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# INSTRUMENTATION FOR WATER AND SEWAGE WORKS

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## I. INTRODUCTION

With the call for process automation in water works after the war, pneumatic and electronic instrumentation was developed and recently, electronic computers have been introduced. During this period, Fuji Electric has been involved in water process automation from the beginning.

Water works instrumentation must have high reliability from the public utility and social standpoints and instrumentation system design in an important point in long term facility planning.

At present with the problems of water shortages and water pollution coming to the fore in accordance with economic, social, cultural and industrial development, automation and savings in energy and labor have become essential since treatment facilities have expanded, scales heve increased, levels have been raised, facilities have become more complex and there are manpower shortages. With higher level equipment and the debut of computers, the basis of automation has been measurement and control. Recent development in instrumentation for water and sewage works are introduced here.

## II. MEASUREMENT AND CONTROL IN WATER SUPPLY WORKS

### 1. Instrumentation Concepts

The aim of water works is to supply users with plenty of pure water at the required pressures. In other words, three conditions must be fulfilled: water quantity, quality and pressure.

The water works process consists of facilities for intake, conveyance, filtration, transport, distribution and supply but the process covers everthing from intake to supply and the earlier stage operations have an important, direct influence on later stage operations.

Operation control of such water works facilities requires systematic management with overall control by one system and not independent control of each facility.

In order to correlate these facilities systematically, ensure safety economy and stability with one system, and achieve rational and highly efficient operation, the introduction of measuring and control equipment which can perform suitable data collection and correct control is essential.

The main reasons for introducing the instrument and control epuipment are as follows:

1) Measurement
(1) Determination of process operating conditions
(2) Establishment of economic operation control policies
(3) Safety control
(4) Routine tests and surveys
(5) Compilation of data for investigations and research

2) Control
(1) Stabilization and prevention of changes in process operation conditions
(2) Maintenance and improvement of accuracy and simplification of quality control
(3) Increasing work speed and efficiency and improvement in productivity
(4) Process simplification and decreasing physical and mental work
(5) Performance of work impossible or unsuitable for humans, maintenance and improvement of safety and sanitation, and improvement of the working environment

The filtration plant converts the load (raw water amount × raw water quality) into (water transport amount × pure water quality) and supplies it to the distribution basin. Control of the filtration plant must maintain the two external loads of raw water quality and pure water demand connected with facilities before and after the filtration plant and also regulate internal water distribution, water quality and water transport.

*Fig. 2* shows a block diagram of a filtration plant. The most appropriate instrumentation system is a completely electronic one in terms of reliability, performance, connections with data processing equiment and machinery, maintenance and plant characteristics.

An electronic instrumentation system has been almost completely established and signals have been standardized for DC 2-wire systems, current trans-

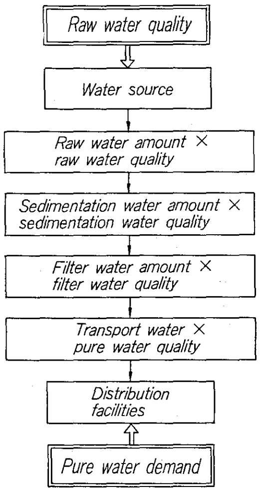


**Fig. 1 Load of filtration plant**

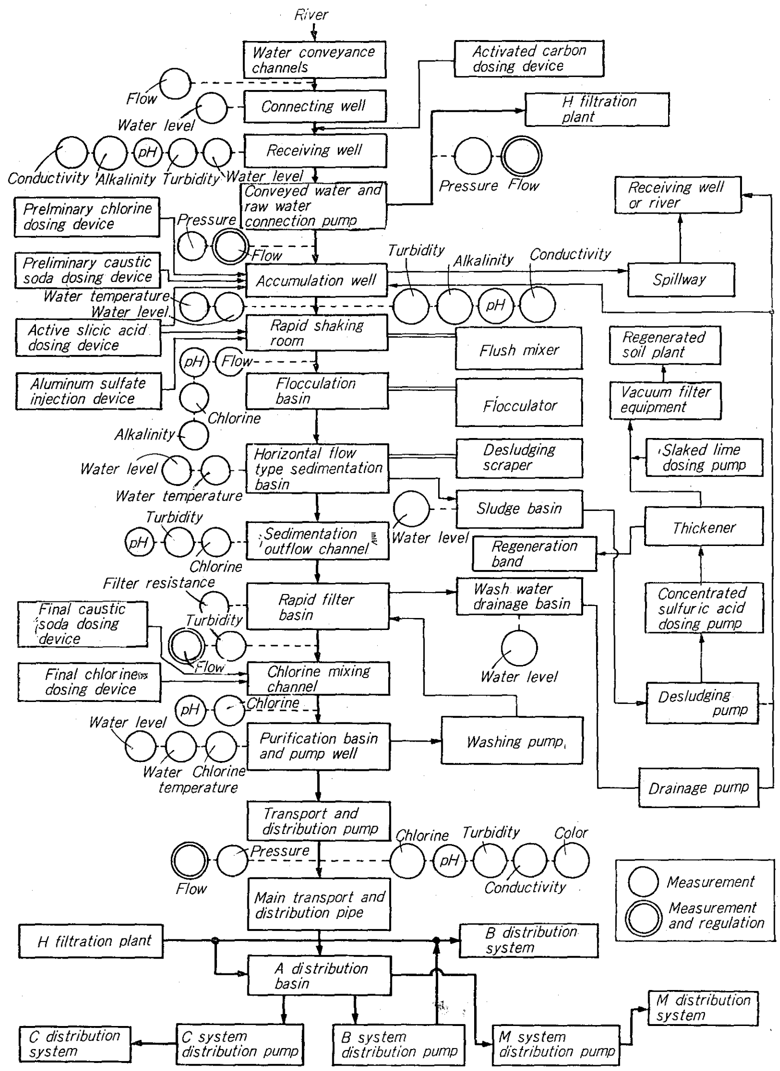


**Fig. 2 Block diagram of filtration plant**

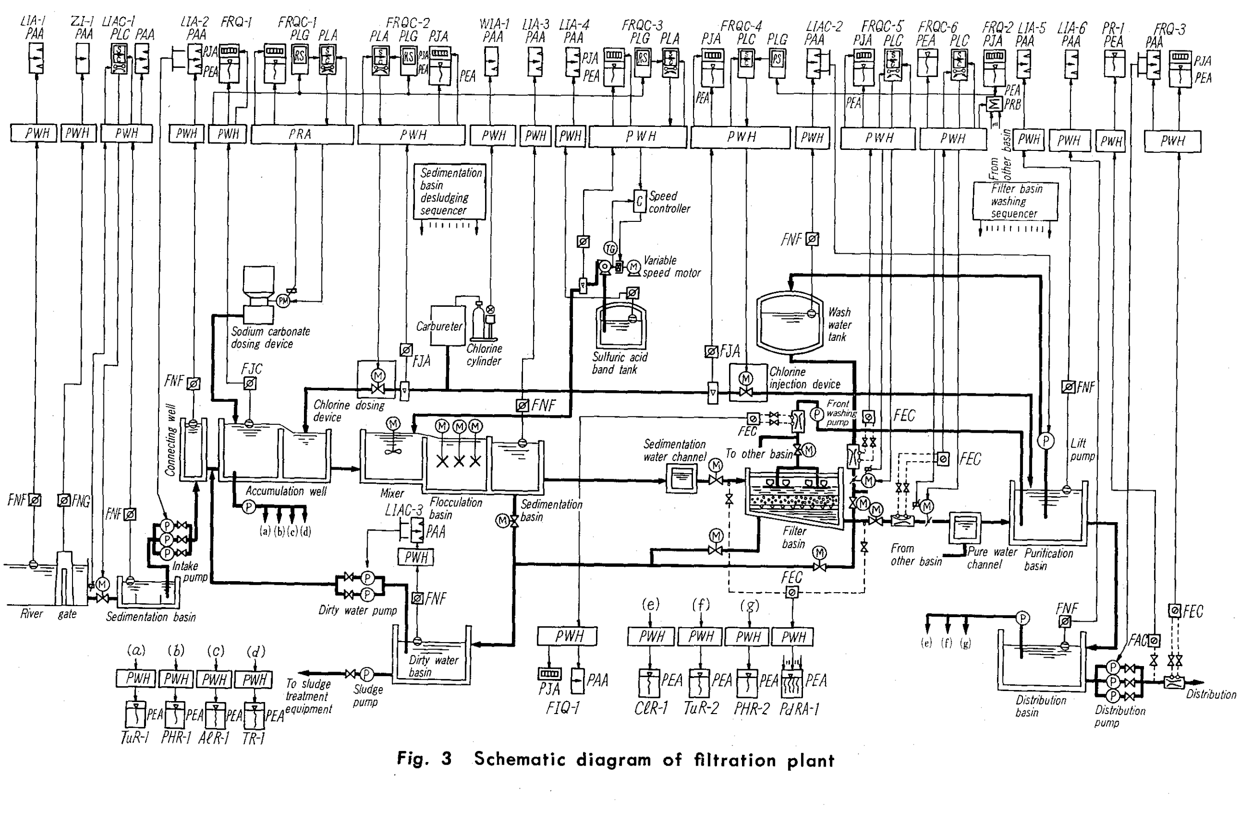


**Fig. 3 Schematic diagram of filtration plant**

*Table 1* **Items of measurement and control**

| Name of facility | Measured items | Controlled items |
|---|---|---|
| Accumulation well | Water level, raw water flow, conductivity, water temperature, pH, alkalinity, turbidity, etc., chlorine dosing amount, gate opening, caustic soda dosing amount, activated carbon dosing amount | Intake gate, intake pump, preliminary chlorine dosing, caustic soda dosing, activated carbon dosing |
| Sedimentation basin | Water level, sludge level, sulfuric acid band dosing amount, flocculation agent dosing amount, pH, turbidity, temperature, alkalinity, residual chlorine | Flush mixer, flocculator, sludge scraper, sludge remover, sulfuric acid band dosing, hydraulic pump, agent dosing |
| Filter basin | Filter resistance, filter flow, turbidity, filter basin flow level, wash water tank water level | Filter flow, front washing flow, back washing flow, washing sequence |
| Purification basin and pumping well | Water level, water temperature, chlorine dosing amount, caustic soda dosing amount, pH, ozone dosing amount | Lift pump, washing pump, transport pump, chlorine dosing, caustic soda dosind, ozone dosing |
| Distribution basin | Water level, flow, pressure, residual chlorine, pH, turbidity, conductivity, color | Flow, pressure, water level, distribusion valve opening, pump rotational speed and numbers |
| Drainage basin and desludging basin | Water level | Return water pump, sludge pump |
| Sludge concentration tank | Amount of sludge, level, concentration, etc. | |
| Sludge dehydration equipment | Dosing amounts, chemical storage tank level, cake weight | Conveyer, dehydrator sequence sulfuric acid dosing, sodium carbonate dosing |
| Power receiving and distribution equipment | Power, voltage, current, power factor, frequency, power consumption | |

mission (DC 4-20mA) and voltage reception (DC 1-5V). Sensor mechanisms such as semiconductor strain gauges which are completely electronic have appeared in place of the mechanical devices and the important controlled type instruments heve been standardized.

Fuji Electric has met these conditions with the IS series of instruments. *Fig. 3* is schematic diagram of an electronic instrumentation system and *Table 2* shows the measured and controlled items.

## 2. Intake Control

Water quantity control in the filtration plant is based on operating pure water treatment which can supply the water required in accordance with the supply area of the filtration plant.

When the intake water is led to the filtration plant by water conveyance channels, quantitative and qualitative control is the raw water source is necessary as well as intake quantitative control considering the time taken between the intake basin and the filtration plant. Therefore, telemetering equipment which can transmit data concerning water levels, amounts and quality to the filtration plant rapidly and accurately is used. The intake pumps and auxiliary devices are remote controlled by telecontrol equipment.

When the water is taken in directly from the river, the river water level is measured and the intake pumps and gates are controlled. The control is performed in association with the control of the amount of water distributed inside the plant but when there are several water sources of various types, it is necessry to investigate economy including water conveyance costs and have a control system which operates in coordinations with all of the facilities in addition to quantitative and qualitative water control.

## 3. Water Quality Instruments

Problems of decreases in the purification capacities of rivers, higher nutrient contents of lakes and ponds, the growth of plankton and orders have increased the importance of such items as turbidity, pH, alkalinity and residual chlorine and necessitate sampling of accumulated water, rapid shaking water, sedimentation water, water from filter, purification and distribution basins and water from pipe outlets. In this case, measurements are made by on-line automatic analysis and chemical dosing control is performed to obtain water of the specified quality.

Water quality investigation items include E. coli contents, ammoniacal nitrogen contents and contents of toxic substances. These are measured in the water quality laboratory.

Current water quality automatic analysis is aimed mainly at effective sedimentation processing of matarials causing turbidity and according to the results, optimum dosing control is performed.

These water quality instruments require on-line processing and shortening of time needed for water quality surveys performed by manual analysis improvements in the accuracy of analytical equipment, and systematization of water quality control including direct coupling between the central and water quality control rooms and demand terminals.

## 4. Chemical Dosing Instruments

1) Preliminary chlorine dosing

Preliminary chlorine dosing is intended to remove plankton, iron and manganese from the raw water. The effectiveness is confirmed by the amount of residual chlorine left in the filtered water several hours after dosing.

Since it is not good for large amounts of nitrogen compounds to be included in water supply or sewage works, chlorine is also dosed to decompose and remove nitogen compounds and only free, residual chlorine remains. This method is known as break point control and the chlorine dosing amounts are controlled to maintain standard values of free residual chlorine and the sedimentation channel outlets.

The chlorine is stored in liquid chlorine cylinders and after gasification in a compressor, it is mixed with pressurized water by an injecter and injected into the accumulation well. Monitoring and control in the chlorine equipment consists of dosing amount control, compressor control, dosing equipment abnormality monitoring, chlorine leak monitoring and sequence control of the chlorine neutralization equipment.

2) Dosing control of flocculating agents and flocculating aids

Flocculating agents and aids are used to flocculate and precipitate out turbidity in the raw water. Flocculating agents include PAC and sulfuric acid band and the aids include activated silicic acid and sodium arginate.

Flocculation and sedimentation are achieved by combining the turbidity causing particles with aluminum hydroxide by means of the flocculating agent to form minute particles of flock which precipitate.

The flocculation aids do not have independent flocculation action. They are used in conjunction with flocculating agents such as sulfuric acid band to heighten the flocculation effects.

Dosing control systems differ depending on whether the chemicals are liquids or powders and consist of the following:

(1) Regulating valve control by direct flow measurement

With this system the control range is wide and the characteristics are good because of the good rangeability and flow measuring accuracy of the regulating valve.

(2) Dosing pump stroke control

When there are small amount to be dosed, the stroke of the dosing machine is detected by electrical resistance changes, the flow is measured indirectly and the stroke is controlled. There are problems related to the limitation on the stroke regulation range and the accuracy and linearity of the stroke signal resistance and it is necessary to correct the output resistance value decided mechanically in the measuring equipment electrically.

(3) Dosing pump rotational speed control

In this system, the dosing amount is controlled by changing the rotational speed of the pump. The dosed amount is measured indirectly from the rotational speed with which it is proportional. The problems are limitations on the speed control range and linearity and these must be considered on the instrumentation side.

(4) Control of dosing pump rotational speed and stroke

In this system, methods (2) and (3) are combined and the dosed amount is expressed as follows:

$$q = \gamma \times S$$

where $q$: dosed amount
$\gamma$: rotational speed
$S$: stroke

This system features a wide dosing amount control range.

The flocculating effect by chemical dosing differs according to the raw water quality but correct pH regulation and aluminum sulphate dosing ratios are

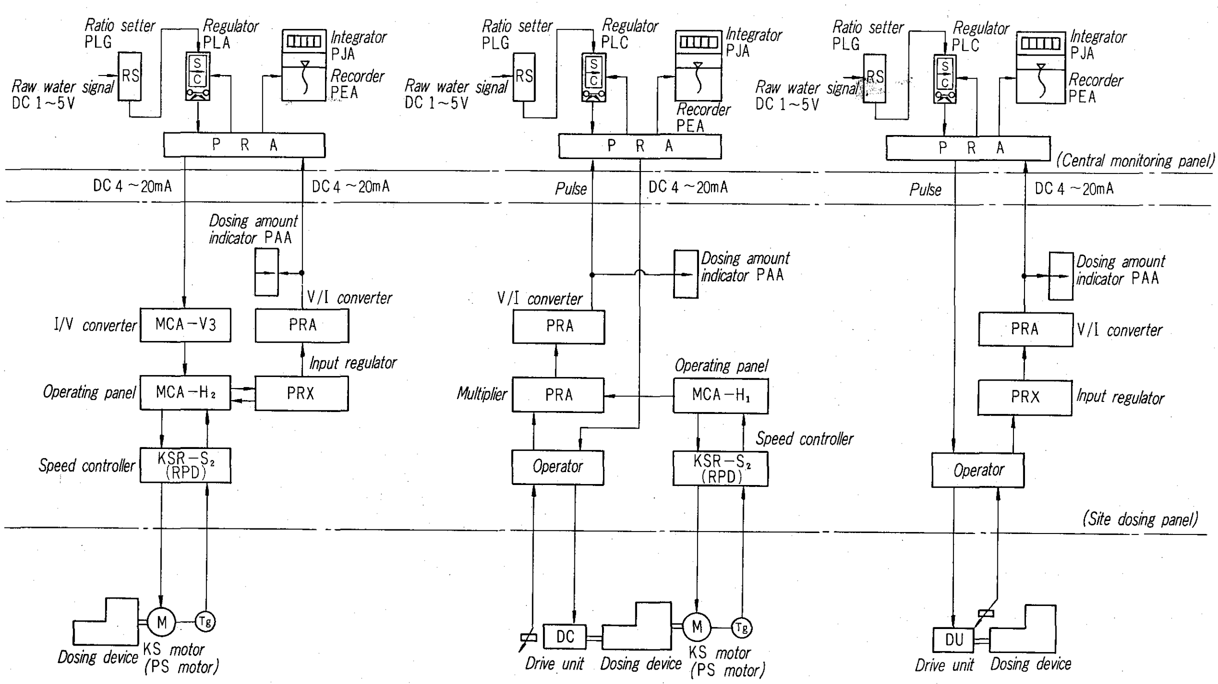


**Fig. 4 Schematic diagram of dosing equipment**

necessary to improve it.

The suitable aluminum sulphate dosing ratio is related to the raw water turbidity, pH, alkalinity, temperature, etc. but it is known to be roughly proportional to the turbidity exponential function and several equations have been reported.

The flocculation/sedimentation effect is monitored by the jar test in the water quality laboratory or the flock formation condition in the sedimentation basin are observed by ITV (industrial television) using an underwater camera.

The flocculation effect can also be checked by measuring the zeta potential of the turbidity particles and the correct aluminum sulphate dosing amount can be obtained.

*Fig. 4* is a schematic diagram of the dosing equipment.

3) Preliminary caustic soda dosing control

An alkaline agent is dosed to heighten the flocculation effect. Flocculation of the turbidity is affected stronger by pH than alkalinity. In colloids, there is a pH value at which optimum flocculation conditions arise and in the case of sticky aluminum hydroxide, this is know as the optimum pH and has been found from experience to be about 7. Flocculation by aluminum sulphate occurs in the pH 5-8 range and flock is formed at pH 6-7.

If the pH is regulated automatically, there will be no obstacles to flocculation/sedimentation even with changes in the raw water turbidity, the flocculation effect will be improved and the aluminum sulphate dosing ratio will be permitted for wide range.

Among the chemicals used, aluminum sulphate, PAC and chlorine are acidic and have an acidation effect on the water so that it is essential to dose an alkaline substance to counteract these chemicals.

Dosing control for alkaline agents can be performed by making the dosing amount proportional to the raw water flow in accordance with the sedimentation basin pH. The control system is the same as that used with the flocculation agent dosing.

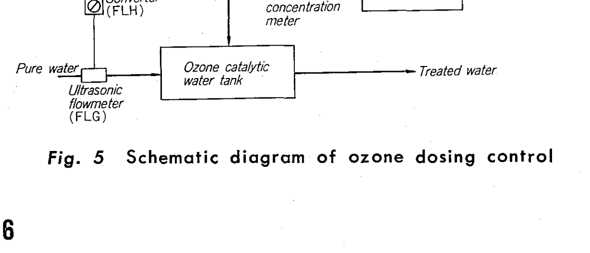


**Fig. 5** Schematic diagram of ozone dosing control

4) Post-chlorine dosing control

Post-chlorine dosing is important for sterilization of the final clean water. Depending on the water works law, chlorine dosing control is such that the free residual chlorine in the water in the supply channels is maintained above 0.1~0.2 ppm (combined residual chlorine at 0.4~1.5 ppm).

However, it is almost impossible in practice to regulate the residual chlorine values at the supply terminals. Therefore, at present, the predicted amount of chlorine consumed in the distribution pipes is added to the pure water basins.

The chlorine dosing control system is proportional dosing control in relation to the total filtered amount in accordance with the residual chlorine in the pure water basin.

5) Post-caustic soda dosing control

A rational method for dosing an alkaline agent so that both the pH of the flocculation sedimentation water and the final treated water are appropriate.

Generally, there are many cases when water with an alkalinity of less than 20 ppm has corrosive characteristics and water with too low a pH value is highly corrosive. However, in such cases, the corrosive characteristics can be kept down if the pH is regulated at approximately 8.0.

This post-caustic soda dosing is important in preventing corrosion of the transport and distribution pipes, etc. (countermeasure against rusty water).

The dosing control method is proportional control of the amount of caustic soda dosed to the total amount of filtered water depending on the pure water pH.

6) Ozone dosing control

Methods for removing odors include the dosing of powdered (granulated) activated carbon, dosing of chlorine dioxide and ozone treatment.

Of these, ozone treatment has several features including higher oxidation capacity than chlorine, no odor and a rapid viral disinfection action, and it is used widely. Ozone dosing is more effective if it is performed on the clean water rather than the raw water.

The ozone dosing ratio is shown by the following equation:

$$\text{Ozone dosing ratio (ppm)} = \frac{\text{(G) gas flow rate (cm}^3\text{/h)}}{\text{(L) water flow rate (m}^3\text{/h)}} \times \text{inlet ozonized gas concentration (g/m}^3\text{)}$$

*Fig. 5* shows the ozone dosing control system.

## 5. Sedimentation Basin Instrumentation

1) Sedimentation basin water level measurement

The sedimentation basin levels are originally designed to be constant but if a range and rate which do not adversely effect the sedimentation efficiency, this regulation capacity can be used for water dis-

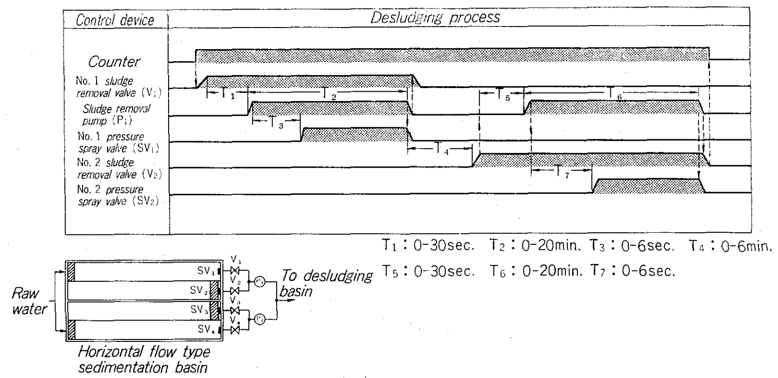


**Fig. 6** Draining operation process in sedimentation

tributed within the plant.

In this respect, monitoring of the sedimentation basin water level, monitoring of the sedimentation basin sludge level and sedimentation basin desludging control are also necessary.

2) Sludge scraper control

Correct desludging is required if the sedimentation basins are to operate effectively.

Control methods for the sludge scraper include scraper starting control in which the sedimentation basins sludge level is measured by a sludge level meter or ITV, or operation of the scraper at set intervals by means of a timer.

Since the amount of accumulated sludge depends on the amount of turbidity in the raw water inflow, another method to be considered is prediction of the amount of sludge accumulated in the sedimentation basins by the product of the amount of raw water inflow times the raw water turbidity and once this predicted amount is reached, the sludge scraper is operated.

Such sludge scraper operation is mainly by sequence control but remote manual operation from a central control room is required in addition to manual operation from site panels.

3) Sludge removal control

Sedimentation basin sludge removal control is necessary to promote flocculation and sedimentation and assure the correct amount of stored water in the sedimentation basins. This sludge removal control is mainly sequence control and is related to the operating frequency of the sedimentation basin sludge scraper.

During desludging, there are many cases when the desludging basin are used also for drainage of the filter basin wash water and it is necessary to investigate the one-time desludging capacity of the sedimentation basins, the washing water drainage capacity of the filter basins, etc. from the standpoint of the treatment facilities. In some cases, it is necessary to provide electrical interlock with the automatic operation circuits of other drainage facilities.

*Fig. 6* shows a time chart of the sedimentation basin sludge removal control sequence.

## 6. Filter Basin Instrumentation

1) Filter flow control

Filter flow control is by the following methods or combinations of them.

(1) Set speed filter flow control
(2) Dampened filter flow control
(3) Filter basin number control

Set speed filter flow control is performed by flowmeters (pressure difference signal generators with Venturi pipes), filter flow regulators and filter flow regulator valves provided for each filter basin. Corrections are made automatically for changes in the filter flow due to filter resistance and constant flow is obtained.

Damping filter flow control is in principle based on a reduction of the filter flow as the filter resistance increases without filter flow control. The following two methods exist for total filter flow control:

(i) Flow regulating valves are placed in each filter basin, the opening of all the regulating valves is regulated and the total filter flow is controlled in a standard basin. The features of this method are that regulating equipment is not needed in each basin and only one set of regulating equipment and a scanner are sufficient.

(ii) Total filter flow control is provided by use in conjunction with filter basin number control.

Filter basin number control is based on varying the number of filter basins in operation in keeping with set values for total filter flow. It can be combined with either set speed filter flow control or dampening filter flow control. Conditions for varying the number of basins are upper and lower limit points of a filter resistance meter or a filter flow regulating valve opening meter in the case of set speed filtering or upper and lower limit points of the filter flow or continuous filtering time in the case of dampening filter flow control.

Of these three filter flow control methods, it is possible to combine one set of slow start equipment and filter flow regulating meters in each filter basin in the set speed filter flow control to prevent excess filter flow at the start of filtering. However, such

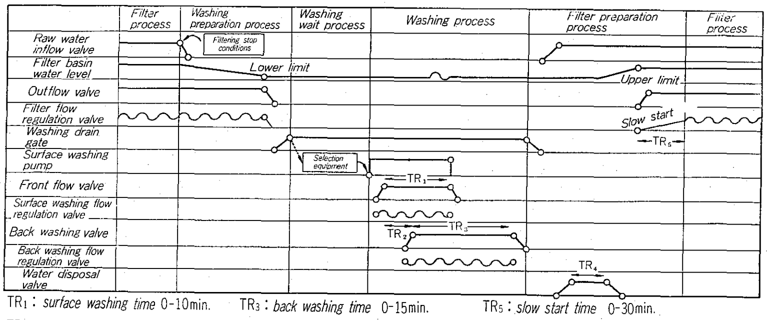


*Fig. 7* Washing control process of filter basin

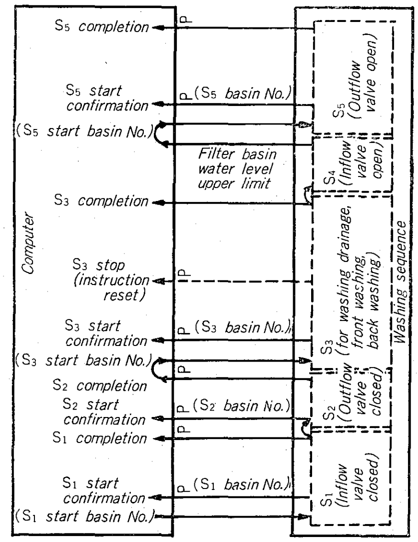


*Fig. 8* Schematic diagram of automatic filter washing

a measure is also required in the case of dampening filter flow control. In filter basin number control, the stopped basins undergo washing immediately and after washing is completed, they can be held in a stand-by condition.

2) Filter basin washing control

The filter basin washing operation is the most complex process in the filtration plant and the amount of work required sharply increases as the number of filter basins increases.

Automation of these operations is achieved by a systematic combination of process control and sequence control and it is a characteristic of filtration plant instrumentation.

The filtration operation consists of the following processes: filter preparation, washing stand-by, washing, filter preparation and filtering. *Fig. 7* shows a washing sequence time chart.

The filter stopping conditions are as follows:

(1) Reaching the upper limit of filter resistance
(2) Reaching the continuous filter time limit
(3) Reaching the lower limit of filter flow
(4) Reaching the upper limit of filter turbidity
(5) Manual washing request

The washing process is performed in order according to a group sequence for which a pin-board sequencer is used. Front washing and back washing flow controls are performed together in the washing process.

In large scale filtration plants where the number of filter basins exceeds 30 or 40, the time required for the washing preparation and filter preparation processes is longer than that of the washing process. When a filter basin has reached the filter stoppage conditions, it enters the filter preparation process and after this process is completed, it enters into the washing stand-by condition. *Fig. 8* shows a signal diagram for automatic washing operation using a computer.

In filtration plants with comparatively few filter basins, filtering is stopped immediately after the filter stoppage conditions are achieved which directly influences the total filter flow. Therefore, if the filter stoppage conditions are reached and another basin is being washed (in the washing preparation or filter preparation processes), filtering is continued and the next basin to be washed is selected after washing of the current basin is completed.

In this case, the various processes are washing waiting, selection of basin to be washed (including washing conditions check), washing preparation, washing and filter preparation.

The washing operations require manual operations from site panels as well as centralized remote automatic operation.

## 7. Water Transport and Distribution Control

Operation of the filtration plant is based on pure water demands and water transport and distribution control and internal clean water distribution control are performed.

Distribution regulation must maintain a constant minimum dynamic water pressure in the demand terminals without respect to the flow. The transport and distribution control methods are as follows:

1) Constant demand terminal pressure control

This method consists of the following two types:

In one type, the dynamic water pressure at the distribution network terminals is fed back to the flow control equipment of the transport pump by telemetering and the flow is controlled at a standard value of the dynamic water pressure. In the other method, the difference in the actual transport pressure with respect to the trasport amount and the standard distribution pressure from the channel resistance curve is detected and transport pump flow control is performed. First, the water transport amount $Q$ is detected, the standard value of the transport pressure is calculated from the relation in the following equation via the function generator and the transport pump flow is controlled according to the difference between this standard value and the actual transport pressure.

$$H_0 = KQ^{1.85} + H_b$$

where $H_0$: standard distribution pressure
$K$: resistance coefficient
$Q$: transport flow
$H_b$: demand terminal pressure

The transport pump speed control methods include the secondary resistance method, the M–G Scherbius method, the thyristor Scherbius method, the Kraemer method and the eddy current junction method. The method is selected on the basis of an overall investigation of the capacity, speed control range, equipment costs, operating efficiency, etc.

2) Constant discharge pressure control

This control keeps the transport discharge pressure constant against changes in demand. This is achieved by pump speed control and number control.

3) Distribution basin water level control

When clean water is pumped up into high pressure distribution basins and the water is distributed by the distribution basin head, the control method is to control the distribution water level by a program or at a constant value in keeping with the demand. Control objects are the filtration plant water transport pump and the distribution basin inflow valve.

### 8. Sludge Treatment Instrumentation

The sludge in the sedimentation basins in a filtration plant can cause disturbances in flocculator operation and also make it difficult to regulate water amounts according to sedimentation basin water levels.

Sedimentation sludge carry-over, filter basin clogging and anaerobic frementation of the sludge in the basin can also occur. *Fig. 9* shows a block diagram of the filtration plant drainage process.

Drainage treatment process instrumentation consists of the following:

(1) Acid treatment process (regulation of sulfuric acid dosing)
(2) Limestone dosing process (regulation of floating limestone)
(3) Dehydration process (regulation of sludge flow and dehydration equipment sequence control)

The purpose of acid dosing regulation is to keep the pH of the sludge at a constant value (2∼2.5) and increase the concentration and dehydration characteristics of the sludge. Therefore, the pH after proportional control is cascade controlled and proportional control of the sludge flow and amount of sulfuric acid is performed.

Regulation of the addition of slake limestone is controlled by proportional flow control of sludge and lime milk to achieve the desired goal.

Dehydration process control systems include filter equipment liquid surface control and mixture regulation tank liquid surface control when there are vacuum filter devices using various types of dehydration equipment, and dehydration equipment sequence control where pressurized filter equipment is used.

## III. MEASUREMENT AND CONTROL IN SEWAGE TREATMENT PLANTS

### 1. Instrumentation Concepts

Recently, there has been a tendency for the scale and range of sewage treatment facilities to expand. To raise the level of performance in such facilities, higher level operation control equipment is required and centralized control systems are being used. To advance the treatment facilities, it is necessary to strengthen maintenance control and in this case the role played by automatic control equipment is tending to increase. The sewage equipment has as its main goal stable operation because it is a public utility. The treatment equipment is to be based on a plant which will expand yearly in accordance with long-term planning.

The special characteristic of sewage treatment equipment must be a flexible, safe and rational measurement and control system.

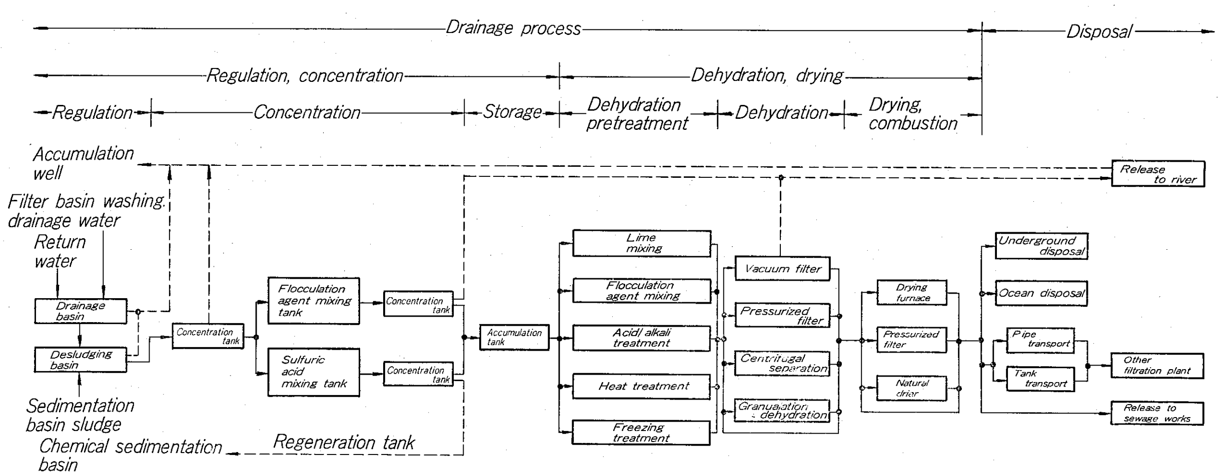


**Fig. 9 Block diagram of draining process**

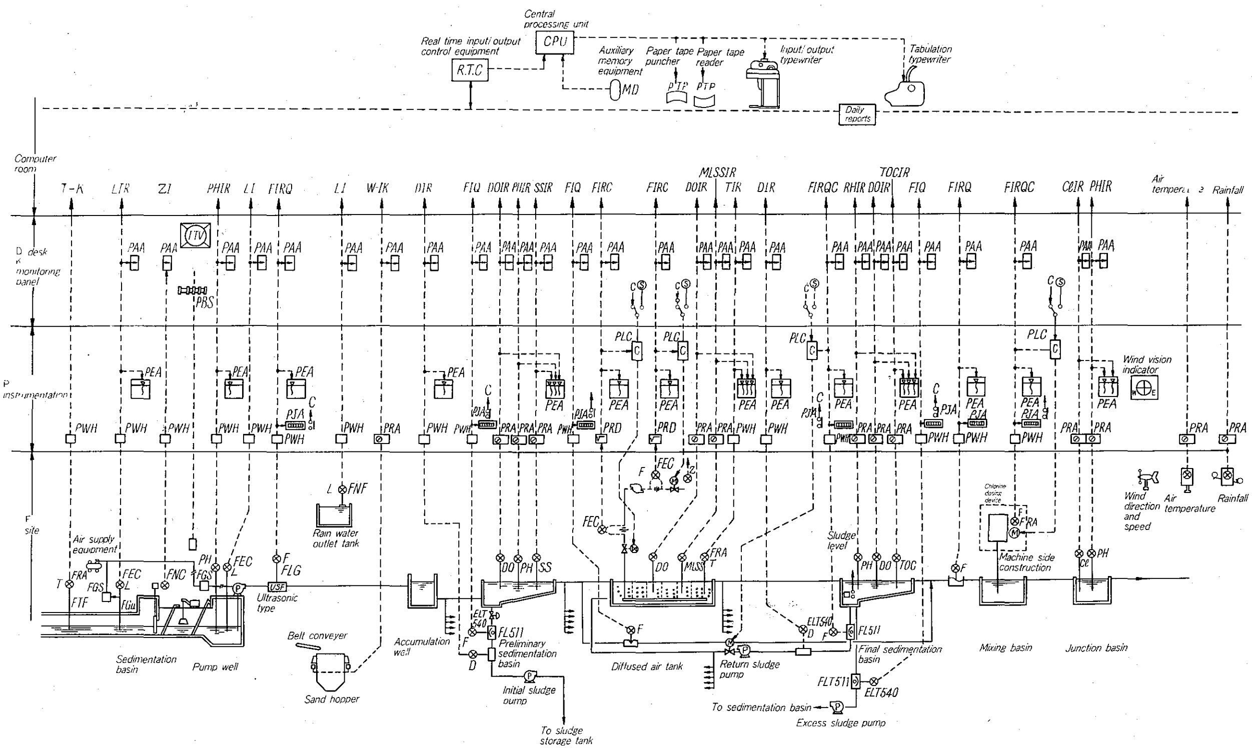


*Fig. 10* Flow sheet of sewage treatment plant

The sewage treatment process is generally the activated sludge method. There is also considerable research underway concerning tertiary treatment. *Fig. 10* shows the flow sheet of an activated sludge type sewage treatment process.

The activated sludge method utilizes physical phenomena and a biological reaction. The former is in the form of the sand basin where sand and coarse dirt are removed and the sedimentation basis where floating substances are precipitated out. The latter is in the form of the aeration tank where organic substances are flocculated, absorbed and oxidized. For measurement and control of these processes, it is necessary to provide good systematic combinations of sensors which make possible stable measurements of sewage and sludge, water quality meters for reliable measurement of water quality, control equipment which promotes the biological reaction, operation control systems for rational operation of the equipment, etc.

## 2. Measurement and Control

*Table 2* shows the measured and controlled items in sewage treatment plants. In sewage treatment plants, sewage treatment equipment and sludge treatment equipment are normally operated in separate buildings but the data from the sludge treatment equipment are controlled in the central control room of the sewage treatment equipment. The following are explanations of the main measured and controlled items.

1) Sewage influent measurement

The sewage influent part consists of an open channel and direct measurement is difficult because of major changes in the amounts of sewage inflow, coarse dirt, etc. Therefore, the influent is estimated by a hydraulic system using the water level gradient of the inflow channel. Air purge systems are often used for detecting of water level.

2) Pump well water level control

The amount of sewage influent to the treatment plant shows repeated wide-ranging load variations with respect to seasonal variations, climatic variations and time variations. Pump control is performed in order to absorb these variable loads, maintain the sand sedimentation efficiency of the sand basins and minimize the pump power consumption. For the pump well water level, the lift efficiency is increase by operating at as high a water level as possible. Therefore, the operating system is economical with operation at a high water level in the range in which the sand sedimentation efficiency is not lowered. *Fig. 11* shows an example of water level control in the pump well. Two different types of water level sensors are used and if an accident should occur in one, there is automatic switching to the back-up side to prevents faults in the system.

Rotational speed control is performed so that operation is between the H and L points of the pump well water level. When the H point is reached, the number of pumps operating is increased and when the L point is reached, the number is decreased. When two pumps for speed control, each with ½ the capacity of the constant speed pump are provided, control down to low flow rates is

**Table 2 Items of measurement and control**

| Name of facility | Measured items | Controlled items |
|---|---|---|
| Sedimentation basin | water level, gate opening, downflow, water level differences, water temperature, pH, BOD, SS, hopper weight | Inflow gate, dust remover, conveyer |
| Dirty and rainwater pumps | Pump well water level, lift amount | Number of pumps, speed valve opening |
| Preaeration tank | Air amount, return sludge amount | Amount of return sludge, ventilation |
| Initial sedimentation basin | Sedimentation sludge removal amount, sedimentation release amount, sludge mass water level, sludge concentration | Sludge removal pump |
| Aeration tank | Inflow downflow amount, return sludge amount, ventilation, DO, sludge concentration | Blower, amount of return sludge, number of blowers, intake |
| Final sedimentation basin | Amount of excess sludge, sludge concentration, processing water level, water level, pH, DO, SS, BOD, TOC | Return sludge pump |
| Sterilization equipment | Chlorine dosing amount $Cl_2$ | Chlorine dosing |
| Release port | Water level, release amount, pH, DO, SS, BOD, temperature | |
| Sludge concentration tank | Amount of sludge, level, concentration, etc. | |
| Sludge digestion tank | Temperature, level, amount of gas generated, amount of digested sludge, separated liquid gas, pressure level, etc. | Digestion tank temperature |
| Sludge dehydration tank | Dosing amount, storage tank level, cake weight, etc. | Conveyer, dehydrater, dosing |
| Sludge burning tank | Temperature, amount of air, furnace pressure, amount of heavy oil, $SO_2$, pH, amount of ash, etc. | Combustion control, furnace pressure control, pH control |
| Power receiving and distribution equipment | Power, voltage, current, power factor, frequency, power consumption, transformer, temperature, etc. | |

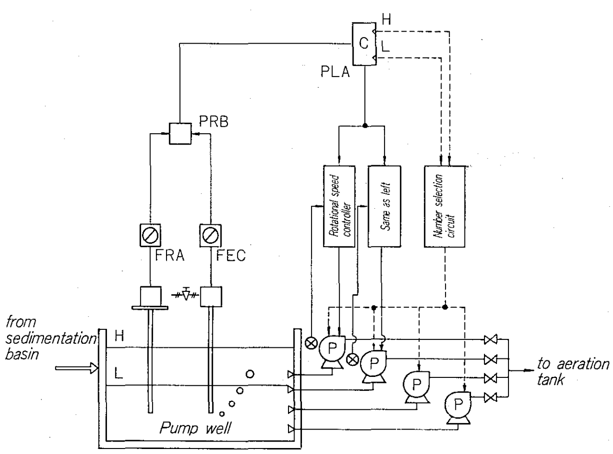


*Fig. 11* **Flow sheet of pump well**

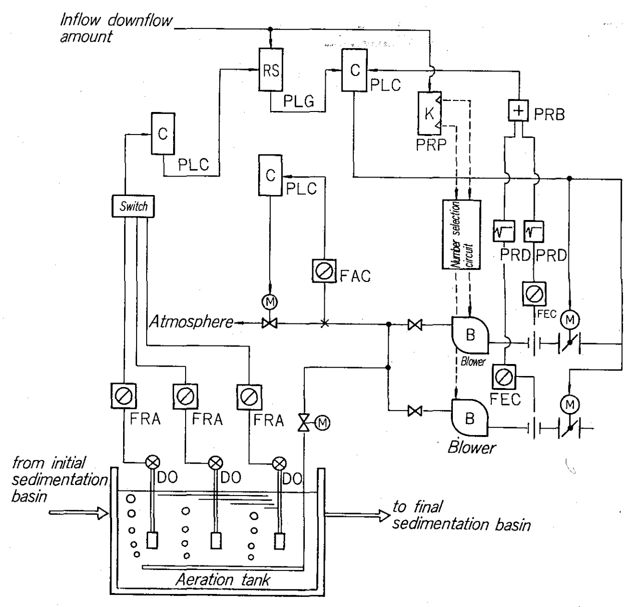


*Fig. 12* **Flow sheet of diffused air flow**

possible when changing over the numbers of pumps. With this type of control, the water level changes are fewer and the control range is wider than with the conventional operating number and discharge valve control and the power consumption due to discharge valve pressure loss is also less. There is also no complex flow regulating operations by the pump discharge valve.

3) Aeration basin air flow control

In BOD removal by the activated sludge method, the removal rate varies according to the sewage influent, diffused air flow to the aeration basin and the amount of return sludge. The diffused air control system shown in *Fig. 12* keeps the DO value at the aeration basin outlet constantly over 1 ppm out of consideration of the ratio control in proportion to the amount of sewage influent and dead time control by the sampling regulator. The DO value inside the aeration basin changes in accordance with physical conditions such as the arrangement of the sewage inlets and outlets, the basin shape, and the form and location of the aeration equipment. Therefore, it is recommended that the DO meter probe equipment be such that several can be attached to the aeration basin and the installation position can be easily changed.

The power consumed by the blower and waste water pump accounts for a major portion of that consumed in the sewage treatment plant and control of these devices is essential for efficient operation of the plant. There are case of diffused air control by discharge valves but the power consumption is large when compared with blower suction valve control and rotational speed control and is also not desirable from the standpoint of the blower surging range. In this case, ventilation control is by regulation of the blower suction side valve and the blower discharge pressure is controlled by the air discharge valve for surging prevention control. The number of blowers operating is changed in accordance with changes in the sewage inflow.

4) Return sludge cantrol

The mixing liquid MLSS in the aeration basin should be maintained at a height in a range so that the supernatant water can be separated well and overflow in the final sedimentation basin. However, when it is too high, the dissolved oxygen in the basin becomes insufficient, it is easy for the sludge to become excessive and the sedimentation efficiency in the final sedimentation basin will fall. In the standard activated sludge method, experience has shown that a concentration range of 1,500~2,000 ppm is suitable. Return sludge control is performed to control the MLSS in the aeration tank. The return sludge control shown in *Fig. 13* regulates the amount of return sludge in respect to the amount of sewage influent and the return sludge rates are changed by the MLSS regulator in the aeration tank. According to conventional experience, the return sludge rate has been 25% but there are cases when this value is based on the assumption that the sewage influent concentration and return sludge concentrations are constant and if the return sludge rate is changed by MLSS control regulator, compensated control with respect to these changes becomes possible.

5) Chlorine dosing control

Chlorine is dosed into the treated sewage in the chlorine sterilization basin and it is discharged into the river. The chlorine dosing control shown in *Fig. 14* is proportional control in which the chlorine is dosed in proportion to the sewage influent rate and the proportional set value is automatically regulated by a correction signal from the residual chlorine meter. Release of the treated sewage in the activated sludge method is performed at a chlorine dosing rate of 2~8 ppm and a residual chlorine value of 1~4 ppm. Chlorine dosing is controlled so that there are less than 3,000 E.coli/cc.

6) Sludge treatment instrumentation

*Figs. 15* and *16* show examples of sludge treatment instrumentation. Processes include concentration and digestion, chemical dosing and dehydration and combustion.

In such sludge treatment processes, it is necessary to use special sensors concerning sludge accumulation, corrosion due to $SO_2$ in generated gas, corrosion due to chemicals, high temperature gas and ash. Required controls include control of the temperature in the tank to aid the active behavior of the anaerobic microorganisms in the digestion tank, chemical dosing control for good separation of the cakes in the dehydrator, combustion control and pH control to remove the $SO_2$ components in the chimney gas.

## IV. CONTROL SYSTEMS

### 1. System Design

The increased scale, complexity and range of water works facilities have brought about qualitative increases in monitoring and control items. For the efficient operation of such complex facilities, the design of a man/machine communication system between the monitoring, control system and the oper-

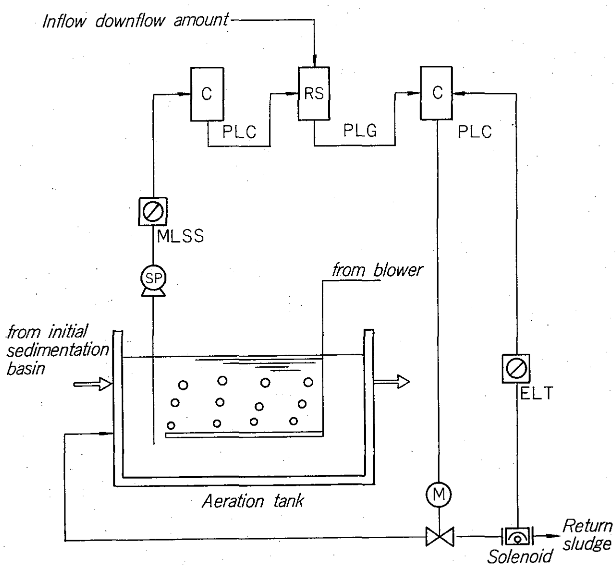


**Fig. 13 Flow sheet of return sludge**

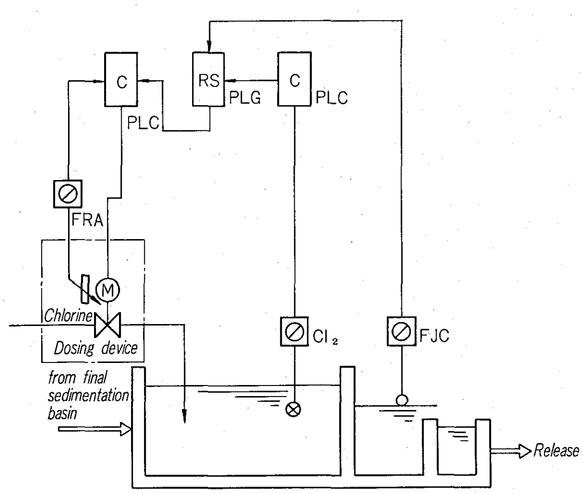


**Fig. 14 Flow sheet of chlorine gas injection control**

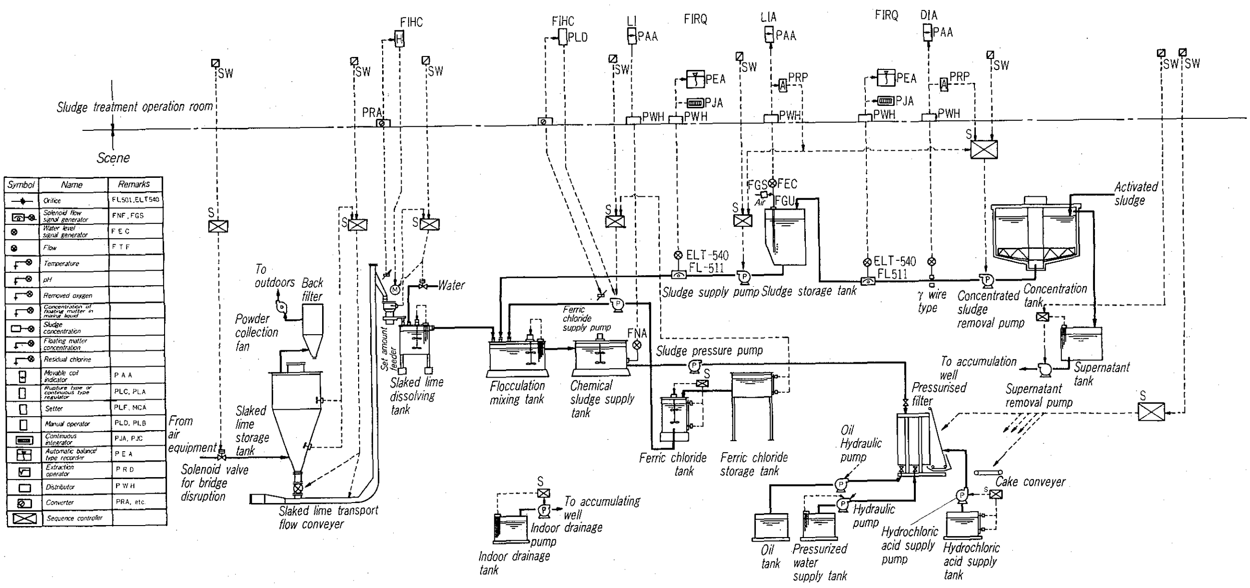


***Fig.* 15 Flow sheet of sludge treatment**

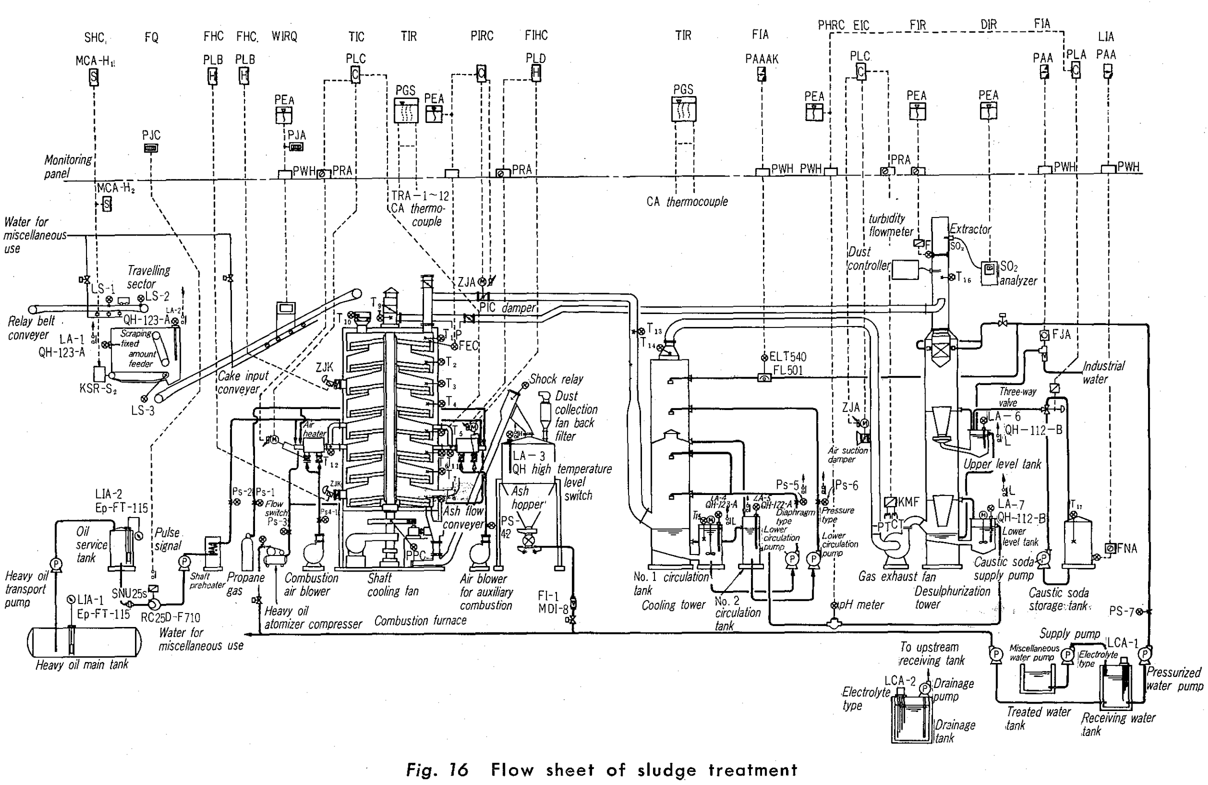


***Fig.* 16 Flow sheet of sludge treatment**

ator is extremely important.

In particular, when designing the system, it is important to include human engineering studies and provide high reliability and a comfortable environment so that the operator can work easily and safely.

## 2. Monitoring and Control Devices

The monitoring and control systems for water works facilities must include hierarchy system components since the facilities cover a wide range, must have unmanned, small scale terminal facilities whenever possible and must have centralized monitoring and control systems for large scale facilities.

The recent trends in monitoring and control systems are as follows:

(1) Use of telemeter/telecontrol systems
(2) Graphic monitoring panels and high density instrumentation
(3) Use of data loggers
(4) Use of CRT displays, slide displays and ITV

(industrial television)

(5) Use of audio equipment, internal broadcasting equipment and telephone equipment

(6) Use of high level monitoring and control equipment with the introduction of electronic computers.

It is now possible to perform highly efficient operation control by means of providing complex facility data in patterns, colors and sounds which are easily for humans to understand visually and audibly.

### 3. Control Systems by means of Analog Instrumentation

1) Monitoring

The monitoring panels bring together the power reception of the performance units of the facilities, power system, intake system, clean water treatment system, water transport and dosing systems, etc. Graphic monitoring panels with easy to control analog instruments, condition indicators, accident indicator lamps, etc. are often used.

The graphic monitoring panels are often of the mosaic type because of the ease of making changes and design considerations. The monitoring instruments are centered around a series of indicators for which correspondence with the facilities understood directly. The recorders are selective recorders by means of trend recorders which stop at the minimum required limits and comparative recorders.

The signal receivers in the monitoring panels are of the single connector distribution system using the distributor method for the instruments which is ideal for high density instrumentation and the standing type receivers which have a short depth.

2) Control

The control desks form a series corresponding with the monitoring panels and the electricity and instruments form a single unit. The operating system is a double operating system intended to prevent operating error and minimize the operating surface in cases where the control objects are telecontrol equipment and important facilities. In addition, single operation systems are used generally with operating switches with a 1:1 relation with the devices.

### 4. Control Systems using Computers

With larger water works, the use of high level centralized control systems employing computers has become common. The computer systems include the SCC and DDC. The man/machine interface equipment includes operator consoles, CRT display equipment and typewriters.

When computers are used, it is possible to provide high speed response, obtain good operating characteristics and monitoring efficiency and design a highly reliable man/machine system by combining various types of high level, high reliability devices.

## V. CONCLUSION

This article has described recent trends in instrumentation and control for water supply and sewage treatment works and has given actual examples of control systems. Many automatic control and operational control systems have been tried for the rapidly expanding water treatment processes and a large amount of technology has been accumulated on the basis of operating results.

This should serve as an approach to the contact between digital and analog control, man and machine and technology and economy which tended to be overlooked in the past. The authors are performing further research and development on this theme.

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