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INSTRUMENTATION AND COMPUTER CONTROL SYSTEM FOR SEIBU WATER FILTRATION PLANT, SAITAMA PREFECTURE

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I. INTRODUCTION

Because of the increases in water demand in Saitama prefecture every year, the Okubo filtration plant supplied with raw water from the Ara river was built in 1966. This plant can supply 400,000m³ of clean water and 250,000m³ of industrial water daily to the central areas of the prefecture. Since this time, population increases and rises in the standard of living have resulted in sharp increases in water requirements so that the first expansion in the above plant was made in 1970 and the second in 1973. This trend has also been seen in the western part of Saitama prefecture where there have been limitations placed on underground water supplies to prevent land sinking. Water requirements have greatly increased and the Seibu water filtration plant with a final processing capacity of 900,000m³ per day was constructed near the Okubo plant site. This plant went into operation on 1 July, 1974. In this article, a plant outline will be give and the instrumentation and control systems, the management system, the computer control system, etc. for this plant will be introduced.

II. PLANT OUTLINE

Site	Urawa city, Saitama prefecture
Land area	Approx. 300,000m²
Water treatment	First period : 250,000m³/day (present) Second period : 250,000m³/day (planned) Third period : 400,000m³/day (planned)
Raw water	Ara river (Water transported from the Tone river to the Ara river by the Musashi water system)
Supply area	10 cities and 2 towns in the western part of Saitama prefecture 7 cities in the central part of Saitama prefecture
Intake method	Natural downflow
Supply method	pressurized pump supply
Construction	Reservoir wells 2 Intake pump wells 2 Diversion well 1 Sedimentation basins 8 (final 28) Filter basins 18 (final 62) Purification basins 6 Site surge tank 1 Ara river transverse equipment 1 set Dirty water teatment equipment 1 set (final 4 sets) Relay pumping station 1

III. BASIC CONCEPTS OF CONTROL SYSTEM

The Seibu water filtration plant supplies water to the western and central regions of Saitama prefecture. The facilities are located next to the existing Okubo filtration plant and the control system is an integrated system which covers both the existing Okubo plant and the new Seibu plant. Therefore, the control system consists of the conventional control system of the Okubo plant and the integrated control system based on the conditions which will be described hereafter. The characteristics of the new Seibu plant are as follows :

1) Increased water treatment capacity
2) Greater space occupancy of control area
3) Combination of control systems for existing and new plants
4) Greater space occupancy and complexity of internal equipment

The basic concepts of the control system according to the above conditions were put into practice in the following design procedures.

1. Hierarchy System Construction

The computer system components consist of the existing Okubo plant computer (FACOM 270-20), the new Seibu plant computer (FACOM-RE) and the upper level control computer (FACOM 270-25). These computers perform analysis of various types of statistics such as control job statistics, make optimum control processings, perform operation controls and do data transmission processing. At the lower level, a data highway type control system

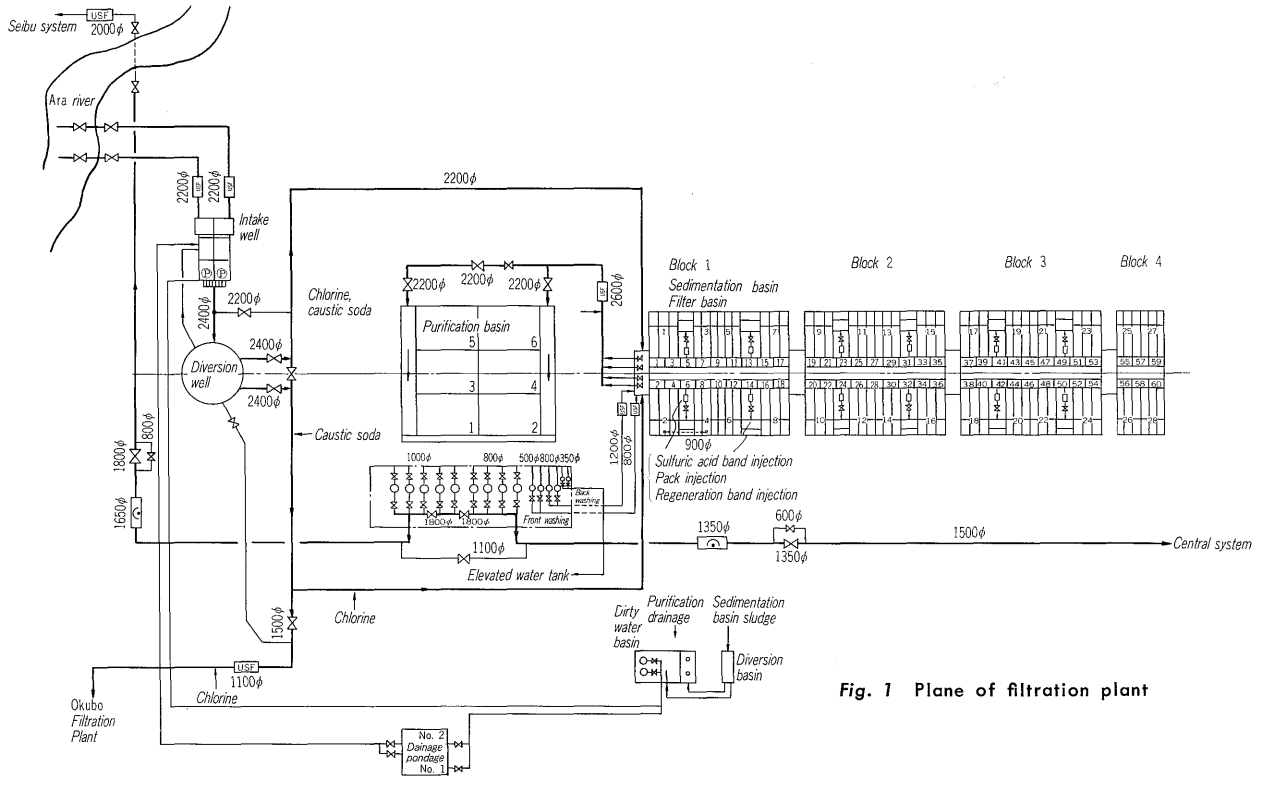


Fig. 1 Plane of filtration plant

(PUC-10 type) is provided and the system performs data transmission with the computers for dosing control and the upper level Seibu plant control.

2. Rationalization, Standardization and Simplification of the Central Control System

The central control room is located in a newly constructed building and the monitoring of both the existing Okubo plant and the new Seibu plant is standardized in one place. For reception, the connection systems of both plants can be easily monitored and for the water systems, a graphic system is used so that evaluations can be made at a glance in connection with the distribution system. The operation display system is divided into the operation part and the accident display part. The operation part has standardized compact operating buttons and the accident display part is divided into different control areas so that evaluation is possible at a glance.

3. Construction of the Control System Suitable for Wide Ranging Control

Since the water supply area is very wide and separated by 20～30km and because of wiring costs and the need for data transmission for the expanded area in the future, the lines of the Nippon Telegraph and Telephone Public Corporation are used. Data from the current 13 supply points are transmitted to the digital telemeter and are processed by the computer via the computer coupling unit. In the central monitoring panel, the measured values of the important points are displayed digitally.

4. DDC Control System for Filtration Plants

A computer was introduced into the existing Okubo filtration plant at a comparatively early time and the plant is operated by SCC (Supervisory Computer Control) which performs accident display and data logging and SPC (Set Point Control) with regulators. However, the DDC (Direct Digital Control) is used for optimum control in accordance with wider ranges and higher levels of the control system based on this experience.

5. Reliability Improvement System Construction

Since the control system is the DDC system as was described previously, it is necessary to take measures considering the MTBF (Mean Time Between Faults) and the MTTR (Mean Time To Recovery) for the total computer system. In this system, measures are taken to prevent effects on the overall system by doubling and switching peripheral equipment and simultaneously by ensuring operation of the important devices when one system is down. In the central control room, conditions are displayed on the graphic panel so that it is easy to understand overall conditions and a manual operaion switch is provided in the central operating panel as an operation back-up function.

6. Construction of the Easy to Control Man/Machine Interface

Because the control system consists of a basic computer control system, the exchange of data between the control system and humans requires

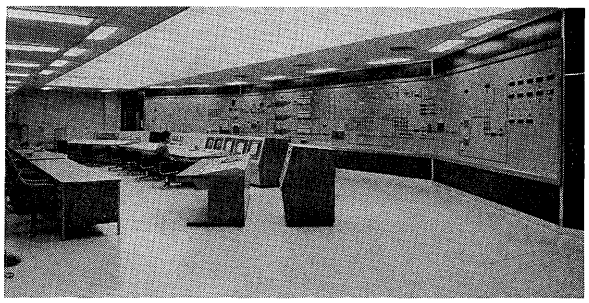


Fig. 2 Central control room of filtration plant

an easy, clear system. In particular, the data exchange with the frequently used CRT display uses the menu system in which data can be retrieved easily. In addition, measuring system display, alarm display and statistics analysis display are employed effectively using 3 CRT displays.

IV. CONTROL SYSTEM AND SYSTEM CONSTRUCTION

The Seibu filtration plant has a control room in a newly constructed 2-story building with a common control system for two plants for geographical reasons, i.e. the Seibu plant is near the existing Okubo plant and for reasons of the water transport system, i.e. water is to be supplied not only to the western part of Saitama prefecture but also to the central part. The computer system located in a special computer room together with the telemeter system on the second floor of the new main building. The main building machinery is also located in special rooms. The site relations are controlled with systems divided as follows for the various stations in order to control the wide area involved.

(1) Water intake equipment
(2) Sedimentation and fiiter equipment
(3) Seibu water transport equipment
(4) Central water transport equipment
(5) Main building equipment
(6) Sludge treatment equipment
(7) Kamiakasaka relay pumping station equipment
(8) Users telemeter equipment (current 13 central and western stations)

The configuration of this main control system is shown in *Fig. 3*. The following sections describe the control systems for the above equipment.

1) Power receiving system

60kV 2-system reception 2-line distribution system

This system consists of three transformer banks of the Okubo filtration plant and two transformer banks of the Seibu filtration plant. On the load side, power is supplied by a bus line for each system to the various. One system is for normal use and one is for standby. An ultra-fuse to decrease the short circit current between the normal and standby circuits.

2) Emergency generator control systems

The Okubo plant has one emergency generator (one more to be added in the future) and the Seibu plant also has one (one more to be added in the

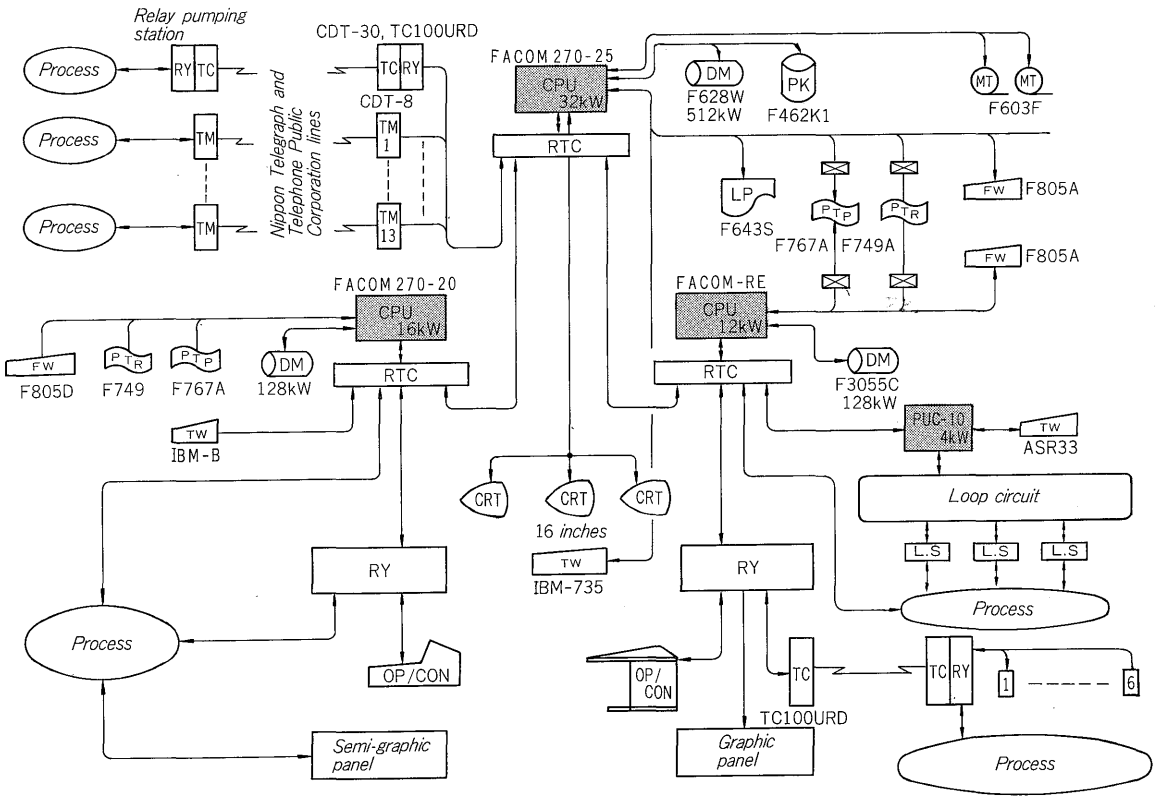


Fig. 3 Configuration of control system

future). They serve a standby power sources for emergencies in both plants and continue to supply power to both by a 3kV line.

3) Measuring system
   Instrumentation system, Teleperm IS system
   Graphic panels, Digital display
4) Control power supply system
   Supply system : central power supply system
5) Computer control system

The computer system as shown in *Fig. 3* is a 3-level hierarchy system. The upper level employs a control computer (FACOM 270-25), the lower level computers for each filtration unit (FACOM 270-20 for the Okubo filtration plant and FACOM-RE for the Seibu filtration plant) and the lowest level a special controller (PUC-10) for dosage control in the Seibu filtration plant. The functions of the overall system are divided in this way.

The special compact computer in the lowest level is responsible for control of chemical dosage amounts and connects the local stations at each dosage point by one loop circuit. It consists of this, the data highway system which receives measurement and control signals and the DPCS (Data highway Process Control System).

To improve reliability, the PTP conversion, three CRT's, operator consoles for each computer system, back-up typewriters, portable consoles, manual operation switches, etc. are used.

6) Man/machine communication system

The man/machine communication devices include CRT display, LP, TW and graphic panels. The CRT display is the heart of the control system during both normal operation and emergencies. Its functions include quantitative process display, system display, set value input/output, alarm and countermeasure display. In particular, the CRT display system has the menu system by which any data among the displayed menu items can easily be retrieved merely by designation by the operator. The CRT's are connected to the upper level computer, have display functions for both the Okubo and Seibu plants and can show almost 300 pictures. A line printer is used to aid the CTR's and any data displayed on the CRT and designated by the operator can be immediately printed out as hard copy.

Since the filtrations plants and water transport systems are large scale, all systems can not be displayed on the CRT's. To compensate for this, the overall system (reception, power and water systems) is monitored by the graphic panels. The important data from the check points (water transport amounts chemical dosage amounts, water transport terminal pressure, etc.) are displayed digitally for understanding at a glance from digital tube display on the graphic panels.

7) Data transport system

There are two types of data transport: data change among the upper and lower level and lower and lowest level computers and among the relay pumping stations and the 13 user stations. The former is performed via real-time control equipment because of transport distances, transport speeds, etc.

The transport control systems, in accordance with the advice of the ISO, is a polling/selecting systems from the high rank. The latter is descrided in section **V. 3.**

V. MEASUREMENT, CONTROL AND DATA TRANSMISSION

1. Measurement

The measurement of each process amount is basically performed by current transmisson (DC 4～20mA) by means of a Teleperm IS system and by a voltage signal receiving system (DC 1～5V).

Fig. 4 is a schematic diagram of the measurement system for each measurement point. Electromagnetic flowmeters are used to measure transport water flow, chemical dosage and sludge flow. In other cases, particularly in places with large diameters, the easy-to-install ultrasonic flowmeters are used.

Items measured related to water quality are raw water pH, turbidity and alkalinity ; rapid shaking basin pH, residual chlorine and alkalinity ; sedimentation basin turbidity, residual chlorine and alkalinity ; and purification basin pH, turbidity and residual chlorine.

Because of the large number of items measured, trend recording by special jacks and selective recording and display by digital switches are used for data monitoring. There are three trend recorders, one each for general, water quality and filter basins. There is one general selective display system and three selective display systems for the filter basins. The instruments are located in the central control room and the auxiliary panels where monitoring is performed.

In addition to analog monitoring, there is also digital display on graphic panels of total values of water main flow and chemical dosage, inflow of filter basins and rapid shaking basins, amounts of power received, flow and pressures at the users' ends, and important data from the relay pumping stations.

Other instrumentation introduced include the ITV system and the climate observation system. The ITV system consists of 14 cameras including existing parts (25 in the future) with switchover between 2 monitors. There is monitoring of the interior of the plant as a whole and block conditions of blocks of basins. The climate observation system feeds wind direction and velocity, humidity, temperature, sunlight, air pressure and rainfall into a computer. Important basic data are compiled from various types of statistics.

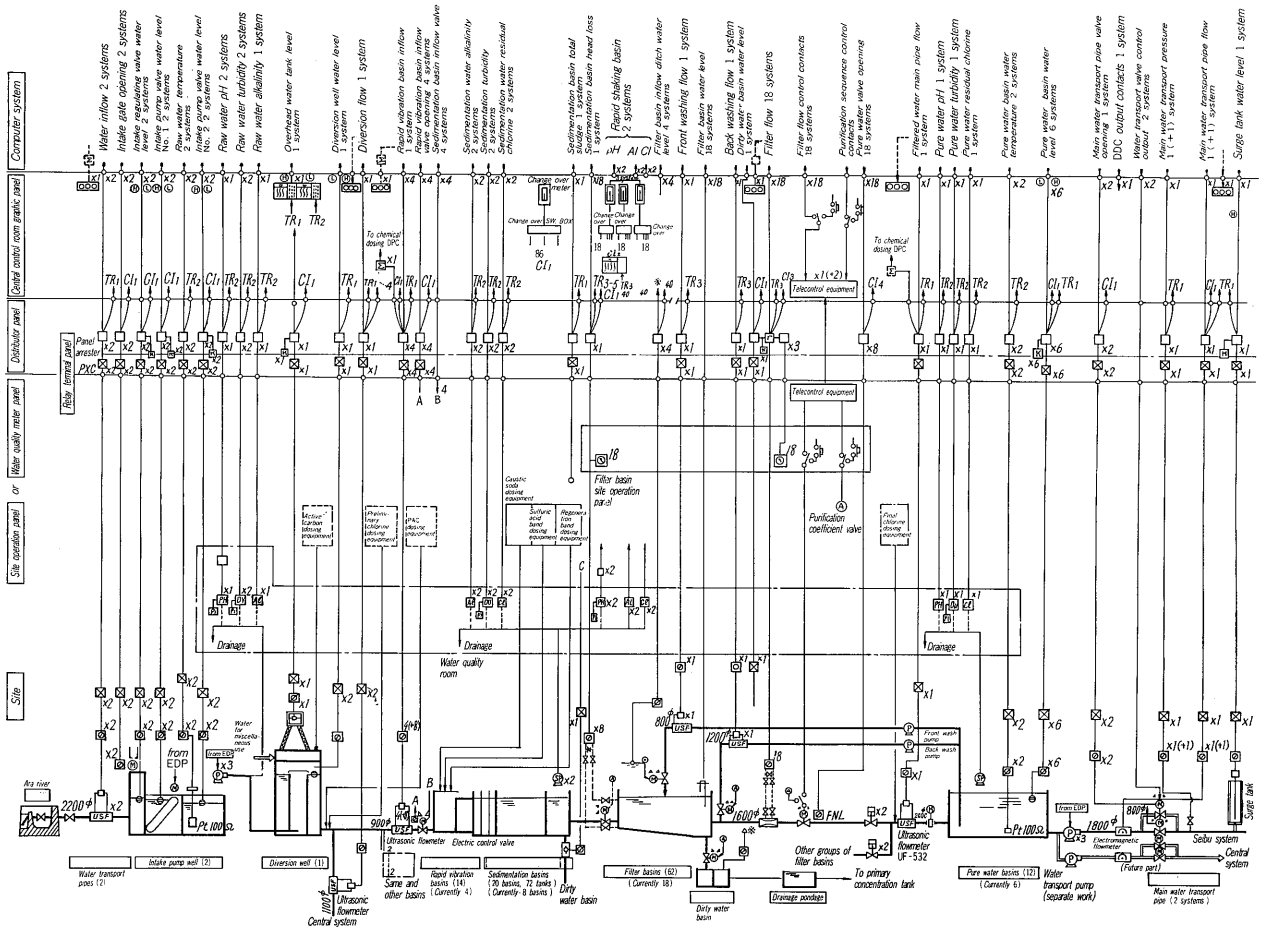


Fig. 4 Schematic diagram

2. Control

1) Filter basin washing control

Washing and flow control is performed by a DDC system using a computer. Automatic washing and flow regulation are performed by means of a program decided beforehand. The filter basins are divided into blocks. Including future parts, there are to be four blocks, each consisting of 18 basins.

The filter basin yard has telecontrol equipment for use between the basin sites and the computer because of the long distance of 1 km between the site and the central control room and the large scale system with many filter basins. Control and display signals are received and automatic washing is performed.

When the computer is down or there is an abnormality in the water transport channels, manual operation from the central operating desks or site operation at one site pillar per filter basin can be performed.

Since the front washing pump has the capacity of the basin washing part, simultaneous basin washing by both automatinc and manual operation is possible.

In the central control room, there are display of the number of each basin, manual operation, washing, faults and stoppages on the graphic panels; analog displays of filter basin head loss, filter flow

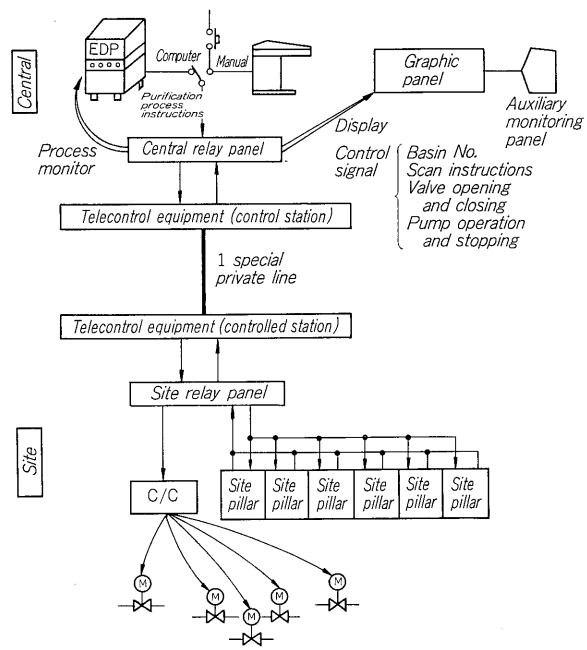


Fig. 5 Block diagram of filter washing system

and outlet valve opening on the auxiliary panels; and display of dirty water basin water levels, etc. related to washing conditions on the operating desks. *Fig. 5* shows a simple block diagram.

2) Chemical dosing control

Chemical dosing is performed as follows: 2 points for caustic soda (5～1,000 ppm), 2 points for activated carbon and 3 points for preliminary chlorine at the diversion well outlet; 4 points for sulfuric acid band (5～120 ppm), 4 points for PAC (5～120 ppm) and 4 points for regenerated band in the rapid shaking basin; and 1 point for final chlorine at the filter basin outlet.

The control system uses a compact computer (PUC-10 type) because of the water treatment plant characteristics, wide-scale internal area control characteristics and degrees of importance in the plant. A single multi-core cable is arranged in a loop from connecting the local stations located at the site and automatic dosing control is performed by a DPCS (Data highway Process Control System) which receives and transmits measurement and control signals.

The DPCS consists of about 30 local stations scattered in three places and a central controller. They can be switched at 0.1 sec. per station and sampling control is performed in sequence. Analog signals from the signal generators are converted into digital signals in the local stations and they are transmitted to the central controller via the single loop-form multi-core cable.

After processing, the central controller transmits the control signals to the local stations using the same loop cable and each valve is controlled. Setting of the chemical dosing rates at this time is by means of instructions from the upper level computer to the controller.

The data lines consist of both automatic operation lines and manual operation lines. When there is a fault in the automatic lines, manual operation can be performed from the portable console and as a back-up when the controller is down, operation can be performed from operation panels located in the central control room and at three places at the site.

For activated carbon, a system of dosing in proportion to the raw water flow is used and operation is performed from the electrical room located in the diversion well.

Fig. 6 shows a flow diagram of the dosing system.

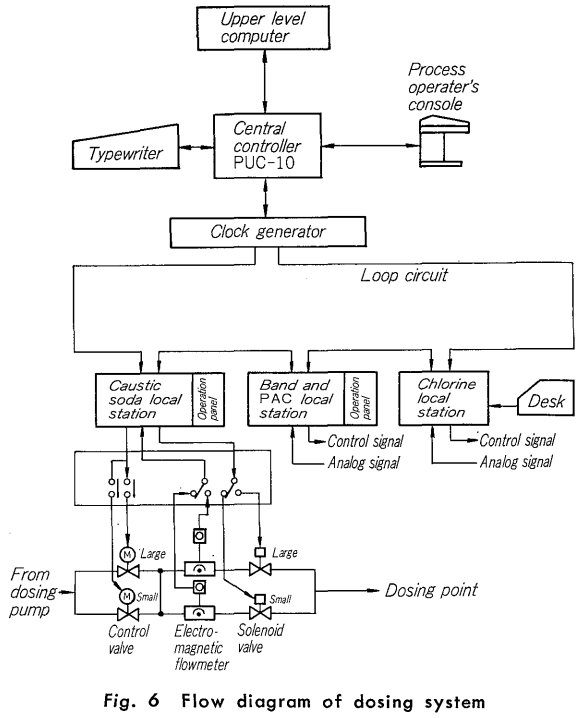


Fig. 6 Flow diagram of dosing system

3. Data Transmission

This system performs data transmission and control among the 13 receiving stations for the Seibu filtration plant (in the future, 20 stations for the Seibu plant and 15 for the Okubo plant), replay pumping station and the filter basin site subcenters. In each relay pumping station in the various local towns, the lines of the Nippon Telegraph and Telephone Public Corporation are used.

1) Local telemeter system

The data from each town and village (inflow, inflow pressure, inflow solenoid opening, inflow distributing basin water level, residual chlorine) are transmitted to the Seibu filtration plant by the cyclic digital telemeter (CDT type) at a transmission speed of 200 Bauds. A 1:1 construction is used.

In the Seibu filtration plant, the data are fed into the computer. Data processing is performed and the data is monitored by CRT display and digital display on the graphic panels of the central control room. Digital display shows flow and pressure values and monitoring is performed by switching at the central operating desk.

Data exchange between the computer and telemeter employs the bit parallel word serial system. Monitoring, distribution network control and data calculations for predicted demands are performed and each processing amount becomes important data for future water distribution scheduling.

The transmission circuits employ one circuit switching between the telemeter and telephone in addition to those for telemeters. This is used mainly for protective telephones.

2) Relay pumping stations

The relay pumping stations is used to distribute clean water from the Seibu filtration plant in the Tokorozawa area.

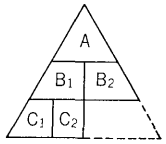
The data are telemetered to the Seibu filtration plant and from the Okubo filtration plant, remote one-man control of the various devices (receiving circuit breakers, special receiving devices, emergency generator, transport pump, receiving tank inflow valve, water transport regulating valves, etc.) is per-

formed using pulse code type telecontrol equipment (TC-100 URD type).

VI. COMPUTER CONTROL SYSTEM

1. Hardware and Processing Jobs

Table 1 shows an outline of the various computer systems and the processing iobs. The upper level computer is a data processing system while that of the lower level is a monitoring and control system.



A : *Overall control level computer* (FACOM 270-25)
B : *Filtration plant level computer* (B_1=FACOM RE, B_2=FACOM 270-20)
C : *Terminal level computer* ($C_1 = C_2$=DPCS)

Fig. 7 Hierarchy system

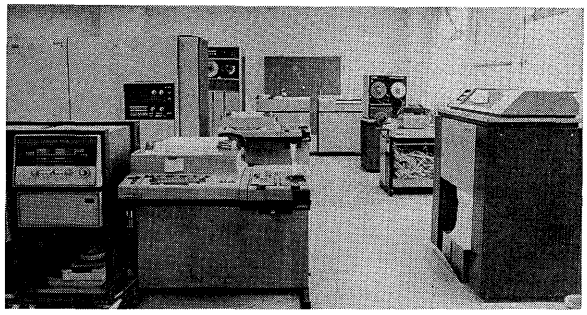


Fig. 8 Computer room

Table 1 **Comparing job with hardware**

Level	Central processing equipment	Connected I/O equipment	Job
Upper level	FACOM 270-25	DM (512kW), DP (2,500kW) PTR, PTP, LP, FW MT×2, CRT×3, I/O TW RTC,OP/CON, TW	1. Overall control of central and western filtration plants 2. Monitoring and control of western users and relay pumping stations 3. Data exchange with operator 4. Compiling of reports and data banking
Middle level	FACOM RE	DM (128kW) PTR, PTP, I/O TW RTC, OP/CON	1. Monitoring and control of western filtration plants 2. Data exchange with upper level computer 3. DDC control system (DPCS) control
	FACOM 270-20	DM (128kW) PTR, PTP, I/O TW RTC, TW, OP/CON	1. Monitoring and control of central filtration plants 2. Monitoring of central relay pumping stations 3. Data eachange with upper level computer
Lower level	DPCS	I/O TW, OP/CON	Dosing monitoring and control

2. Software System

1) Application software components

The application programs are as classified in *Fig. 9* and data transmission and the service subsystems are matched with the interface between the computers on the basis of simultaneous control of

Table 2 **General features of program system**

Subsystem name \ OS name	ROSP	PCPS	M III/3
Scheduling	Overall control of application program	Same as left	Same as left
Process input processing	—	Input processing for Seibu filtration plant	Input processing of central filtration plants
Job statistics	Seibu and central data statistics, compiling of reports	—	—
Control statistics	User predictions by correlation and feedback analyses, etc.	—	—
Process monitoring	Monitoring of users and relay pumping stations	Upper and lower levels, variations, SF, maintenance	Same as left
Power system monitoring	—	Seibu load monitoring	Monitoring of power failures, restarting of power transmission, central load
Process control	Back-up for relay pumping stations and Seibu DDC	Seibu filtration plant control	Control of central filtration plants
Operation control	Operator console input/output	Back up and operator console input/output	Same as left
CRT display	CRT input/output	—	—
Data transmission	Signal transmission and receiving with PCPS and M III/3	Signal receiving and transmission with ROSP	Same as left
Service	Off-line data exchange, MT input/output	Off-line data exchange	Same as left

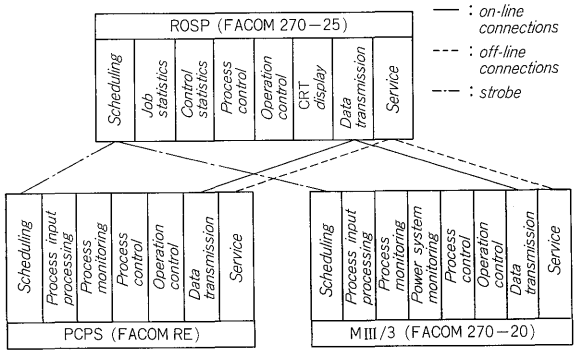


Fig. 9 **Software configuration of application program**

the scheduling subsystems. These subsystems have the functions shown in *Table 2*. Independent computer application is also possible.

2) Process data processing

(1) Process input processing

In the lower level filtration plant computer, analog, pulse and digital inputs are received. These are all transmitted to the upper level processing computer. Wide ranging telemetering data is fed directly the upper level computer.

(2) Statistics

The input data undergo clerical processing in the upper level computer or the so-called control statistical processing which includes correlation and feedback analyses based on time series data, demand predictions, etc.

(3) Process monitoring

Upper and lower level checks for water and liquid levels, water quality, pressures, etc.; excess and insufficiency checks for chemical dosing; and variation rate checks for water quality and pressure are performed. Fault conditions in process devices are detected at operation restoration points as SF input and maintenance control is performed for powering devices from operating time integrations.

(4) Power system monitoring

Rapid detection of power interruption, guidance concerning retransmission of power and load distribution instructions during emergency generator operation are performed. When a power failure is detected, operation is stopped for all of the process control programs and the process conditions are maintained the same as before the power failure.

3) Process control

(1) Control systems

As can be seen in *Table 3*, the PCPS is applied in the Seibu filtration plant by means of the DDC control system and the MIII/3 is used in the Okubo filtration plant by means of the SPC control system. The upper level ROSP performs back-up control of the Kamiakasaka relay pumps and the 23 DDC loops of the PCPS. The amounts of water transported to the Okubo and Seibu filtration plants are instructed from the upper level.

(2) Internal water distribution system

On the basis of the required amounts of water transport, filtering flow, sedimentation basin inflow and water intake are alloted with stress on the

Table 3 **Process control items**

OS	Control items	Operation	Number	Control systems
ROSP	1. Relay pumping station flow	Pump on/off	3	Number of pumps
	2. Relay pumping station receiving tank water level	TC regulation control	2	SPC
	3. Relay pumping station water transport pressure	TC regulation control	1	SPC
	4. Seibu DDC back-up	Valve opening/closing	23 loops	DDC
PCPS	1. Water intake	Gates, pumps	3	Sequence control
	2. Sedimentation basin inflow	Valve opening/closing	4	DDC
	3. Dirt intake	Pump on/off	8	Sequence control
	4. Filter flow	Valve opening/closing, number of basins	18	DDC
	5. Filter basin purification	Various types of valves	18	Sequence control, simultaneous 2-basin purification
	6. Amount of water transport	Pump on/off, number of revolutions	3	Sequence control, DDC
	7. Water transport pressure	Valve opening/closing	2	DDC
	8. Dosing	DPCS guide	14	Sulfuric acid band, caustic soda, PAC, chlorine
	9. Driving power factor	SC on/off	12	Sequence control
M III/3	1. Water intake	Pump on/off	6	Sequence control
	2. Industrial water sedimentation basin inflow	Regulator setting	2	SPC
	3. Clean water sedimentation basin inflow	Regulator setting	5	SPC
	4. Filter flow	Regulator setting	24	SPC
	5. Filter basin purification	Purification instructions	24	Sequence control
	6. Amount of water transport	Pump on/off	26	Sequence control
	7. Water transport pressure	Regulator setting	4	SPC
	8. Dosing	Regulator setting	24	SPC (sulfuric acid band, PAC, caustic soda, chlorine)

following three points:

(a) Constant water level in the filter basin inlet conduits

(b) Purification basin water level can vary within the permissible range.

(c) Operation at suitable number of filter basins and filter speeds

(3) Filter basin washing

The washing conditions are head loss, filtration time and optional washing demands and a group washing sequence has been achieved with the universal program "SSAD II". This SSAD II is a software adaptation of the conventional relay sequence and simultaneous parallel washing of two basins is possible.

(4) Determination of water transport pressure

The primary pressure to ensure the required residual pressure and the relay pumping station pressure are calculated on the basis of the William Hazzen average wear hear loss system.

(5) Chemical dosing

There are three computer control modes: fully automatic, semi-automatic and semi-manual. With full automatic operation, measuring control is completely automatic. Under semi-automatic operation, the turbidity and alkalinity values are indicated and carried out automatically. The dosing rate must be indicated in the semi-automatic mode.

4) Man/machine interface

Each computer system has interface functions with individual operators but the CRT display system in the ROSP consists completely of interface equipment and has the following features:

(1) Screen retrieval is performed by a menu type retrieval system.

(2) Hard copying can be performed by line printer equipment.

(3) Displays of all plant systems are included.

There are 160 screen displays including plant data displays and plant condition pattern displays.

(4) Numerical value up-dating is possible.

There are 80 displays for settings including standard values and control constants.

(5) Alarm and guidance displays are all by CRT. Displays are classified as those for abnormalities such as analog input broken wires, changes, upper/lower limits, sequence faults and control delays and their countermeasures, as well as power device maintenance demands, etc.

5) Data exchange between computers

(1) Couplings between computers

The couplings are RTC direct linkages but when there is an interruption in transmission, data can be exchanged by paper tape or back-up poerator consoles.

(2) Transmission control

A polling selecting system for the upper level computer is used.

(3) Transmitted data

There is transmission from lower to upper levels of process conditions every minute, process variations every 5 minutes, report compilation data every hour or at set intervals and alarms at random. Setting instruction values are transmitted from the upper to lower levels.

3. Data Banking and Reporting

Conventionally, reporting including hourly, daily and monthly reports is usually performed by several ordinary typewriters. In this system, measured process amounts exceeding 1,000 points are collected in a data bank on a short-term basis and on magnetic tapes on a long-term basis. About 50 items related only to water flow and pressure values are given out once a day on a line printer. Data from the bulk memory can be retrieved by the CRT. In all cases, processing is by the upper level overall control computer.

VII. CONCLUSION

The above article has introduced an outline of the Seibu filtration plant. Details of the sludge treatment equipment and the Okubo filtration plant and interrelations with water supply will be introduced in another paper because of lack of space. However, it is necessary add to and expand the control system in accordance with increased water demands and plant expansions. It is considered that this system will become a higher level control system on the basis of future operating results.