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COMPUTER-SIMULATION TECHNOLOGY IN WATER AND SEWAGE WORKS

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I. FOREWORD

Computer simulation of systems using numerical models are used civil engineering design, water and sewage works facilities design, and total management system design and application, studies on improvement of the control systems, training, etc. and their effect is increasing. Today, it has become indispensable in the design and operation of water and sewage works systems.

This report outlines the applications, usage objectives and application method of simulation and introduces examples of application to water and sewage works and environmental pollution diffusion analysis.

II. APPLICATIONS OF SIMULATION

Computer simulation is used in system planning and design for pre-evaluation and to study control method improvements. It is also used as a tool (CAD: Computer Aided Design) to assist in design, but generalized applications are omitted here.

In system operation, maintenance, and management, computer simulation is used as a tool for setting the operating point and selecting the control settings while operating part of the software incorporated in the control system online or with operator intervention offline. It is also frequently used as a model for operation, maintenance, and management personnel education and training.

The main applications of the Fuji Electric simulation models associated with water and sewage works are shown in *Table 1* and *Table 2*.

III. APPLICATION OF SIMULATION

Regarding the application of simulation, the objective is analyzed and a precision numerical model matched to the purpose is built. The points which should be given special attention at this time are:

(1) Clarification of the purpose of the simulation
(2) Acquisition of the objective composition and structural parameters
(3) Selection of the numerical model and analysis method matched to the purpose
(4) Correspondence confirmation of the simulated result and the actual data of the phenomena.

The procedure when a numerical model is built and process characteristics analysis and control analysis based on the objective process and its actual data is shown in *Fig. 1*.

To perform simulation, the objective process must be

Fig. 1 Simulation application procedure

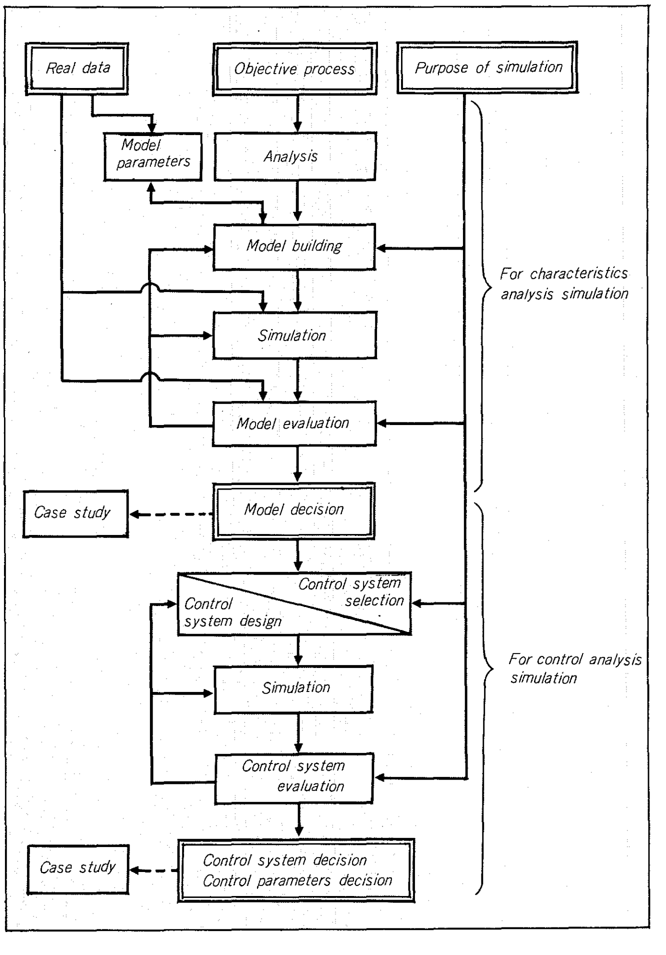


Table 1 Sewage works simulation record

No.	Objective facility, process	Name	At planning and design		At operation, maintenance, and management		
			Social Environmental Safety Maintenance-ability	Labor saving CAD	Greater effectiveness Resources conservation Energy saving Productivity	Reliability Stability Operability Control-ability	Education Training
1	Sewage works, civil engineering facilities	Sewage flow forecasting	○			○	
		Rainwater flow forecasting.	○			○	
		Storm overflow forecasting				○	
		Trunk reserve regulation control			○	○	
		Regulation reservor optimum operation use			○	○	
		Plant operation analysis			○	○	○
2	Pumping station	Pump fuzzy control			○	○	○
		Flow forecasting and control	○		○	○	
		Pump variable speed power consumption simulation			○	○	○
		Pump facility cost comparison			○	○	○
		Flow gate control			○	○	
		Pump control method study			○	○	
		Water hammer analysis	○			○	
3	Sewage treatment, blower station	Secondary treatment static characteristics analysis			○	○	
		Secondary treatment dynamic characteristics analysis			○	○	
		Secondary treatment control analysis			○	○	
		Simulation for water quality control (online semi-static)			○	○	
		Pure oxygen method simulation			○	○	
		Respiration speed control			○	○	
		Blower power calculation for various airation control methods			○	○	
		Peak cut and units control of return pump			○	○	
		Sludge storage tank capacity design	○		○	○	
		Rainstorm load forecasting and control	○			○	
		General purpose control method analysis		○			
4	Sludge treatment	Sludge thirmal conditioning process analysis			○	○	
		Sludge digestion process analysis			○	○	
		Sludge digester control model			○	○	
		Sludge multi-stage incinerator analysis	○		○	○	
		Sludge multi-stage incinerator various control analysis		○	○	○	
5	Outlet, river harbor	Open channel flow velocity distribution analysis	○			○	
		Open channel abnormal flow analysis	○			○	
		Flushing water river pollution analysis	○			○	
		Flushing water harbor pollution analysis	○			○	
6	Power supply calculation	Short-circuit calculation	○			○	
		Power source load capacity calculation			○	○	
		Peak cut analysis			○	○	

Table 2 Waterworks simulation record

No.	Objective facility and process	Name	At planning and design		At operation, maintenance, and management		
			Social Environmental Safety Maintenance-ability	Labor saving CAD	Greater effectiveness Recources conservation Energy saving Productivity	Reliability Stability Operability Control-ability	Education Training
1	Dam, river, headrace	Small hydroelectric generator		o	o		
		River flow forecasting			o	o	
		Water use simulation			o	o	
		Dam flow, storage amount forecasting	o			o	
		Dam, gate control simulation	o			o	
		Open channel dynamic characteristics simulation	o			o	o
2	Water-intake, flow distribution	Water source operation management simulation			o	o	
		Water quantity, quality dynamic calculation	o			o	
		Water quantity, quality static calculation	o			o	
		Optimum water amount distribution simulation			o	o	
		Intermediate-term demand forecasting	o			o	
		Long-term demand forecasting	o				
		Water hammer analysis	o			o	o
3	Clear water works operation	Works operation simulation			o	o	o
		Optimum dosing control simulation			o	o	
		Pump optimum efficiency calculation			o	o	
		General purpose control method analysis		o			
4	Distributing reservoir, piping network operation	Pump power-saving control simulation			o	o	
		Short-term demand forecasting			o	o	
		Optimum water level operation control			o	o	
		Leakage survey calculation			o	o	
		Pipe network calculation			o	o	
		Optimum pipe network calculation			o	o	
		Optimum monitoring post decision calculation			o	o	
		Optimum distributing block calculation			o	o	
		Optimum block water supply simulation			o	o	
		Distributing pressure control system			o	o	

represented by a physical model or statistical model. A physical model is an arithmetic expression based on known rules or certain assumptions. A statistical model is a model with which the unique expression of relation is found from the measured data by statistical techniques. Its simulation can be static or dynamic. Dynamic simulation is simulation which analysis the normal state, and is performed by solving an expression in which the time terms in the numerical model are replaced by zero. On the other hand, dynamic simulation is simulation which analyzes the transient states of the objective process.

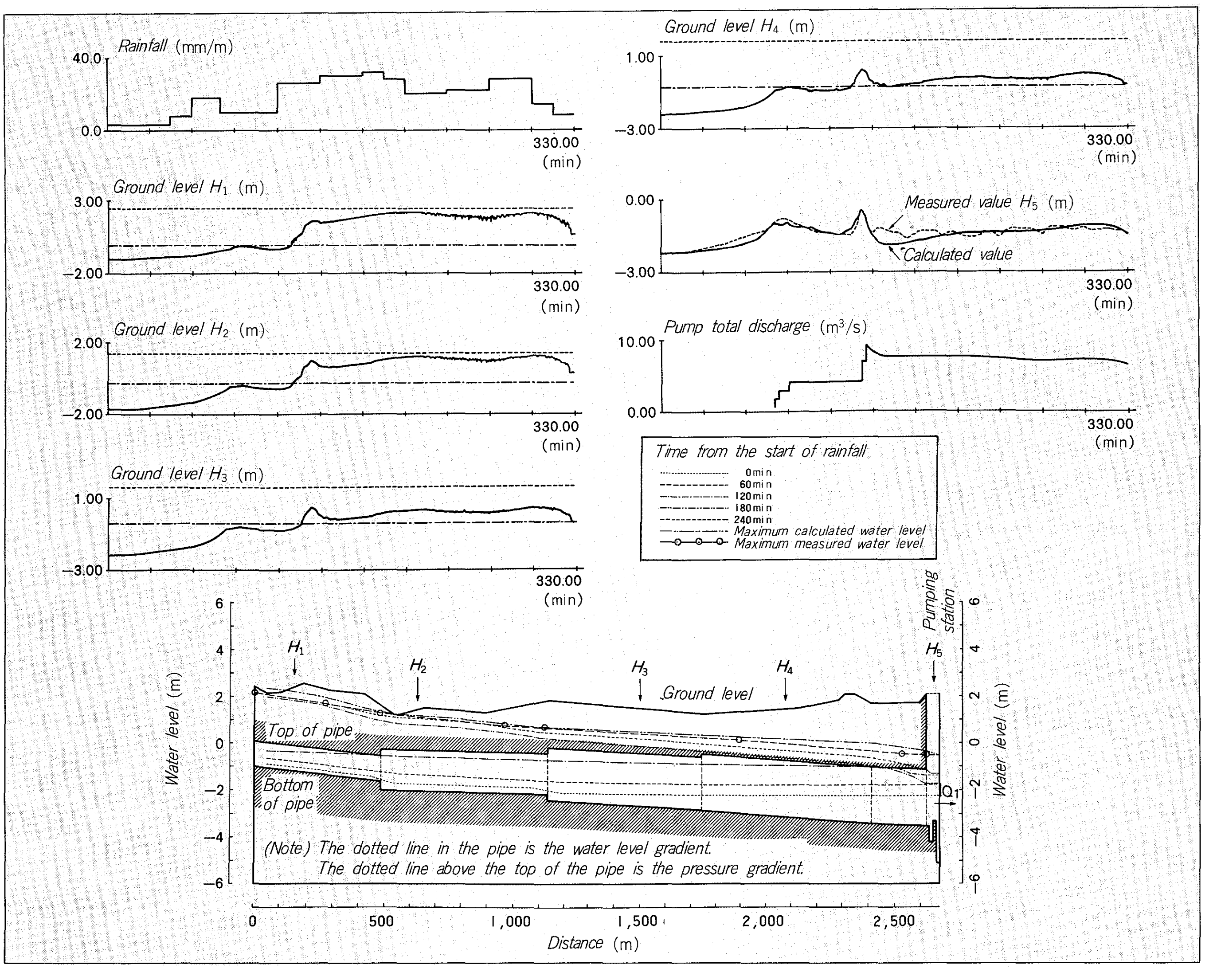
To perform analysis to introduce the action of the objective process to positive operation by some method, a control system model must be added to the numerical model of the process and simulation must be performed simultaneously.

IV. APPLICATION TO SEWAGE WORKS

4.1 Runoff of rainwater Simulation

Besides being a mojor cause of outside disturbance to the processing system, the runoff of rainwater is a water quality pollution problem and is the cause of flooding in

Fig. 2 Time change of water level distribution of sewage pipe by rainfall



drainage zones. Therefore, programs which simulate the rainwater runoff phenomena and pollution load runoff phenomena (BOD, COD, SS) have been packaged. These programs also permit analysis of the flooding phenomena and initial pollution runoff phenomena (first flush phenomena) in drainage zones. Validity verification is performed by means of the actual data and is used in sewage pipe and retardation basin design, rainwater pump and relay pumping station capacity selection, and control system design. *Fig. 2* is an application example which reproduces the water level rise and inundation generation in pipe when it is raining by simulation. (The time is the rainfall continuation time.)

4.2 Treatment plant operation simulation

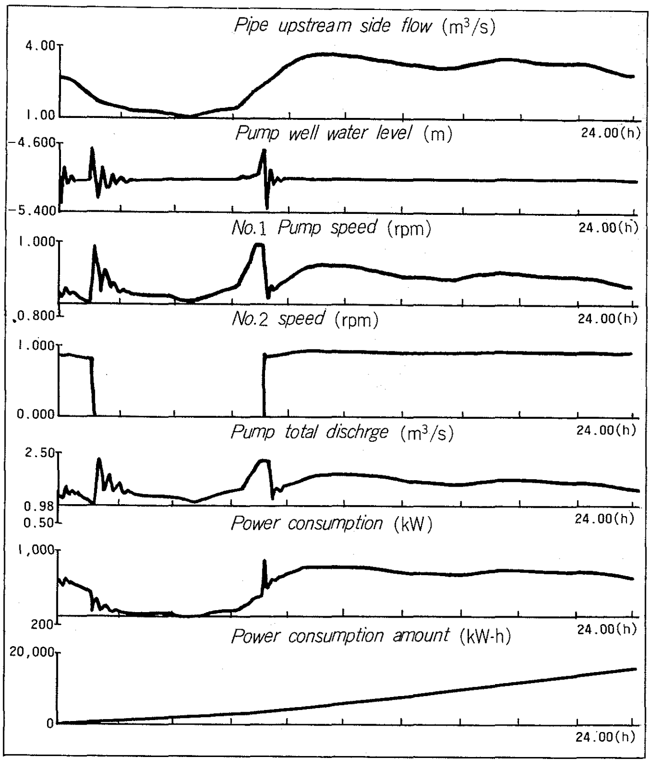
This simulation permits analysis of the flow of sewage inside and outside the treatment plant, including the control system, and is effective in grasping the sewage flow condition, control system design and evaluation, running cost calculation, pump accident pre-evaluation, etc.

In *Fig. 3*, control simulation of two sewage pumps was performed and the pump operating conditions and the power consumption at that time were forecasted. Running cost reduction effect and control system evaluation is possible with these results. Moreover, they can also be applied to analysis of inundation and the air hammer phenomena when pump trouble occurs and to analysis of treatment plant and relay pumping station cooperative control.

4.3 Activated sludge simulation

The activated sludge treatment method is widely used in sanitary sewage treatment and is the most effective biological treatment method. Two package programs, static and dynamic, are available for simulation of this treatment process and it is used in comparison studies of various control methods (DO control, MLSS control, total sludge quantity control, etc.) and their evaluation. Simulation also confirms the good correlation with field tests, and is effective in water quality management and water quality control. Moreover, a system which performs simulation by using actual data directly with an online

Fig. 3 Sewage pump control simulation example



computer and performs water quality management has been developed and is actually operating.

4.4 Blower control simulation

The power consumption of the aeration blower of the aeration tank accounts for about 40% of the total cost of a treatment plant and an economical facilities plan and control system are also desirable from the standpoint of energy saving. This simulation can compare the total costs, including the running cost and initial facilities investment according to the scale of the treatment plant, and decide the most economical blower type, number and flow control system. *Fig. 4* is part of an application example in which the necessary cost by blower facility contents and control system was calculated by simulation with a 20,000m^3/d scale treatment plant as the objective.

4.5 Vertical type multi-stage incinerator sludge incineration simulation

Today, about 10% of the activated sludge is incinerated. However, the demand for reduction in the amount and stabilization of sludge, this proportion is expected to increase. However, incineration requires a large amount of auxiliary fuel and energy-saving type contorl technology is desired. The purpose of this simulation is analysis of the sludge incineration process (drying, incineration, cooling) and the design and evaluation of its contorl system. Therefore, the sludge incineration conditions in a vertical multi-stage incinerator can be reproduced by computer, the sludge incineration characteristics grasped, and the control system for stable combustion and energy saving can be studied and its validity verified. This model can also be used in the study of the cooling control system in self-combustion of the sludge with polymer.

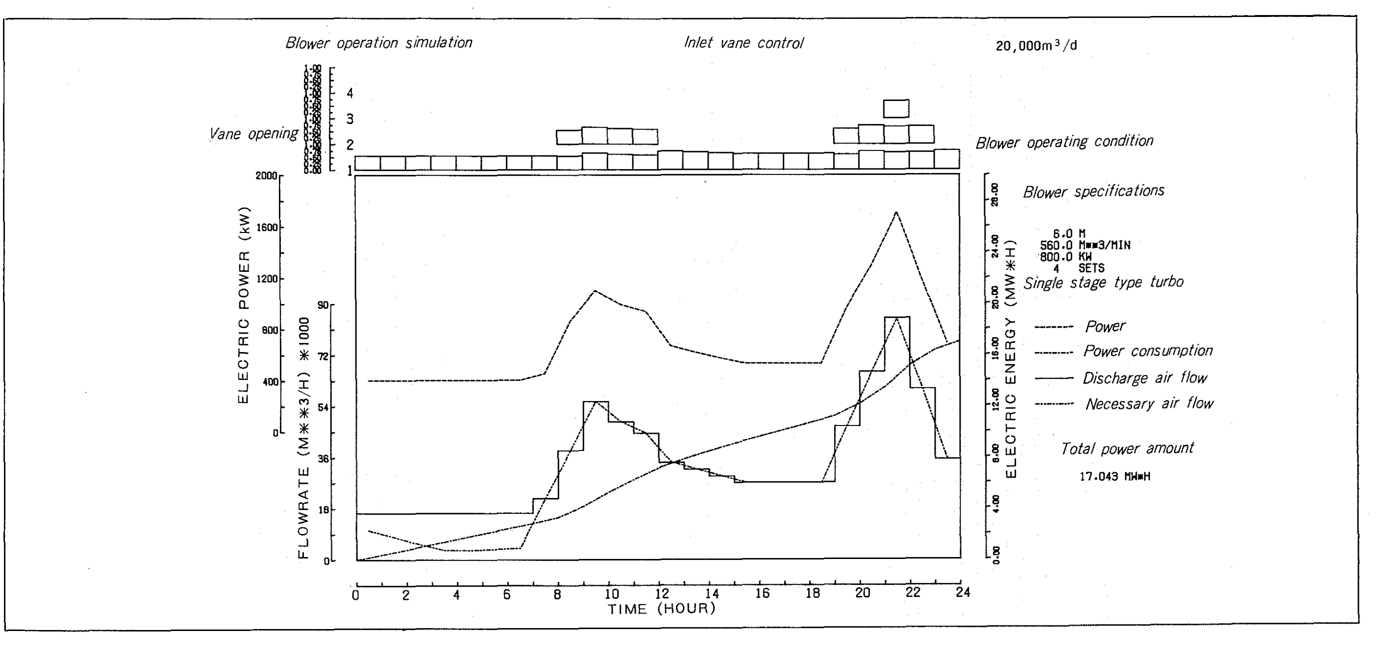
V. APPLICATION TO WATERWORKS

5.1 Water hammer simulation

The pressure change caused by stopping of the pumps and opening and closing of valves in water conveyance and distribution pipes is called water hammer. Many simulations can be performed by using the simulation program "FUJI-HYTRAN", which analyzes the transient phenomena at valve control, etc., besides this water hammer phenomena.

The analysis technique is numerical calculation of the expression of continuation of the one dimensional flow in

Fig. 4 Simulation example of blower by inlet vane control



the pipe and the operation equation by a characteristic curve method.

Fig. 5 is an example of water hammer simulation when an intake water pump is stopped by an accident.

5.2 Pump power comparison simulation

When planning a pump facility, the initial facility cost, power cost, maintenance cost, etc. differ with the number of units installed, control system, etc., and from their total cost, the pumping station must also be the most optimum facility. Therefore, a simulation program for calculation and comparison of the amount of power used by various pump facilities is provided.

Fig. 6 is an exmaple of the results of comparison of the daily power consumption of a daily maximum 60,000m^3 distributing pumping station (190kW x 6 units).

5.3 Demand forecasting simulation

There are various demand forecasting methods. An example of forecasting of the hourly distributed amount for the next 24 hours by the following method is shown in *Fig. 7*.

First, the daily distributing amount for the next day is forecast. The forecasting factors are the actual distributed amount of the last three days and the forecast maximum temperature for the current day and the linear forecasting expression for fair weather. The coefficients are appropriately selected by using a Carlman filter. This daily distributed amount forecast value is multiplied by the time coefficient of the pattern corresponding to the weather, day of week, season, etc. and is made the hourly distributed amount at each time tomorrow.

5.4 Distributing reservoir operation simulation

The distributing amount from the distributing reservoir changes considerable during one day. On the other hand, it is demanded that the water conveyance amount to the distributing reservoir be as constant as possible. Therefore, operation is performed for the purpose of smoothing the flow in amount or minimizing the number of adjustments based on the restriction that the distributing reservoir water level be maintained within upper and lower limits.

When the flow in amount is controlled by number of feed pumps, there is also an operating method which minimizes the amount of power used by the pumps.

Fig. 8 shows an example of the operating method

Fig. 6 Changes in power used

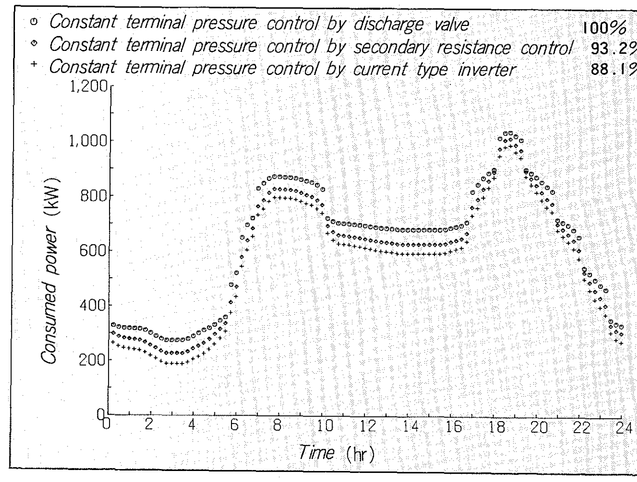


Fig. 5 Transient response at pump power supply tripping

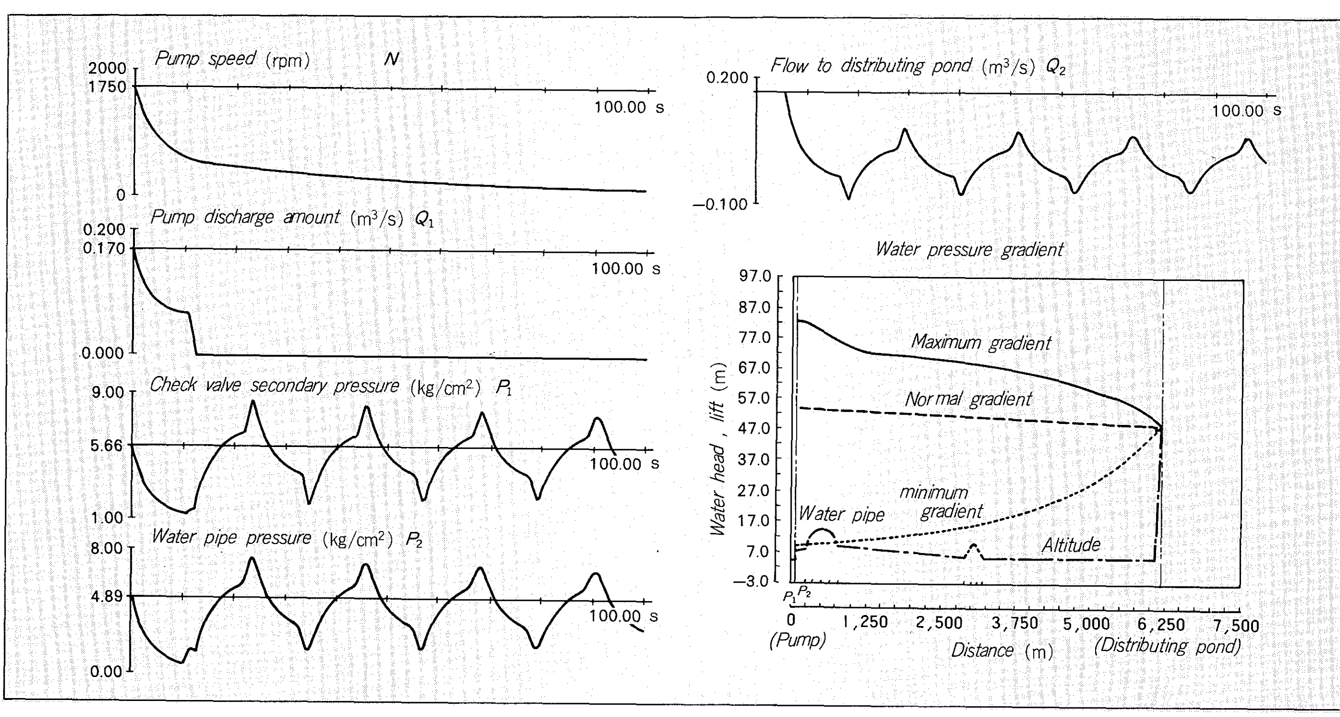


Fig. 7 Distributing amount forecasting

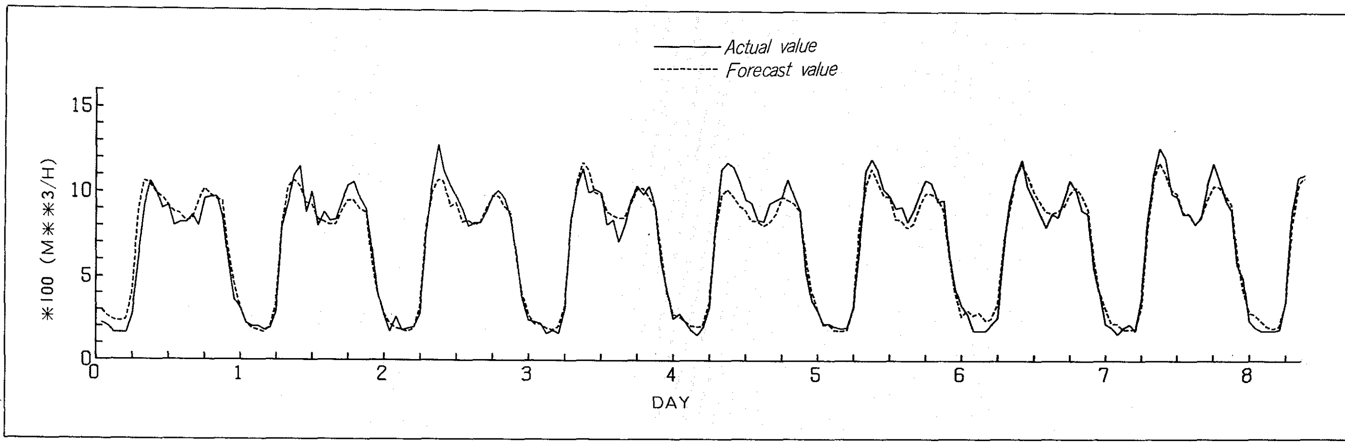
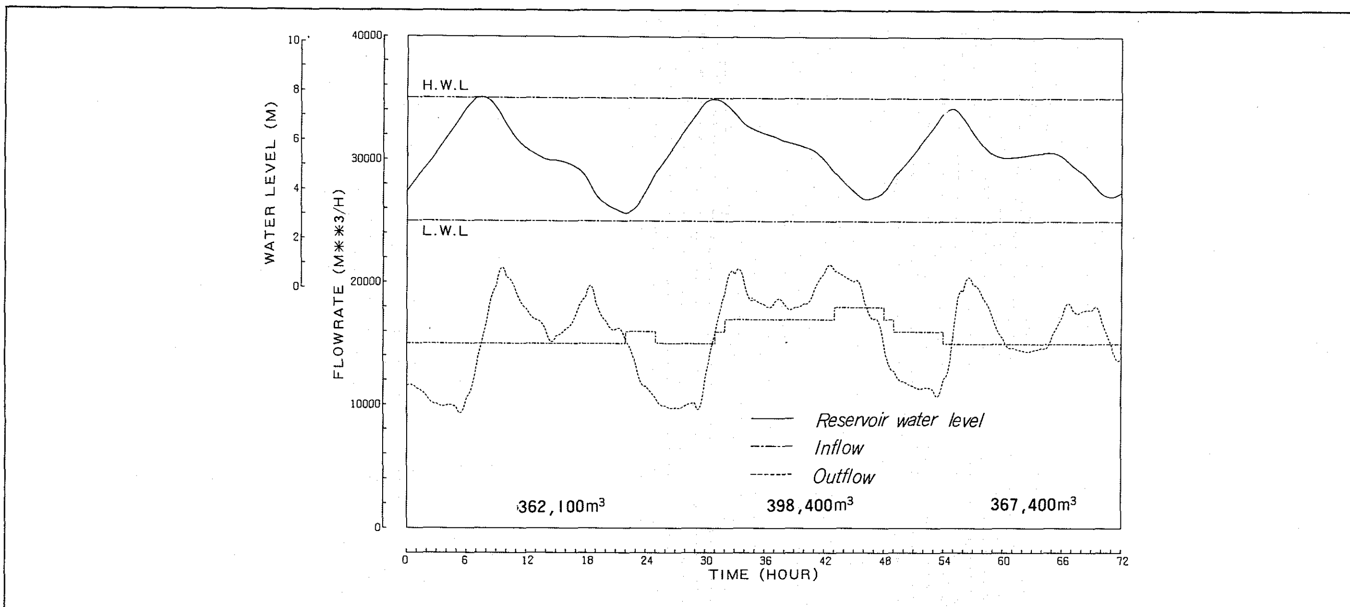


Fig. 8 Distributing reservoir operation simulation



which minimizes the number adjustments solved by the DP method.

5.5 Distributing control simulation

An example of distributing the water from three distributing reservoirs by natural flow and contorlling the pressure by pressure reducing valves at eight points and a pressure pump at one point is described below.

The pressure of the distributing pipe network should be as low as possible within the allowable range to prevent leakage and for safety. Thereupon, the method which solves the operating amount which minimizes the amount of leakage by the LP method with the pressure pump pressure and pressure reducing valve pressure reduction as the operating amounts is used. The restriction conditions are the lower limit of the pressure and the upper and lower limits of the changing amount at the node.

Fig. 9 shows the pressure distribution by the pipe network calculation obtained as a result. The lower limit of the pressure shall be 1.5kg/cm^2.

VI. ENVIRONMENTAL POLLUTION DIFFUSION ANALYSIS

Today, the numerical forecasting and reproduction of the environmental pollution diffusion of water systems by simulation is the most widely performed. This is mainly the result of the accumulation of abundant data by experiments and actual measurement and improvement of computer and simulation technology.

Three examples at Fuji Electric are given below.

6.1 Example of analysis of diffusion of pollution in rivers

A pollution diffusion analysis example is shown in *Fig. 10*. The part of the figure where the contour lines are dense indicates the polluted water outlet with jet flow simulated. The cleaning action of the river itself is ignored and cleaning by the ocean flowing the downstream part is considered. Moreover, the flow velocity data is the result

Fig. 9 Distributing pipe network pressure distribution

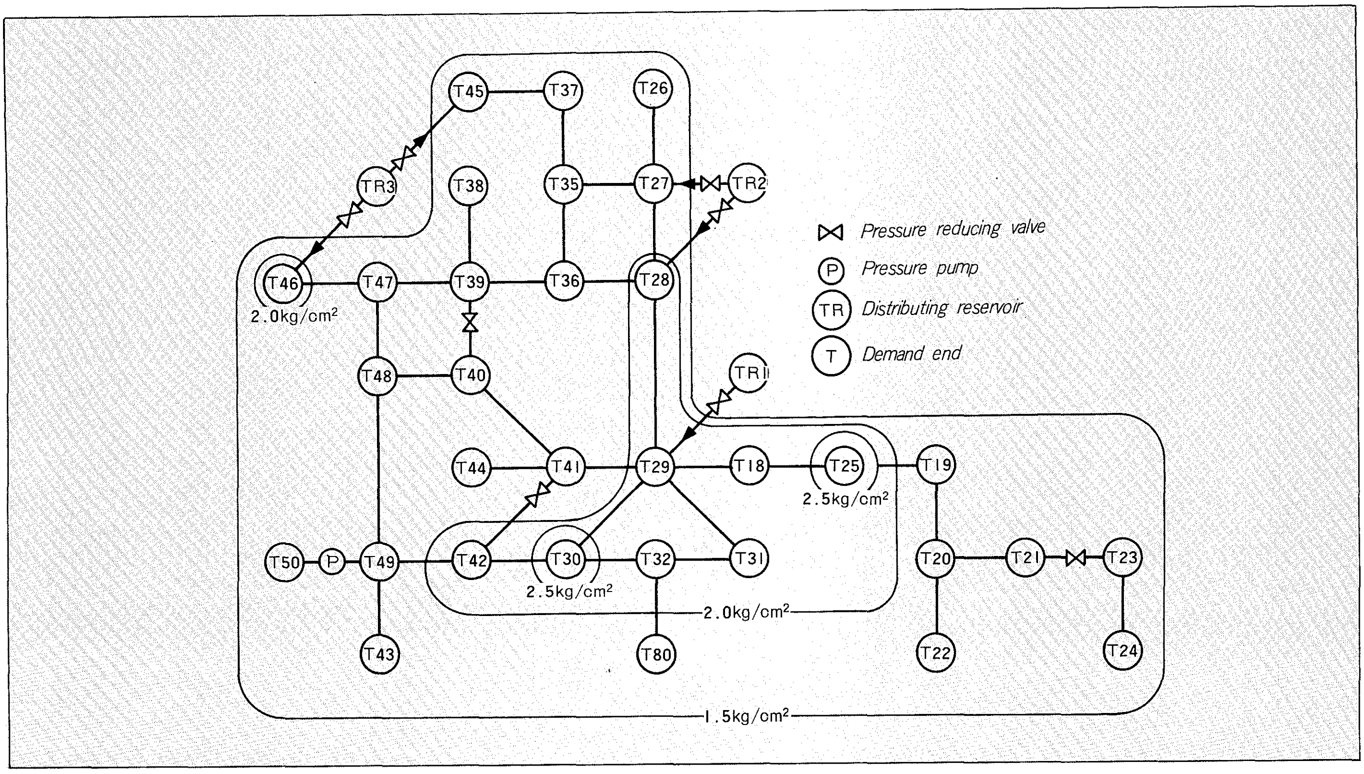
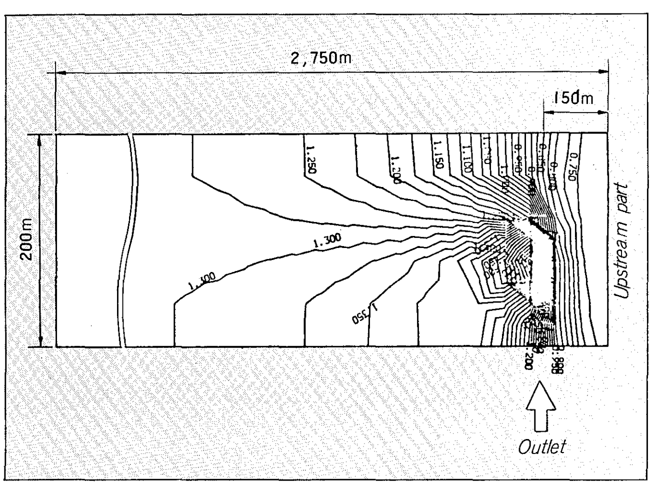


Fig. 10 Example of analysis of pollution diffusion in a river (BOD distribution)



of precalculated shallow water wave analysis.

6.2 Example of analysis of pollution diffusion in a bay

An example of flow diffusion analysis of COD (chemical oxygen demand) in a bay is described. In addition to the flow diffusion of the flow in load from rivers, the internal production of organic matter by photosynthesis and the biological process called decomposition are considered. The same Fuji development program as that of the previous example was used in bay flow analysis.

6.3 Example of analysis of warm waste water diffusion at a canal

Diffusion analysis of the warm waste water in a canal adjacent to a thermal power plant was performed. Originally, the purpose was forecasting of the temperature rise of the circulated water. The fluid field was suitable assumed and the heat dissipation from the surface fo the canal at which is dependent on the water temperature was considered.

VII. CONCLUSION

In the above, we have described new simulation techniques for water and sewage works.

In the water works it is selfevident that, with the increase of water demand and the rising shortage in water sources, the water distribution adjustment to dislodge or eliminate water leakage or shortage will become more and more vital in future for the maintenance and control of water supply.

On the other hand, in the sewage works facilities are being more complex due to the increase basin wide sewage works and city processing amount, the social demand for better water quality, centralization of sludge processing, etc. From such a background, system simulation to pursue energy saving, resources conversation, control and operation stability, etc. has come to be indispensable in facilities and management system design.