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MEASUREMENT AND CONTROL EQUIPMENT FOR WATERWORKS

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I. INTRODUCTION

Fuji Electric has considerable experience in the manufacture of process measurement equipment for use in waterworks. Recent trends in waterworks include increases in the input, the development of facilities for environmental sanitation, enlargement of the areas served in order to achieve industrial economy and the use of more large scale equipment. Because of these trends, automation is necessary in order to facilitate the control of such complex systems.

The waterworks process sequence is water intake, dosing with various chemicals, sedimentation, filtration, reduction of bacteria and distribution of the purified water. The controls required for each of these processes are water level control, pressure control, flow control, dosing control, filtration flow control and washing control.

In the measuring equipment field, the trend is away from separate control for each process toward centralized control in one center. Even if all of the individual process values are maintained at the desired values, there is still the problem of whether the individual values are correct or not. Therefore a very high level of control is necessary and because the conditions are always changing this becomes difficult. This is known as optimum control and is possible by means of computer control.

In addition to measurement and control of the purification process, sequence control is also required. For example, the filter bed washing sequence control starts washing in the filter bed when required. Since this is one type of batch process it is usual with process control computers which perform real time control and high level decision making under normal conditions to have sequence control carried out by separate equipment so as not to lower the utilization efficiency.

Recently, serious consideration has been given to the automation of sequence control for each process, but as yet this has become very popular. One of the main reasons for this is that in sequence control all the processes differ so that different sequences must be planned for each and therefore it is desirable to standardize the sequences as much as possible.

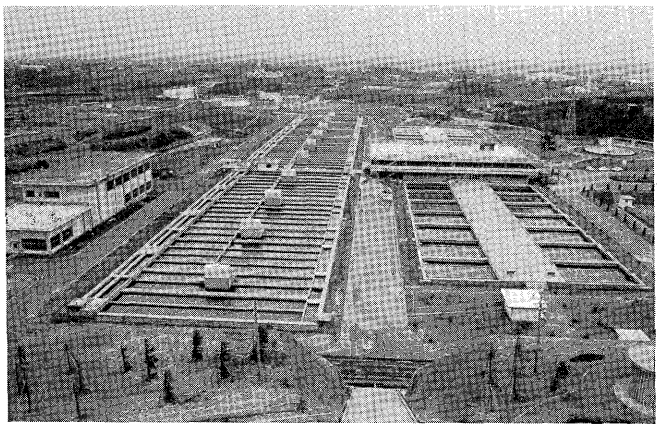


Fig. 1 Panoramic view of Kosuzume Waterworks

This article will introduce a typical example of sequence control for automatic filter bed washing at the Kosuzume Waterworks of the Yokohama Waterboard. In the main works, the filter bed is more than 300 m from the central control room. By using telecontrol equipment, several filter beds can be controlled with only 4 transmission lines. A new system of sequence automation has been developed by combining the telecontrol equipment and the automatic filter bed washing sequence.

The following will be devoted mainly to this washing control.

II. OUTLINE OF EQUIPMENT

The equipment and treatment capabilities for this waterworks are as follows.
(*Table 1* and *Fig. 2* show the pure water 20,000 m^3/hr equipment)

Pure water purification plant	
High speed sedimentation basin :	16 basins
Treatment capacity (max.) :	40,000 m^3/hr
Industrial water purification plant	
High speed sedimentation basin :	6 basins
Treatment capacity (max.) :	15,000 m^3/hr

Table 1 **Details of Equipment**

Name	Number	Detection Terminal (location)	Type of Indication	Measureing Range	Signal Receiver	Remarks
Intake water summation flowmeter	1	Measurement panel (central control room)	Record, integrate	0~50,000 m³/hr	Meter	
Crude water flowmeter No. 1	1	Venturi with inner dia. of 1800 mm	Record, integrate	0~20,000 m³/hr	Meter	Dosing instructions, including all electrically operated components
Crude water flowmeter No. 2	1	Venturi with inner dia. of 2000 mm	Record, integrate	0~12,000 m³/hr	Meter	Dosing instructions, including all electrically operated components
Crude water summation flowmeter	1	Measurement panel (central control room)	Record, integrate	0~50,000 m³/hr	Meter	Including previous crude water flow
Filter bed input well water level meter	1	Float-type (filter bed)	Indication, alarm	0~3 m	Meter	
Filter head loss meter	28	Differential pressure type (filter bed)	Record, alarm	0~3 m	Meter	
Filter flowmeter	28	Venturi with inner dia. of 600 mm	Record, control	0~1000 m³/hr	Meter	Motor control valve
Total filter flowmeter	1	Measurement panel (central control room)	Record, integrate	0~25,000 m³/hr	Meter	Dosing instruction
Filter summation flowmeter	1	Measurement panel (central control room)	Record, integrate	0~50,000 m³/hr	Meter	
Master flow setter	2	Measurement panel (central control room)	Set	0~100 m³/hr	Meter	
Filter bed water level meter	28	Polarity type (filter bed)	Lamp indication	—	Lamp	
Filter bed operation panel (local)	1	Each electric motor valve	Operation	—	Desk	
Filter continuation time measurement euuipment	28	Pulse counter	Time display	0~120 hr	—	
Automatic washing equipment	2	—	Set, process indication	—	—	Pinboard type
Telecontrol equipment	2	—	—	—	—	Filter bed control
Back wash water flowmeter	2	Venturi with inner dia. of 1000 mm	Record, integrate	0~100 m³/min	Meter	Including electrically operated components
Surface wash water flowmeter	2	Venturi with inner dia. of 300 mm	Record, integrate	0~10 m³/min	Meter	Including electrically operated components
Back wash tank water level meter	1	Differential pressure type	Indication, alarm	0~5 m	Meter	
Water supply summation flowmeter	1	Measurement panel (central control room)	Record, integrate	0~50,000 m³/hr	Meter	
Central instrument panel	1	—	—	—	—	Graphic type
Central operating panel	1	—	—	—	—	
Electric power equipment	1	—	—	—	—	Power reception, control center
Telephone equipment	1	Automatic telephone switchboard (10 lines)	—	—	—	
Broadcasting equipment	1		—	—	—	
Sediment water, pure water pH meter	2	Dosing room, supply pump locations	Indication	2~12 pH	Meter	Dosing instruction
Sediment water, pure water chlorine residue meter	2	Dosing room, supply pump locations	Indication, record	0~3 ppm (sediment water) 0~5 ppm (pure water)	Meter	Dosing instruction
Maintenance parts	1					

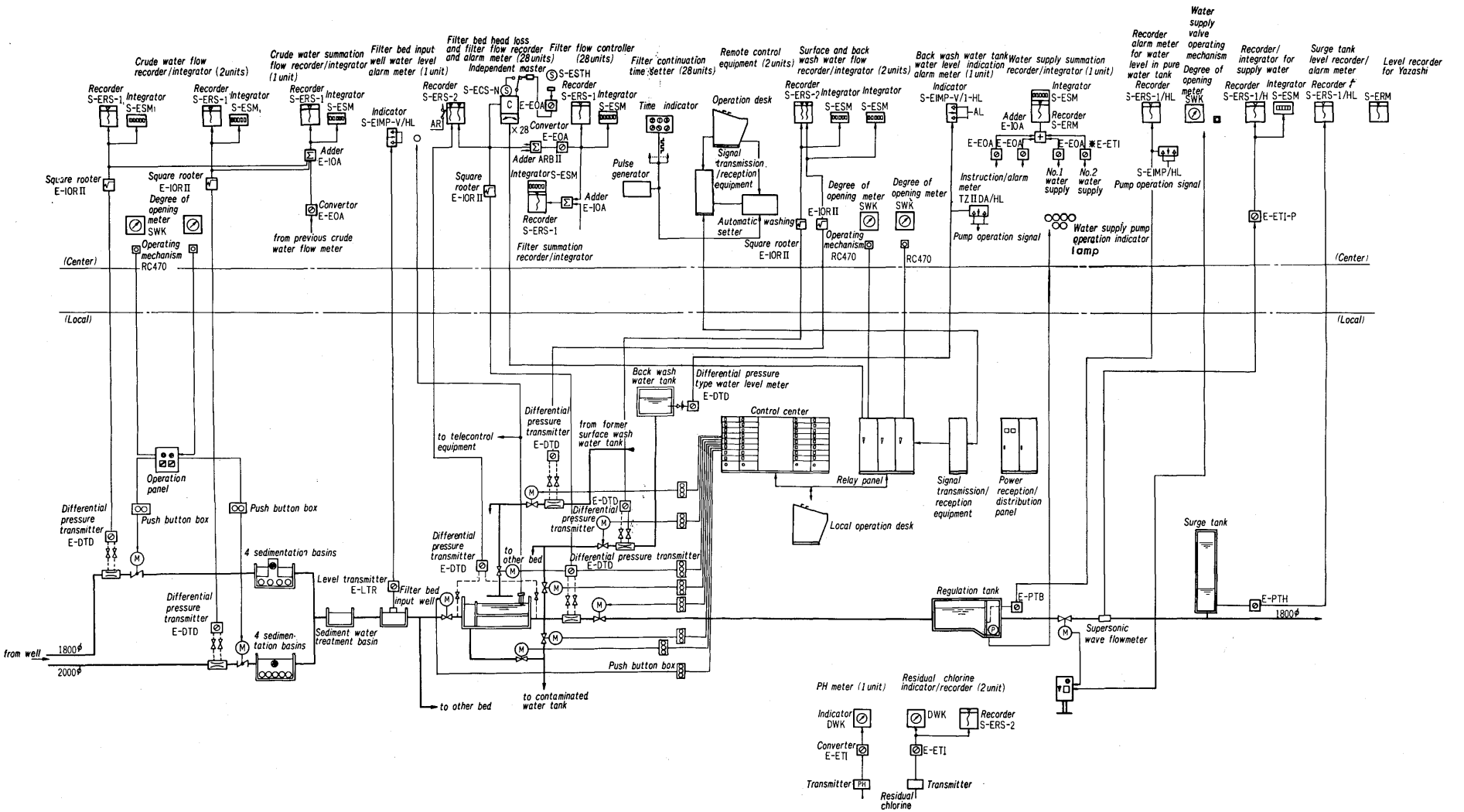


Fig. 2 **Instrumentation diagram**

III. FILTER BED WASHING CONTROL

1. Washing System

Filter bed washing can be performed either from the local operation room or the central control room. When carried out in the central control room, there are two possible systems, automatic and manual. When carried out at the local site, the central conversion switch on the operation desk is switched to LOCAL which means that all operations are then switched to the local operation desk. Then the desired filter bed is selected by means of a push-button and washing of that bed is then possible manually by operating the motor valve switches in the proper sequence. Both automatic and manual washing are possible from the central control room and the desired system can be chosen by the system conversion switch on the central operation desk.

When a filter bed is carrying out filtration automatically and anyone of the following conditions arise :

1) The filter head loss reaches the upper limit,
2) The filter continuation time reaches the set value,
3) The need for washing is revealed by pushing one of the "Manual selection push buttons",

a "washing required" signal is generated for the filter bed in question. If the operation switch of the filter bed in question is turned to the stop position and "selection cancellation" occurs, the washing signals then ceases. When a washing signal arises for one of the filter beds, the selection scanning circuit commences operation and this circuit ceases once the required bed has been selected for washing. When one bed has been selected and a washing signal occurs for another bed, selection scanning is performed until selection of the second bed has been completed. However, if yet another signal arises, the selection scanning circuit will not be activated. In other words, once the bed for which the signal arises initially is selected, more than two selections can not be performed since the selection circuit will not be activiated. This "off" condition of the selection circuit is not released until one washing is complete so that if there is one bed with "washingun derway" signal on and one with "washing standby" on, no other bed can be selected for washing.

When the bed has been selected, the following points are checked by a pinboard type automatic washing setter before washing begins.

1) The operation conversion switch is not set at LOCAL
2) The system conversion switch is not set at MANUAL
3) There is no accident in any of the valves of the selected bed

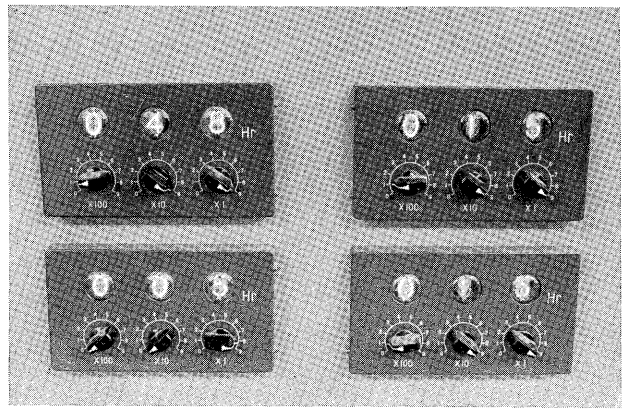
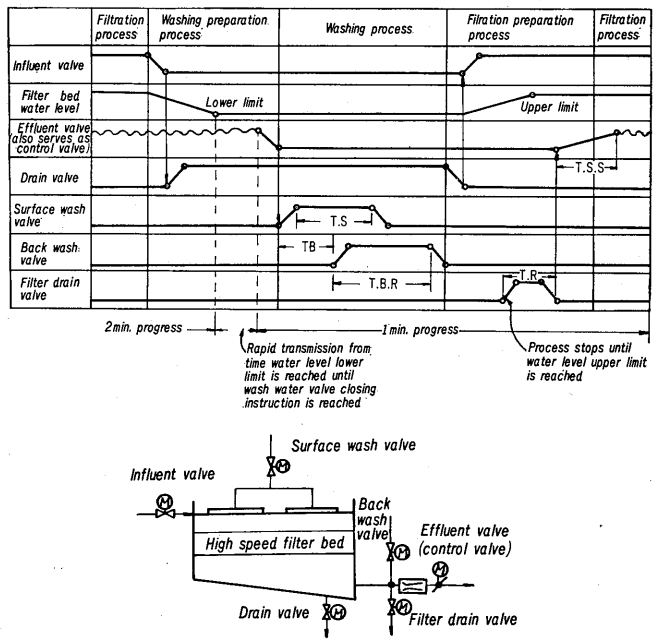


Fig. 3 Continuation time setter



TS : Surface wash set time 0~5 min
TB : Back wash initial set time 1~10 min
TBR : Back wash set time 1~5 min
TR : Filter drain set time 1~10 min
TSS : Slow start set time 2~60 min

Fig. 4 Time chart for filter-washing

4) The water level in the back wash water tank is at the specified value or above
5. The water level in the waste water basin is at the specified level or below.

When all of the above conditions are fulfilled, a signal to start washing in the specified bed is generated and washing is carried out in accordance with the time chart set on the pinboard type setter.

2. Filtration Continuation Time Setter

As was described above, the washing signal is generated by measuring the filtration continuation time. This setter uses a digital type pulse counter instead of conventional motor timer. *Fig. 3* shows an external view of the setters.

3. Pinboard Type Setter

With this pinboard type setter, the washing sequ-

ence can be established simply by inserting pins into the board in accordance with the desired process. Since there are lamps to indicate process changes and given warnings of interlock delay among the valves, the entire washing process can be checked at a glance. *Fig. 4* shows the washing time chart for automatic washing.

The pinboard setter can set switching times and intervalve operation command intervals (times) for six valves—the crude water valve, pure water valve, drain valve, surface washing valve, back washing valve and filter drain valve. The time taken to reach the lower limit of the water level in the filter bed during the washing preparation process is not fixed due to filter draining, the process is speeded up to the point where the washing valve closing command is generated when the water level lower limit is reached by lengthening the time which the washing valve is open. During the washing preparation process, there is a check of the upper limit of the filter bed water level, but the process comes to a stand still once the filter drain valve opening command level is reached, and when the filter drain valve opening command is given at the time the water level upper limit is reached, the process continues again.

Command signals from this equipment are fed into the telecontrol equipment. When the telecontrol equipment is connected, the time between the issuing of the opening signal by the pinboard setter and the return of the total valve opening limit signal and the time between issuing of the closing signal and the return of the total closing limit signal differs from that of previous systems. A time delay results because the data are double checked in the telecontrol equipment, but this is actually no problem since the time between issuing of the open or close signals and the return of the total open or close limit signals is only increased by about 2 minutes.

Standard specifications for the equipment are given below.

No. of levels :	8 levels (including process change indicator lamps)
No. of circuit :	50 circuits per level
Clock pulse :	30 sec. 1, 2, 5, 10 min used independently or in combination
Process speed :	about 0.5 sec./bit
Auxiliary relay :	Type HH17–CSC 5 contacts or a wire spring relay
External view :	Front surface of acryl, access doors on both sides
Pin holes :	8 levels × 50
Pins :	100 supplied
External dimensions :	panel flush mounting type
Height :	340 mm
Width :	620 mm
Depth :	350 mm
Power source :	Ac 100 v 50/60 Hz
	Dc 48 v

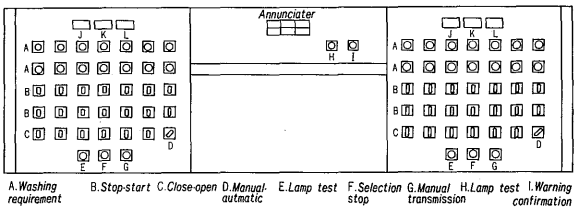


Fig. 5 Surface layout of desk board

4. Central Operation Desk

The central operation desk contains all the operation conversion switches and indicator lamps necessary for central manual operation of filter bed control.

These operation controls are divided into 2 groups, each for 14 filter beds. Each group contains controls for its portion of the beds and the operation system can be selected. Compared with the former system in which there were controls for each of the beds, this system is much more compact. *Fig. 5* shows the surface layout of the central control desk.

5. Connection with Telecontrol Equipment

With the telecontrol equipment, control is performed by selecting one of the many control points from the various areas controlled. After one control operation is completed, a new one can begin. This also can apply to filter bed washing control. Since there is a limitation on the amount of water in the back wash water tank, no more than two filter beds can be washed simultaneously. When considering control by the former system, the following lines were needed between each filter bed and the central control room : a influent valve, a effluent valve, a drain valve, a surface washing valve, a back washing valve, and a filter drain valve as well as total valve opening, closing and limit lines. When the number of filter beds was large and the distance between the site and the central control room long, the cost of the distribution line material would be very high and it would also not be economical from the viewpoint of maintenance. With this equipment, washing control can be effected with only one 4-wire line-2 wire for control and 2 for control and 2 for supervision. The 28 filter beds are divided into 2 groups and for each group of 14 beds, there is 1 set of telecontrol equipment.

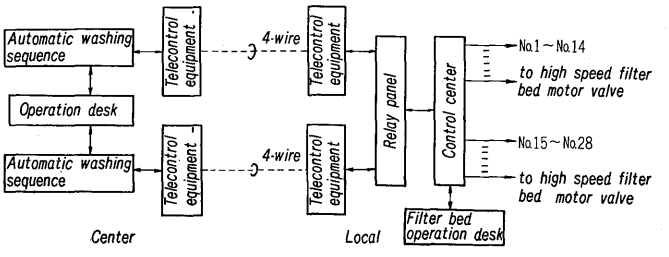


Fig. 6 Block diagram of filter control

Table 2 **Control and Supervision Points of Telecontrol Equipment**

No.	Control Item	Point	Indication Item	Point
1	Wash filter signal	14	Local operation	1
2	Effluent valve control filter selection signal	14	Under repair	14
3	Effluent valve control (open/close) signal	6	Wash filter selection confirmation	14
4			Filter bed high water level	1
5			Filter bed low water level	1
6			Wash valve completely open	5
7			Wash valve completely closed	5
8			Wash valve accident	5
9			Effluent valve completely closed	14
10			Effluent valve accident	14

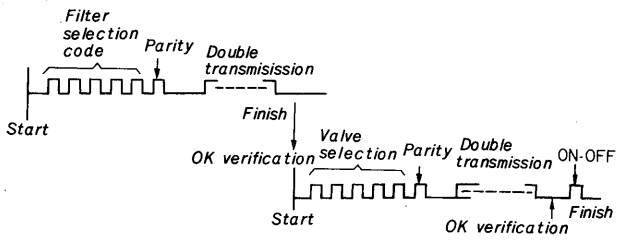


Fig. 7 Code unit of control

Besides control of filter bed washing, starting and stopping of the filtration process is also possible. Control of the pure water valve is possible in such a way that even if one filter bed is being washed, the effluent water valve of another bed can be controlled by interrupting the washing in progress as long as there is no transmission from the local site.

1) Control

When a signal for selection of the filter bed to be washed is sent manually or automatically from the central control room, the input circuit is formed in such a way that no other control input can be fed in and even if there is a momentary cut-off, the number of the bed to be washed and the valve memory circuit is maintained until transmission of the control signal is completed. After this, a pulse code signal indicating the bed number is formed in the signal formation circuit and transmitted to the site. This signal is sent twice and when it is received at the site, if the contents of the first and second parts are the same, the number of the filter bed is detected by a decoding circuit and the contents are transferred to the memory circuit. At the same time, an OK verification signal is sent back to the center. When this signal is received at the center, the valve selection code and the open/close code are then transmitted. When these are received at the local site, the valve control signal is generated if a verification shows that the signals are correct.

Control of the effluent valve is performed in the same manner but when the bed to be washed is already in the bed selection memory circuit at the site, and a signal is fed to the memory circuit of another bed for pure water valve control, this memory is cleared once the pure water valve control is completed. The memory of the number of the filter bed to be washed is maintained until the washing bed selection input signal is cancelled at the center.

Even with voltage variations of 90～130 v, the pulse code time will not change since the pulse generator circuit is coupled with a set voltage circuit. Therefore, even when there are voltage variations, there will be no disturbances in the operation. Once the power is interrupted and started again, control input signals entered previously are cleared and confirmation and reoperation are required. This is to prevent erroneous operation in case the memory circuits are disturbed by the power interruption.

2) Supervision

For supervision, 75 positions are divided into 5 groups of 15 positions each, and group contents and group numbers are transmitted when there is some change in the conditions.

The transmission system is of the pulse code type. Fifteen positions make up one group and there is double transmission for each group. However, the selection code is common for one group and subsequently the on/off signals for each position are transmitted in order according to marks or spaces. If there is an OK verification at the center, supervision output is transmitted. If conditions change, only the

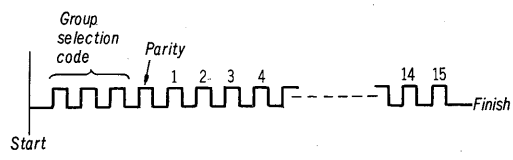


Fig. 8 Code unit of supervision

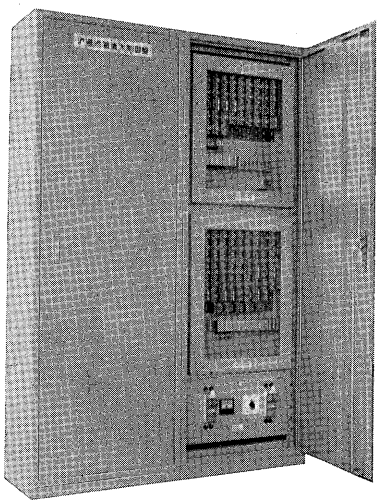


Fig. 9 Telecontrol equipment

group which contains the position where the change has occurred is activated on the condition of all positions in the group is transmitted by a supervision signal.

When conditions change at exactly the same time in each group, the highest level group is given priority for transmission and once this group is completed, transmission supervision of the low level groups is performed. When conditions change in the high level group during transmission of another group, transmission for the high level group begins once the group being transmitted at the time is completed. When the conditions of several points in the same group change, this is transmitted simultaneously but when changes occur in positions in the same group during transmission, this is not indicated but after completion of transmission, transmission is started again for the same group.

3) Equipment specifications

Standard specifications for the telecontrol equipment are as listed below.

Type :	SF 30
No. of signals :	Control 20, supervision 30
Main components :	Wire spring relays
Signal system :	Pulse code type Control : double transmission of selection code, OK verification signal return code + control Supervision : 5 positions in one group, double transmission for each group
Transmission lines :	Control signal 1 circuit, supervision signal 1 circuit
Power source :	Dc 100/110 v for standard, in case of ac, dc power equipment attached
Power consumption :	Control and controlled equipment, about 200 va
External dimensions :	2,350 mm (H) × 600 mm (W) × 200 mm (D)

6. Site Relay Panel

The site relay panel contains the relays for operation between the site equipment and the telecontrol equipment. Control relays (HH23P type) ideal for automatic control of various types of equipment are used in the panel.

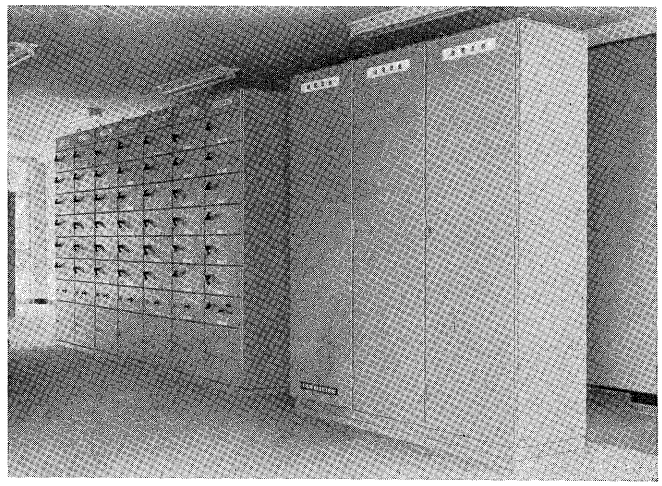


Fig. 10 Relay panel at local

7. Motor Valve Control Center

The various types of contactors and autobreakers used for motor valves around the filter beds are all located in an independent control center to facilitate operation and maintenance. All of the motor valve units can be tested by inserting operation testing units. The necessity often arises to separate the filter beds from the purification basins for repair and maintenance of the motor valves. For this reason, the control center contains regulation switches for each filter bed. When these switches are ON, the motor valves of the bed in question can be operated from the local motor valve operation box.

Fig. 11 Control center for motor valve

If a regulation switch is ON, any kind of adjustements of the bed in question can be carried out since this bed is cut off from the purification basins. When the regulation switches are operated, the conditions at the time, whether filtration or stoppage, are maintained.

8. Local Operation Desk

The local operation desk is used at the filter bed site when washing is not being carried out. If the operation conversion switch is switched to LOCAL, washing operations can be performed at the site for beds selected from the center. The desk also indicates various bed conditions such as adjust, select, valves completery open, fault and completely closed. Adjust is indicated by the control center conversion switch. There is one group of washing operation control switches for 14 beds and selection is performed in the same way as at the center. *Fig. 12* shows an external view of this desk.

IV. DOSING CONTROL

1. Aluminum Sulfate Flow Control

Aluminum sulfate is injected into the sedimentation basin as a coagulant to aid in precipitating out the turbid materials in the crude water. The amount

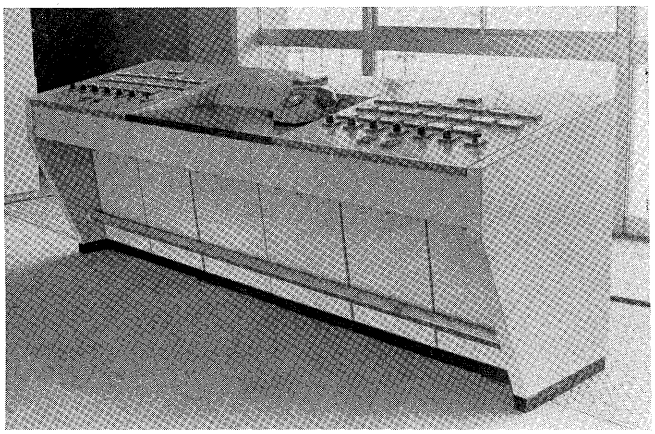


Fig. 12 Desk board at local

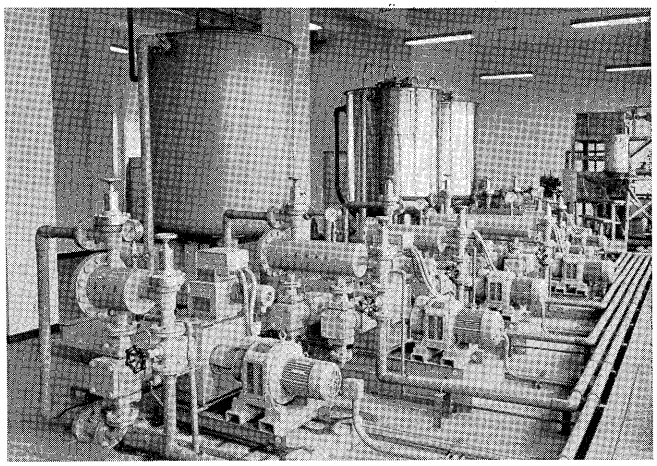


Fig. 13 Dosing pump

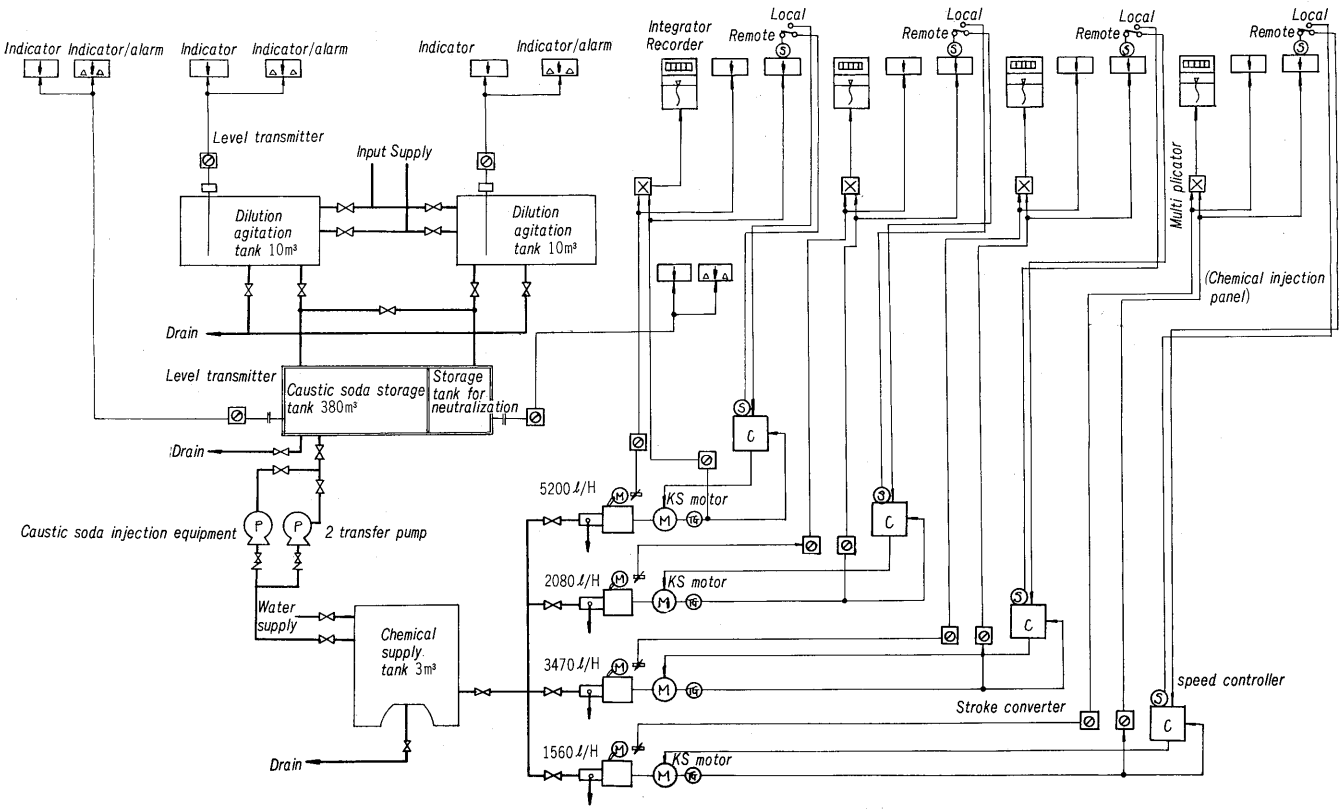


Fig. 14 Dosing instrumentation diagram

injected is measured and the injection is controlled.

Injection is performed by an injection pump which requires stroke and speed reduction. For this pump, the Fuji KS motor was employed since it has proven excellent in respect to speed control. This KS motor has a speed regulator attached. The set speed value and the value of the KS motor speed detected by the tachogenerator are compared and the difference is controlled by PI operation. The control system generally employs ratio or set value control. In this equipment, set value control was used.

2. Caustic Soda Injection Control

Caustic soda is injected into the crude water to help coagulate the alkaline elements in the crude water. Injection control is carried out by liquid level meters in the dilution and storage tanks. *Fig. 14* shows an instrumentation diagram for dosing.

3. Alginic Soda Injection Control

Alginic soda is also injected as an agent to help coagulation like caustic soda. Control is by the same means as with caustic soda.

Fig. 15 shows the main panel in the dosing room. All dosing operations are indicated here including the conditions of the injection pumps. Setting and recording of the amounts of chlorine, aluminum sulfate, caustic soda and alginic soda to be injected is also possible here.

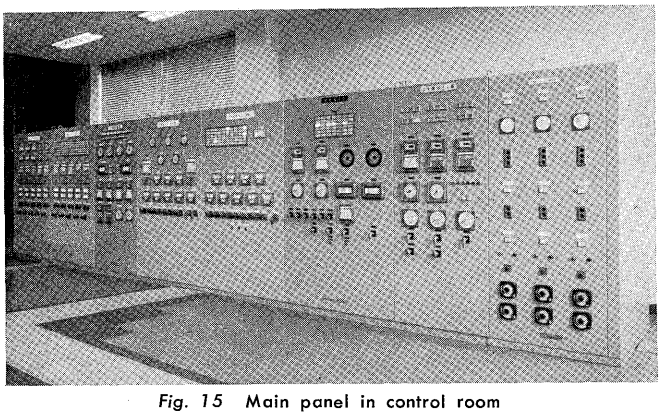


Fig. 15 Main panel in control room

V. CENTRAL CONTROL PANEL

The central control panel is very important since all plant operations can be supervised from it and therefore it should be simple to operate.

In a large scale plant like this one, the system tends to become complex so that everything must be thought out in great detail. *Fig. 16* shows the panel layout in the central control room. The systems are arranged from water intake to distribution. Various types of meters and devices for each system are included. Since the graphic system is used, it is easy to observe the condition of the water treatment at a glance.

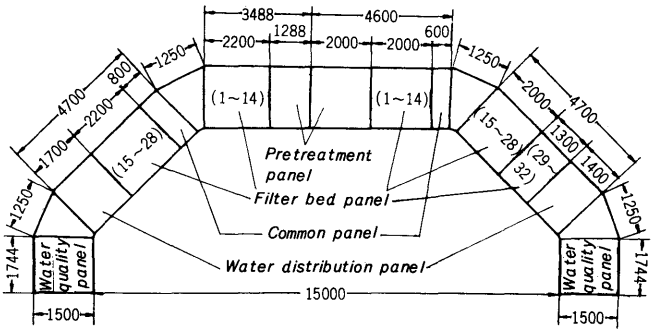


Fig. 16 Panel layout in central control room

Fig. 17 Central control room

VI. CONCLUSION

This article has contained an outline of the measurement and control equipment in the Kosuzume Waterworks. At present, the instruments in one section of the filter beds are being adjusted since they will soon be put into operation. Filter bed sequence control employs a new system utilizing telecontrol techniqhes which it is hoped will contribute in some way to future systems. Efforts are now being concentrated on developing another new sequence control system. The authors wish to thank all those who helped in this work.