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MICRO-CONTROLLER SYSTEM FOR WATER AND SEWAGE WORKS

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I. INTRODUCTION

The instrumentation for water and sewage works have made great progress in the last several years. Because of the higher levels and greater diversity operation and the higher levels maintenance of water and sewage works, the role of instrumentation has been rapidly increasing.

Recent water supply and sewage treatment facilities have faced such new problems as wider ranges managements, power savings and conservation of natural resources. Together with these trends, the scope of instrumentation for recent water supply and sewage works has been greatly expanded from mere measurement and automatic control for equipments to the management of working.

Therefore, the instrumentation for water and sewage works has come to the level which centralized control systems with the introduction of computers systems are being used and the importance of instrumentation has increased.

The progress in electronics is still remarkable and the appearance of microcontrollers has had great influence in various fields. In the field of instrumentation, microcontrollers have brought about a revolution in instrumentation system and new instrumentation system using microcontrollers have been advocated and have gone into use. In that place, we also had developed the microcontrollers systems (the FUJI MICREX-P) in 1975.

In the case of water and sewage works instrumentation, it has become necessary to consider new instrumentation system according to the appearance of these new techniques because of the increased importance of instrumentation and demands for higher reliability. Therefore, there must be instrumentation system which are well adapted to the characteristics of water and sewage works. It has been necessary to investigate not only hardware but also the software of water and sewage works. We have developed the FUJI MICREX-W (W: water and waste water) system, a new instrumentation system for water and sewage works employing microcontrollers, by bringing together water and sewage works control technology gained from long years of experience and technology in the fields of instrumentation system, computer control system and telemeter and telecontrol system to meet these needs. This system is shown here.

II. BASIC CONCEPTS OF THE FUJI MICREX-W

Water and sewage works instrumentation has reached the stage where computers are used and this has resulted in not only larger scales and higher levels but has also given rise to many problems. The basis of this is digitalization, greater complexity because of the very high level of centralization and handling of accidents. This new instrumentation system must be able to solve these problems and this indicates the concepts on which the instrumentation should be based.

The FUJI MICREX-W has been developed from this standpoint. The following are the basic concepts:

1) Improved reliability by decentralized control

A centralized control system using one computer has wide ranging effects when the main computer breaks down and according to circumstances, gives entire facilities the serious damages. The FUJI MICREX-W has decentralized functions because of the use of many microcontrollers and the system reliability has been greatly improved by functional and risk decentralization so that the entire facilities are not affected during a controller breakdown.

2) Improved expansionability by decentralized control

By the decentralized control system, expandability of both the software and hardware has been improved. In centralized control system, the software for control system and management system are lorded in the common computer and when the some section of software is improved, it is necessary to stop all operation of computer control system until the renovation is completed. In the decentralized control system, when the software for management is improved, it is not necessary to stop control system by microcontrollers and when the software for control system is improved, it is necessary to stop only the microcomputer concerned. When the management and control system is expanded in conformity with expanded facilities, it is necessary to stop the existing system for long periods while the new system is connected with the existing system in the case of centralized control systems but when the control system is decentralized, the new microcomputers can be inserted in the existing data way by means of connectors.

3) Improved processing speed by means of decentralized control

Centralized control system have software for both

control and management in the central computer. Since one computer can not process two or more software programs simultaneously, a software priority sequence is established. Therefore, when a high priority sofrware is required while some other software is being processed, the software currently being processed is stopped temporarily and the high priority software is executed or when the priority is the same, it is necessary to wait until the software being processed is completed. As a result, even when CRT display or remote manual operation is required, the processing is in a hold condition. In decentralized control systems, the basic functions of management, control, display and operation are decentralized and can each be processed independently so that there is no need to wait for required processing.

4) Harmony between analog and digital instrumentation

Conventional analog and digital instrumentation (including sequences) has grown from many separate fields and there are cases where there is no standardized compatibility. In water and sewage works especially, compatibility is very difficult by the presence of both sequence control and analog instrumentation. In the FUJI MICREX-W, there is both digital and analog control system in one controller and the instrumentation has been designed so that there is no problem and the two can exist together in harmony. Functionary, the system has the high level data processing functions of the microcomputers and various types of processing and control which can not be done in analog systems are possible. Simultaneously, the analog devices (senser and operation terminals, receivers, etc.) and digital devices (controller, transmitters, consoles, etc.) are compatible and in harmony with no discord.

5) Consideration concerning man-machine system completeness and ease of use

In comparison with analog indicators and recorders, the CRT display and plasma display has a much better expression capacity and can offer much quantity of data to operators. Such man-machine systems are possible for the first time by the presence of microcomputers.

The FUJI MICREX-W effectively combines CRT and plasma display and is a complete man-machine system. Alarm information is by means of a self-diagnosing system and also man-machine dialogue is facilitated by programming of the POL and FIF types.

6) System construction flexibility

Instrumentation system for water and sewage works differ somewhat according to the scale of the facilities. The instrumentation system must be optimum from every respect. Conventional computer system are mainly for large-scale facilities and almost no consideration has been given to their use in small scale facilities.

The FUJI MICREX-W employs the system type for large scale facilities and the single function type for small-scale facilities. This system has great flexibility since it can be easily structured to fit any scale of facilities.

As execution systems of water and sewage works based on expansion and additions, these are systems in which expansion is possible by units one by one and systems in which temporary investment centralization during the initial construction work is avoided.

7) Compatability with the computer system

Water and sewage works are characterized by long-term expansion. The progress in computer technology has been remarkable and it holds unlimited possibilities in future. In the cases of facility and operation expansion and technical progress, there is the possibility of introducing a computer in the instrumentation system and also the possibility of linkage with another computer system. In the latter case, it is necessary that it is possible functionary to link up with a computer system. The FUJI MICREX-W has been designed for linkage with the FACOM computer series and a suitable heirarchy system has been included.

8) Rationalization of transmission by the data way

In centralized control system using computers, the instrument wiring work becomes centralized and the scale and complexity increases. Especially in water and sewage works, the weight of instrumentation wiring work is system for signal transmission so that installation costs are low, the work is simplified and transmission reliability is increased.

9) Unification for both hardware and software

The microcontroller system consists of hardware and software. Therefore, it is essential to provide all of the software (for both water supply and sewage treatment) simultaneously with the hardware. This point differs from analog systems. The FUJI MICREX-W has been systematized simultaneously for both the hardware and software and this systematization has been developed especially for both water supply and sewage treatment. Therefore, packaging is possible in both cases, optional combinations can be used and there can be various system structures. We have accumulated a wide range of experience in water treatment control techniques over many years.

10) System design which combines electric equipment and instrumentation

Water works equipment combines electric equipment and instrumentation for complete control functions. Therefore, the control system must be designed to include these two. The FUJI MICREX-W has been designed as a system which combines electric equipment and instrumentation for power reception, pumps and blower micros.

III. Construction and application of the FUJI MICREX-W

The FUJI-MICREX-W consists of hardware and software. *Fig. 1* shows the structural diagram of the system. The hardware consists of the micro-controller (DDC-μW) and sequence controller (SQC-μ) located at the site; and the data logger (LOG-μ), CRT display (CRT-μW) and operator console (POC-μW) which are connected in a loop by the microdata way (DPCS-μ) and form the microcontroller system. These are connected to the host computer system (PANAFACOM U-series computers) by interface controllers (IFC-μ) and form a hierarchy structure.

The software consists of the basic software for each piece of equipment and also various types of microcontroller systems for water works, sedimentation basins, filter

basins, chemical injection equipment, water quality, sludge, treatment equipment, pumps equipment, power receiving equipment; and various microcontroller systems for sewage works, blowers, pumps, sludge dehydration, sludge incineration and power receiving equipment. This software forms complete control system introduced into each DDC-μW This hardware and software can be divided into three stages as shown in *Fig. 1.* This forms a hierarchy system.

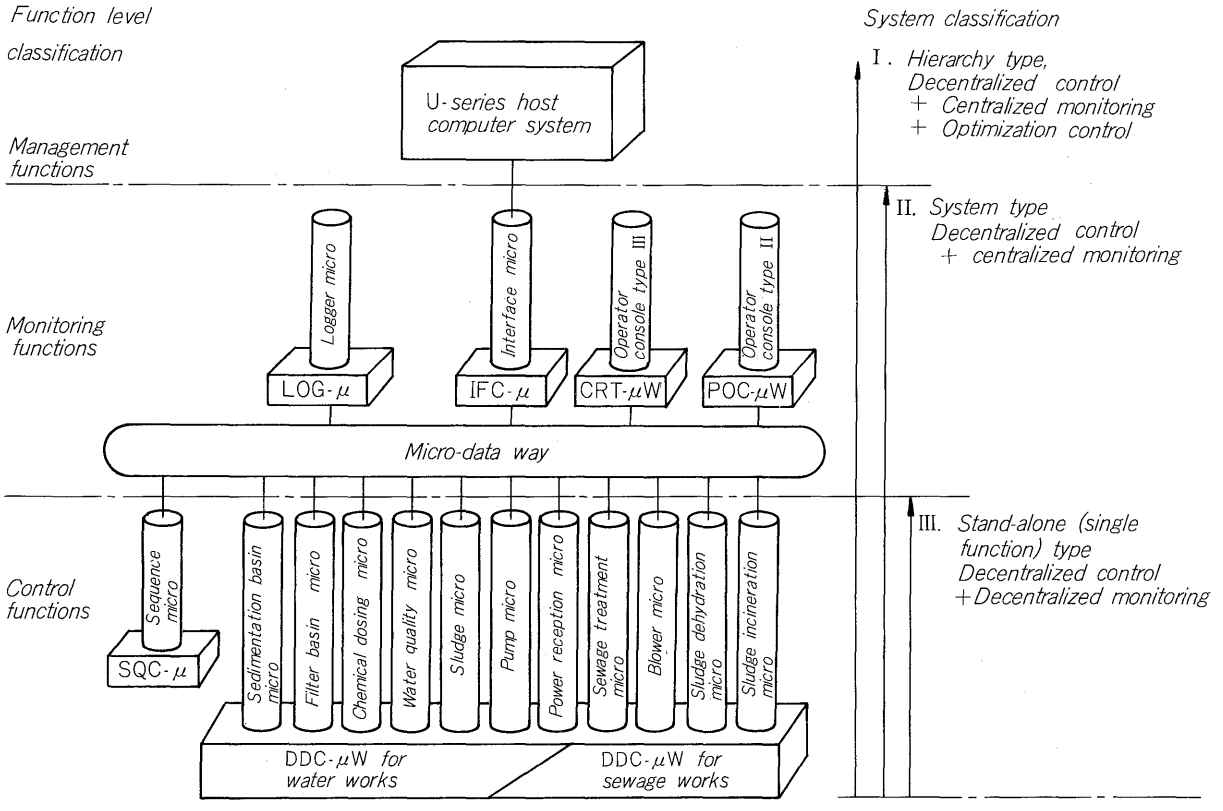

Fig. 1 FUJI MICREX-W system

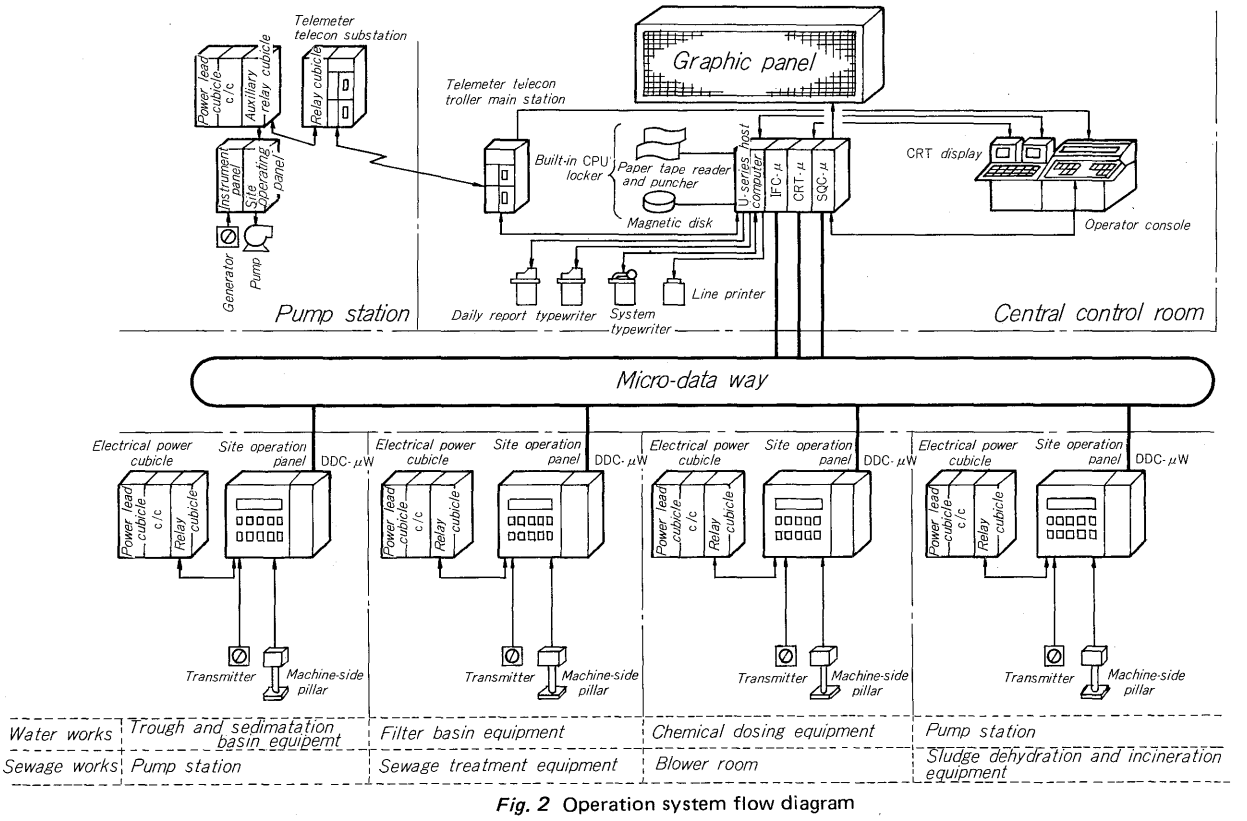

Fig. 2 Operation system flow diagram

The lowest stage (third stage) is of the single-function stand-alone type and has mainly automatic control functions and data gathering function for the terminal equipment (DDC and sequence control). There is a microcontroller (DDC-μW) for each type of equipment (sedimentation basins, etc.) and decentralized control is performed by means of functional decentalization and detached disposition. Therefore, by means of suitable combinations, it is possible to adapt freely over a wide range from small-scale to large-scale facilities.

The second and third stages contain combinations of control microcontrollers (LOG-μ, CRT-μW, POC-μW) with monitoring functions so that decentralized control and centralized monitoring are possible. All of this control and monitoring are performed by microcontrollers used in the form of a system. This system is ideal for ordinary medium and small-scale facilities.

The first stage has a host computer which is coupled to the second and third stages to form a hierarchy system. In addition to decentralized control and centralized monitoring, it has high level control functions such as integrated control and optimization control by the upper limit computer. It is generally ideal for large and medium scale facilities. These control functions are high level with no division by microcontrollers and include all batch and on-line operations such as integrated facility operation control, general plant control, integrated data control, system development and facility management control.

Fig. 2 shows the operation system flow diagram for the FUJI MICREX-W. All operations can be performed either in the central control room or at the site and there is optional selection between manual and automatic operating modes. There are many operating systems which can be operated from any location. These operating system are divided into those for normal operation and those for emergency cases as shown below.

- Normal
  - Central
    - Automatic: Settings from host computer
    - Manual: Settings and remote/ manual operations from CRT-μW and operator console
  - Site
    - Automatic: DDC control from DDC-μW
    - Manual
      - Manual settings from DDC-μW
      - Manual operations from site panels
      - Manual operations from machine side panels
- Emergencies
  - Central emergencies
    - Center: Manual: Settings and remote/ manual operations from CRT-μW and operator console
    - Site: Automatic / Manual: (same as normal case)
  - Micro-emergencies
    - Center: Manual: Settings and remote/ manual operations from CRT-μW and operator console
    - Site
      - Automatic: Analog operations by back-up controllers
      - Manual
        - Manual operations from site panel
        - Manual operations from machine side panel

In normal cases, operation is automatic in principle, but a manual system can be utilized in cases when it is necessary to introduce operations requiring human interven-

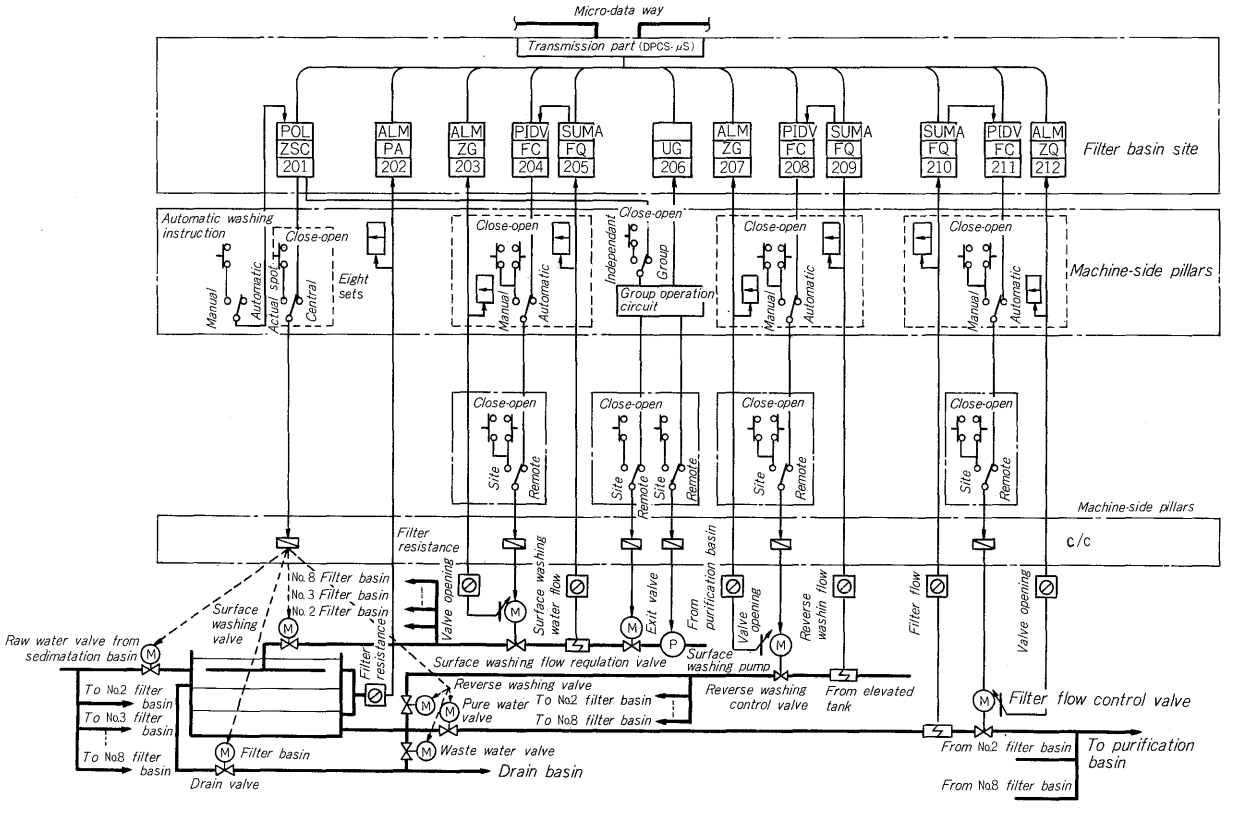

Fig. 3 Control flow diagram for filter equipment

tion.

Settings and instructions include settings of control set point, alarm settings, sequence timer settings, and starting and priority sequence settings.

In the case of emergencies, site automation is possible by means of central remote manual operations and back-up units. This is one of the features of this system. *Fig. 3* shows a flow diagram for the filter basins.

IV. FUJI MICREX-W FOR WATER WORKS

Fig. 4 shows the system flow diagram and functional distribution. Microcontrollers (DDC-μW type) are used for all of the equipment and each control system is formed by adding the software for each type of equipment. As can be seen in the diagram, the software is decentralized for each unit and is of the package type. It is applied according to the equipment scale and control system. In the case of decentralized control, the method of decentralization is important and an overall decision must be made on the basis of the scale of the facilities as a whole, the layout of the equipment site and its environment, the functional distribution, breakdown countermeasures, future expansions, etc. The decentalization shown in the figure is considered ideal for waterworks.

1) Sedimentation basin micro

This microcontroller the sedimentation basin and related equipment. The maximum control range of one DDC-μW is four sedimentation basins, and one intake basin, rapid vibration basin and sludge basin each. The six types of software are packaged as shown in the *Fig. 4*.

2) Filter basin micro

This microcontroller can be used with up to 12 filter basins of the ordinary gravity and vacuum siphon type filter basins. The six types of software are packaged as shown in the *Fig. 4*.

3) Chemical dosing micro

This microcontroller is for controlling the dosing of coagulants (alum, PAC), preliminary and later alkali and preliminary and later chlorine. A maximum of two dosers of each type can be controlled. There are six types of software packaged as shown in the *Fig. 4*.

4) Water quality micro

This microcontroller is used for water quality control including dosing control of chemical such as coagulants (alum, PAC), preliminary and later alkali, preliminary and later chlorine, and activated carbon; as well as turbidity, alkalinity, residual chlorine, electrical conductivity, water temperature, etc.

5) Sludge micro

This microcontroller is mainly for control of sludge dehydration and can control up to two hydrators. The five types of software are packaged as shown in the *Fig. 4*.

6) Pump micro

This microcontroller controls water intake and water intake pumps. Control of up to eight pumps, i.e. number control of six and speed control of two, is possible. The nine types of software are packaged as shown in the *Fig. 4*.

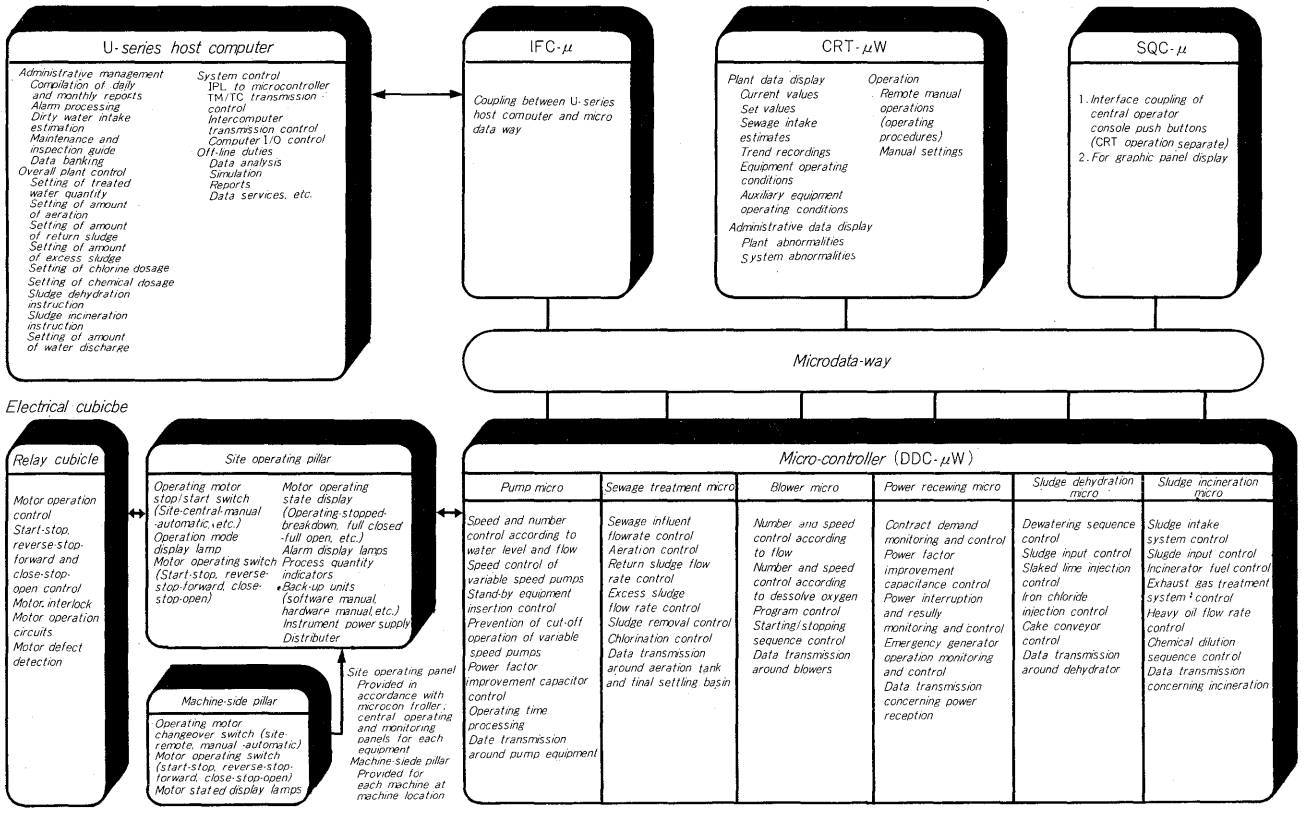

Fig. 4 Decentralized control system flow diagram (for sewage works)

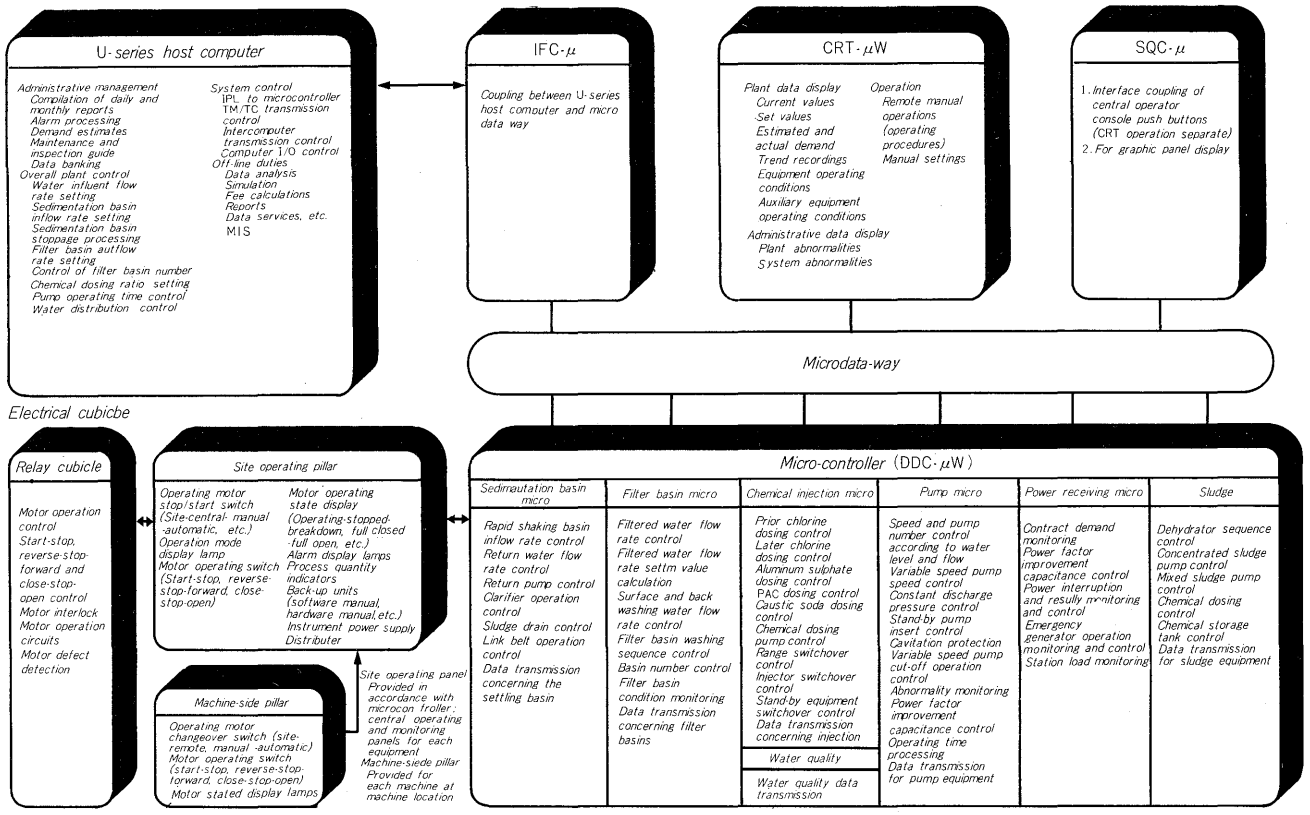

Fig. 5 Example of decentralized control system flow diagram (for water works)

7) Power receiving micro

This microcontroller controls the power receiving equipment. The package contains five types of software.

V. FUJI MICREX-W FOR SEWAGE WORKS

Fig. 5 shows the system and functional distribution. Microcontrollers (DDC-μW type) are used for each type of equipment and the control system in each case consists of this microcontroller and the respective software. The decentalization concept for the sewage works is almost the same as that for the water works but special consideration has been given to future expansions. The vertical division for each system is appropriate for water and sludge treatment systems. The decentralization shown in the figure appears to be optimum.

1) Sewage treatment micro

This microcontroller controls the one zone sewage treatment system and can control four initial sedimentation basins, aeration tanks and final sedimentation basins each and one chlorine mixing basin with one DDC-μW. The six types of software are packaged as shown in the *Fig. 5*.

2) Blower micro

This microcontroller controls the aeration tank blowers and can control up to six blowers: three for number control and three for speed control. The four types of software for DDC and sequence control are packaged as shown in the *Fig. 5*.

3) Pump micro

This microcontroller controls the sewage pumps and relay pumps. It can control up to eight pumps: six for number control and two for speed control. The seven types of software are packaged as shown in the *Fig. 5*.

4) Sludge dehydration micro

This microcontroller controls sludge concentration and dehydration. It can control up to two dehydrators and the software package contains five types.

5) Sludge incineration micro

This microcontroller performs complete control of the incinerators. The most common incinerators controlled are the multi-stage type. There are six types of software packaged as shown in the *Fig. 5*.

6) Power receiving micro

This microcontroller performs general control of the power receiveing equipment. The four types of software are packaged as shown in the *Fig. 5*.

VI. FUJI MICREX-W HARDWARE

The FUJI MICREX-W hardware has been designed to match the characteristics of water and sewage works. Common hardware (DDC-μW) is used and various types of software can be introduced. The various types of controllers have sufficient input/output capacity, operation processing capacity and control capacity for each type of water and sewage works equipment.

The intelligence level is increased and it is possible to obtain management, control and transmission functions with only the microcontroller. The hardware can withstand site conditions.

1. Microcontrollers for DDC Control (DDC-μW)

The DDC-μW microcontroller can perform DDC and sequence control and has various types of operation processing and transmission functions.

One microcontroller is used for each type of water and sewage works equipment. Water and sewage works facilities are characterized by a mixture of DDC and sequence control with the greatest weight on sequence control. Since DDC and sequence control are closely related to the operation of each type of equipment, one microcontroller which can perform both types of control makes analog and digital coordination and program compilation easy, facilitates program maintenance, decreases wiring and is more economical.

These DDC-μW have been designed so that they have more than sufficient functions to be used in all types of water and sewage works facilities. They have the following specifications:

No. of DDC loops:	max. 32 loops
DDC operating cycles:	2 – 8 sec. (variable)
No. of sequence steps:	max. 2,000 steps
Analog input points:	max. 128 points
Pulse input points:	max. 32 points
ON/OFF input/output points:	max. 448 points
Memory capacity:	28k words(core+PROM)

With this range of input/output points, it is possible to form a system by freely combining printed boards according to the number of plates. There is a maximum of 1,000 sequence steps but it is possible to expand the core in 4k work units if necessary and also increase the sequence steps in units of 2,000 steps. In this way, it is possible to increase the DDC-μW functions in accordance with the number of microcontrollers. Applications include [filter basin flow control (DDC) + filter basin washing control (sequence control) + filter basin number control (sequence control)] in water works and [pump speed control (DDC) + pump number control (sequence control) + pump starting/stopping control (sequence control)] in sewage works, which require one DDC-μW each.

The basic software of the DDC-μW includes the initial program loader, micromonitor, communication control program, operation subroutines, input/output control subroutines and the self-diagnosing program. All of them are packaged and the most appropriate system can be formed by suitable combinations of these. There are the following 14 types of operation subroutines:

(1) PID control mode (position type)
(2) PID control mode (speed type)
(3) PD + manual reset type
(4) Proportional control mode
(5) Cascade control mode
(6) ON/OFF control mode (with 2-position hysteresis)
(7) ON/OFF control mode (with 3-position hysteresis)
(8) Forward/reverse operations
(9) Alarm indication
(10) Multiple-point indication
(11) Analog integrator
(12) Pulse integrator
(13) Time coefficient occurrence curve type
(14) Time coefficient occurrence step type

2. Operator Console Type III (CRT-μW)

This is an operator console consisting mainly of CRT display for water and sewage works. For indications and operations, special water treatment system indicators, data indicators and setting and operating methods which can be used easily by water works operators are applied. There are also many standard types of indicator screens for water and sewage works from which the user can select freely. A special operating feature is central remote manual control from the CRT-μW. The CRT-μW functions are as follows:

Display type:	data, comments, graphs, patterns and skeletons
Display character:	4,000 (40 columns x 100 lines)
Types of character:	128 (numerials, English alphabet, alias characters)
Display color:	7 colors
Monitor:	20 inches
Water works screen:	26 types
Sewage works screen:	26 types
Others:	alarm indicator lamps, selection push-button switches, condition display lamps, operation push-button switches, setting push-button switches

3. Operator Console Type II (POC-μW)

This is an operator console using 10-key type push button switches and plasma display for medium and small-scale facilities. It is an intelligent type console with a built-in microcontroller. It is used mainly for site operations or as a stand-alone DDC-μW type operator console. The main functions are as follows:

Display types:	data, comments
Display character:	256 (8 columns x 32 lines)
Types of character:	128 types (English alphabet, numbers, alias characters, special symbols)
Others:	alarm display lamp, selection push-button switches, condition display lamps, operation push-button switches, setting push-button switches

4. Logger Micro (LOG-μ)

This is a compact data logger in which the hardware and software from a double package using microcontrollers. By using the DDC-μW type microcontroller for each type of equipment and can be employed in stand-alone type, the LOG-μ can be employed in control system. The main func-

tions are as follows:

Input point:	max. 128 points
Scan speed:	32 points/sec.
Upper/lower limit alarm:	max. 120 points
Print-out item:	max. 40 points
Alarm output:	max. 64 points

There are optional and alarm print-outs.

5. Micro-sequence Controller (SQC-μ)

This is a sequence controller built-in microcontroller. In addition to sequence control, it is also a microcomputer which can also perform analog calculation. It can be used for sequence control and also as various kinds of relay panel. The functions are as follows:

Types of instruction:	27 types
Operation capacity:	logical operations, branching, transmission, numerical operations, special operations
Sequence step:	max. 1,000 steps
Input/output point:	Interrupt input: max. 4 points Digital input/output: max. 512 points Analog input: max. 16 points Pulse input: max. 8 points

6. Back-up Units

Back-up units are used for the loops necessary for back-up and manual operations. The types and functions are as follows:

Controller:	Analog PID control, measured and set value indicators, setting and manual operators, automatic/manual changeover switches
Setting selector:	site setting
Manual selector:	site setting

VII. FUJI MICREX-W SOFTWARE

The FUJI MICREX-W software consists of:

1) Basic software
2) Application software
3) Support software

The basic software consists of:

1) Initial program loader
2) Micro-monitor
3) Data transmission program
4) Operation subroutines
5) Input/output control subroutines
6) Self-diagnosing program

These programs are all of modular structure and can combined and assembled as required.

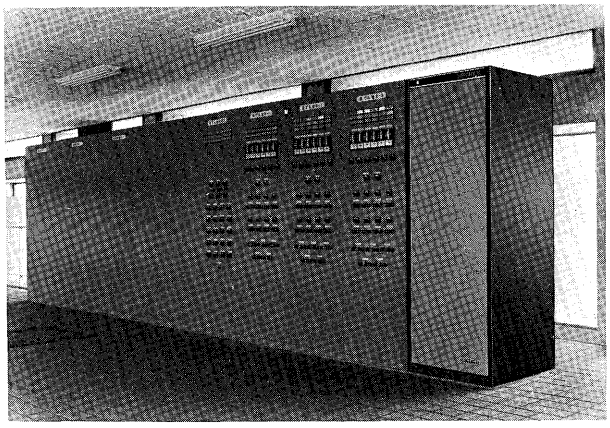

Fig. 6 Exterior view of FUJI MICREX-W

The application software is especially for water and sewage works, with a software package prepared for each type of equipment. It can be used freely by selecting among stand-alone, decentralized and back-up types. It is shown in *Fig. 4* and *5*. The basic concepts used in the construction of the application software are as follows:

The parts which can be standardized as "problem oriented" types whenever possible. FIF (Fill in the Form) type package programs are also offered. Simple procedures can be achieved with POL (problem oriented language).

From the standpoint of maintenance, the system is such that there can be corrected without the language level down as possible after the site equipped and auxiliary methods can also be offered. In this way, it is possible to compile and alter programs without any knowledge of programming and the water treatment software version-up is possible.

The support software is used to improve the programming efficiency when the standard program range is insufficient or standard programs and package programs are compiled.

VIII. CONCLUSION

The living environment has recently demanded a high reliability in water and sewage works. The concept of highly reliable system using microcontrollers and decentralized control appeared at exactly the right time. Progress in electronic parts such as micro-processors has inevitable expanded into the field of digital systems. Conventionally, such systems limited to large-scale facilities where computers could be used but microcontrollers will result in the expansion of digital systems to small and medium-scale facilities. At the same time, the weight of software is being stressed.

The FUJI MICREX-W system has been developed with consideration given to all of these problems and it is hoped that it can operate satisfactorily in a wide range of facilities from large to small scale.