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REVIEW OF CONTROL SYSTEM FOR WATER AND SEWAGE WORKS

Hiroshi Funabashi
Yuki Itoh
Masaaki Yamamoto

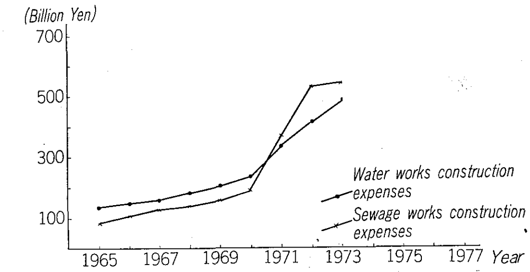
I. INTRODUCTION

There are many pressing problems related to water such as the increasing water demands, water shortages, public nuisance, water pollution and environmental protection. These problems must be tackled as a part of the nation's welfare and water treatment facilities are being constructed at a rapid rate.

Instrumentation and control technology for water and sewage works has a history of about 10 years and during this time rapid progress has been made. In particular, there have been complete changes in the control systems with the use of the computer, the progress in transmission techniques and the consolidation of wide area water supply and river basin sewage systems. There has been a great expansion both functionally and spatially from narrow to wide ranging control. Already system technology must be considered for not only the instrumentation but also the machinery and equipment concluded and the MIS of top management is also included. Recently, the Kanagawa Water Supply Enterprise starting operation of a wide area water supply system and its control system is offered as a model of such systems. At present, water and sewage control as one type of environmental control is the most advanced among the equipment in various industries. This article will review the history and present conditions of water and sewage works control for wide area water supply and river basin sewage systems, and also give a preview of the future.

II. OUTLINE OF THE WATER WORKS FIELD

With greater urbanization and improved living standards, both the amount of water used per person and the total demand have greatly increased every year. With the high level of economic growth, demands for industrial water have also rapidly increased. In keeping with these great annual increases in water requirements, the expenses required for the construction of water works have also risen as shown in *Fig. 1*.



(Water works expenses are from the Water Works Yearbook—1974 edition and the sewage works expenses are from the publication "Japanese sewage works—present conditions and problems" which came out in January, 1974.)

Fig. 1 Transition of construction expenses for water and sewage works

Because of the trend for industries and the population to be concentrated in the cities, water demands have become extremely unbalanced. Therefore, an unbalance arises between demand and supply and regional water shortages have become serious. According to "Wide Ranging Irrigation Survey-2nd Report" published in August, 1973 by the Ministry of Construction, it is predicted that by 1980 the nationwide amount which can be supplied in respect to demand will rise to 6.34 billion m^3 but in 8 regions including Tokyo and the Kyoto-Osaka area, there will be a shortage of 4.2 billion m^3 of water.

To solve this problem, work on the development of new water resources, the more efficient utilization of resources and water accommodated flexibility. In keeping with this, it is necessary to extend driving channels, allot water quotas among the various sources and coordinate the operation of filtration plants and control ranges have been greatly expanded. The urban population concentration has expanded distribution areas, caused increases in the construction service reservoirs and pumping stations and also expanded the control ranges in these facilities. Because of this, the system of handling each facility separately as has been done usually is no longer appropriate and wide area control systems for water works which provide total conrol of groups of water sources, filtration plants, service reservoirs and pumping stations are required.

However, because of the pollution problem, sewage and sludge treatment are obligatory by law to remove pollution and because of the oil crisis, there are strong demands for the efficient utilization of natural resources, such as saving chemicals and electric power and preventing leaks. As these, from the functional standpoint, new types of control are needed.

For systemized operation of many facilities spread over a wide area, the problems facing the water works are raising the level of water works facilities, automation and widening the control areas.

In the sewage field, the important factors are preventing water pollution because of the pollution problem and spreading and improving sewage works to the civil minimum. The expansion and equipping of sewage treatment facilities are progressing rapidly. Originally, Japan was far behind Europe and North America in this field and as can be seen in *Fig. 1*, sewage works construction expenses appear to have risen more steeply than those for water works construction.

Because sewage treatment is undertaken from the standpoint of preventing water pollution, control ranges have expanded both qualitatively and spatially because of the expansion of treatment areas in keeping with the increases in population, river control, effluent regulations, strengthening of maintenance and higher levels of sewage treatment. The remarkable aggravation in water pollution has promoted eutrophication water pollution due to organic compounds as well as phosphorous and nitrogen and new advanced treatment is required. As a measure against the predicted water shortages, the reutilization of sewage is being investigated and advanced treatment are also needed in this field. Such tertiary treatment of sewage is being studied from various standpoints and in addition to the conventional biological treatment methods, new treatment processes such as physical-chemical treatment are required.

Under such circumstances, in the sewage field also, there is need for expanded control areas, expanded control objects, qualitative control expansion and wide area control.

III. HISTORY OF WATER WORKS INSTRUMENTATION

Instrumentation for water works processes was first considered positively in the later fifties and early sixties. Fuji Electric started supplying instrumentation systems to water works plants at about this time and since that time, the company has been a pioneer in the field of water works instrumentation. Therefore, Fuji Electric's history of water works instrumentetion can probably be said to be the history of such instrumentation in Japan.

The later fifties was a period of pneumatic instrumentation and thereafter, electronic tube type self-balancing instruments gradually came into use.

In 1960~61, a compact series of instruments with the small electronic tube type self balancing instrument using the standard DC signal appeared. At this time. almost all water works instrumentations systems were electronic. Fuji Electric produced the TELEPERM Q series.

In 1961, analog telemeter equiqment was first used for data transmission between water sources, service reservoirs and filtration plants. The Fuji TTL-18S type was used in this case.

In 1962, a computing logger (FIDAP 400A) was installed in the Nagasawa filtration plant in Kawasaki city for the first time in Japan. Thereafter, the use of computers and data loggers in water works greatly increased. In 1967, the FACOM 270-20 was installed in the Asaka filtration plant in Tokyo and also in the Okubo filtration plant in Saitama prefecture. These were expanded from the first computing logger to computer control.

Computer control in water works in Japan is limited mainly to filtration plants but in 1969, a FACOM 270-20 was delivered to the Japan World Exposition Committee as the No. 1 distribution control computer and in 1971, a FACOM 270-25 was supplied to the Kobe waterworks. This gave rise to planning for distribution control by computers in various places.

From about 1963, transistor type telecontrol equipment has been used for remote monitoring and control in relay and intake pumping stations, etc. The Fuji Electric TC-100URD telecontrol equipment was used in this case and thereafter, it has been widely employed for remote monitoring and control of no-manned pumping stations.

In 1963, the pin board sequencer featuring automated sequence control appeared and was utilized in washing filter basins, desludging and pump operation.

In 1964, the electronic instrument series was improved and the DC 2-wire type and transistor type electronic series were introduced. These are equivalent to the Fuji TELEPERM S series instruments. The use of semiconductors as circuit elements has greatly improved the reliability of the instru-

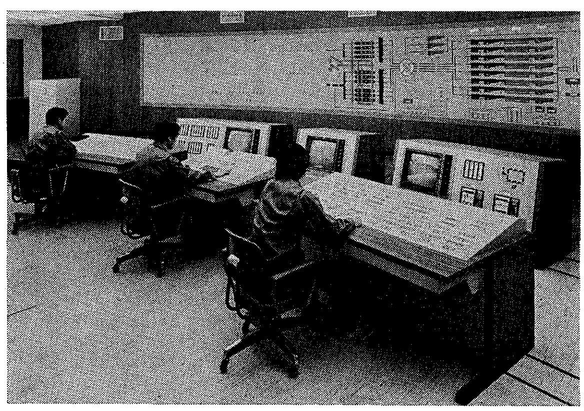


Fig. 2 Control room at the Arakawa treatment center of the Ara-river basin wide sewage works

ments.

From 1967, the cyclic digital telemeter equipment came into use. The Fuji CDT series corresponds to this type of equipment.

In 1971, signal systems of DC 4~20mA current trans mission and DC 1~5V voltage reception became standardized throughout most of Japan. Simultaneously, the intrinsic safety explosion-proof system and vertical instruments came into use and planning for water works almost always employed vertical instruments. This type is represented by the Fuji Electric TELEPERM IS system.

From 1971, the 1 : N type telemeter telecontrol equipment came into use. This equipment is ideal for water works where data is to be collected in one control center from many site substations. This type of equipment is represented by the Fuji NTC type telemeter telecontrol equipment.

In 1972, a FACOM 270-25 type computer and instrumentation equipment were supplied for the Ara river basin sewage treatment system, a typical example of a large scale river basin sewage plant control system. This was the first computer to be installed in a river basin sewge treatment plant in Japan and thereafter, it became the model case for sewage treatment instrumentation. In the same year, a FACOM-RE type computer system was installed in the Tokyo Shibaura sewage treatment plant and computer control was opened to urban sewage treatment plants. From this time, CRT display was introduced in water and sewage works and a new control system with a wide functional application was established.

In 1973, a complete DDC system using a FACOM-RE was tested successfully in the Nagasawa filtration plant in Kawasaki city. This started at trend toward shifts to the DDC control system for filtration plants.

As is clear from the above, there is no lack of computers in water and sewage works control. Simultaneously, with progress in the development of elements such as transistors, IC's and LSI's, the computer systems have been improved functionally to include the FIDAP, FACOM 270-20, FACOM 270-25, FACOM-R and FACOM U-200.

In the software field, basic and application software have been completed and in the control

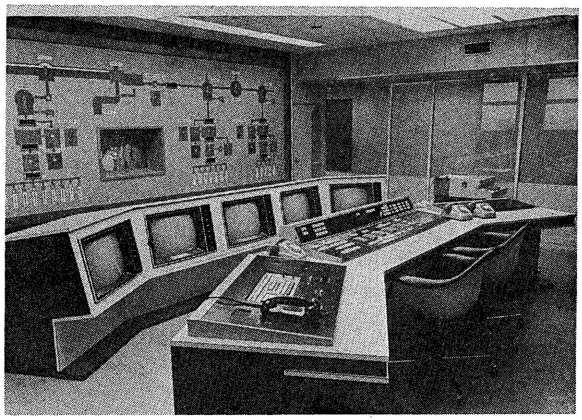


Fig. 3 Central control room at the Kanagawa water supply enterprise

systems, there has been development from SPC (Set Point Control) to DDC (Direct Digital Control) and SCC (Supervisory Computer Control).

From 1972, a new sequencer appeared. This sequencer is a combination of logical circuits using IC's and the stored program system. The hardware and software are separated which leads to flexibility both functionally and in respect to time. In sewage system sequences there are initial difficulties in deciding the specifications and there are many improvements and additions. Therefore this equipment is very effective and is utilized for pump control, filter basin washing control, sludge treatment, etc. Fuji Electric delivered a universal sequencer (USC-4000 type) to the Tokyo Shibaura Treatment Plant.

In 1973, the first wide area water works control system in Japan was ordered by the Kanagawa Water Supply Enterprise. The hierarchy system in this case included a large scale computer (FACOM 230-45S type) and four small computers (FACOM-RE types, etc.) and various techniques were used such as the INQ system (inquiry system), TSS (time sharing system), a computer network by 400 MHz wireless line, a DDC system with duplex computers for filtration plant, and a data highway system. This system is attracting attention not only in Japan but internationaly as a model case for future wide area water supply systems.

In 1974, a computer system was delivered to the Seibu Filtration Plant in Saitama Prefecture. This

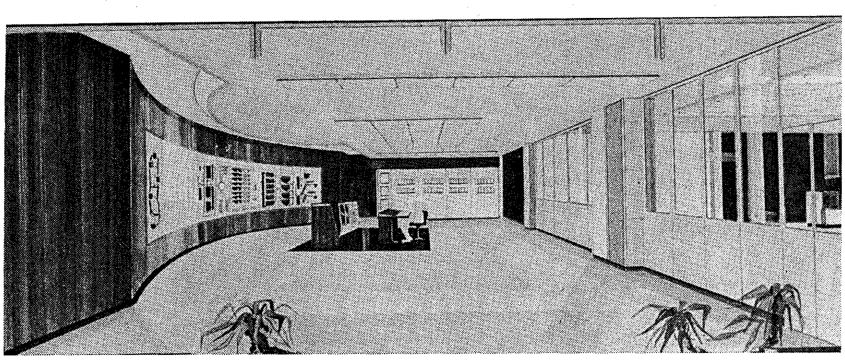


Fig. 4 Example of control room design

system consists of a FACOM 270–25, a FACOM 270–20, FACOM RE and PUC–10 computers hierarchy system. It also utilizes the data highway system and a mutual control system between filtration plant was established.

As the result of such continuous efforts, the reliability of the water works computer control systems has been greatly increased through progress in hardware and software and a water works data processing system has been established. At present, Fuji Electric has received orders for about 40 sets.

Great progress has also been made in the layout of the control room and the design of supervising and operating panels. Since the use of centralized control systems, the complete plant operation has been centralized in the control room. At the same time, from the conventional durable design, there has been a shift to the use of human engineering design methods which stresses the humans performing the operations and new designs have appeared.

Efforts are now continuing toward the development of water quality instrument and the development and improvement of application software through the quantitative analysis of water quality and hydraulics.

IV. BASIC POLICIES FOR WATER WORKS INSTRUMENTATION

The characteristics of water and sewage works processes are: 1) public utility 2) wide ranges, 3) indicision, 4) continuity, 5) multiplicity and 6) delays with large capacity equipment. Therefore, the points to be considered in water and sewage works instrumentation are as follows:

1) When required by the user, the water and sewage works must offer the needed amount of service. In water works, safety and reliability must be especially high.
2) Since the users of water and sewage works cover a wide area, the plants involved in the process are also scattered over a wide area. Since the operation of these plants must be coordinated, wide area control systems using computer control and data transmission systems are required.
3) The demands and amounts treated in water and sewage works differ in accordance with the season, day of the week, time, weather, temperature, etc. Simultaneously, the water quality also changes. When controlling water and sewage processes, it is necessary to estimate changes in water quantities and qualities and appropriate forecast control is required.
4) Water and sewage works must offer users their services continuously. In principle, water works equipment control must assure safety at both normal and abnormal times and the functions must always be maintained.
5) The equipment making up water and sewage works processes is characterized by the use of physiochemical and biological reactions and is very diverse covering civil engineering, machinery and electrical equipment. The instrumentation of such equipment requires complete investigations of the diversity and characteristics.
6) Water and sewage works processes include large capacity equipment such as settling basins and service reservoirs and process time delays are long. In the control of such equipment, forecast control must be performed to absorb these delays and safety must be assured.

V. CONTROL SYSTEM FUNCTIONS

The needs of the wide area water works and the river basin sewage works described in section **II** expand the control area of the water and sewage works and a total control system is essential.

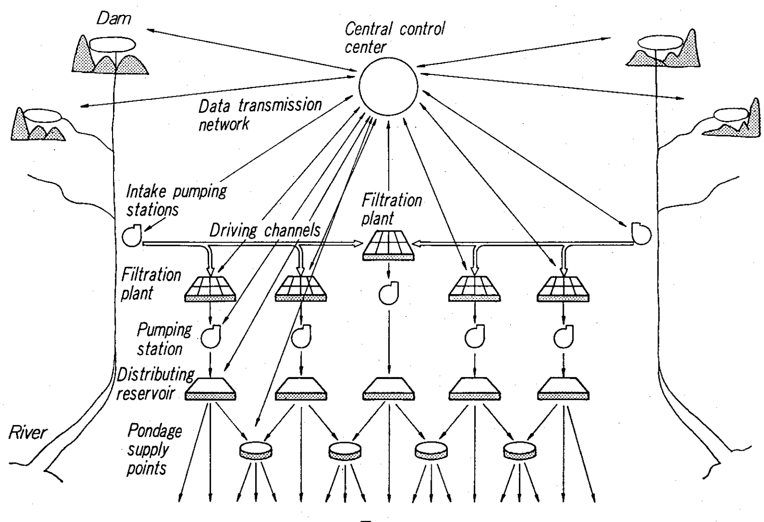


Fig. 5 Systematic diagram of wide area water supply system

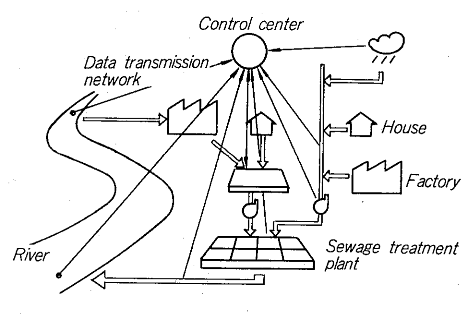


Fig. 6 Systematic diagram of river side basin sewage system

However, progress in the field of instrumentation and control has resulted in a shift from narrow control to wide management. The category of instrument has also expanded from the conventional physical and chemical measurements to condition, pattern and forecast instrumentation. The progress in transmission devices has expanded instrument and control ranges spatially and the word teleautomation has been coined.

There has also been rapid progress in the field of information processing and the control ranges have shifted from scattered to centralized control and from the sensor base to the data base.

The achievements in the instruement and control field and the data processing field match the wide area control needs of water and sewage works and make possible the use of total control systems.

1. Outline of Control System

The control system is a total control system for water works processes consisting of water sources, intake pumping stations, filtration plant service reservoirs, etc. and for sewage works processes consisting of relay pumping stations, trunk lines, sewage treatment plants, etc. Systematic diagrams of the wide area water supply system and the river basin sewage system are shown in *Figs. 5* and *6* resspectively.

The functions of the control system for the water works processes are given below:

1) Monitoring and forecasting of the storage capacity in the water sources, water source operation planning and control of possible intake amounts
2) Monitoring and forecasting of river flow and water quality, monitoring possible intake amounts
3) Control of intake to intake pumps, control and monitoring of operating conditions
4) Control of intake to the filtration plant, chemical dosing control, operation control of settling basins and filter beds, control and monitoring of filtration plant operation conditions
5) Planning of service reservoir operation, distribution control and estimations, estimation of distribution conditions
6) Operation control of drainage and desludging equipment, operating condition control and monitoring

The functions of the control system for the sewage work processes are as follows:

1) Monitoring and estimation of river water quality and flow
2) Monitoring and estimation of flow and quality of sewage influent to relay pumping stations, pump operation control, control and monitoring of operating conditions
3) Control of sewage influent to sewage treatment plant, sludge removal control, return sludge control, air control, effluent control, control and monitoring of equipment operating conditions
4) Chemical dosing control for sludge treatment equipment, dehydrator control, furnace control, control and monitoring of equipment operating conditions

2. Control System Effects

In plants with facilities scattered over a wide area such as in water and sewage works, the introduction of a total control system is highly effective.

1) Easiness of total control from the centralized control system

The data required for process control and management are all transmitted on-line to the central control center so that total control of the whole system is possible.

2) More efficient use of personnel

Since the data are collected in the center, it is possible to assemble the personnel who perform control and management in one place and they can be used more effectively.

3) Unmanned operation of local stations

The local stations such as pumping stations and distributing reservoirs can be unmanned because of the centralized control.

4) Easy collection, storage and utilization of data

After collection, each type of data is arranged and edited and then stored in the computer. The total analysis of the process characteristics is possible by these data.

5) Improvement of equipment operating efficiency

Since operating instruction systems for the various sites with mutual coordination are centralized, coordinated operation for each site can be performed efficiently.

6) Simplification of operation

Because daily operating reports, operation records, etc. are compiled automatically, the operators can easily operate the equipment.

7) Easiness of management control

Management control operations such as inventory, acconnting and personnel are easy to performed because various types of on- and off-line data are preserved for long periods.

8) Data provided for management planning

Data can be supplied for long-term equipment operation planning, equipment investment planning, personal planning, etc.

3. Control System Management

Since the control range of the water and sewage works control system is wide and diverse, its success or failure depends on the management system. Definition of the control area between the center and the sites and their relations, definition of the control instruction systems, etc. are particularly important.

The principles of control system management are that all operations and controls related to operation of all of the processes are performed from the center. At the sites, operation and control instructions are received from the center and concrete control is performed for the coresponding equipment at the site.

At the center, control level is job such as management and future planning of equipment, materials, power and personnel, control of water quantities and qualities of system data collection and storage and high level data processing. At the sites, regular work such as operational and maintenance control of equipment and devices is performed.

4. Main Points in Control System Design

The main points related to design concerning control system scale, hardware components, software components, etc. are as follows:

1) Investigation of system management and control organization

This is closely related to the user's organization and control system. The principles of the system components are decided by the normal and abnormal management systems and control networks.

2) Investigation of system management items and job share between the center and the sites

The center computer scale, need for site computers and their scale are decided by the system control items and the job share.

3) Investigation of system reliability

The reliability required for the system is determined by the work which the system is to perform. Investigations concerning reliability include those on the system back-up during abnormalities.

4) Investigations of data transmission contents and amounts

These factors are determined from the management system, control items, job share, etc. Transmitted data must be carefully investigated both quantitatively and qualitatively and it must be able to meet the requirements.

5) Transmission method investigation

Investigations are made of the trausmission method and speed from the amount of data transmitted, the required reliability, the transmission distance, geographical conditions and transmission goals.

6) Investigation of system introduction schedules and future expansion measures

Computer introduction time discrepancies for the center and the sites and future expansions are related to the flexibility for hardware and software components.

5. Control System Control Items

The control system control items can be roughly classified as equipment control and management control. Equipment control is divided into management and control at the center and management and control at the sites.

1) Center equipment control functions

- Control items common to water and sewage works processes

(1) Equipment operating conditions monitoring
(2) Operation control
(3) Determination of equipment operating capacity
(4) Equipment operation planning
(5) Editing and storage of collected data
(6) Water system simulation
(7) Process characteristics analysis

- Control items required for water works processes

(1) Dam control
(2) River control
(3) Demand estimations
(4) Distribution control
(5) Water quality control

- Water works process water quantity instruction items

(6) Intake pump intake amount
(7) Filtration plant intake amount
(8) Return water flow
(9) Distribution flow

The water quantity instructions are ordered as the set points with time considering the water system time delays.

- Optimum operation instructions in water works process

(10) Coagulant injection rate
(11) Alkali injection rate
(12) Preliminary chlorine injection rate
(13) Post-chlorine injection rate
(14) Sedimentation basin operation instruction
(15) Filter bed operation instruction
(16) Return water flow

- Control items required for sewage works processes

(1) Waste water influent estimation
(2) Treated water quantity and quality control
(3) River control

- Water quantity instructions in sewage works processes

(4) Relay pumping station water conveyance flow
(5) Sewage influent amount to sewage treatment plant
(6) Treated water effluent amount

- Optimum operation instructions in sewage works processes

(7) Sludge return rate
(8) Aeration flow
(9) Sedementation basin desludging instructions
(10) Chlorine injection rate
(11) Thickner operation control
(12) Chemical injection rate
(13) Digester operation instruction

2) Site equipment control functions

(1) Site equipment operating conditions monitoring
(2) Operation control
(3) Equipment operation control
(4) Control by center water quantity instructions
(5) Control by center optimum operation instructions
(6) Site proper control items

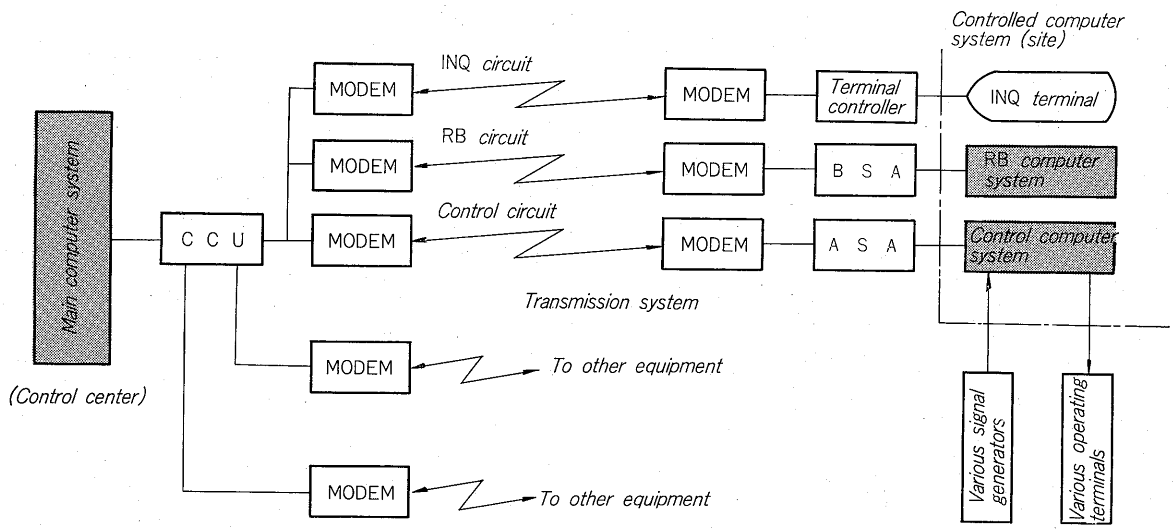


Fig. 7 Skeleton diagram of supervisory control system

(7) Center instruction back-up

3) Management control functions

The following items are center management control functions:

(1) Treatment cost calculations
(2) Inventory control of purchases such as chemicals
(3) Various types of statistical processing
(4) Ofen of basic data related to planning and decisions such as equipment investment planning and personal plan by long-term demand forecasts, etc.
(5) Rate accounting work
(6) Fixed investment management work
(7) Accounting work
(8) Personnel control work

4) Other control system functions

(1) Data transmission
(2) INQ (inquiry) function
(3) Remote batch function

VI. CONTROL SYSTEM CONSTRUCTION

As can be seen in *Fig. 7*, the total control system is made up of hardware consisting of the main computer system, the site computer system, the transmission system, instruments, electrical equipment and devices, as well as the software.

The main computer system is located in the center as the core of the total control system. The main computer system performs data collection, editing, processing, analysis and various types of decisions. Based on the results of these procedures, it sends out various types of instruction, operator notifications, etc. The main computer system stores various types of data, i.e. acts a data bank. Since all data from each subsystem are centralized in the wide area water works system, there is a very large amount of data and processing and analysis become complex so that a large scale computer is used.

The site computer system has a master/slave relation with the main computer system and it performs site control by means of instructions from the master system. It performs site data collection and editing, transmission to the center and reception of instructions from the center, and transmission of operating instructions to various devices. When there is an abnormality in the main computer system or in the data transmission system, the site computer system has a very important back-up function. The site computer system is closely connected with the processes and performs on-line operation so that a highly reliable mini-computer is used.

The transmission system is the nerve system of the total control system and consists of communication control equipment, MODEM, transmission circuits, etc.

The instruments are used for measuring various process values at the sites. The measuring items include water quantity and quality, status measurement and pattern recognition. The measured data are fed in by on-line and in-line method. Off-line data are used for management and analysis. The points in instrument selection include accuracy and reliability.

The electrical equipment plays two roles in the system. Electric power equipment provides electric power for blowers, pumps, solenoid valves, etc. The power supply equipment includes receiving and transformer equipment, an emergency generator and distribution equipment. This equipment acts as the energy and drive power source for the system.

The software includes basic software for the computer system itself and application software for operation of the control system.

1. Control Center Main Computer System

The composition of the control center computer system differs depending on the number of sites controlled by the center, the items processed in the center, the job sharing especially with the site com-

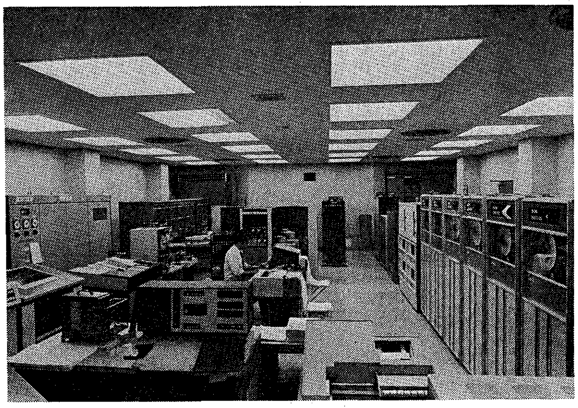


Fig. 8 Example of computer room at control center

puter system, abnormality measures, etc. but it consists of the main computer system and the LU (Linkage Unit) system.

The jobs of the main computer system include on line jobs such as data collection, various types of control processing and INQ (inquiry) terminal control; and batch jobs such as various types of analysis, and batch jobs related mainly to RB (Remote Batch) processing, and management batch jobs such as data banking, MIS, etc. Especially in large scale systems, when the on-line jobs, control batch jobs and management batch jobs are congested, the main computer system is double and one system is used for on-line and the other for batch jobs, the jobs being shared accordingly. The main computer system employs a large scale computer with a main memory capacity of 64∼192 kW. This is equivalent to the Fuji FACOM 230-45S. Peripheral equipment includes magnetic drum equipment, disk pack equipment, magnetic tape equipment, system typewriters, card readers, line printers and CRT displays.

The LU system performs mainly primary processing of data collected from the sites and data transmission. When there is an abnormality in the main computer system, the LU system performs buffering of receiving data and also transmits recovery data at the time of recovery to normal when there is an abnormality in the site system. The LU also performs operator console and graphic panel control. The LU system is connected to both the site systems and main computer system and is in the form of a double system when especially high reliability is required. In the LU, a mini-computer with a main memory capacity of 16∼32 kW is used. This is equivalent to the Fuji FACOM U200. Peripheral equipment includes magnetic drum equipment, system typewriters, paper tape readers and punchers and CRT displays.

Data transmission between the LU and main computer systems is performed via a channel to channel adapter (CCA). The data transmitted from the LU to the main computer are mainly process values and operation and accident data for various devices at the site. The data from the main computer to the LU are mainly water quantity set points and optimum set points.

The abnormality measures for the center computer system are decided from the center system functions, the job share between the main computer system and the LU system, etc. When there is an abnormality in the main computer system or the LU system, the control center has at least the following functions.

(1) Data collection is possible (continuity of data collection).
(2) Measured data display is possible (continuous monitoring).
(3) Manual setting is possible (especially related to water quantities) (continuous setting).

2. Site Computer System

The composition of the site computer system is determined from the site scale, the computer system functions, the job share with the center computer system, the back-up functions during system abnormalities, etc. The components of the site computer system are the control system, the RB (Remote Batch) system and the INQ (inquiry) system.

The functions of the site computer system are a control function, RB function and INQ function.

This control function is shared by the control system and the main items are data collection, SCC/DDC, operating condition monitoring and completion of daily operating reports.

The RB function is shared by the RB system and it is a TSS (Time Sharing System) by which the large scale computer located in the control center can be used from the site computer room via a line. Batch jobs such as technical calculations and process analysis are possible.

The INQ function is shared by the INQ system. The CRT display, key board printer or other terminal equipment located in the site are connected to the large scale computer of the center and various types of data in the center computer are utilized by on-line.

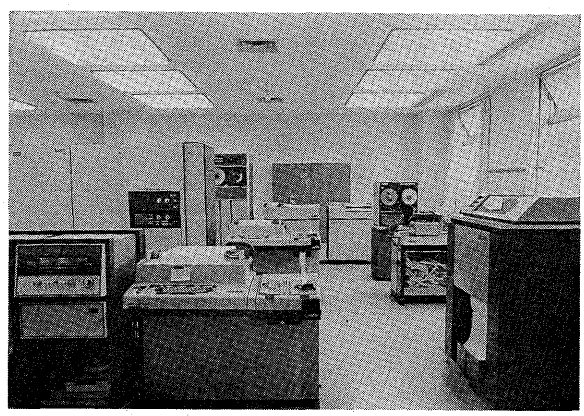


Fig. 9 Example of computer room at substation

The construction of the site computer system is simplex, duplex or dual and the construction type depends on the system scale, functions, system abnormality measures, etc. The simplex system is suitable for comparatively small scale sites and has only the control function. The duplex system is a large scale system in which the control and RB functions have one computer each. The dual system is for large scale sites and sometimes uses a data highway system.

In the site computer system, a compact control computer with a main memory capacity of 16~32 kW is used which is equivalent to the Fuji FACOM U200. For the peripheral equipment, magnetic drum equipment, system typewriters, paper tape readers and punchers, line printers and CRT displays are required. In the RB system, a card reader is also necessary.

The system abnormality measures are considered mainly in respect to the control function. In the simplex system, there is generally a back-up system using analog instruments. In the duplex system, there is back-up of the control system by the RB system. In the dual system, when there is an abnormality on one side, simplex operation is continued by the normal side.

The RTC (Real Time Controller) process input/output control equipment has an interface with the instruments and there are two systems, a 1 : 1 direct system and a data highway system.

3. Man/Machine Interface Equipment

The man/machine interface equipment consists of the operator console, CRT display, graphic panel, logging typewriter, etc. These devices are dealed with directly by the operator both during normal operation and when troubles such as plant accidents occur. Therefore the monitoring and operation must be easy and a clear sharing of functions is essential.

The functional sharing is as follows:

(1) Graphic panel

Whole water system graphic display

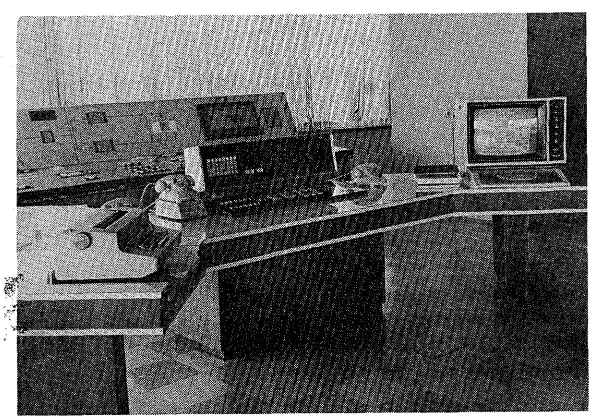


Fig. 10 Example of control room

Operation and accident display of main equipment in water system

Main data digital display

(2) CRT display

Abnormality display and operation guide for each device

Detailed data display (related data, time series data, etc.)

Operation display of each device

(3) Operator console

Data display and setting of loop specified by operator

CRT display screen selection

Accident display of computer system components

(4) Logging typewriter and line printer

Compilation of daily operation reports

Print-out of abnormality and related data

Recording of operating conditions of the processes

4. Transmission System Components

The transmission system transmits various types of data arising in the various subsystems and the center system. It is important to transmit a large amount of data correctly and rapidly.

The devices making up the transmission system are classified as computer data transmission equipment, the data highway system, and telemeter and telecontrol equipment.

The transmission object functions for the transmitted data are as follows:

Site computer→center computer: measured values, device operation and accident reports, site equipment operating data, data requests

Center computer→site computer: water quantity set values, optimum set values, replys to data requests

Instruments→site computer: measured values, device operation and accident data

Site computer→operating terminals: operation instructions

Computer terminals→center computer: data requests

Center computer→computer terminals: replys to data requests

The connection control system of the transmission equipment is of two types: the contension system and the polling selecting system. The contension system transmits when any station call another station and the polling selecting system transmits in the order the center calls the sites.

The transmission is either by wire or wireless. The wireless system is used often recently in the 400 MHz waveband where the deterioration of air conditions is remarkable. The line system is often used by renting public lines which are convenient in respect to equipment construction costs and maintenance.

The public utility standard lines used for data transmission are the A1, C2, D1, D5 and D7 ratings.

Table 1 Specifications of communication control unit

Name	Communication control unit (CCU)				Line control unit (LCU)
Model	F1805K	F1805L	F1801K	F1801L	F7004A
Communication system	Full double/ half double	Same as left	Same as left	Same as left	Same as left
Synchronizing system	Start/stop system	Same as left	Same as left	Start/stop/SYN	Same as left
Sign unit numbers	6, 7, 8	6, 7, 8	5, 6, 7, 8	5, 6, 7, 8	5, 6, 7, 8
Communication speed	under 200BPS	1,200BPS 200BPS	under 1,200BPS	under 4,800BPS	under 4,800BPS
Maximum line capacity	124	96	16	16	32
Connected computer	F230-45, 55	Same as left	Same as left	Same as left	FU200

Data transmission with the computer is performed via the C2, D5 and D7 ratings. The A1 and D1 ratings are used in the telemeter telecontrol e-quipment.

1) Data transmission equipment

The communication control unit (CCU) and line control unit (LCU) are connected to the center computer and perform transmission with the sites. The control functions of the CCU and LCU include line control such as synchronous checks and line monitoring, mutual conversion between bit information and characters; character processing such as parity checking and sign checking; program control such as data transmission control, and interface control such as interrupt processing and data transfer. As can be seen in *Table 1*, there are various types of CCU and LCU depending on the synchronous system, the communication speed and the maxi mum line capacity. The CCU is used to large scale computers such as the FACOM 230-45S and the LCU employs mini-computers such as the FACOM U200.

The asynchronous adapter (ASA) and the binary synchronous odapter (BSA) are line connection terminals for the FACOM U200 computer. The ASA has a communication speed of 1,200BPS and a start/stop synchronous system. The BSA has a communication speed of 2,400BPS or 1,200BPS and an independent synchronous system.

The terminal for CRT display (FACOM 2901A type) is used as the INQ terminal.

The universal terminal (FACOM 1520 or FACOM 1530) is connected to the key board puncher, paper tape reader/puncher, etc. and is used for the message conversion system, INQ system, TSS, etc.

The modulation and demodulation equipment (MODEN) is placed at the communication line connection points and modulate the signal to match the transmission line characteristics.

2) Data highway system

Tha data highway system is a sort of transmission system which has several ports and these are connected in a loop form by only a pair of special cable for data transmission. This is used when equipment is scattered over a comparatively wide area as in the filtration plant and disributing reservoir. The advantages of this system are the savings in construction costs for wiring and back-up systems.

Fuji Electric has the MPCS system (Multiple Process Control System) for large scale system and the DPCS (Data highway Process Control System) for small systems.

3) Telemeter telecontrol equipment

The telemeter telecontrol equipment has been widely used from previously in water works. The types of the equipment include the direct wiring and carrying systems, analog and digital system and (1 : 1) and (1 : N) systems. They are selected in accordance with the lines, amount of data, reliability and transmission speed. Fuji Electric has the cyclic digital telemeter (CDT type), the (1 : N) telecontrol (NTC type), telecontrol equipment (TC-100URD type), analog telemeter (TTL-18S type) and direct telecontrol equipment (F series).

5. Instruments

The instruments used in the control system are water hydraulic and quality sensors and control receivers.

The water hydraulic sensors include flowmeters, liquid level meters and pressure gauges. The flow meters are of the electromagnetic, ultrasonic, differential pressure, weir and other types, and the liquid level meters are of the float type, static capacity type, flange type, etc.

The hydrualic sensor signal conversion system has shifted from the former pressure balanced type to the completely electronic semi-conductor strain gauge type. These are excellent in reliability and response.

Fuji Electric uses the TELEPERM IS system based on the semiconductor strain gauge system.

The water quality sensors include turbidity meter, the residual chlorine meter, the alkalinity meter, the pH meter at the water works and DO meter, the TOC/TOD meter, the SS meter and the sludge concentration meter at the sewage works. They play

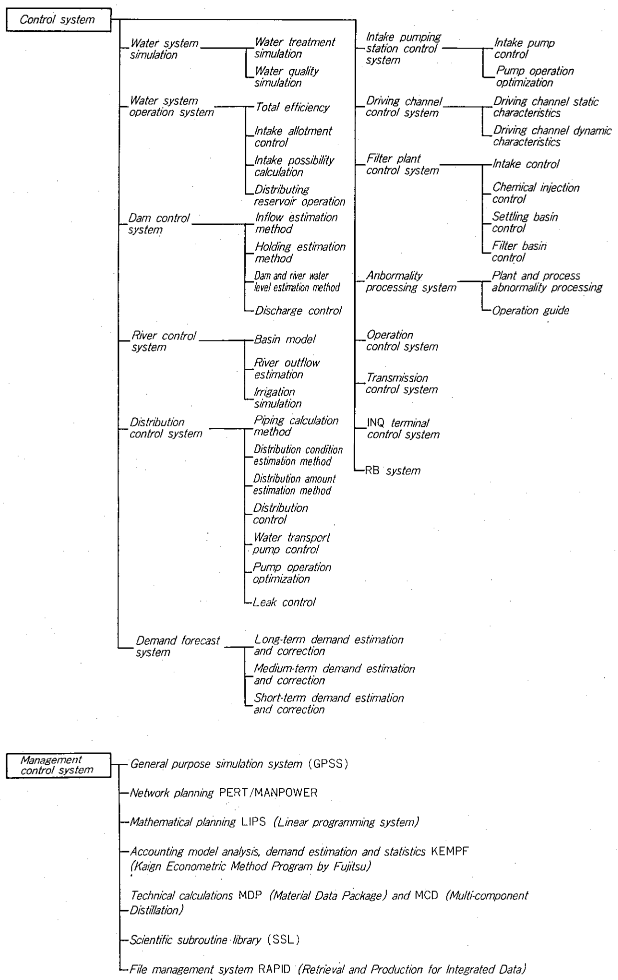


Fig. 11 **Construction of application software for wide area water supply control**

an important role in the control system.

6. Electrical Equipment

The electrical equipment consists of receiving and distribution equipment as power supply equipment and motor drive equipment as powering equipment. This equipment supplies the energy for the system.

The power receiving and distribution equipment includes power sources such as very high voltage receiving equipment, high voltage receiving equipment, transformer equipment, load center and control center; and static type CVCF, etc. as computer continuous power supply equipment.

The powering equipment includes motors for pumps and blowers and various types of motor valves.

The motor speed control is performed by such systems as the Kramer system, Scherbius system, static Leonard system and the KS and PS motors.

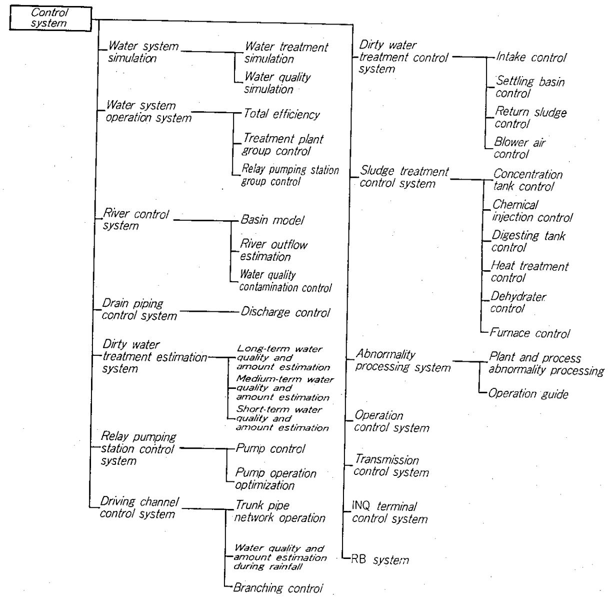


Fig. 12 **Construction of application software for river side basin sewage control**

The electric operating devices to drive the motor valves are not simple powering devices but requires various functions by which they should be considered as control devices. Fuji Electric produces the WRA series of motor drive devices.

7. Software

The computer system software consists of basic software and application software.

1) Basic software

The basic software centered around the monitor is the basic programs for computer system operation and there are software system for each type of equipment.

The software systems for the control center FACOM 230-45S computer is the OSII.

The software systems for the site FACOM U200 computers are the COMOS, DIMOS and POPS.

2) Water and sewage works software

The application software consists of control software and management software. The functions of the control software include equipment control, control processing and process characteristics analysis. *Fig. 11* shows the control software for wide area water supply systems and *Fig. 12* shows it for river basin sewage systems. The management software employs various types of statistical processing and model analyses as shown in *Fig. 11*.

3) Data transmission software

The date transmission software is employed in the transmission of data between the center and sites and is decided according to the transmission text, transmission control method, etc.

VII. DIRECTIONS OF WATER AND SEWAGE WORKS CONTROL TECHNOLOGY

With the introduction of welfare policy, the future of water and sewage works is bright. Water and sewage works control technology will also make great advances in the future. However, there are several problems which must be solved.

For instrumentation, hydraulic and water quality meters are being developed. The development of highly reliable on-line instruments is naturally required and it is also necessary to increase the measurement frequency of in-line systems with little measuring time required. Sensors for plant control must not be specified from the exterior but must arise from the techniques used in the system. For this, user cooperation from the site is essential.

In computer control, the basic control elements have been established by efforts to date. This must be followed by the development of application software appropriate for water works. This will involve overall efforts from not only the electrical and instrumentation fields but also the civil engineering, mechanical and sanitary engineering fields. First, it will probably be necessary to reconsider the optimization of water works equipment operation. Then, in order to clarify the software logically as previously, it must be backed by actual operation in a real plant.

Computer is effective ways to achieve this, and computers installed in the various treatment plant must be utilized efficiently. It is necessary to think of it growth from the delivery stage and not finish at the installation stage.

The control system in computer control is centered around the CRT display. They have been used in the Ara river basin sewage treatment center and the Nagasawa filtration plant in Kawasaki city. Further, the CRT display can be put to better use and the future trends should be man/machine communication by only CRT with display method, conversation method and other methods.

From the hardware standpoint, the microcomputer has attracted attention with the appearance of the one-chip CPU. This might be used independently for pumps, filter basins, chemicals, etc. and these might be controled totally by a central system. In other words, the system would divide the computers functionally between control and management. Perhaps the period has come when the computer can be considered more by itself and be handled like an instrument.

In transmission techniques, there have been major changes with wide area water works and computer developments. Digital techniques are being introduced for both transmission and measurements and the data highway system, an example of this, is drawing considerable attention. Since the equipment in water and sewage works is arranged in blocks, the data highway should be easy to apply but further investigations must be perforormed including the electrical distribution lines.

New techniques include such unique developments by Fuji Electric as the ozone generation equipment and the freeze/melting dehydrater. In the future, there will be new control technology in such fieds as wide area water supply, river basin sewage system, sludge treatment, tertiary treatment and reutilization of waste water.

VIII. CONCLUSION

Water and sewage works control systems have been outlined above. In the field of wide ranging control, the water and sewage works systems are probably the most advanced. However, this has not been achieved in a short time and water and sewage works control has a long history with many results. For wide area control, completely integrated system technology is required. This system technology must encomposs everything from the planning and design stages including civil engineering, mechanic, electrical equipment and instrumentation. At the same time, water and sewage works control must not be considered only as water treatment but also as one stage in environmental. Water and sewage works control should develop greatly in the future.