervision 48 point Control 30 points	Measurement 3 points Supervision 16 points Control 12 points	Measurement 20, 30 points Supervision 96 points	Measurement 27 points Supervision 144 points Control 100 points	Measurement 60 points Supervision 288 points Control 100 points
Transmission line	NTT telephone line (code transmission, D-1 standard) Communication line (private line)				NTT telephone line (D-1 standard) Communication line (private line)

The MPCS has a basic transmission rate of 1M bits/sec and uses an efficient transmission system that displays superior transmission performance regardless of the transmission performance regardless of the transmission data volume. Its flexible system configuration features a troubleshooting function, trouble backup function and abundant other RAS functions indispensable when employed in water treatment processes and connection not only to the PFU Series computer and Fuji MICREX system, but also to all other computers.

DPCS dataway system is used FUJI MICREX system and telemeter system (DISTA Series). It has an effective transmission rate of 5k words/sec and permits transmission between arbitrary equipment ($N:N$). Besides, DPCS itself contains a microcomputer and features self-diagnosis, automatic disconnection when trouble occurs, IPL from a higher level, etc. It can also be connected to the PFU Series computer, MPCS, compact controller and a wide range of other digital control equipment through an interface controller.

These dataway systems are mainly used when building a distributed control system in clean water plants and sewage treatment plants and serves to improve the management and control capabilities and system reliability and in simplifying cable work and maintenance.

2) DISTA series

The DISTA series are remote supervisory and control equipment mainly developed and commercialized for water treatment processes. It has been serialized as shown in Table 6 so the best model for the number of measurement points and status supervision items of the application site.

The DISTA-200 has been made an energy-saving, compact type through the use of C-MOS IC and is used at small distributing reservoirs having a comparatively small number of supervisory and control items. The DISTA-220 is an

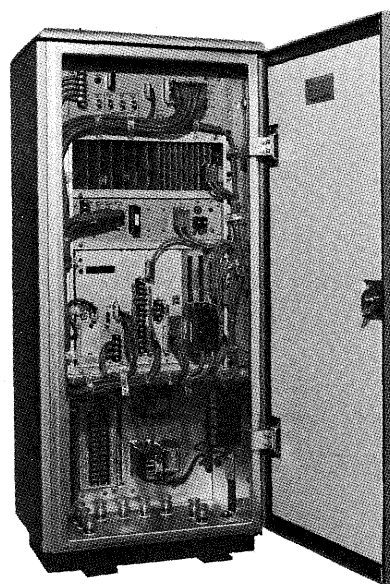


Fig. 3 DISTA-220

outdoor type with an integrating pulse counter and distributor and is used as a water-conveyance pipe network monitor. The DISTA-1000 features system expansion, improved RAS functions, data way connection and other capabilities through the use of a microcomputer and is used as the centralized supervision and control master station of large pumping stations and water intake reservoirs.

3) Supervisory and control system for small waterworks

The supervisory and control system for small waterworks is a package system consisting of a ($1:N$) remote supervisory and control master station or process input/output equipment to which a data logging function and

Table 7 Specifications of supervisory control system for compact plant

Application	Management in small clean water plants and pumping stations Centralized management of distributing reservoir, relay pumping station Centralized management of distributing pipe network
Inputs/outputs	128 (max)
Code inputs	32 (BCD 4 digits) (max)
Operation faulty inputs	512 (max)
Upper and lower limit alarms	120 (max)
Hourly report processing point	120 (max)
Daily reportprocessing points	40 (max)
Typewriter	Ricoh Typer V
Contents of CRT display	Data display, graph display, water and sewage facility system display, alarm display
CRT monitor	20 inches, color: 2000 characters equivalent
Connectable slave telemeter stations	Max 16 stations (1 : N system)

CRT display function has been added. Its specifications are outlined in Table 7.

This system is applicable to distributing reservoir, relay pumping stations and other water conveyance centralized management systems and management systems in small water processing plants, and permits simplification of graphic panels consisting of indicator lamps and provides substantial labor saving by automatic generation of management reports.

4) Multimicrocomputer system

The multimicrocomputer system provides all the needed functions by arbitrary connection of various micro units by a multi-MPU bus. Besides a telemeter function transmission unit, supervisory and control unit having CRT display control and data logging functions, and a display unit that control the graphic panel display, a process input/output unit and computer coupling unit are available.

This system is used as a large telemeter system and as a water conveyance facility, sewage relay pumping facility, etc. centralized management system.

3. Man-machine system

A digital control system demands efficient data exchange between the plant and operator. A CRT display and typewriter are used for this purpose.

1) CRT display

The CRT display is extremely useful as a digital system man-machine device. It can display data, text, graphs, and skelton diagrams. Besides displays 4000 characters, Kanji characters, English characters and numerics on one screen, it can display an extremely large volume of information in

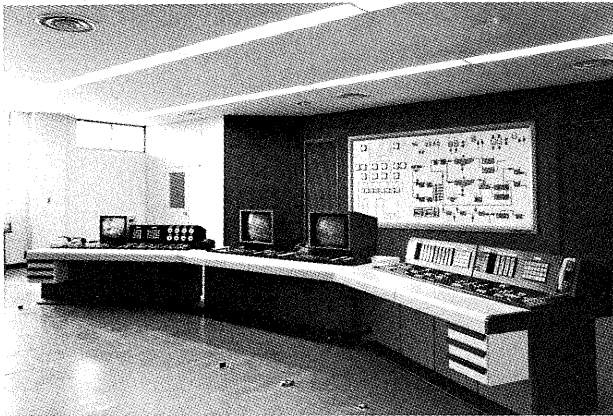


Fig. 4 CRT system

Table 8 Specifications of CRT-μ

Type	CRT-μ	
Connectable microcontroller	Max 2 lines (DPCS-μ)/display controller	
	Max 30 microcontroller/display controller	
	Max 2 CRT displays (with keyboard)/display controller	
	Screen	20 inches, color (7 colors)
	Display system	Characters Max 4000, with Kanji characters
	Number of screens	18
	Dustproof construction	Standard
Auxiliary storage	Mini disk 1	
Trend recording output (Option)	Max Analog outputs 8 (DC 1~5V)	

seven colors.

A light pen is used for screen selection, device selection, etc. to improve operability.

Recently, it has been used with a hard copy device for simultaneous display and copy.

In the past, a CRT display required a computer and was expensive. However, an extremely cheap display has been made possible through the adoption of a microcomputer. In the future, it is sure to be used extensively even in medium and small facilities. (Table 8)

2) Logging (LOG)

A data logger is used to automate generation of daily, monthly, and annual reports.

Data loggers are grouped into a compact logger (analog 16 points DI 48 channels), LOG-μ type logger (analog 128 points), and computer logger by number of inputs.

Use in water and sewage works is grouped into power, water treatment, chemical dosing, running time, alarm messages, etc. and can be used to generate hourly and daily reports containing voluminous data.

The introduction of a data logger is extremely effective in automating operator report generation work.

3) Digital display

Digital display of measured data and calculated data has become widespread and digital displays are widely used.

From 3 to 6 digital numerical displayers incorporated into the supervisory panel and supervisory console are widely used in water and sewage works.

Flow, water level, valve position, and many other data are displayed.

Recently, displayers which display both analog and digital values and plasma displays that can display a large number of associated data have appeared, and the performances and applications of the digital displayer have expanded.

4. Data processing system

The data processing system is located at the highest level of a digital control system and is centered about a computer and controls, supervises, and manages the entire water treatment processing. The Fuji Electric PFU Series

computer system is such a system and features a main memory expandable up to 2M bytes, user microprogram function, and many other special features, as well as an interrupt function and abundant I/O functions which meet the demand for a high speed processing, highly reliable system through the use of a high-speed data bus. Special water treatment process standard software W-TCS for waterworks and S-TCS for sewage works are available as software systems. These systems have operating system and process control basic packages as their nucleus and consist of man-machine system packages that perform data transmission, system supervision and control, automatic logging, system operation, etc., special process control packages, SCC and

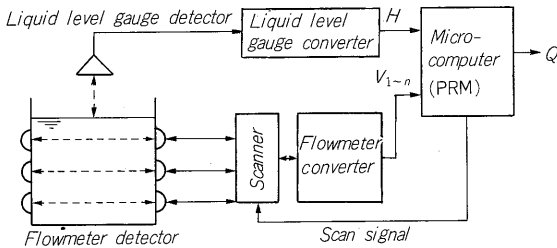


Fig. 5 Flow measurement system of open channel

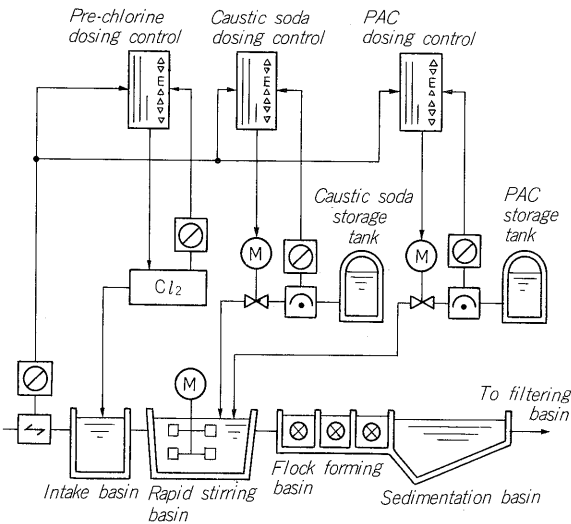


Fig. 6 Application to chemical control

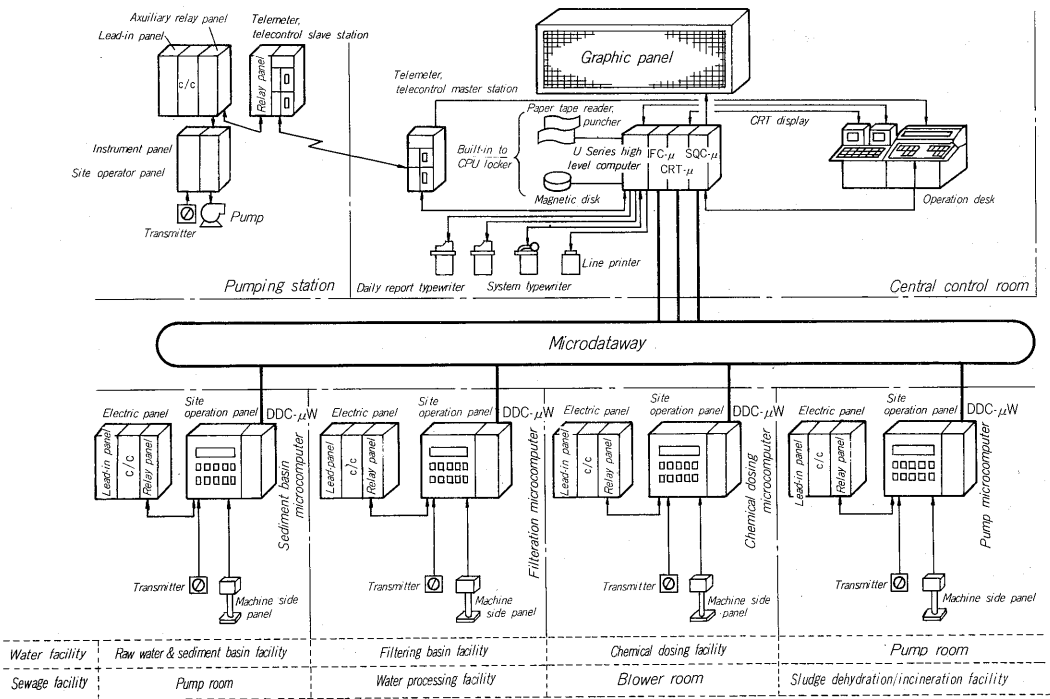


Fig. 7 Application of FUJI MICREX-W system

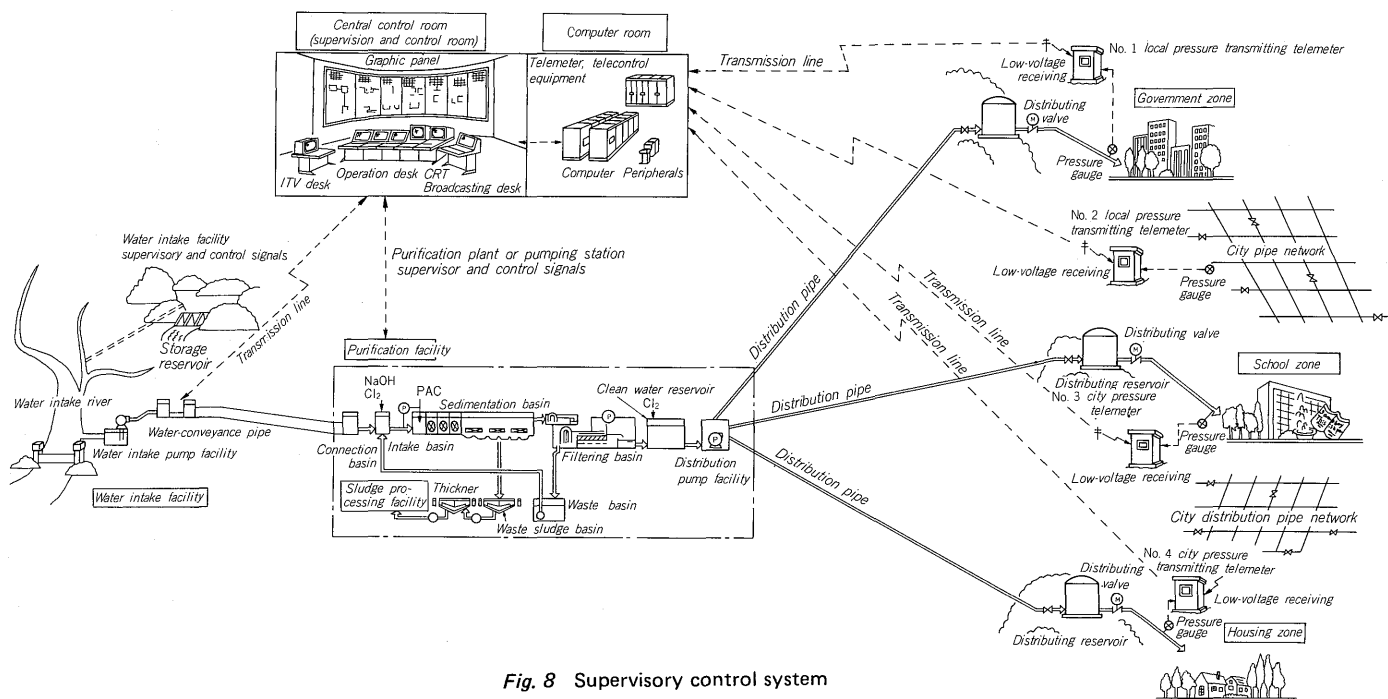


Fig. 8 Supervisory control system

optimization packages, etc. DP (dynamic programming), LP (linear programming), Kalman filter, self-regression, non-linear planning, pipe network calculation, etc. has been compacted for control use as these tools.

III. DIGITAL CONTROL SYSTEM APPLICATION

Examples of systems applied to water and sewage equipment are given.

1. Flow measurement of open channel by digital calculator (Fig. 5)

This system measures and calculates the average flow velocity distribution of the entire cross-section of an open channel and finds the Flow velocity distribution in the depth direction by multi scanning measurement and integrates the entire depth and calculates the flow amount. Calculation, scan signal generation, and measuring sensor selection are performed by a microcomputer.

2. Application of compact controller (Fig. 6)

Many compact controllers are used as single loop controllers with numerous calculation functions, DDC functions, and sequence functions in chemical dosing control (proportional cascade control) and sewage DO control.

3. Purification plant and treatment plant control system (Fig. 7)

The FujiMICREX W System is applicable to purification plants and treatment plants, and is especially suitable for systems in which the facilities are frequently expanded and reconstructed.

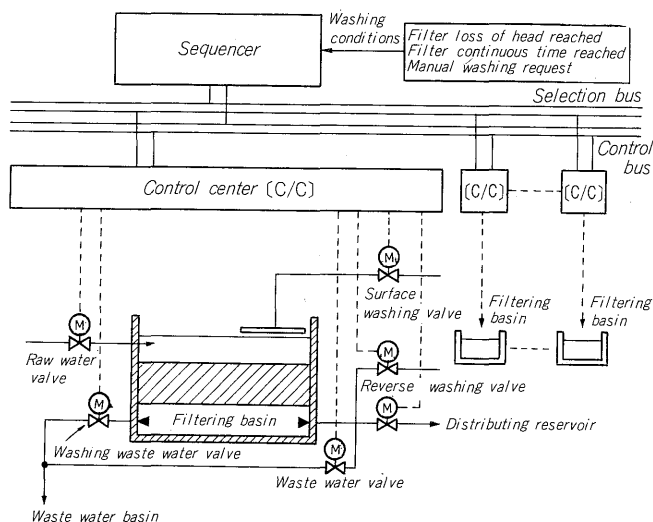


Fig. 9 Application of filter washing control

4. Centralized control system (Fig. 8)

A dataway is used for local transmission, and a telemeter, telecontrol system, multimicrocomputer system, etc. is used for distant transmission. Fig. 8 shows a typical centralized supervisory and control system.

5. Sequencer application (Fig. 9, Table 9, Table 10)

Examples of application of a sequencer to a waterworks are given in Fig. 9, Table 9, and Table 10.

Table 9 Application of sequencer system for waterworks

Type	Stored program system		
	SC-5	SC-10	SC-20
Program capacity	1k words	2k words	4k words
Number of calculation relays	100~200	200~300	400~600
Water intake feed pump		○	○
Sediment basin, waste water basin	○	○	
Filter washing	○	○	○
Distribution pump		○	○
Sludge dehydration	○		

IV. CONCLUSION

The digital control system was introduced and its application examples shown. We are confident that the

Table 10 Application of sequencer system for waterworks

Type	Stored program system		
	SC-5	SC-10	SC-20
Program capacity	1k words	2k words	4k words
Number of calculation relays	100~200	200~200	400~600
Sand basin	○		
Pump facility		○	○
Blower facility		○	○
First sedmination basin facility	○		
Final sedmimentation basin facility	○		
Chroline facility			
Digestion tank facility			
Chemical dosing facility	○		
Dehydration facility	○		
Slude incineration facility		○	○

Note) The kinds indicated by the ○ are judged according to the scale of the facility.

systemized and unitized digital control system meeting the needs for more complex, multi-function systems will display its power as the ideal supervisory and control, highly reliable control system in the water and sewage control fields in the future.