Instrumentation, Control and Sensor Technology for Waterworks

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1. Introduction

Japan has built up a rich social framework in an environment that has been blessed with the benefits of water. A close relation between the utilization of water resources and social activities has always been maintained. Recently, the water quality of drinking water resources, rivers, lakes and marshes, has degraded year-by-year due to advanced industries, higher living standards and concentrated population. In addition, water shortages due to a lack of rain because of global climactic abnormalities are also making unfavorable circumstances for water volume. On the other hand, waterworks, which form the basis for our standard of living, are becoming more widespread and a stable supply of high quality “safe and good tasting water” is required for the coming 21st century.

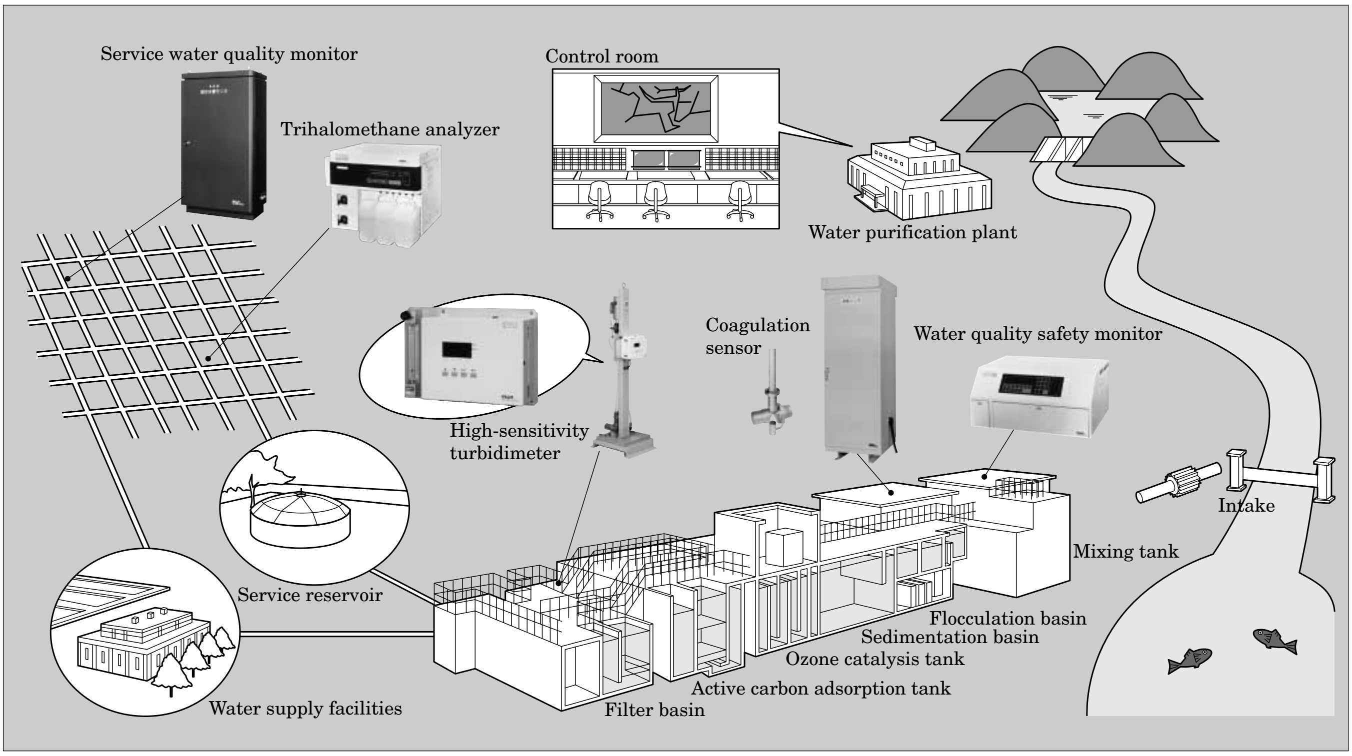
Responding to such needs of the times, Fuji Electric has contributed to problem solving with various system technologies - energy, plant, process and EIC (Electricity, Instrument and Computer) systems - which have been cultivated for many years in the field of waterworks.

This paper will introduce new water quality sensors and original process control and instrumentation systems for waterworks that respond to the latest water environment changes.

2. Sensors

System technology that has responded to water quality changes is represented in the newly developed water quality sensors. Figure 1 shows the relation between the process flow of waterworks and the water quality sensors.

Fig.1 Relation between process flow of waterworks and water quality sensors



2.1 Water quality safety monitor

To verify the safety of a water source, fish are generally kept in raw water and their behavior observed to determine if any abnormality exists in the water. This method has such problems as ambiguity in the observation of fish behavior and the labor required to constantly maintain the many fish in a healthy condition. Thus, another automated method has been required. With a dissolved oxygen electrode, the water quality monitor introduced here directly detects reduced respiration activity of bacteria (nitrifying bacteria) sensitive to acute toxicants in water, and issues an alarm. This monitor is not capable of determining toxicants but automatically samples water for inspection if any toxicant is infected, and this allows the toxicant to be identified later with a precise analyzer.

2.2 Coagulation sensor and controller

In the coagulation-sedimentation process, an important treatment in water purification plants, the coagulant injection rate is largely determined based on raw water quality or the manual analysis of a jar test, however satisfactory results have not been achieved in many cases when the raw water quality suddenly changes. Based on the fluctuation in absorbance of irradiating light, the coagulation sensor and controller measure the mean diameter of flocculated particles in mixing tanks and flocculation basins of the water purification plants. The controller performs optimized coagulant injection control.

2.3 High-sensitivity turbidimeter

Mass infection of the pathogenic organism cryptosporidium occurred in 1996 in the Kanto district of Japan, and the pollution source was believed to be city water. The Japanese Ministry of Health and Welfare issued then tentative guidelines for cryptosporidium that required the turbidity in the effluent from a filter basin to be kept under 0.1 degree. Following these guidelines, Fuji Electric has developed a new type of high-sensitivity turbidimeter. Utilization of the front light scattering particle counter method has allowed this turbidimeter to measure the super-low turbidity of 0.001 degree, impossible for the conventional transmitting light method and the surface light scattering method, and to simultaneously measure particle size distributions (0.5, 1.0, 3.0 and 7.0µm or greater). In the field of waterworks, this highly precise hybrid turbidimeter will be a critical device for a new epoch.

2.4 Trihalomethane analyzer

As treated in the new water quality standards, monitoring the concentration of trihalomethane in city water is extremely important because trihalomethane is feared to be a carcinogen. However, gas chromatography, an existing analyzing method, requires skill and time because of its complicated pretreatment and is incapable of continuous measurement by batch processing. Thus, a simpler and faster measuring analyzer has been desired. This trihalomethane analyzer is for laboratory use and analyzes quickly and automatically the total trihalomethane in sampled water with a fluorometry method based on the Fujiwara Reaction.

2.5 Service water quality monitor

In Japan, automated daily inspection of the water quality (pH, turbidity, color, residual chlorine, electric conductivity, water temperature and water pressure) as prescribed in the waterworks law is coming into widespread use mostly in large cities, but a color meter which only identifies some colors has been used as a substitute for the color inspection. In coordination with the Japan Water Works Association, Fuji Electric has developed the world's first monitor that is capable of identifying all hues. This monitor can detect color gradations of city water such as red water, white water and black water and has a performance equivalent to that of human eyes. The monitors are placed at multiple points along a water distribution network. Obtaining real-time data by continuous monitoring has enabled the realization of advanced water management such as ensuring the safety of service water quality and preventing expansion of damage due to faults or disasters by centralized monitoring, and monitoring the flow time from the water purification plant by continuous measuring of water pressure, pH and residual chlorine concentration.

3. Process Control Technology

Water management and control represents a technology for handling changes in the water volume. The phrase "water management" often refers to water intake management, water supply management and water distribution management, and here water management and control shall cover these three wide areas.

3.1 Water supply management and control

The principle objective of water supply management and control is to economically and effectively distribute the water volume from a water intake to a service reservoir. Figure 2 shows an overview of water supply management.

(1) Water demand prediction

The prediction of water demand forms the basis of water supply management. Daily demand is predicted for each service district, and based on the results, the water distribution for all the water purification plants and intake stations in a city is determined. Moreover the hourly demand is predicted by calculation from the predicted daily water volume, and then the hourly

Fig.2 Overview of water supply management

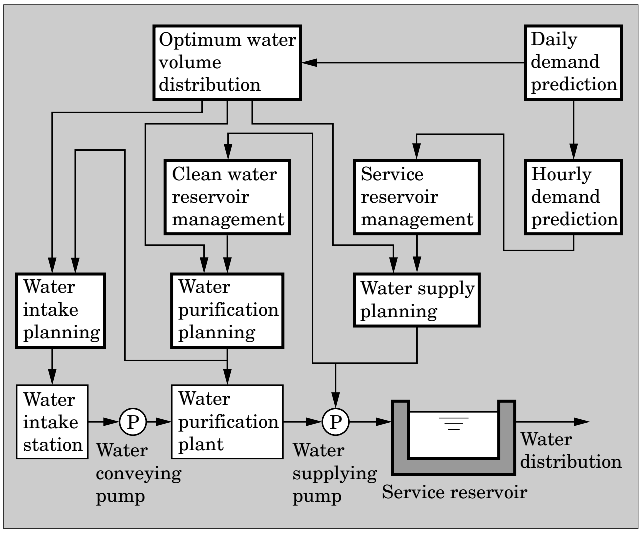
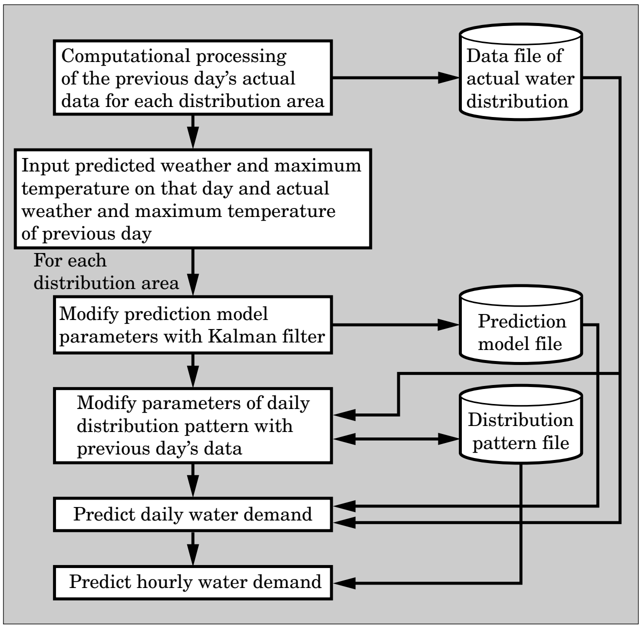


Fig.3 Online processing flow of demand prediction



supply water volume to service reservoirs is planned. An online processing flow of the demand prediction is illustrated in Fig. 3.

(2) Optimum water volume distribution

The supply water volume from each water purification plant is determined when the demand of each service district is planned. The supply water volume plan is prepared such that the management cost is minimized when the water intake capacity, water purification capacity and water supply capacity of each water purification plant are limited. The water volume distribution can be determined to minimize the total limited volume of service water during a water shortage. It is possible to examine the water management plan and to quickly respond to abnormalities such as contamination of the source water by a toxicant.

(3) Service reservoir management

When hourly changes in the water volume from a service reservoir are predicted, it is possible to level off the supply water volume to the service reservoir and to devise a supply water plan for minimizing the number of changes to running supply water pumps. Every approach is combined to optimize each service reservoir. If the service reservoir receives water via the supply water pumps, the number of running pumps is controlled, and if water is received via the inflow valves, water inflow control (stepwise or continuous) is performed.

(4) Water management support simulation

The water management plan for maintaining stable service water volume and pressure is designed under variously assumed conditions in normal and abnormal circumstances, and simulation of the results is performed.

(a) Online simulation

The water level variation of each basin is calculated using the online data (present water level, planned water volume and predicted water demand) at the time of the simulation. Simulation is also performed with modified settings for the change of the planned water volume

(b) Water management planning simulation

Simulation of abnormal circumstances, modified distribution systems or facilities, and for the optimum adjustment of water management plans can be performed under flexible conditions.

3.2 Water distribution control

Water distribution control mainly aims to reduce the quantity of leakage by adjusting water pressure, to evenly serve water during a water shortage, and to maintain the safety of water quality.

(1) Pipe network calculation

The pipe network calculation is a basic analysis method in water distribution control. This method computes the water pressure and flow distribution in a pipe network with given network parameters (pipe networking topology, demand distribution, etc.), and is used to design pipe routing at new installations or during renovation.

(2) Selection of water pressure monitoring point

Based on the result of the pipe network calculation, the pipe network is broken into several blocks and water pressure monitoring points are set up at one or more positions in each of the blocks. If there are multiple positions, the block area is divided to obtain the most effective allocation according to cluster analysis utilizing the similarity of water pressure variations. Then, monitoring points are selected at the positions where there is a large influence and where there is little influence on the water pressure of the pipe network.

(3) Distributed water pressure control (water pressure adjustment)

Water pressure control adjusts the water pressure in each of the blocks with the water pressure adjusting valve for that block. All the logical control is implemented by onsite digital regulators. However, the water pressure setting of each block is determined by a central computer or an operator and transmitt d to each onsite regulator.

(4) Water distribution control support simulation

A water distribution control plan is designed under various assumed conditions of normal and abnormal circumstances, and simulation of the results is performed.

(a) Water pressure adjustment simulation

For fair and appropriate service water volume under normal and abnormal circumstances, this simulation obtains the operating information for water pressure adjusting valves and control valves from the mutually given data of service water volume, secondary pressure, end pressure and valve openings.

(b) Pipe network management simulation

Under mostly abnormal conditions, this simulation performs economical management by modifying boundaries of the distribution areas.

(c) Calculation of effect of water pressure adjustment

The effect of reduced service water volume by adjusting water pressure is calculated.

(d) Analysis of residual chlorine concentration

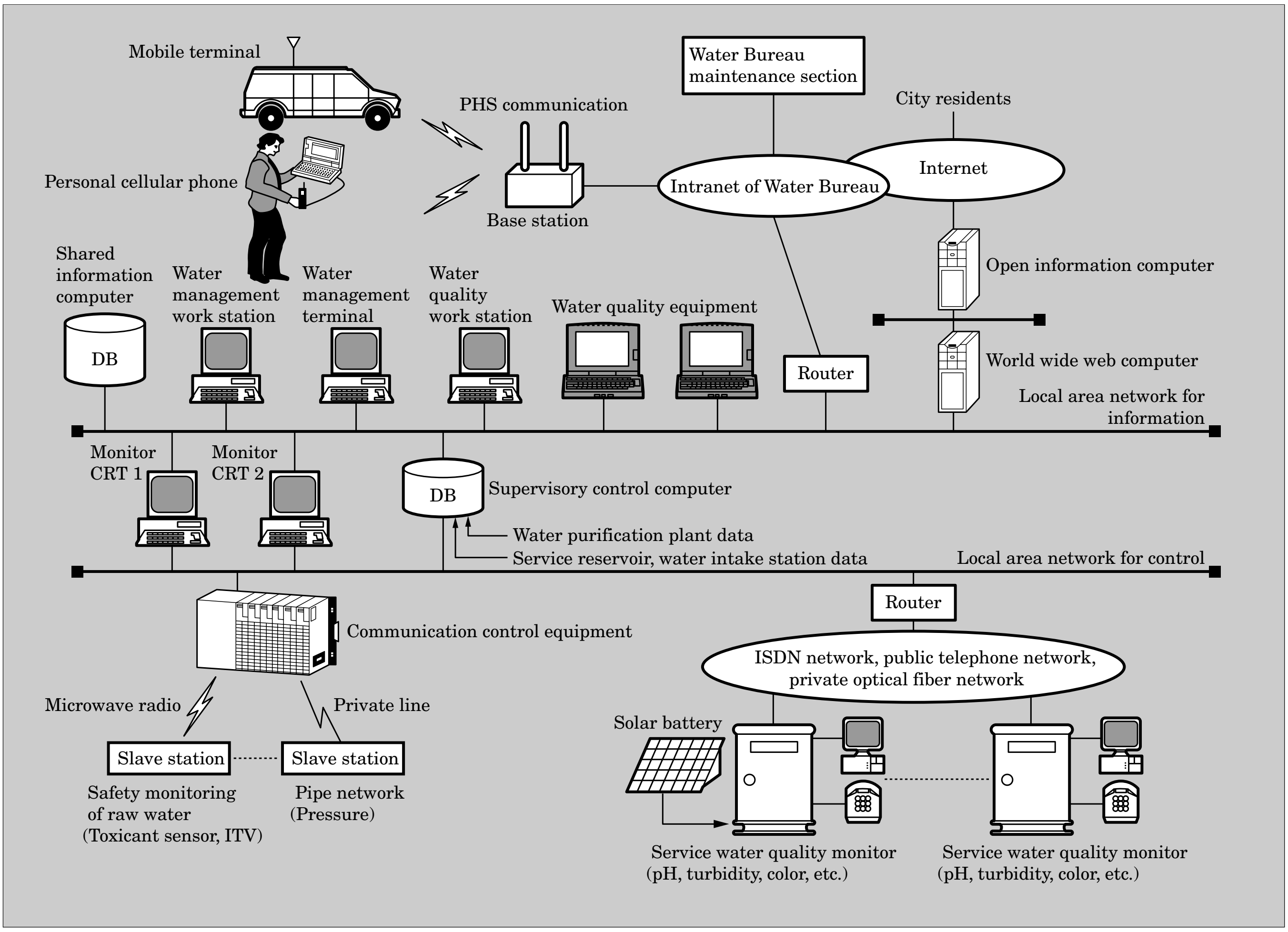
The distribution of residual chlorine concentration at service reservoirs and water faucets is estimated by calculating consumption of the residual chlorine concentration in the pipe network.

3.3 Example of water management system

Water supply management has been mostly introduced into big-city areas such as Tokyo Metropolis, Osaka Prefecture, Kanagawa Prefecture, Yokohama City and Kobe City. In many supervisory control systems for water purification plants, the function of water supply management is included in the supervisory control of external facilities. On the other hand, water distribution management is mainly applied in regional cities such as Matsuyama City, Takamatsu City, Kumamoto City and Matsumoto City. To realize water distribution control, some initial investment such as dividing the pipe network into blocks and providing onsite facilities is still required depending on the scale of the waterworks plant.

In Matsuyama City, time limitations were placed on the feed water during the water shortage of 1994.

Fig.4 The latest waterworks management system



At that time, water distribution control with automatic pressure control valves was implemented in 77% of all the districts and played an important role in the countermeasures against the water shortage.

4. Instrumentation System Technology

Sensor and process control technologies have been introduced as system technologies for waterworks countermeasures against water pollution and water shortages or leaks. Of the instrumentation system technologies that comprehensively manage the aforementioned technologies, this section will describe the technologies most easily affected by disasters, data transmission and power supply technologies.

Figure 4 illustrates an example of an instrumentation system configured with the latest technologies.

4.1 Data transmission

(1) Communication line

Selection of a communication line is important in the configuration of an instrumentation system. The line should actually be selected on the basis of cost-effectiveness after sufficient study of the geographical condition, regional characteristics (whether radio waves can be received, or whether any telephone lines are near) and reliability (especially in disasters), as well as performance (transmission speed, capacity, etc.)

(2) Network technology

Use of the internet or intranet is effective for information exchange (supervisory control data, maintenance and management data) between the city residents and related sections of the Waterworks Bureau. In case of an emergency such as an earthquake disaster, the personal handy-phone system (PHS) is necessary for obtaining accurate onsite information. On the other hand, employment of a general purpose LAN and a standard communication protocol allows different companies to be linked with each other through routers and exchange information between the supervisory control system and other related systems.

4.2 Power supply technology

Power supplies are especially important, along with transmission lines, for information communication during disasters. As a countermeasure against power failures, uninterruptible power supplies (UPS) are required for sensors, transmission systems and computer systems. Utilization of solar batteries is also under consideration as emergency power sources for the water quality monitors placed in pipe networks within a city.

5. Conclusion

System technology that responds to changes in the water environment, together with global environmental problems, will become increasingly important in the future. Fuji Electric will continue to provide various system technologies for the effective utilization of limited water resources and supply of safe and good tasting water. We will strive to create a waterworks total management system suitable for the information society of the 21st century.

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