UDC 628. 16-523

COMPUTER CONTROL SYSTEM FOR THE ASAKA WATER PURIFICATION PLANT, TOKYO METROPOLITAN BUREAU OF WATER WORKS

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I. OUTLINE OF CLEAR WATER PROCESS

The Asaka Water Purification Plant is the main plant of the Tokyo Metropolitan Bureau of Water Works. The first construction stage for completion of one half of the plant was started from October, 1966. As the Tone River Water Works Development Project progressed, the second stage was completed in 1968 and the third stage in 1970. At this latter time, the entire plant was completed.

The daily amount of water treated is a standard of 1,700,000 m^3 and a maximum of 2,600,000 m^3. In the Higashimurayama purification plant, there is a large capacity pumping system which can deliver 760,000 m^3 of raw water daily. This is therefore one of the largest water purification plants in the world.

Of the several new developments used in this plant, the computer control system deserves special mention. However, this was already described when the first stage was introduced in March, 1967 (Vol. 40, No. 10 Fuji Electric Journal in Japanese).

The raw water for this purification plant is taken from the Tone River (Tone Intake barrage), Musashi Aqueduct, Ara River, Akigase Dam and Asaka Aqueduct in that sequence. Intake is by natural down flow into the cellar which is 30 m beneath the raw water pumping station. It is then conveyed to a receiving well by means of a pump head. During this process, chlorine, caustic soda if required and activated silicic acid are injected. Then the water is conveyed from the receiving well to the sedimentation basins (horizontal flow, 2 storys, 3 levels, 32 basins) via a rapid mixing chamber, aqueduct and flocculation basin. In the rapid mixing chamber, aluminum sulfate, regenerated aluminum sulfate, polyaluminum chloride and activated silicic acid are injected. The flock produced in the flocculation basin by rapid and slow mixing effectively causes adhesion of the suspended particles such as clay particles which cause the turbidity of the raw water and these settle out. From the sedimentation basins, the water is filtered through high speed filters (96 in all) consisting of layere of sand to remove minute flock carried over from the sedimentation basins. In principle, the water is then stored in the clear water reservoir after post chlorination treatment in the post chlorination duct for disinfecting. Caustic soda can also be injected into the post chlorination duct in order to regulate the pH value of the clear water.

The clear water stored in the clear water reservoir is transmitted and distributed by pump pressure in accordance with changes in the water requirements. The water transmission system relays the water via the distribution basin and the distribution pump of the Kami-Igusa distribution and is supplied mainly to the Jonan District.

II. CONSTRUCTION OF THE COMPUTER CONTROL EQUIPMENT

(1) Control processing unit ······1 (FACOM 270-20)
(2) Real time controller (5 lockers) ······························ 1 (FACOM 2731A)
(3) Input/output unit ··················2 (FACOM WRITER F801A)
(4) Photo tape reader···············1 (FACOM 749A)
(5) Paper tape puncher ············4 (FACOM 767A)
(6) Line printer ·····················1 (FACOM 743L)
(7) Logging typewriter ············7 (IBM 30 inch—4, IBM 20 inch—3)
(8) Operator console ···············1
(9) Relay panel ·····················1 (7 lockers)

1. Central Processing Unit

Main internal memory magnetic core 32K words
Secondary memory
inner magnetic drum 131K words
outer magnetic drum 131K words

2. Number of RTC Input/Output Points

(1) Interruption trap input ···············80 points (8 levels)
(2) Analog input ············400 points (Input voltage: 0.2 to 1.0 V, including AD converter check)
(3) Code input ············84 points (1,344 bit contact input)
(4) Pulse input

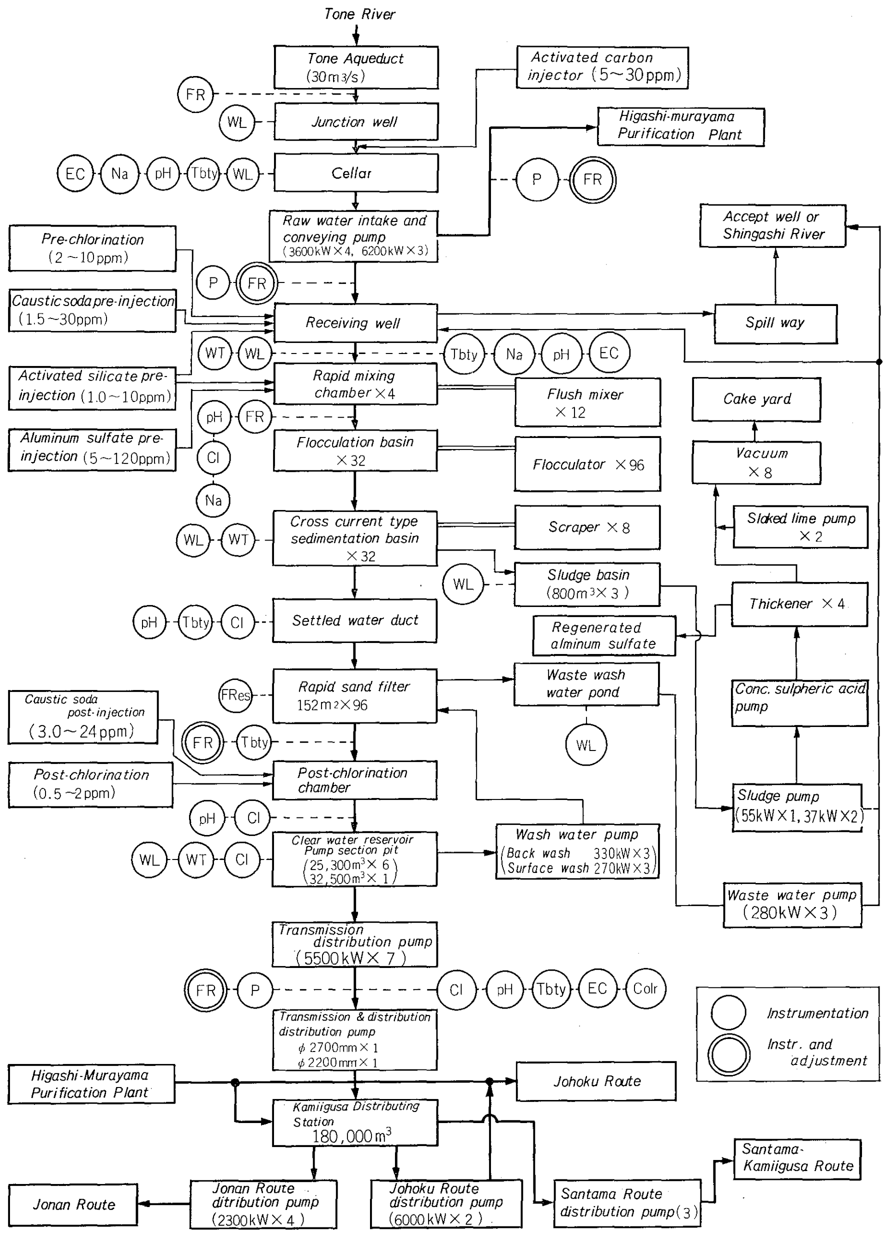


Fig. 1 Schematic diagram of Asaka Purification Plant

············16 points (1 point : 4 bit counter)

(5) Analog output

············8 points (0 to −8 V)

(6) Code output *

············20 points (320 bits)

(7) Typewriter output

············11 points (including 4 punchers)

(8) Preset counter

············4 points

(9) Change analog input

············96 points, 8 points

* : Of 20 points, 12 points, (= 192 bits) are gated code output (100 ms contact make)

III. OUTLINE OF APPLICATION PROGRAMS

Since the water purification plant had continuous processing, the application of the computer control system is divided into three systems :

(1) System started using constant time interval interrupt with an RTC clock

(2) System started by interrupt signal from the exterior

(3) System started by start command from operator

Fig. 2 shows the constitution of the plant program.

1. Daily Report and Data Collection

The daily report and data collection are performed in the 5 logging typewriters and 4 paper tape punchers.

1) Daily report

There are 5 types of daily reports :

(1) Daily report 1..related to chemical injection, 56 items 30-inch TW

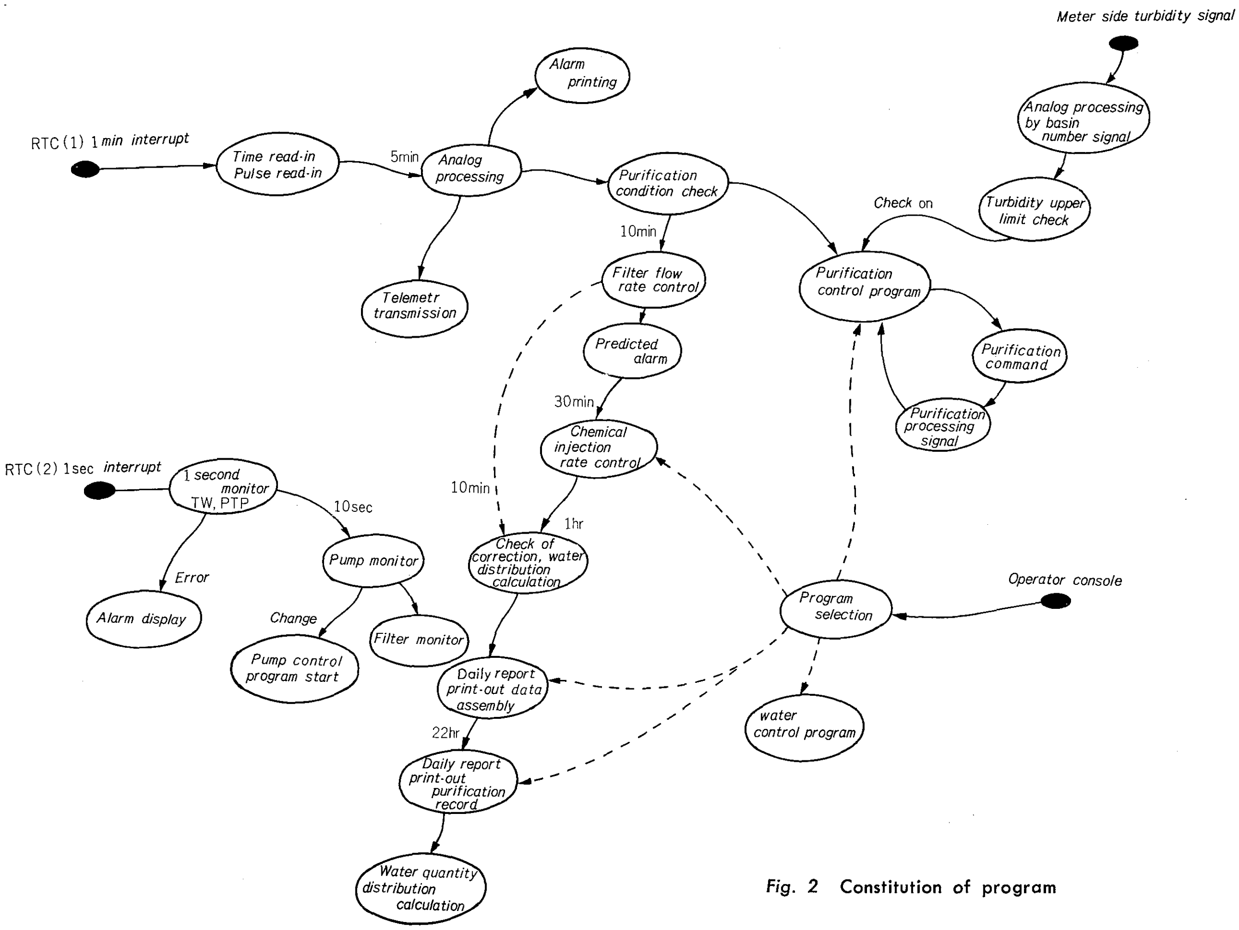
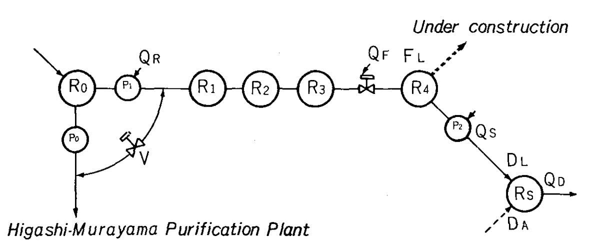


Fig. 2 Constitution of program



R_0:	Cellar	P_2:	Transmission pump
R_1:	Receiving well	Q_R:	Intake flow
R_2:	Sedimentation basin	Q_F:	Filter flow
R_3:	Filter	Q_S:	Transmission flow
R_4:	Clear water reservior	Q_D:	Distribution flow
R_5:	Kami-Igusa distributing plant	F_L:	Clear water reservoir level
V:	Reverse flow valve	D_L:	Distribution basin level
P_0:	Conveying pump	D_A:	Distribution basin area
P_1:	Intake pump	↙:	indicates control object

Fig. 3 Group of water facilities for apportionment of flows

(2) Daily report 2...General 58 items, 30-inch TW
(3) Daily report 3...Related to water quality 60 items, 30-inch TW
(4) Filter daily report 1···flow rate of each filter 20-inch TW
(5) Filter daily report 2···related to water purification

2) Data collection

The following four punchers conduct data collection

(1) Chemical treatment ··························98 items
(2) Water quantity and movable weir opening ···········216 items
(3) Washing water ································20 items
(4) Monthly report ································32 items

3) Monthly report

There are two types of monthly reports.

(1) General ···31 items
(2) Chemical injection ··························26 items

These compilations and data collections are all handled by the standard compiling program.

2. Control of Water Quantities

The water transmission control system will be described in 4 parts: 1) water intake control, 2) filter flow rate control. (*Fig. 3*). 3) water transmission control and 4) water distribution control.

1) Water intake control

One part of the raw water led into the cellar of the raw water pumping station is conveyed into the Higashimurayama Purification Plant and also is controlled in this purification works. The following factors can be considered for basic calculations of the water intake:

(1) Calculation from predicted requirements
(2) Calculation from water concessions

There is a very close relation between (1) and (2). (1) is the predicted requirement, i.e. the prediction of the water required one day or several hours before, and the water intake is an amount corre-

Table 1 Principal pumping equipment of the Asaka Purification Plant

	Name	Type of pump	Size of pump (Suction × delivery dia) (mm)	Discharging capacity (m³/s/unit)	Total head (m)	Motor output (kW/unit)	Range of speed control (%)	Revolution (rpm)	Number installed
Raw water	Raw water conveying pump	Vertical shaft, single suction single stage, volute	1,400×1,000	4.17	120	6,200	100-80	407-326	3
Raw water	Intake pump	Vertical shaft, single suction single stage, volute	1,800×1,400	10.00	29	3,600	100-80	285-228	4
Clear water	Transmission pump	Horizontal shaft, double suction single stage, volute	1,500×1,000	5.5	80	5,500	100-70	580-406	4
Clear water	Distribution pump	Horizontal shaft, double suction single stage, volute	1,500×1,000	5.5	80	5,500	100-70	580-406	3

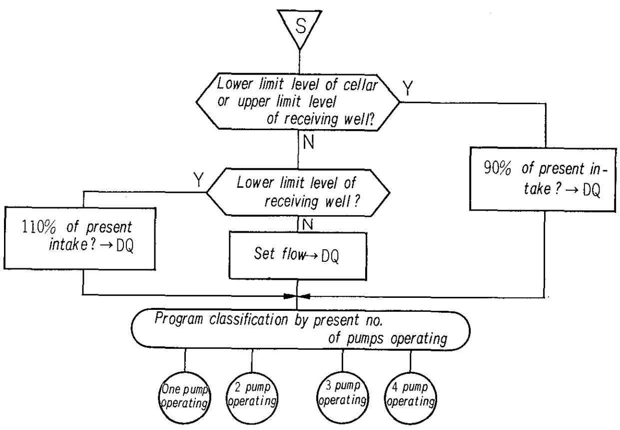


Fig. 4 Flow diagram

Table 2 Control system of filter system

		Control calculation point		Desired value
Control system	I	Computer control/manual for filter system	1	Present actual flow rate
	II	Set period calculation every 10 min.	1	Set value
			2	Average of 2 amount of raw water
	III	Optional calculation by water distribution control	1	Calculated value of water distribution
Filter system	I	Total decay		
	II	Constant+decay		
	III	Total constant		

sponding to this predicted requirement. Since there are many factors involved such as the weather, these predictions are difficult and and at present careful investigations are being conducted.

In the case of (1), a constant amount of water which is the water concession is fed in under normal conditions, the capacities of the clear water reservoirs and the distribution stations are used effectively and this method can be executed as the first step in fulfilling the requirements.

In method (2), difficult factors to predict such as the weather are also included and there is a problem of accuracy. Investigations on these points are now

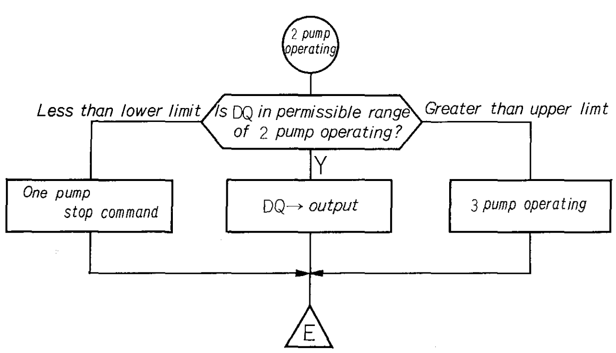


Fig. 5 Flow diagram

underway. Until the calculation of water intake becomes possible, amounts set by the operator are being used.

For reference, specifications of the main pump in the pumping station are given in *Table 1*. These are for an unprecedentedly large piece of equipment.

The amount of water intake set by the operator is distributed among several pumps as shown in *Fig. 6* and pump starting and stopping is performed. The upper and lower limits shown in *Fig. 6* can be changed from the operator's console and the number of pumps can also be controlled by the use of electric power. Simplified flow diagrams are shown in *Figs. 4* and *5*.

2) Control of the filtration process is by the system outlined in *Table 2*. In this system, the flow amounts and the outflow valve opening for each filter are calculated in such a way that the water level in each sedimentation basin remains constant. Control is thus achieved for each of the filter system.

Conversion between (Computer $_{EDP}$⇌manual $_{MASTER}$) and (constant$_C$⇌decay$_D$) is performed from the filter operation desk and the control is performed for the 96 filters in 8 groups of 12 each.

By making comparisons between the desired filter value and the actual value as shown in *Table 2*, the

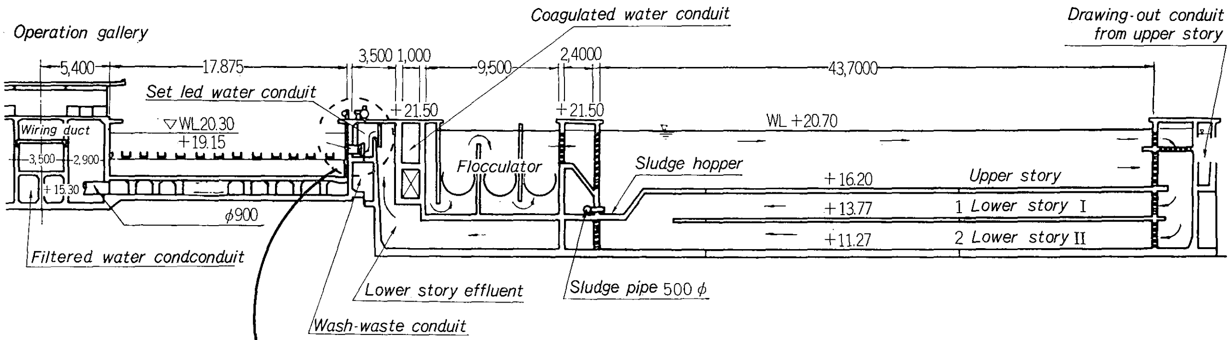
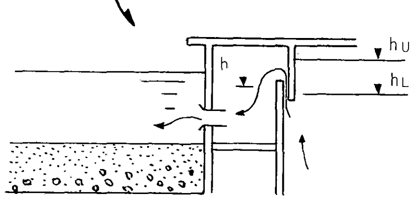


Fig. 6 General view of filter and settling basin



calculation system differs but here, details of a system by which control is performed every 10 minutes in a constant filter system for all groups will be introduced.

The desired filter value can be achieved theoretically in the constant filter system, by proportional distribution in the operating filters of the discrepancy with the desired value. However, since this is a large scale purification plant, a condition arises in which the water levels of the sedimentation basins are not the same due to the difference in distances from the receiving well even when the opening of the outflow valves are the same for each group in order to control the filter flow. Therefore, as control of the proportional distribution of the discrepancy continues, the water levels of the sedimentation basins become unbalanced to provide a stable water level in the sedimentation basins.

In the calculation system using a filter flow instruction, the sedimentation basin water level is a parameter and it is possible to control both the filtration process and the water levels of the sedimentation basins are shown in *Fig. 9*. The following is a description of the calculation method for the sedimentation basins and filters.

The following designations are used:

h_{t10}: water level 10 minutes before [m]

h_t: present water level [m]

S: area 9435.8 m^2 [m^2]

QA: required processing amount (desired value) [m^3/h]

The change of the amount of water in the sampling period (10 minutes) $\varDelta TQ$ is:

$\varDelta TQ$=(present water level—water level 10 min. before)×area$=(h_t-h_{t10})\cdot S$

The symbols shown in *Fig. 6* are defined as follows:

h_u: upper limit water level of settled water conduit

h_L: lower limit water level of settled water conduit

h_{ti}: present water level of i group

h_{t10i}: water level of i group 10 minutes before

Q_u: water level overflow=(present water level—upper limit level)×area

Q_L: water level underflow=(present water level—lower limit level)×area

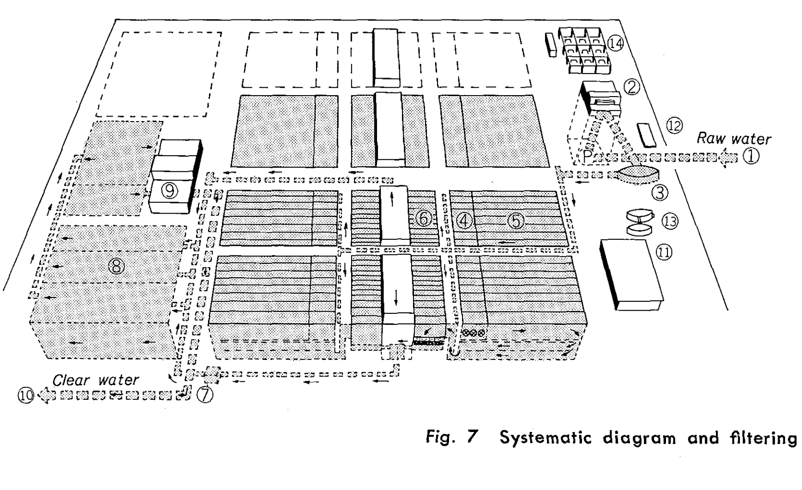
i: 1 to 8

AO: calculated value of filtered amount

From this the distribution for i group can be obtained:

$$QS_i=\frac{\text{present level of each group}}{\text{sum of current levels of each group}}\times\text{processed amount}$$

$$=\frac{h_{ti}}{\sum_{i=1}^{8}h_{ti}}\times QA$$



1: Intake tunnel
2: Raw water pumping station
3: Receiving well and rapid mudding chamber
4: Flocculation basin
5: Sedimentation basin
6: Rapid filter
7: Post-chlorination chamber
8: Clear water reservoir
9: Administration house and clear water pumping station
10: Clear water piping main
11: Chemical plant
12: Wash-waste and sludge basin
13: Suldge thickener
14: Substation

Fig. 7 Systematic diagram and filtering rate control

The coefficint of change in water quantitity for i group is as follows:

$$\Delta Q_t = \left(\frac{h_{ti}}{\sum_{i=1}^{8} h_{t1}} - \frac{h_{t10i}}{\sum_{i=1}^{8} h_{t10i}} \right) \times QA$$

The calculated value of the filtered amount can be calculated in two ways: by the difference between the present water level and the level 10 minutes before and by the upper or lower limit overflows.

(1) With the upper limit overflow $\cdots AO = Q_u + Q_s + \alpha$

(2) With the lower limit overflow $\cdots AO = Q_L + Q_s + \alpha$

This α is the difference with ΔTQ which is the amount of change between the water change coefficient ΔQ and the amount 10 minutes before. The rate of the change in the sedimentation basin water levels is shown as positive or negative values. The outflow valve opening instruction is expanded by a square scale of the AO value and the control output is given separately for each group. From the equations, the sedimentation basin water levels can be kept the same and the required amount of water can be filtered, but in the case of filtration control for all groups, the same amount is not filtered in each group. *Fig. 7* shows a systematic diagram of the purification system and filtering rate control.

3) Water transmission control

The clear water processed in this plant is divided into two parts: one part is transmitted to the Kami-Igusa Distribution Station and the other part is distributed directly to the city center. Here, the the control of the water transmitted to the Kami-Igusa Distribution Station will be described.

By adding up the predicted amount for the Kami-Igusa Distribution Station *TFDQ* (for one day, set from the operator's panel) or the actual amount distributed 24 hours previously *TQD*, the average transmission amount becomes 1/24 of this value and the average transmission amount is adjusted so as to achieve the desired water levels of the Kami-Igusa supply basins (refer to *Fig. 8*) which are obtained statistically beforehand. However, since there are limits on the amount of power used, this adjustment can not be accomplished rapidly and and must cover a period of time.

(1) Calaculation of Kami-Igusa distribution amount *QD*

Table 3 Comparison of controlling output

Condition \ Control output		Pump automatic starting	Flow rate control	Horn	No. of pumps indication	Flicker horn	± symbol
I	Completely automatic	○	○	*2○	○	○	*4○
II	Semi-automatic	×	○	*2○	○	×	○
III	Manual	×	*1×	*3○	○	×	○

*1: Flow rate setting indication value only
*2: Automatic stopping or manual stopping
*3: Manual stopping only
*4: Flicker operation is completed when operation starts

The amount of water distributed from time $(t-1)$ to time (t) includes the amount of water from other systems taken into the Kami-Igusa distribution station and can be claculated from the following formula:

$$(DL_{t-1} - DL_t) \times 24{,}000 + Q_{st} \quad \cdots\cdots\cdots\cdots (1)$$

where DL: Kami-Igusa supply basin water level
Q_s: amount of water transmitted
t: time

(2) Calculation of transmission amount Q_s

As can be seen from *Fig. 11*, the calaculation method for the amount of water transmitted differs between 1 to 5 and 6 to 24 hours.

(a) Calculation between 1 to 5

$$QD_{t-1} + (AD - DL_t)/(6-t) \times 24{,}000 \quad \cdots\cdots\cdots (2)$$

where, AD: desired amount of Kami-Igusa distribution at 6:00 (set value)

(b) Calculation between 6 and 24

$$TQD/24 \text{ or } TFQD/24 \quad \cdots\cdots\cdots\cdots\cdots (3)$$

(c) Correction calculation

Even when the amount of water calculated by (1) is transmitted to the Kami-Igusa supply basins, it is necessary to make a correction in the amount when the predicted 6:00 a.m. water level (DLMAX of *Fig. 8*) is not achieved or the calculation shows that the water level is below the lower limit (DLMIN). Since corrections for each hour are not sufficient, they are made every 10 minutes and the transmission amount is changed accordingly.

(3) Control of number of transmission pumps

The number of transmission pumps can be controlled by manual, semiautomatic or completely

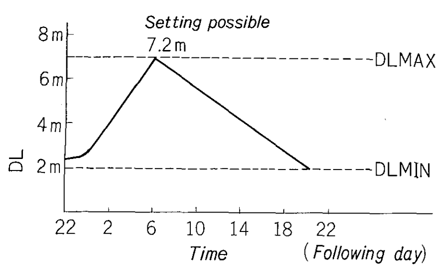


Fig. 8 Estimation diagram for water level of supply water basin

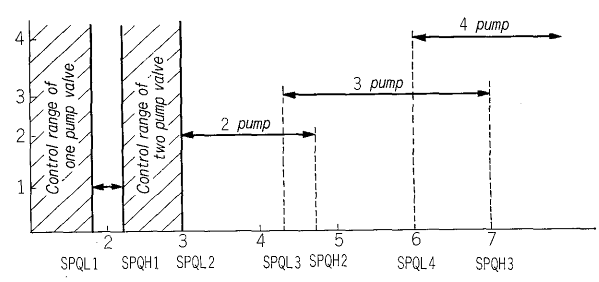


Fig. 9 Relation between flow and pump number

automatic control of the pump sequence. The control output is compared in *Table 3*.

As can be seen from this table, there is a normal output which is not related to the pump conditions and the program construction is as follows.

(a) Pump operation monitoring every 10 seconds
(b) Pump sequence monitoring every minute
(c) Control program for number of transmission pumps

The number of pump control program (completely automatic only) is monitored every minute and a calculation of the water distribution is made. The number of pumps to be operated to supply the required water is calculated and pump operation or stop instructions are given. Then, there is monitoring every 10 seconds to check whether or not the pump starting and stopping is correct. The operating condition is stored and when the instruction is not being followed, an error occurs, an alarm is printed out, the most appropriate flow rate for the number of pumps operating at that time (there are cases of upper and lower limits) is given out and control is performed to minimize changes in the flow rate. *Fig. 9* shows the relation between the number of pumps and the flow.

4) Distribution control

This distribution control is pressure control which differs from the transmission control. Three control systems can be selected: (1) control using the set effluent pressure value, (2) control using the set value of the desired pipe end pressure and (3) control by the actual pipe end pressure. These systems are described below.

(1) Control using the set effluent pressure value

In this case a value set beforehand is controlled as the effluent pressure (setting every 24 hours).

(2) Control using the set value of the desired pipe end pressure

The Hegen William's equation is as follows:

$$P_0 = 10.666\, C^{-1.85} \times D^{-4.87} \times L \times Q^{1.85} + H + P$$

where: C: coefficient
D: pipe diameter 2.2 m
L: length of pipe to desired pipe end
Q: flow rate (m^3/s)
H: standard difference between pump and desired pipe end (m)
P: desired value of pipe end residual pressure (m)

By using this equation, the effluent pressure is calculated from the desired value of the residual pressure at the pipe end, and used as output.

(3) Control by the actual pressure at the pipe end

The pump effluent pressure P_0 is claculated as follows:

P_0 = previously set value of effluent pressure + (set value of desired pipe end pressure—actual pipe end pressure)

The calculated value of P_0 is the instruction output for the pump effluent pressure.

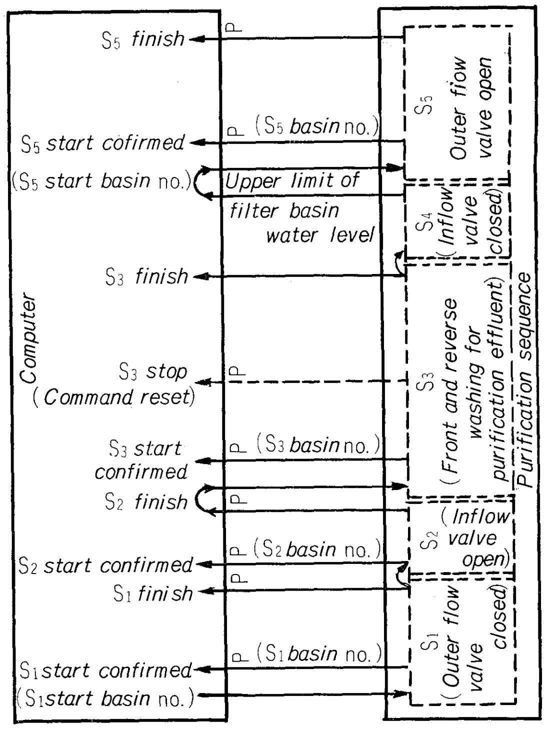


Fig. 10 Schematic diagram of automatic filter washing

3. Filter Control

Washing in the filters is all by means of a washing sequence controlled in the central control room, in the case of manual control from the site desk. The computer control equipment receives data of the sequence which is shown in *Fig. 10*, and automatic washing is performed.

When performing filter washing control, the computer performs the following operations:

(1) Calculation of the filter time
(2) Check-out of the filters in the washing condition and recording of these filters in the memory.
(3) Operation shifted to the S_1, S_3 and S_5 processes
 3–1 Monitoring of conditions for each process
 3–2 Changing of the numbers for each processing filter
(4) Monitoring of all filters

There are five types of washing condition as follows. The conditions differ for constant filtering and delay filtering.

(a) Upper limit of filtering time .... constant and decay
(b) Lower limit of filter resistance .... constant
(c) Upper limit of filter resistance .... constant
(d) Upper limit of filter water turbidity .... constant and decay
(e) Upper limit of filter mixed turbidity .... constant and decay

In the case of the upper limit of mixed turbidity (5), 3 basins priority washing are performed according to filters resistant value progressively (the turbidity of unit groups with 8 groups of 12 filters each for a total of 96 filters is known as mixed turbidity).

In the case of 2-filter simultaneous automatic filter washing, the required washing time for the minimum filtering time (15 hours) can not be minimum filtering time (15 hours) can not be maintained and therefore, the filters are divided into two groups of 48 each.

There are also 2 filter washing control desks in the control room and each one has a sequence. These are also two program systems and the program which processes the data signal from the sequence is at a higher level than the other program and data signals are not picked up or dropped. Processing when delays occur during washing, conversions from automatic to semi-automatic washing, elimination of delays, stopping, shifts to other processes such as S_1, S_3 and S_5, etc. can be performed by special programs.

The signals for the start and completion of each of the sequence processes, whether the control be

Table 4 **List of chemical injection**

Name of chemical	Application	Injection ppm	Injection point: Raw water intake pipe	Injection point: Rapid mixing chamber	Injection point: Post chlorination chamber
Chlorination Pre	Disinfectant and oxydation agent for iron, manganese, etc.	2~10	○		
Chlorination Post	Deodorizer	0.5~2			○
Caustic soda Pre	Alkali aux. agent	1.5~30	○		
Caustic soda Post	Anti-corrosive pH regulator	1.5~30			○
Aluminum sulfate	Coagulator	20~120		○	
Regenerated aluminum sulfate	Coagulator	6~30		○	
Activated silicic acid	Aux. coagulator	1~10	○	○	
Activated carbon	Deodorizer	5~50	Celler		

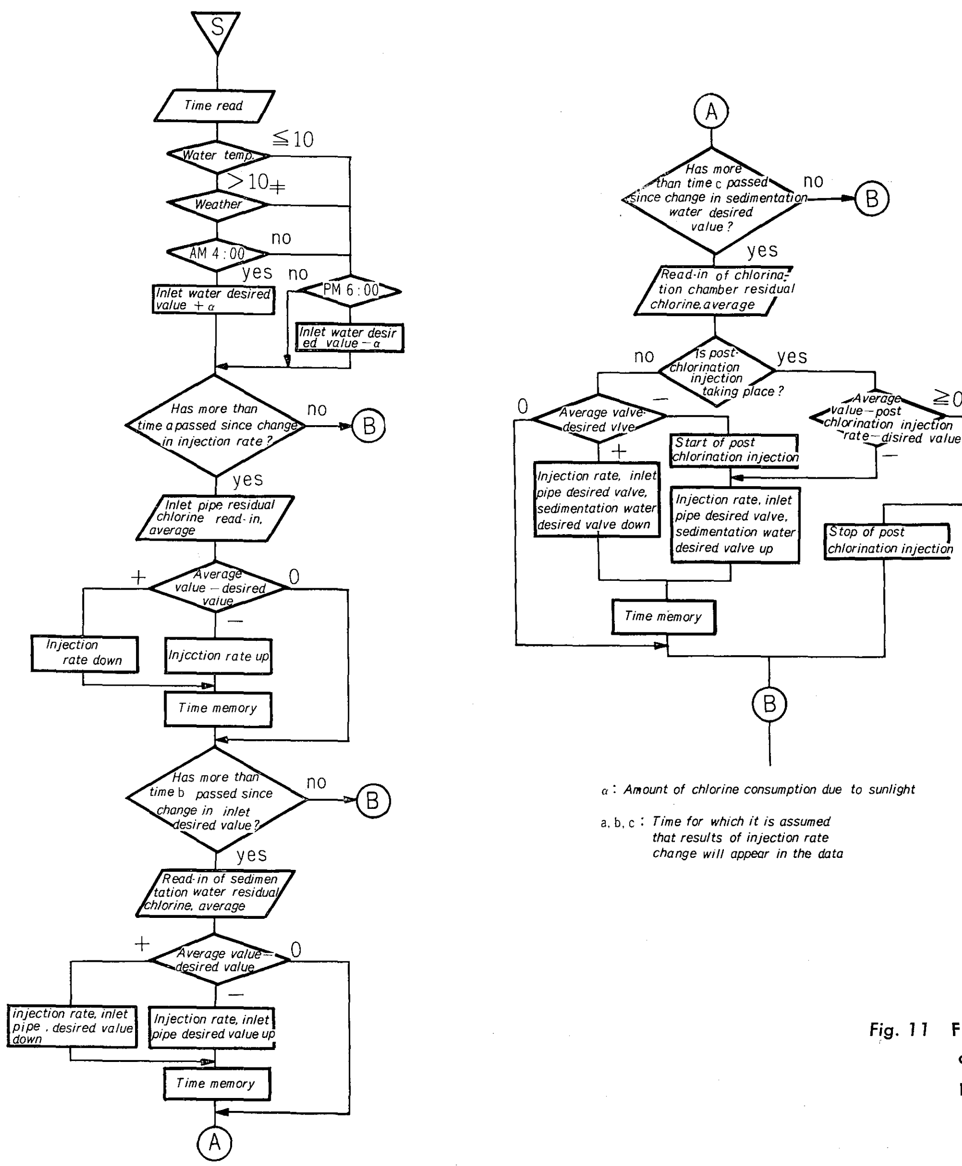


Fig. 11 **Flow diagram of chlorine preinjection**

automatic or semi-automatic, are transmitted to the computer, and operation desk display and condition memory storage are performed. Operation changes can be conducted smoothly, both automatically and semi-automatically.

The daily filter washing reports are typed out at 22 : 00 hours and contain the starting and stopping signals for each process which are entered in the daily report file. This report gives the operating conditions of all 96 filters.

4. Water Quality Control

Water quality control is even more important than washing control. The clear water must pass certain quality standards since it is to be supplied for drinking. Therefore it is necessary to remove many impurities by means of chemicals. The chemicals used in this plant are as follows.

The injection rate control follows the sequence given in *Table 4*.

1) Pre-chlorination rate control

Prechlorination is intended to remove algae and iron and manganese salts from the raw water. In this plant, however, since there is an acid treatment process at the dirty water exhaust, the iron and manganese are a problem of circulating deposits and the latter is considerably more important, *Fig. 11* shows the flow diagram of chlorine preinjection.

2) Post-chlorination rate control

Since, in this plant, sufficient chlorine remains in the water from pre-chlorination for disinfecting during washing, post-chlorination is rare except in cases where the amount of chlorine required in the raw water increases such as in the case of heavy rains. The standard value of residual chlorine in the clear water is set from the operator's console. This standard value is compared with the actual amount of the residual chlorine in the clear water and if there are any differences, the injection rate is changed. If the standard value of residual chlorine in the clear water is set at 0, post-chlorination control is not necessary.

3) Injection rate control of aluminum sulfate and regenerated aluminum sulfate.

Aluminum sulfate and regenerated aluminum spulfate are both cohesion agents but regenerated aluminum sulfate undergoes changes in concentration and in order to obtain the same cohesion results, it is necessary to change the injection rate in accordance with the concentration. In this plant, regenerated aluminum sulfate is injected first in principle but when there is no regenerated aluminum sulfate or when the turbidity is very abnormal due to a typhoon, etc, aluminum sulfate is used alone or both are used together. The concentration of regenerated aluminum sulfate and the ratio of ordinary aluminum sulfate is set from the operator's console. If 0 is set for both, 7% solid conversion is performed from the set concentration for the injection of regenerated aluminum sulfate and the injection rate is calculated. *Fig. 12* shows the flow diagram for aluminum sulfate injection. The equation for calculating the aluminum sulfate injection rate is as follows :

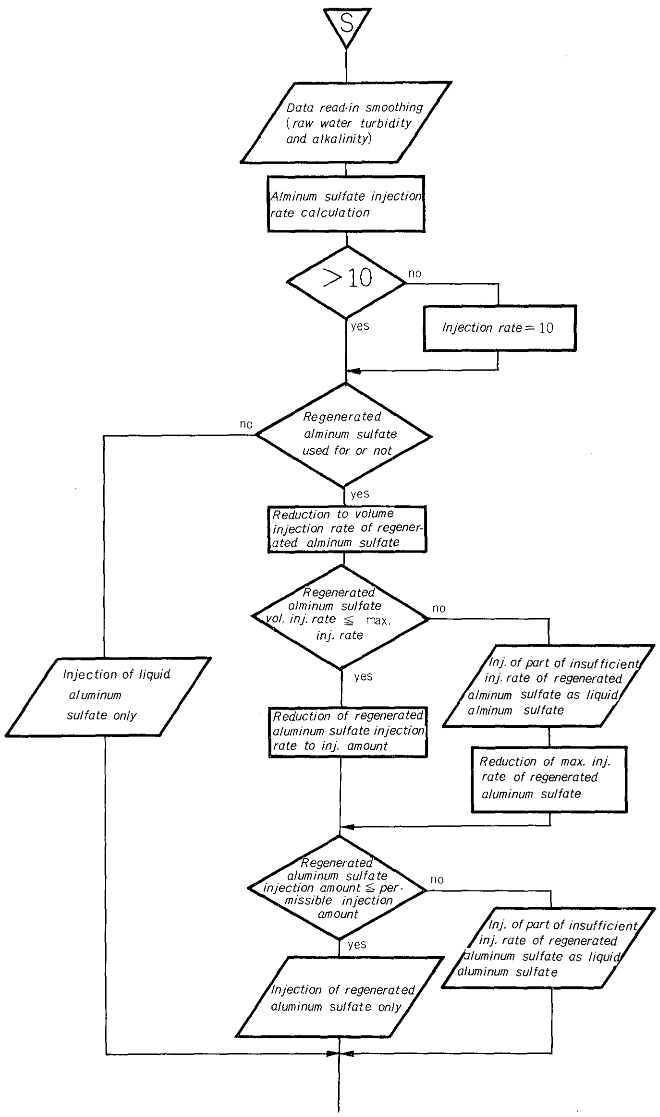


Fig. 12 Schematic program flow up aluminum sulfate

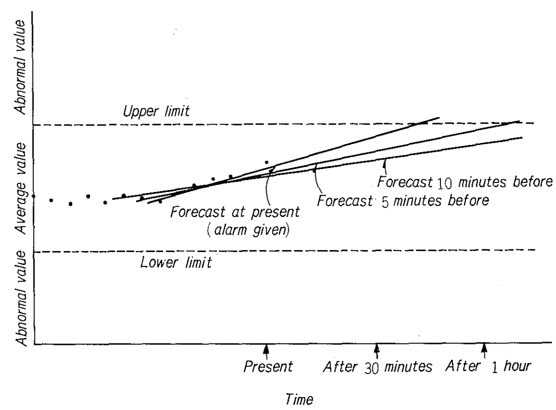


Fig. 13 Explanatory diagram of estimation method

***Table 5* List of objects of estimation**

Name	Type of check	Remarks
Cellar turbidity	Upper limit	When over 300 ppm within one hour
Receiving well alkalinity	Upper/lower limit	When 30~70 ppm range is exceeded within 30 min.
Receiving well electric conductivity	Range of change	When change is more than 30 $\mu℧$/cm whith one hour
Raw water conduit pH	Upper/lower limit	When 6.3 to 7.5 range is exceeded within 30 min.
Settled water turbidity	Upper limit	When 10 ppm is exceeded within 3 hours
Settled water residual chlorine	Upper/lower limit	When 1.2 to 1.8 ppm range is exceeded within 3 hours
Clear water turbidity	Upper limit	When 1 ppm is exceeded whthin 2 hours
Clear water PH	Upper/lower limit	When 6.0~8.0 ppm range is exceeded within 2 hours
Clear water residual chlorine	Upper/lower limit	When 0.8 to 20 ppm range is exceeded within 2 hours

$$C = KT^{\alpha}A^{b}$$

where C: calculated value of the injection rate of aluminum sulfate
K: constant 0.4266
T: receiving well turbidity (ppm)
A: receiving well alkalinity (ppm)
α: constant 0.3264
b: 0.7515

4) Caustic soda preinjection rate control

This performs control so as to compensate for the changes in the pH due to chemical injection and the pH value of the raw water. From the operator's console, the desired pH value of the rapid mixing chamber and the amount of change in injection rates are set, the desired values are compared with actual values and if there are any differences, the injection rate is adjusted by the change only. This control is performed by obtaining desired values by the trial and error method.

5) Caustic soda post injection rate control

The desired value of the clear water pH and the amount of change in the injection rate are set from the operator's console. The control method is the same as for caustic soda preinjection rate control.

6) Active carbon injection rate control

If the computer does not receive the current signals, control is not possible.

The above has been an explanation of chemical injection. An outline will now be given of the forecast warning which checks whether or not these controls are being performed properly.

7) Forecast warning (*Fig. 13*)

There is no problem when the chemical injection is being performed correctly, but since model systems are being developed for the various chemicals used, complete control is not possible. The upper and lower limits are set beforehand, an approximate linear expression is obtained by the method of least square from data of the past 7 times (the data read in time interval differs depending on the data) and when the upper or lower limit value is attained within a previously decided time, a warning is given so that the operator can take precautions. A list of the objects of the forecast is given in *Table 5*.