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WIDE REGION WATER CONTROL SYSTEM FOR KANAGAWA WATER SUPPLY ENTERPRISE

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I. INTRODUCTION

Recently, a large scale computer system (FACOM 230-45S) was delivered as a wide ranging water control system to the control center of the Kanagawa Water Supply Enterprise. The reason for introduc ing this computer system was to achieve interrelated operation using data communication by wireless equipment from the control center to various machine rooms such as the Iizumi pumping station newly constructed by the Kanagawa Water Supply Enterprise, the Sagamihara pumping station, the Sagamihara filtration plant, the Nishinagasawa filtration plant and the Isehara filtration plant which is now under construction. The complete water system from intake to distribution is monitored and controlled to ensure smooth control and management. This system is the first to employ a large scale computer in a water works and it is used in a wide region water control system covering Kanagawa prefecture and the three cities of Kawasaki, Yokohama and Yokosuka.

II. OUTLINE

Fig. 1 is a map of the station and *Fig. 2* an outline of the process flow line. Raw water released from the Sakawa dam is taken into the Iizumi pumping station. After the raw water is pumped up to the Soga connecting well by the Iizumi pumping station, it flows down naturally through a conduit about 30km long to the Sagamihara intake well via the Isehara diversion well. On the way, water is pumped up by the Isehara diversion well and is conveyed to the Isehara filtration plant. After pumping up at the Sagamihara pumping station, the water is conveyed under pressure to the Sagamihara and Nishinagasawa filtration plants. At each filtration plant, the water is supplied to the four enterprises included via the distribution basins and supply points after purification.

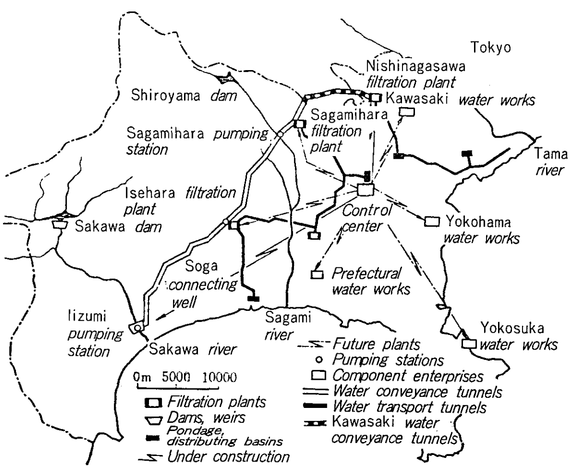


Fig. 1 Map of station

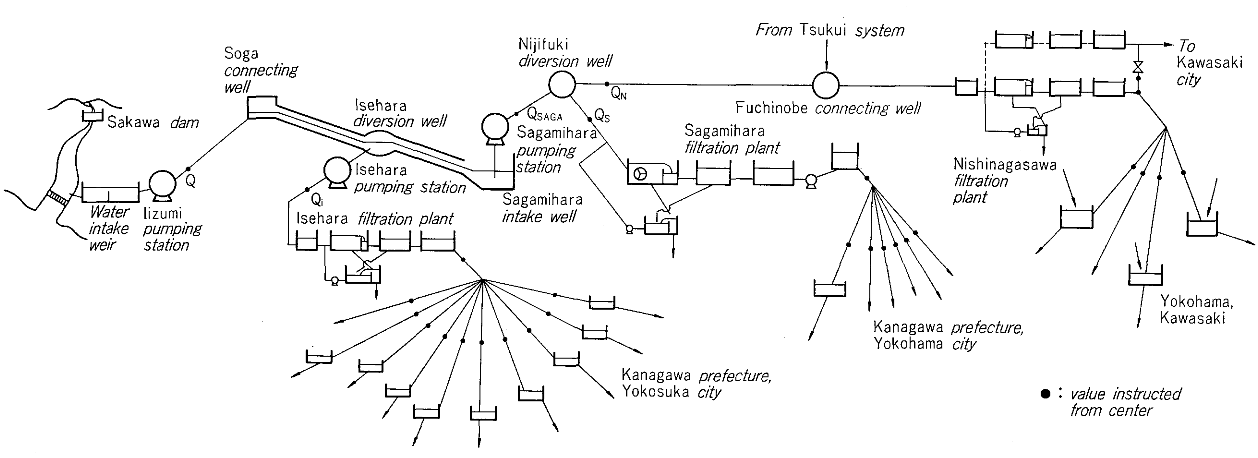


Fig. 2 Outline of process flow line

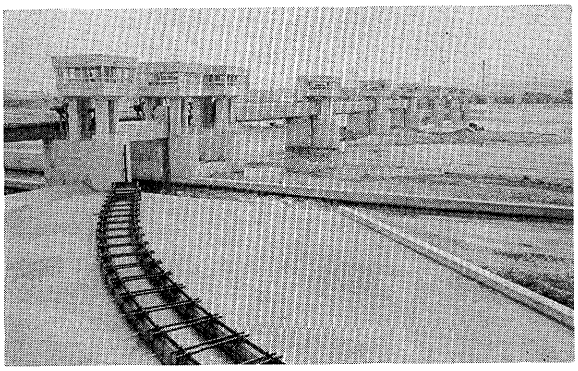


Fig. 3 Intake weir

The control system is an overall control system covering the total water system from intake to distribution. It is intended to achieve water supply circulation, efficient utilization of water and optimum distribution control both quantitative and qualitatively. Therefore, a large scale computer was installed in the control center to perform control of the entire system.

The system consists of 1 water source, 3 filtration plants, 3 pumping stations, 19 supply points, 4 component enterprises and the control center.

The control center is connected either directly or indirectly to the facilities by radio signals and performs overall control. The basic instructions concerning water quantities and quality for the whole system are sent from the control center. The various site machine rooms have subsystems which control the facilities in the site on the basis of the basic instructions.

The control center sends water quality and quantity instructions directly to four machine rooms, i.e. the Iizumi pumping station, the Isehara filtration plant, the Sagamihara filtration plant and the Nishinagasawa filtration plant.

In the future, the control center will also perform data communication by an INQ system with the four enterprises, i.e. Kanagawa prefecture, Yokohama, Kawasaki and Yokosuka.

The Iizumi pumping station controls the pumping station itself, the Sakawa dam and the Soga connecting well on the basis of instructions from the center.

The Isehara filtration plant controls the plant itself, the Isehara pumping station and 9 supply points on the basis of center instructions.

The Sagamihara filtration plant controls the plant itself, the Sagamihara water quality center and 6 supply points on the basis of center instructions.

The Nishinagasawa filtration plant controls the plant itself and 4 supply points on the basis of the center instructions.

The control center, these four site machine rooms and the four enterprises are connected by a 400 MHz multi-directional, multiplex radio wave centered at the control center and data transmission is performed at 1,200BPS.

The transmission circuits consist of a total of 17: four each of control, INQ, TSS and telephone circuits between the control center and the four machine rooms and one INQ circuit between the control center and the four enterprises.

The center has overall control functions including collection of data from each machine room, determination of operating conditions, monitoring, compilation of control data, storage, processing of various types of data, instructions to machine rooms, communications between machine rooms and enterprises and computer TSS.

Outlines of each facility are given below.

1) Amounts of water distributed

Kanagawa prefecture	378,000m^3/day
Yokohama	563,000m^3/day
Yokosuka	19,000m^3/day
Kawasaki	495,000m^3/day
Approx.	1,460,000m^3/day

2) Facilities

(a) Storage and intake facilities

Storage dam	$5{,}450 \times 10^4$m^2
Intake weir	160×10^4m^2
Iizumi intake pumping station	6,500kW $\times$ 4 362m^3/min $\times$ 82m

(b) Water conveyance routes

Water conveyance tunnels	Max inner diameter 3.8m $\times$ length 30km
Water conveyance pipes	Max inner diameter 3.1m $\times$ length 12km
Connecting wells & diversion basins	4 basins
Water conveyance pumping stations	4,600kW $\times$ 4,312m^3/min $\times$ 67m

(c) Water purification facilities

Isehara filtration plant	22×10^4m^3/day, sedimentation basins $\times$ 4, filter basins $\times$ 16
Sagamihara filtration plant	40.7×10^4m^3/day, sedimentation basins $\times$ 12, filter basins $\times$ 32
Nishinagasawa filtration plant	93.8×10^4m^3/day, sedimentation basins $\times$ 12, filter basins $\times$ 36
	160×10^4m^3/day

(d) Water transport facilities

Water transport pipes	inner diameter 2.8～1.1m, length 95km
Pondage	4 basins

III. BASIC CONCEPTS OF THE CONTROL SYSTEM

In the design of the wide region water control system the process characteristics must be carefully analyzed to ensure that system management runs smoothly. In this system, the following basic policies were used in the design.

1) Overall control system (Hierarchy system of central overall control + machine room inde-

pendent control)

The process controlled by this system is intended to distribute efficiently water from 1 source to 4 users (component enterprises) so that water network control (water quantities and quality and inlet and outlet) continuously from intake to distribution. Therefore, centralized overall control is essential.

An independent machine room control system making possible operation and water distribution in each machine room separately so that water can be supplied continuously to the users even when the center computer is stopped temporarily. This system is such that it operates the machine room prior to operation of the control center.

2) High reliability system (non-stop system)

In the wide region water control system, high reliability is essential out of consideration of the public utility characteristics of the process, the wide region, the wide range of equipment, the size of the treatment facilities, etc. In this system, when there is an abnormality in any part including the control center computer, the transmission equipment and the machine room PDC, the system is never completely down and continuous operation of each machine room is possible.

The reliability sequence is as follows:

(1) Machine room site operating panels
(2) PDC (Process Digital Control)
(3) Data transmission system
(4) LU (Linkage Unit)
(5) Central computer (FACOM 230-45S)
(6) TSS (Time Sharining System)

3) Effective utilization of a large scale computer INQ, TSS system

A large scale computer was used for the wide region water control. The main reasons for this were process control and the data bank but to utilize these "large scale" functions, the INQ and TSS systems were used so that the computer could be used commonly from not only the control center but also from all of the machine rooms. With these systems, it is possible to perform remote operation via the radio circuits from the terminal equipment in the machine rooms and the control center computer can be used freely just as if it is near at hand.

4) Two computer system: process control computer and data bank computer

The control center has two large scale computers: a control computer and a data bank computer. The control computer (FACOM 230-45S) is connected to the PDC equipment and the INQ and TSS equipment in each machine room and has on-line real-time functions.

The data bank computer (TOSBAC-5600) is connected to the control computer via CCA equipment and is used for data storage and clerical calculations. Its main function is batch job processing.

5) Wireless data transmission

Data transmission between the control center and each machine room is performed by wireless circuits. This system is used because of the importance of communications during disasters such as typhoons, and also for economy considering the wide transmission ranges. A 400MHz multi-directional multiplex system is used for high reliability.

6) Use of optimum control algorithms

One of the features of this system is the development and use of algorithms of a feed forward system based on demand predictions for water conveyance control in conduits which cover 30km and have large time constants.

IV. CONTROL CENTER SYSTEM COMPONENTS

Fig. 4 shows the system components of the control center. The control center consists of a computer room and a control room. The following control system equipment is provided in the computer room:

Control computer (FACOM 230-45S) 1
  Memory capacity: 327kB
  Cycle time: 700ns/2 bytes
Magnetic drum equipment (FACOM 6622L) 1
  Memory capacity: 6,144kB
Magnetic tape equipment (FACOM 603M).........6
Set disk pack (FACOM 472L) 4
  Memory capacity: $58,352 \times 10^3$ bytes per pack
Card read-out equipment (FACOM 668K) 1
Line printer (FACOM 647L) 1
  Print-out speed: 1,260 lines/minute
Typewriter (FACOM 795A).............................3
Character display equipment (FACOM 6221D) ...1
  No. of characters displayed: 50 characters $\times$ 20 lines
Linkage unit (FACOM U-200) 2
  Memory capacity: 40kB
  Cycle time: magnetic core: 650ns
Interface control unit (ICU) 2
Typewriter (FACOM 795A) 2
Communication control equipment (FACOM 1801k) 1
  Communication system: completely double communication
  Communication speed: 1,200BPS
  Transmission control: call/reply system, polling system
Circuit connection equipment (LUT).................1
Set MODEM (MD-12B) 1
  Modulation system: frequency modulation
  Communication speed: 1,200BPS

A photograph of the computer room is shown in *Fig. 5*.

The FACOM 230-45S computer is a large scale computer with excellent cost performance. It is completely equipped with software including application programs, on-line packages and operating systems.

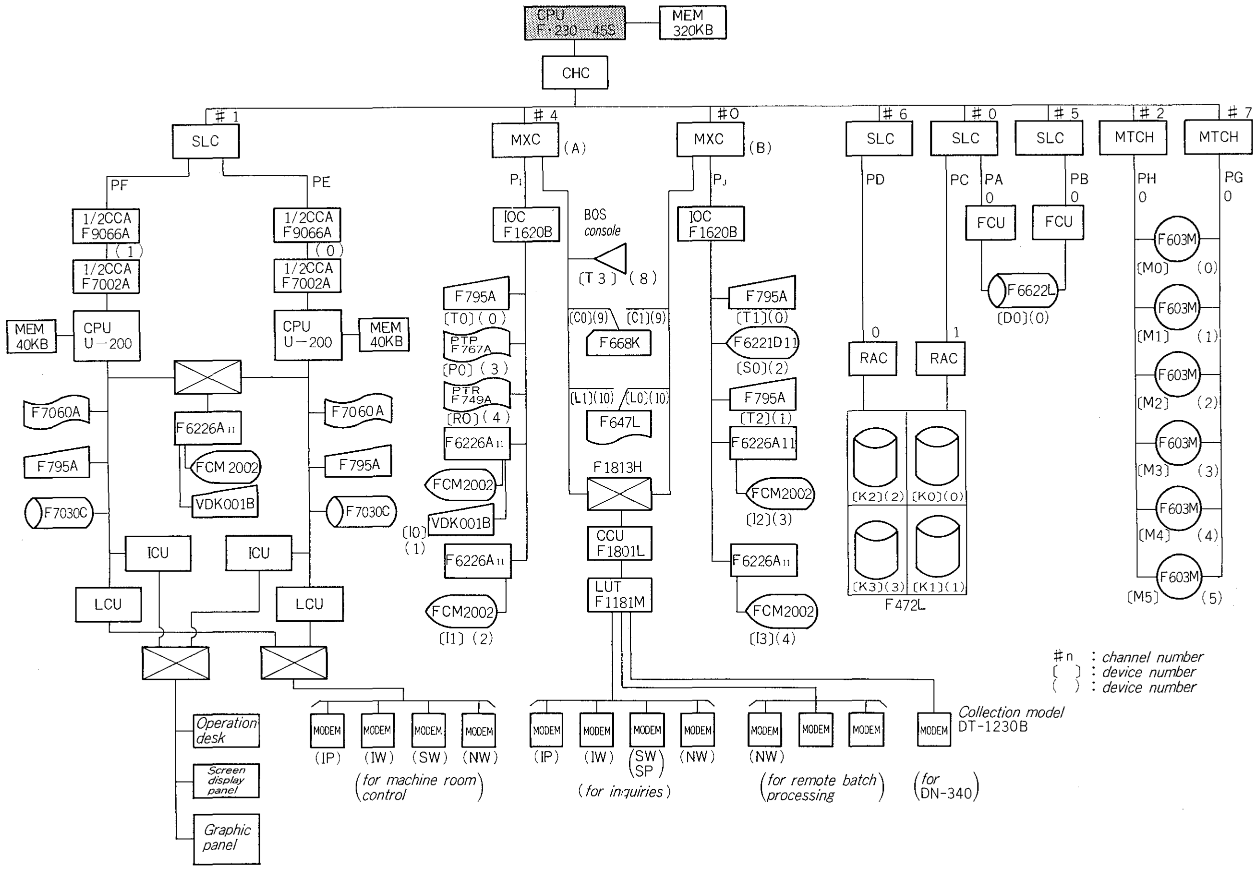


Fig. 4 **Constitution of computer system**

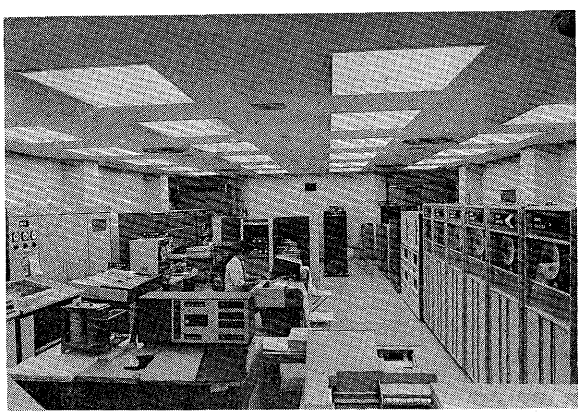


Fig. 5 Computer room

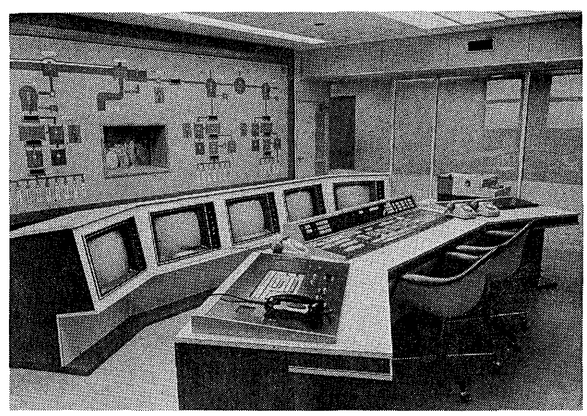


Fig. 6 Operation room

A high capacity, high speed magnetic drum is employed in the job stacking file for high speed internal processing and multiple program processing supporting real time/batch parallel processing. A page address system is used which makes possible simultaneously effective utilization of the memory range and reductions in overhead. The memory equipment is divided into several blocks and the fail-soft concept is used in the simplex system.

The linkage equipment is of the FACOM U-200 system which has built in high speed magnetic core memory equipment, processing control equipment, optimum signal control adapters, standard input/output control adpaters and operating panels. This system employs a semi-dual system which ensures higher reliability.

The central control room is located next to the computer room. It contains mosaic type monitoring panels, CRT panels (CRT×5), operating desks, application typewriters (FACOM 795A) and telephone equipment. *Fig. 6* shows a photograph of the central control room.

V. CONTROL CENTER FUNCTIONS

1. Computer Room

The data from each machine room are transmitted by radio wave and collected by the set

MODEM. After input processing by the LU, the data are fed into the control computer (FACOM 230-45S). The input data are filed in the auxiliary memory equipment after various operations and data processing by the computer.

The magnetic drum is used for the roll-out file of the on-line processor and the disk pack is used for the system volume, the on-line master file, files for each function, constant file and stored data (instantaneous values for 7 days and processed values for 1 month). The magnetic tape is used for batch job program file-save, and storage of statistical and process characteristics analysis data.

The LU (FACOM U-200) serves as a linkage (circuit control) between the machine room PDC equipment and the control computer. In addition to performing jobs such as operator console input/output, graphic panel display and screen display, the LU also has back-up functions for the control computer. In other words, when the control computer is stopped, the LU only can guarantee functions required for control such as data collection, data storage, data display and on-line control and can also maintain system operation.

The INQ supplies data to INQ terminal equipment in accordance with calls from machine varroms for various types of required data (water quantity and quality data and operating information for the entire water system). It also offers necessary data by interrupt instructions from the center.

The TSS performs joint utilization and batch jobbing of the center control computer from the terminal equipment in the site machine rooms via the TSS circuits.

2. Control Room

The monitoring panels are mosaic type graphic panels which illustrate the entire water system and perform digital display of the main water quantities, main accident displays from each machine room (water level, water quality and equipment abnormalities) and operation display of the supply points controlled by the filtration plants. Screen display devices are provided in the monitoring panels and detailed plant contents are displayed on 80 equipment screens. Accident locations are displayed at 88 spots.

The CRT panel consists of 5 CRT displays. The displays of the four CRT's on the FACOM 230-45S include for the entire system, the menu, water quantities, water levels, water quality and water pressures as well as control instruction values; for the pumping stations, the manu, water quantities, water levels, water quality, water pressures, measured data from the intake wells and sedimentation basins, pump operating conditions and control instruction values; for the filtration plants, the menu, water quantities, water levels, water quantity, water pressures, measured data from the accumulation wells, sedimentations basins, filter basins, purification basins and supply points and control instruction values.

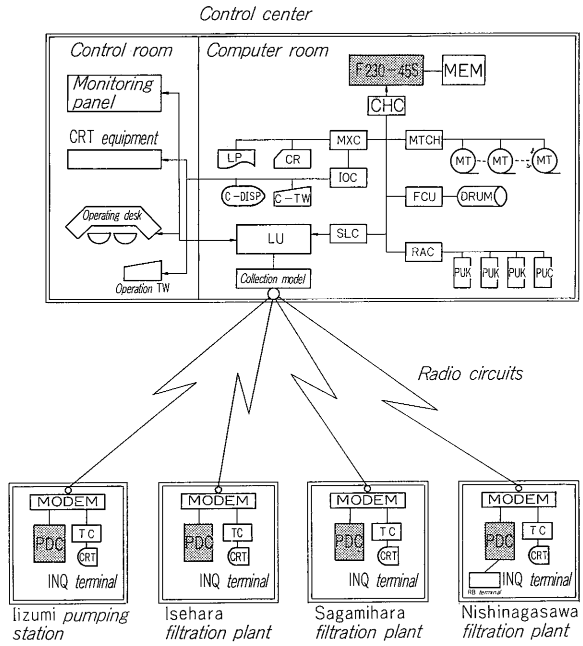


Fig. 7 Connection of center to station

In addition, there are abnormality displays and operation guide displays by screen display instructions by means of interruptions from other programs (example: water system operation program).

The one CRT connected to the LU performs display (water quantities, water quality, control instruction values) in the case of manual operation by the operator when the main computer is stopped.

The operator console is used when the operator wishes to learn of conditions throughout the entire water system from the center or machine rooms and for the manual generation of data settings and control instructions when intervention of the center operator is necessitated by an abnormality, accident, etc. Central manual control is performed in each machine room unit.

The components are a display part and a setting part. The display part consists of displays of time, circuit abnormalities, accidents (for the main equipment in each machine room and the center), machine room operating conditions, main LU system, completion of control data transmission, various data errors (loop numbers, function numbers, data values), irregularities, abnormal loop generation, operator consoles and screen faults. The setting part consists of settings for CRT display switching, machine room designation, loop designation, function designation, control instruction data, screen selection, cut-off designation, control designation (SEND, SENT), abnormal loop confirmation, screen display or deletion, alarm confirmation, key board, set value resetting, operator console confirmation, lamp checking and bell locking.

The application typewriters are connected to the FACOM 230-45S. Operator input consists of demand prediction program selection, water system application processing algorithm selection, recovery time input for main machine room equipment faults, initiation of communication with the data bank and test call instructions. Output from the main computer consists of contents of manual control instructions, details of abnormal loop generation, confirmation of test calls from data bank, confirmation of test calls from LU, confirmation of test calls from the INQ terminals and measured data from manual input.

3. Main Center Jobs

The main center jobs are classified as follows:

1) Data collection and monitoring (checking upper and lower limits of measured data, divergence checks, estimation of data defficienies)
2) Control instruction editing and processing
(1) Flow related items (pumping station intake set values, filtration plant treatment set values)
(2) Filtration plant control (chemical dosing ratio setting, sedimentation basin control, filter basin control)
(3) Daily report processing and compilation
(4) INQ processing
(5) TSS processing
(6) Communication with data bank
(7) Circuit control

VI. SOFTWARE COMPONENTS

The software consists of basic software of the computer and application software for the operation of this water control system.

1. Basic Software

The OSII of the FACOM 230-45/55 is used as the operating system. This OSII operating system has the following features which make it ideal for the safe and smooth monitoring and control of a wide regio water system:

1) Module construction
2) Multi-programming
3) Multi-program processing (priority and parallel processing)
4) On-line processing
5) High reliability
6) Interchangeability

The main constituents of this OSII are control programs and processing programs as shown in *Fig. 8*. The relation to the application software is also shown in the figure.

2. Application Software

The application software is intended for the smooth management of the control system. Since this wide region system has open water channels with long dead times compared with the process time constants, the control algorithms feature prediction control as a basis for time countermeasures and demand predictions. They also include safety control (security control) processing during abnormalities such as plant and process abnormalities. The individual programs are based on module construction and are planned for high reliability and expandability from both the software algorithm and structural standpoints.

Fig. 9 shows the design of the application software. Its contents are given below.

1) Communication program with the machine rooms

Control data from the FACOM 230-45S, recovery data and data for the Iizumi graphic panels are transmitted to the machine rooms. At set times polling is performed in each machine room, the measured data are buffered, other emergency data are received and processing tasks are started depending on the

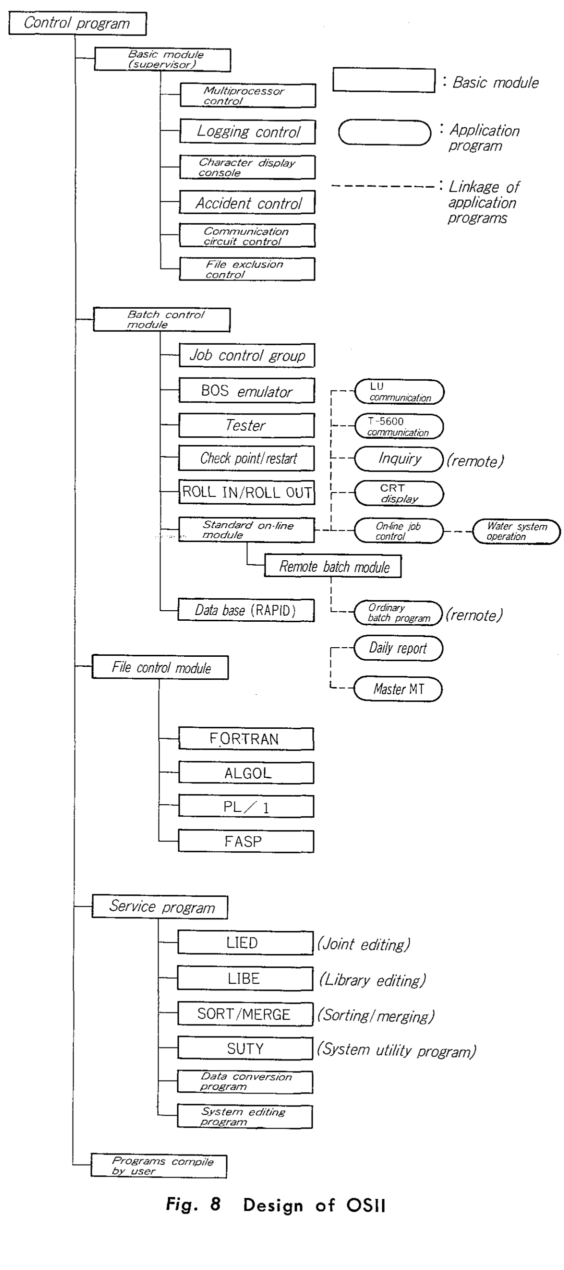


Fig. 8 Design of OSII

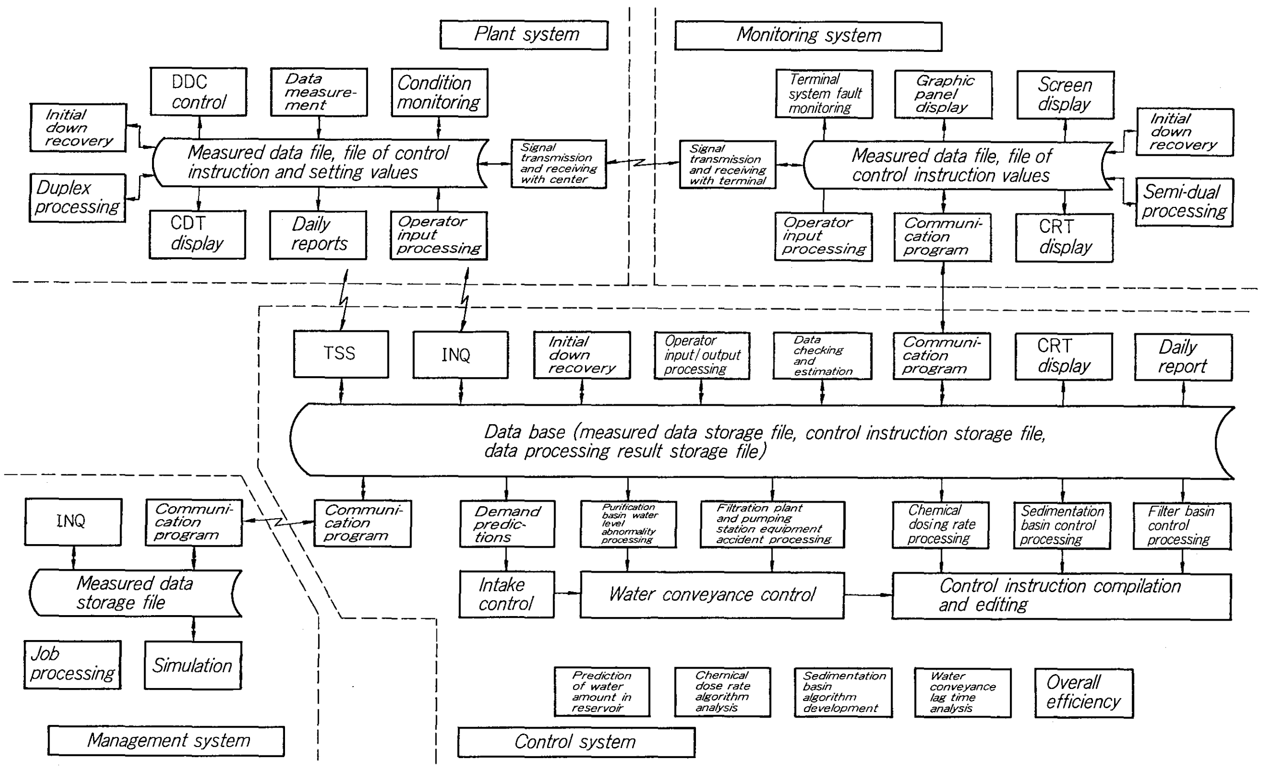


Fig. 9 **Design of application software**

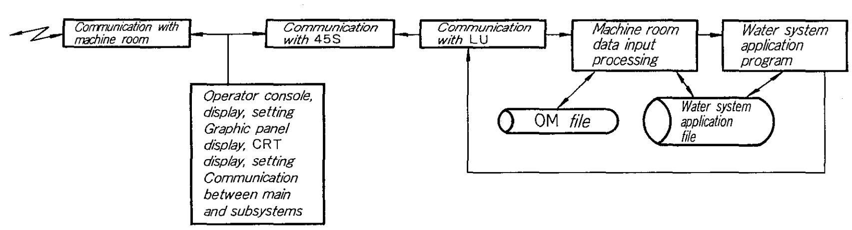


Fig. 10 **Diagram of program**

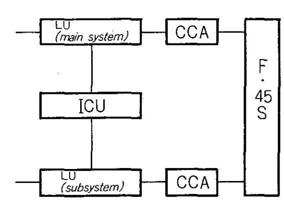


Fig. 11 **Diagram of preprocessor**

data contents.

2) Operator consoles and CRT input/output programs

Monitoring of accidents and irregularities for the whole system in the center, data displays to the operator consoles and CRT's and manual setting of control instructions to the machine rooms are performed.

Because semi-dual construction is used in the processor to ensure high reliability, data is communicated between the main system CPU and the subsystem CPU. Data storage, etc. for different texts and different machine rooms every fours hours is also performed.

3) Communication program with the FACOM 230-45S

This program transmits measured data and emergency data from the machine rooms, input data from the operator consoles, etc. to the FACOM 230-45S and transmits data received from the 45S to machine room communication processors. This data communication transmits and receives block unit texts and provides access to the registers in the CCA (Channel to Channel Adapter). The basic software used is SOM for the FACOM 230-45S and SCAIOX for the LU.

4) Communication program with the LU

These programs edit texts of hourly, 5-minute and emergency data of each machine room received from the LU; edit and feed in manually set data control instructions from the operator consoles; and transmit to the LU CRT screen selection and display prepared in the 45S and control instructions required by water system operation processors.

5) Machine room data input processing program

This program checks data defficiencies in received texts, performs error checks on the transmission channels (upper/lower limit and divergdency checks), performs bit data logic checks and estimates data defficiencies by the designated calculation method. Data which have been checked or estimated are accomodated in the OM file (On-Line Master file) or the water system operation file. An APC (Available Plant Capacity) file is compiled to determine the effective equipment capabilities of the plant.

6) Water system operation program

This program is the heart of the control structure

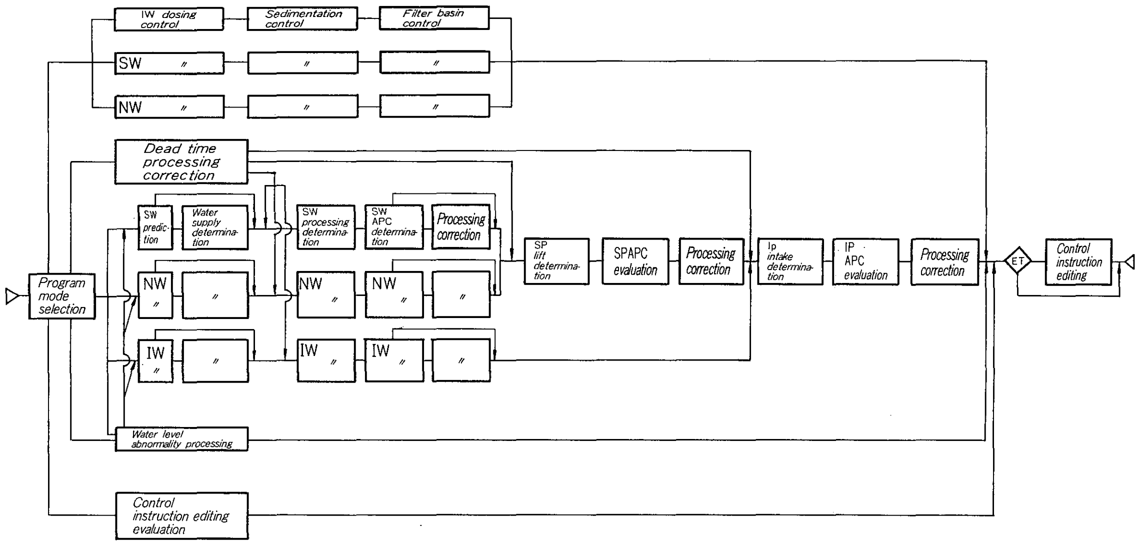


Fig. 12 Diagram of water control

Table 1 Control calculation table

Method	*Daily water distribution*	*Hourly water distribution*	*Remarks*
Method of least squares	1. $\hat{Q}=aq+b$	2. $Q_{(t)}=D_n \cdot \hat{Q}$ $d_n \rightarrow \boxed{\frac{1}{1+TS}} \rightarrow D_n$ $q/\hat{Q}$: *the day before* 3. $D_n=\alpha d_n+(1-\alpha)d_n$ $\alpha=\frac{\Delta t}{T}$	4. $X=Z \cdot B+E$ 5. $J=E \cdot E' \rightarrow mm$ 6. *Because* $B=\partial J/\partial B=0$ 7. $B=(\overline{ZZ'})^{-1}\overline{ZX}$ $y=ax+b$ $J=\sum_{i=1}^{M}((y_i)-(ax_i+b))^2 \rightarrow mm$ $a=\frac{\Sigma(x_iy_i)-\Sigma x_i\Sigma y_i}{\Sigma x_i-(\Sigma x)^2}$ $b=\frac{\Sigma y_i\Sigma x_i^2-\Sigma x_i\Sigma(x_iy_i)}{\Sigma x_i^2-(\Sigma x)^2}$
Auto-feedback	8. $\hat{Q}=\sum_{m=1}^{M}a(m)Q(s-m)$	9. $\begin{pmatrix} q_1(5) \\ \vdots \\ q_N(S) \end{pmatrix} = \sum_{m=1}^{M}\begin{pmatrix} a_1(m) & \cdots a_{1N}(m) \\ \vdots & \\ a_{N1}(m) & \cdots a_{NN}(m) \end{pmatrix}\begin{pmatrix} q_1(s-m) \\ \vdots \\ q_N(s-m) \end{pmatrix}$	10. $\hat{Q}(s)=\Sigma a(m)Q(s-m)+E(s)$ 11. $J=\overline{E \cdot E'} \rightarrow mm$ A : 12. $\sum_{m=1}^{M}(Am)R(\ell-m)=R(\ell)$ $\ell=1 \sim M$ 13. $Rij(\ell)=\frac{1}{N}\Sigma qi(s+\ell)qj(s)$ $\ell=0 \sim L$
Method of moving averages	14. $\hat{Q}=\frac{Q(s-1)+\cdots\cdots+Q(s-n)}{N}$	15. $q(s)=\frac{q(s-1)+\cdots\cdots q(s-n)}{N}$	
Karman filter	10. $\hat{Q}(s)=A_1Q(s-1)+$ $\cdots\cdots+A_NQ(s-n)$	$q(s)=a_1q(s-1)+\cdots\cdots+a_Nq(s-n)$	17. $X(s)=\sum_{m=1}^{M}a(m)X(s-m)+\varepsilon(s)$ 18. *If* $\Gamma(s-1)=[X(s-1),X(s-2)\cdots\cdots X(s-m)]$ $H(s)=[a(1)\cdots\cdots a(m)]$ 19. $X(s)=\Gamma(s-1)H(s-1)+\varepsilon(s)$ 20. $H(s)=I \cdot H(s-1)+\delta(s)$ *Numerical solution* 21. $H(s)=H(s-1)+A(s)[X(s)-\Gamma(s-1)H'(s-1)]$ 22. $A(s)=S(s)H'(s)[H(s)S(s)H'(s)+Q(s)]^{-1}$ 23. $C(s)=S(s)-A(s)H(s)S(s)$ 24. $S(s)=C(s)+R(s)$ $=[I-A(s-1)H(s-1)]S(s-1)+R(s-1)$ 25. Q : *covariance series of* ε R(s) : *covariance series of* $\delta(s)$

of this system and the following are the details of its construction.

(1) Demand prediction program

There are various control calculation methods including the method of least squares, the self-feedback method, the Karman filter method and the method of shifting averages as shown in *Table 1.* However, from the results obtained so far, the method of least squares has been found preferable. In this case, the estimated daily amount of water distributed is obtained, this is multiplied by the various time band coefficients and the distribution amount for each time band is estimated. The time band coefficients are obtained by exponential levelling (primary delay filter) of the results from the previous day.

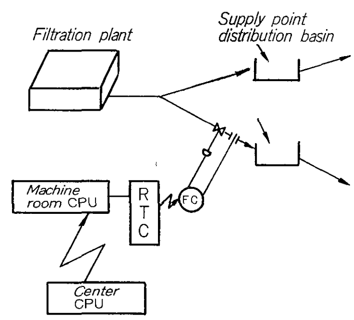


Fig. 13 SPC by TC of station

(2) Supply point control program

The amount of water transported to the supply points is controlled in accordance with the amount which should by transported to achieve the demand predictions (in case of pipe transfer) but when the predicted amount is accumulated at one time in a buffer (basin transfer), the control instruction is calculated by performing buffer level control and once the center instruction amount has been sent to the machine room, SPC is performed by telecontrol.

(3) Program to decide amounts treated by filtration plants

The purification basins of the filtration plants are taken as buffers and the treatment amount instruction is taken as the basin inflow amount (standard total filter flow) with the amount of sludge outflow added. The algorithm for deciding the inflow as the operating amount for the buffer model is obtained by simulated trial and error so that

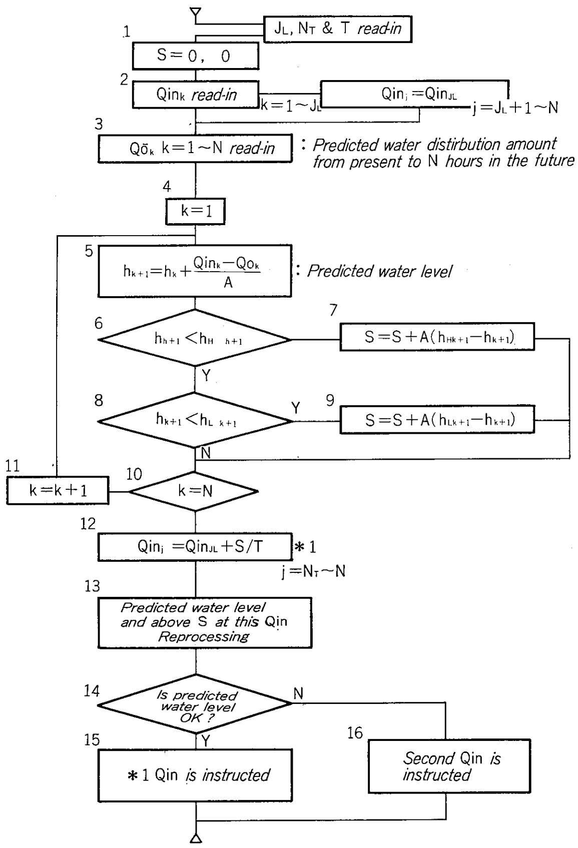


Fig. 14 **Flow control of filtration plant**

there are various types up to the theoretical value by means of LP, DP, etc. However, since there are to be few changes in the operating amount, a stable solution must be obtained for the on-line processor, etc., the method shown in *Fig. 14* was used.

In this case, the treatment amount is decided so that the predicted water level for 24 hours after the dead time can be accomodated within the permissible pattern. The dead time here is defined as the time until the water taken in by the Iizumi pumping station reaches each machine room and since it is very long in this system, being almost equal to the time lag (L of e^{-Ls}) of the open water channels, the control modes consist of two different types: the prediction control mode after the dead time (the normal operation algorithm) and operation within the dead time (against abnormalities).

(4) Sagamihara pumping station lift determination program

The lift is the tatal of the amounts treated in the Nishinagasawa and Sagamihara filtration plants (after the dead time). The lift instruction value is obtained by subtracting the predicted treatment amount of the Isehara filtration plant from the previous intake of the Iizumi pumping station. When this instruction value is raised by the Sagamihara APC, the amounts treated in the Nishinagasawa and Sagamihara filtration plants in the low level system are redistributed according to the current APC instruction amounts. When abnormalities become complex such as during duplication of abnormalities in the Sagamihara and upper level Iizumi plants, the corresponding treatment is determined by obtaining the corresponding pattern in the decision table and correcting the operating value.

(5) Iizumi pumping station intake determination program

The intake instruction value from the current time point is the predicted treatment amounts after the dead time for the Nishinagasawa, Sagamihara and Isehara filtration plants. When plant abnormalities are involved, the various treatment amounts for the lower levels are recorrected as instructions according to the APC at that time and the Sagamihara instruction value is also calculated accordingly.

The following of the center instructions for the Sagamihara and Iizumi pumping stations is entrusted to the PDC (Process Digital Controller) of each pumping station by pump number and rotational speed control.

(6) Process and plant abnormality processing program

(a) Process abnormalities

Because the control instructions become unsuitable quantitatively during prediction errors or plant abnormalities, the water levels of the purification and distribution basins exceed the permissible values. Qualitatively, when dosing control is not effective because of rapid changes in raw water turbidity, alkalinity, pH, etc., the turbidity, residual chlorine, etc. at the outlets of the sedimentation basins, purification basins, etc. exceed the permissible values. To counteract this, quantitative countermeasures include P. INQ to the faulty machine room and water level predications during the dead time and recorrection of the treatment amounts by prediction control after the dead time as well as manual operation guides sent to the operators. Qualitatively, the above-mentioned detrimental changes are absorbed by FF (Feed Forward) elements and postponed stable control is performed by FB (Feed Back) control. However, suitable control measures are also considered by continuous identification of process models and determination of optimum chemical dosing ratios.

(b) Plant faults

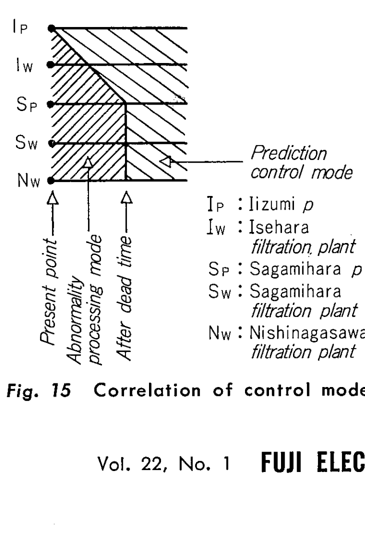


Fig. 15 **Correlation of control mode**

Table 2 Calculation of mode table

Processing pattern		Abnormal conditions					Basic ECB post					Plant abnormality						Water level abnormality			Plant and water level abnormality repetition					
Basis	Analogy	IP	SP	SW	NW	IW	44	48	59	60	66	Starting 39	32 35 38	41	56	63	68 69	Starting 68	32 35 38	39 69	Starting 39 68	32 35 38	41	56	63	69
1	17					○		○		○		◎	○			○	○	◎	○	○	◎	○				○
2	10 18 26				○		○				○	◎	○		○		○	◎	○	○	◎	○				○
3	11 19 27				○	○	○					◎	○		○	○	○	◎	○	○	◎	○				○

The required operating values are not obtained when there are complete or partial faults in the intake pumps, operating valves, etc. As a countermeasure, operating values are corrected by the abnormality processor on the basis of APC prediction trends and predicted recovery times set by the operator.

(c) Program starting during abnormalities

When an abnormality becomes complex, for example when an abnormality within one plant or from another plant reoccurs or spreads, or when mutual duplication of plant or water level abnormalities is considered, there is the possibility of some increase in the corresponding treatment patterns. The corresponding treatment algorithm is also flexible until certain operating experience is accumulated. In this system, a decision table has been designed concerning abnormality classification and corresponding program starting and the corresponding program is selected according to the abnormality pattern.

(7) Filtration plant control program

(a) Dosing control

The dosing control program is adapted to each machine room (filtration plant). The following instructions are sent to each plant from the center: (1) aluminum sulfate or PAC dosing ratios, (2) caustic soda dosing ratio, (3) preliminary chlorine dosing ratio, and (4) final chlorine dosing ratio. The treated water quality is specified in the water treatment policies but *Table 3* shows the control objects for these center operating values (dosing ratios).

In each plant which has received these dosing ratios, the amounts of chemicals to be dosed are calculated from the raw water flow or filter basin flow and set value flow control is performed. For example, *Fig. 16* shows the relation between the flow and the calculation of the dosing ratio for aluminum sulfate or PAC.

Table 3 Dosing ratio setting and control object

Control objects	Center operation (dosing ratio)
Sedimentation basin outlet turbidity	Aluminum sulfate or PAC dosing ratio
Sedimentation basin outlet alkalinity (pH)	Caustic soda dosing ratio (preliminary alkali)
Purification basin outlet alkalinity (pH)	Caustic soda dosing ratio (final alkali)
Sedimentation basin outlet residual chlorine	Preliminary chlorine dosing ratio
Purification basin outlet residual chlorine	Final chlorine dosing ratio

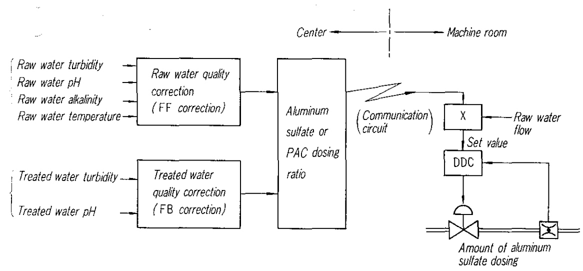


Fig. 16 Diagram of proportional control of aluminum salfate and PAC dosing

(b) Sedimentation basin control

The sedimentation basin control program is adapted to each plant. The following instructions are sent from the center to each machine room: (1) flush mixer rotation speed, (2) flocculater rotational speed and (3) sludge blow-off interval. The control objects in respect to these instructions (center operating values) are as shown in *Table 4*.

Table 4 Sludge blow-off of sedimentation basin and control objects

Control objects	Center operation
Sedimentation basin outlet turbidity	Flush mixer rotational speed, floccuater rotational speed
Amount of sludge blow-off (1 time)	Sludge blow-off interval

In this case the flocculater rotational speed setting is controlled to ensure optimum flocculation efficiency after the dosed raw water enters the sedimentation basins but there is a correlation of the cascade type with the afore-mentioned dosing ratio setting for aluminum sulfate or PAC. Setting of the sludge blow-off interval is performed by overall evaluation of the turbidity, quantities, etc. of the raw and treated water and calculation of the time gap between operation of the desludging valves. Group sequence control is performed in each machine room.

(c) Filter basin control program

Depending on the operating time, the filter efficiency of the filter basins drops because of clogged filter mesh. Quantitatively, the filter resistance of the sand layers increases and changes in the filtering flow rate occur. At such times, it is necessary to stop operation and wash the filter basin. In such cases, the numbers of the basins to be washed are given in the center every hour. These decisions are made by determining the continuous filtering times and the degree of filtering continuity according to the filter resistance as indices, feeding in the stopping conditions for equipment with high values and determining the numbers of the basins to be washed. The basins which will require washing in a few hours are also predicted and when the washing delay is estimated, the measures for the estimated delay resulting from the washing instructions given at that time are also included. The washing software sequence is handled by the site DDC.

7) Batch jobs

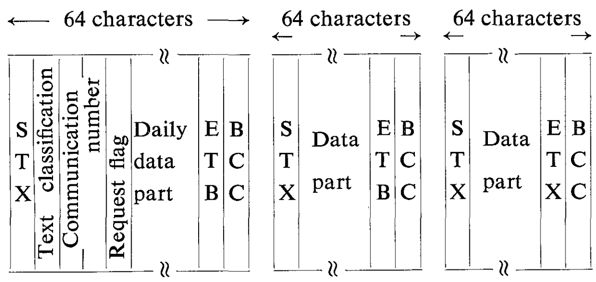
The pipe network calculation program is used for the estimation of distribution conditions at the supply points. In the future, an on-line program will be added to this. When the possible intake by the Iizumi pumping station is calculated, it is necessary to include such items as estimates of the amount of water released from the dam and the amount of water flowing into the Sakawa river from other rivers during this time. Therefore, a batch program is applied including dam control (especially release flow control), estimation of dam inflow and estimation of river flow rates. An operating system and algorithms are established in this way.

8) Data transmission control program

The data transmission networks play an important role in the management of this system and not even one network can be cut off. In the case of wireless networks, it must be considered that transmission can deteriorate with time and also in certain locations because of urban noise but in this system, measures have been taken in the software to prevent erroneous transmission by repeated transmissions in accordance with the transmission control methods. The contents of the data transmission of this system are given below.

(1) Text composition

Data transmission between the center and each site is performed in text block units.



(Head block) (Middle block) (Final block)

The texts can be classified into the following four types depending on the degree of importance of the data:

Text classification	Text classification contents	Transmission from center	(Note) Transmission from each site	No. of texts per facility	Block length	Block no./text
1	Important texts	Yes	Yes	1	64 characters	Optional
2	Ordinary texts	Yes	Yes	1	64 characters	Optional
3	Emergency texts	Yes	Yes	1	64 characters	Optional
4	Test calls	Yes	Yes	1	64 characters	1

All texts are assigned a 2-column communication number for each site unit. In the case of emergency texts and test calls, these do not have the significance of a space code.

Request flag	Contents
0	Text not requested
1	Important text requested
2	Ordinary text requested
5~10	Text dusing change
11~14	Text during abnormality
15~20	Demand

The data part displays one word (16 bits) hexadecimally and this is expressed by the ISO code in the transmission networks.

(2) Starting conditions and times

	Transmission from each facility to center	Transmission from center to facilities
Set time processing	(1) Data transmission from each facility (important texts-ordinary texts) is possible only when data request signals are received from the center. (2) Data requests from the center are normally made at 5 minute intervals.	Transmission of control and instruction operating signals (important texts) from the center to the facilities is usually performed at one-hour intervals.
Emergency processing	(1) Emergency texts from each facility can be transmitted at any time. (2) When the facilities themselves are transmitting or receiving, the emergency transmission is made after this is completed.	(1) Emergency texts from the center can be transmitted at any time. (2) When there is reception or transmission with the facility in question, emergency transmission is made when this is completed.

(3) Priority and transmission frequencies

In data transmission, the priorities and transmission frequencies according to the type of text are as follows:

	Priority	Transmission frequency
Emergency text	1 High	n
Important text	2 ↑	n
Ordinary text	3 ↓	1
Test calls	4 Low	1

	Transmission from facilities to center	Transmission from center to facilities
Emergency texts	Maximum of "n" consecutive transmissions which are ended when it becomes bad. $n=1\sim3$.	Maximum of "n" consecutive transmissions. If necessary after completion, transmission can be shifted to the next facility. ($n=1\sim3$).
Important texts	When transmission is impossible, transmission rights are transferred to the next facility and after transmission to water filtration plants and intake and distribution facilities, transmission is made again upon request from the center. If this is not possible, transmission is stopped.	When transmission to the facility concerned is impossible, transmission is shifted to the next facility. After transmission to the filtration facilities and intake and distribution facilities, transmission is started again and if it becomes bad, it is stopped.

	Transmission from facilities to center	Transmission from center to facilities
Ordinary texts	Transmission is by a text request from the center. If impossible, it is stopped without any retransmission.	If transmission is impossible, it is stopped without retransmission.
Test calls	If transmission is impossible, transmission is stopped without retransmission.	Same as left

(4) Processing during network faults

When there is notification from the network program that transmission is impossible, processing is as follows:

		Facility processing	Center processing
Emergency texts	Transmission from facilities to center	When transmission is impossible because of application program even when "n" transmissions are requested, an operator call message is given out and transmission is stopped.	No special processing for faults is performed.
Emergency texts	Transmission from center to facilities	No special processing for faults is performed.	Same as upper left.
Important texts	Transmission from facilities to center	When transmission is impossible, processing is stopped. Transmission is restarted on basis of a request from the center. However, contents which could not be transmitted previously are disregarded and the transmission data are compiled at the time the request is received. When retransmission is also impossible, a count of the network down time is started. (Monitoring of the time estimated for the retransmission request is also required.) When the network is obstructed for a long time, the processing is in the network down mode.	If data can not be transmitted from the facility even when requested, the transmission request is shifted to the next facility. After processing is completed in other facilities, a transmission request is made again to the facility concerned. When retransmission is impossible, a count of the network down time is started. When set time data transmission is impossible for "n" consecutive times, processing enters the network down mode for that facility.
Important texts	Transmission from center to facilities	Current conditions are maintained and if required, processing is changed manually.	When transmission to the facility concerned is impossible and retransmission is also impossible, and operator call message is given out and processing is completed. When a set time data request is made to a facility and transmission "n" consecutive times is impossible, a message is given out and processing enters the network down mode. When transmission processing is performed "m" seconds after transmission of control or instruction operating signals to a facility and transmission is impossible, a message is given out and processing enters the network down mode.
Ordinary texts	Transmission from facilities to center	When transmission to the center is impossible, processing is stopped.	When a transmission request is sent to a facility and reception is impossible, processing is stopped.
Ordinary texts	Transmission from center to facilities	There is no special processing for faults.	When transmission to the facility is impossible, processing is stopped.

(5) Methods of recovery from network faults

Recovery from the network down mode is achieved when there is normal transmission of a test call message.

VII. CONCLUSION

The above has been an outline of the hardware and software of the control system for the control center of the Kanagawa Water Supply Enterprise wide region water system. This system is to go into operation in 1975 and is presently being tested. Operation results based on these design concepts will be reported later. Security control such as prediction control and abnormality processing has been the basis for the growth and expansion of both hardware and software to raise the level of the system. The authors wish to thank the approximately 40 persons in the Enterprise, the Fuji Electric Group and the Fujitsu Group who have cooperated in this work.