# Totally Integrated Water Control Technology for the Waterworks

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## 1. Introduction

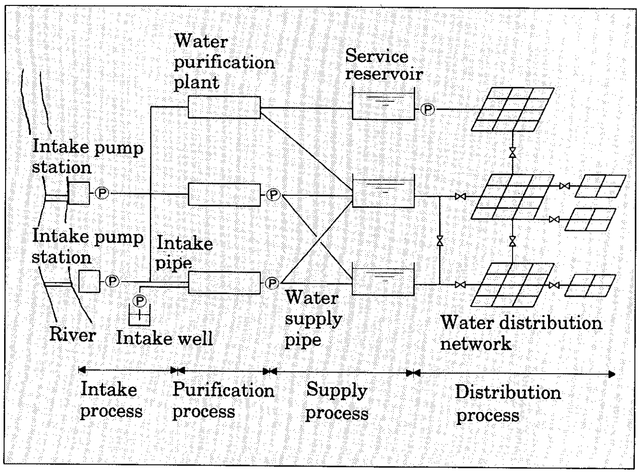
The dearth of water caused in the summer of 1994 by record temperatures, the least rainfall the Japanese have ever experienced, and Great Hanshin-Awaji Earthquake in January 1995 has reminded us of the value and importance of the water supply systems. In Japan, the saturation level of the water supply system reached 95.3% at the end of 1993, indicating that almost all Japanese people now use tap water.

Since the water supply systems are so widely spread, civilians and industries alike are negatively affected, once the water supply is interrupted or reduced due to a lack of water or an earthquake.

Although it is important to secure appropriate water resources for meeting the demands of water from the viewpoint of a "highly stable water supply," it is also necessary to establish certain measures for efficient and economical utilization of limited water resources in areas where the water demand is exceptionally high.

This paper summarizes the totally integrated water control technology developed by Fuji Electric as one of the measures for realizing efficient and economical use of limited water resources.

Fig.1 Outline of the waterworks




## 2. Objective of Integrated Water Control

Figure 1 shows the outline of the waterworks. In general, a system that includes a part or the entire raw water control, water supply control and water distribution control is called an integrated water control system. Though integrated water control includes raw water control in water purification plants, relatively simple water level control and flow rate control occupy most of the functions of the integrated water control system. This paper describes the control technology that covers these three major areas.

The purpose of raw water control, inclusive of reservoir control, is to effectively use and apportion raw water. In water supply control, flow rate control is conducted on the planned route and quantity of water supply from the water purification plants to water distribution bases such as the service reservoir and booster station. The distribution control regulates water distribution from the water distribution bases to the taps of the customers.

### 2.1 Objective of water supply control

The specific objective and expected effects of water supply control, including raw water control, follow. Hereinafter, raw water control will be included under water supply control.

(1) Economical charge distribution of water quantity in the waterworks

Operation costs are lowered by efficiently and economically distributing charges of water quantity over several water intake sources, purification plants and water supply facilities.

(2) Stabilization of quantity and quality of water treated in the water purification plants

Peak cut is facilitated in the water purification plants by leveling the quantity of the water supply. In addition, the quality of the purified water is stabilized by leveling the purification quantity of raw water.

(3) Efficient pump operation

Instrument malfunction is reduced by lowering the frequency of starts and stops of the water supply pumps. This is achieved by a minimum of changes in the number of pumps to be operated. By effectively operating the pumps at night, the cost of electric power is reduced.

(4) Automatic operation of the facilities

By automating the operations of the facilities, collective centralized control of the facilities scattered over the area is facilitated, and automatic start and stop of the pumps as well as automatic flow rate setting in the control valves are realized. Also, the number of man hours for operation control is reduced.

(5) Response to anomalies

Quick planning of integrated water control and response are facilitated against various anomalies such as interruption of the facility functions or limited water intake caused by accidents or natural disasters.

### 2.2 Objective of water distribution control

The specific objective and expected effects of water distribution control are as follows:

(1) Prevention of water leakage

The quantity of water leakage depends upon water pressure. Since water pressure is high at night when demands for water decrease, the quantity of leakage increases. High water pressure may cause a break in the distributor pipes. Therefore, the quantity of water leakage and the frequencies of accidents are reduced by appropriately controlling water pressure.

(2) Countermeasures against water shortages

The quantity of water consumption may be divided into that affected and not affected by water pressure. Water pressure dependent water consumption is suppressed by lowering the water pressure. By lowering the water distribution pressure over the entire service area, water consumption is suppressed and the disadvantages of a reduced water supply is evenly distributed to the customers. When time-limited water supply is unavoidable, the present centralized control facilitates can operate the valves for stop and restart of the water supply.

(3) Direct water supply

Up to now, water has been supplied to three or more story houses and buildings through water tanks. However, a direct water supply system has been promoted for up to five story houses and buildings due to hygienic considerations and better service for the residents. To realize the direct water supply, it is necessary to more meticulously control the water pressure through the maintenance of water supply pipes, provision of booster pumps, etc.

(4) Supply of safe and potable water

A supply of "safe and potable water" can be attained by injecting chlorine at the purification plants or distribution bases so that the necessary but minimum residual chlorine concentration can be maintained at the taps.

## 3. Integrated Water Control Technology

The element technologies necessary for water supply and distribution control will be explained below. Figure 2 shows an outline of water supply control, and Figure 3 shows an example of a water distribution pressure control system.

Fig.2 Outline of the water supply control

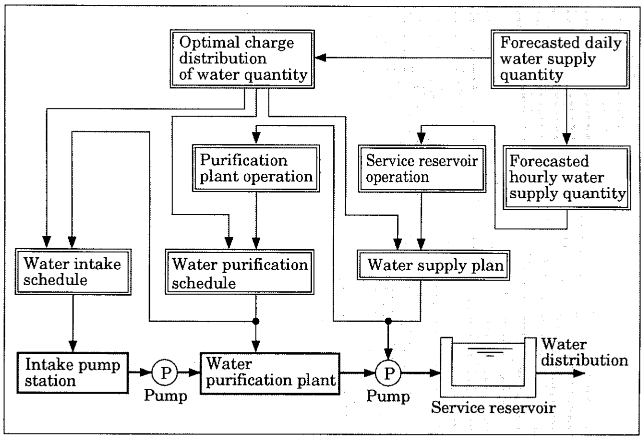
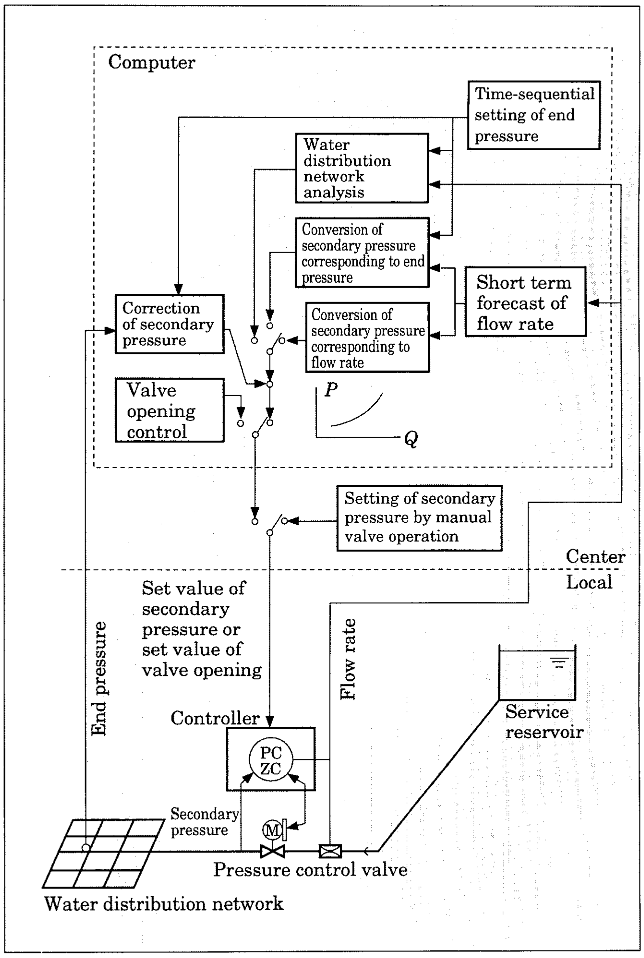



Fig.3 Example of the water distribution pressure control system




### 3.1 Water supply control technology

(1) Forecast of water consumption

Forecast of water consumption is the foundation of water supply control technology. Water consumption quantity per day is forecasted for each water supply area, and charge distributions of water quantity to the water purification plants and water intake stations all over the city are determined based on this forecasted water consumption quantity. Furthermore, the forecasted water consumption quantity per day is utilized in forecasting water consumption quantity per hour, and water supply plans for the service reservoirs are set for each hour.

(2) Optimal distribution of water quantity

Once the forecasted water consumption for each water supply area is determined, it is then necessary to determine the routes and water quantities for intake, purification and supply at each purification plant and intake station most economically. The water quantity distribution plan is determined by minimizing the operation costs of the waterworks with the water intake, purification and supply capabilities of each facility as the limiting factors. During a water shortage, water quantity distribution can be determined so that the total upper water supply limit is minimized.

(3) Scheduling of water supply flow rate

If the time variation of the water supply's flow rate from the service reservoir is forecasted, a water supply schedule can be determined. This schedule levels the water supply flow rates to the service reservoirs and minimizes the frequency with which the number of operating water supply pumps must be changed. Two methods – a method that optimizes the water supply flow rate for each service reservoir and a method that optimizes the water supply flow rate in a water supply system including several service reservoirs – are used in conjunction. When water is received through the water supply pumps, it is controlled by the number (combination) of operating water supply pumps. When water is received through the inflow valves, it is controlled by the flow rate (stepwise or continuous).

(4) Simulation for operation support

Water supply operation is planned, and its results are simulated under various estimated normal and abnormal conditions.

(a) On-line simulation

In an on-line simulation, water level variations are calculated for each service reservoir from on-line data (present water level, planned water supply quantity, forecasted water consumption quantity) at the time of simulation. The planned water supply quantity is also simulated for setting changes.

(b) Simulation of operation plan

Under flexible conditions, an operation plan can be simulated to reorganize the water supply networks and facilities during abnormal conditions or to optimally adjust the water supply plan.

### 3.2 Water distribution control technology

(1) Pipe network calculation

Pipe network calculation, which calculates distributions of pressure and flow rate in a pipe network based on the various pipe network parameters (connections of the pipes, distribution of water consumption, etc.), is the most fundamental method of analysis for water distribution control.

(2) Selection of pressure monitoring spots

A pipe net work is divided into a number of blocks, with one or more pressure monitoring spots set in each block.

In setting a number of pressure monitoring spots, a block is further divided into sectors by cluster analysis, which focuses on the similarity of pressure variations. The pressure monitoring spots are set in the sectors which are the most and the least influential to pipe network pressure so that the pressure monitoring spots may be distributed most effectively.

(3) Water distribution pressure control

In water distribution pressure control, the pressure in each block is controlled by a pressure control valve. All the control logic is loaded onto digital controllers installed on each local site. The reference values of the water pressure are determined by a central computer or by an operator. These values are then transmitted to the controllers located in each local site.

(4) Simulation of pressure control

Simulation of pressure control is a simulation for obtaining the operation data of the pressure control valves and slice valves. This simulation is conducted to adjust the water distribution quantity at a fair and proper value under normal and abnormal conditions. Water distribution quantity, secondary pressure, end pressure and opening of the valves are all given equal weight.

(5) Simulation of pipe network applications

A simulation of pipe network applications is conducted for economical application of the pipe network which accompanies a change of boundaries between water distribution blocks mainly during anomalous conditions.

(6) Calculation of pressure control effect

The effect of a reduced water supply is calculated by controlling the water distribution pressure.

(7) Analysis of residual chlorine in the pipe network

Distributions of residual chlorine in the service reservoirs and at the pipe ends are estimated by calculating the consumption of residual chlorine in the pipe network.

## 4. Design Process for Integrated Water Control

### 4.1 Design process for water supply control

Figure 4 shows the steps in constructing a system for water supply control.

### 4.2 Design process for water distribution control

Figure 5 shows the steps in constructing a system for water distribution control.

Fig.4 Design process for the water supply control system

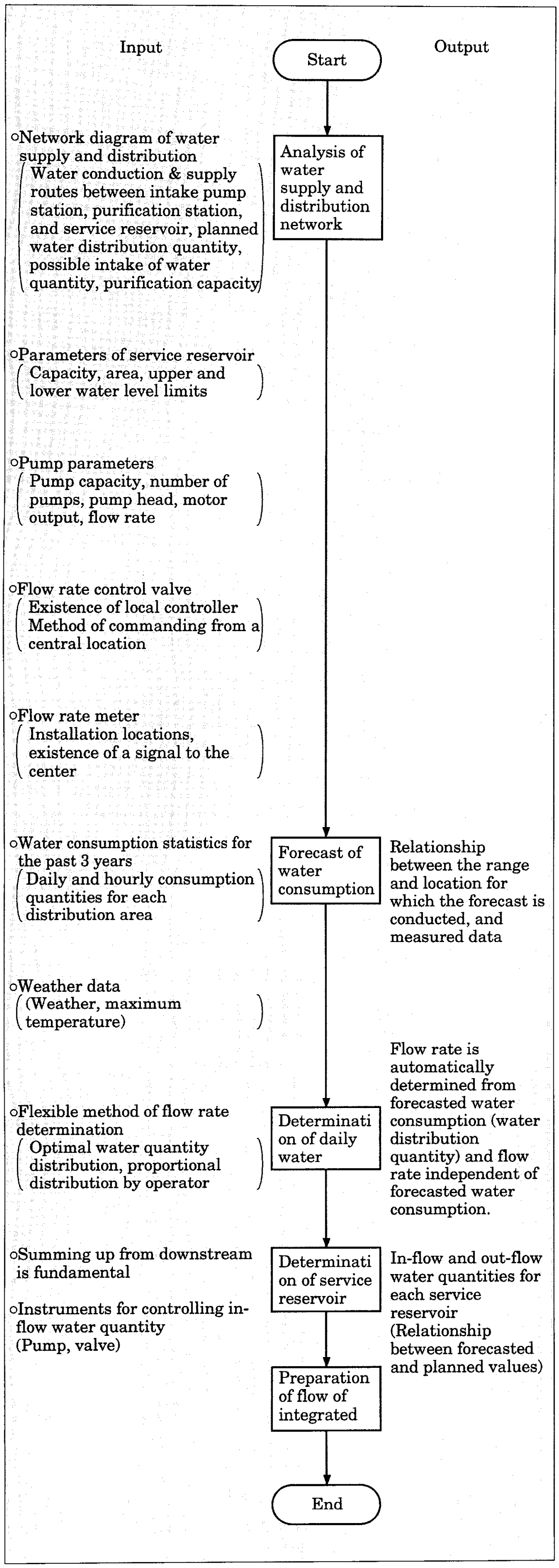



Fig.5 Design process for the water distribution control system

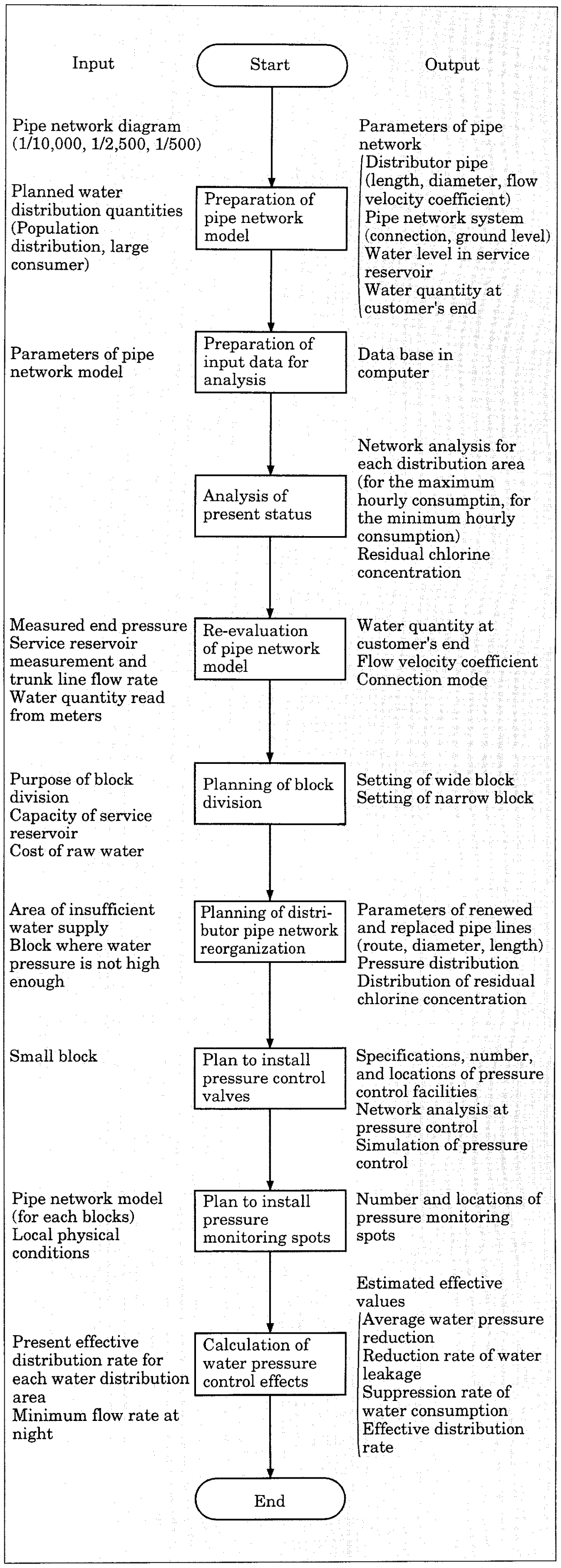


Fig. 6 Block diagram of the integrated water control system

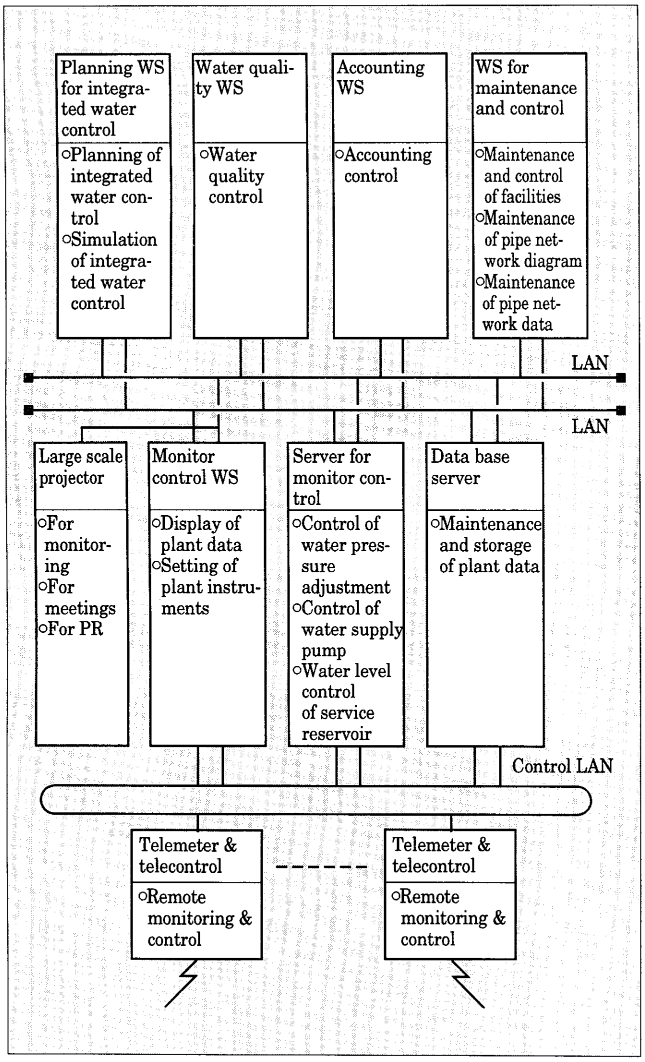
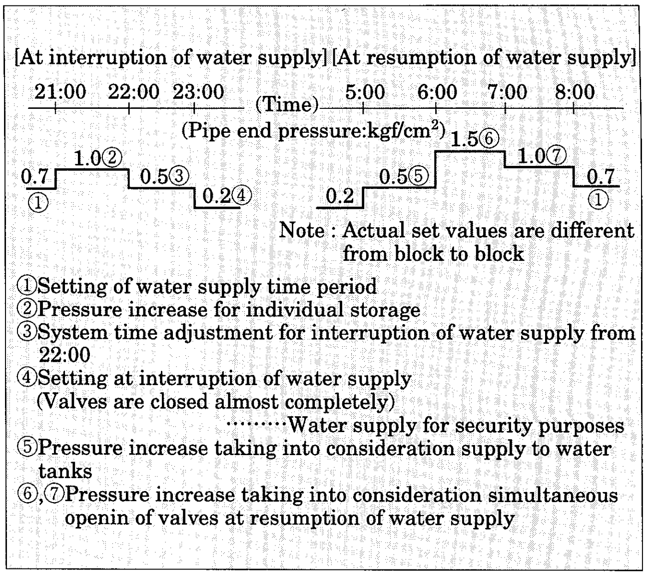



Fig. 7 Set values of pipe end pressure




## 5. Example of an Integrated Water Control System

Figure 6 shows an example for realizing an integrated water control system.

If necessary, at least two and sometimes multiple instruments are installed.

## 6. Countermeasures Against Water Shortage

During the anomalous water shortage in 1994, the water level of the Ishite river, the major water source for Matsuyama City in the Ehime Prefecture of Japan, and the underground water level around Matsuyama City dropped drastically. Inevitably, water distribution was suppressed and water was supplied only within a limited period during the day. The totally integrated water control system supplied by Fuji Electric to the Public Service Bureau of Matsuyama City will be described below.

### 6.1 Roles of the totally integrated water control system

(1) Lowering the water distribution pressure by pressure control valve

From the first limitations imposed on the water supply, water distribution pressure decreased from the usual $19.6 \times 10^4$ Pa (2.0 kgf / $cm^2$) to $9.8 \times 10^4$ Pa (1.0 kgf / $cm^2$) by operating the pressure control valves. This pressure reduction was performed by the automatic pressure control system installed at the Ichinoide's purification plant.

(2) Time-limited water supply by pressure control valves

Water supply and interruption of the water supply were performed by operating the pressure control valves automatically for 77% of the entire service areas and manually opening and closing the valves for the remaining 23%. For automatic control of water supply and interruption, a schedule for each hour was input into the computer. Figure 7 shows an example of a schedule for setting the values of the pipe end pressure in the computer.

### 6.2 Effects of the totally integrated water control system

A considerable quantity of water was conserved by pressure reduction and by voluntary water conservation. By conducting a large part (77%) of the pressure control operations in the computer, only a minimum number of workers to conduct the manual operations for the remaining 23% was needed, saving personnel expenditures. Thus, this totally integrated water control system was quite effective in reducing expenses during a water shortage as well as in facilitating an even distribution of water.

## 7. Conclusion

During the anomalous water shortage in the summer of 1994, a tremendous amount of money was expended on countermeasures, especially in areas where water supply was urgent. These countermeasures included the securing of water and valve operations for a time-limited water supply. Since then, the totally integrated water control system has attracted much attention due to its effectiveness in reducing expenditures.

As the Great Hanshin-Awaji Earthquake has taught us, the reliability of our water supply systems must be improved. Items for improvement include totally integrating the water control technology for realizing a mutually backed-up water supply network of conducting and water supply pipes; minimizing the areas and periods in which the water supply is interrupted; realizing local water supply within each water distribution block; and provisions for making the waterworks more earthquake resistant.

Fuji Electric is continuing its efforts to develop the totally integrated water control system, which must strengthen its support functions, combine various simulation and decision support tools to facilitate the planning of countermeasures against disasters, and be of value to the community.