# The Design Criteria for Water Supply Facilities

# 2012

Chapter 1. Introduction

Chapter 2. Water Intake Facilities

Chapter 3. Water Storage Facilities

Chapter 8. Mechanical, Electrical and Instrumentation Equipment

（The Excerpt）

Ministry of Health, Labour and Welfare

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These criteria are the extracts from “Design Criteria for Water Supply Facilities 2012”,
Japan Water Works Association:

1. Introduction
2. Water Intake] Facilities
3. Water Storage Facilities
8. Mechanical, Electrical and Instrumentation Equipment

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# 1. Introduction

## 1.1. General

### 1.1.1. Characteristics of these Design Criteria

The Water Supply Law, that is the basic law for water supply, aims at "providing clean and abundant water at inexpensive prices" by means of water supply "to contribute to the upgrade of public sanitation and the improvement in living environment", and so stipulates the water quality standards, the facility standards etc. in it. Water supply facilities shall be planned and designed in accordance with the facility standards.

The water supply industry is now required to reliably provide safe water at all times at a higher level as a lifeline indispensable to maintain citizen's life and urban activities. In order to achieve these aims, such a wide variety of issues, which encompass from the construction of facilities to their maintenance, shall be tackled including refurbishment of aged facilities, for which it is time to carry out full-scale replacement, increasing resistance of facilities against earthquake and their reform; preparedness against such various risks as terrorism, the new type of influenza etc. in addition to natural disasters of earthquake, flood etc., consideration to environment for realization of a low-carbon society and so forth.

These design criteria precisely respond to these issues while conforming to the latest Ministerial Ordinances; and their contents are the practical guidelines to meet the needs for water supply which are going to be highly diversified and advanced. Since the "Ministerial ordinance to establish technical standards" is enacted to be a performance standard, so it only provides limited concrete standards, consideration is given in the Criteria so that water utilities can smoothly conduct planning and design of facilities while realizing their local characteristics and originality.

Besides, although the Criteria reference such criteria as the "Criteria for anti-earthquake construction of water supply facilities and annotation 2009" (Japan Water Works Association) and the "Criteria for the operation and maintenance of water supply 2006" (Japan Water Works Association) on the duplicated topics, their especially important contents are clearly described in the Criteria as well.

### 1.1.2. Basic Concept of the Provision of Facilities

Although an expansive and quantitative provision of water supply facilities used to be practiced so far to achieve the coverage of water service and response to the increase in water demand, the important point is now shifting to the qualitative change in the provision of water supply to realize safety and reliability of water service and the improved level of service. What is more, it is important to accomplish sustainable water supply while coping with the risks of the decreasing water demand as the era of diminishing population is coming while the need for facility replacement is growing. Furthermore, it is important to economically and efficiently provide sustainable water supply while aiming at the reduction in the life cycle cost with a view of the entire system of water supply. Specifically speaking, the provision of high-quality water supply facilities embodied with a proper scale of systematic safety, which possess strong resistance to drought and earthquake as well as reliably serving more palatable and safer water.

Since the contents of water service have been diversified and complicated due to the need to construct a water supply system with consideration to environment and introduce new water treatment facilities and so forth, water utilities are required to fulfill the accountability at the time of setting the purpose of the project; and provide facilities in consideration of social trend, the needs of consumers etc. with their understanding. However, the specific goal at the required level and the process to achieve it may largely differ depending on the natural and social conditions under which the respective water utilities are situated. As such, water utilities are required to set their own goal for the provision of facilities based on the local characteristics and the size of the project. As it consumes time to achieve the goal, it is needed to draw a synthetic master plan based on long-term prospects.

The following points shall be taken into account at the time of providing facilities and the implementation of a project.

### 1. Preparation of a master plan and its revision

At the time of preparing a master plan for the provision of water supply facilities (Hereinafter referred to as the “master plan” in this chapter), it is important to aim at the conformity with such a development plan at the higher level as “a regional water supply development plan” etc. while taking into consideration long-term regional and social development plans of the government and local self-governing bodies. To be concrete, it is required to draw a proper future plan examining the size of the facilities based on the precise water demand forecast, which reflects the population estimate and the economic growth rate etc. in accordance with the development plan at the higher level.

Moreover, there is a possibility for the water demand forecast to largely deviate from the actual performance due to the inconsistency between the master plan and the social needs, decline in population, the change in social circumstances and so forth. Therefore it is desirable to establish a body, which can operate the water utility applying the PDCA cycle, practice examination and evaluation, and revise the master plan if required.

At the time of designing water supply facilities, it is desirable to not only abide by the related laws and regulations but also understand that the facilities are composed of various equipment and apparatus related to civil engineering, architecture, mechanical engineering, electrical engineering and so forth, and make the facilities harmonized as a whole. The entire steps to be taken from the preparation of the master plan to design through construction are presented in Figure 1.1.1.

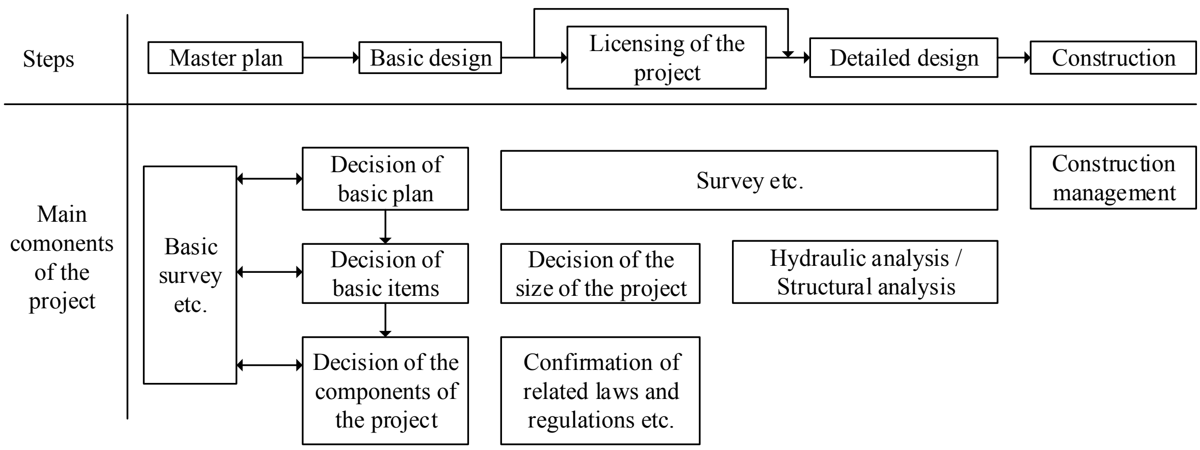



**Figure 1.1.1 Steps for the provision of water supply facilities**

### 2. Preparedness for an emergency

It is required for water utilities to secure water service not only at the normal times but, as much as possible, also at such an emergency as disaster of an earthquake, drought as well as at the time of an accident etc. (Referred to as “at an emergency” in this chapter). To meet such needs, it is required for the water supply facilities to secure quantitative safety well-balanced for the water supply system as a whole, and so the preparedness as the ability to cope with the emergency shall be strengthened. For instance, the water treatment plant shall possess certain allowance in its output; the water mains network shall be strengthened; trunk mains shall be doubled; the anti-disaster capability of equipment and apparatus shall be improved and so forth.

**3. Reduction in the cost**

In addition to the provision of facilities with higher safety and reliability, it is important to examine the life cycle cost of the entire water supply facilities so as to synthetically review the initial and running costs.

To achieve this objective, the series of facilities from the water source to the tap shall be considered as a system so that the water supply facilities shall be laid out so as to reliably and efficiently function as a whole by means of organic cooperation with respective facilities. Besides, as for respective facilities, it is needed to secure safety and raise their efficiency through an extensive study with a view of introducing state-of-the-art technologies as well.

**4. Sufficiency in Operation and Maintenance**

Consideration is needed for the facilities to be designed and laid out so that their improvement and replacement can easily be undertaken in future since they eventually get deteriorated over time. In addition, the construction of a water supply system of which operation and maintenance (O&M) can be easier while the facilities are becoming diversified.

**5. Explanation to the consumers and reflection of their views**

To have recognition of the consumers on a plan of a project or activities of the water utility, the water supply utility shall make the goal of its project clear using the performance indicators (PI) of the Guidelines on Water Supply Utilities.

**6. Consideration to the environment**

As environmental problems such as global warming, acid rain, disruption of the ozone layers etc. are getting serious in a global scale in the recent years, measures to tackle conservation of the earth’s environment such as saving resources and energy etc. are extensively required. Water supply utilities are expected to improve the efficiency of the utilization of energy, actively use untapped energy etc. so as to contribute to build a low-carbon society. Besides, they are required to reduce the quantity of waste, positive use of recycled resources and so forth.

### 1.1.3. Improvement and replacement of facilities

The history of modern water supply in Japan started in the 19$^{th}$ century, and many water supply facilities have been constructed. From now onward, not only the facilities built at the early stage of the development of water supply but also many of those constructed in the expansion era, especially in the “high growth period”, are becoming superannuated. It is important to improve and replace the facilities according to a plan so as to maintain safe and reliable water service to the future. Postponement of the improvement and replacement work shall not be allowed even if a large amount of investment is necessary for the work; and it does not bring the increase in the income of the utilities. Therefore, an improvement and replacement plan shall be prepared and steadily implemented with consideration to long-term financial management using the asset management method etc.

Furthermore, when applying the asset management method, it is important to study and understand the status quo of the facilities, and undertake measures for the leveling of the quantity of the operation from the view points of reliable water service and maintenance of profitable operation. Besides, at the time of improvement and replacement of respective facilities, as same as the case of expansion and new construction, the circumstances during the operation of the facilities shall fully be taken into account including such aspects as water demand, the trend of raw water quality, consumer’s needs, the change in natural, social and environmental conditions. The study shall be conducted on not only the part of the facilities to be improved or replaced but also the entire water supply system.

It is essential for the improvement and replacement of facilities to be implemented in a positive and deliberate manner according to long-term prospects so as not to miss the appropriate timing. The following aspects shall be taken into account:

**1. Improvement and replacement work with consideration to the entire water supply system**

Improvement and replacement of facilities are carried out to secure the capacity of providing water service when they are superannuated and upgrade their functions so as to materialize the consumer's needs and efficient business operation. When implementing improvement and replacement, the functions the facilities must primarily possess and those they possess at present shall be examined and evaluated so that the prioritization, e.g., advanced implementation, schedule and components of the improvement/ replacement project shall be studied.

The water supply system can function with secured safety and reliability of its entire facilities (water source, water intake, storage, raw water transmission, water treatment, treated water transmission, and water distribution). Given this, improvement and replacement of facilities shall be undertaken with consideration to the entire water supply system acknowledging future water demand and the level of service, reforming the system into a proper size and a restructured body, examining the level of safety and so forth.

**2. Examination and evaluation of the facilities**

For improvement and replacement of facilities, proper judgment on their timing and contents of the project is required. The timing and the required work of improvement and replacement will differ depending on such local characteristics as the surroundings of the project site and the environment under which the facilities are used. Therefore, it is desirable to carry out the evaluation of the condition of the facilities based on a functional examination, and reflect its result to the implementation plan.

**3. Aspects to be considered for an improvement and replacement project**

For improvement and replacement of facilities, consideration shall be given to the preparation of the existing facilities including the provision of redundancy in capacity, pluralization of the system etc. so that the work of improvement and replacement becomes possible. For instance, provision of excess capacity is necessary in advance for improvement and replacement of a water treatment plant etc. by means of preparing substitute facilities so that the output of the plant would not become short. In the case of replacement of water mains, it is desirable to prepare a network of water transmission and distribution, which enables flexible water management, so as to secure normal level of water service by means of switching to another system. What is more, detailed implementation plan shall be prepared; and progress control shall be practiced so that water service is not interrupted due to a delay in completion of the work.

In case the replacement work is undertaken while running the existing facilities, it is required to carry out the work maintaining the functions of water treatment, transmission, distribution etc. and volume of water production and quality.

**4. Ease of operation and maintenance and improvement in function**

As efficient management of water supply facilities is requ8ired, consideration to the ease of operation and maintenance (O&M) of facilities and so forth is important while dealing with consumer's needs, the declining size of staff etc. It is also essential to feed the problems related to the day to day O&M back to improvement and replacement facilities as well as upgrade the reliability and ease of O&M by means of merging and abolition of facilities.

### 1.1.4. Risk management

Since tap water is used not only for living but also various urban activities, it is one of the most important lifelines. In the case of suspension of water service due to certain trouble in the water supply system, its impact on citizen's lives and urban activities is becoming increasingly larger than ever. As such it is important to reduce, as much as practically possible, the damage caused by all the risks, which potentially jeopardize reliable water service, such as disaster of earthquake etc., accident, terrorism and so forth. Therefore, the need for provision of facilities in consideration of these risks is becoming more important than before.

Risk management is also important to do the duty of serving water as much as possible even at an emergency. As the water source and the water supply facilities are used for a scours of years after their construction, the provision of facilities shall be undertaken fully considering the natural and social environment surrounding the respective water utilities.

**1. Earthquake-resistance of facilities**

Earthquake-resistance of the water supply system as a whole is needed to serve water as much as possible even at the time of an earthquake disaster. To this end, it is important to provide in an efficient manner the earthquake-resistance of the water supply system as a whole as well as to evaluate the earthquake-resistance of each facility. In addition, it is desirable to develop an anti-earthquake plan considering the key facilities, important facilities, their social roles as the priority for anti-earthquake measures.

**2. Guaranty of security**

It is also important to strengthen the security of facilities as the measure against terrorism, invasion by unknown individuals etc. For instance, equipment and a method for the provision for the security shall be selected taking into account the need for covers on filters etc., reinforcement of monitoring of unmanned facilities and so forth.

**3. Provision of drinking water for an emergency**

As a measure to provide drinking water to be used at an emergency of serious damage on water supply facilities caused by a strong earthquake etc., there are the provision of a water cistern for a time of earthquake disaster, the installation of emergency cut-off valves, the provision of mutual water transfer between neighboring water utilities by means of interconnecting their transmission and distribution mains and so forth. To this end, the setup of an organization to reliably function at an emergency is needed. Moreover, strong cooperative measures and mutual assistance systems participated by neighboring prefectures, cities and towns and related organizations are required from the wide area point of view. Thence, it is desirable to establish a system for preparing and operating such facilities with due consideration to the local characteristics.

**4. Strengthening of the management system**

In addition to natural disasters and terrorism, such various risks are conceivable as unexpected water pollution, drought, floods, the new type of influenza etc. related to water supply, and so the provision of water service as much as possible at an emergency caused by such risks is required. As such, a water safety plan and a Business Continuity Plan (BCP) shall be prepared; the enforcement of cooperation and the conformity with the office for disaster measures, other self-governing bodies and water utilities; and it is desirable to prepare for the risks in consideration of such aspects.

It is essential for the drawings of finished facilities, charts for operation and management etc. shall be stored in separate places in expectation that such a place become inaccessible or lost in a disaster. Furthermore, it is desirable for such documents to be stored by both cities or utilities, for which a mutual assistance agreement is contracted, located fur from each other.

**5. Provision of reliable water service**

At the time of the Great East Japan Earthquake, the operation of water treatment plants etc. were troubled due to power outage and the shortage in fuel for power generation. Moreover, shortages in supply of sodium hypochlorite was brought about due to the damage to the factory of the chemical and its shortened operation due to rationed power supply; short supply of activated carbon because of rise in demand for the removal of radioactive substances occurred. Therefore, for risk management from now on, examination shall be practiced so as not to bring about shortcomings to secure the provision of reliable water service.

## 1.2. Master Plan

### 1.2.1. General

The master plan is a long-range and synthetic plan related to the basis of the components of the project, in which the respective water utilities and bulk water suppliers (Hereinafter referred to as "respective water utilities etc.") are going to undertake facility improvement, replacement, expansion etc. in the near future under the natural, social local circumstances, and contains a basic goal, principal items and components to be provided.

The following items shall be taken into account when preparing a master plan:

1. Securement of a quantitatively reliable water source
2. Securement of qualitative safety of water
3. Securement of proper water pressure
4. Provisions against a disaster and accident
5. Improvement and replacement of facilities
6. Consideration to the environment
7. Consideration to sanitation

**[Interpretation]**

The master plan is a long-range and synthetic plan to be the basis of the provision of water supply facilities, and must have components in conformity with the conditions pertaining to such facilities.

To meet such requirement, the need for facility replacement and the prospect of financial performance shall be understood utilizing the way of thinking and analytical method etc. given in the "Manual for Asset Management". It is important to reflect the result of the analysis to the development vision for the regional water supply; at the same time, establish near and medium-term goals; prepare a master plan and implementation plans for the respective schemes; and carry out the provision of facilities according the plans. The master plan represents specific components of the provision in the development vision for the regional water supply (See Figure 1.2.1).

Additionally, as to analysis, evaluation of the status quo and setting of development goals in the master plan, quantitative expressions shall be used insofar as possible, and performance indicators (PI) and the concept of asset management shall effectively be utilized.

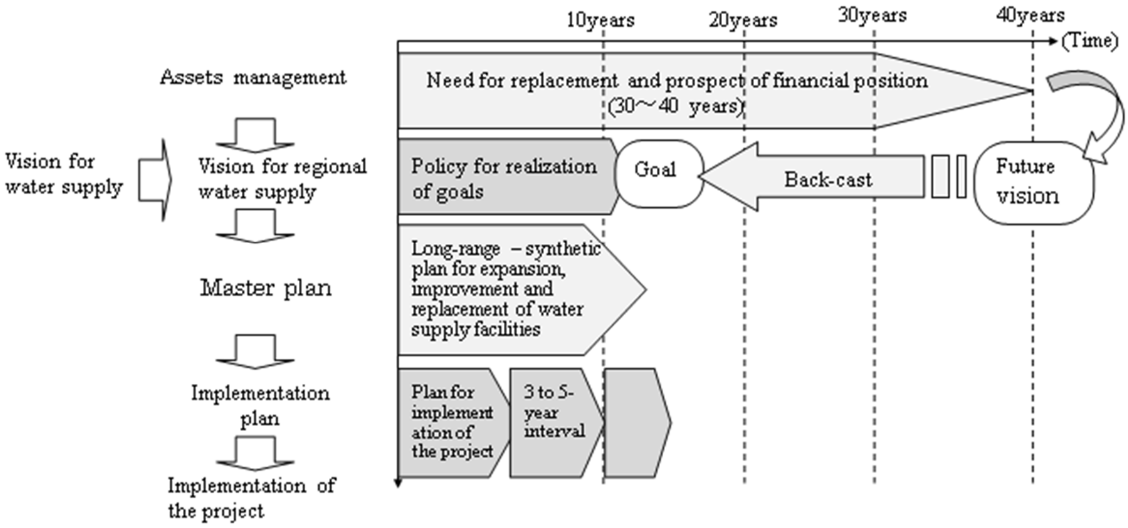



**Figure 1.2.1 Relationship between asset management and the master and other various plans**
(Ministry of Health, Labor and Welfare: Composed based on the Manual on Asset Management in Water Utilities)

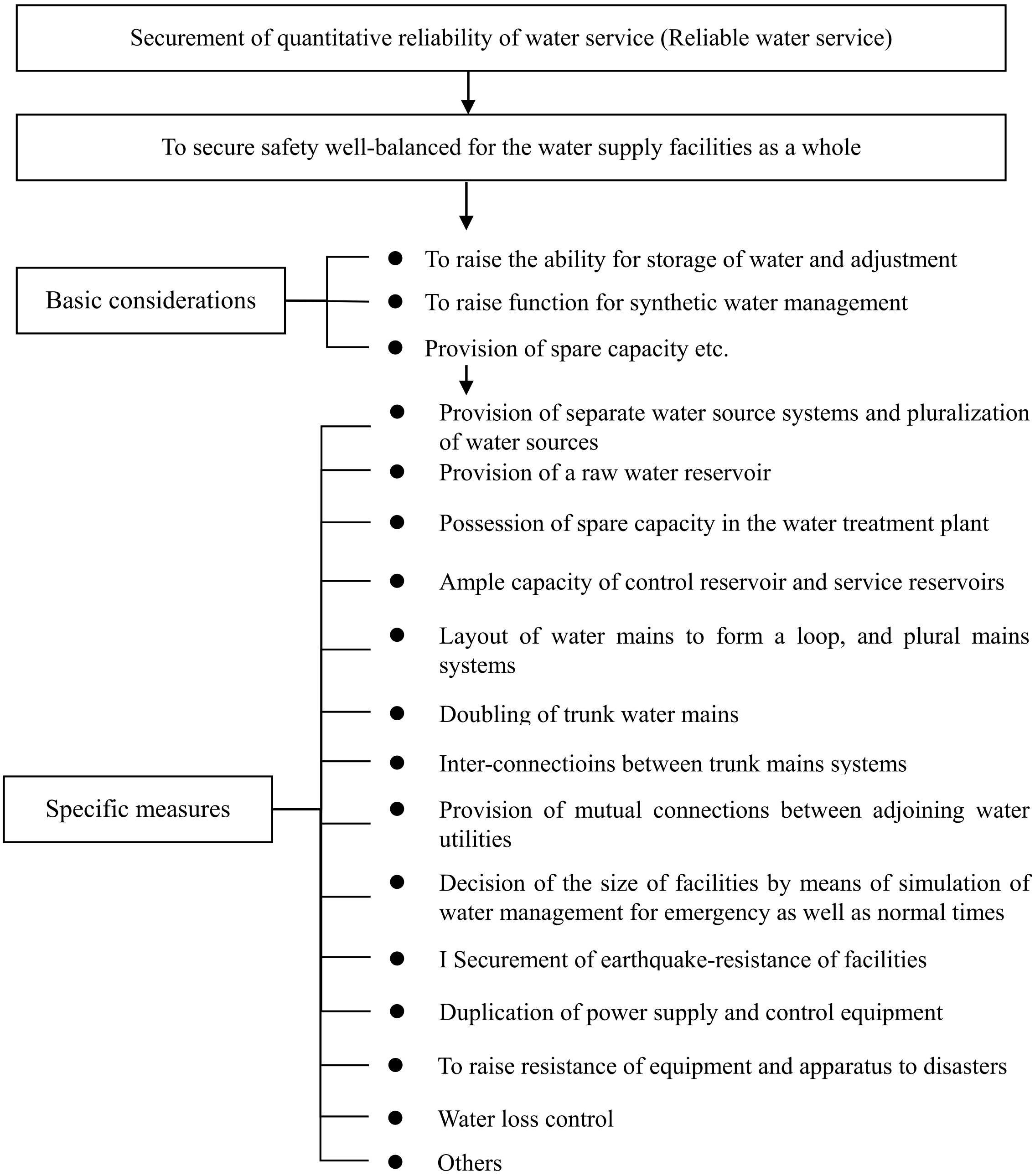
**On the item 1.;**

To secure water service not only meeting water demand at the normal times but also even at the time of such emergency as an earthquake, drought, accident etc. avoiding serious troubles to be caused to residents, it is required to secure the quantitative reliability well-balanced as to the entire water supply facilities with due consideration to the securement of water sources through water service (See Figure 1.2.2).

Specifically speaking, consideration shall be paid to pluralization of water sources, provision of a raw water retention reservoir, spare capacity of the water treatment plant, sufficient capacity of service reservoirs and their proper layout, connections between water mains to form a loop and pluralization of water mains systems, interconnections between trunk mains, mutual connection between neighboring water utilities, which enables them to feed water to each other, and so forth; simulation of water management by not only normal but emergency scenarios; and determination of the required volume of service reservoirs, sizes of water mains, capacities of pumps etc.

What's more, to determine the design quantity of raw water abstraction, design output of water treatment, design volume of water service etc., they shall be determined based on the quantities to be assumed for water management at not only the normal times but at an emergency, and water sources to meet the quantity shall be provided.

Although the securement of reliable water service is the basic requirement, the means to meet such requirement are closely related to the natural and social conditions, the measures shall not be selected in a uniform manner, but they must be in conformity with the characteristics of respective utilities and their financial conditions.




Note: The measures for reliable water service shall not be in a consistent form, but ones, that conform to the conditions of respective utilities, shall be selected.

**Figure 1.2.2 Basic steps for securement of reliable water service**

### 1) Water source and water storage facilities

It is necessary for the water source and the water storage facility to reliably secure intake of design quantity of raw water. To this end, the reliability of the water source shall be improved so as to cope with such various risks from near and mid-term point of view as unstable precipitation due to the climate change in addition to the need to fulfill the water demand, and the superannuation of facilities.

**(1) Development of the water source**

In many cases, the yield of a newly developed reservoir is set based on the magnitude of the design drought to return once in ten years judging from geological conditions and the financial reasons. Since in case the magnitude of the drought is assumed to be large, the reliability of water service will become high, when determining the magnitude of the drought, its study and evaluation shall be carried out taking into consideration the state of the past droughts.

**(2) Maintenance of the reservoir**

As reservoirs diminish over time for its capacity due to piling sand, in case sand has accumulated beyond the prescribed amount it becomes difficult to keep the design yield from the reservoir due to the reduction in its capacity. In such a case, it is useful to recover the capacity of the reservoir by dredging or raising of the dam etc.

**(3) Preservation of groundwater**

Since, of water sources, groundwater is a useful water source within a proper range of pumpage, its utilization shall be managed with consideration to water quality as well as the upkeep of pumping function. It is desirable that the groundwater source, even if it is not in use in normal times, shall be maintained to be used at an emergency.

**(4) Pluralization of water sources**

For improving the reliability of the water source, it is desirable to have water sources located in separate rivers and groundwater systems and provide facilities, which enable interchangeable utilization of water sources. The possession of different types of water sources or water sources located in different water systems, even if they are the same type of water sources, makes it possible to disperse the risk related to a drought or an accident, and effectively deal with the expansion, improvement and replacement of facilities.

**2) Water intake and raw water transmission facilities**

The standard for the design water intake volume is to be set at 110 percent of the design daily maximum water service volume including about 10 percent of safety factor.

**(1) Raw water interconnection facilities**

In case more than two water intake facilities can be provided, it is desirable to build raw water interconnection facilities for a mutual connection between the intake facilities including other neighboring utilities etc. In this case, the quantity to be conducted by the interconnection facilities shall be determined based on the experience with the past drought, and the quantity to be assumed for not only normal times but an emergency.

**(2) Raw water regulation basin**

The raw water regulation basin provided as part of the raw water transmission facilities can raise the reliability of water service by regulating the raw water flow qualitatively as well as quantitatively at not only normal but also emergency times.

**3) Water treatment facilities**

As the water treatment facilities are required to possess high reliability as basic facilities, consideration shall be given so that adverse influence to water service is not induced as much as possible even at the times of emergency and improvement and replacement of these facilities.

**(1) Systematization and dispersion of water treatment facilities**

The division of water treatment facilities into plural systems shall be examined as preparation for an emergency and improvement and replacement of the facilities. Dispersion of the water treatment facilities into plural water treatment plants shall also be considered.

**(2) Design water treatment flow and system capacity**

The design water treatment flow shall be determined based on the design daily maximum water service volume plus the process water to be consumed in the water treatment plant. The quantity of the process water is to be set with reference to experiences of the existing similar facilities since it differs from a plant to another.

It is desirable to determine the capacity of the water treatment facilities based on, in addition to the design water treatment flow, the spare capacity to be secured for dealing with incidences of raw water pollution, an accident on the facilities, and improvement and replacement of the facilities. The spare capacity for a plant with plural series of facilities shall be set at the equivalent to the capacity of one series and 25 percent or so of the design water treatment flow as the standard. However, the spare capacity shall not be set across the board, but provided in consideration of the condition of respective water utilities as same as the other measures for reliable water service.

**4) Water transmission and distribution facilities**

The basis for the design water transmission flow shall be the design maximum daily water service volume; and that for design water distribution flow shall be the design maximum hourly water distribution flow also considering the fire-fighting water flow depending on the size of the water utility.

**(1) Provision of water transmission and distribution mains**

The reliability of water service will largely depend on water transmission and distribution facilities which assume the function of transportation of treated water. Therefore, the provision of substitute function is required so that reliable water service can be secured even at an emergency and times of improvement and replacement of facilities. It is also necessary to implement such measures as interconnections between adjoining water transmission and distribution facilities, which enable flexible water management, making the sizes of series of distribution facilities appropriate, improvement of water distribution network, augmentation of the capacity of the regulation reservoir and service reservoirs and so on.

**(2) Division of the service area into blocks and control system**

To carry out smooth control of water management at not only normal times but also an emergency, and secure appropriate water service, division of the service area into blocks and provision of loops for distribution mains etc. shall be made.

Moreover, it is desirable to install valves, pressure gauges, flow meters etc. at suitable locations; and provide remote monitoring and control equipment etc. so as to make water distribution control system more functional.

**(3) Service reservoir**

Since the service reservoir possesses the function of storage and flow regulation, at the time of its construction, a water management plan for an emergency and the replacement of facilities; and its capacity, location, ancillary facilities etc. shall be determined in accordance with the characteristics of respective water utilities. Besides, the service reservoir shall be located inside the service area in consideration that it becomes a base for emergency water service at an occasion of the interruption of regular water service due to an emergency and accident.

Although the standard effective capacity of a service reservoir is the 12-hour quantity of the design daily maximum water service volume, it is desirable to be set as large as possible, provide plural water inflow sources, and install an emergency shut-off valve to retain water for water service at a time of disaster.

In case the capacity of the service reservoir is large compared with the distribution flow, or it is situated far from the water treatment plant, appropriate water quality control is specially needed for monitoring and control of residual chlorine etc. at the reservoir.

**(4) Regulating reservoir**

The capacity of the regulating reservoir of the bulk water supply shall be determined taking into consideration the hourly changes of supply flow, the method of water management at an emergency, situation of recipient water utilities about their provision of service reservoirs etc.

**5) Others**

As for the mechanical, electric and instrumentation facilities, their reliability shall be high enough with the provision of double sourcing of power receiving equipment for the preparation for power failure or breakdown, installation of power generators, pluralization of control circuitries for respective telemeters, redundant installation of major equipment and provision of standby units etc.

**On the item 2.:**

Since the water supply is the basic urban facility which is almost solely responsible for supply of water to the city such as water for living, and urban activities etc., it is required to supply safe and quality water.

On the other hand, the issue of water quality concerned with water supply is becoming complicated including pollution of water sources, taste and odor due to eutrophication of lakes and impounding reservoirs, accidents related to chemicals etc., deterioration of water quality caused by inappropriate upkeep of receiving cisterns and so forth. To secure the safety of tap water, cooperation is needed with related organizations responsible for the administration of sanitation and environment.

It is essential to aim at continued upgrading of management level by means of comprehensive management of water supply from the water source to the tap as a one-body water supply system through respective undertakings in accordance with a “safe water plan” etc.; and continued examination and review of the performance. Besides, for strengthening of the management system as a unity for the water supply system, it is important to improve the accuracy of testing by means of strengthening the system of water quality testing, so it is useful to use the accreditation mechanism of the GLP (Good Laboratory Practice).

**1) Measures related to water sources**

**(1) Lobbying to the organizations responsible for environmental administration and cooperation therewith**

Since measures for the protection of water source quality are conducted by environmental administration offices, administrators of river basins etc. in most cases, it is needed to lobby those offices more actively and get engaged for the implementation of the measures based on close cooperation and connection with them.

**(2) Measures for protection of water quality of water sources**

As the specific measures, there are measures for household wastewater in the water source area; ones for wastewater from factories and businesses; ones for agricultural and livestock wastewater; proper treatment of leachate from waste; introduction of treated wastewater; preservation of the environment of the river basin and restraint of development; cleaning of the river and so on. Especially, for lakes and impounding reservoirs, there are circulation of lake water; selective water intake; dredging of bottom sediments; improvement of water quality by aquatic plants; control of reservoir water by discharge etc. Another examples are the ownership of forested water source areas by the water utility to preserve the water source quality; and participation by the utility in forestation of the water source area.

**(3) Measures for protection of water quality at the water intake point**

The point of water intake shall be at the most suitable point in respect to water quality considering change in environment in future. It is desirable to install such facilities as oil fences to stave off the intrusion of such pollutants as oil brought by an accident, such a raw water monitoring device as aquarium using fish etc., monitoring equipment applying automatic analyzer for the inspection of water quality etc.

**2) Measures for water treatment**

Although a good water source, of which water can adequately be treated by the ordinary method of treatment, is to be selected in principle, advanced methods of treatment etc., may have to be introduced as a measure to be originally undertaken by the utility depending on the trend of the raw water quality.

**(1) Introduction of advanced water treatment**

Advanced water treatment facilities shall newly be introduced or expanded in case a difficulty is currently encountered by the water utility for water treatment by the ordinary method, in case the same trouble is experienced by other water treatment plants using the water from the same water source system, and in case the same incidence is expected due to the condition of the occurrence of pollution, the state of water pollution; the progress in the eutrophication of the lake and impounding reservoir. Moreover, in case a need for advanced water treatment is expected at the existing water treatment plant, it is desirable to provide a lot and ample difference in water levels between facilities for the introduction of advanced treatment facilities.

**(2) Measures for chlorine-resistant pathogens, chlorinated organic compounds and musty odors**

In case there is a fear of invasion of such disease-causing chlorine-resistant organisms as cryptosporidium or giardia in the raw water, a complete removal measure shall be provided including filters, which can remove such organisms, and/or ultra violet ray treatment apparatus, which can inactivate them etc. so that the tap water shall not be polluted.

Additionally, for reduction in such chlorinated organic compounds as trihalomethanes and musty odor, the curtailment in the dosage of pre-chlorination, change in its injection point, the use of an alternative oxidation agent etc. shall also be examined in addition to the introduction of advanced water treatment.

**(3) Measures for water quality accidents**

It is desirable to provide oil removal apparatus, powdered carbon feeders and so forth for prevention of a water quality accident by the invasion of oil, chemicals etc.; and feeders of acid and alkaline agents shall be installed or augmented to cope with change in raw water pH which would adversely affect water treatment. The covers over the filters etc. need to be examined for prevention of the invasion of harmful substances, which float and descend in the air and will adversely affect the water quality.

**3) Measures for water transmission, distribution and water service**

**(1) Maintenance of residual chlorine**

It is imperative to maintain a prescribed amount of residual chlorine even at the tap from the sanitation point of view. However, a great imbalance in the residual chlorine concentration may occur depending on the distance from the water treatment plant, especially, in the case of very large service area. In such an instance, the residual chlorine concentration shall be monitored at not only the plant but also at proper locations in the water transmission and distribution systems, and additional dosing of chlorine shall be made in the water transmission and distribution systems so as to aim at maintenance of residual chlorine.

**(2) Replacement etc. of water distribution mains and water service pipes**

As for water distribution mains and water service pipes, such measures are required as improvement and/or replacement of aged mains and lead pipes, and their cleaning according to a schedule so as to resolve the deterioration of water quality such as red water, turbidity etc. As to the small-scale water supply with a cistern with an effective volume of smaller than 10 $m^3$, its positive management in cooperation with the office of sanitation administration is needed while switching to direct pressure water service is a useful measure.

**On the item 3.;**

While energy saving and prevention of water leakage shall be practiced, proper water pressure shall be maintained so that pleasant water service can be provided.

Respective water utilities shall originally determine the minimum dynamic water pressure, the maximum static water pressure of water distribution mains and the type of water service as targets in accordance with the state of the provision of respective water supply facilities, the progress of urbanization, local geological features etc.; and the standards for the minimum dynamic water pressure, and the maximum static water pressure shall be 150 kPa and 740 kPa respectively.

**On the item 4.;**

Water utilities etc. are required to provide measures for securement of water supply even at the time of such natural disaster or emergency as an earthquake, localized heavy rain, accidental water pollution, terrorism and so forth.

**1) Preparatory and temporary measures**

As for measures for a disaster and an accident, preparatory measures shall be provided in advance to minimize the damage by means of application of an earthquake-resistant mechanism to facilities, provision of a substitute function etc. It is important to provide adequate measures for disasters and accidents, with reference to the local disaster-prevention plan of the community, such as the establishment of a system of emergency water service and temporary restoration, with which early recovery becomes possible, and is acceptable from a citizen's point of view.

**2) Introduction of earthquake-resistant facilities abiding by the Ministerial Ordinance**

As the Ministerial ordinance to establish technical standards was partly revised in March 2008 with respect to the earthquake-resistance of water supply facilities, it clearly defined the earthquake-resistant ability to be possessed by water supply facilities depending on the levels of their importance and the magnitude of the earthquake (See Table 1.2.1).

**Table 1.2.1 Classification of the anti-seismic ability of water supply facilities and the level of their importance**

**The anti-seismic ability of water supply facilities**

| | Level 1 vibration | Level 2 vibration |
|---|---|---|
| Important facilities | Not to harm sound functions | Damage is light not seriously affecting the functions |
| Ones other than the above | Damage is light not seriously affecting the functions | |

Level 1 seismic vibration: Seismic vibration of which probability of occurrence is high during the facilities are in service.
Level 2 seismic vibration: Seismic vibration of the greatest magnitude at the location in question conceivable from the past through the future.

**Classification of the level of the importance of water supply facilities**

| | |
|---|---|
| Important facilities | • Facilities of water intake, storage, raw water transmission, treatment, treated water transmission<br>• Of water distribution facilities, ones of which damage causes serious lateral damages in a high probability<br>• Of water distribution facilities, the service reservoir etc. with the largest capacity in a water supply which does not possess trunk water mains |
| Ones other than the above | • Other facilities than the above |

**On the item 5.;**

**1) Scheduled improvement and replacement**

It is crucially important to carry out the improvement and replacement of water supply facilities on a schedule so as to secure reliable water service through the future.

It is essential to foresee the mid- and long-term need for facility replacement and financial balance applying the asset management method etc., and aim at the optimization and leveling of the quantity and cost of the operation of water supply.

**2) Securement of substitute function and examination of the system for operation and maintenance**

Since the work of improvement and replacement of facilities accompanies the suspension of operation thereof for a certain period, it is required to minimize the influence of such work to the function of the water supply system as a whole by means of providing the substitute function etc. in advance.

At the time of improvement and replacement of facilities, the importance and the ensuing level of operation and maintenance (O&M) shall be taken into account; and it is desirable to synthetically study the life cycle cost and the situation of the operation.

**On the item 6.;**

**1) Need for energy saving**

The environmental issues such as global warming have become the problem to be tackled as priority domestically as well as internationally. Above all, as the water supply utility etc. has a feature as an energy-consuming industry, it is required to actively contribute to the protection of environment by means of such a measure as the reduction in $CO_2$ etc., so it is important to make efforts for more energy saving, introduction of a new energy etc. and curtailment in the consumption of resources.

**2) Specific methods of operation**

As the specific examples, there are raw water transmission, treated water transmission and water distribution by gravity, change to high efficiency and top-runner equipment, inverter control of pumps etc. for energy saving. As for new energy sources, there are solar power, small-scale hydraulic power generation utilizing surplus water pressure, window power etc. Concerning the reduction in consumption of resources, there are the reduction in the chemical dosage thanks to the optimization of water treatment processes, utilization of dewatered sludge cake, increase in efficiency owing to the prevention of water leakage, recycling of wasted construction material and reduction in its disposal and so on; and these methods shall positively be reviewed by the water utility depending on their condition.

**On the item 7.;**

**1) Utilization of the space above the service reservoir**

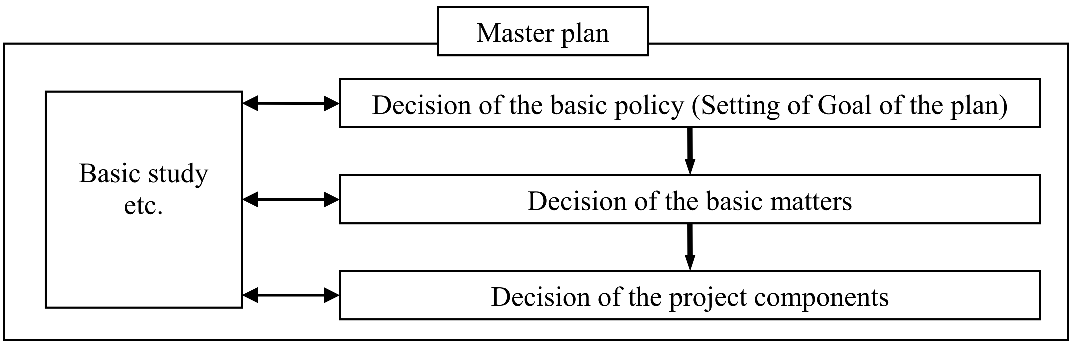
In case the space above the service reservoir is opened to the public as a park or playing ground, or a reservoir is constructed underneath a space, which has been used by another purpose, adequate attention shall be paid to sanitation and not to cause trouble to the normal operation of the water supply facilities.

**2) Materials and equipment for water supply**

Equipment, materials, paint etc. for use in water supply shall be selected based on their safety in terms of sanitation so that they will not adversely affect the tap water quality, for example, elution of harmful substances, taste and odor when they come in contact with water. In addition, the materials shall carefully be chosen so that they will not cause rusting and "red water" by corrosion.

### 1.2.2. Steps for preparation of a master plan

The following are the steps to be taken for preparing a master plan:




**[Interpretation]**

Each water supply utility has its own history, and the size of its facilities, its management system, and its financial position, which are different from those of other utilities. Moreover, geographical features, geological characteristics, such natural condition as the state of water sources, and possibility of the occurrence of a disaster, land use, situation about development of the district, such social condition as attitude of the consumers etc. are different from a society to another to which water supply utilities belong. Given this, it is needed for each water utility by itself to examine a policy suitable to the features of the district, to which it belongs, and prepare a master plan.

**1. Decision of the basic policy**

The basic policy presents the overall goal of the provision of facilities based on mid- and long-term need for replacement and forecast of financial balances so as to sustainably undertake sound utility operation. In other words, the respective water utilities shall carry out studies on the natural and social status, the trend of water demand, the tendency of the yield and quality of water sources, the attitude of consumers, problems related to the existing facilities, and set the design goal for the provision of facilities compatible to the characteristics of the utilities etc.

What's more, it is desirable to quantitatively set the design goal using the PI (performance index) etc.

**2. Basic survey**

The basic survey is a survey to study the basic policy, basic matters and the components of the project.

In case further survey is judged to be necessary for achieving what was determined at respective stages of preparing the master plan, an additional survey shall be undertaken to enrich the project components.

**3. Decision of the basic matters**

Since the basic matters are always the base for providing replacement, ant-seismic measures and reform, expansion etc. when undertaking the provision of any facilities, the design year, the design service area, the design population served, the design volume etc. are determined based on various surveys.

Furthermore, the design year defined herein shall be the mid- and long-term design period including the provision of all the facilities.

**4. Decision of the project components**

Such components of the project as the contents of the facilities to be provided (objective facilities and their size), the implementation schedule and rough cost estimates shall be determined based on various basic surveys including their evaluation, and shall be classified into an appropriate number of subprojects.

**5. Reflection of the consumer's needs and revision of the plan**

At the time of preparing a master plan, it is important to understand the consumer's needs in advance, conduct public hearing for consumers, and make efforts to reflect their opinions. Besides, revision of the plan is needed, if required, in case the surroundings of the plan have changed.

### 1.2.3. Decision of the basic policy and steps for preparation of a master plan

The following matters shall clearly be defined at the time of deciding the basic policy:

1. Matters related to the service area
2. Matters related to the compatibility with a plan at the higher level
3. Matters related to the level of water service
4. Matters related to the measures for disasters and accidents
5. Matters related to O&M
6. Matters related to consideration to the environment
7. Matters related to management of the water utility

**[Interpretation]**

**On the item 1.;**

The service area is the most important matter to the water utility which is an exclusive enterprise in the area, and closely related to the operation of the enterprise in terms of expansion, contraction, merging and abolition of the enterprise. The water utilities shall always make efforts for expansion of water service, and at the same time set a long-term goal based on the understanding of water demand in and outside of the service area, the status of development of the city, and the position of financial management.

**On the item 2.;**

The water utilities etc. need to determine its policy paying adequate consideration to such development plans at the higher level as master plans and so forth of the district and the city it belongs.

**On the item 3.;**

The mission of the water utility is to contribute to the advancement of public sanitation and improvement of living environment by providing abundant clean and inexpensive water. To this end, it is desired that the utility should possess a facility development plan which will enable sufficient water service needed even at an emergency while aiming at safe and reliable water service at the normal times. Furthermore, the utility is required to understand the broad needs of consumers and make efforts to be able to provide more quality water service as demanded by its customers.

**On the item 4.;**

As water service is expanded to a very high level, and the function of cities has become very high, the possible influence to the lives of citizens and city activities caused by the suspension or reduced water service is very great. Therefore, the water utilities shall set their development goal so that influence to the customers is limited to a minimum even at an emergency.

**On the item 5.;**

When establishing the basic policy for the provision of water supply facilities, consideration to O&M is necessary, so the basic policy shall be set in respect to the following matters in the occasion to prepare the plan for the facilities:

(1) Understanding of the work volume required for O&M and the level of technologies, and the proper evaluation of the ability of O&M at present

(2) Establishment of the O&M system taking into consideration the level of the O&M for the future based on the result of (1)

(3) Replacement and O&M taking into consideration the life cycle cost

(4) Provision of facilities with consideration to the ease of water quality control

**On the item 6.;**

As to consideration to the environment, the goal shall be set with a principle to aim at the efficient application of energy, and reduction in the emission of $CO_2$ and pollutants of environment.

**On the item 7.;**

When establishing the basic policy, consideration shall be practiced on the influence given to the financial operation by the matters related to the above items 1 to 6. Namely, as a lot of funds are necessary to accomplish expansion and merging of service areas, service of safe water, strengthening of capability to cope with emergency, enhancement of O&M, scheduled investment is required. For that aim, it is useful to establish efficient development plan based on the prospect of financial balances utilizing the asset management method. The public-private partnership (PPP) shall also be examined for strengthening the management foundation.

### 1.2.4. Basic survey

> The basic survey for the preparation of a master plan shall be carried out in accordance with the following items after understanding the present status:
>
> Additionally, the survey shall be conducted with reference to the study items presented in the respective chapters.

1. Collection and study of basic data necessary for the decision of the service area
2. Collection of data necessary for the determination of the water service volume and study on related plans
3. A survey of the synthetic plan at the higher level, the related plan for the water supply project or the one for bulk water supply project
4. A survey of the natural and social conditions required for the decision of the location and structure of the water supply facilities
5. Collection and study of data on water supply facilities of water utilities of the same size and similar nature and their experience of operation
6. A survey of the possibility of application, yield and quality of various type of water sources
7. Evaluation of the existing facilities to decide the scope and time for the facilities for which improvement or replacement is required.
8. Evaluation of the influence to the environment to prevent the pollution and the protection of the environment

**[Interpretation]**

**On the item 1.;**

When determining the design service area, the natural and social conditions in the administrative area and the future plans related to such aspects shall be grasped; especially, the present status and future prospects of the water demand of each area, which has different land use and industries from the other, shall be studied.

In this case, although there is a need to set the service area as wide as possible considering the importance of the social role of water supply, the degree of difficulty of O&M, economy etc. shall also be studied.

**On the item 2.;**

Although, since the water service volume for the design year is the root of the master plan, the survey shall be undertaken on the following items to rationally determine it, attention shall be paid to the objectivity which is strongly required for the various data to be studied.

**1) Experienced water service volume**

As to the experience of the water service volume by the use category or the size of services, the data for at least past ten years or so shall be collected taking into account whether or not the period is appropriate as well as consideration to the design period. In case there is special water demand, it shall also be studied. For instance, data on population on recreation, water demand from it, water service to ships etc. shall be collected and studied.

**2) Factors related to the fluctuation of water demand by use category**

Data collection shall be conducted for the factor analysis of water demand by use category. “Reference 1-5 Demand estimates by use category” shall be referenced for the details.

**3) Situation of the use of groundwater**

In the districts where groundwater is directly used in addition to the ordinary water supply, the situation of the use of groundwater shall be grasped through a survey on the actual practices. Especially, buildings, which consume a large quantity of groundwater, and the trend of the regulation for the use of groundwater shall also be studied, and their shift to tap water shall be forecast.

**4) Water demand in similar cities**

The trend of per capita per day water demand by use category in cities, of which characteristics, status of development etc. are similar to the city in question, shall be surveyed.

**5) Plan related to water demand**

A survey shall be conducted on the plan on the development of the city, the one on the housing, the one on the location of industries, the one on the provision of sewerage, the regional master plan on the city plan etc.

**On the item 3.;**

Since there is a need to pay attention to the synthetic plan in case such a plan has been made, the contents of the plan, e.g., the long-range prospect on water demand, the basic policy for the provision of water supply and so on shall adequately be surveyed.

**On the item 4.;**

It is desirable for the water supply facilities to be situated where their construction and operation are safe and easy, and the influence of floods and earthquakes is small. To this end, the following items shall be surveyed in respect to the natural and social conditions of the location where the facilities are to be situated:

**1) A survey on the natural condition**

For the survey on the natural condition, Table 1.2.2 is to be referenced.

**2) A survey on the condition related to the location**

For the survey on the condition related to the location, Table 1.2.3 is to be referenced.

**3) A survey on the land use plan**

For the survey on the land use plan, Table 1.2.4 is to be referenced.

**Table 1.2.2 Survey on the natural condition**

| Category | Purpose | Survey Item |
|---|---|---|
| Survey on topography and geology | Decision of location of water supply facilities | Locations of roads, hills, lakes, rivers etc., difference in land elevations, principal bench marks and so on |
| | Judgment on layout and structure of facilities, difficulty of construction, and anti-seismic measures | Foundation, soil quality, groundwater level, existence of faults etc. Note 1) |
| Survey on record of disasters | Existence of past disasters in the proposed site | Scale and damage of disasters by earthquake, tsunami, storm, flood etc. Note 2) |

Note 1) Data shall as widely as possible be collected and sorted on the existing charts of soil quality, soil survey data by boring etc., data on groundwater level, situation of land subsidence etc.

Note 2) Maps of preparedness for earthquake and magnitude of its threat, hazard maps of tsunami, flood, land slide etc. and so forth shall be confirmed.

**Table 1.2.3 Survey on the condition of location etc.**

| Category | Purpose | Survey Item |
|---|---|---|
| Survey on the proposed site for the facilities and its surroundings | Difficulty of construction | Status of road construction and improvement, situation of road traffic, state of local development, shape of houses, ownership of lots, awareness and way of thinking etc. of residents in the surrounding area. |
| Survey related to the existing facilities | Protection of the culture of the local community | Buildings etc. of which preservation is demanded for their historical and cultural values. Note 1) |
| Survey on the habitat of rare fauna and flora | Existence of past disasters in the proposed site | Survey on the habitat of rare fauna and flora in accordance with "Endangered wild animals of Japan (Revised) – Red Data Book" , Ministry of Environment, etc. |

Note 1) Cultural assets possess a value as the symbol of the town, which has been cherished by the residents for a long time, so attention shall be paid to carry out the survey and examination from different angles even of other cultural assets than ones protected by the law so as to apply at the time of providing facilities.

**Table 1.2.4 Survey on the land use plan etc.**

| Category | Purpose | Survey Item |
|---|---|---|
| Survey on the regional land use designation Note 1) | Measures for the regulation on land use | (1) Urban area (Urban planning act: city planning areas)<br>(2) Agricultural area (Law on development of agricultural promotion area: agricultural promotion areas<br>(3) Wooded region (Forest Act: Privately owned forest covered by the regional forest plan, forest reserve)<br>(4) Natural park area (Natural park law: special area, ordinary area)<br>(5) Natural reserve area (Natural Conservation Law: Virgin natural environment reserve area, natural environment reserve area) |
| Survey on cultural assets etc. Note 2) | Protection of cultural assets etc. | National treasures, important cultural properties, historical spots, scenic spots, natural monuments, buried cultural assets (ancient tombs, ruins of residents), world heritages |
| Survey on the development plan etc. Note 2) | Prevention of competition with other development plans etc. | Objective areas under the urban area development project (land reallocation project, new residential urban area development project, industrial estate forming project, urban area redevelopment project etc.), the road and streets plan, the land improvement plan and so forth |

Note 1) A survey shall be conducted on designation of areas, which was imposed on the proposed project site and its surroundings, and the regulated matters of the areas. There are areas covered by the respective laws presented in ( ) of the survey items (1) to (5), designation of areas and respective regulatory matters.

Note 2) There are other cultural assets designated by prefectures than those designated by the nation according to the Law for the Protection of Cultural Properties. It is needed to survey documents, among buried cultural assets, related to the area in question, buried cultural assets, which have yet to be identified by a local history etc.

Note 3) The existence of other project plans in the proposed construction site and its surroundings shall be surveyed.

**On the item 5.;**

The type and quality of water sources, the method of water treatment, the layout of the facilities, the level and experience of operation etc. shall be surveyed on as many existing water supplies with similar characteristics as possible. The result of such a survey will be a reference for the determination of the treatment method suitable for the water quality of the water source, rational layout of facilities etc.

In the case of expansion, a detailed survey shall be carried out on the existing facilities including reevaluation of their capacity so that the new facilities can function together with the existing ones as an organic body.

- Water source
  - River water
    - River water (Natural flow)
    - Lake water (Natural flow)
    - Impounding reservoir water (including discharged flow)
  - Groundwater
    - Infiltrated water
    - Shallow groundwater (Groundwater in the aquifer shallower than the first impermeable layer)
    - Deep groundwater (Groundwater in the aquifer deeper than the first impermeable layer)
  - Seawater, brackish water, rainwater
    Water supplied from other water utility

**On the item 6.;**

Water sources for water supply are classified as follows:

Surface water, especially the surface water of the river has characteristic to be strongly affected by precipitation.

Of groundwater, the pressurized deep groundwater is a stable water source within a range of pumpage since it is rainwater stored in the groundwater basin for a long time as the seasonal fluctuation of precipitation is absorbed.

**1) Yield of water**

**(1) In the case of surface water**

［1］Hydrological survey

Collecting data on the hydrological surveys at least for the recent ten years in the country and the prefectures, the flow, water level etc. throughout the year shall be surveyed. Especially, since it is indispensable to understand the flow and water level at the time of drought, it is desirable for the experience with the existing maximum drought etc. to be surveyed in consideration of the characteristics of the water source area based on the long-term fluctuation of precipitation.

**(2) In the case of groundwater and infiltrated water**

Existing data on the strata and groundwater and infiltrated water shall be collected by means of existing wells etc., and aquifers, water veins and strata structures shall be studied by means of electric prospecting or seismic wave prospecting if needed, and subsequently pumping tests shall be conducted by means of providing a test well or by the use of the existing wells.

**2) Water quality**

The purpose of the water quality survey of water sources is primarily to examine whether or not the water source quality is suitable from the present through the future, and secondarily to judge what water treatment method should be selected.

**On the item 7.;**

The evaluation of the existing facilities shall be undertaken to examine the safety of water quality, quantitative reliability, securement of proper water pressure, O&M, upkeep management etc. on all the facilities from the water source facilities through the tap so as to achieve the design goal, clearly show the matters to be improved during the design period, and contribute to the decision of components of the project.

The specific items, for which examination and evaluation shall be conducted on respective facilities, are presented in Table 1.2.5.

**Table 1.2.5 Survey on the conditions of location**

| Category of facility | Items of survey and examination | |
|---|---|---|
| | Common item | Specific item |
| Water source and storage facilities | • Fall in function due to aging<br>• Anti-seismic nature | Decline in intake capacity due to the change in the river bed and the attachment of such organisms as golden mussels on the inside of pipe etc. |
| Intake and raw water transmission facilities | | Occurrence of taste and odor due to deterioration in raw water quality |
| Water treatment facilities | | Trouble of bad water and drop in conducting ability due to rusting etc. inside the water mains, increase in water leakage, condition of flexible expansion joints due to uneven subsidence etc. |
| Facilities of treated water transmission, distribution and service | | Out-of-date status following the technological advancement, advanced state of monitoring and control owing to strengthening of the turbidity control etc. |
| Instrumentation | | Decline in intake capacity due to the change in the river bed and the attachment of such organisms as golden mussels on the inside of pipe etc. |

**On the item 8.;**

Since the construction of water intake, storage facilities etc., wastewater from the water treatment plant, noise and vibration of pumps in operation etc. may potentially cause adverse effects to the environment of the surroundings, environmental impact evaluation shall be carried out for the prevention of public nuisance and the protection of the environment if required.

### 1.2.5. Decision of basic matters

When preparing a master plan, the basic matters of the plan shall be clarified in accordance with the following items:

1. Design year
2. The design year is the objective time period for the master plan, so the point of time 10 to 20 years ahead of the time of preparing the plan.
3. Design service area
4. It is an area where distribution mains are laid, and water is served by the design year, and determined based on a wide area point of view.
5. Design population served
6. It is determined based on the population estimate in the administrative area.

7. Design water service volume
8. It is as principle determined based on the water demand by water use category. As for the bulk water supply utility, the design bulk water flow shall be determined based on the demand estimate from the recipient utilities as a whole, or the total of the design water service volumes of the recipient utilities.

**[Interpretation]**

**On the item 3.;**

The design population served is obtained as the product of the population in the design service area by the design percent of population served to the former. The population of the design service area is set as the balance of the estimate of population in the administrative area less the estimate of the population outside the design service area.

Design population served = Population in the design service area
×Design percent of population served to the former

Population in the design service area = Estimate of population in the administrative area
－Estimate of the population outside the design service area

It is desirable for the estimate of population in the administrative area to be in conformity with the basic plan prepared by the local public body etc. and the regional water supply development plan.

The estimate of the population outside the design service area and the design percent of population served to the population in the design service area shall be determined based on a synthetic examination of the past experience, the water supply facilities development plan and so forth.

**On the item 4.;**

The design water service volume shall be computed in accordance with Article 2 (Basic data required for determination of the water service volume) of 1.2.4 Basic survey and Article 3 (Design population served) of this clause etc.

The design water service volume, which is determined based on the computation of the design daily average water service volume or the design per capita per day water consumption, will decide the outline of the master plan, and is a factor which will give a large impact to the future operation of the utility. Therefore, the respective utilities are required to set it to echo such local characteristics as the future social and economic trend, the tendency of the nature of the city and its development etc. also based on full understanding of the consumer’s needs.

Namely, the estimate of water demand (demand forecast) such as the design daily average water service volume or the design per capita per day water consumption is necessary for the determination of the design water service volume. When estimating the design water service volume, it shall be kept in mind that such changes in the water demand structure as the trend of the population served, such factors as water saving and water recycling, which influence the water demand, the use of groundwater etc. are properly and rationally reflected.

Furthermore, although the estimate is in general made for the entire service area of the water utility, it is often needed to prepare plans for proper layout of water distribution facilities, the provision of trunk distribution mains network etc. based on the estimates by district. As such, it is also considered necessary to make estimate by district, where such a land use plan as the designated land use district etc., or district, where water distribution blocks are set.

**1) Estimate of the water service volume**

Estimate of the water service volume stands for estimating water consumption (revenue water).

Although, in principle, it is estimated by water use category, it is estimated by the size of water service (connection) in case consumption figures by water use category are unavailable.

The water use flow by water use category shall be estimated for such respective uses as water for living, water for business and trade, industrial water, and other uses for the future.

**(1) Computation based on the daily average water use by use category or the size of service**

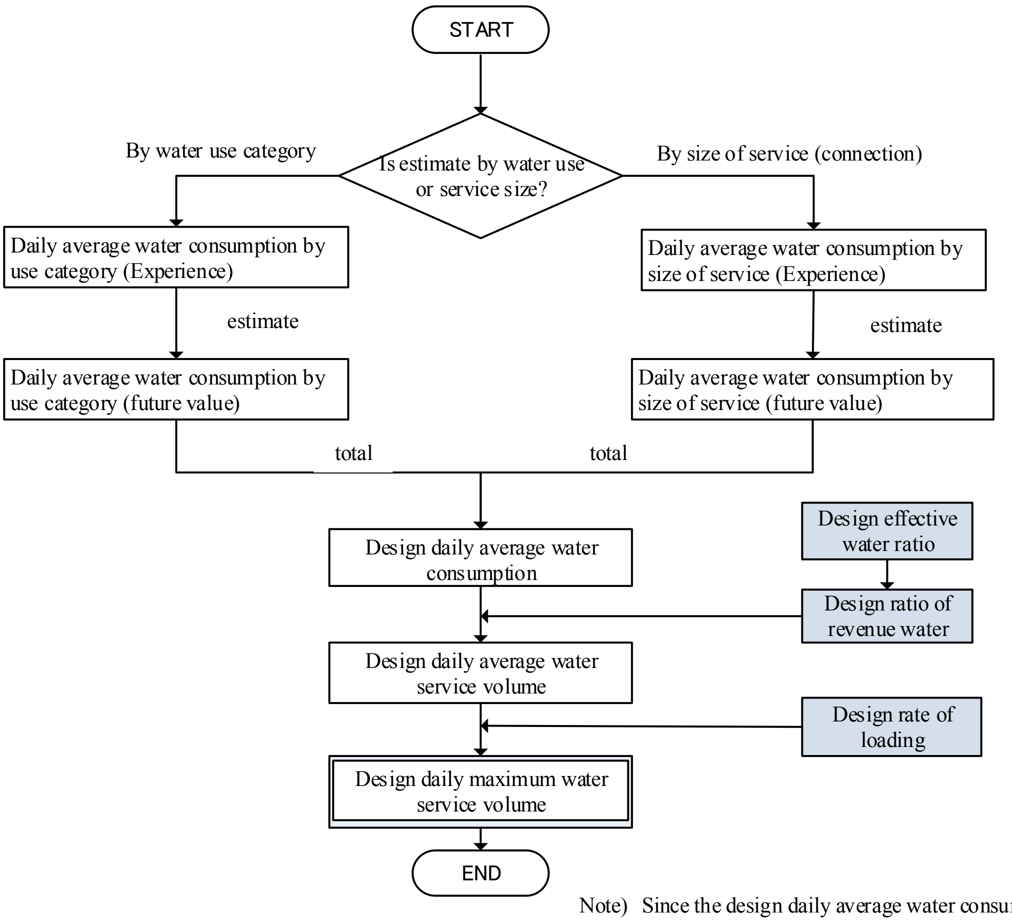
General steps of computation of the design water service volume are illustrated in Figure 1.2.5.

Effective water ratio = Effective water／water service volume

Design ratio of revenue water = Design effective water ratio － non-revenue water ratio
(where non-revenue water ratio = non-revenue water／water service volume)

Design daily average water service volume
= Design daily average water consumption／Design ratio of revenue water

Design daily maximum water service volume
= Design daily average water service volume／Design rate of loading




Note) Since the design daily average water consumption is generally estimated based on experienced values of the average water consumption by use category (size of service), a procedure to compute the daily average daily water consumption based on the design ratio of revenue water is presented here.

**Figure 1.2.5 General steps for computation of the design water service volume**

[1] Design effective water ratio

The effective water ratio is an indicator which shows whether or not the water, served through water supply facilities and water service products, is used effectively. Although the design effective water ratio is determined with reflection of the development plans for water distribution and service etc., it is desirable to aim at as high a value as possible taking into consideration the conditions related to the future plan for reduction in water leakage and so forth. As the effective water ratio is affected by the situation of water distribution control and block-wise division of the distribution system, the extent of direct pressure water service, the magnitude of the aging of facilities etc., it shall be determined with consideration to such factors.

[2] Design rate of loading

The rate of loading indicates the magnitude of variation in the water service volume; changes by the size of the city; and fluctuates according to the nature of the city, the meteorological conditions etc. The daily maximum water service volume is largely affected by the situation of water use depending on the day of week and weather, so it cannot be said that it embodies chronological nature. Thus, when setting the rate of loading, the status of the respective cities shall be examined while taking into adequate consideration the condition of fluctuation related to the past experience, weather, drought etc.

The experience of the size of the city and the rate of loading is illustrated in Figure 1.2.6

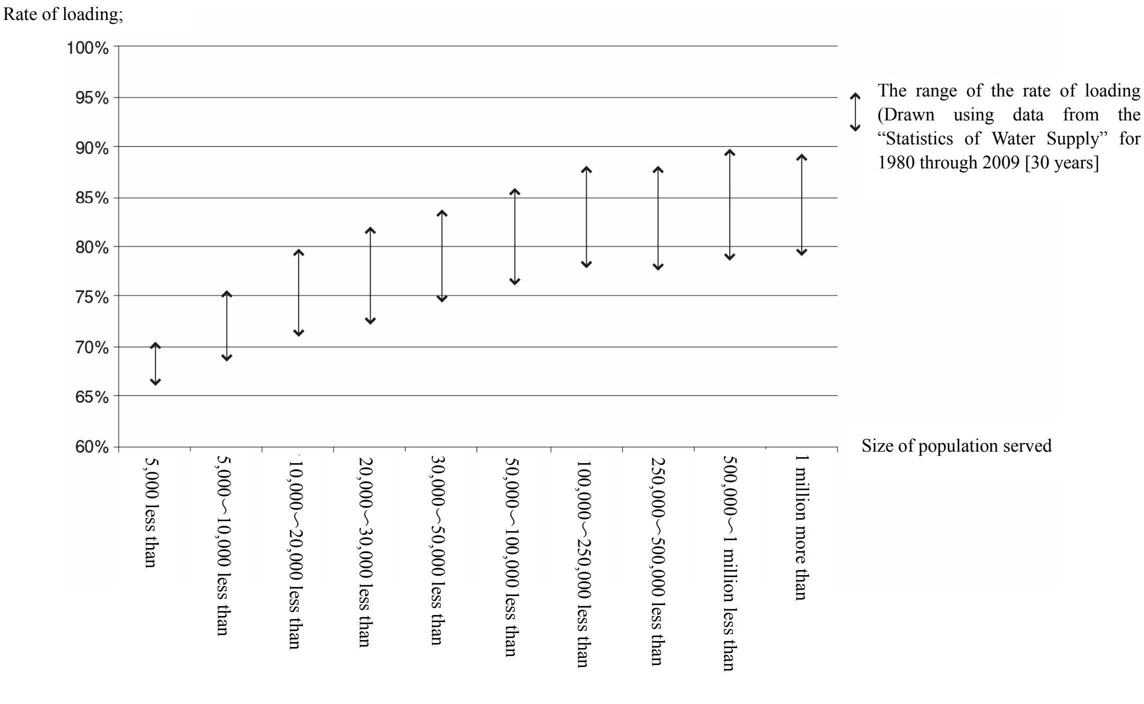



**Figure 1.2.6 Experience of the size of the city and the rate of loading**

### (2) Computation based on per capita per day average water consumption

The design daily average water service volume can also be computed based on per capita per day average water consumption in case the components of water consumption and other basic data have not been provided.

Design daily average water service volume
= Design per capita per day average water consumption × Design population served

**2) Estimate of water demand**

As main methods of the estimation of future water demand, there are [1] estimation by chronological trend analysis; [2] estimation by multiple regression analysis; [3] estimation by factor analysis; [4] estimation by analysis by the use purposes; and [5] other methods of estimation (multivariate analysis method, system dynamics analysis etc.)

What's more, when selecting an estimation method, it is important to employ well suitable method after comparison of some number of methods.

### 1.2.6. Decision of the components of the project

> For the decision of the components of the project, the scope, work schedule, rough cost estimate etc. of the project shall clearly be identified taking into account the integration of facilities as a whole.

**[Interpretation]**

When determining the components of the project, consideration shall be made so that the volume, capacity etc. are well balanced between facilities; that there is no idle part of facilities from the view point of capacity of the facilities as a whole; and that the facilities can meet without significant surplus or deficit the water demand up to the design year in regard to the growth in the demand.

The timing of the implementation of the respective projects shall be determined based on the actual working capacity of the facilities considering the priority and urgency of respective facilities, temporary lowering of capacity of the facilities due to the improvement or replacement work and so forth.

Furthermore, financial aspects shall also be examined through the preparation of a financial plan based on the cost of the provision of respective facilities and their time of implementation so as to examine if there is a financial difficulty, and, at the same time, carry out the evaluation of the project.

**1. Components of the project**

The components of the project are largely divided into the expansion plan mainly consisting of the expansion of facilities, the replacement plan mainly for the improvement and replacement of facilities, and the plan (other plans) for such a software-type scheme as the operation of the utility. The components of the project become so extensive as the following; and they are expected to raise the reliability and safety of water supply facilities as they mutually function in coordination.

**1) An expansion plan**

An expansion plan may contain new construction of water transmission and distribution mains, service reservoirs etc., new construction or strengthening of a water treatment plant, development of a new water source, provision of facilities for receiving bulk water and so on.

**2) A replacement plan**

A replacement plan may accommodate such large variety of projects as provision of water treatment facilities, facilities of raw water transmission, treated water transmission and distribution, an integrated system of water management from the intake through distribution, instant collection of water quality data, provision of a telemeter and remote control system for remote operation of unattended facilities and so on.

### 3) Other plans

Adequate examination is required to accurately understand customer's needs, improve the level of water service, strengthen and establish the foundation for utility operation. For that purpose, examination of the efficient provision and O&M of facilities together with such operations as management, clerical work, personnel management, business promotion etc. as one body is needed. For example, such operations include the optimization of clerical work and technical management by the introduction of the IT, automatic water meter reading, the mapping system and so on.

## 1.2.7. Explanation and public announcement to consumers

| |
|---|
| When making explanation and public announcement to consumers, the need, benefits, profitability etc. of the project shall be clarified. |

## [Reference 1.3] Examples of planning of a master plan

As an example of planning of a master plan for a water supply project, the water supply project of A city is presented as a model.

### 1. Outline of A City

### 1) Social condition

The city, as the central city in the XX plain, has a present population of XX thousand, where the agricultural industry in its outskirts, fishery and XX industries prosper. In and around 19XX when the preceding town was incorporated as a city, its population was XX thousand, which rapidly grew by an increment of XX persons per year from FY XXXX through FY XXXX. The city's built-up area accordingly expanded quickly. However, the population has been leveled off in the recent years.

### 2) Natural and geophysical conditions.

The city is situated at the mouth of XX river in the XX plain. Since the area upstream of XX river is a prominent area of heavy snowfall, where the annual precipitation amounts at XXXX mm, the flow in the river is relatively stable. The A dam was built on this river, which enables the abstraction of XXX,XXX $m^3$/day.

### 2. Outline of the water supply

### 1) History

The water supply of the city was founded in XXXX. Its water source is the surface water of XX river. The design year was set at FY XXXX; the service area was the urbanized area of the city at that time; the design population served as XX thousand persons; and the design water service volume was XX,XXX $m^3$/day.

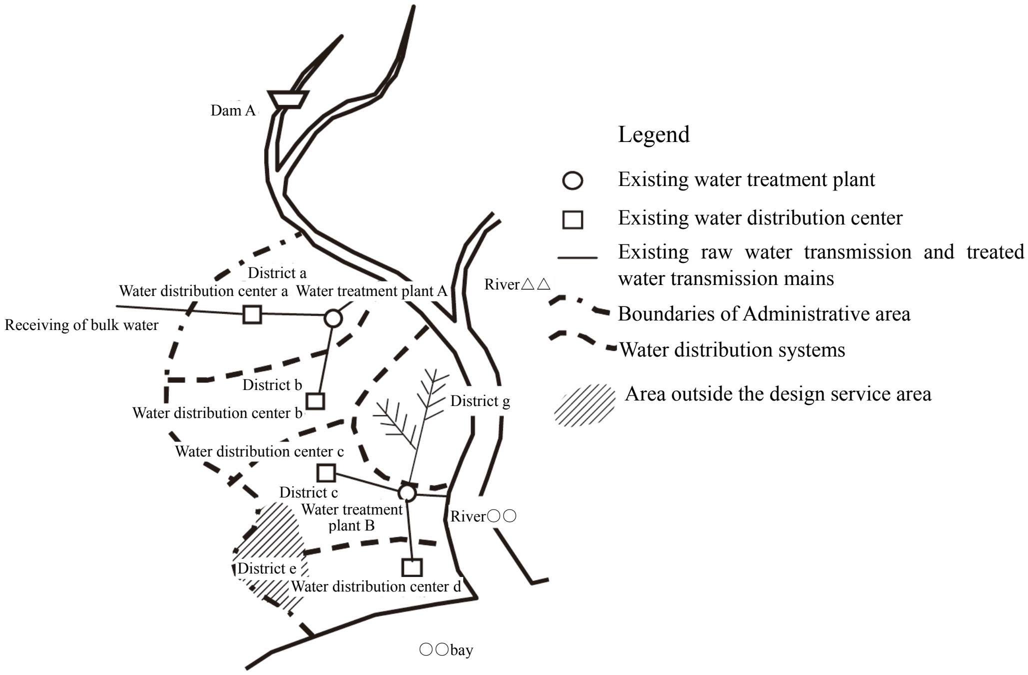
Thereafter, the plan was revised in FY XXXX and FY XXXX to meet the increase in water demand due to the expansion of the urbanized area and the growth in population.

### 2) Present status of water service

The service area, population served, water service volume etc. as of end FY XXXX are presented in Reference Figure 1.3.1 and Reference Table 1.3.1.

**Reference Table 1.3.1 Present status of water service (FY XXXX)**

| | |
|---|---|
| Population in the administrative area | XXX,XXX persons |
| Population in the service area | XXX,XXX persons |
| Population served | XXX,XXX persons |
| Population served as % of population in the administrative area | XX.X % |
| Number of households served | XX,XXX households |
| Number of services | XX,XXX services |




**Reference Figure 1.3.1 Outline of A city's water supply facilities**

**3) Outline of facilities**

**(1) Water sources**

Natural river water and water from the impounding reservoir

Quantity of the vested water right XXX,XXX $m^3$/day

**(2) Water intake and raw water transmission facilities**

○○○………

**(3) Water treatment facilities**

| | Water treatment plant |
|---|---|
| Plant A | XX,XXX $m^3$/day |
| Plant B | XX,XXX $m^3$/day |
| Total | XX,XXX $m^3$/day |

### (4) Treated water transmission and distribution facilities

a. Capacity of service reservoirs

| | Capacity of service reservoirs |
|---|---|
| Water treatment plant B | X,XXX $m^3$ |
| Water distribution center a | XX,XXX $m^3$ |
| | ⋮ ⋮ |
| Total | XX,XXX $m^3$ |

b. Lengths of treated water transmission and distribution mains

Treated water transmission mains……….Pipe diameter XXX mm – XXX mm
Length XXXX m
Distribution mains………………………. Pipe diameter XXX mm – XXX mm
Length XXXX m
Distribution submains……………………Pipe diameter XXX mm – XXX mm
Length XXXX m

## 3. Problems related to the present status

As, in addition to the traditional fishery and sea-food processing industries, the high-tech industry is prospering in the city, the life style of citizens is transforming from the traditional fishing-and-agricultural-village style to an urban style. The water demand is slightly declining due to the stagnant growth of population and the customary practice of water saving.

As the aging of the distribution mains in the old towns of the city progresses, a large quantity of water leakage is occurring and the trouble of red water is frequent among the city's water supply facilities. As such, the replacement of the distribution mains is required.

The water quality of △△ river, which is a tributary of ○○ river, is deteriorating due to the delay in the progress of the provision of the sewerage. Because of this, as the raw water quality at the water treatment plant, which intakes water right downstream of the confluence of △△river with ○○river, is getting worse, consumers complain about the taste and odor of the tap water in summer in the service area, measures to tackle the problem shall be taken quickly.

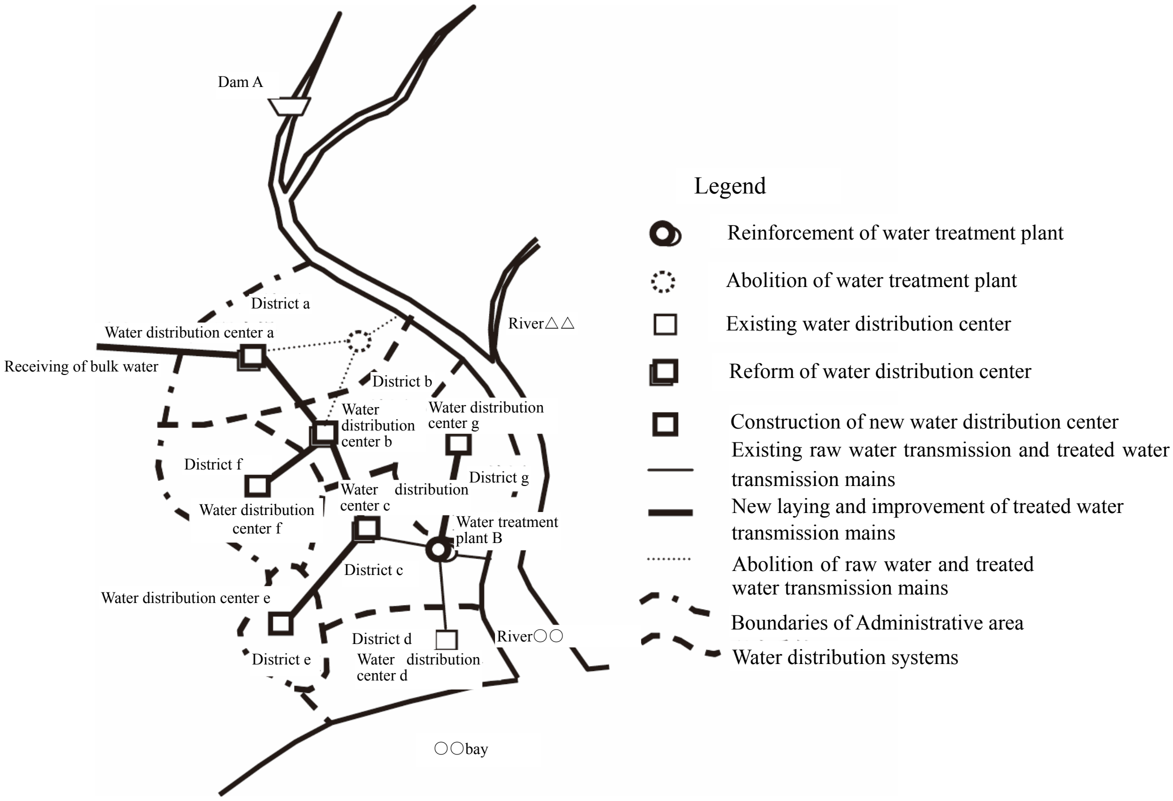
The off-shore earthquake, which hit the city in XXXX, caused a heavy damage to the water supply facilities in the north of the city. In an area, the lives of citizens were paralyzed because of the suspension of water service for good half a year. According to the performance index (PI), the ratio of water mains, which have been given earthquake-resistant measures, is as low as XX percent. Besides, in the river ○○basin there are a number of chemical factories, and accidental water pollution often occurs. Especially, last year, as cyan was discharged from ○○chemical plant, and water intake was forced to be stopped for about ○hours, trouble was brought about as water service was suspended or reduced in and around the elevated area. Given such an experience, the provision of water supply facilities to cope with an emergency needs to be undertaken.

Furthermore, since almost half of the staff will be retiring for the coming five years, the maintenance of technical capability in future will be an important issue.

## 4. Basic policy

### 1) Areas to be served by water supply

The existing design service area shall be expanded so as to accommodate the District e in it (See Reference Figure 1.3.2).




**Reference Figure 1.3.2 A schematic of A City water supply facilities development plan**

**2) Relationship with the plan at the higher level**

The provision of water supply facilities will be carried out taking into consideration the plan for “the formation of the town for safe lives” at which A city is aiming in its basic development plan. The city will continue to receive XX,XXX $m^3$/day of water from the ○○bulk water supply utility in accordance with the plan for provision of regional water supply.

**3) Level of water service**

a. Aged water mains, which cause an accident, water leakage and red water, will be replaced.

b. Advanced processes of water treatment will be introduced aiming at prevention of water with taste and odor.

c. Direct pressure water service will be extended up to medium-story buildings. Additionally, the city will positively administer the sanitary upkeep of cisterns at homes.

**4) Preparedness for emergencies**

a. To secure water service at the times of water pollution etc., mutual interconnection water mains will be provided so as to enable the backup between water treatment plants, and augment the capacity of service reservoirs up to 12 hours of the daily water service volume.

b. To secure water service when an earthquake hit, earthquake-resistant measures will be provided on the raw water transmission, treated water transmission and distribution mains. In addition, emergency water service points will be provided.

### 5) O&M

a. To make easy the management of water pressure and quantity, a water distribution center will be built, and the distribution systems will be reorganized.

b. The management equipment will be provided so as to make efficient O&M of the water treatment plant and water management.

### 6) Consideration to the environment

New energy sources such as small-scale hydro-power, solar power etc. will be utilized.

### 7) Business management

a. Water supply facilities will be maintained in healthy condition, and business operation will be made sound from an asset management point of view.

b. To strengthen the management foundation, public-private partnership for the O&M of the water treatment plant (third party commission) etc. will be considered.

## 5. Basic matters

### 1) Design service area

The entire administrative area will become the design service area.

### 2) Design year

The design term of project implementation will be 15 years from FY XXXX to FY XXXX.

### 3) Design population served

The design population served will be set at XX,XXX persons as a result of the utility's own population forecast with reference to the future population estimate in the A city's comprehensive development plan.

### 4) Design water service volume

The design daily maximum water service volume is set at XXX,XXX $m^3$/day based on the estimate by means of the estimation method by use category.

## 6. Determination of components of the project

Based on the evaluation of the existing facilities, the components of the project and its work schedule are determined as follows taking into account the balance of the facilities as a whole, compatibility with the financial plan, the priorities of the respective facilities etc. (See Reference Figure 1.3.3.).

### 1) Plan for expansion ………………Project cost XXX million yen

### (1) Expansion of the service area

a. Laying of new distribution mains………Pipe diameter XXX mm –XXX mm
Length XXXX m

b. Laying of new treated water transmission mains
………Pipe diameter XXX mm; Length XXXX m

The pipe materials used are ductile iron pipe with anti-seismic joints, welded steel pipe for the diameter of more than 75 mm; polyethylene pipe with fusion joints, and poly-vinylchloride pipe with RR long joints for the diameter of 50 mm.

c. Construction of a new water distribution center
e District……Capacity of the service reservoir X,XXX $m^3$

**(2) Abolishment of the water treatment plant**

The water treatment plant A will be abolished since the area in charge of the plant will be served with water to be received from a bulk water supply utility.

**2) Plan for the provision of water treatment facilities**

……..Project cost XXX million yen

**(1) Introduction of advanced water treatment methods**

An advanced water treatment method will be introduced in the water treatment plant B so as to eliminate water with taste and odor.

**(2) Improvement of the control system of the water treatment plant**

The instrumentation system of the water treatment plant B will be replaced. The power receiving system will be duplicated.

**3) Plan for provision of water distribution facilities**

…………….Project cost XXX million yen

**(1) Replacement of aged water mains**

a. Replacement of asbestos cement pipe with ductile iron pipe with anti-seismic joints…….
Pipe diameter XXX mm –XXX mm,
Length XXXX m

b. Replacement of cast-iron pipe with ductile iron pipe with anti-seismic joints…….
Pipe diameter XXX mm –XXX mm, Length XXXX m

**(2) Expansion of area for direct pressure water service**

Booster pump stations will be installed in Districts c and d; and distribution mains will be improved or replaced……………

Pipe diameter XXX mm –XXX mm, Length XXXX m

**(3) Augmentation of service reservoirs**

……To increase by XX,XXX $m^3$

Construction of new service reservoirs e, f and g XX,XXX $m^3$

**(4) Mutual interconnection of treated water transmission mains.**

a. Between service reservoirs a and b…….. Pipe diameter XXX mm
Length XXXX m

b. Between service reservoirs b and c…….. Pipe diameter XXX mm
Length XXXX m

c. Remodeling of water distribution center ………Reservoirs a, b and c
(Along with the remodeling, power generation equipment will be installed.)

Unit: '000million yen

| Name of project / Year | | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | Project cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plan for expansion | Expansion of service area; | | | | | | | | | | | | | | | | YY |
| | Abolition of a water treatment plant | | | | | | | | | | | | | | | | |
| Plan for provision of water treatment facilities | Introduction of advanced water treatment method | | | | | | | | | | | | | | | | YY |
| | Improvement of control equipment of water treatment plant | | | | | | | | | | | | | | | | |
| Plan for provision of water distribution facilities | Replacement of aged water mains | | | | | | | | | | | | | | | | YYY |
| | Expansion of area for direct pressure water service | | | | | | | | | | | | | | | | |
| | Augmentation of capacity of service reservoirs | | | | | | | | | | | | | | | | |
| | Mutual interconnection between treated water transmission mains | | | | | | | | | | | | | | | | |
| | Optimization of service area | | | | | | | | | | | | | | | | |
| Plan for provision of telemeter control system | | | | | | | | | | | | | | | | | YY |
| Plan for provision of earthquake-resistance for facilities | Earthquake-resistance for raw water transmission mains | | | | | | | | | | | | | | | | YY |
| | Earthquake-resistance for water distribution mains | | | | | | | | | | | | | | | | |
| | Provision of emergency water service points | | | | | | | | | | | | | | | | |
| | Consideration to provision of interconnection mains between neighboring water utilities | | | | | | | | | | | | | | | | |
| Examination of utilization of new energies | | | | | | | | | | | | | | | | | YY |
| Project cost | | YY | | | | | YY | | | | | YY | | | | | YYYY |

**Reference Figure 1.3.3 An example of work schedule**

**(5) Reorganization of the water distribution systems**

a. The Districts a, b and f, which are currently supplied from water treatment plant A, will be served with water received from the bulk water supply utility.

b. A new service reservoir will be built in the District g to which water from the water treatment plant B is currently supplied. ………...
Capacity of the service reservoir XX,XXX $m^3$

c. A water distribution center will be provided in the District f, which is elevated, to make it an independent service area………….
Capacity of the service reservoir XX,XXX $m^3$

d. Provision of water distribution mains
Pipe diameter XXX mm –XXX mm, Length XXXX m

**4) Plan for provision of telemeter control system**

…………Project cost XXX million yen

**5) Plan for provision of earthquake-resistance for facilities**

…………Project cost XXX million yen

**(1) Earthquake-resistance for raw water transmission mains**

The raw water transmission mains will be made earthquake-resistant by means of the pipe-in-pipe method. …………. Pipe diameter XXX mm –XXX mm, Length XXXX m

**(2) Earthquake-resistance for water distribution mains**

Replacement of important distribution mains with mains with earthquake-resistant pipes

Pipe diameter XXX mm –XXX mm, Length XXXX m

**(3) Provision of emergency water service points**

Earthquake-resistant tanks will be installed in a park etc. so as to provide emergency water service points…….Capacity XXX$m^3$, at XX points

**(4) Examination of mutual assistance between neighboring water utilities**

The provision of interconnection mains between neighboring water utilities, execution of training for the preparation for an emergency etc. will be studied and discussed.

**6) Examination of the consideration to the environment**

In addition to the provision of covers on filters in the water treatment plant, the utilization such new energy as small-scale hydraulic power and solar power will be discussed.

**[Reference 1.5] Estimation of water consumption by use category**

Estimation of water consumption by use category is conducted by classifying water consumption by use category, and by estimating it for each use category. In addition, for the classification purpose, the table of standard classification by water use category as shown in Reference Table 1.5.1 shall be referred to. The procedure of the standard estimation by this method is presented in Reference Figure 1.5.1.

**Reference Table 1.5.1 Standard classification of water use categories**

| Primary classification | Secondary classification | Tertiary classification | Note |
|---|---|---|---|
| Water for living | For ordinary homes | For housework | Solely for housework (ordinary residence, apartments, common use taps) |
| | | For housework cum business | In addition to housework, used also for business (house attached to a shop) |
| Water for business and trade | For public offices | Public agency | School, hospital, organization of national and local public body excepting factories |
| | | For the public | Public toilets, public fountains for drinking, fountains |
| | | For other uses | Non-profitable facility other than public agency and not classified into other use categories |
| | For schools | For school | School, kindergarten, vocational school |
| | For hospital | For hospital | Hospital, maternity hospital, clinic etc., |
| | For office | For office | Company, other corporate body, organization, office for personal use |
| | For businesses | For businesses | Hotel, Ryokan, department store, supermarket, ordinary business without residence, restaurant, wedding hall, sauna, exclusive use for car washing for bus and taxi company, theater, recreation facility etc. |
| | | For public bath | |
| Water for factory | For factory | For factory | |
| Others | For other uses | For other uses | Water service for ship, water supply to other water utility |
| | | | Water used in water supply utility, under-registration of water meter etc. |

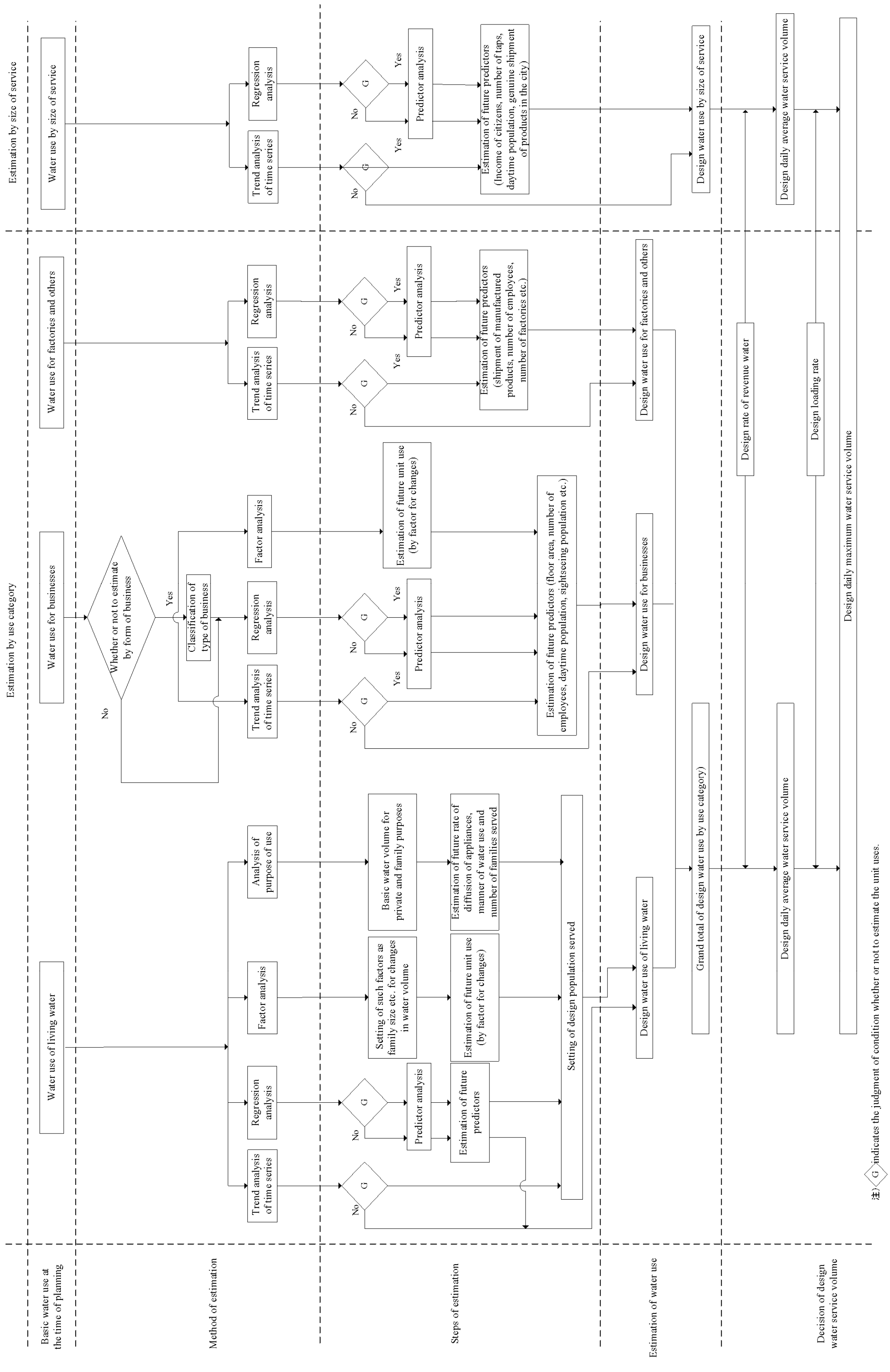
The trend of the family size and per-capita per-day consumption of water for living is presented in Reference Table 1.5.2, and per-capita per-day water consumption by family size is shown in Reference Table 1.5.3. An example of a survey on the basic water consumption by purpose of use is given in Reference Table 1.5.4. An example of a survey on the unit use by form of operation is presented in Reference Table 1.5.8.

**Reference Table 1.5.2 Family size and the level of per capita per day water use**

| City | FY | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| G City | Family size (persons/household) | 3.18 | 2.92 | 2.86 | 2.74 | 2.64 | 2.54 | 2.48 | 2.42 | |
| | Per-capita-per-day water use (L/capita･day) | 231 | 214 | 247 | 265 | 260 | 259 | 244 | 235 | Unit use for living |
| | Per-capita-per-day water use (L/capita･day) | 318 | 320 | 344 | 353 | 335 | 330 | 315 | 293 | Revenue water per capita per day |
| A City | Family size (persons/household) | 2.75 | 2.69 | 2.62 | 2.48 | 2.35 | 2.22 | 2.13 | 2.06 | |
| | Per-capita-per-day water use (L/capita･day) | 338 | 321 | 335 | 364 | 366 | 356 | 340 | 322 | |
| B City | Family size (persons/household) | 3.06 | 2.82 | 2.70 | 2.50 | 2.36 | 2.21 | 2.10 | 2.02 | |
| | Per-capita-per-day water use (L/capita･day) | 193 | 206 | 228 | 263 | 266 | 259 | 254 | 253 | |
| F City | Family size (persons/household) | 3.35 | 3.11 | 2.68 | 2.51 | 2.39 | 2.30 | 2.22 | 2.15 | Statistics Year Book (City's features) |
| | Per-capita-per-day water use (L/capita･day) | — | — | — | — | — | 264 | 248 | 238 | Statistics Year Book (Housework use/population served) |
| C City | Family size (persons/household) | — | 2.95 | 2.91 | 3.10 | 2.57 | 2.43 | 2.32 | 2.22 | |
| | Per-capita-per-day water use (L/capita･day) | 265 | 259 | 242 | 217 | 224 | 225 | 223 | 223 | Water volume for housework use |
| D City | Family size (persons/household) | 2.77 | 2.72 | 2.68 | 2.55 | 2.41 | 2.33 | 2.24 | 2.16 | Population served/number of households served |
| | Per-capita-per-day water use (L/capita･day) | 128 | 159 | 178 | 194 | 202 | 205 | 204 | 205 | Water volume for housework use |
| E City | Family size (persons/household) | 3.07 | 2.81 | 2.77 | 2.65 | 2.50 | 2.36 | 2.24 | 2.15 | |
| | Per-capita-per-day water use (L/capita･day) | 189 | 197 | 225 | 259 | 260 | 263 | 249 | 245 | Unit use for living |

**Reference Table 1.5.3 Per capita per day water use by family size (L/capita･day)**

| City \ Number of persons | 1 person | 2 persons | 3 persons | 4 persons | 5 persons | 6 persons | Average | Note (Year of survey); |
|---|---|---|---|---|---|---|---|---|
| G City | 260 | 267 | 244 | 196 | 179 | 182 | 237 | FY 2009 |
| B City | 253 | — | — | — | — | — | — | As the data is not added up by family size, the figures are induced from the average. (FY 2010) |
| D City | 241 | 228 | 209 | 182 | 169 | 164 | 215 | FY 2010 |
| E City | 245 | — | — | — | — | — | — | FY 2010 |




**Reference Figure 1.5.1 Standard steps for estimation of water use by use category and one by size of service**

**Reference Table 1.5.4 Basic water use by use purpose**

| Classification / City | Private purpose (L/capita･day) | | | Family purpose (L/family・day) | | | | | Note |
|---|---|---|---|---|---|---|---|---|---|
| | Bathing | Bathing | Hand wash・face | Bath (water-pour type) | Laundry | Kitchen | Water sprinkling | Others | |
| E City | 28 | 50 | 7.7 | 115 | 147 | 157 | 17 | 19 | FY 1997 |
| F City | 85 | 43 | — | 259 | 208 | 170 | 29 | 19 | FY 1998 |
| G City | 42 | 52.7 | 27 | 136.6 | 163.8 | — | 33 | — | FY 1988 |
| I City | 40 | 31 | 30 | 160 | 180 | 129 | — | 54 | FY 1995 |
| H City | 39 | 36 | 20 | 194 | 160 | 76 | — | 80 | FY 1995 |

**Reference Table 1.5.8 Unit use by the form of operation**

| Classification / Type | | Government building・office | School | Hospital | Hotel | Restaurant | Department store | Super market |
|---|---|---|---|---|---|---|---|---|
| Water use volume | Per floor ($L/m^2$・day) | 8.1 | 8.3 | 22.4 | 24.2 | 205 | 21.8 | 12.4 |
| | Per employee (Guest) (L/capita・day) | 127.0 | 40.0 | — | — | 57.8 | — | — |
| | Per bed (L/bed・day) | — | — | 1290 | 2002 | — | — | — |
| Note | | Including a few tenants | Per primary, middle, high school staff + student excluding swimming pool use | | | | | |

Prepared based on an excerpt from Handbook of heating, air-conditioning and sanitary engineering, 11th edition, Volume III, p.III-77and 80, The heating, air-conditioning and sanitary engineering of Japan:

LEGEND

| City | Design population served (10,000 persons) |
|---|---|
| A City | 1240 |
| B City | 275 |
| C City | 232 |
| D City | 215 |
| E City | 145 |
| F City | 147 |
| G City | 67 |
| H City | 10 |
| I City | 7 |

(JWWA : Statistics of Water Supply 2009)

## 1.3. Basic Matters for Designing

### 1.3.1. General

Water supply is a system composed of facilities of water intake, water storage, raw water transmission, water treatment, treated water transmission, water distribution and water service covered by the fields of civil engineering, architecture, mechanical engineering, electric engineering, instrumentation etc., and they function as a unity. Therefore, designing shall be carried out making harmony among facilities as a whole and taking into consideration the following matters so as for respective facilities to achieve required functions:

1. To be based on the related laws and standards;
2. To satisfy the structurally safe and hydraulic conditions, and possess the required supply capacity;
3. To be safe in terms of water quality;
4. To be reliable and efficient;
5. To be able to serve water, as much as possible, without suspension even at such an emergency as disaster of an earthquake and accident (hereinafter referred to as "at an emergency"), and able to rapidly restore the facilities. Additionally, not to bring about serious lateral damage along with the damage to facilities.
6. To give consideration to the provision of a spare capacity, decentralization of facilities, diversification of water source systems etc. and raise the reliability of water service;
7. While taking account the economic benefits of the entire life cycle in facilities, to be advantageous for construction and O&M;
8. To give consideration to improvement, replacement, expansion etc. in future;
9. The respective facilities are suitable for the protection of environment. Especially, at designing, energy saving, utilization of new energies, effective utilization of resources shall be taken into consideration.

### 1.3.2. Locations and layout of entire water supply facilities

The locations and layout of entire water supply facilities shall be examined based on the following items, and determined according to the result of examination;

1. To make compatibility with the geography, and utilize it as much as possible;
2. To be suitable to such future form of the city as the trend of population so as not to cause a trouble to improvement, replacement and expansion of the facilities;
3. Not to cause suspension of waster service as much as possible even at an emergency;
4. To be able to reliably obtain good quality raw water up to the future;
5. To be able to undertake construction and O&M of facilities safely and easily, and give consideration to rationality and economy.

**[Interpretation]**

The ordinary structure of water supply facilities is presented in Figure 1.3.1. In addition, the methods of raw water transmission, treated water transmission, water distribution between respective facilities are shown in Figure 1.3.2. At the time of determining locations and layout of these facilities, comparison shall be made, in accordance with the following, so that respective facilities can work with their original functions, and, additionally, they raise the reliability of the entire system.

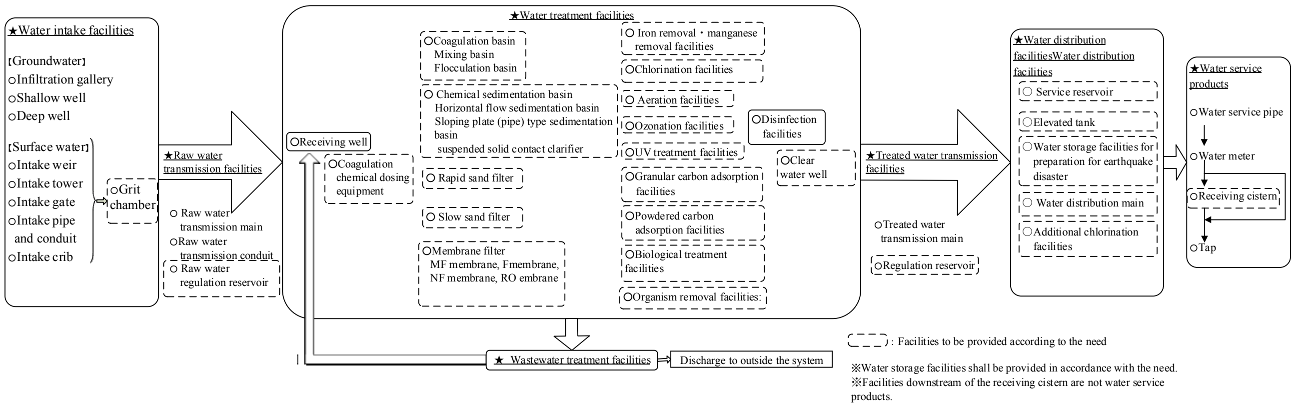



**Figure 1.3.1 Ordinary structure of water supply facilities**

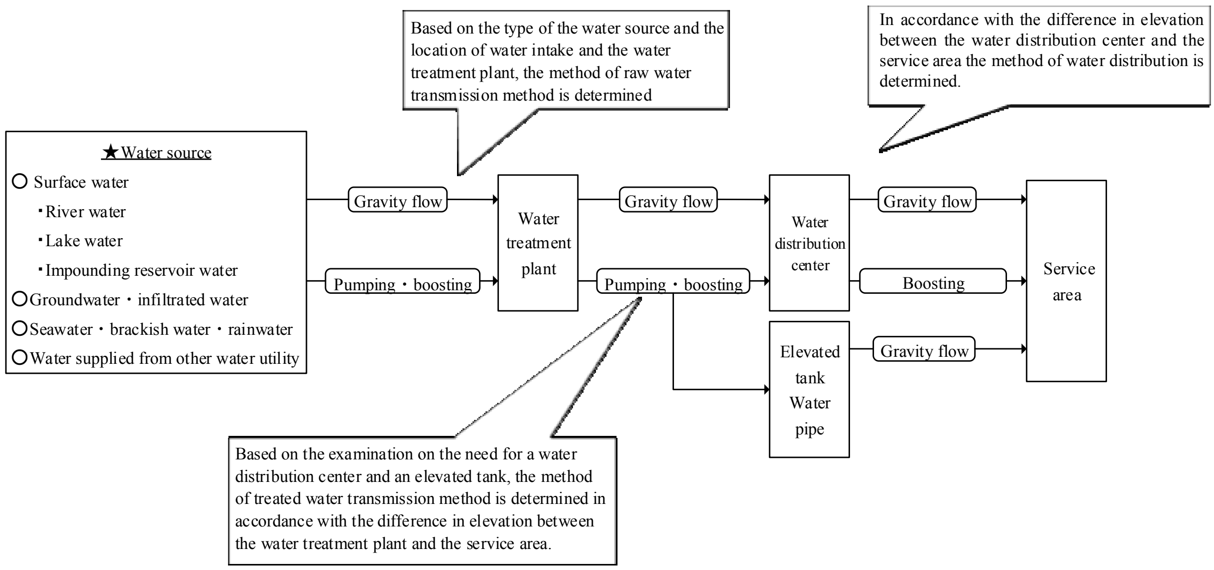



**Figure 1.3.2 Methods of raw water transmission, treated water transmission and water distribution**

**On the item 1.;**

The locations of the intake station, the water treatment plant and the water distribution center and the methods of raw water transmission, treated water transmission, and water distribution shall be determined in consideration of the effective utilization of such geography as the difference in elevations between respective facilities.

**On the item 2.;**

For improvement, replacement and expansion of facilities, it is important to divide the system of facilities into subsystems in terms of the structure and the layout so that the respective subsystems can be operated without interference to other subsystems. Especially, as for facilities in the water treatment plant, the possibility for the introduction of, in addition to the ordinary treatment, advanced water treatment facilities, and the provision for an allowance in capacity of the plant shall be examined, so it is desirable to take into consideration equipment and facilities to be added in future according to the need.

What's more, in case a lot for facilities, the lot shall be selected so that no trouble shall be brought about when implementing improvement, replacement and expansion of facilities in future, and it is needed to secure sufficient space.

**On the item 3.;**

It shall be considered that water service should not be suspended or reduced as much as possible, of course, at normal times, but also even at an emergency. To this end, consideration shall be given to not only the characteristics of the foundation and the difference in elevations of the ground but also the strengthening of resistance to an earthquake as well as the formation of networks of treated water transmission and water distribution mains, the division of the service area into blocks, the securement of spare capacity, the decentralization of facilities, the provision of multiple water sources etc. so that reliability of water service through both sides of the prevention of disasters and the restoration after them is to be improved.

**On the item 4.;**

When selecting the type of water sources and the location of intake point, attention shall be paid to the protection of the water source so that quality raw water, with which water quality in conformity with the water quality standards can be served through the future by water treatment, can be obtained. Additionally, it shall be secured that raw water can reliably be obtained by means of multiplication of water sources, interconnections between water sources etc. for preparation for a drought and so forth.

**On the item 5.;**

**1) Comparison in both facets of construction and O&M**

When selecting locations for the intake station, water treatment plant, water distribution center and the routes for water transmission mains between them, comparative plans for them shall be prepared, and comparative studies shall be carried out on the ease of obtaining land, the shape of and traffic on the roads for burying of water mains, the magnitude of complexity of buried objects, the quality of the foundation, the level of groundwater, the volume of earthwork, the ease of securement of the route for transportation of construction materials, the safety of construction work etc. Besides, the layouts of facilities, for which the ease of maintenance and inspection after completion, substituting function (multiplication of systems) during their replacement, sound construction work etc. are considered, shall be compared and the one, with which the O&M and replacement are sure and easy, shall be chosen. Therefore, from the points of view of construction and O&M, with attention paid to the life cycle cost and undertaking the cost-benefit analysis etc. the most advantageous setup of the overall layout of facilities, structure, hydraulic profile, the method of raw water transmission, treated water transmission and water distribution and so on shall be selected while taking into consideration the rationality and economic benefits.

**2) Cost of construction and maintenance of functions**

Since the safety of water service and the maintenance of functions for a long time for water supply facilities are the first thing to come, attention shall be paid to unexpected loss in respect to O&M may be brought about if a plan is made excessively curtailing the construction cost.

### 1.3.3. Securement of the safety of water supply facilities

When designing, the following matters shall fully be considered to secure the safety of water supply facilities:

1. To secure the safety of facilities for a disaster or an accident;
2. Not to impose adverse effect to the environment by noise, vibration, wastewater, exhaust gas etc. related to water supply facilities

**[Interpretation]**

**On the item 1.;**

To secure the safety of water supply facilities for a disaster or an accident, the following matters shall be considered when preparing design:

**1) Location and structure of water supply facilities**

To secure the safety of water supply facilities for such natural disaster as an earthquake, storm and flood damage etc., in addition to the geography and geology, the record of disasters in the past shall be studied when selecting the locations of water intake, water storage, water treatment facilities, distribution facilities and the important trunk mains. Based on the study, as safe locations as possible shall be selected, and, at the same time, adequately safe structure for the preparation to these disasters shall be chosen when designing the respective facilities.

**2) Suppression of damage by a disaster**

In case water pollution occurs or part of facilities is broken or stops to work, facilities, with which shut-off, drainage, control of water pressure etc. can be practiced if needed, shall be provided so as to suppress the damage by the disaster and prevent lateral damage as well as enable early restoration. It is desirable to provide such measures as emergency cut-off valves on the regulation reservoir and service reservoir, remote operation of valves, a wireless communication system between facilities for their monitoring, control and mutual contacts and so forth.

As such, it is important to examine the water supply system from a view point of the suppression of the damage by a disaster so as to make its influence to a minimum.

**3) Safety measures for chemicals**

At an emergency the leak of such chemical as chlorine gas or inundation etc. as a result of the damage on water supply facilities may cause damage on the health of the residents and their assets such as houses in the surroundings at times. Special attention shall be paid to the design of the earthquake resistance of the storage facilities of such chemicals as chlorine, neutralization equipment and ancillary pipes and valves etc. Provision shall be made so that no leakage of chlorine gas etc. occurs at the worst, and that no mixing of alkaline chemical and acidic ones shall happen even in a case of leak. It is needed to examine the change of the liquid chlorine to such a chemical as sodium hypochlorite etc.

**On the item 2.;**

Consideration shall be practiced in that noise, vibration, wastewater, exhaust gas etc. caused by the construction and operation of water supply facilities would not adversely affect the environment. Especially, the influence of construction of facilities to the surroundings, wastewater from the water treatment plant and noise and vibration of pumping stations in their surroundings become a problem at times.

### 1.3.4. Steps of designing and the standards to be observed

> Designing of water supply facilities shall be undertaken after sufficient study based on the master plan abiding by related laws and standards.

**[Interpretation]**

**1. Steps of designing**

The steps of the designing of water supply facilities in general consist of (1) identification and confirmation of the conditions of design, (2) basic design, (3) detailed design.

**1) Confirmation of the conditions of design**

The conditions of design consist of the structural conditions (shape of the structures), geological conditions (condition of soil), material conditions (properties of materials), load conditions (elements of the loads), conditions of land (prospect of securement for a lot and regulations on the land use) etc., which shall be clarified as the condition originally given to the structure as a result of the master plan, topographical survey, geological survey, environmental study etc.

**2) Basic design**

Under the basic design, rough examination, comparison and so forth of the structure, method of construction etc. of the objective facility are carried out prior to detailed design.

**3) Detailed design**

Under the detailed design, based on the basic design, the shape, size etc. of the objective facility by structural analysis etc. are determined; sections and other details are designed; and a bill of quantities and design documents required for construction are prepared.

The typical steps for detailed design are presented in Figure 1.1.1. An example of the steps for detailed design of a standard water treatment plant (mainly for civil facilities) is shown in Figure 1.3.3; and those for water mains in Figure 1.3.4.

### 1.3.5. Preparation of design documents

> The preparation of design documents shall be carried out in accordance with the following:
>
> 1. As the design documents, which in general constitute contract documents together with a contract, consist of drawings, specifications (standard specification and particular specification), the document for site explanation and the document on the answers to questions on the explanation etc. and are the important documents required for placing a contract, they shall clearly indicate required matters.

**[Interpretation]**

**On the item 1.;**

The design documents shall clearly show locations, shapes, sizes, specifications etc. of civil facilities, buildings, machinery, electrical equipment and so forth. The design documents are usually edited in the order of civil facilities, buildings, machinery and electric equipment, and edited first with drawings showing the entire facilities followed by the detailed drawings.

An example of the composition of design drawings for a water treatment plant is presented in Table 1.3.3.

**(Basic Design)**

**Surveys etc. (study on existing data and site reconnaissance and so on)**

(1) Confirmation of project plan, data on site survey, geological survey etc.
(2) Geography etc. (site boundaries, condition of surroundings, land elevation, drainage, access roads, route of power supply etc.)
(3) Geology (The relationship of data on geological surveys with the actual site condition)
(4) Condition of existing facilities (Type, size, hydraulic profile, locations of connections, magnitude of aging etc. of the existing facilities) etc.

↓

**Confirmation and sorting of basic conditions**

(1) Locations of facilities to be designed, the area of the site, existence of various regulations etc.)
(2) Location, yield, water quality of the water source(s) and location of its intake
(3) Type of water treatment
(4) Relationship with the existing facilities etc.
(5) Examination of power receiving and distribution equipment etc.

↓

**Examination of the water treatment flow**

(1) Type of water intake and raw water transmission
(2) Type of water treatment
(3) Type of wastewater treatment etc.

↓

**Examination of the method of O&M**

(1) Type of monitoring and control
(2) Organization for O&M etc.

↓

**Examination of the layout plan**

(1) Layout of respective facilities
(2) Plans for pipe laying and wiring
(3) Architectural planning etc.

↓

**Examination of facility plan (including coordination between facilities)**

(1) Plan for civil facilities
(2) Plan for buildings
(3) Plan for machinery
(4) Plan for electric equipment
(5) Plan for environmental improvement etc.

↓

**Hydraulic examination**

(1) Hydraulic analysis of respective facilities (including hydraulic coordination with the existing facilities)
(2) Design ground elevation and design elevations of respective facilities) etc.

↓

**Examination of the method of construction**

(1) Comparison of economic benefits, time period, the ease, influence to the surroundings of construction
(2) Preparation of plan for construction, plan for carry-in and carry-out of materials and equipment, and work schedule

↓

**Preparation of drawings for the basic design**

(1) Civil work: general plan, hydraulic profile, structural drawings, pipe laying plan etc.
(2) Architecture: design drawings, drawings for architectural machinery equipment, drawings for architectural electric equipment etc.
(3) Machinery: Basic flow sheet, layout plan for main mechanical equipment etc.
(4) Electric equipment: general site plan, diagram of main distribution system, skeleton diagram, layout plan for main electric equipment, drawings for instrumentation facilities etc.

**(Detail Design)**

Confirmation and sorting of conditions for design

(1) Confirmation of the contents of basic design related to the object of design and respective design standards etc.
(2) Prior to structural analysis, confirmation of design condition, method of computation, loading conditions, weight, main dimensions, shape and route for carry-in and –out of equipment etc.
(3) Prior to design of temporary work, confirmation and measurement of formula for computation of earth pressure, design parameters, method of earth retaining, method of drainage, plan for roads for temporary work

Hydraulic analysis, structural analysis etc.

(1) Civil work: structural analysis of main structure, structural analysis of temporary facilities, hydraulic analysis, computation of capacity of facilities etc.
(2) Architecture: structural analysis, design and computation of equipment
(3) Machinery: computation of capacity of facilities, listing of machinery, examination of safety and reliability of special apparatus, table of weight of main equipment and setting of load on architectural structure etc.
(4) Electric equipment: computation of power capacity of facilities, book of outline operation, table of weight of main equipment and setting of load on architectural structure etc

Preparation of design drawings

See Table 1.3.3 An example of composition of design drawings (the case of detailed design of a water treatment plant)

Preparation of bill of quantities.

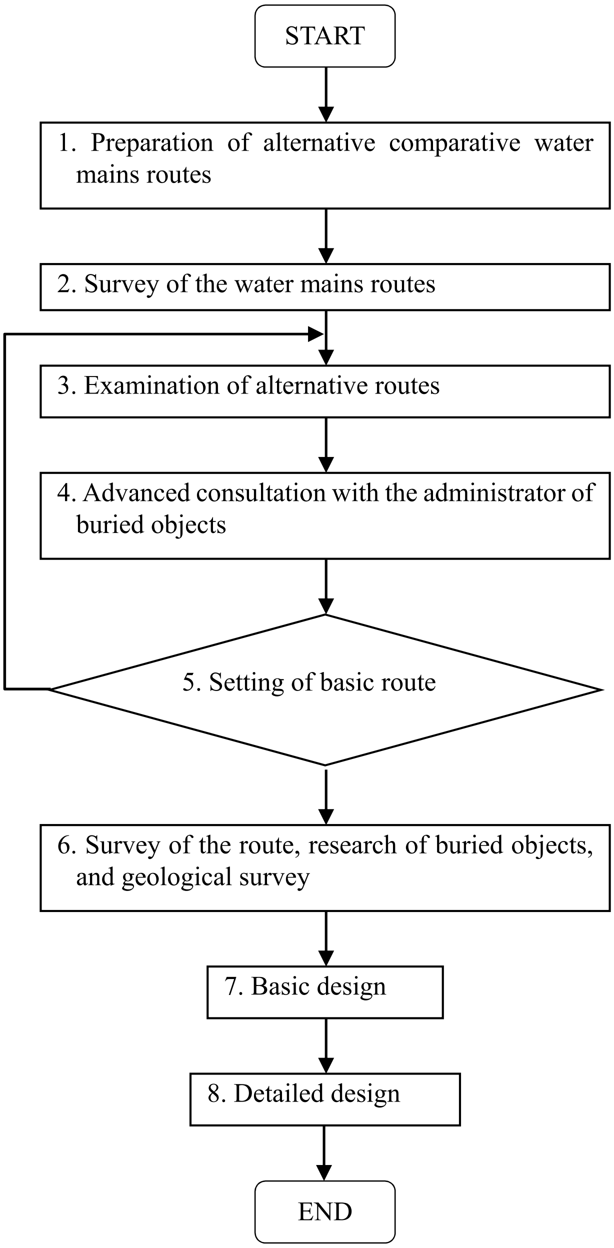
(1) Bill of quantities
(2) Book of calculation of construction term
(3) Book of components of design
(4) Detailed technical specifications etc.

Preparation of documents required for various permission application and reporting

↓

**(Process of contracting of construction)** **(Various formalities)**

**Figure 1.3.3 An example of designing of a water treatment plant**




1. In general, more than two routes of water mains between the start and end points along the planned route shall be prepared in the scale of 1/2,500 to 1/5,000.

2. Conducting site survey along the proposed routes, the existence of object on the road and buried ones, the condition of the route including the surroundings.

2'. Collection of various information on the condition and structure of buried objects from the administrators of roads, rivers and buried objects.

2". The routes shall be selected synthetically judging the evaluation of the routes in terms of method of construction, term of construction, construction cost, influence of construction, ease of the work, need for disposal of obstructs, and so on.

3. Detailed examination shall be conducted to discuss with the administrators of buried objects. The type of water mains, laying method, the method of crossing the road, river, and railroad shall roughly be examined; and basic drawings shall be prepared.

4. Coordination shall be made with administrators of sewerage, gas, power supply, communication on locations of buried objects and method of construction, and with the administrator of the road on the locations of exclusive occupation, methods of pavement restoration etc.

5. Based on the examination and discussion with the administrators of buried objects, the basic route shall be determined.

6. To obtain basic data for design of water mains, plane survey, cross-sectional survey, study of buried objects, soil survey and study of hums if required.

7. Basic design shall be carried out including examination of pipe materials, pipe wall thickness, selection of locations for exclusive occupation, decision of locations of gate valves, air valves etc., examination of earth retaining, dewatering, construction methods for daytime and night time etc. The area, for which water service is suspended when connecting with the existing water mains, shall be examined.

8. Detailed design shall be undertaken based on the result of the basic design. A center line survey, profile leveling etc. on the locations of exclusive occupation by the water mains shall be carried out. A final adjustment shall be implemented on the occupation of the road, regulation of traffic, method of construction, protection method of adjoining structures, lease of land etc. Design drawings, specifications, plan for construction, bill of quantities, bill of estimated cost etc. shall be prepared.

**Figure 1.3.4 An example of designing of water mains route (trunk main)**

**Table 1.3.3 An example of the composition of design drawings**
**(The case of detailed design of a water treatment plant)**

1. Civil facilities
   (1) Location map
   (2) General plan
   (3) Hydraulic profile
   (4) Plan for earthwork and plan for temporary work
   (5) Plan for foundation work ….. framing plan and plan for improvement of foundation
   (6) Plan for structures ….. ground plan and plans for longitudinal and cross sections
   (7) Detail drawing …… plan for interfaces, plan for blockout, detail drawing for expansion joints, detail drawing for setting handrails etc.
   (8) Plan for concrete reinforcement
   (9) Plan for in-plant pipe laying ….. ground plan and plans for profile and cross section
   (10) Plan for landscaping ….. passages in the plant, gates, details of fences, details of drainage in the premises, layout of horticulture etc.

2. Architecture
   (1) Architectural design drawing ….. guide map, layout plan, mensuration plan, table of finishing, ground plan, elevation, sectional plan, sectional detail drawing, detail drawing, plan for development view, framing plan for ceiling, plan for furniture, particular specification, table of scope of work, check list for laws and regulations etc.
   (2) Architectural structure plan ….. framing plan, framing elevation, list of sections, plan for rahmens, plan for detailed reinforcement, reference plan for blockout, plan for standard reinforcement, etc.
   (3) Plan for architectural machinery equipment ….. system drawing (air-conditioning, ventilation, water supply and drainage, sanitation, fire-fighting, others), pipe laying plan at respective floors, sectional plan, detailed drawing, particular specifications etc.
   (4) Plan for architectural electric equipment ….. system drawing (lighting fixtures, power equipment, fire-alarm equipment, weak current equipment, communications, clocks, broadcasting, lightning arresting equipment etc.), wiring plan at respective floors, particular specifications etc.
   (5) Perspectives of main buildings

3. Machinery
   (1) Flow sheet
   (2) Layout plan for entire facilities
   (3) Respective layout plans
   (4) Sectional layout plan
   (5) Plan for entire system of piping
   (6) Detailed drawings
   (7) Hydraulic profile

4. Electric facilities
   (1) General plan in the premises
   (2) Skeleton diagram for main circuits
   (3) Flow diagram for instrumentation
   (4) Plan for system and composition for monitoring and control
   (5) Plan of external forms of equipment
   (6) Layout plan of equipment
   (7) Plan for the system of wiring and piping and their layout plans
   (8) Plan for the system of grounding
   (9) Plans for wiring and piping (rack, duct, pit etc.)

## 1.4. Basic matters of structure of facilities

### 1.4.1. General

The ordinary structure of water supply facilities shall be determined in consideration of the following based on the design bearing the age of service of the entire system and the service life of respective facilities in mind.

**1. Loads to be assumed**

The facilities shall be structurally safe against such expected loads as dead weight, working load, water pressure, earth pressure, wind pressure, seismic force, snow load, ice pressure, buoyancy and lifting pressure etc. and need to possess economic benefits and durability.

**2. Coordination between related facilities and equipment**

Most water supply facilities are composed of civil, architectural, mechanical, electric facilities and equipment as one body. As such, at the time of designing, coordination between related facilities and equipment shall adequately be implemented; their structures shall be made not to adversely affect the functions and O&M of respective facilities; and attention shall be paid so that strength and space for future improvement and replacement are provided.

**3. Consideration to water pollution and sanitation**

Facilities shall be so structured that there is no danger of leakage and pollution from outside, and shall be hygienic and water-tight with careful selection of materials and workmanship. In addition, the materials and equipment themselves used for the facilities shall be of nature not to cause water pollution.

**4. Measures against corrosion by chemicals, attrition by water flow etc.**

Since there are facilities, which possibly suffer from corrosion by chlorine, coagulation chemicals etc., and attrition by water flow, mechanical equipment etc., they shall have resistance to corrosion and attrition as needed with careful selection of materials, design and workmanship.

**5. Measures against salt damage of facilities situated near the seashore**

Facilities situated near the seashore tend to suffer from such salt damage as deterioration in concrete, quick corrosion of equipment and materials and so on. To avoid or reduce such damage, the durability of the facilities shall be secured by proper means of such measures against salt damage as design, materials, selection of anti-corrosion method in accordance with the environmental condition.

**6. Preparedness for natural disasters**

Preparedness for natural disasters shall also be examined from a disaster-reduction point of view with reference to the experiences of floods, tsunami etc. in the past.

### 1.4.2. Design load and external force

> The design of facilities shall be carried out with a proper combination of loads and external forces which work during construction and after the completion. Such main loads and external forces as dead weight (empty weight), water pressure etc. shall be in accordance with the following:
>
> 1. The standard unit mass of materials used for design shall, except for special ones, be the values shown in Table 1.4.1.

2. The working loads shall be computed according to the actual condition of the facilities in question.
3. The water pressure shall be computed as working static water pressure and dynamic water pressure according to the type of the facilities.
4. The earth pressure shall be determined by means of a proper formula which is used commonly.
5. The wind pressure shall be computed by wind speed pressure multiplied by the coefficient of wind force.
6. The seismic forces shall be determined in accordance with the importance of the facility and the level of the rocking for its standard anti-seismic function, and computed according to the anti-earthquake design method.
7. The snow load shall be computed by the unit volumetric mass multiplied by the maximum vertical depth of snow pile.
8. The ice pressure shall be considered for the design of a structure, for which the surface area of ice is small in relation to the thickness of the ice.
9. The influence of temperature changes shall in general be considered for designing structures.
10. The buoyancy for a basin-like structure, which is placed in ground with high groundwater level, shall be considered for the case it is empty.
11. The lifting force shall be considered in case difference in water levels in front and rear of the structure occurs.

**[Interpretation]**

**On the item 1.;**

The standard unit mass of materials used for design shall, except for special ones, be the values shown in Table 1.4.1.

**Table .1.4.1 Unit volumetric mass of materials**

| Material | Unit volumetric mass (kg/m$^3$) |
|---|---|
| Reinforced concrete | 2,450 – 2,500 |
| Prestressed concrete | 2,500 |
| Concrete | 2,300 – 2,350 |
| Cement mortar | 2,150 |
| Earth (clay, loam and the like) | Dry: 1,400<br>Wet: 1,,600<br>Saturated 1,800 |
| Sand | Dry: 1,600<br>Wet: 1,800 |
| Gravel | Dry: 1,700<br>Saturated 2,100 |
| Stone | 2,600 |
| Brick | 1,200 – 2,200 |
| Wood (zelcova, larch) | 800 |
| Cast iron | 7,250 |
| Ductile iron | 7,150 |
| Steel, cast steel, forged steel | 7,850 |
| Lead | 11,400 |
| Copper | 8,900 |

**On the item 2.;**

The working load shall be computed in accordance with the use of the structure assuming the article it carries. Especially, as for such heavy item as machinery, working load shall be computed based on the actual condition with proper values of weight of the article including weight of their base, weight in operation etc.

It is desirable to design the control room, switch gear room etc. so that they can deal with a future change in location, replacement etc. of equipment.

**On the item 3.;**

Water pressure shall properly be computed for such a type of facilities as the intake tower, the service reservoir, water mains etc. taking into account the change in water level, flow velocity, shape, size etc. of the structure.

**On the item 4.;**

Among structures, which receive earth pressure, the lateral force working on retaining walls and underground walls is in general computed by Rankine's, Coulomb's or Terzaghi's formulae, and are sorted into active earth pressure, static earth pressure and passive earth pressure according to the difference in the movement of the structure. Besides, Marston's, Jansen's or Spangler's formulae etc. are normally used for calculating the lateral and vertical earth pressures which work on such buried objects as buried water mains, culvert etc.

**On the item 5.;**

Wind pressure shall be considered for such water supply facilities as an elevated tank, water pipe, radio station tower etc. which are vulnerable to the influence of wind.

**On the item 10.;**

In case a basin-like structure, water conduit etc. of water supply facilities are constructed in ground with high groundwater level, the safety of the structure at the time of high water level shall be confirmed, and such measures shall be made as its dead weight is made heavy; the structure is fixed on the foundation to increase its resistance to buoyancy; or the groundwater level is lowered in advance and so forth. Caution shall be made since unexpected rise in groundwater level may be brought by the entry of rainwater etc. even during construction,

**On the item 11.;**

In case there is difference in water levels in front and rear of such structures as the dam body, intake weir and grit chamber, upward force (lifting pressure), of which strength is different depending on the location, acts on the bottom of the structure. Their stability shall be confirmed when computing their stability if required.

### 1.4.3. Foundation and substructure

When surveying and designing the foundation and the substructure, the following points shall be considered:

1. The survey of foundation shall be performed by the method established by the JIS and the Japan Geotechnical Society.
2. The allowable bearing force of the foundation shall be determined by the condition of the

foundation, the size, shape, depth etc. of the substructure. Additionally, the possibility of liquefaction of the foundation and measures for it shall also be studied.

3. The substructure shall be safe in terms of structural bearing stress against the subsidence or deformation of the foundation as it transmits the load and external forces, which act on the structure, to the foundation.
4. Different types of substructures shall not be used for the same structure as a general rule.
5. In case designing a pile foundation, one that is the most suitable shall be selected taking into account the load, the foundation and the condition for construction.
6. In case designing a underground structure in a cold region, frost in the ground and frost heaving shall be considered.

### 1.4.4. Concrete structure

The concrete structure shall be in conformity with the following

1. Proper measures to restrain such early deterioration as corrosion of reinforcing bars and cracking in concrete shall be provided for concrete and reinforced concrete taking consideration the materials used, condition for construction, environment etc.
2. For concrete and reinforced concrete structures, for which water roofing is required, the contents of concrete and reinforcing bars, the structure of the joints of concreting and the expansion joints shall properly be determined to prevent harmful cracks. As the concreting joints and expansion joints become a structural weak point in some cases, careful examination is required.
3. The portion of concrete surface, which is exposed to such severe action as attrition, degradation, corrosion etc., shall be protected with a proper material.
4. In case paint for anti-corrosion and water proofing is applied on the inner surface of a basin-like structure, a paint material, which possesses protective property for concrete, and does not cause water pollution, shall be used.
5. In a cold district, proper measures shall be provided against frequent freezing and thawing on the surface of concrete.

### 1.4.5. Steel structure

The steel structure shall be in conformity with the following:

1. The steel material shall be the most suitable to the condition of the structure.
2. Members of the steel structure shall be simple in composition, and the structure shall also be as simple as possible.
3. Maintenance of the anti-corrosion of the steel structure shall be easy.

# 1.5. Materials, equipment and chemicals for water supply

## 1.5.1. Policy for selection

Materials, equipment and chemicals used for water supply shall be selected fully taking into account the following:

1. To be durable for use for a long time;
2. Not to cause an adverse effect on water quality when coming in contact with water;
3. O&M thereof can be implemented reliably and easily;
4. Not to impose much influence to the environment.

# 2. Water Intake Facilities

## 2.1. General

### 2.1.1. Basic Matters

Water sources for water supply are classified into the surface water (river water, lake water and impounding reservoir water) and the groundwater. In any case, the water intake facilities shall be able to reliably abstract water of as much good quality as possible, of which operation and maintenance (O&M) can be easy, and for which measures for dealing with a disaster and conserving the environment shall be considered.

**1. Reliable water intake**

The water intake facilities shall be able to reliably abstract water of the design intake water volume irrespective of types of water sources throughout the year. In the case of surface water, it is needed for them to be able to reliably intake water even at the times of a flood and drought. Especially, in the case of the river water, such floating objects as driftwood, weeds etc. tend to clog the intake mouth, which make water intake impossible. Besides, rolling stones and piling of earth and sand at the time of flood will hinder intake of water; and the lowering of river water level due to scouring of riverbed will affect the water intake at the time of drought at times. In the case of groundwater, the amount of water abstraction may be reduced due to abnormally low water level if groundwater is pumped beyond an allowable limit. In the case of unconfined groundwater, intake of the required volume may become difficult due to low water level at the time of a drought.

When installing the water intake facilities, the location, where the design intake water volume can reliably be obtained, and the proper intake method shall be selected.

**2. Securement of quality raw water**

The water intake facilities shall be built at a location, where water quality is good as the raw water, and no water pollution will occur throughout the future. Especially, in the case of river water, intake facilities shall be located where the inflow of sewage and other wastewater is avoided, and the seawater will not reach. In the case of groundwater in a coastal region, wells shall be drilled where there is no influence of seawater.

An organization for liaison and communication between concerned parties is required to be set so as to quickly find an accident of water pollution.

**3. Measures for a disaster and protection of environment**

The water intake facilities shall be constructed at a location, where the influence of such an emergency as a disaster, and an accident to water intake can be made to a minimum. Accordingly, water supply facilities including the water intake facilities shall be divided into multiple systems.

When installing water intake facilities, attention shall be paid to conserve the natural environment through an adequate survey on the influence to the surroundings, and take into account such measures as energy saving for the facilities

Especially, as to the river water, when selecting the site for water intake, location of the intake facilities at upstream of the river shall adequately be considered since the saving in energy can be expected by locating the intake facilities at as much upstream as possible.

**4. Ease of O&M**

It is required that O&M of water intake facilities can safely and easily be performed even under such bad condition as a flood. Additionally, facilities, with which the intake of water can be stopped at not only an emergency but the time of inspection, shall be provided. It shall be considered at the beginning that their structure can accommodate future expansion or replacement so as not to require acquisition of a large land or big work at the time of expansion or replacement of the facilities in future.

**5. Compliance with the laws and regulations**

Formalities in accordance with the laws and regulations are needed for the construction of water intake facilities.

### 2.1.2. Design volume of water intake

> The design volume of water intake shall, as standard practice, be set at the design daily maximum water service volume with ten percent or so of a safety factor.

**[Interpretation]**

The design volume of water intake shall be determined considering the water loss from intake through water treatment in addition to the design daily maximum water service volume. It is appropriate, in general, to provide ten percent or so of a safety factor to the design daily maximum water service volume as the design volume of water intake.

The water loss consists of water leakage from various facilities from the intake point through the water treatment plant, process water consumed during water treatment, sludge, evaporation etc. and its volume differs depending on the condition of respective facilities, the method of water treatment etc. Especially, in case the water is recycled from the wastewater treatment facilities to the receiving well, it shall be kept in mind that the water loss becomes smaller in the plant.

In case the groundwater can be supplied only with disinfection, the water loss during raw water transmission can be neglected in many cases since no process water is needed. In such an instance, the design volume of water intake almost equals the design daily maximum water service volume.

What's more, the water loss in the water distribution and water service facilities is included in the design daily maximum water service volume.

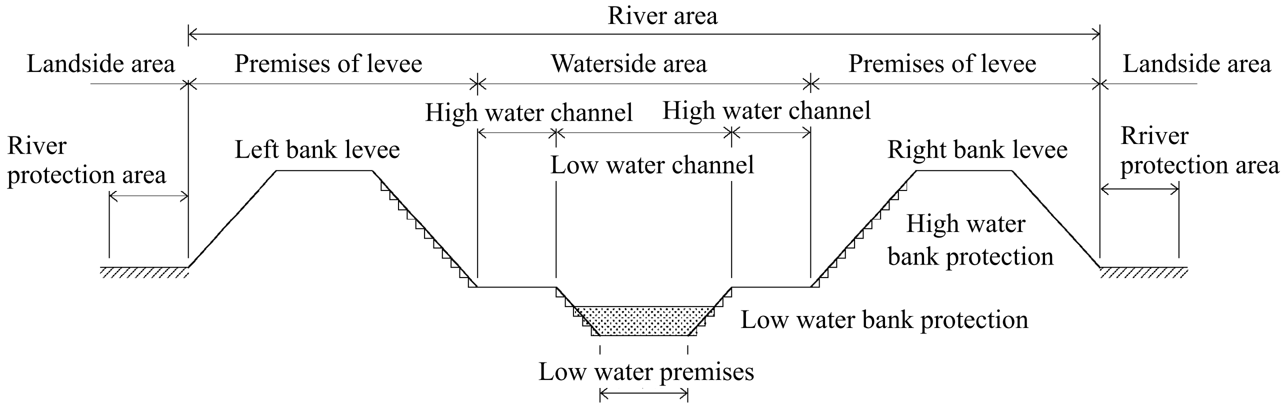
### 2.1.3. Selection of water intake facilities

> As for the water intake facilities, taking into consideration the situation of the intake point, the volume of intake etc. the most suitable type of facilities shall be selected from the intake weir, intake tower, intake gate, intake pipe or conduit, intake crib, infiltration gallery, shallow well, and deep well.

**[Interpretation]**

At the time of the selection of water intake facilities, it is needed to study on the type of water source, the status of the intake point, the volume of intake, the condition of construction, regulations by the River Law etc. The water intake facilities shall be selected in accordance with Table 2.1.1. However, the table is prepared based on the following concept:

1. The items are roughly lined up according to their priority.
2. As to the size of water intake volume (Table 2.1.1 Item 4), 100,000 $m^3$/day or larger as the large scale, 50 to 60 thousand $m^3$/day as the medium scale, and less than 10,000 $m^3$/day as the small scale are assumed (likewise hereinafter in this chapter).
3. As for the nomenclature for river etc., Figure 2.1.1 shall be referred to:



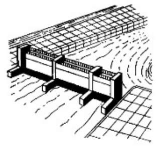
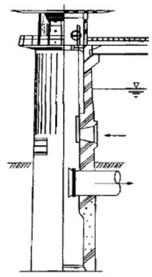
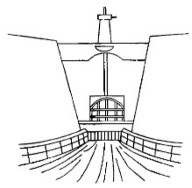
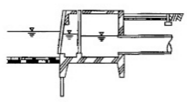
Note) The right side is the right bank towards the river mouth

**Figure 2.1.1 Names of parts of rivers etc.**

**Table 2.1.1 Selection of water intake facilities**

## A. Intake of surface water

A-1 In case withdrawing river water

| Item | Type of water intake | Intake weir | Intake tower | Intake water gate | Intake pipe or conduit |
|---|---|---|---|---|---|
| 1 | Schematic |  |  |  |  |
| 2 | Function, purpose | By heading-up the river and securing the design intake water level, reliable water intake becomes possible. The weir functions together with intake mouth, grit chamber etc. | If installed where the water depth is larger than a certain value, reliable intake is possible despite change in water level. Intake from selected water level is possible with mouths at different depths. | Works with an intake mouth together with screen, water gate, sand pit etc. | A facility to withdraw river water through a mouth of pipe or conduit installed in low water bank protection, and conduct water to the landside area. |
| 3 | Characteristics | The effects of reliable intake and grit sedimentation is large. Suitable for withdrawing a large quantity of water on a river where development is advanced, or the river flow is unstable. | Economical in the case of intake of a large volume. Especially, suitable in case a large volume of water is withdrawn. Generally more economical than the weir. | Although in case river condition, riverbed, and water level are stable, construction and O&M are relatively easy, and reliable abstraction is possible, measures to secure the intake volume and their control are needed at the times of drought, flood and freezing. | Suitable for a river of which condition is stable, and change in water level is small. As the facility is constructed below the ground, it will not be troubled by water flow, and cause no hindrance to river improvement or navigation. |

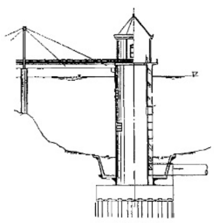
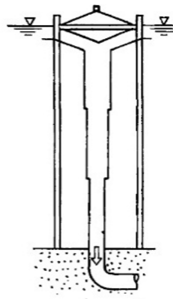
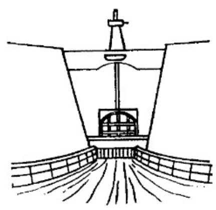
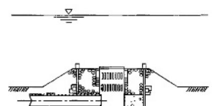
| Item \ Type of water intake | | | Intake weir | Intake tower | Intake water gate | Intake pipe or conduit |
|---|---|---|---|---|---|---|
| 4 | Basic factor | Size of intake volume | In general suitable for abstraction of a large volume. However, simple ones are at times used for small- and medium-scale water intake. | In general, used for withdrawing large- or medium-scale water intake. Especially, suitable for the large scale. | In general used for withdrawing a small volume of water. However, at times used for a large scale combining with a weir. | Generally used for withdrawing for smaller than medium scale volume. In some cases, used for a large scale together with a weir. |
| 5 | | Stability of water intake | Reliable water intake is possible. | Relatively reliable water intake is possible. | Unreliable as affected by the flow condition. However, in case the river condition is stable, and for a small facilities in case management is good, reliability increases. | Relatively reliable water intake is possible. However, the intake may be troubled where change in river condition is large. |
| 6 | Legislative factor | Restriction by the river law | Shall be installed perpendicular to the river. The main body of the movable water gate shall be of a lift-up type except one, to which the effect of flood is small, or a small one. | The shape shall be oval as a general rule, and its major axis shall be parallel to the direction of the flow. | Except for the case of mountain torrent and small stream, which do not receive influence of flood, there are many parts, which are regulated by the ordinance on management of structures etc. built in river. | The earth cover of the pipe shall be larger than 2 m as a general rule. Even in an inevitable case, the position shall be lower than the design level of riverbed. |
| 7 | External factor | Intake point | Desirable where the both banks are parallel, the length of the straight section is more than double the width, and the water-route Note) is stable. The mouth shall be made where the stream center approaches the bank. | Suitable where river condition is stable, and the droughty water level is more than 2 m. There are many examples in mid-stream section of the river. | Generally used in a small stream at upstream section of a river. A location, where riverbed is stable, and the whole face of the water gate will not be buried, is to be selected. | Suitable where the river condition is stable, and there is no fear for the intake mouth is buried. |
| 8 | | Status of riverside land | Unsuitable where the river condition largely changes since the intake mouth is often buried. | Unsuitable where the river condition largely changes since the intake mouth is often buried or exposed. | Suitable only where change in riverbed is small. Water intake becomes impossible where lowering of riverbed is remarkable.<br>Unsuitable to a river with double sections | Unsuitable where the river condition largely changes since the intake mouth is often buried or exposed. |
| 9 | | Size of river | In general suitable to a large river. | In general used for a large river. | Suitable to the upstream section of a small to medium river. | In general suitable to a medium to large river. |
| 10 | | Condition of river | Water intake is possible even in case the river condition is unstable. | Suitable for a river of which condition is relatively stable | Suitable for a river of which condition is stable | Suitable for a river of which condition is relatively stable |

| Item | | Type of water intake | Intake weir | Intake tower | Intake water gate | Intake pipe or conduit |
|---|---|---|---|---|---|---|
| 11 | External factor | Status of inflow of earth and sand etc. | Inflow of earth and sand etc. is very little in case grit-gate is properly maintained and the intake mouth is functionally designed. Thus the load on water treatment plant is light. But as floating debris tend to be trapped on screen, a measure for it is needed. | Unlike the weir, inflow of earth and sand is unavoidable. By operating the gate according to the water level, it can considerably be prevented. A protective facility is needed for driftwood, debris etc. | Inflow of earth and sand is almost unavoidable; and measures for debris are difficult either. | Inflow of earth and sand is unavoidable to certain extent. |
| 12 | | Status of water quality | Utilizing grit-gate etc. raw water with minor contents of earth and sand can be withdrawn. | Withdrawing water from water depth with not much influence of water quality using the function of selective intake. | Vulnerable to change in water quality | Vulnerable to change in water quality |
| 13 | | Status of stream center | Unless situated where the stream center (especially water-route) is stable, there is threat of burying of the intake mouth. But it can be avoided by providing an undersluice. | Unsuitable where the stream center is unstable since the intake mouth may be buried or exposed. | Suitable for a river of which stream center is stable | Suitable for a river of which stream center is stable |
| 14 | | Status of water depth | Almost no influence | Water intake becomes impossible where water depth of more than a certain level is not secured in drought. More than 2 m of water depth is needed. | Water intake becomes impossible where water depth of more than a certain level is not secured in drought. | Water intake becomes impossible where water depth of more than a certain level is not secured in drought. Generally, installed as the crown of the conduit comes 30 cm lower than the droughty water level. |
| 15 | | Geological condition | Although it can be constructed in any ground by selecting the type of foundation, good ground is desirable as much as possible from the safety and economic points of view. | Although it can be constructed in any ground by selecting the type of foundation, good ground is desirable as much as possible from the safety and economic points of view. | Although it can be constructed in any ground by selecting the type of foundation, good ground is desirable as much as possible from the safety and economic points of view. | Although it can be constructed in any ground by selecting the type of foundation, good ground is desirable as much as possible from the safety and economic points of view. |
| 16 | | Weather condition | Since the river flow slows down due to heading-up, easily affected by freezing. In such a case, a submerged weir may have to be considered. | In case more than two mouths are provided at the two levels, the influence of freezing or waves can be reduced to a minimum by operating the gates. | No need to specially consider about waves. Special measure is required for freezing. | As flashboards are provided for a control purpose, no influence of waves. Special measure is required for freezing. |

| Item \ Type of water intake | | | Intake weir | Intake tower | Intake water gate | Intake pipe or conduit |
|---|---|---|---|---|---|---|
| 17 | Internal factor | Construction cost | Large in general | Large in general | Large in general | Small in general. However, it may become large due to cost of ancillary facilities required for protective facilities depending on the condition of the river. |
| 18 | | Operational condition | The grit-gate shall properly be maintained to perform intake reliably. | Studying the status of sand pile in the tower more than once a year, sediment flushing shall be made. | Proper O&M are needed since the intake mouth may be buried or exposed due to the influence of change in riverbed or flood. | Proper O&M are needed since it may be affected by change in riverbed or flood. |
| 19 | Factor related to construction | Condition for construction | As generally construction becomes large scale, detouring of river, and insulation of the site are needed. | Although such temporary work as insulation etc. can be small scale, consideration shall be given not to hinder the flow. | Since temporary insulation is in general made, temporary water way etc. shall be considered. | Since the insulation work intrudes the low water channel and affects the section of flow, temporary water way etc. shall be considered. |
| 20 | | Timing of condition | Desirable to construct in the low water period since the work is difficult in high water period although it depends from river to river. | Desirable to construct in the low water period since the work is difficult in high water period although it depends from river to river. | Desirable to construct in the low water period since the work is difficult in high water period although it depends from river to river. | Desirable to construct in the low water period since the work is difficult in high water period although it depends from river to river. |

Note) Water-route means a line along points in river stream where water depth is the biggest.

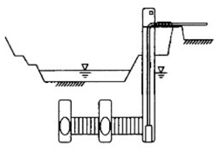
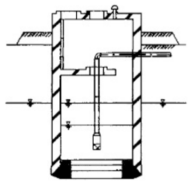
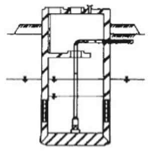
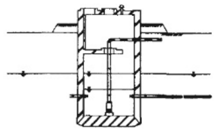
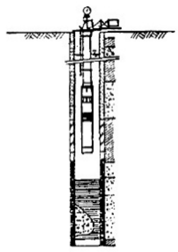
A-2 In the case of water source of a lake or impounding reservoir

| Item \ Type of water intake | | Intake tower | | Intake water gate | Intake crib |
|---|---|---|---|---|---|
| | | Fixed type | Movable type | | |
| 1 | Schematic |  |  |  |  |
| 2 | Function, purpose | Used in many cases as the facility for withdrawing a large volume of water from a lake or impounding reservoir. By providing the different locations of the mouths, selective water intake is possible. | Commonly used in case water depth is especially large in a lake or impounding reservoir, and construction of intake tower of ordinary concrete structure is difficult. | Works with an intake mouth together with screen, gate, sand pit etc. | Commonly used as small to medium scale intake facility for a lake. Its structure is simple, and construction is also relatively easy. Water on the surface layer of the lake cannot be withdrawn. |

| Item | | | Intake tower: Fixed type | Intake tower: Movable type | Intake water gate | Intake crib |
|---|---|---|---|---|---|---|
| 3 | Characteristics | | Even at a lake or impounding reservoir, where change in water level is large, the design water intake volume can reliably be abstracted. | As the merit, surface water is withdrawn in accordance with change in water level. Intake from the desired level is also possible. | Although, in case the lake bed and level of intake are stable, construction and O&M are easy, and reliable intake is possible, measures for securement of intake volume and its adjustment are needed. | Can be constructed in a short term, and secure reliable withdrawal. |
| 4 | Basic factor | Size of intake volume | Generally suitable for withdrawal of large volume. | Used irrespective of the size of intake. | In general, used for water intake for small to medium volume. | In general, used for water intake for small to medium volume. |
| 5 | | Stability of water intake | Reliable water intake is possible. | Reliable water intake is possible. | Reliable water intake is possible. | Reliable water intake is possible. |
| 6 | External factor | Intake point | Although more effective where the water depth is large from water intake point of view, the location near from the shore is desirable from O&M point of view. | More effective where the water depth is large. | Location, where the condition of the lake etc. is stable, especially, where the front of the water gate be not buried, is desirable. | Considering incidence of burial, location, where foundation is stable, and water depth is not too large from O&M point of view, is desirable. |
| 7 | | Size of lake etc. | In general, used for a large lake etc. | In general, used for a large lake etc. | In general, used for a small lake etc. | Not affected by size of lake etc. |
| 8 | | Change in water level | Almost no influence | Almost no influence | Suitable for a lake with small change in water level | Almost no influence. However, attention shall be paid so that the crib is not exposed. |
| 9 | | Status of water quality | Relatively good water can be obtained as selective intake is possible by operation of the gate | As selective intake is possible, intake can be performed in accordance with water temperature and quality. | Directly receive change in water quality of lake etc. | Directly receive change in water quality of lake etc. |
| 10 | | Status of water depth | Although there is almost no influence, unsuitable in case water depth is too big from the safety point of view. | Suitable in location where water depth is big. | Almost no influence | Although intake can be performed without influence, suitable where water depth is relatively small since O&M is generally difficult in case water depth is large. |
| 11 | | Geological condition | Good ground is desirable. Adequate foundation work shall be implemented in case weak ground is inevitably used. | In certain cases, there will be almost no influence depending on its type. | Good ground is desirable. | Although unsuitable to weak ground, it can be accepted in case ground is available to which the crib can be fixed. |

| Item | | Type of water intake | Intake tower: Fixed type | Intake tower: Movable type | Intake water gate | Intake crib |
|---|---|---|---|---|---|---|
| 12 | External factor | Weather condition | Influence of waves and freezing can be avoided to certain extent by operation of the water gate. | Caution shall be practiced as it directly receives influence of waves and freezing in the case of direct intake of surface water. | Directly receives influence of waves and freezing. Especially, it is cautioned that intake becomes impossible by freezing at times. | Almost no influence |
| 13 | | Relationship with navigation | Danger is small if the sailing route is avoided since it is exposed above water. | While avoiding the sailing route, marking of its location is needed in some cases. | Almost no influence | Sailing route shall be avoided, and marking etc. is needed as it is submerged. |
| 14 | Internal factor | Construction cost | As it is a relatively large construction work, the construction cost is high, especially, where water depth is large. | Large in general. | Large in general. | Large in general. |
| 15 | | Condition for maintenance | Studying the status of sand pile in the tower more than once a year, sediment flushing shall be made. | O&M shall be performed paying attention to sliding of the intake mouth. | As there is anxiety for intake mouth to be buried or exposed by change in the lake, proper O&M are needed. | A regular inspection is desirable mostly in dry season. It shall be cautioned that intake is easily interrupted in lake where piling of earth and sand is large. |
| 16 | Factor related to construction | Condition for construction/ time | There is no restriction in case it is built at the same time when the reservoir is newly constructed. In case it is installed in an existing lake or reservoir, the water level needs to be lowered to the required level for the work, the work is restricted for coordination and its timing, especially, in the case of a multiple purpose reservoir. | | In general, insulation is needed. | Although as the work is relatively small, construction is easy, under-water work or temporary insulation is required in some cases. |

B. Intake of groundwater (including infiltrated water)

| Item \ Type of water intake | | | Infiltration gallery | Shallow well: Well crib type/ casing type (Incomplete penetration well) | Shallow well: Well crib type/ radial collection well/ casing type (complete penetration well) | Deep well |
|---|---|---|---|---|---|---|
| 1 | Schematic | |  |  | Lateral collection well  Radial collection well  |  |
| 2 | Function, purpose | | A facility to collect infiltrated water in landside area, riverside area, former riverbed etc. | Installed in landside area, and riverside area. There are well crib type, and sunk casing type. Water is collected from its side walls or bottom | Installed in landside area, and riverside area. The radial collection well is big in diameter and collect water by collection pipes driven radially and horizontally at the level close to the bottom. | Collects water from a confined aquifer, and its casing diameter is mostly 150 mm to 400 mm. Pumping is performed by submerged-motor pumps in most cases. |
| 3 | Characteristics | | In case the condition of infiltrated water is stable, relatively good quality of water can be expected. It is effective when no facilities can be built on the ground. If the depth of burial is shallow, there is anxiety for the facility to be exposed or washed away. | Although it is a simple means of abstracting water, it tends to be affected by the condition of the ground surface. | Since the depth of collection pipes is large, natural purification can be expected, so suitable to a river etc. in which pollution is advancing. The radial collection well generally has as much collection area as covered by collection pipes compared with a shallow well. | Pumped-up groundwater in general possesses stable temperature and water quality. |
| 4 | Basic factor | Size of intake volume | In general used for intake of medium-scale volume. | In general used for intake of small-scale volume. | Although generally used for intake of small-scale volume, used for medium-scale volume incase aquifer is thick. | As to well, used for intake of relatively large-scale volume. |
| 5 | | Stability of water intake | Since buried under riverbed, so maintenance tends to be inadequate, insufficient intake may result due to clogging. | Relatively reliable water intake is possible. | Reliable water intake is possible unless excessive pumping is made. | Reliable water intake is possible. |

| Item \ Type of water intake | | | Infiltration gallery | Shallow well: Well crib type/ casing type (Incomplete penetration well) | Shallow well: Well crib type/ radial collection well/ casing type (complete penetration well) | Deep well |
|---|---|---|---|---|---|---|
| 6 | Legislative factor | Restriction by the River Law | It is required to secure more than 2 m of earth cover. | Construction in river protection area and riverside land will subject to the Law. | Construction in river protection area and riverside land will subject to the Law. | None. |
| 7 | External factor | Intake point | Suitable where there are an aquifer with good permeability, and no possibility of lowering of riverbed. | As it tends to be affected by the condition of the ground surface, it is desirable to avoid where there is possibility of pollution. | Suitable where permeability is adequate and the depth of the aquifer is sufficient. | An area where confined aquifer exists. |
| 8 | | Condition of riverside land | Location, where possibility of exposure of the facility is large due to change and lowering in riverbed, is unsuitable. Besides, location, where there is large piling of earth and sand, is unsuitable. | Almost no influence | Almost no influence | No relationship |
| 9 | | Size of river | Used irrespective of the size of the river. | Used irrespective of the size of the river. | Used irrespective of the size of the river. | No relationship |
| 10 | | Condition of river flow | Almost no influence | Almost no influence | | No relationship |
| 11 | | Condition of inflow of earth and sand | Since infiltrated water is collected, there is no inflow of earth and sand, so water quality is generally good | Since infiltrated water is collected, there is no inflow of earth and sand, so water quality is generally good | In general good quality of water can be obtained. | Small in general |
| 12 | | Condition of water quality | Although in case condition of infiltrated water is good, relatively good quality of water can be expected, in case it is installed in riverside land, water quality may become deteriorated due to direct influence of surface water. | Although better than surface water, since vulnerable to the influence of the ground, attention shall be paid to deterioration in water quality in case there are residences, factories etc. in the surroundings. | | In general, water quality is good and stable. |

| Item \ Type of water intake | | | Infiltration gallery | Shallow well: Well crib type/ casing type (Incomplete penetration well) | Shallow well: Well crib type/ radial collection well/ casing type (complete penetration well) | Deep well |
|---|---|---|---|---|---|---|
| 13 | External factor | Condition of stream center | Although its influence is small, location, where the stream center is stable, is desirable. | Although, in general, influence is small, location, where the stream center is stable, is desirable. | Generally influence is small. | No relationship |
| 14 | | Condition of water depth | Almost no influence | Almost no influence | | Almost no influence |
| 15 | | Geological condition | Suitable to riverbed of which permeability is good. | Suitable to gravel layer with good permeability. | Suitable where aquifer is thick enough and good in permeability. | Suitable where aquifer is thick enough and good in permeability. |
| 16 | | Weather condition | Almost no influence | Almost no influence | | Almost no influence |
| 17 | Internal factor | Construction cost | Small in general. However, it may become large because such work as submerged work etc. is additionally needed in case aquifer is deep. | Large in general | Construction cost may be large in case aquifer is deep. | Large in general |
| 18 | | Construction of maintenance | Regular or ad hoc removal of sand from the galleries is needed. Inspection is difficult in normal times as they are situated under water. | As yield changes in relation to flow of river, proper management of pumping is needed. | Since the function may become low due to excessive pumping, regular monitoring of water level in not only the production well but wells in neighboring area and the observation well. | Management is needed so that pumping does not become excessive, so it is important to pay attention to always watch the natural water level and that in operation. |
| 19 | Factors related to construction | Construction of construction | In case the earth cover (5.0 m as standard) is relatively large, attention shall be paid as easily affected by condition of flow and geological property. | In the case of riverside land, as easily affected by flow, caution is required. In case construction is carried out in the vicinity of the levee, influence to the foundation of the levee shall be considered. | | Attention shall be paid not to give influence to the surroundings. |
| 20 | | Timing of construction | In the case of riverside land, ditto to the case of the intake weir. There are relatively few restrictions for the timing | In the case of riverside land, ditto to the case of the intake weir. In the case of landside area, there are relatively few restrictions for the timing. | | Almost no restrictions for the timing. |

### 2.1.4. Improvement and replacement of raw water intake facilities

Improvement and replacement of raw water intake facilities shall be undertaken in accordance with the following:

1. The intake facilities of surface water are required to be maintained their function for a long time. Hence, their inspection and maintenance shall properly be carried out, and their improvement and replacement shall be undertaken systematically.
2. The groundwater intake facilities sustain a decline in yield due to clogging of screens and so forth; and drawdown in water level or deterioration in water quality is brought about because of change in the surroundings etc.
   As such, the condition shall be monitored installing measurement apparatus, and, in addition, systematic improvement and replacement of the facilities shall be implemented.
3. At the time of improvement and replacement of the water intake facilities, consideration shall be practiced to provide proper capability of resistance to an earthquake.

**[Interpretation]**

**On the item 1.;**

**1) Proper O&M, improvement and replacement**

Since such intake facilities of surface water as intake weir, intake tower and intake water gate are large in size, of which location for installation is limited, and cannot be rebuilt easily, their function shall be maintained for a very long time. To properly maintain the capacity of water intake, it is needed to execute proper and adequate inspection and maintenance of the facilities as well as to aim at their improvement and replacement in accordance with their deterioration over time and change in the environment.

**2) Measure for change in riverbed**

Since the intake facilities of surface water are installed in a riverside land, their stability as civil structures is impaired due to the lowering of the riverbed as a result of scouring by a flood, which gives a heavy impact to the function of water intake.

To avoid such an incidence, such measures as strengthening of the front apron, riverbed protection etc. should be provided so as to raise their safety.

**3) Such steel structures as the gate and ancillary facilities**

Materials etc. for such steel structures as the gate and such ancillary facilities as mechanical and electric equipment shall be selected based on proper evaluation of their components and parts for their economic lives taking into account their functions and properties. As such, it shall be considered that the structures etc. of the equipment shall be so designed that their maintenance, repair, improvement, and replacement can easily be made. A spare of the gate, or doorstops for flushboards shall be provided in advance as preparation for repair of the main body of the gate; and scaffolding for the work of replacement of parts, and repainting of steel components shall be furnished.

**On the item 2.;**

**1) Monitoring of the function of water intake**

Since, in the cases of such groundwater intake facilities as infiltration gallery, shallow well, deep well etc., the decline in their function appears as the change in water level, water volume, water quality over time, improvement and replacement shall systematically be implemented based on the synthetic evaluation of pumping test data obtained at the time of well sinking, data on day-to-day operation etc.

Such measurement apparatus as water gauge, flow meter, turbidimeter etc. need to be installed on the well from the time of well sinking so that required data on water abstraction can be collected.

**2) Measures for prevention of water pollution**

Although the groundwater is a water source, of which water quality is good with small fluctuation, in case it is polluted by seawater, wastewater from a factory etc. its influence sustains for a long time. Since the restoration from the incidence of pollution is sometimes difficult, measures for water pollution shall be provided in advance.

As for measures for water pollution of the well etc., there are selection of the intake point with no possibility of pollution, preservation of environment in the catchment area, shutoff of the route of pollution, installation of facilities for removal of t he pollutants etc.

**3) Other matters of attention**

Since main part of the groundwater intake facilities are buried in the ground or water, and they need to be stopped at the time of improvement etc., consideration is required that layout and structure of equipment such as space for its carry-in and –out, and handling and so forth so that repair of clogging of screens, replacement of submersible-motor pumps, etc. can be implemented as easily and quickly as possible.

## 2.2. Intake of surface water

### 2.2.1. General

**1. Structure and location of water intake facilities**

Water intake facilities shall have sufficiently safe structures against expected load, and can reliably abstract the design raw water intake volume.

At the time of installation of the water intake facilities, proper structure, location etc. shall be determined through coordination with the administrator of the river.

**2. Equipment for the water intake facilities**

Equipment for monitoring of water quality, in addition to one for measurement of the water level and water flow, shall be installed, if required, for the water intake facilities to secure reliable water intake. Additionally, fencing around the water intake facilities shall be provided for safety and the prevention of pollution, and the entry of ordinary people shall be prohibited.

In case lake water or water of an impounding reservoir is directly withdrawn, there is seasonal difference in water quality depending on water depth in the stratification phenomenon. Besides, since various microorganisms and algae breaks out close to the water surface; turbidity increase at the time of flood; and water temperature is markedly different by depth; water intake mouths shall be installed according to the depth so as to selectively abstract water of good quality.

### 2.2.2. Survey

> A survey shall be undertaken on the proposed point of water intake and its surroundings on the following matters:
>
> 1. Such status of the river as flow and water level etc.
> 2. Master plan for development of the river basin
> 3. Situation of water use
> 4. Geography and geology
> 5. Water quality etc.
> 6. Influence to the environment

**[Interpretation]**

**On the item 1;**

**1) In case river water is withdrawn**

The future flow and water level of the river shall be determined from observation data on the water level and flow of the river for as long a period as possible at the proposed intake point. In case these data are unavailable, the future flow and water level shall be derived from the date collected in the vicinity of the proposed intake point.

Admitting that it is ideal to locate the intake mouth where the riverbed is stable and there is no inflow of earth and sand, practically speaking, sand always drifts in water, and the riverbed changes due to the movement of earth and sand at the time of a flood. At the time of planning and designing the water intake facilities, the movement of earth and sand and its nature, piling on or scouring of the riverbed related to the movement, the volume of earth and sand flowing into the intake mouth etc. shall be considered.

When planning and designing the water intake facilities to be installed near a river mouth, such necessary surveys as waves, tide level and the retroactive reach of seawater so that seawater does not intrude the intake mouth.

**2) In case lake water is withdrawn**

Surveys shall be conducted on the maximum flood level, design high water level, the relationship between the water level and the volume of water in the lake, profile of the lake, condition of the bottom of the lake etc. as the reference for selection of the location of the intake facilities, the method of abstraction and so on.

**3) In case water is abstracted from an impounding reservoir**

Refer to 1) and 3.2.2 Survey 1. Hydrology.

**On the item 2.;**

The river development master plan, which prescribes the matters as the basis for the implementation of river conservation work, shall be understood. In case the river development master plan does not exist, a study shall be made on the design high water flow, design high water level, design cross section, annual plan for river improvement work etc. which are determined under the river improvement plan for the ongoing river improvement work.

**On the item 3.;**

In case water is newly withdrawn, the balance of the river flow (the standard droughty water discharge) less the river maintenance flow and the quantity necessary for the existing users shall be enough for the quantity required for the new user. Given this, a study shall be conducted on the existing water rights for water supply, irrigation, industrial water supply, hydraulic power generation etc.

In addition, since fishing rights are established on rivers and lakes in many cases, coordination shall be made with the holders of fishing rights so as not to face a problem afterwards.

A survey is required on the situation of the use of infiltrated water if any, and on the size of boat, quantity of its traffic, time of traffic etc. in case there is navigation of ships.

**On the item 5.;**

**1) Relationship between precipitation and water turbidity**

When evaluating the result of surveys on turbidity, a study shall be carried out to clarify whether or not the cause of high turbidity is mainly due to the natural factor of flood brought by precipitation or the manmade factors of construction work, discharges from the dam etc.

The river flow increases and its turbidity become high. Thus, it is needed to study on the relationship between the river flow and the turbidity. Especially, such other data as annual trend of the maximum turbidity at the time of the past floods, their duration etc. shall be studied.

When evaluating the result of surveys on turbidity, a study shall be carried out to clarify whether or not the cause of high turbidity is mainly due to the natural factor of flood brought by precipitation or the manmade factors of construction work, discharges from the dam.

**2) Change in turbidity during the year**

The water quality is affected by such manmade pollution as wastewater from a factory, city sewage, domestic wastewater, livestock sewage, agricultural chemicals, fertilizers etc.; and changes in relation to weather, geology etc. of the river basin. As described in 1.2.4 Basic survey, a water quality survey shall be undertaken to judge if the quality of raw water is suitable for the present and future, and what method of water treatment shall be chosen (See 5.1.2. Survey).

The points of water sampling for water quality tests shall be selected from the proposed intake site, at the confluence with a tributary upstream, and a location where the typical characteristics of water quality is found. To this end, sampling shall be made synthetically surveying topography, geography, etc. irrespective of surface water or groundwater.

**3) Phenomena of eutrophication, temperature stratification etc.**

Lakes and impounding reservoirs in general change from an oligotrophic lake to an eutrophic lake by piling of carcass of animals, earth and sand etc. with which such nutritive salts as nitrogen, phosphorus etc. accumulate. In that process, owing to these nutritive salts, the production of organisms increases. As a result, such phenomena occur as discoloration of water, decline in transparency, outbreaks of algae, change in species of fish etc. In case nutritive salts are fed in a large quantity by the artificial pollution etc., the eutrophication progresses markedly fast. For the water quality survey of a lake, the measurement of such substances is indispensable as nutritive salts of inorganic nitrogen, phosphorus as phosphoric acid, transparency, chemical oxygen demand (COD), and dissolved oxygen (DO).

The flow and quality of water of the feeder river give significant influence to the water quality of the lake or impounding reservoir. Hence, it is necessary to survey the flow and quality of water of the feeder river over time. It is desirable to survey on the effluent river from the lake so as to grasp the balance of the water quantity and pollutants and their trend.

The influence to use water from a eutrophied lake is as follows:

(1) Increase in the chlorine demand due to ammoniac nitrogen
(2) Occurrence of odor due to the growth of plankton etc.
(3) Clogging of filters due to plankton etc.
(4) Trouble with red water caused by elution of iron and manganese from the substratum
(5) Hindrance to the coagulation-sedimentation process

Especially, the occurrence of odor in water is a big problem. Even though no problem is happening at the time of planning, as there is a case where the problem occurs all of a sudden 3 to 5 years later, a study on such organisms as plankton etc., nutritive salts etc. shall continuously be executed as well as their trend over time.

**4) Identification of the source of pollution**

Efforts shall be made to identify the existence and types of factories, businesses etc. as a source of pollution, the situation of discharge of pollutants and so forth in the vicinity and the catchment area of the water source. Locations, quantity, names of discharged substances shall be plotted on a map for easy reference.

**5) Condition of protection of water quality**

It is clear that the influence of household wastewater, especially such non-fecal wastewater from kitchen etc. is large to the pollution of lakes. Data shall be collected on the sewerage development plan as well.

**6) Present status and future forecast of water quality**

Synthetically examining the items of the study, on the present status and future forecast of water quality at the intake location in question, and adding observations from the point of the water supply utility, efforts shall be made to reflect the result of the study to the selection of the method of water treatment, management of the water source etc.

**7) Others**

Since the water quality of the lake is strongly affected by the environment of such surroundings as the river basin, existence of the source of pollution, such property as the storage volume, depth etc. of the lake, wind speed, its direction etc., those matters shall be studied.

Springs in the lake give large influence to the yield and water quality of the lake. Navigation of ships may cause pollution by oil etc., As such, a study on these matters shall also be conducted. Additionally, the possibility of pollution by recreation facilities on the lakeshore and tourists shall be taken into account.

**On the item 6.;**

When installing the water intake facilities, the influence of such ecosystems as fish, birds, plants etc. and landscape in the surroundings shall adequately be studied.

**2.2.3. Selection of intake location**

The location of water intake shall be selected according to the following:

1. To be able to reliably abstract the design raw water intake volume

2. Good quality of water can be obtained for the future as well as present.
3. Structural safety can be secured.
4. Not to be too close to the facilities for management of the river, and other workpieces.
5. Not to be troubled by the implementation of the river improvement plan.
6. Reduction in environmental burden shall be taken into account.

**[Interpretation]**

**On the item 1.;**

**1) In case river water is abstracted**

It is desirable that the water intake site is selected where the water level is stable all year around; there is only small possibility for the change in flow center and the rise or fall in riverbed in the future as well; and the flow is gentle.

**2) In case lake water is abstracted**

A location, where the water level is stable all year around; the design intake water volume can be secured even in a drought; and there is no influence of earth and sand brought by a feeder river to water intake, shall be selected for the intake of lake water.

**On the item 2.;**

**1) In case river water is abstracted**

The point, where wastewater is drained, shall be avoided as the intake point even if all other conditions are favorable.

In case the water intake is installed near a river mouth, a location, where there is no intrusion of seawater, shall be selected.

**2) In case lake water is abstracted**

As to abstraction of lake water, a location, where water is markedly polluted due to scouring of deposits on the lake bottom, a location, where the corrosion of the lakeshore by waves by strong winds; or a location floating debris gather, shall be avoided.

**On the item 6.**

By means of selecting the location of the intake site as upstream as possible, such effects to lessen load to the environment as utilization of potential energy, simplification of the water treatment processes owing to clear raw water etc. can be expected.

## 2.3. Intake weir

### 2.3.1. General

The intake weir is a facility to enable reliable water intake by means of securing the design water level, which is built traversing the river, and consists of the main body of the weir and the intake mouth, which are composed of a lift-up gate or a rise-and-fall gate (See Figure 2.3.1).

The intake weir is suitable in cases relatively large volume of water is withdrawn; water is withdrawn together with such other water users as irrigation; the condition of the river is unstable; precise flow control for water intake is required for the river where water utilization is in an advanced stage.

The structure of the weir is divided into movable weir and fixed weir. The former can adjust water level, whereas the latter cannot.

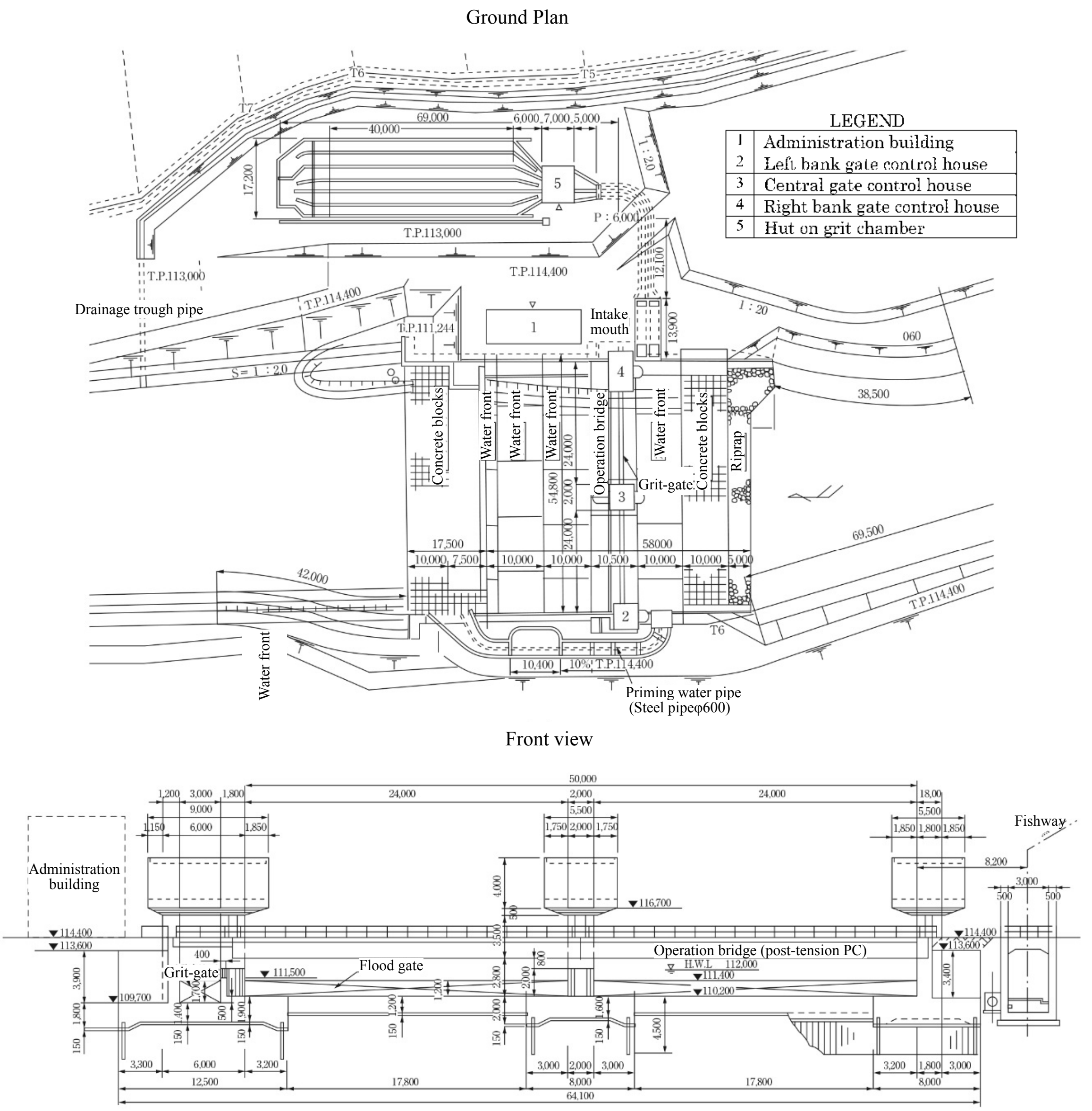



**Figure 2.3.1 Intake weir (Tsutsumigawa intake facilities, Aomori city water supply department (65,000 m$^3$/day)) (Unit: mm)**

### 2.3.2. Location and structure

The location and structure of the intake weir shall be in conformity with the following:

1. The location shall be where the gut (water-route) is stable and close to the intake mouth; and the change in the riverbed is small.
2. The structure shall, as a general rule, be straight-line, perpendicular to the stream line of the flood, and installed in a straight section of the river.
3. The weir shall be located so that it gives as small influence to a river workpiece as possible due

to the rise in water level at the times of filling and a flood.

4. The sill level of the movable weir shall be so set that the flow is not interrupted considering the deign elevation of riverbed, the present elevation of riverbed, the future change in the riverbed etc.
5. The weir shall be a reinforced concrete as the general rule.

**[Interpretation]**

**On the item 2.;**

If the intake weir is installed where the direction of the flow center of a flood is not perpendicular, or where the width of the river becomes narrow, where the river meanders etc., the stability of the structure is largely affected as the impact working on the weir, the scouring force acting on the riverbed etc. get markedly large as the river flow is disturbed at the time of a flood.

### 2.3.3. Movable weir

The movable weir shall be in conformity with following:

1. The gate shall be of the lift-up type or the rise-and-fall type.
2. The gate shall in principle be of a steel structure.
3. The grit-gate is to be installed to maintain the water-route and enable the smooth water intake.
4. The spillway shall be provided to make the flood safely flowing down.

**[Interpretation]**

**On the item 1.;**

There are two types of movable gates, namely the lift-up type gate (See Figure 2.3.2) and the rise-and-fall type gate. As the rise-and-fall type gate is operated by a hydraulic cylinder etc, its open-and-shut is not securely performed due to deposit of sand etc. at times. Given this, the lift-up type is employed for important rivers etc. in principle.

**On the item 3.;**

The grit-gate is installed close to the intake gate to maintain the water-route, prevent flow of earth and sand into the transmission conduit when abstracting water, and make easy the discharge of earth and sand piling in front of the intake mouth. It is desirable to set the sill of the grit-gate 0.5 m to 1.0 m lower than the spillway.

**On the item 4.;**

The spillway is provided to secure the design intake water level, and make the flood safely flowing down.

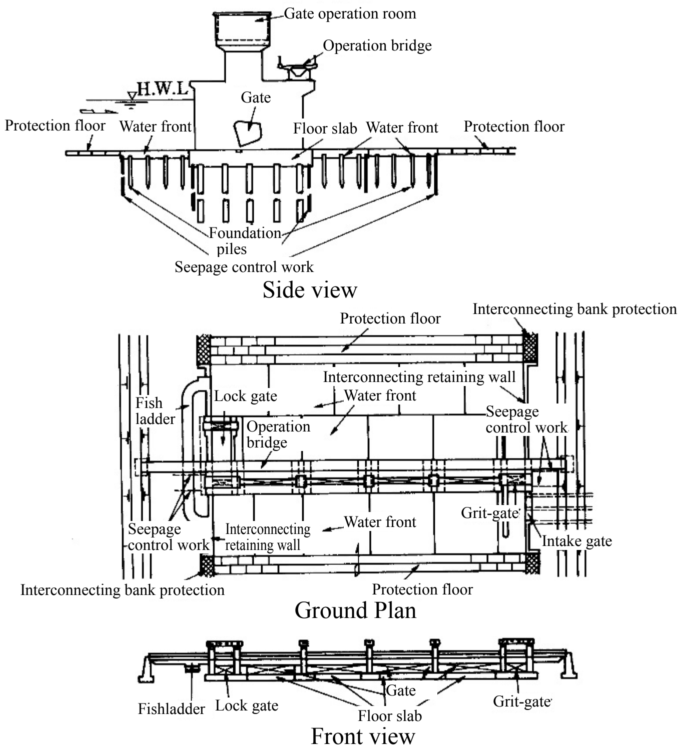



**Figure 2.3.2 Names of parts of a movable weir with a lift-up type gate.**

**(Technical standards for soil-corrosion control – Annotation, Chapter 1 Design, Ministry of Land, Infrastructure, Transport and Tourism)**

## [Reference 2.5] Grit-gate and spillway

### 1. Grit-gate

1) The standard flow of sediment flushing required for the removal of earth and sand shall not be less than the ordinary water discharge in the river in question. However, the droughty water discharge shall also be considered for the river where flowing-down of earth and sand is large in quantity, and sediment flushing is expected to be frequent.

2) The flow velocity of sediment flushing shall be sufficient for flushing out the earth, sand and gravel which are expected to pile up near the intake mouth. The required velocity of flushing is determined according to the size and shape of sand and gravel.

Considering that the flow velocity required to move stand-still gravel is about 1.5 times that for bed load transport, the required sediment-flushing velocity is obtained by the following formula, which is a variation from the Lacey formula multiplied by 1.5:

$$Ve = 1.5C\sqrt{d}$$

Where,

Ve : Required sediment flushing velocity (m/s)

C: Coefficient by the shape of gravel. 3.2 to 3.9 as the standard. Small in case the gravel is roundly shaped; large in case it is squarely shaped. It shall be set at 4.5 to5.5 in case gravels agree each other.

1.5: Safety factor

d: Maximum diameter (generally 0.3 m)

3) The width of the grit-gate shall be so determined that the required sediment flushing velocity is obtained by the standard sediment flushing flow, and that it does not become a barrier for flow-down of drift-wood etc. at the time of a flood.

The width of the grit-gate is generally obtained by the following formula.

$q = Ve^3/g$

$L = Q/q$

where,

L: Width (m)

Q: Standard sediment flushing flow ($m^3/s$)

q: Flow per unit width (($m^3/s$)/m)

Ve: Required sediment flushing velocity (m/s)

g: Gravity constant ($m/s^2$)

The value of q is commonly 2 to4 ($m^3/s$). In case it is larger than this, it is more convenient to divide the entire width into certain traves so that operation can be made in accordance with the change in flow.

4) As sediment-flushing is carried out in a short period of time, the slope of the water front of the grit-gate shall be so designed that the flow becomes a supercritical flow.

The slope of the water front of the grit-gat is in general obtained by the following formula:

$le \geqq n^2 g^{10/9} / q^{2/9}$

where,

le: Critical gradient (in general 1/20 to 1/100)

n: Roughness coefficient

q: Flow per unit width (($m^3/s$)/m)

g: Gravity constant ($m/s^2$)

5) The upstream area of the grit-gate shall be in a state of a water channel; and guide walls shall be provided to force the flushing of sediments.

## 2. Spillway

1) The entire flow section of the movable weir less the flow section of the grit-gate is generally called the flow section for the flood gate.

2) The sill elevation of the spillway shall be the same to that of the design riverbed so that it does not become an obstacle to the flow of the design high water discharge, so the sill level is to be set 0.5 m to 1.0 m higher than that of the grit-gate.

3) The trave of the spill gates (center-to-center distance of pillars of the weir) shall in general be determined in accordance with Reference Table 2.5.1.

**Reference Table 2.5.1 Design high water discharge and the trave of weir pillars**

**(Ordinance for river management structures etc)**

| Design high water discharge (Unit: $m^3/s$) | Trave of weir pillars (Unit: m) |
|---|---|
| Less than 500 | 15 |
| More than 500, less than 2,000 | 20 |
| More than 2,000, less than 4,000 | 30 |
| More than 4,000 | 40 |

### 2.3.4. Height

> The height of the intake weir shall be determined so that the design raw water intake volume can reliably be abstracted.

**[Interpretation]**

The height of the intake weir shall in principle be determined as the sum of the design water intake water level and required allowance. The allowance is to be provided for waves etc. and normally is 10 cm to 15 cm.

The design filling water level is in general 50 cm lower than the high water riverbed, and not higher than the landside area. However, such special provision as embankment in the landside area or the high water riverbed is needed in an inevitable case due to the condition of the topography etc.

Furthermore, the height of the rise-and-fall weir shall be lower than 1/2 of the design water depth (the design high water level less the design riverbed level), and the height of its main body shall not be more than 3 m (See Figure 2.3.3).

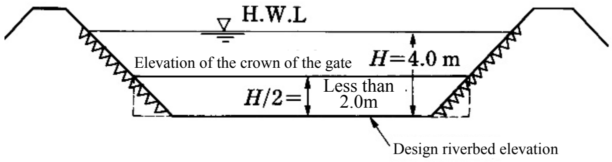



**Figure 2.3.3 Crown height of the rise-and-fall weir**

### 2.3.5. Water front

> 1. A water front shall be provided to prevent scouring of the downstream part of the weir by overflowing water, or strong water flow at time of partial opening of the gate.
> 2. The water front downstream of the weir shall have a structure to withstand the lifting pressure.

**[Interpretation]**

**On the item 1.;**

The water front shall in principle be constructed with reinforced concrete, and the joint between the water front and the bottom slab shall be water tight and durable to uneven settlement (See Figure 2.3.4 and Figure 2.3.). The length of the water front shall be long enough to prevent the scouring of the riverbed.

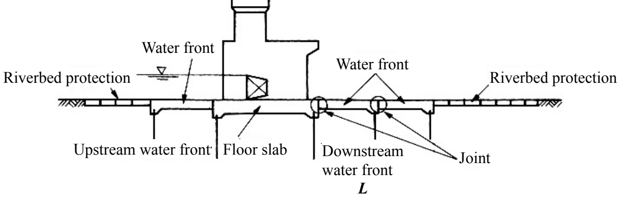



**Figure 2.3.4 Water front**

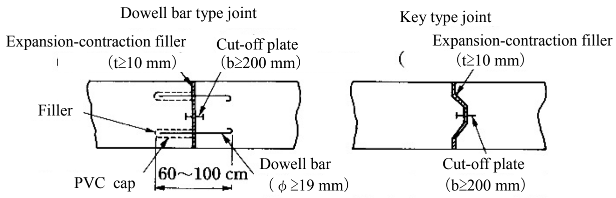



**Figure 2.3.5 Joint of water front**

**On the item 2.;**

Although the thickness of the water front shall be determined taking into consideration the uplift brought by the difference between the upstream water level and the downstream water level, the weight of water, the vertical load under construction and so on, it is in general set at 50 cm to 1 m or so. The thickness of upstream water front shall be 1/3 to 1/2 of that of the downstream one.

It is useful to provide seepage control walls to make the seepage route long so as to reduce the uplift.

The seepage control wall shall be in principle be a cut-off wall of concrete structure or a sheet pile structure (See Figure 2.3.6, Figure 2.3.7)

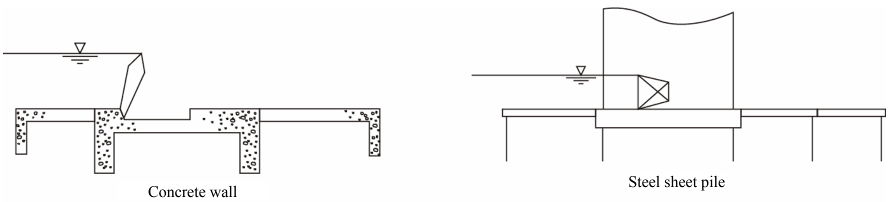



**Figure 2.3.6 Structure of seepage control wall**

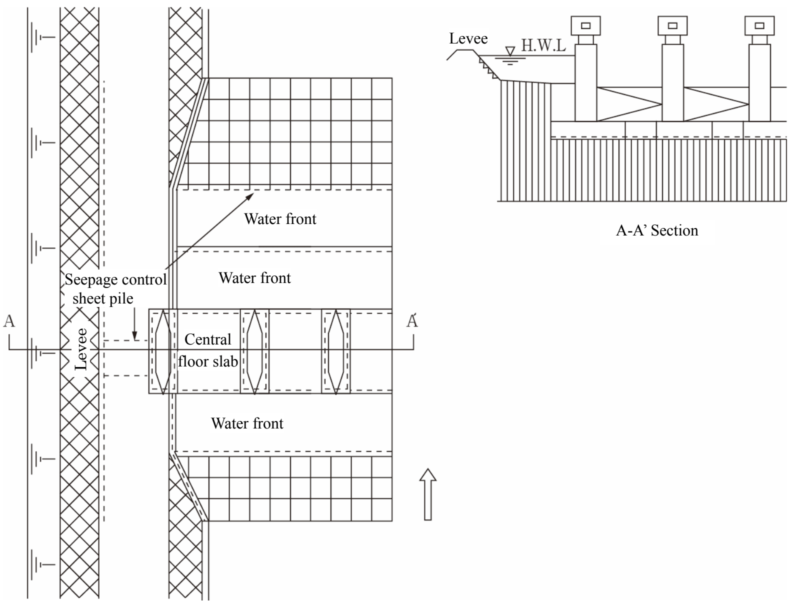



**Figure 2.3.7 Location and structure of seepage control walls**

### 2.3.6. Riverbed protection

> 1. Riverbed protection shall, as a general rule, be provided at both upstream and downstream of the water fronts.
> 2. The structure of the riverbed protection shall, as a general rule, possess flexibility.

**[Interpretation]**

**On the item 1.;**

The riverbed protection, which has functions to reduce the flow velocity and control the flow, is a workpiece built horizontally on the riverbed to prevent scouring, and placed at both upstream and downstream of the water fronts for the purpose of the protection of the main body of the levee and the water fronts (See Figure 2.3.8).

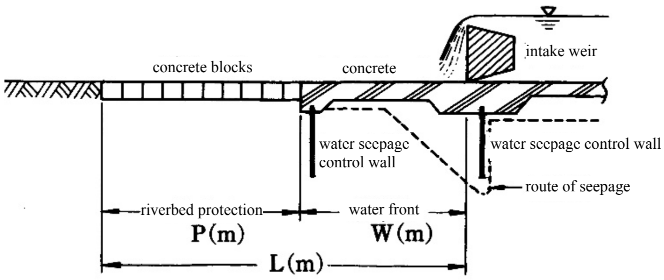



**Figure 2.3.8 An example of structures of a water front and riverbed protection**

**On the item 2.;**

The nature of the riverbed protection shall change from hard to soft according to the distance from the main body of the levee. The commonly used types are concrete block floor, riprap floor, sunk sticks floor etc. and their combination.

### 2.3.7. Water intake mouth

> The structure of the water intake mouth shall be in conformity with the following:
> 1. It can at all times abstract the design volume of raw water intake; earth and sand do not pile up or flow in the mouth; and its maintenance is easy.
> 2. Its sill level shall be 0.5 m to 1.0 m higher than that of the grit-gate.
> 3. The standard inflow velocity to it shall be 0.4 to 0.8 m/s.
> 4. Its width shall be so determined that the sill level and the inflow velocity are maintained within their standard ranges.
> 5. Screens shall be provided before the sluice gates.
> 6. A water intake apron shall be provided insofar as land is available.
> 7. The design water level of water intake shall be determined calculating the head loss from the intake mouth to the starting point of raw water transmission.

**[Interpretation]**

**On the item 1.;**

Screens, sluice gates, gate pillars, water intake apron, grit-gate, spillway etc. shall be installed at the water intake mouth to withdraw the design raw water intake volume.

The water intake mouth shall be set in right angle to the slope of the levee where the water-route is near the shore and enough water depth is maintained.

**On the item 2.;**

Since the vertical distribution of contents of sand in river water rapidly starts to increase from the 0.6H (H: water depth), and becomes the maximum at 0.8H below the surface, it is beneficial for the sill of the intake mouth to be as high as possible (See Figure 2.3.9).

**On the item 3.;**

The inflow velocity to the intake mouth needs to be determined according to the status of the riverbed, the condition of the stream, contents of sand, quantity of debris etc. It is set at 0.4 to 0.8 m/s as the standard.

**On the item 4.;**

The width of the intake gate shall be so determined that abstraction of the design maximum intake volume is possible. In case the width is large, it may be divided into some traves by means of arranging gate pillars (The standard width is 1 to 2 m with a manual winding device; and 3 to 6 m with a motorized winding device).

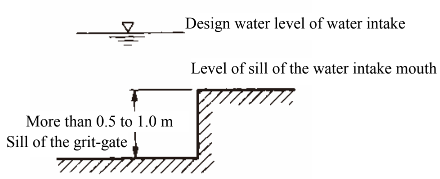



**Figure 2.3.9 Sill level of the water intake mouth**

**[Reference 2.8] Width of the intake mouth**

The width of the intake mouth shall be determined in accordance with the following formula:

$$B=Q/(H \cdot V)$$

where,

B : Width of the intake mouth (m)

Q : Maximum volume of water intake ($m^3/s$)

H : Depth of inflow water (m)

V : Inflow velocity

**On the item 5.;**

The screens shall cover all the face of the sluice gates to prevent inflow of debris, water weed, driftwood, floating ice etc., and be set at the angle of 70 degrees or so to easily remove debris at the river side. The screen shall be made of stainless steel; the bars of it shall be round bars, and the interval of the bars shall be 3 to 5 cm.

**On the item 6.;**

The intake apron stands for the connecting section between the intake gate through the raw water transmission conduit, which gently leads the water from the river to the conduit (See Figure 2.3.10).

**Figure 2.3.10 Water intake yard (Intake mouth under the joint project, Kanagawa Prefecture)**

**On the item 7.;**

The types of head loss are as follows:

1. Head loss due to inflow
2. Head loss due to the steps of the intake mouth
3. Head loss due to the gate pillars
4. Head loss due to the screens
5. Head loss due to friction
6. Head loss due to rapid reduction in sectional area
7. Head loss due to gentle reduction in sectional area
8. Head loss due to curving

### 2.3.8. Ancillary facilities

> The water intake weir shall be equipped with such ancillary facilities as an operation bridge, fish ladder, lock for ships, drift wood channel, lock, warning devices etc. if required.

## 2.4. Intake tower

### 2.4.1. General

The intake tower is a tower-like structure built in river, lake, impounding reservoir, and water is directly drawn in the tower with intake mouths provided on its side wall (See Figure 2.4.1). It is a concrete structure, which commonly possesses multi-stage mouths with gates properly arranged. A floating type of intake tower with concrete structure is at times suitable in case the water depth is especially large in a lake or impounding reservoir. If certain water depth is secured even at a drought, the intake tower is suitable as the water intake facility in a river, lake or impounding reservoir even if the annual change in water level is large; and its maintenance is relatively easy. What's more, since raw water transmission to the landside area can, as a merit, be done by not only gravity flow but pumping, it is not affected by topographical restrictions.

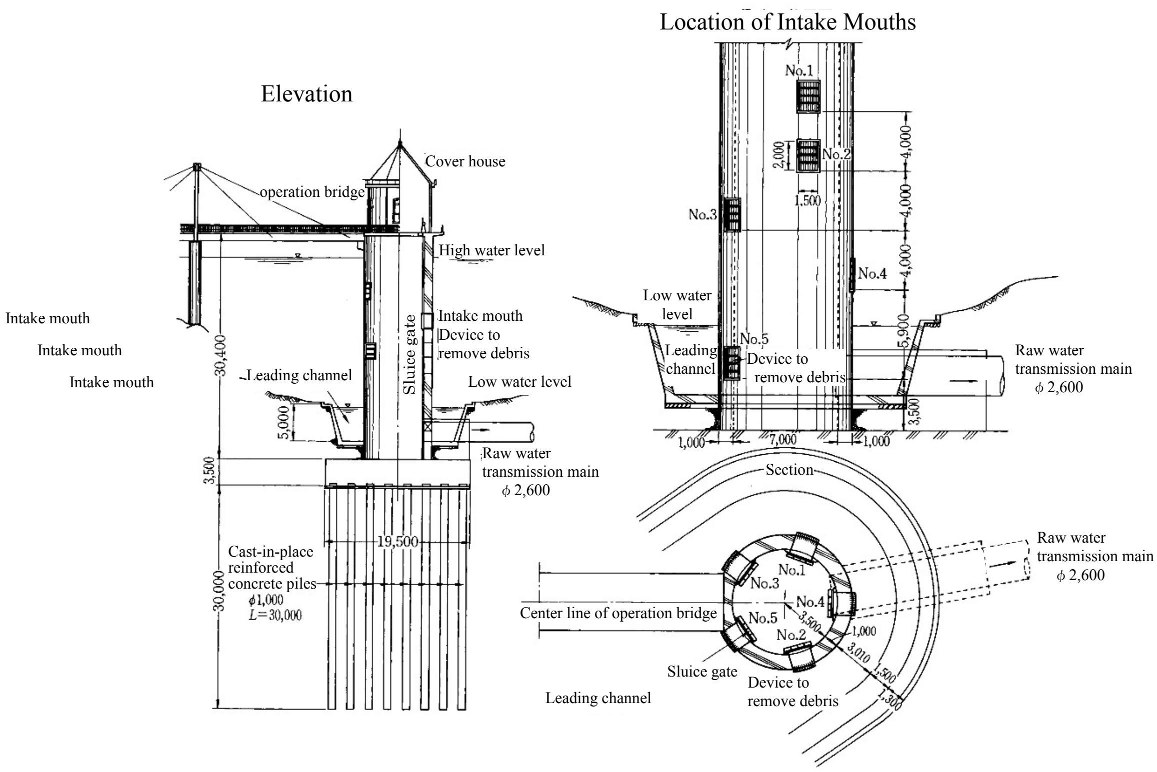



**Figure 2.4.1 An example of the intake tower (No.2 intake tower, Yamaguchi reservoir, Tokyo Metropolitan Water Department) (Unit: mm)**

### 2.4.2. Location and structure

The location and structure of the intake tower shall be in conformity with the following:

1. The location shall be where the smallest water depth is maintained 2 m or more throughout the year; and where the stream center runs as close to the levee as possible in case it is installed in river.
2. The intake tower, which is built by means of the well crib sinking method, shall be furnished with a steel curb shoe and thick concrete wall with sufficient reinforcement.
3. In case there is a possibility of scouring, the riverbed around the tower shall be paved with stone or concreting for floor consolidation.

**[Interpretation]**

**On the item 1.;**

Unless 2 m of water depth at the minimum at a drought is secured, the installation of the intake mouth for abstraction of the design water intake volume is difficult. Furthermore, in case the tower is installed in the river, it is advantageous for maintenance to locate it where the stream center runs as close to the river bank as possible since the tower can be built near the bank, which makes the length of the operation bridge short.

### 2.4.3. Shape and height

The shape and height of the intake tower shall be in conformity with the following:

1. The plan (horizontal section) of the intake tower shall be ringed and round or oval. In case it is built in a river, the shape shall in principle be oval, and its main axis shall be parallel to the direction of the flow.
2. The inner diameter of the tower shall be large enough to properly arrange the intake mouths.
3. The crown of the tower and the base surface of the operation bridge shall be higher than the design highest water level of the river, lake or impounding reservoir.

**[Interpretation]**

**On the item 1.;**

The tower shaped round or oval excels in terms of appearance as well as structure. In case the tower is built in a river, its shape shall be oval, of which main axis shall be set parallel to the direction of the flow so as not to disturb the flow.

### 2.4.4. Intake mouth

The intake mouth of the intake tower shall be in conformity with the following:

1. Even at the design lowest water level, the location shall enable to reliably abstract the design water intake volume.
2. The face of the mouth shall be rectangular or round
3. The face of the intake mouth shall be fit with a screen to ward off the inflow of debris.
4. A sluice gate, butterfly valve or sluice valve shall be furnished inside or outside of the tower body.

**[Interpretation]**

**On the item 1.;**

The intake mouth installed at the lowest level shall be at the design lowest water level so that the design intake water volume shall reliably be abstracted even at a drought. In addition, it is desirable to provide multi-stage mouths so that the withdrawal of water at not only the design highest water level but layers of water at the middle level shall be possible. For that purpose, caution shall be paid not to weaken the structure of the tower.

**On the item 2.;**

The shape of the intake mouth shall be rectangular or round in regard to the shape of sluice gate, sluice valve etc.

The standard sectional area of the mouth is set for the inflow velocity of 15 to 30 cm/s in the case of the river, and 1 to 2 m/s in the case of the lake or impounding reservoir.

**On the item 3.;**

An iron grating with a spacing of 3 to 5 cm is commonly furnished in front of the intake mouth as a screen. A raking device shall be fit with the screen to remove the debris stuck to the screen; or a spare unit of the screen shall be provided.

**On the item 4.;**

In the case of the river, the sluice gate etc. shall be placed inside the tower wall to prevent collision with driftwood etc. Besides, in the case of the lake or impounding reservoir, they are often installed outside.

### 2.4.5. Ancillary facilities

| |
|---|
| An operation bridge, lighting fixtures, driftwood fence, trash removal device and lightning rod shall be installed at the intake tower. |

**[Interpretation]**

The operation bridge is a facility necessary to connect the tower with the bank for the O&M purposes, and its width shall in general be more than 1 m.

## 2.5. Intake water gate

### 2.5.1. General

The intake water gate is a facility built close to water to abstract surface water of a river or the outer stratum of lake water; and water abstracted by it is transmitted through a tunnel or pipe connected to it (See Figure 2.5.1).

Its structure is commonly of reinforced concrete of a water gate type; a water gate, with which volume of water intake is adjusted, is fit at the square or horse shoe type inflow mouth; and, in addition, a screen is furnished before the water gate to ward off the inflow of such trash as driftwood.

The intake water gate is suitable for abstracting water of small to medium volume at a location where the water level and the riverbed are stable; and its O&M is relatively easy.

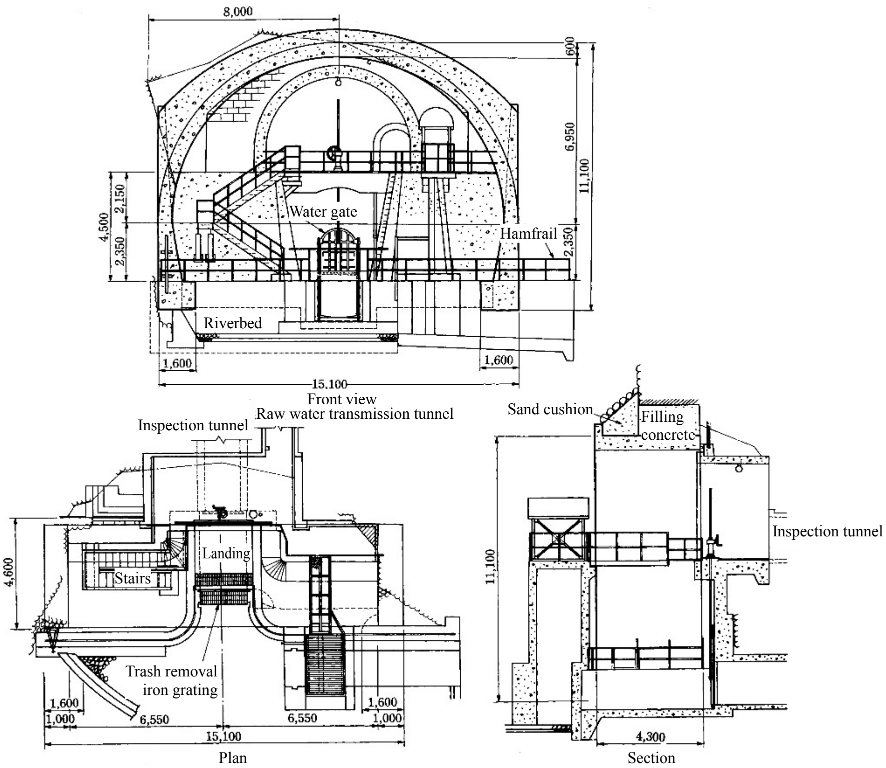



**Figure 2.5.1 An example of a water intake water gate (Nigachi intake facilities, Sendai City Water Department) (Unit: mm)**

### 2.5.2. Location and structure

The location and structure shall be in conformity with the following:

1. The water intake gate shall be built on firm and good foundation.
2. When determining the size of the gate, attention shall be paid on the appropriate flow velocity so as to reduce the inflow of sand and gravel as much as possible.
3. A gate shall be fit on the gate pillars; and the structure of the pillars shall be of reinforced concrete.
4. A screen shall be installed before the gates.

**[Interpretation]**

**On the item 2.;**

When determining the size of the water gate, the standard inflow velocity shall be smaller than 1 m/s.

### 2.5.3. Sluice gate type water gate

The sluice gate type water gate shall be in conformity with the following:

1. Even if the water level in the river is at the high water level, it can reliably be opened and closed, and possess water-tightness.

2. In the case of a device operated under power, it shall also be operated manually.
3. In case there is a possibility for sand and gravel to flow into the water gate, flushboards shall be installed upstream of it.

**[Interpretation]**

**On the item 1.;**

A gate, which is made of steel or cast iron, is used in pinciple (See Figure 2.5.2).

**On t he item 2.;**

Admitted the operation of the sluice gate is generally motorized, it shall be considered that it can also be operated manually preparing for power failure or a breakdown. It is desirable for the width of the sluice gate to be less than 3 m in the case of manual operation only so that the operation and maintenance are easy. Although in case the volume of water intake is small, one gate will suffice, it shall be divided into several units if the volume is large.

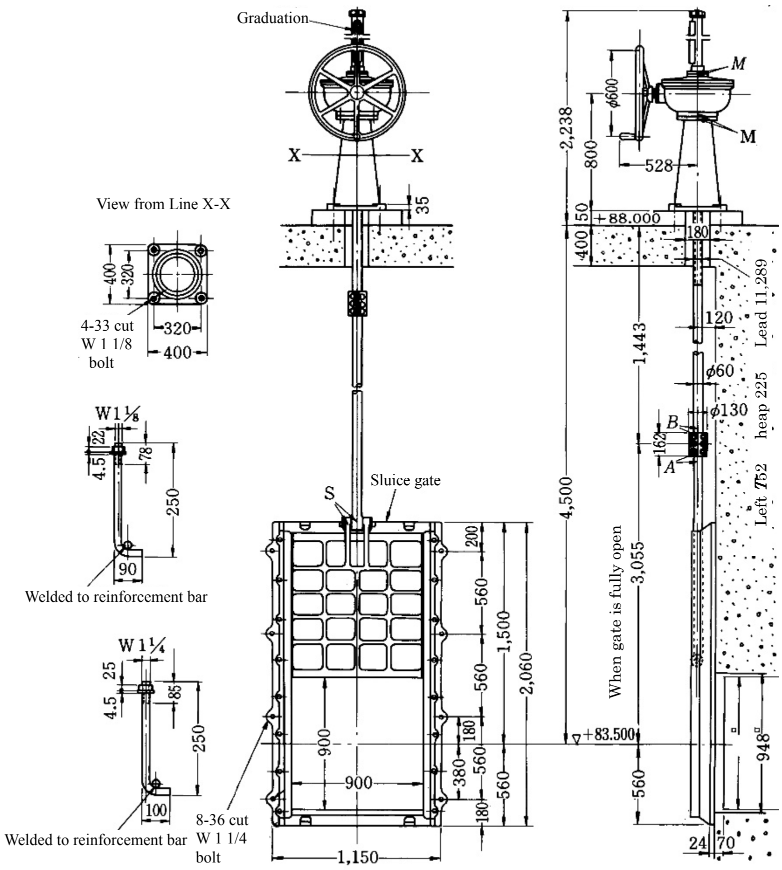



**Figure 2.5.2 An example of the sluice gate (Moniwa water treatment plant, Sendai City Water Department) (Unit: mm)**

### 2.5.4. Flushboard type water gate

The flushboard type water gate is installed to prevent the inflow of earth and sand and shall be in conformity with the following:

1. It shall possess sufficient strength against water pressure, and pile of earth and sand. Measures

for surfacing shall be provided in the case of wooden structure.

2. The size per gate shall be determined taking into consideration the ease of operation.

**[Interpretation]**

**On the item 1.;**

As the material for flushboards, channels or Is used as steel material, and rectangular lumbers of Japanese cypress are used as wood (See Figure 2.5.3). However, wood shall not be used where driftwood or drift stones would hit hard the water gate at a flood.

**On the item 2.;**

As the flushboard type water gate is handled manually, its width is commonly set at less than 3 m. The winding device shall safely and securely be operated even at the time of a flood.

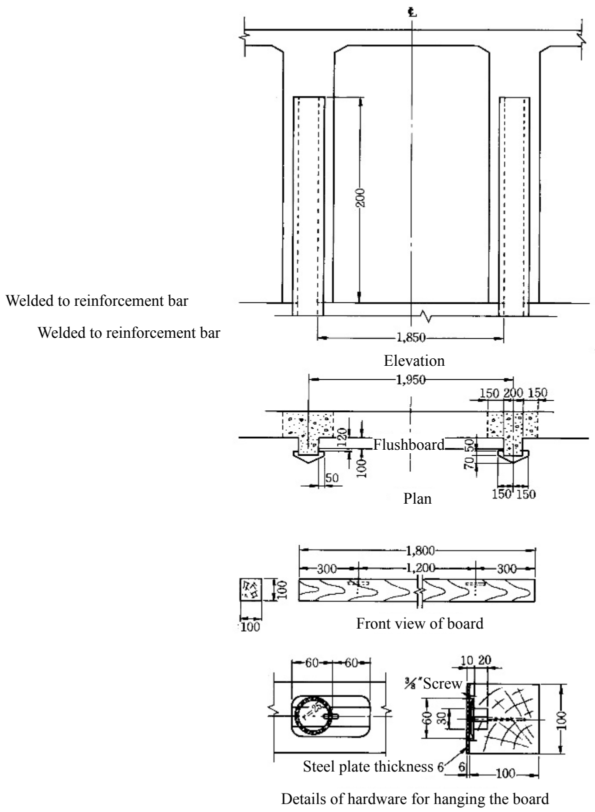



**Figure 2.5.3 An example of the flushboard water gate (Unit: mm)**

### 2.5.5. Sand trap

In case the length of the channel from the water gate to the grit chamber is very large, a sand trap shall be provided close to the gate, of which structure makes the removal of sand deposit easy.

[Interpretation]

Gravel and rough sand flow into the water gate built in the river and pile there at the time of a flood, which often impedes water intake. Therefore, it is desirable to provided a grit chamber close to the water gate. However, in case it is difficult to build a grit chamber, a small sand-trapping facility is sometimes needed, which is called the sand trap.

## 2.6. Water intake conduit

### 2.6.1. General

The water intake conduit is a facility to directly withdraw surface water through a water intake mouth installed right angle to the bank slope, and transmit the water to the landside area by gravity (See Figure 2.6.1). It is suitable for the intake of water at a river with stable flow condition and a small change in flow. Besides, its O&M is relatively easy. However, at a river, of which bed significantly changes and stream center is unstable, it is easily subject to the condition of the river and there is a possibility for the water intake mouth to be buried, or for the conduit to be exposed due to scouring. Therefore, the location of the facility shall carefully be chosen, and at the same time caution shall be paid for the prevention of scouring of the riverbed and the major bed. Besides, in case a lot of trash flows in due to a flood etc., it becomes difficult to abstract the design intake water volume, so measures shall be considered to prevent such an incident.

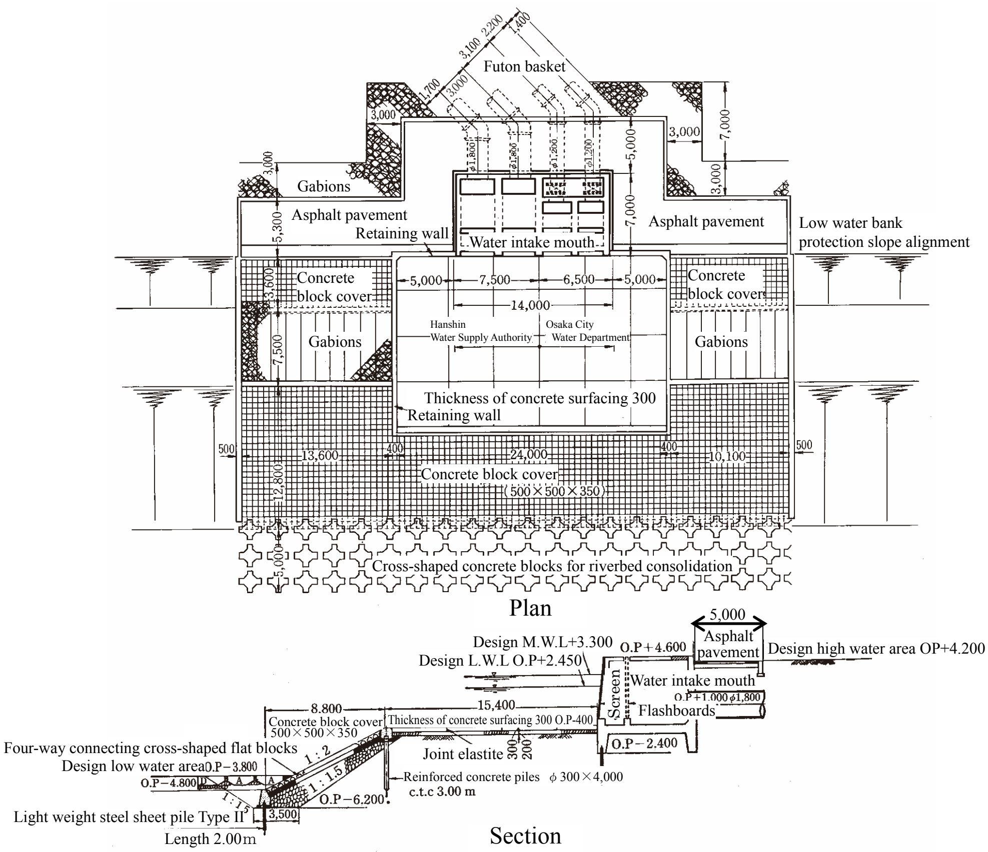



**Figure 2.6.1 An example of the water intake mouth (Kunijima water intake mouth for Osaka City Water Department, Hanshin Water Supply Authority) (Unit: mm)**

### 2.6.2. Water intake mouth

> The water intake mouth shall be in conformity with the following:
>
> 1. Its structure shall be of reinforced concrete.
> 2. Its sill level shall be determined in consideration of the future change in the riverbed.
> 3. Flushboards and a screen shall be furnished before it.

4. A sluice gate or sluice valve shall be installed upstream of the intake conduit.
5. A sand trap shall be provided if required.

**[Interpretation]**

**On the item 2.;**

The sill level of the water intake mouth shall be determined based on a study on the changes of the riverbed in the past, and the possibility of its lowering in future so that secured intake of the design water intake volume does not become difficult due to the lowering of the riverbed.

To make its structure enable abstraction of water even at the time of the maximum drought, it shall be considered to set the crown of the conduit 3o cm lower than the drought water level or so. The elevation of the bottom of the conduit shall be set at the sill level of the flushboards or lower.

**On the item 3.;**

The flushboards are installed to adjust the height of the water intake mouth from the riverbed in accordance with the change in the riverbed; and, in addition, they are provided to prevent the inflow of earth and sand as well as water stopping. The average flow velocity in the conduit is 0.6 t o 1 m/s by gravity flow. The opening area at the inflow section of the flushboards shall be secured to make the average flow velocity to be 1/3 to 1/2 of that in the conduit.

The structure of the screen shall be so designed that its detachment is possible, and it is commonly formed by placing steel bars or rods at 3 to 5 cm interval.

**On the item 4.;**

For the purpose of stopping water at an emergency, time of repair and so forth, a sluice gate or a sluice valve shall in principle be installed upstream of the conduit.

**On the item 5.;**

In case the length of the conduit is large, a sand trap is at times provided so as not to make sand etc. flowing to the conduit. As the standard, the sand trap shall be 30 to 50 cm deep and 3m long or so, and a manhole shall be provided for the work of the removal of sand etc.

### 2.6.3. Structure of the conduit

The water intake conduit shall be in conformity with the following:

1. The structure of the conduit shall withstand the inner and external pressures.
2. In case it is installed in the riverside land, as the general rule, it shall be laid 2 m deeper than the level of the design high water area.
3. In case the conduit crosses under the bank, it shall in principle have a flexible structure. Additionally, a sluice valve etc. shall in principle be furnished on the conduit so that water is stopped firmly and easily at an emergency.
4. After installation of the conduit, protection of the slope of the bank so as not to affect the bank.
5. More than two conduits shall be installed insofar as possible in consideration of an emergency case etc.

**[Interpretation]**

**On the item 1.;**

The conduit shall structurally withstand both internal and external pressure, and be of reinforced concrete, pre-cast concrete pipe, steel pipe, or ductile iron pipe.

**On the item 3.;**

The conduit shall have a flexible structure so as to follow the subsidence of the foundation occurring after its completion and not to make the portion of the bank around the conduit a weak point for the entire bank. The portion of the conduit situated under the bank and other portion shall be connected with joints, which possess water-tightness and flexibility (See Figure 2.6.3).

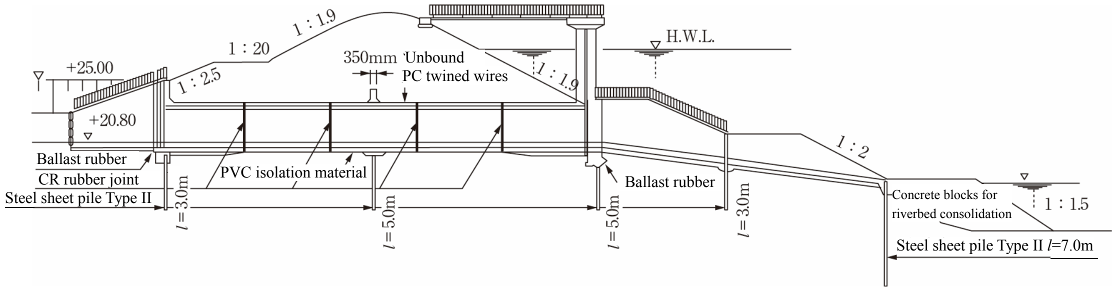



**Figure 2.6.3 An example of the flexible structure of a trough gate on weak foundation**

# 2.7. Intake crib

## 2.7.1. General

The intake crib is a box-type or cylindrical water intake facility, which is built submerged at the bottom of a lake (See Figure 2.7.1).

Water is abstracted through many openings provided on its side wall, and used for the intake of small to medium scale water volume.

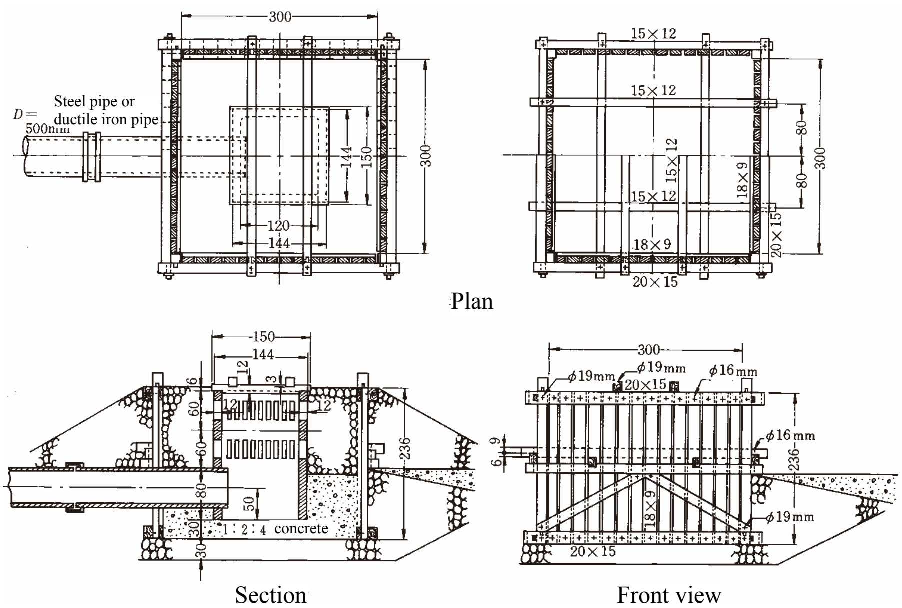



**Figure 2.7.1 An example of the structure of a water intake crib (Unit: cm)**

### 2.7.2. Location and structure

> The location and structure of the intake crib shall be inconformity with the following:
>
> 1. It shall be installed where the lake bottom floor is stable.
> 2. It shall be out of the sailing route. In case it is unavoidably installed close to the sailing route, sufficient water depth shall be secured.
> 3. The main body of reinforced concrete shall firmly be fixed on the lake floor.

**[Interpretation]**

**On the item 1.;**

Since in case the intake crib is installed where the change in lake floor is big, there is a possibility of damage, burial etc., it is needed to be placed where the lake floor is stable.

**On the item 2.;**

In the vicinity of the sailing route, it is desirable to float buoys etc. surrounding the intake crib to show an off-limit area; and install the crib where the minimum water depth is more than 3 m so as not to be damaged by navigation of ships.

**On the item 3.;**

To avoid the damage to the openings, and their clogging by earth and sand etc., the circumference of the openings shall be protected by an adamant wooden frame, concrete frame etc., and, in addition, riprap and concreting shall be made inside and outside of the crib. The standard inflow velocity into the crib shall be 0.5 to 1 m/s.

## 2.8. Grit chamber

### 2.8.1. General

The grit chamber is a facility to settle and remove the sand which flow in together with the raw water (See Figure 2.8.1).

### 2.8.2. Location and shape

> The location and shape of the grit chamber shall be in conformity with the following:
>
> 1. Its location shall be in the landside are as closely to the intake mouth as possible.
> 2. The shape of the chamber shall be rectangular, and the inflow section and the outflow section of the chamber shall be gently expanded and reduced in the width respectively.
> 3. More than two units of the chambers shall be provided.

**[Interpretation]**

**On the item 2.;**

If the section of a channel rapidly expands, drift of flow and backward flow occur, so the efficiency of grit settling is reduced, which lowers the performance of the chamber. Because of this, it is good to gradually expand and reduce the width of the channel at the inflow and outflow sections respectively

(See Figure 2.8.2). , In general, the angle of expansion of the inflow section shall be as small as possible. In case the angle of expansion exceeds 40 degrees, such a proper device as guide walls or flow-uniforming walls shall be provided.

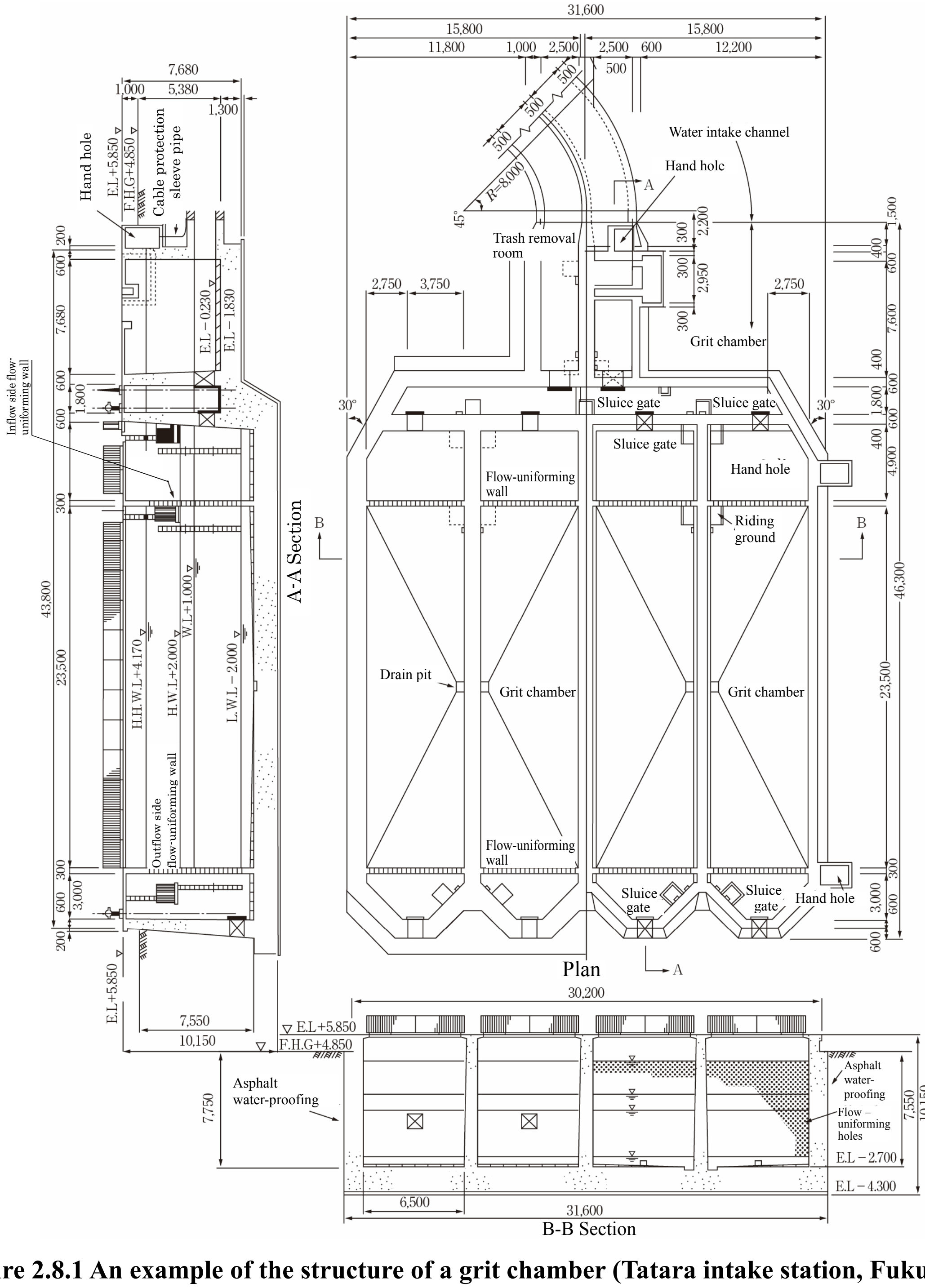



**Figure 2.8.1 An example of the structure of a grit chamber (Tatara intake station, Fukuoka City Water Department) (Unit: mm)**

**On the item 3.;**

More than two units of grit chambers shall be provided considering the occasions of cleaning, inspection, repair etc.

In case only one unit is installed because of the limited space and other restrictions, a bypass pipe shall be provided so that cleaning or repair work can be performed for a short period of time in the case of the raw water, of which quality allows the operation without the grit chamber.

### 2.8.3. Structure

The structure of the grit chamber shall be in conformity with the following:

1. In principle, it shall be of reinforced concrete, and be safe to buoyancy as well.
2. Its overflow rate shall be 200 to 500 mm/min as the standard.
3. The average flow velocity in the chamber shall be 2 to 7 cm/s as the standard.
4. The length of the chamber shall be computed from the effective depth, the settling velocity, average flow velocity etc.
5. The high water level of the chamber shall be lower than the design lowest water level of the intake mouth so that the design intake water volume can flow in.
6. The crown elevation of the chamber shall be set at the high water level with an allowance of 0.6 to 1 m.
7. The effective depth of the chamber shall be 3 to 4 m as the standard, and a grit deposit depth of 0.5 to 1 m shall be added.
8. A channel shall be provided in the center of the chamber bottom for the removal of sand with a slope of 1/100 in the longitudinal direction, and an inclination of 1/50 or so in the transverse direction.

**[Interpretation]**

**On the item 2.;**

The overflow rate of the grit chamber is determined in consideration of the settling velocity of the particle to be settled, the magnitude of the uniformity of flow etc. (See 5.5 Chemical sedimentation basin).

In this instance, the overflow rate of 200 to 500 mm/min is employed as the standard with reference to the past experience. Besides, the retention time shall be 10 to 20 minutes of the design intake water volume as the standard.

**On the item 3.;**

Empirically assuming that the average flow velocity is 2 to 7 cm/s, the settled sand will not float and move again.

**On the item 4.;**

The length of the grit chamber shall be computed by the following formula. The standard width of the chamber shall be 1/8 to 1/3 of the length.

$$L = K \left(\frac{H}{U} V\right)$$

where,

L: Length of the chamber (m)

H: Effective depth (m)

U: Settling velocity of the sand particle to be settled (cm/s)

V: Average flow velocity in the chamber (cm/s)

K: Coefficient (safety factor) 1.5 to 2.0

The settling velocities of the sand particles are shown in Table 2.8.1.

The diameters of the particles to be settled are normally 0.1 to 0.2 mm or so.

**Table 2.8.1 Settling velocities of sand particles***

| Particle diameter (mm) | Settling velocity (cm/s, 10 deg. C.) | Density |
|---|---|---|
| 0.30 | 3.2 | In case of 2.65 |
| 0.20 | 2.1 | 〃 |
| 0.15 | 1.5 | 〃 |
| 0.10 | 0.8 | 〃 |
| 0.08 | 0.6 | 〃 |

＊Ellms: Water purification, 1928.

**On the item 7.;**

The effective depth of the chamber shall empirically be set at 3 to 4 m as the standard.

Although the depth of grit deposit is determined by the annual piling depth of sand and the number of its removal work, it is normally set at 0.5 to 1 m.

**On the item 8.;**

The slope of the chamber floor is provided for the convenience of sand removal and drain, so standardized values are presented.

### 2.8.4. Ancillary facilities

The ancillary facilities of the grit chamber shall be in conformity with the following

1. A sluice valve, sluice gate etc. shall be furnished at its inflow and outflow mouths.
2. In case it is built at a location, where the groundwater level is high, a surfacing prevention device shall be fit for safety.
3. Screens and trash raking equipment shall be installed as the facilities for the removal of trash if required.
4. Sand dewatering equipment shall be provided if needed.

**[Interpretation]**

**On the item 3.;**

Bars of the screens shall be round or flat steel bars, and their interval shall normally be 2.0 to 2.5 cm.

## 2.9. Intake of groundwater

### 2.9.1. General

**1. Classification and characteristics of groundwater**

The groundwater exists in the two forms, i.e., stratum water and fissure water. In case the aperture filled with water is an interstice of soil particles, it is called stratum water (aperture water), and in case the aperture is a crack, crevice, opening etc. of rock, it is denoted as fissure water.

The stratum water is divided into the unconfined groundwater, and the confined groundwater.

The unconfined groundwater is groundwater contained in a stratum of sand, gravel etc. situated at a shallowest level in the ground, of which water level fluctuates in relation to the precipitation and volume also increases or decreases. Since the aquifer is shallow from the ground surface, it is vulnerable to pollution from the ground surface. The shallow well etc. is commonly used as the intake facility of the unconfined groundwater.

The infiltrated water is a kind of unconfined groundwater, which is river (lake) water flowing under the riverbed (lake floor) or its vicinity. An infiltration gallery, shallow well etc. is used as the intake facility of the infiltrated water.

As its aquifer is sandwiched by impermeable strata, the confined groundwater possesses pressure, and naturally appears on the ground in some cases. The confined groundwater mainly exists in a stratum, which have interstice like sand and gravel, its temperature is almost constant throughout the year, and its quality is in general good. The deep well is used as the intake facility of the confined groundwater.

What's more, the spring is the stratum water or fissure water, which gushes out to the ground.

**2. Quality of groundwater and point of attention for its intake**

Since the rate of the replenishment of groundwater is normally very slow, its excessive pumping will cause land subsidence as the balance of withdrawal and replenishment is disrupted, and bring about the seawater intrusion to the groundwater in the coastal area. Therefore, it is necessary to abstract groundwater at a proper production rate (See 2.9.5 Determination of pumping discharge rate).

As the groundwater contains mainly dissolved inorganic matters and organisms living underground depending on the soil condition and environment, its quality shall be understood.

Since the level of the groundwater fluctuates through the year, and its quality changes according to the water level, it is desirable to take as many samples of water in relation to the condition of the water level when evaluating the water quality.

### 2.9.2. Survey

For the intake of the groundwater, a survey shall be conducted on the following items as a general rule:

1. Preliminary survey
2. Hydrological and geological survey
3. The water quality survey shall be in conformity with 2.2.2 Survey, 5. Water quality.

**[Interpretation]**

Since the prerequisite for development of groundwater is the confirmation whether or not sufficient groundwater exists, it is desirable as much hydrological data [Note 2)] on the region in question and data related to the groundwater as possible shall be collected and examined. Unless these data are available, a geological survey at the ground level, electrical prospecting, and other hydrological and geological surveys need to be undertaken.

**On the item 1.;**

Data need to be collected under a preliminary survey consist of drawings of the topography and geography classification, precipitation and river flows, histograms of the existing wells, plans of groundwater surface, trend of pumping production and groundwater level, water quality etc. Furthermore, the critical pumping rate (See 2.9.5 Determination of pumping discharge rate), the natural groundwater level, the trend of groundwater level in the high water and drought seasons, and water quality shall be surveyed; and the actual balance of groundwater in the region in question shall be evaluated, if possible, based on the relationship of the total discharge volume to the pumping water level of the existing wells in the region, the hydraulic gradient, its permeability coefficient and so forth.

A survey shall in advance be conducted on the situation of the regulation on the abstraction of groundwater for the prevention of ground subsidence, condition of pollution of groundwater, the status of land use, the plan on the land use in future and so on.

**On the item 2.;**

As hydrological and geological survey, there are geological survey on the ground surface, electrical prospecting, seismic prospecting, boring survey, electrical logging etc., based on these surveys, the geological structure of the study area, interfaces of strata, their permeability etc., and the available quantity of groundwater shall be identified.

**1) Geological survey on the ground surface**

Based on the topographical and geological data, a reconnaissance survey shall be conducted by means of a hammer and clinometer to measure the strike and inclination of strata so that very conceptual topography and geology are understood.

**2) Electric prospecting**

It is a method to conceptually identify the structure of strata and the level of groundwater by means of conducting electric current in the ground to measure the apparent specific resistance of the soil. As the specific resistance method, there are the horizontal method and the vertical method.

Under the horizontal method, two current electrodes and two potential electrodes are placed on straight lines at uniform spacing, the specific resistance at the depth, which is equivalent to the distance between the electrodes, is measured; and the survey is carried out in a number of locations.

Under the vertical method, like the horizontal method, using four electrodes, they are placed at a certain space, and the specific resistance is measured for the depth equivalent to the spacing; then the spacing of the electrodes are widened one step after another so that the specific resistance of the strata is measured according to the spacing. This method is especially useful for a survey of weak ground; and survey of the depth of 300 m or so is possible in case the condition for setting of electrodes is favorable.

**3) Seismic prospecting**

It is the method to conceptually understand the geological structure based on the propagation velocity of the seismic wave caused by the explosion of explosive in the ground. It is suitable to the prospecting of strata with high consolidation: and used in case the base rock is shallow, and for the survey of the fissure water.

#### 4) Boring survey

This survey is conducted to obtain reliable soil samples; and can identify the interfaces and the permeability of aquifers together with the following electrical logging.

At the time of survey, since it is difficult to judge the structure of strata from the slime obtained during the work of boring, it is desirable to take undisturbed samples each time of change in strata.

Furthermore, it is desirable to obtain the permeability of each stratum according to the depth by means of measuring the lowering speed of water level in the boring hole after pouring water from a tank truck or a polyethylene container.

#### 5) Electrical logging

Under this survey, electrodes are lowered in the bare bore hole to measure the apparent specific resistance of the bore hole $\rho$ and the natural potential SP. The chart indicating the relationship between $\rho$, its depth, SP and its depth is named the electric logging chart. It is a method to identify, by analyzing the chart, the nature of the strata, depth, thickness, and at the same time, to understand the outline of the aquifer.

Although there are the 2-electrode method, 3-electrode method, and 4-electrode method, the 2-electrode method and 4-electrode method are commonly used.

#### 6) Confirmation by the test boring

##### (1) Boring of the test well

Based on the result of the electrical prospecting etc., it is desirable to select the location of the test well, select the several points, which are endowed with the most favorable conditions, bore the test wells, and conduct testing of respective aquifers.

This test well is not only to know the outline of the strata and groundwater but right to possess the structure, which enables a precise pumping test, so the finished diameter shall be at least 150 mm or larger.

Additionally, boring several observation wells around the test well if required, the change in the groundwater level around the test well in relation to the pumping tests on the test well shall be measured. Based on this, not only the exploitable pumping discharge can be identified but the magnitude of influence to the existing wells in the surroundings can also be studied so as to obtain data for the determination of the proper distance between wells. The convenient use of observation wells as the monitoring wells for the O&M shall also be examined.

##### (2) Testing of respective aquifers

Respective aquifers possess their own water pressure different from each other, and their water quality is different each other at times.

Although, for conventional wells, water is abstracted from multiple aquifers so as to obtain as much water as possible, the aquifers shall properly be selected from the view points of water volume, quality and level of respective aquifers from now on.

Given this, it is desirable that testing of the respective aquifers shall be undertaken from the stage of the test well.

### 2.9.3. Selection of the intake location

The location of water intake shall be in conformity with the following:

1. It does not affect the existing wells or infiltration galleries.
2. In the case of a coastal region, it is not affected by seawater, and consideration shall be given to the influence of tsunami as well.
3. It is not affected by seepage in the ground of pollution in the vicinity.

**[Interpretation]**

**On the item 1.;**

In case the area affected by the aquifer in question is known by the pumping test etc., the location, where the drawdown of water level of the existing wells with in the area is less than 10 to 20 cm, shall be selected.

### 2.9.4. Decision of the aquifer for water intake

The aquifer for water intake shall be selected based on the following data to be obtained during drilling of the test well:

1. Soil samples taken every time the stratum changes.
2. Existence of quantitative and qualitative changes in the slurry[Note1)], a gush of water, water loss[Note 2)] etc. during boring.
3. The result of the electric logging.

Note 1) The slurry is a solution of raw clay, powdered bentonite etc., the stable solution in another name, and a stabilization agent indispensable when boring relatively soft strata. The slurry forms a sticky wall on the outside of the bare hole, prevents the fall of the strata, and makes easy the lifting and lowering of slime, bits, casing etc.

Note 2) Water loss means the phenomenon that the slurry used for boring leaks out to the aquifer. This occurs in case the void of the aquifer is large; and the location, where there is water loss, is commonly said to be a good aquifer. However, sometimes, groundwater leaks away in a region where groundwater is excessively exploited and the pressure of aquifers become markedly low.

**[Interpretation]**

**On the item 1.;**

The hole of a deep well is drilled as bare hole, in which slurry is pumped to prevent the collapse of the wall of the hole, down to the prescribed depth. Therefore, it is impossible to know the yield or quality of the aquifers during drilling.

At the final stage of boring when the casing fit with screen is lowered and pumping is started, the yield and quality of water are known. Even if the prescribed yield and quality of water cannot be obtained it is technically almost impossible to replace the casing.

Therefore, 500 g of typical soil sample shall be collected from each stratum, conduct sieving tests if possible, and make a column chart of the strata formation, taking into account the solidness (or softness) of the strata, the impact the drilling machine receives etc., as the reference for selection of the locations of the aquifers.

**On the item 2.;**

The phenomenon, that the level of slurry used during well drilling abruptly changes due to gush of water or seepage of the slurry, is a proof that the stratum under work at present has permeability, so it shall be noted on the column chart as a factor for the decision of the production aquifer.

**On the item 3.;**

Admitting the precision of the column chart depends on the method of drilling and the personal competence of the site engineer, the electric logging method is used as a method to examine it objectively (See Figure 2.9.3).

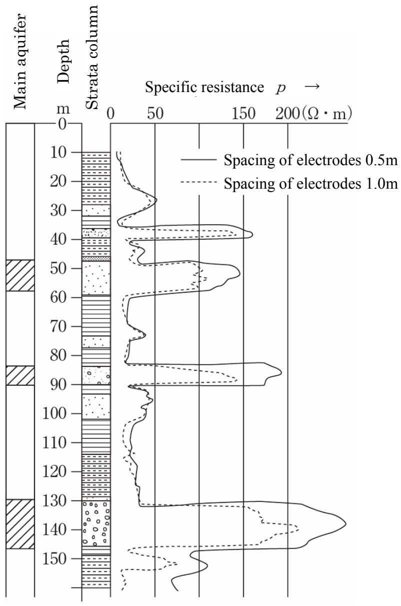



**Figure 2.9.3 Electric logging chart**

The principle of the method is the utilization of the difference in electric resistance of gravel, sand and clay (See 2.9.2 Survey), so the change in strata, the progress of aquifers etc. can be judged. The apparent specific resistance of ordinary strata is as follows:

1) In the case of gravel layer: 200 to 500 Ω・m
2) In the case of sand and gravel layer: 150 to 300 Ω・m
3) In the case of sand layer: 100 to 150 Ω・m

The favorable condition of stratum for water production is 1), 2) and 3) in order. In case the apparent specific resistance exceeds 1,000 Ω・m for the first aquifer, it does not bear water in many instances. What's more, even for a sand layer or sand-gravel layer, in case the apparent specific resistance falls below 100 Ω・m, it has been affected by salt, iron, wastewater etc. in many occasions, so it would better be omitted from the object for water intake.

Although the decision for the production aquifer is implemented from various facets points of view, there have conventionally been many wells, which abstract water from many aquifers at the same time with screens inserted at every aquifer at any location so as to abstract as much water as possible.

However, since the aquifers possess their own respective pressure, an aquifer fit with a screen may let escape water produced by another aquifer through the screen, which rather make it difficult to obtain the required yield of water.

Given this, in case the production layer is determined, only as good aquifer as possible, which has good permeability and acceptable water quality and stable water level, shall be selected so that a screen is set there.

### 2.9.5. Decision of the volume of water production

The decision of the volume of water production shall be in conformity with the following:

1. The proper pump discharge, in case the design water intake volume is obtained by a single well, shall be judged by a pumping test.
2. In case the design water intake volume is obtained by more than two wells (including existing wells), the decision of the design water intake volume shall be made as follows:
   1) The number of the wells shall be determined in consideration of the mutual influential areas of the wells.
   2) The pump discharge shall be a safe value, with which the water level does not continuously draw down at the test well as well as wells in the neighborhood.

**[Interpretation]**

The decision of the pump discharge of a well is in general carried out as shown in the flow diagram in Figure 2.9.4.

The definitions of the various pump discharge are as follow:

(1) Maximum pump discharge: The maximum pump discharge obtained during pumping test.

(2) Critical pump discharge: The pump discharge beyond which the water level quickly draws down and the well is damaged.

(3) Proper pump discharge: The pump discharge at less than 70 percent of the critical pump discharge.

(4) Safe pump discharge: (1) to (3) are the pump discharge of each well. The safe pump discharge denotes a pump discharge, which can be maintained for a long time without breaking the balance in water quantity of the groundwater area (water basin).

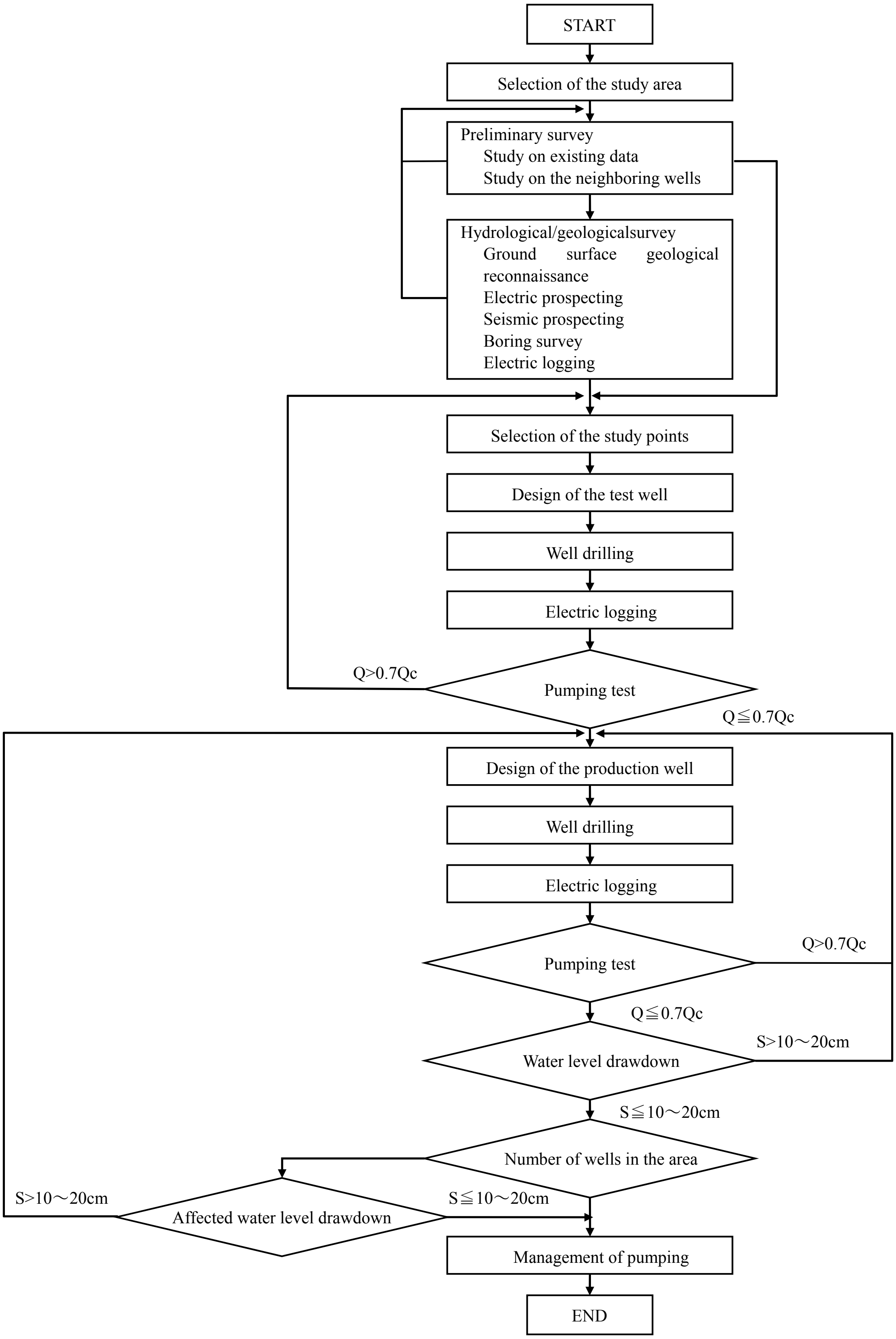
**On the item 1.;**

In case the critical pump discharge is obtained through a stepwise pumping test, the well can be used as the production well with a discharge of less than 70 percent of it as the safe pump discharge. Even unless the critical pump discharge is obtained, insofar as the design water intake volume is obtained within the pump discharge acquired during the pumping test, the well can be used as the production well.

In case the critical pump discharge is not obtained due to the insufficient capacity of the pump, and the maximum pump discharge realized during the pumping test is less than the design water intake volume, an aquifer test shall be undertaken. Incorporating the hydraulic parameters, obtained by the test, in the hydraulic formula (See Reference 2.16), the pump discharge is computed with the assumed well diameter, and then the design water intake volume, the diameter of the production well and the capacity of the pump are determined also taking into account the specific discharge (the daily pump discharge per meter of drawdown in water level ($m^3$/day/m)) etc.

**On the item 2.1);**

In case the design water intake volume cannot be obtained by a single well, the number of wells shall be determined based on the computation of the influential area by the hydraulic formula (See Reference 2.16) in consideration of the layout of wells as well as referring to the data obtained in 2.9.2 Survey.




Note)1 As the pumping test, there are a stepwise pumping test to study the capacity of each well, and the aquifer test to understand the nature of the aquifer.

Note)2 Management of pumping stands for controlling the pump discharge in the entire area so that the influence to the water level drawdown is limited to less than 10 to 20 cm.

Note)3 Q: Design water intake volume $Q_c$: Critical pump discharge s: Influenced water level drawdown

**Figure 2.9.4 Flow diagram for decision of pump discharge**

**On the item 2.2);**

In case pumping is made by more than two wells, since pumping of a well often affects the other wells even if pumping is made with an appropriate pumping discharge, the pumping discharge, with which the water level does not drawdown continuously, shall be found by means of a pumping test and the observation of water level in the neighboring wells.

**[Reference 2.14] Method of pumping test**

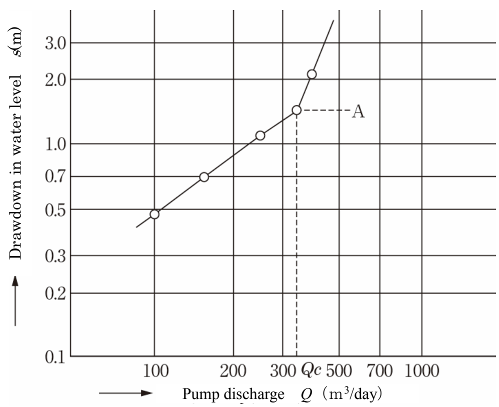
The pumping test is undertaken to study the nature of the aquifer and the capacity of the production well. As the pumping test, there are the stepwise pumping test, the aquifer test etc. (See Reference Figure 2.14.1).

**Reference Figure 2.14.1 Pumping test of a shallow well**

**1. Stepwise pumping test (See Reference Figure 2.14.2)**

Purpose: To obtain the critical pump discharge and specific discharge

Method: Setting the pump discharge into several steps (normally 6 to 7 steps), pumping is continued for a certain period of time, and, after the water level is stabilized, pumping is carried on with another step of increased discharge. Pumping is again continued until the water level becomes stable, and the test moves to the next step. After repeating this process for some times, the relationship between the pump discharge and the water level drawdown is plotted on both logarithmic graph paper. At the stage with small pump discharge, the line connecting the points becomes a straight line. As pump discharge further increase, an inflection point A appears; the pump discharge with respect to this point is denoted the critical pump discharge $Q_c$. Besides, in case the discharge from the aquifer is extremely large, and it exceeds the capacity of the testing pump, an inflection point does not appear, so the critical pump discharge cannot be found.




**Reference Figure 2.14.2 Stepwise pumping test curve**

## 2. Aquifer test

As the aquifer test, there are (1) the continuous pumping test with a constant pump discharge; and (2) the water level recovery test. In addition, observation wells are in some case needed to carry out the aquifer test.

Purpose: To obtain the nature of the aquifer, i.e., the transmissivity T, the permeability coefficient k, and the storativity s.

Method: (1) A test to know the difference $\Delta s$ of the drawdown through the continuous pumping test with a constant pump discharge, setting a pump discharge at less than the critical pump discharge, while a continuous pumping test is undertaken and the relationship between the water level drawdown and time is plotted on both logarithmic graph paper so as to obtain the difference $\Delta s$ of the drawdown.

(2) The water level recovery test is another test to know the difference $\Delta s$ of the drawdown. After the completion of the continuous pumping test with a constant pump discharge, the relationship between the recovery of water level and time is recorded in that the relationship between the remaining water level to recover (the difference between the original and the current water levels) s' and t/t' is plotted on both arithmetic and logarithmic axes of semi-logarithmic graph paper respectively and the t/t' – s' curve is drawn so as to obtain $\Delta s$ in the same manner as (1).

## 3. Time interval for measurement of water level during a pumping test

The time interval for measurement of water level during a pumping test can be determined with reference to Reference Table 2.14.1.

**Reference Table 2.14.1 Water level measurement interval for pumping test**

**Production well;**

| Time from start of pumping or after its termination (min) | Interval of measurement (min) |
|---|---|
| 0…… …… … 10 | 0.5 |
| 10…… …… … 15 | 1 |
| 15…… …… … 60 | 5 |
| 60…… …… … 300 | 30 |
| 300…… …… … 1,440 | 60 |
| 1,440…… …… At termination of test | 480 |

**Observation well;**

| Time from start of pumping or after its termination (min) | Interval of measurement (min) |
|---|---|
| 0…… …… … 10 | 2 |
| 10…… …… … 15 | 5 |
| 15…… …… … 60 | 10 |
| 60…… …… … 300 | 30 |
| 300…… …… … 1,440 | 60 |
| 1,440…… …… At termination of test | 480 |

## [Reference 2.16] Analytical method of pumping test

For the analysis of a pumping test, the following methods etc. are used:

(1) The method by Thim etc. by means of an equilibrium equation Note 1)

(2) The methods by C.V. Theis, Jacob et al by means of a non-equilibrium equation Note 2)

The transmissivity T, permeability coefficient k (See Reference Table 2.15.1), and storativity S can be obtained by the following formulas 1) to 6) etc. by means of drawing the Theis's t~s curve, Jacov's t~s curve, t/t' ~s' curve by a recovery test etc. Nonetheless, it shall be from the hydrological point of view which value should be employed.

What's more, the symbols used here are the following:

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Not 1) The equilibrium equation is an equation to be established on the assumption that the water quantity discharged by pumping and the quantity flowing from the surrounding aquifers are in equilibrium.

Note 2) The non- equilibrium equation is an equation to be applied in a state that the water quantity discharged by pumping and the quantity flowing from the surrounding aquifers are not in equilibrium but change over time, namely, in non- equilibrium state.

| Symbol | Unit | Annotation |
|---|---|---|
| S or H−h | m | Water level drawdown |
| Q | $m^3/s$ | Pumping discharge |
| T | $m^2/s$ | Transmissibity |
| k | m/s or cm/s | Permeability coefficient (hydraulic conductivity) |
| M | m | Thickness of aquifer |
| S | − | Storativity |
| R | m | Radius of influence |
| rw | m | Effective radius of well |
| r | m | Center to center distance between a production well and an observation well |
| t | s | Time from start of pumping |
| t´ | s | Time from termination of pumping |
| s´ | m | Residual water level to recover |
| u～W（u) | − | Well function |
| Lt | m/（$m^3/s$) | Coefficient of laminar flow loss |
| Tf | m/（$m^3/s$）$^2$ | Coefficient of turbulent flow loss |
| N | − | Number of data |

**1) Thim's formula**

$$Q = \frac{2\pi \cdot k \cdot M(H-h)}{2.31\log_{10}(R/r_w)}$$

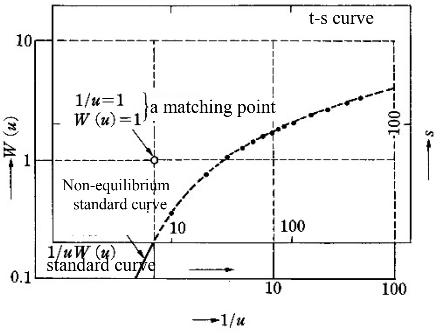
**2) Theis's standard curve analysis method (See Reference Figure 2.16.1)**

Plotting the pumping duration t on the abscissa of both logarithmic graph paper, and the drawdown of water level s of the observation data on the ordinate, a t~s curve is to be drawn. Fitting the standard 1/u~W (u) curve on the above curve to find a matching point, and reading values of t, s, 1/u, and W(u), T, k and S are computed by the following formulae:

$$T = \frac{0.0796 \cdot Q}{s} \cdot W(u)$$

$$k = \frac{T}{M}$$

$$S = \frac{4 \cdot T \cdot t}{r^2 (1/u)}$$




**Reference Figure 2.16.1 Theis's standard curve method (Hydrogeology Handbook, Toshio Murashita, Shokosha Co., Ltd.)**

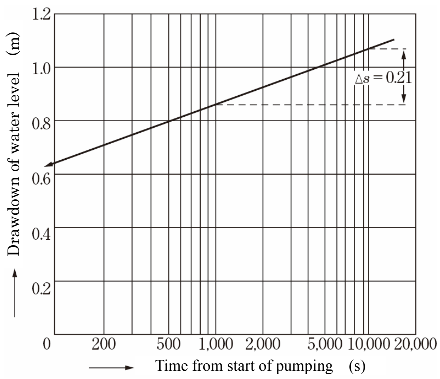
**3) Jacob's straight line analysis method (See Reference Figure 2.16.2)**

Plotting the pumping duration t on the logarithmic scale of semi-logarithmic graph paper, and the drawdown of water level s on the arithmetic scale from the observation data, a t~s curve is to be drawn. Assuming Δs as the drawdown in a logarithmic cycle for t, and t0 as the intersection with the curve s=0, T, k and S are computed by the following formulae:

$$T = \frac{0.183 \cdot Q}{\Delta s}$$

$$k = \frac{T}{M}$$

$$S = \frac{2.25 \cdot T \cdot t_0}{r^2}$$




**Reference Figure 2.16.2 Jacob's straight line analysis method**

**An example of computation**

Using semi-logarithmic graph paper, assigning t on the logarithmic abscissa and s on the ordinate, and plotting the respective values, the result will appear as Figure 2.16.2.

The difference Δs of s in a logarithmic cycle for t is computed as follows:

Δs＝1.04−0.83＝0.21（m）

| t（s） | s（m） | Q（$m^2/s$） |
|---|---|---|
| 1,200 | 0.861 | 0.018 |
| 1,800 | 0.910 | |
| 3,600 | 0.955 | |
| 6,000 | 1.002 | |
| 9,000 | 1.025 | |
| 10,000 | 1.062 | |

Then, extrapolating this straight line towards the arrow and reading the value t at the intersection with s=0, namely, t0 (In this case, reading will not be made unless another semi-logarithmic graph paper is stuck together.), t0=0.12 sec can be obtained.

$$T = \frac{0.183 \cdot Q}{\Delta s} = \frac{0.183 \times 0.018}{0.21} = 0.0157\left(m^2 / s\right)$$

$$k = \frac{T}{M} = \frac{1.57}{M}\left(cm / s\right)$$

$$S = \frac{2.25 \cdot T \cdot t_0}{r^2} = \frac{2.25 \times 0.0157 \times 0.12}{r^2} = \frac{0.0042}{r^2}$$

**4) Water level recovering method (See Reference Figure 2.16.3)**

When stopping pumping at a well, which has been carried out for a known period of time, the water level in the well will rise. Assuming that the replenished volume of water is equivalent to the volume of pumping, the non-equilibrium equation can apply.

Assigning t/t' on the semi-logarithmic scale and the residual water level to recover s' on the arithmetic scale, a t/t'~s' curve is to be drawn. Δs' can be obtained by the similar operation as the straight line analysis method.

$$T = \frac{0.183 \cdot Q}{\Delta s'}$$

An example of computation

Plotting the relationship between s' and log t/t' according to the following table on semi-logarithmic graph paper, Reference Figure 2.16.3 is obtained.

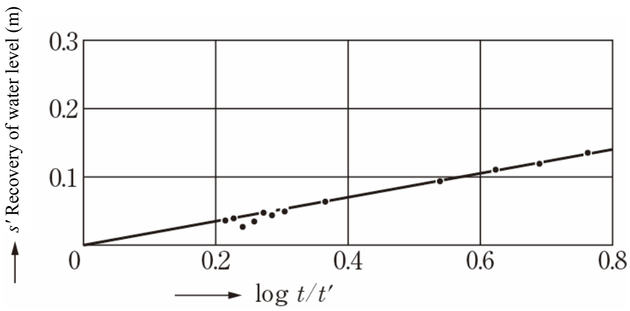
| Time | s´ | t´ | t | t/t´ | log t/t´ |
|---|---|---|---|---|---|
| 13.11 | 1.070 | 0 | 191 | - | - |
| 15 | 0.427 | 4 | 195 | 48.7 | 1.6875 |
| 20 | 0.292 | 9 | 200 | 22.1 | 1.3443 |
| 30 | 0.200 | 19 | 210 | 11.0 | 1.0414 |
| 40 | 0.160 | 29 | 220 | 7.6 | 0.8808 |
| 50 | 0.135 | 39 | 230 | 5.9 | 0.7709 |
| 14.00 | 0.117 | 49 | 240 | 4.9 | 0.6902 |
| 20 | 0.095 | 69 | 260 | 3.76 | 0.5752 |
| 40 | 0.082 | 89 | 280 | 3.15 | 0.4983 |
| 15.00 | 0.071 | 1.09 | 300 | 2.76 | 0.4469 |
| 20 | 0.064 | 1.29 | 320 | 2.43 | 0.3945 |
| 40 | 0.057 | 1.49 | 340 | 2.28 | 0.3579 |
| 16.00 | 0.052 | 1.69 | 360 | 2.13 | 0.3283 |
| 20 | 0.049 | 1.89 | 380 | 2.05 | 0.3118 |
| 40 | 0.048 | 2.09 | 400 | 1.91 | 0.2810 |
| 17.00 | 0.041 | 2.29 | 420 | 1.83 | 0.2625 |
| 20 | 0.038 | 2.49 | 440 | 1.77 | 0.2480 |
| 40 | 0.035 | 2.69 | 460 | 1.71 | 0.2330 |

When s'=0.1, log t/t' =0.6,

$$T = \frac{0.183 \cdot Q}{\Delta s'} \log \quad t / t'$$

$$= \frac{0.183 \times 0.018 \times 0.6}{0.1} = 0.0197\left(m^2 / s\right)$$

is obtained.




**Reference Figure 2.16.3 Water level recovery method**

**5) Method to obtain the sphere of influence (Non-equilibrium equation)**

The sphere of influence can be obtained by the following formula:

$$W(u) = \frac{T \cdot S}{0.0796 \cdot Q}$$

Obtaining u by the u~W (u) function table,

$$R = \sqrt{\frac{4T \cdot t \cdot s}{S}}$$

In addition, there is also a method to grasp the capacity of each aquifer through tests of the yield from respective aquifers as an aquifer test.

**6) The method to obtain the laminar flow loss coefficient, and the turbulent flow loss coefficient**

The drawdown of water level in the production well is in general obtained by the following formula

$$s = L_f Q + T_f Q^2$$

Dividing both sides of the above formula,

$$s / Q = L_f + T_f Q$$

as this linear expression is obtained, from the data from a step-wise pumping test and a constant flow continuous pumping test, plotting Q on the abscissa, s/Q on the ordinate, and drawing a straight line, an intercept is found as Lf, and the gradient is obtained as Tf.

What's more, to obtain Lf and Tf by means of least-squares method,

$$\sum s / Q = L_f N + T_f \sum Q$$
$$\sum s = L_f \sum Q + T_f \sum Q^2$$

where,

N : Number of data

Then the above simultaneous equations shall be solved.

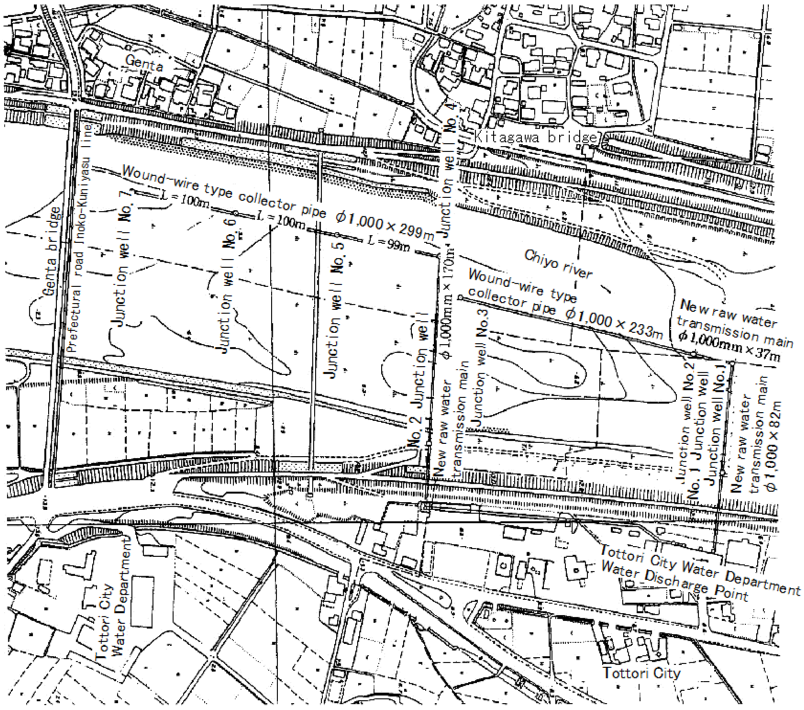
## 2.10. Infiltration gallery

### 2.10.1. General

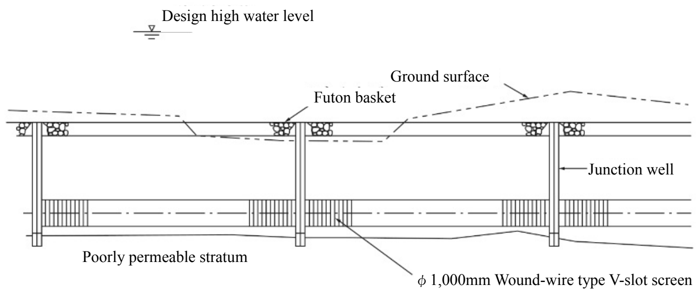
The infiltration gallery is a conduit, which is laid under the river floor of the riverbed or the former riverbed and possesses the function to collect water, and a facility to abstract infiltrated water or groundwater, which has free surface, namely, unconfined groundwater (See Figure 2.10.1).

To install the infiltration gallery, a good aquifer of gravel or sand layer shall be selected, and then stable water intake is possible insofar as the condition of the river is good.

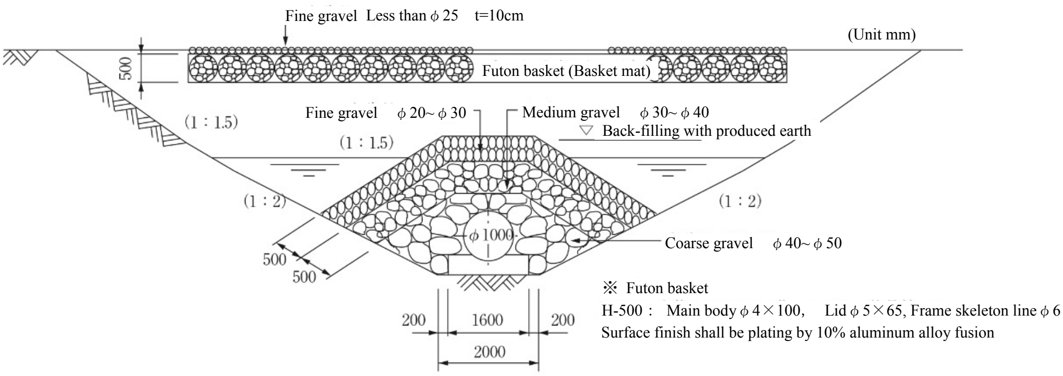
It has a merit that its installation is possible even where no structures can be built on the ground.




Plan of laying of infiltration gallery




Profile of laying of infiltration gallery




Section of laying of infiltration gallery

**Figure 2.10.1 Drawings of infiltrated gallery (Tottori City Water Department)**

### 2.10.2. Location and structure

The location and structure of the infiltration gallery shall be in conformity with the following:

1. The direction of installation of the infiltration gallery shall be determined so that effective water intake becomes possible based on precise understanding of the condition of infiltrated water flow.

2. The infiltration gallery shall be buried at sufficiently deep position so as not to be exposed or washed away.
3. The length of the infiltration gallery shall be determined based on the result of a permeability test by means of a test well etc. In this case, the standard inflow velocity from the opening of collection holes (slots) shall be less than the critical traction velocity of sand grains.
4. Wound-wire type screen pipe or perforated concrete pipe shall be used as standard practice.
5. For installation in a riverside area where scouring is possible, the gallery shall be protected by reinforced concrete frames etc.

**[Interpretation]**

**On the item 1.;**

It is an efficient way to install the infiltration gallery at the perpendicular angle to the direction of the flow of infiltrated water as much as possible taking into account the topography, the lot etc.

Where the infiltrated water is affluent, they are, at times, installed parallel or nearly parallel to the direction of the flow.

To augment the yield, one or several branch pipes are diverged from the main gallery in some cases.

**On the item 2.;**

Although it is desirable for the infiltration gallery to be buried deeper than 5 m so as not to be directly affected by surface water, the depth shall be determined in consideration of the condition of the aquifer, the depth of the impermeable stratum, the water quality etc. It shall be more than 2 m beneath the river floor of the low water channel in case it is installed in the riverside land.

**On the item 3.;**

The length of the infiltration gallery shall be determined applying the hydraulic formula, which conforms to the condition of the gallery, based on the result of the permeability test, by means of test well etc., as stated in 2.9.2 Survey, 2. Hydrological and geological surveys, 4) Boring survey, and 2.9.5 Decision of pump discharge. When determining the length, the inflow velocity from the opening of collection slots shall be less than the critical traction velocity of sand grains so that the openings are not to be clogged by sand etc. (See Table 2.10.1).

**Table 2.10.1 Classification of earth and its critical traction velocity**

| Classification of earth | Fine sand | Medium sand | Coarse sand |
|---|---|---|---|
| Grain diameter mm | 0.05～0.25 | 0.25～0.5 | 0.65～2.0 |
| Critical traction velocity cm/s | 1.00～1.50 | 1.50～1.7 | 1.70～3.7 |

**On the item 4.;**

The materials of the wound-wire type screen pipe or the perforated concrete pipe (See 2.10.3 Opening of collection slots) shall be corrosion-resistant, strong and durable.

The standard shape of the pipe shall be round. It is desirable for its inner diameter to be more than 900 mm so that such O&M as inspection and repair become easy.

### 2.10.3. Opening for collection of water

> The opening for collection of water shall be so designed that water is effectively collected, and that there is little possibility of clogging.

**[Interpretation]**

The wound-wire type screen pipe (See Figure 2.10.2) has merits that its structure prevents easy clogging since the inflow velocity can be small owing to its large ratio of opening, and that it is corrosion-resistant because of its stainless steel material.

Since, if the diameter of the holes of the perforated reinforced concrete pipe is too large, the inflow of sand becomes large; if too small, clogging will occur, the standard diameter shall be 10 to 20 mm, and the number of holes shall be determined at 20 to 30/$m^2$ taking into consideration the aquifer and the inflow velocity.

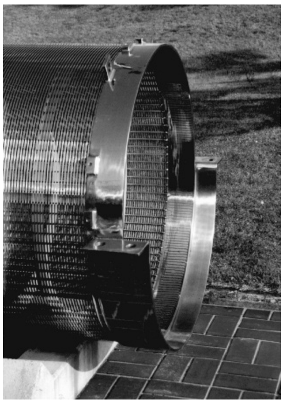


**Figure 2.10.2 Structure of the wound-wire type screen pipe**

### 2.10.4. Gradient and flow velocity in the pipe

> The infiltration gallery shall be level, or gently inclined towards the direction of the flow, and the average flow velocity in the pipe at its end shall be less than 1 m/s.

**[Interpretation]**

To perform equalized water intake as a whole, the gradient of the infiltration gallery shall be level or inclined at a gradient of less than 1/500 as much as possible.

The flow velocity in the pipe at its end is set at less than 1 m/s on average.

### 2.10.5. Joint and backfilling

> The joints and backfilling of the infiltration gallery shall be in conformity with the following:
>
> 1. The joint shall be selected in accordance with the pipe material.
> 2. Around the infiltration gallery, filter layers shall be provided by filling coarse gravel, medium gravel and fine gravel in order for depth of more than 50 cm each from inside towards outside, and the earth shall be backfilled over them.

**[Interpretation]**

**On the item 2.;**

Around the infiltration gallery, to prevent the inflow of sand and make the inflow of infiltrated water easy, coarse gravel (diameter 4 to 5 cm), medium gravel (diameter 3 to 4 cm) and fine gravel (diameter 2 to 3 cm) in order from inside towards outside for depth of more than 50 cm each shall be filled as a filter layer, and the earth shall be backfilled over them.

The yield from an infiltration gallery installed beneath riverbed diminishes due to the pile of mud on the riverbed in some cases.

### 2.10.6. Junction well

> The junction well of the infiltration gallery shall be in conformity with the following:
>
> 1. Junction wells shall be provided at the end, points of branching and other required points of the infiltration gallery.
> 2. Its size shall be as big as maintenance work can easy be done, and its structure shall be water-tight.

**[Interpretation]**

**On the item 1.;**

To make inspection and repair work easy, junction wells (See Figure 2.10.3) shall be provided at the end, points of branching and turning, and other required points of the infiltration gallery.

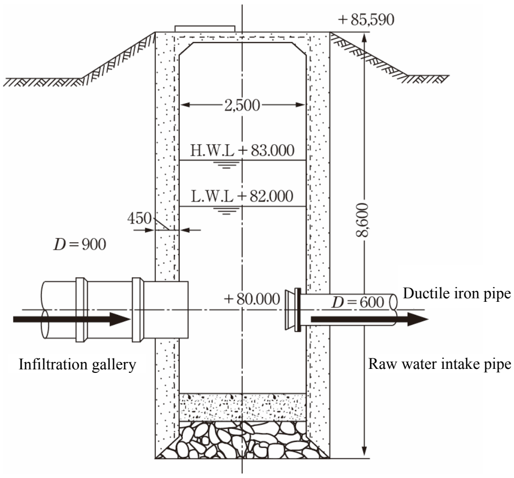



**Figure 2.10.3 Structure of the junction well (Unit: mm)**

**On the item 2.;**

The inner diameter of the junction well shall be more than 1 m so as to make easy inspection and removal of sand in the well.

## 2.11. Shallow Well

### 2.11.1. General

The shallow well is a well to abstract unconfined groundwater or infiltrated water; which is in general installed by means of sinking a concrete well crib in the ground so that water is collected from its bottom or side wall into the well, and that the water is pumped up by a submersible motor pump etc.

In addition to the well crib, there is a case where a steel casing etc. is installed and water is collected through a screen on its side (See Figure 2.11.1 and Figure 2.11.2).

There is a radial collector well, which has collector pipes driven horizontally and radially so that water collected into the well. Provided there is an aquifer with adequate water volume and good water quality, reliable water intake is relatively easily possible.

To aim at reliable water intake from a shallow well, a good aquifer shall be selected, and the structure of the well crib, the depth of the well bottom, the capacity of the pump etc. need to be properly determined. Additionally, measures required for the prevention of pollution from the ground surface need to be implemented.

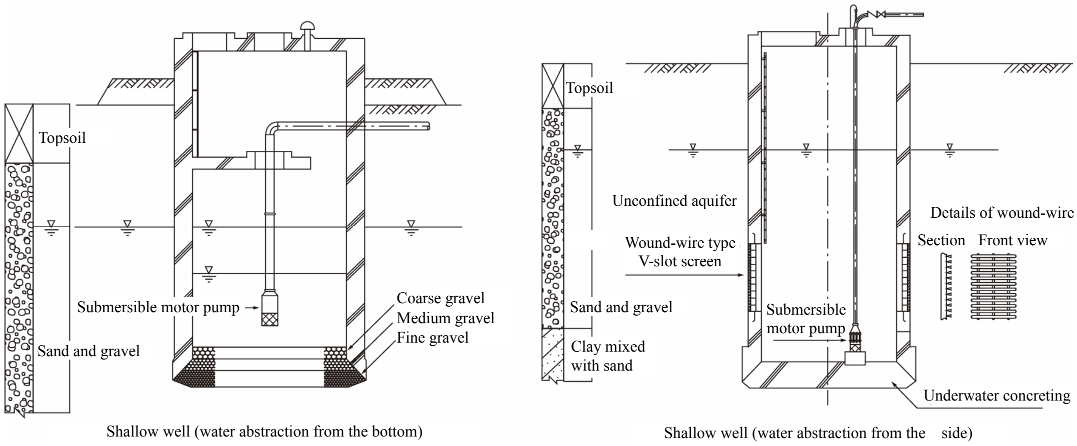



**Figure 2.11.1 Structure of the shallow well**

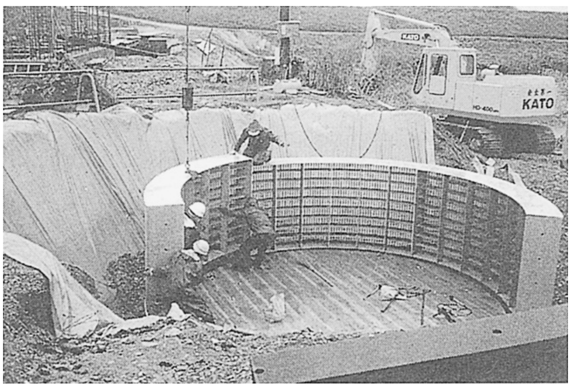



**Figure 2.11.2 Wound-wire screen mounted on the sidewall**

### 2.11.2. Shape and structure

The shape and structure of the well shall be in conformity with the following:

1. In the case of the well crib
   1) The standard structure shall be of cylindrical reinforced concrete.
   2) In case the aquifer is thick and water is collected from the bottom, the size of the well shall be determined based on the result of a pumping test; the distance between the well bottom and the impermeable stratum shall properly be maintained; and hard and clean gravel shall be placed covering the bottom floor.
   3) The standard inflow velocity from the bottom shall be less than the critical traction velocity of sand.
   4) In case the aquifer is thin, the position of water collection shall be set on the sidewall near the bottom of the aquifer, and the well bottom shall be a slab of reinforced concrete. The position of water collection shall be set lower than the low water level in the well.
2. In the case of the casing, the shape and structure shall be in conformity with 2.12 Deep well.

**[Interpretation]**

In Japan, many shallow wells are dug because the sand and gravel layers containing plentiful groundwater are abundant near the surface of the ground.

For a well with the depth of 8 to 20 m, well cribs are installed while digging is in progress. For deeper wells, the method to drive steel pipe etc. is rather common since there are many sand layers which easily collapse.

In the case of the well crib, water is collected from the side or the bottom depending on the volume of water intake and the thickness of the aquifer; and in the case of the casing, water is collected from the side.

**On the item 1.1);**

Although, since the water quality of the shallow well is vulnerable to the condition of the ground surface, the deeper the better, the depth of the well is mostly 8 to 20 m. The standard shape of the well shall be round.

Its structure shall be of reinforced concrete or fabrication of reinforced concrete blocks, and its sidewall shall possess sufficient strength so that there is no fear of collapse.

**On the item 1.2);**

In case the aquifer is thick and so the non-penetrated well, which collects water from the bottom, is employed, the distance between the well bottom and the impermeable stratum shall be maintained more than 1/4 of the outside diameter of the well to reduce the resistance of the incoming flow.

The inflow velocity needs to be kept less than the critical traction velocity of sand, so that sand does not flow in from the bottom; and, even in case the volume of groundwater or infiltrated water is abundant, too small a diameter of the well crib shall be avoided.

To avoid the inflow of sand from the aquifer into the well, or scouring of sand during pumping, the well bottom needs to be covered with coarse gravel (diameter 4 to 5 cm), medium gravel (diameter 3 to 4 cm) and fine gravel (diameter 2 to 3 cm) in order from the lower level each in the thickness of 30 cm totaling 90 cm or so.

**On the item 1.3);**

Table 2.10.1 shall be referenced on the critical traction velocity.

**On the item 1.4);**

In case the aquifer is thin in respect to the water intake volume, especially, when there is a possibility of water level draw down in a drought, the structure of the well shall be a well, which is penetrated down to the impermeable layer so that water can be abstracted up to close to the bottom of the aquifer, so the well bottom is closed by reinforced concrete to make a complete penetrated well, and water is abstracted from the side of the well crib.

In this case, the position of the water collection needs to be set lower than the lowest water level of the well. The position of the water collection shall be set in conformity with 2.10.3 Opening for collection of water.

### 2.11.3. Layout of plural number of wells

> In case more than two wells are installed close to each other, their spacing shall be determined so that no interference will occur.

**[Interpretation]**

Since, if the space between wells is too small, extreme drawdown of the water level will be brought about by mutual interference, which may cause such trouble as inflow of sand, they shall be laid out with proper spacing in accordance with 2.9.2 Survey, 2.9.3 Selection of intake location and 2.9.4 Decision of the aquifer.

It is advantageous for water intake to lay out the wells in a line at right angle to the direction of flow of groundwater or infiltrated water.

In case wells are laid out in parallel to the direction of the flow of groundwater or infiltrated water, the wells situated upstream can soundly abstract water while it is possible that the ones situated downstream will have difficulty to sufficiently withdraw water by the influence of the upstream ones.

### 2.11.4. Radial collector well

> The structure of the radial collector well shall be in conformity with the following:
>
> 1. The diameter of the well crib shall be as large as the machine for driving the collector pipes can easily be operated.
> 2. The structure of the well crib shall be safe against the earth pressure, buoyancy etc.

**[Interpretation]**

As the structure of the radial collector well, collector pipes are driven from the crib wall horizontally and radially into the aquifer. As the diameter of the well becomes as large as the extent of the collector pipes, it is advantageous for the intake of large volume of water.

The radial collector pipes shall have a proper length and diameter suitable to the direction of groundwater flow and the topography of the surroundings.

It is desirable that the bottom of the well crib reaches the impermeable stratum (mudstone etc.); and that a corrosion-resistant ball valve is fit on each collector pipe inside the crib so that water intake can be suspended at the times of inspection and repair.

**On the item 1.;**

The diameter of the well crib shall be as large as needed for the work of driving perforated collector pipes by an impact-hammer, or the work of installing wound-wire type screen pipes in the sheaths inserted in the holes drilled by the boring machine in advance (See Figure 2.11.3).

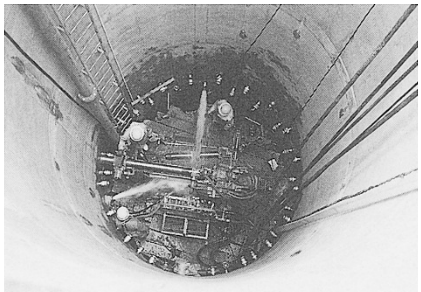


**Figure 2.11.3 Work of insertion of collector pipes**

**On the item 2.;**

The well crib shall be of reinforced concrete, and its bottom is also closed by reinforced concrete. Its structure shall be safe against the earth pressure, up-lift pressure and buoyancy since all the water in the crib is in some case drained for the work of inspection and repair.

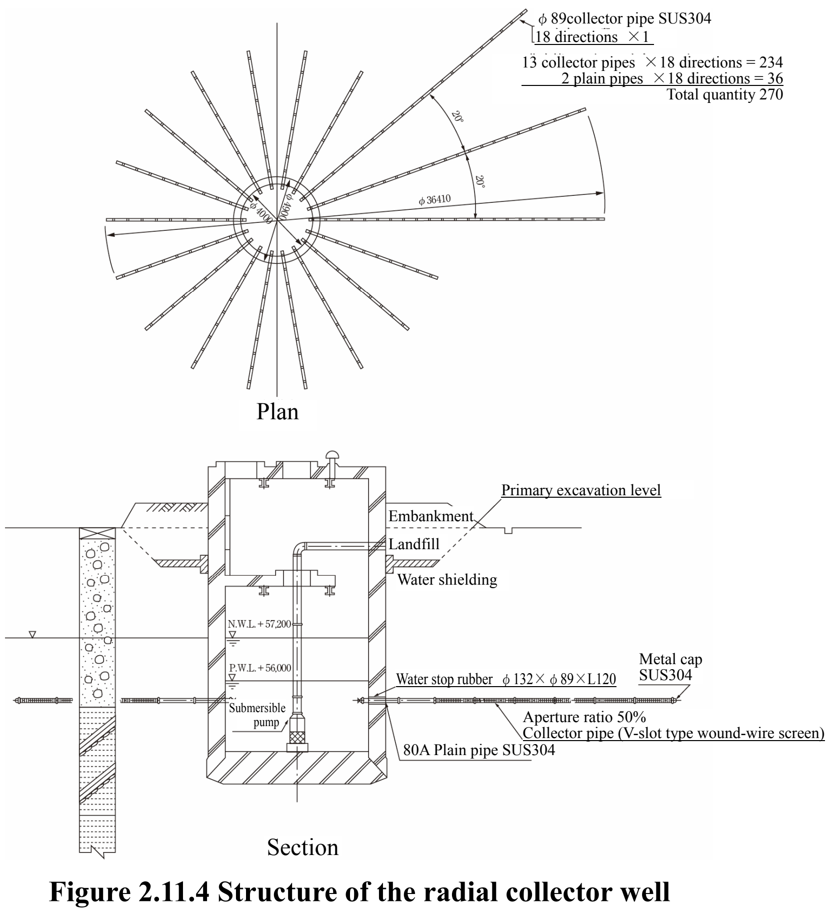



**Figure 2.11.4 Structure of the radial collector well**

### 2.11.5. Ancillary facilities

The ancillary facilities of the shallow well shall be in conformity with the following:

1. The well crib shall be higher than the ground surface, and a cover, ventilation hole, manhole etc. shall be installed.
2. The periphery of the well shall be well-drained and protection shall be provided so that the wastewater does not intrude.
3. A water gauge shall be installed in the well. An apparatus to watch the water quality shall be installed if needed.

**[Interpretation]**

**On the item 1.;**

The well crib shall be 30 cm higher than the ground surface so that wastewater etc. shall not come into the well from outside, and a cover shall be placed on the well.

A ventilation hole for responding to the change in water level in the well, a manhole needed for the access at the time of inspection shall be installed. A fine-meshed wire netting shall be fit on the ventilation hole to prevent the intrusion of trash, insects etc.

Additionally, an access hole for carry-in and –out of equipment for improvement work and so forth shall be provided.

**On the item 2.;**

Since surface water or wastewater easily comes into the well along the sidewall of the well crib, the periphery of the well shall be well drained; and sealing of the upper void between the crib wall and the bore hole shall be made by clay etc. so that wastewater does not permeate to the ground (See Figure 2.11.4).

## 2.12. Deep well

### 2.12.1. General

The deep well is a well, which abstracts water from a confined aquifer, consists of the casing, screen, riser pipe and submersible motor pump. It can relatively obtain large quantity of water of good quality in a small lot. Water is pumped directly from a screen installed on an aquifer; and the screen is deeper than 30 m in many cases, and deeper than 600 m in some cases.

For the deep well, the certain thickness of aquifer is needed whereas the planar extent of the aquifer shall be considered for the shallow well.

Therefore, the screen for a deep well shall be as long as the thickness of the aquifer.

To reliably secure the intake of required water volume, a good aquifer shall be found based on an adequate survey, and a screen suitable to the aquifer shall be installed, and a pump, of which capacity is suitable to the abundance of water in the aquifer, shall be selected. Consideration is needed to select a pump with high versatility so as to cope with its imperative stop.

The provision of a spare well etc. needs to be considered so as to secure reliable water service even at the time of reduction in water production due to clogging of the screen or damage in the screen or casing etc.

### 2.12.2. Well drilling

Drilling of the deep well shall be in conformity with the following:

1. The method of well drilling shall be selected in consideration of the topography, geology and environment of the site.
2. Drilling shall be performed while keeping the bore hole plumb.
3. When applying slurry, caution shall be paid not to bring about such an accident as the collapse of soil layers or water loss.
4. The soil samples shall be collected, and electric logging shall be carried out after the completion of drilling.
5. The work of sinking the casing shall be performed quickly.
6. Attention shall be paid not to leave voids during gravel shrouding.
7. The removal of slurry and finishing shall be carried out carefully.
8. Pumping test shall securely be undertaken, and final checking of the inside of the well shall be made.

**[Interpretation]**

**On the item 1.;**

Drilling methods of the deep well are largely classified into the open-hole method and the cased-hole method (pull-back method).

By the open-hole method, the bore hole is filled with slurry to prevent the collapse of the hole, drilling of a bare hole is continued down to the prescribed depth while forming slurry wall, and a casing together with a screen(s) mounted on it is lowered as soon as the drilling is finished.

By the cased-hole method, drilling is performed while a temporary casing is inserted using only plain water without slurry in principle.

**On the item 2.;**

If the bore hole is curving, the bit etc. for drilling may be detained in the hole, satisfactory finishing may not be made due to insufficient gravel shrouding, or the casing cannot be lowered in the worst case.

**On the item 4.;**

The samples taken from respective strata and electric logging will provide data indispensable for the decision of the location of the screen.

As for the samples of respective strata, 500 g of soil is needed each time for sieving test.

**On the item 6.;**

As for gravel for shrouding, the one, which is shaped as round and uniform as possible, and compatible with the slot of the screen and the nature of the production aquifer, is favorable. Sieving of gravel shall be carried out as required and 20 percent more quantity than computed shall be prepared. When pouring it, the constant quantity shall continuously be poured while checking the poured quantity and the depth of filling at a regular time interval so that no cavities are left.

The gravel shall in general be filled up to 5 to 10 m above the upper end of the screen situated at the highest level, and the remaining upper section shall be sealed with cement milk, raw clay and bentonite so that pollutants are blocked from intruding the well.

### 2.12.3. Structure

> The structure of the deep well shall be determined in consideration of the proposed depth, discharge, the level of groundwater, water quality etc.

**[Interpretation]**

The relationship between the discharge from the well and the diameter of the casing is in general prescribed as follows:

(1) In case pumping discharge is smaller than 1,500 $m^3$/day: Casing diameter= 250 mm (Diameter of the rise pie = 100 mm)

(2) In case pumping discharge is more than 1,500 $m^3$/day and smaller than 2,500 $m^3$/day: Casing diameter= 300 mm (Diameter of the rise pie = 125 to 175 mm)

(3) In case pumping discharge is more than 2,500 $m^3$/day: Casing diameter= 350 mm (Diameter of the rise pie = 175 mm or larger)

Steel pipe (JIS G 3452: Carbon steel pipes for ordinary piping) is used for the casing, and its wall thickness is determined according to the hardness and depth of the soil. In case corrosion by the water quality and galvanic corrosion is possible, thick wall pipe (JIS G 3454: Carbon steel pipes for pressure service), stainless steel pipe (JIS G 3468: Large diameter welded stainless steel pipes) or plastic pipe is used.

The submersible motor pump is used for pumping for the deep well.

The specification of the submersible motor pump is determined by the pump diameter, discharge, total lift, number of revolution, pump efficiency, shaft power etc., and the ones with a diameter of up to 200 mm are standardized under the JIS (JIS B 8324: Submersible motor pumps for deep well).

In case a large submersible motor pump with a diameter of more than 200 mm is used, the power source voltage, the starting method of motor etc. shall be examined.

As to the location of the well pump, the location at ③ in Figure 2.12.3 may induce inflow of sand; at ④, the installation cost of the pump becomes high, resistance for pumping is large, and the temperature around the motor will rise. Therefore, the location at ② is the most favorable. However, the location at ④ is sometimes chosen in an inevitable case. In the case of ①, pumping of the prescribed volume cannot be achieved.

In Figure 2.12.4, a structure of a deep well is presented, for which the upper section of the well is finished by a casing in advance, and drilling is resumed in case the production aquifer is very deep, and there is a possibility for the upper section of the bore hole to collapse due to loss of water etc.

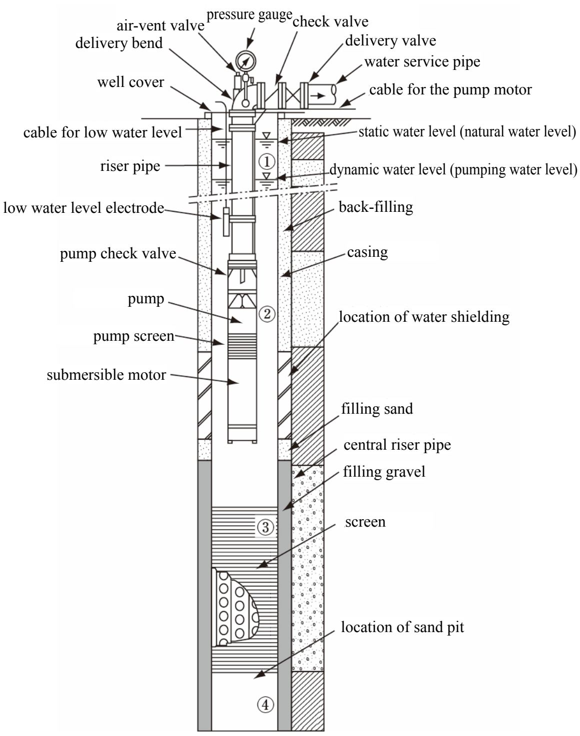



Figure 2.12.3
Location of installation of well pump

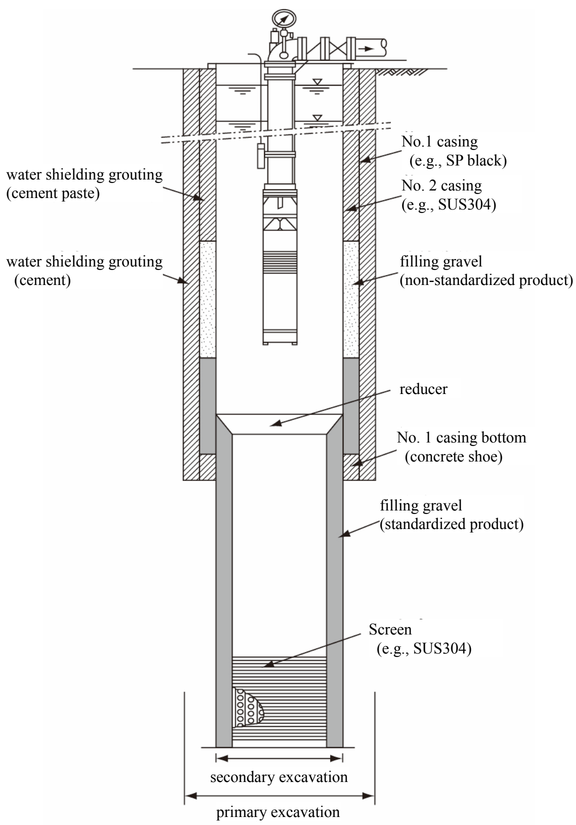



Figure 2.12.4 Structure of the deep well

### 2.12.4. Layout of more than two wells

> In case more than two wells are installed, they shall be laid out in a zigzag pattern perpendicularly to the direction of the flow of groundwater; and the spacing between them shall be determined so that no mutual interference should occur.

### 2.12.5. Screen

> The screen for a deep well shall be in conformity with the following:
>
> 1. The location of the screen shall be at the confined aquifer, and a closed-end pipe is to be installed at the bottom of the screen as a sand trap.
> 2. The inflow velocity of groundwater into the screen shall be as slow as possible.
> 3. Its structure shall be suitable to the shape and size of the gravel which forms the production aquifer.
> 4. Its material shall be stainless steel etc. which possesses high strength and anti-corrosiveness.

**[Interpretation]**

The screen is a perforated pipe to be inserted to the section of production aquifer of the well, which used to be called strainer. It can be said that its performance determine the relative merits of the well; in other words, it is the heart of the well.

**On the item 1.;**

In some cases sand is forced to flow in water during pumping, a 5 to 10 m long closed-end pipe shall be placed underneath the screen as a sand trap.

**On the item 2.;**

The standard inflow velocity to the screen shall be smaller than the critical traction velocity of sand (See Table 2.10.1).

**On the item 3.;**

In general, a wound-wire type screen with V-slots compatible to the gravel of the production aquifer and the size of the filling gravel shall be used to prevent the inflow of sand.

### 2.12.6. Ancillary facilities

1. A level gauge, tap for water sampling for water quality test etc. shall be installed in the well; and the data needed for O&M shall always be stored.
2. The pump house shall be placed higher than the ground surface to avoid inundation, and, at the same time, provision for resistance to the earthquake shall be made.
3. A spare power generation unit and a spare pump unit shall be provided as required.
4. Materials used shall be stainless steel etc. which possess ample strength and corrosion resistance.

# 3. Water Storage Facilities

## 3.1. General

### 3.1.1. Basic matters

As the basic matter to provide reliable water service, water sources, from which the design water intake volume can steadily be abstracted throughout the year, shall be secured.

In case groundwater or natural surface water of a river with an abundant yield can be used, no water storage facilities will be required. However, in case surface water is newly abstracted, the development of water sources is needed since there will be competition with other users.

**1. Role and conditions for construction of water storage facilities**

The water storage facilities are the facilities to store water in the high water season; and absorb the fluctuation in precipitation so that reliable water intake is secured. Therefore, at the time of its construction, not only the status of the construction site, the volume of storage, and the design intake water volume but also the economic benefits need to be studied.

**2. Site for construction**

The site for construction of the water storage facilities is desirable where the quality of stored water is as clean as possible, and where there will be no possibility of pollution in future as well.

In case they are inevitably constructed at a location where water quality is not always good, environmental pollution sources etc. shall be surveyed, future water quality shall be forecast and such water quality protection measures as the prevention of eutrophication etc. need to be positively implemented. To this end, it is needed to not only monitor the incoming pollution load from the surroundings of the storage facilities but also provide such facilities as a circulator-aerator in the impounding reservoir, and intake mouths for selective abstraction of water etc.

**3. Consideration to the environment**

At the time of construction of water storage facilities, consideration shall be given for the facilities not to adversely affect the environment of the surrounding area adequately taking into account their influence to the environment.

Since an adverse effect of the water storage facilities to such environment as their surroundings and lake water is conceivable depending on the contents of the plan for the water storage facilities and the method of their implementation, measures required for the conservation of the environment need to be undertaken based, as much as possible, on the forecast of the influence of the plan to the environment. The water sources for water supply are mainly classified into surface water (river water, lake water and impounding reservoir water) and groundwater. In any case, the water intake facilities shall be able to reliably abstract as good quality raw water as possible, and be easily maintained with consideration to measures for disasters and environmental conservation.

**4. Location, type and structure**

The location and type of water storage facilities shall be determined in accordance with their storage capacity, topography and geology of their construction site taking into consideration the safety and economic benefits. Their structure shall be safe against an earthquake and waves caused by strong wind.

### 3.1.2. Type of water storage facilities

> For selection of the type of water storage facilities, the design water intake volume, future water quality, location of construction, structural stability, economic benefits, influence to the environment etc. need to be examined.

**[Interpretation]**

In case water storage facilities are constructed, their size and type shall synthetically be examined mainly with a focus on the design water intake volume and the securement of water quality taking into account the condition of river flow etc., topography and geography of the site, structural stability, economic benefits of construction and operation and maintenance (O&M), influence to the environment etc.

Water storage facilities are classified by type into the impounding reservoir (dam reservoir), lake, retarding basin, estuary barrage, retaining pond, subsurface dam etc. as shown in Table 3.1.2.

Water storage facilities are classified by purpose of use into the water storage facilities constructed exclusively for water supply, and the multi-purpose storage facilities jointly constructed for the uses for flood control, hydraulic power generation, irrigation, industrial water supply etc. in addition to water supply.

The exclusive water storage facilities have a merit that the water quantity and quality can be managed on the utility's own initiative since they are constructed by the water utility itself. However, since high level of technologies is required for their planning, construction and operation, and their economic benefits are inferior to the former in some cases, examination shall be practiced which type can be employed and is more advantageous.

On the other hand, in case the water source for water supply is developed under a multi-purpose water storage facilities project, since there is a case of advanced development of water sources as stated in 3.3 Multi-purpose water storage facilities, the intention of the water supply utility about the allocation of the investment, the plan for the water intake, the structure, operation etc. need to be reflected to the project design.

Table 3.1.2 presents the comparison of main water storage facilities.

**Table 3.1.2 Classification of water storage facilities by type**

| Classification | Method and characteristics of water storage |
|---|---|
| Dam reservoir (impounding reservoir) | By damming up a valley or river by a concrete, earth or stone structure, water in a high water period is stored, so the river water is utilized effectively by means of controlling the discharge of water. |
| Lake | A movable weir or gate is installed at the outlet of a lake to regulate the water level, and the volume within the high and low levels is the effective stored. |
| Retarding pond | Utilizing a retarding pond, which used to be regarded only from flood control point of view, the usable water volume is secured by dredging the floor of the pond. |
| Estuary weir | By building a weir near the mouth of a river, the river water, which used to be impossible to be used, can be utilized. |
| Pond | Although it was originally constructed for irrigation, it is used for water supply after it is redeveloped by dredging etc. |
| Underground dam | Building a shielding wall in the aquifer to block the flow of groundwater, water is stored. In a coastal region, the wall prevents the intrusion of seawater etc. from downstream. It has actually been used in islands etc. where intake from a river etc. is difficult.<br>As its merits, the ground surface can be used for other purposes; the burden to the environment is light; reliable water intake is possible; and the water temperature is stable and so forth. Some large scale facilities have been built for irrigation. |

**Table 3.1.3 Comparison of main water storage facilities**

| Item \ Type | Exclusive dam for water supply | Multi-purpose dam | Estuary weir etc. to store water |
|---|---|---|---|
| Capacity to be developed | Mostly small scale | Development of large storage can be expected | In general, development of a small to medium scale of storage can be expected. In the case of an estuary weir, the minimum maintenance flow in downstream shall be secured by regulating the weir. Such regulated amount of water can be utilized. |
| Quality of stored water | Relatively good quality of water can be stored since the operation is performed by the water utility itself. | Since the operation is performed by a joint management body or the administrator of the river vested by the water utility, the water utility shall request the operator to realize its intention and to maintain the water quality as good as possible. | In the case of the estuary weir, attention shall be paid to the chlorine ion concentration. |
| Location of construction | On a small river in many cases. | Constructed on a river with relatively affluent flow together for the purpose of flood control in many cases. | In the case of the estuary weir, constructed at the mouth of a river near the area, from which water is demanded, and often has the function to prevent salt damage to water for irrigation. In general, the weir serves as the intake weir as well. |
| Economic benefits | The cost is rather expensive. | Locations suitable as the dam site have been exploited, it is getting relatively expensive. | In general, cheaper than the dam. |
| Others | Water utilities are required to possess high level of technologies. As the scale is generally small, its influence to the environment is small. | As its scale is large, and a large area is submerged, the influence to the environment is heavy. What's more, the construction consumes a lot of time. | Important points are consideration to fishery downstream, water use realized by damming up the river, consideration to a flood etc. |

### 3.1.3. Improvement and replacement of water storage facilities

Improvement and replacement of water storage facilities shall systematically be carried out in accordance with the following:

1. Proper measures for the inflow of earth and sand shall be made in consideration of the surroundings of the impounding reservoir, geology, economic benefits etc.
2. Required repair, strengthening etc. of such structure as a dam etc. shall be undertaken after examining the observation data and the materials of studies. At the same time, such measures as the prevention of water leakage and conformity with the standards required under the structural ordinance for river management facilities shall be considered. Additionally, in case the resistance to an earthquake of the facilities is insufficient, proper measures for improvement in resistance to earthquake shall systematically be implemented.
3. For ancillary equipment, improvement and replacement work shall be carried out not to impair its operability and reliability based on its day-to-day inspection and upkeep.

**[Interpretation]**

Although as the water storage facilities, there are one with a dam, and the other one by a lake etc., this section only deals with such structures as a dam etc. to dam up a river, and the facilities composed of the impounding reservoir etc. as a result of the former.

Since the water storage facilities are large scale facilities in terms of space as well as structure, and they are equipped with various facilities used for operation, it is important to properly maintain the dam structure and their ancillary facilities.

Therefore, it is needed to regularly implement inspection and upkeep, timely carry out repair of facilities to maintain their function, and undertake improvement work for reinforcement of the function of the storage facilities according to the situation.

On the occasion of such upkeep and replacement, as restriction in storage and curtailment in water intake are accompanied in many cases, systematic water intake becomes difficult, so there is a possibility to hinder reliable water service.

Given this, when constructing water storage facilities, it shall be planned that, together with the securement of the safety of the dam body, measures are implemented to protect the slope of the banks of the reservoir, and to prevent and dispose of the inflow of earth and sand, and that it is provided to make easy the upkeep and replacement of such ancillary facilities as the gate etc.

**On the item 1.;**

The slope of banks of the impounding reservoir is easily subject to land slide or collapse due to the fluctuation of the water level in the reservoir. Besides, at a valley or a mountain stream, scouring or piling of earth and sand tends to occur due to the concentrated inflow of rainwater. Since these phenomena are largely affected by topographic and geological conditions, it is needed to take such adequate measures as a detailed survey and examination in advance.

**On the item 2.;**

Since the structures of a dam etc. are built solidly, and their life is long, overall reconstruction is seldom made, but, in general, repair and reinforcement are implemented.

The need for repair, reinforcement etc. shall synthetically be judged from deterioration, abnormal deformation, uplift pressure, amount of leakage etc. of such facilities as the dam body, which impair their structural stability.

**On the item 3.;**

The function and reliability of such ancillary facilities as the gate, valve, level gauge need to always be secured, and they shall be not only inspected and kept up but also systematically improved or replaced so that proper operation and management of the storage facilities do not become difficult (See 8.1.3 Improvement and replacement of facilities).

## 3.2. Exclusive water storage facilities

### 3.2.1. General

The exclusive water storage facilities (exclusive impounding reservoir) are constructed for the purpose of developing a new water source. There are two methods of water intake: one that directly abstracts water from the impounding reservoir, and the other one with which water is once discharged to a river and withdrawn from it downstream.

### 3.2.2. Survey

| |
|---|
| When planning exclusive water storage facilities, a survey shall be conducted on the respective matters of the following: |

1. Hydrology
2. Topography and geology
3. Situation of water use
4. Water quality
5. Sand deposit
6. Compensation etc.
7. Influence to the environment
8. Others

**[Interpretation]**

**On the item 1.;**

Under a hydrological survey, data on precipitation, flow (flood flow, six-month flow, droughty flow etc.) of the river basin, water temperature, atmospheric temperature, evaporation etc. need to be collected. Especially, since the water use plan is drawn based on the data on water flow in the past, the data on precipitation and river flow shall be collected for as long a period as possible (at least 10 years). In case data of actual measurement is insufficient, such another method as low flow analysis, or conversion from data collected in other similar river basin and so forth need to be used.

Therefore, data required for these analyses shall be collected, and at the same time simultaneous flow measurements shall be conducted at the proposed site of the storage facilities and the points to be used for computation of water balance.

**On the item 2.;**

The outline of the topography in the river in question shall be grasped, and at the same time it is needed to identify the topography and geology of the peripheral of the proposed site of the storage facilities in detail. Especially, since the dam is one of the largest manmade structures, and it exerts its benefits for a long time, sufficient consideration needs to be given to assure its safety. As such, a thorough survey shall be conducted on the property of the foundation at the proposed dam site.

**On the item 3.;**

As to the river where the water storage facilities are planned to be built, the situation of its water uses shall be identified through a survey on the existing uses (for water supply, irrigation, industrial water supply, hydraulic power generation etc.) and preparation of a system diagram of water intake points and users, research of authorized and traditional water rights, survey of actual volume of water intake, and so on. In addition, fishing rights on the river in question and sea area, which are supposed to be affected by the above facilities, shall also be studied (See 2.2.2 Survey).

**On the item 4.;**

The basic protective measure for the water quality in the water source for water supply is to reduce the pollution load which flows in from the river basin. Since the water stored for a long time is often suspected to be eutrophic, the pollution load from the river basin shall be studied in coordination with the office of environmental protection (See 1.2.4 Basic survey and 2.2.2 Survey).

**On the item 5.;**

The storage capacity of the impounding reservoir diminishes due to progressive sand sedimentation after the completion of the reservoir; and the river bed and water level upstream of the reservoir rise at times due to sand piling and backwater. Therefore, the condition of inflow of earth and sand, their grain size and density and state of the river shall be observed and tested; and the relationship between the flow and transported quantity of earth and sand need to be studied based on such surveys.

**On the item 6.;**

The ratio of the amount of compensation to the total cost of construction of the storage facilities is in the rising trend. Survey on the outline of properties, for which compensation is likely required, shall be conducted from the time of planning, and the rough cost needs to be computed.

**On the item 7.;**

Since construction of the storage facilities gives influence to the natural surroundings etc., prescribed formalities in accordance with The Environmental Impact Assessment Law etc. need to be applied. Even in the case of a project for which the law does not apply, data on researches and studies on such natural environment as vegetation, fish, birds, insects, natural monuments, cultural assets etc. shall be collected and sorted. At the same time, an environmental study and an environmental impact assessment shall be conducted if required.

**On the item 8.;**

On the occasion of constructing water storage facilities, setting of the site of preparatory work at other lot than the acquired one, the method of transportation of materials etc. shall be examined; and appropriate method and means shall be determined.

The road project, the river project etc. of the region related to the water storage facilities shall be studied, and it is needed to prepare a plan for the facilities to be harmonized with the above projects.

### 3.2.3. Design standard year

| |
|---|
| The design standard year to be used for determining the storage capacity required to abstract the design water intake volume is in general the year of the No. 1 drought returning every 10 years. |

**[Interpretation]**

Admitting it is ideal that, for the design standard year, the year of drought of the largest scale among droughty years for a long period is selected, huge capacity of storage is required in such a case. Contrarily, if a year of smaller magnitude of drought is selected as the design standard year, a year, when the design water intake volume cannot be withdrawn, will repeatedly occur in a short period of time. In Japan, it is common to adopt the droughty year of the No. 1 drought returning every 10 years as the design standard year in consideration of the magnitude of safety of water intake and the economic effect of the water utility.

When determining the design standard year, hydrological data for as long a period as possible (20 to 30 years. Recent 10 years in an unavoidable case) shall be collected, and the droughty year equivalent to the consecutive 10 years with No. 1 drought returning every 10 years (No. 3 drought in the case of 30 years, and No. 2 drought in the case of 20 years) shall be selected. In the river system, where a multi-purpose dam project has become in reality, the standard design year compatible with the project shall be adopted.

### 3.2.4. Determination of required capacity of water storage

| |
|---|
| The required capacity of water storage shall be determined according to the following matters: |

1. It shall be determined based on the computation of water balance in the design standard year.
2. In the computation of water balance, it shall be clarified that the design water intake volume can reliably be abstracted, and that the normal river flow shall not be interrupted.

**[Interpretation]**

**On the item 1.;**

Although water balance computation can the most securely be performed if it is conducted in per-day basis, since what the river flow affects at the maximum is the drought continuing for a certain period of time rather than the maximum drought, it is sufficient to conduct the computation in the semi-ten-day basis. Given this, the per-day flows are averaged for a semi-ten-day period, and then the water balance computation for the intake of the design intake water volume shall be conducted.

In case water balance computation is conducted, computation is at times made assuming that the impounding reservoir is full in each year; it is desirable to continuously conduct the computation beyond the one-year period since it sometimes takes for consecutive two years for the reservoir to be filled (See Figure 3.2.1).

What's more, in case a preliminary examination is made, the use of the hydrograph method, the cumulative flow curve method (Rippl method) etc. can conveniently be used.

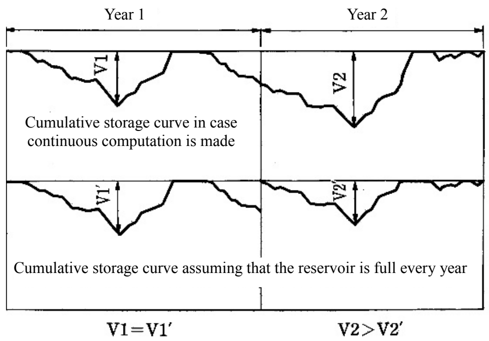



**Figure 3.2.1 Storage capacity curve in water balance computation**

**On the item 2.;**

The flow required for the maintenance of normal river flow means the flow to secure the existing water rights (the traditional water rights, and already authorized water rights), navigation, fishery, tourism, preservation of the cleanliness of stream, prevention of salt damage, prevention of clog of the river mouth, protection of river management facilities, maintenance of groundwater level, protection of fauna and flora etc. It is also called the river maintenance flow, and is the minimum flow, with which the proper use of the river and the maintenance of proper function of the stream can be sustained. As such, it needs to be proved by the water balance computation that the design water intake volume can reliably abstracted without jeopardizing the above functions.

**[Reference 3.1] Example of water balance computation for estimation of required storage capacity for development of a dam (Construction of a multi-purpose dam, Vol. 2, Dam Technology Center, 2005)**

The required storage capacity is obtained as follows: the required volume is found by semi-ten-day period as the balance of discharge from the reservoir to maintain the required flow (the design water intake flow + the normal flow) at the reference intake point and the quantity of influx to the reservoir;

cumulative totals are made; and then the maximum one of the cumulative totals is the required storage capacity. This process of computation is called the water balance computation. The size of the water storage capacity is so determined that the water balance is satisfied as a result of computation.

## 1. Condition of computation

- A water use plan of a dam project shall aim at compensating the existing water rights and the water use to be newly developed downstream of the dam.
- The usable capacity of the dam reservoir is 12,400,000 $m^3$(a flood season).
- The obliged discharge from the dam for preservation of environment is set at 0.3 $m^3/s$ at right downstream of the dam.
- The secured water flow at the reference point B shall be the existing water rights from Point B to Point C; the one at the reference point C, the existing water rights from Point C to further downstream and ones to be newly developed.
- The newly developed flow is 2.5 $m^3/s$ as the city water.

## 2. Example of water balance computation

An example of water balance computation and its procedures are presented in Reference Table 3.1.1, Reference Table 3.1.2, Reference Figure 3.1.1, and Reference Figure 3.1.2.

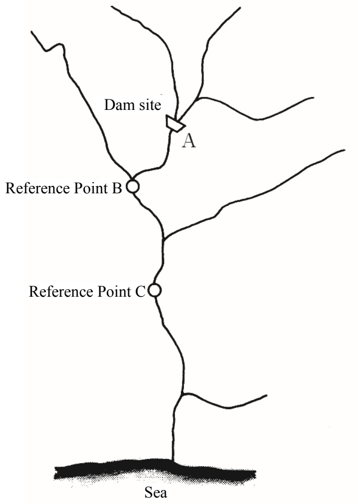
**Reference Table 3.1.1 Example of water balance computation of a dam reservoir**

Unit: $m^3/s$

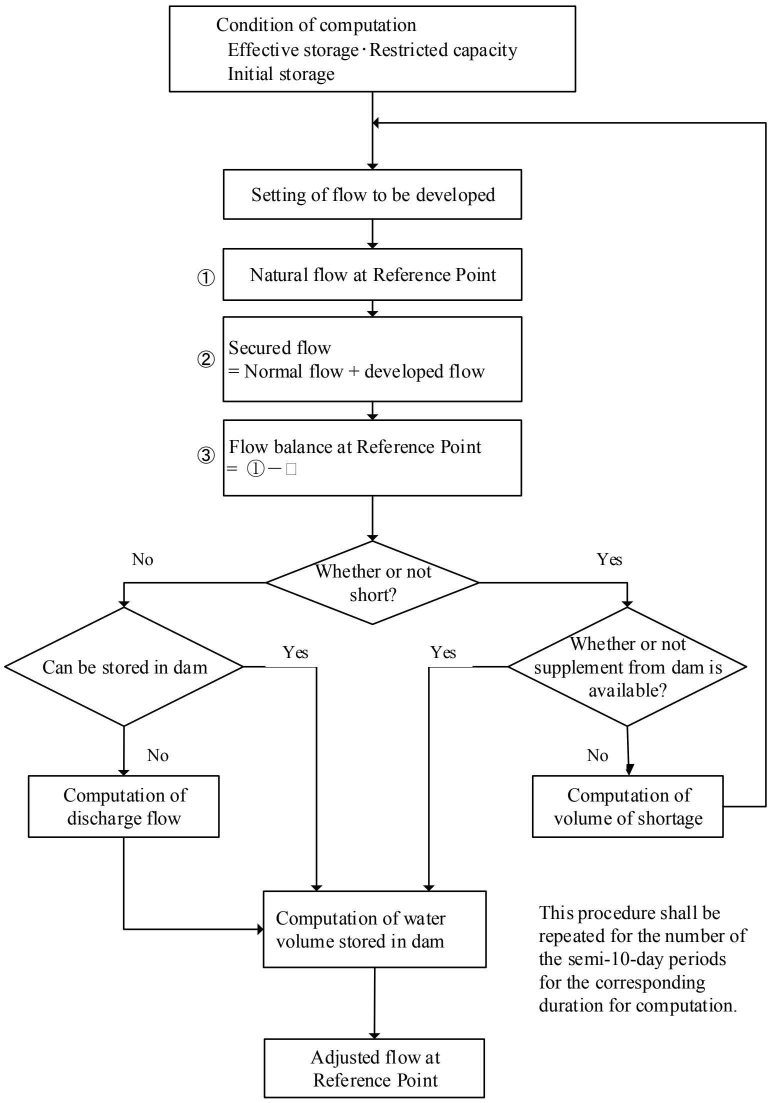
| Date | Reference point B | | | Reference point C | | | Adjustment at reference point | | | Dam site A | | | | | | | Table of dam operation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) |
| | Point B natural flow | Unspecified secured flow | Unspecified flow balance | Point C natural flow | Unspecified secured flow | Unspecified flow balance | Unspecified surplus flow with supplement | Water use to be newly developed | Balance (7) less (8) | Flow at dam site | Unspecified supplemental flow | Total supplemental flow | Flow available for storage | Flow to be stored | Semi-10-day supplemental storage 1,000 $m^3$ | Cumulative dam storage 1,000 $m^3$ | Discharge from dam | Reference point flow after dam operation |
| July ‘XX | | | | | | | | | | | | | | | -899 | 12,400 | | |
| | 3.20 | 2.72 | 0.48 | 3.52 | 3.10 | 0.42 | 0.42 | 2.50 | -2.08 | 1.58 | | -2.08 | | | 899 | 11,501 | 3.6 | 5.60 |
| | 12.66 | 2.72 | 9.94 | 15.19 | 3.10 | 12.09 | 9.94 | 2.50 | 7.44 | 6.27 | | | 6.27 | 2.08 | | 12,400 | 4.19 | 13.11 |
| | 14.02 | 2.72 | 11.30 | 15.42 | 3.10 | 12.32 | 11.30 | 2.50 | 8.80 | 6.94 | | | 6.94 | | | 12,400 | 6.94 | 15.42 |
| | 36.80 | 2.28 | 34.52 | 40.48 | 1.14 | 39.34 | 34.52 | 2.50 | 32.02 | 18.22 | | | 18.22 | | | 12,400 | 18.22 | 40.48 |
| | 7.16 | 2.28 | 4.88 | 7.87 | 1.14 | 6.73 | 4.88 | 2.50 | 2.38 | 3.54 | | | 2.38 | | | 12,400 | 3.54 | 7.87 |
| | 1.82 | 2.28 | -0.46 | 2.00 | 1.14 | 0.86 | --- | 2.50 | -2.50 | 0.90 | -0.46 | -2.96 | | | - | 10,866 | 3.86 | 4.96 |
| | | | | | | | | | | | | | | | 1,534 | | | |
| Aug. | 1.24 | 2.28 | -1.04 | 1.36 | 1.14 | 0.22 | --- | 2.50 | -2.50 | 0.61 | -1.04 | -3.54 | | | - | 9,336 | 4.15 | 4.90 |
| | 1.20 | 2.28 | -1.08 | 1.32 | 1.14 | 0.18 | --- | 2.50 | -2.50 | 0.56 | -1.08 | -3.58 | | | 1,529 | 7,790 | 4.14 | 4.90 |
| | 0.86 | 2.28 | -1.42 | 0.95 | 1.14 | -0.19 | --- | 2.50 | -2.50 | 0.43 | -1.61 | -4.11 | | | - | 6,014 | 4.54 | 5.06 |
| | 0.60 | 1.55 | -0.95 | 0.66 | 1.86 | -1.20 | --- | 2.50 | -2.50 | 0.30 | -2.15 | -4.65 | | | 1,547 | 4,005 | 4.95 | 5.31 |
| | 3.54 | 1.55 | 1.99 | 3.89 | 1.86 | 2.03 | 1.99 | 2.50 | -0.51 | 1.75 | | -0.51 | | | - | 3,785 | 2.26 | 4.40 |
| | 4.07 | 1.55 | 2.52 | 4.48 | 1.86 | 2.62 | 2.52 | 2.50 | 0.02 | 2.01 | | | 0.02 | 0.02 | 1,776 | 3,795 | 1.99 | 4.46 |
| | | | | | | | | | | | | | | | - | | | |
| | | | | | | | | | | | | | | | 2,000 | | | |
| | | | | | | | | | | | | | | | -220 | | | |
| | | | | | | | | | | | | | | | 10 | | | |
| Sep. | 16.0 | 1.55 | 0.05 | 1.76 | 1.86 | -0.10 | --- | 2.50 | -2.50 | 0.79 | -0.10 | -2.60 | | | - | 2,672 | 3.39 | 4.36 |
| | 3.50 | 1.55 | 1.95 | 3.85 | 1.86 | 1.99 | 1.95 | 2.50 | -0.55 | 1.73 | | -0.55 | | | 1,123 | 2,435 | 2.28 | 4.40 |
| | 1.70 | 1.55 | 0.15 | 1.87 | 1.86 | 0.01 | 0.01 | 2.50 | -2.49 | 0.84 | | -2.49 | | | -238 | 1,359 | 3.33 | 4.36 |
| | 1.38 | 1.55 | -0.17 | 1.52 | 1.86 | -0.34 | --- | 2.50 | -2.50 | 0.68 | -0.51 | -3.01 | | | - | 59 | 3.69 | 4.53 |
| | 14.26 | 1.10 | 13.16 | 15.68 | 1.10 | 14.58 | 13.16 | 2.50 | 10.66 | 7.06 | | | 7.06 | 6.76 | 1,076 | 2,979 | 0.30 | 8.92 |
| | 20.44 | 1.10 | 19.34 | 22.48 | 1.10 | 21.38 | 19.34 | 2.50 | 16.84 | 10.12 | | | 10.12 | 9.82 | - | 7,221 | 0.30 | 12.66 |
| | | | | | | | | | | | | | | | 1,300 | | | |
| | | | | | | | | | | | | | | | 2,920 | | | |
| | | | | | | | | | | | | | | | 4,242 | | | |
| Oct. | 3.78 | 1.10 | 2.68 | 4.16 | 1.10 | 3.06 | 2.68 | 2.50 | 0.18 | 1.87 | | | 0.18 | 0.18 | 78 | 7,299 | 1.69 | 3.98 |
| | 4.00 | 1.10 | 2.90 | 4.40 | 1.10 | 3.30 | 2.90 | 2.50 | 0.40 | 1.98 | | | 0.40 | 0.40 | 173 | 7,472 | 1.58 | 4.00 |
| | 22.08 | 1.10 | 20.98 | 24.29 | 1.10 | 23.19 | 20.98 | 2.50 | 18.48 | 10.93 | | | 10.93 | 10.63 | 4,592 | 12,064 | 0.30 | 13.66 |
| | 6.04 | 1.10 | 4.94 | 6.64 | 1.10 | 5.54 | 4.94 | 2.50 | 2.44 | 2.99 | | | 2.44 | 2.44 | 1,054 | 13,118 | 0.55 | 4.20 |
| | 4.30 | 1.10 | 3.02 | 4.73 | 1.10 | 3.63 | 3.20 | 2.50 | 0.70 | 2.13 | | | 0.70 | 0.70 | 302 | 13,420 | 1.43 | 4.03 |
| | 3.55 | 1.10 | 2.45 | 3.9 | 1.10 | 2.80 | 2.45 | 2.50 | -0.05 | 1.76 | | -0.05 | | | -26 | 13,394 | 1.81 | 3.95 |

## Reference Table 3.1.2 Procedures for water balance computation of a dam reservoir

| Item | Annotation | Computation example | |
|---|---|---|---|
| | | Sept. 4th semi-10-day period (at supplement) | Sept. 5th semi-10-day period (at storing) |
| (1) Point B natural flow | Flow into Reference Point B before the dam project | 1.38 | 14.26 |
| (2) Unspecified secured flow | Existing water rights from Point B to Point C | 1.55 | 1.10 |
| (3) Unspecified flow balance (3)=(1)-(2) | Water balance at Point B after securing (2). (-) value means supplement needed from dam | 1.38-1.55=-0.17 | 14.26-1.10=13.16 |
| (4) Point C natural flow | Flow into Reference Point C before the dam project | 1.52 | 15.68 |
| (5) Unspecified secured flow | Existing water rights from downstream of Point C | 1.86 | 1.10 |
| (6) Unspecified flow balance (6)=(4)-(5) | Water balance at Point C after securing (5). (-) value means supplement needed from dam | 1.52-1.86=-0.34 | 15.68-1.10=14.58 |
| (7) Unspecified surplus flow with supplement (7)=l(3),(6)l min | Either smaller one of (3) or (6). But 0 when the value is (-). | (-0.17,-0.34)min=-0.34<br>-0.34>0 | (13.16,14.58)=13.16 |
| (8) Water use to be newly developed | Water use to be newly developed at Point C | 2.50 | 2.50 |
| (9) Balance (7) less (8) (9)=(7)-(8) | Water balance at Point C after securing (5) and (8). (-) value means supplement needed from dam | 0-2.5=-2.50 | 13.16-2.50=10.66 |
| (10) Flow at dam site | Flow into dam site before the dam project | 0.68 | 7.06 |
| (11) Unspecified supplemental flow | Total supplemental flows for (2) and (5) from dam. (-) values of (3) and (6) are only summed up. | -0.17+(-0.34)=-0.51 | --- |
| (12) Total supplemental flow (12)=(9)+(11) | Total supplemental flows for unspecified flow and water use to be newly developed (8) from dam. At the procedure (11), (-) values of (9) are only summed up. | -2.50+(-0.51)=-3.01 | --- |
| (13) Flow available for storage (13)=l(3),(9),(10)l min | Flow, which can be stored without affecting downstream water uses. The smallest of flows at Reference Points (3), (9), (10). But when the value is (-), no storage can be made since it is the time to supplement. | (-0.17,-2.50,0.68)min=<br>-2.50-<0→0 | (13.16,10.66,7.06)min=7.06 |
| (14) Flow to be stored | Flow to be stored in dam reservoir. (13) shall be adjusted when the reservoir is full, or discharge to downstream is obliged. | 0 | 7.06<br>After adjustment<br>7.06-0.3=6.76 |
| (15) Semi-10-day supplemental storage<br>At supplement:<br>(15)=(12)*days of semi-10-day period *86,400<br>At storing:<br>(15)=(14)* 〃 〃 〃 | Supplemental volume or storage for the semi-10-day period. When the value is (-), it is time to store. | -3.01*5*86,400= -1,300,000 $m^3$ | 7.06*5*86,400=3,050,000$m^3$<br>After adjustment<br>6.76*5*86,400=2,920,000$m^3$ |
| (16) Cumulative dam storage (16)=$(16)_{-1}$+(15) | Assuming that the reservoir is full at the start of computation of the water use capacity. | 1,359,000 $m^3$-1,300,000 $m^3$<br>=59,000 $m^3$ | 58,000 $m^3$+3,050,000 $m^3$<br>=3,108,000 $m^3$<br>After adjustment<br>58,000 $m^3$+2,920,000 $m^3$<br>=2,978,000 $m^3$ |
| (17) Discharge from dam<br>At supplement:(17)=(10)-(12)<br>At storing:(17)=(10)-(14)<br>However,(17)≧0.3 | Flow at the dam site after dam operation. When the flow is less than 0.3 $m^3$/s, 0.3 $m^3$/s shall be maintained. | 0.68-(-3.01)=3.69<br>(>0.3) | 7.06-7.06=0<0.3 short<br>Storage is adjusted (14)<br>After adjustment<br>7.06-6.76=0.3 |
| (18) Reference point flow after dam operation<br>At supplement:(18)=(4)-(12)<br>At storing:(18)=(4)-(14) | Flow at Reference Point C after dam operation | 1.52-(-3.01)=4.53 | 15.68-6.76=8.92 |




**Reference Figure 3.1.1 Locations of water balance computation**




**Reference Figure 3.1.2 General flow diagram of water balance computation**

In this example of computation, the maximum value appears in the fourth semi-ten-day period of September when the cumulative storage in the dam reservoir becomes the smallest. In other words, the required storage is 12,341,000 $m^3$ as the balance of the usable capacity 12,400 less the storage volume in fourth semi-ten-day period of September 59,000 $m^3$.

What's more, in case the cumulative storage in the dam reservoir becomes negative in the computation, such a change in the plan as reduction in the newly developed water use or increase in the usable water storage is needed.

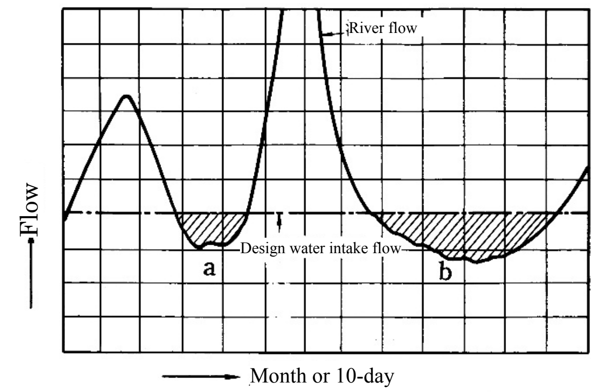
**[Reference 3.2] Computation of required storage capacity by a simplified method**

**1. Method by means of a hydrograph**

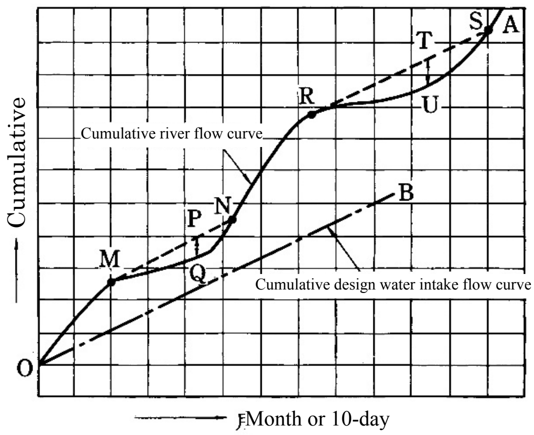
In this method, the changes in river flow by month or 10-day period are illustrated, the design water intake volume for the corresponding period are plotted in the graph, and the maximum one (b) among the areas surrounded by these lines is obtained. The value of the area is the total supplemental flow, i.e., the required storage capacity (See Reference Figure 3.2.1).

**2. Method by means of a cumulative flow curve diagram (Rippl's method)**

In this method, the river flow and the design water intake flow in every month or 10-day period are accumulated to draw respective cumulative flow curves: a line (MN or RS) in parallel to the cumulative line of the design water intake flow is drawn from the point (M or R), where the gradient of curve starts to get gentler than the cumulative line of the design water intake flow, to the point (N or S) where the line gets to the curve of cumulative river flow; and the maximum value of the vertical distance (PQ or TU) between the two curves is obtained, which is the required storage capacity in the period. In case the design water intake flow changes from month to month, its cumulative line becomes a curve (See Reference Figure 3.2.2).




**Reference Figure 3.2.1 Method by means of a hydrograph**




**Reference Figure 3.2.2 Method by means of cumulative flow curves**

### 3.2.5. Prerequisites for the structure

1. The type of the dam shall be determined based on the examination of the topography of the dam site, geology, spillway, and materials of the dam body.
2. As for foundation ground, the geological property of the dam site, such characteristics as the thickness, dip, permeable faults, crevices etc. of the strata, which support the dam body, shall be examined.

3. The spillway of the dam shall be of the scale, type and layout to dispose of the flood, and can assure the safety of the facilities.

4. Since the discharge facilities for releasing water for water supply, the maintenance of river flow etc. are operated under high water pressure, their structure shall possess good compatibility with the dam body, and not adversely affect the downstream section of the river.

5. The structure of the dam shall have required water-tightness and durability in consideration of the property of the type of the dam, foundation ground, spillway etc., and, at the same time, shall be safe against the expected loads.

**[Interpretation]**

**On the item 1.;**

The types of dam are classified into the concrete dam and the fill dam by materials of the dam body. The concrete dam is sorted into the gravity dam and the arch type dam; and the fill dam is classified into the surface shield type, uniform type, zone type by the structure of the section, which performs water-shielding function (See Figure 3.2.2). Additionally, the fill dam is sorted into the earth-fill dam and the rock-fill dam by the material of the dam body.

When selecting these types, the size of the dam, the topography and geology of the dam site, the size of the spillway, and the availability of material of the dam body shall adequately be studied; and the most suitable one shall be selected in synthetic consideration of such conditions as the environment of the surroundings, economic benefits etc. (See Table 3.2.1).

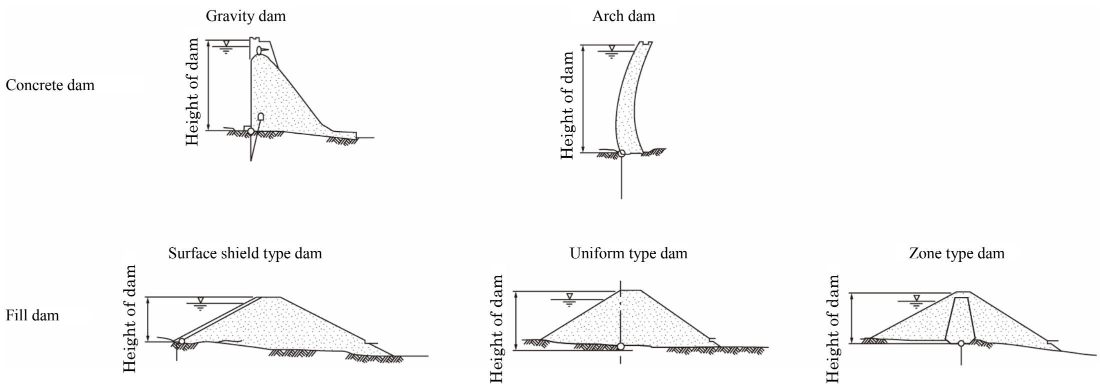



**Figure 3.2.2 Types of dam**

**Table 3.2.1 Difference in design method by type of dams (Technical standards for soil-erosion control of the river (Draft) and Annotation, Volume of Design [I], Ministry of Construction)**

| Dam type | Basic assumption | Standard design condition for the dam | Design parameters |
|---|---|---|---|
| Gravity type Concrete dam | Two-dimensional elastic body | 1) Resultant force of external forces shall fall within the middle third of the plan of the dam body<br>2) The safety factor by the Henny's equation is larger than 4.<br>3) The stress occurring in the dam body does not exceed the allowable stress. | According to on-site test:<br>Shear strength of base rock $\tau_0$<br>Internal friction coefficient $f$<br><br>According to concrete composition test:<br>Property values of concrete<br>Strength of concrete |
| Arch type Concrete dam | Three-dimensional elastic body | 1) The stress occurring in the dam body does not exceed the allowable stress.<br>2) The safety factor by the Henny's equation is larger than 4. | |
| Fill dam | Two-dimensional non-elastic body | 1) As to the slip circle, the safety factor is larger than 1.2 by the Slice method. | Of fill material & foundation according to indoor triaxial tests:<br>Adhesive force C<br>Internal friction angle $\phi$ |

**On the item 2.;**

**1) Concrete dam**

**(1) Gravity dam**

As the force to be transmitted to the base rock becomes large in relation to the height of the dam, strong base rock with sufficient shearing stress is needed as the foundation rock near the largest section.

**(2) Arch dam**

As to the riverbed, although the restriction on the shearing force is smaller than the case of the gravity dam, base rock needs to be strong from the bottom to the top of the dam, and have sufficient strength to withstand the thrusting force of the arch. Since the thickness of the dam is small, the condition on the permeability of the base rock is considerably strict.

**2) Fill dam**

Since the fill dam can in general transmit the load from the dam body to broader base rock than the concrete dam, the restriction from the strength of the foundation is small. As the requirement for the foundation, the prescribed impermeability and shearing force are required at the water-shielding zone; and shearing force and resistance to the piping phenomenon are required in other area than the water-shielding zone.

**On the item 3.;**

The maximum water level at ordinary operation of the dam is always the normal full water level. However, from the need to secure the safety of the dam, and to eliminate obstacles related to the management of the river, the flood level is set as the maximum water level corresponding to dam operation. Therefore, a spillway etc. shall be installed so as to safely discharge the inflow volume from the normal full water level to the design flood level to downstream.

Since the spillway of the free-overflowing type shall be of a concrete structure as a rapid stream must be dealt with, an overflow type concrete dam is economical. In the case of the fill dam, as the issue of the safety related to overflow of a flood is more serious than the concrete dam, the spillway shall be built separately from the dam body.

As the riverbed downstream of the dam is often scoured by discharged water, and it causes problems with the safety of the dam and the management of the river, the riverbed shall be protected by the provision of an energy dissipater etc.

**On the item 4.;**

The water of the dam reservoir, except for water supply which is directly withdrawn from the reservoir, is discharged through an outlet conduit etc. for the purpose of lowering the water level for water use, the maintenance of normal flow function of the river, management and upkeep of the reservoir and the dam and so forth.

Since this discharged water has pressure corresponding to the water level of the reservoir, the structure of the discharge conduit shall be strong and have required water-proofing nature, its opening and closing shall be reliable, and it needs to be located in consideration of its compatibility with the dam body.

The discharge facilities shall be equipped with a gate etc., which can control the flow rate and suppress the energy of the flow, to safeguard against the effect of vibration, scouring of the riverbed, impact etc. so as not to give adverse influence to the facilities and its surroundings.

To aim at rational management of the dam, and effective utilization of the hydraulic energy the dam possesses, it is desirable to consider about the introduction of hydraulic power generation facilities at the time of planning the energy-dissipating gate etc.

### 3.2.6. Measures for protection of water quality

| |
|---|
| In case occurrence of troubles is expected due to water pollution in the reservoir, measures for protection of water quality shall be undertaken. |

**[Interpretation]**

**1) Characteristics of quality of the reservoir water**

The quality of the reservoir water is closely related to the weather, the environment of the catchment area, the capacity of the reservoir, water depth, the operation of the reservoir etc., and different from the quality of the ordinary river water. In other words, the reservoir stores river water for a long time, and its water depth is deep. Because of this property, there are some reservoirs where eutrophication is in progress. If taste and odor occur due to the growth of algae caused by eutrophication, the load on water treatment increases resulting in the increase in the cost of water treatment.

**2) Measures for protection of water quality**

**(1) Coordination with the related organizations**

The measures for protection of water quality in the reservoir are sorted into protective measures in the catchment area and ones in the reservoir, and it is important to raise the effectiveness of the measures in that the measures in both areas are systematically and synthetically implemented.

As there are many organizations concerned with the storage facilities and its catchment area, a plan as the basis of the measures shall be prepared based on synthetic coordination among these organizations etc. with the offices of environmental protection as the primary operator. Besides, as for actual measures, the protection of the natural environment in the surroundings of the reservoir, regulatory measures for sources of pollution, the implementation of sewerage projects and so on are to be undertaken. As such, the water supply utility shall lobby the related offices and organizations based on the understanding of all the contents of the measures.

**(2) Laws on the protection of water quality**

**(3) Protection of the water sources**

As one of the protective measures for water sources, it is useful for the water utility to acquire forests and fields in the catchment area to raise the water-cultivating function of the forest surrounding the dam lake and prevent water pollution caused by uncontrolled development of the area, and positively undertake a project etc. for promotion of the recognition of the water sources and the importance of the cultivating forest in the water source area through dialogues between people from both upstream and downstream areas so that the tap water is reliably served in good quality through the future. –

**(4) Protection of water quality in the reservoir**

As for measures for the protection of water quality in the reservoir, there are the felling of trees in the submerged area, which become one of causes to bring about eutrophication, spraying of chemicals, circulation of the reservoir water, dredging of sediments etc., and since these measures can be implemented by the water utility itself, they need to be positively carried out while observing the trend of water quality in the reservoir and the progress of the measures to be conducted for the conservation of the water quality in the catchment area.

## 3.3. Multi-purpose storage facilities

> In case securing water source through participation in a project of multi-purpose storage facilities (multi-purpose dam etc.), the following matters shall be taken into consideration.
>
> 1. The components of the project shall be identified in each stage of survey, construction and completion, and the water utility shall take required steps so that the mission of the utility can fully be achieved while making coordination with the executing body of the dam project and other concerned offices.
> 2. In case more than two entities as water users participate in the project, joint use of water intake and transmission facilities shall be examined.
> 3. The allocation of the developed yield of water shall be made based on the synthetic adjustment of respective project plans of the participants so that the effects of their purposes can be realized as a whole.
> 4. Coordination shall be made between the water utility, the executing body of the project and other concerned offices for specific items of management so that the prerequisite purposes of the water supply utility are achieved and that smooth operation can be made.
> 5. To aim at the effective use of the limited water resources, the securement of water sources by means of transfer of water use purposes etc. shall be examined.

**[Interpretation]**

**On the item 1.;**

The multi-purpose storage facilities have more than two purposes such as water supply, flood control, hydraulic power generation, irrigation, industrial water supply etc. Laws and regulations in respect to the relationship between the executing body of the project and the water supply utilities, in case water resources for water supply is developed under multi-purpose water storage facilities, are presented in Table 3.3.1.

Construction of the multi-purpose water storage facilities is normally set out through a preliminary survey and the implementation plan study. The water supply utility shall determine the water use quantity to be borne by the water storage facilities by the time of the preparation of the master plan and the basic agreement with the executing body of the project. A plan for future water demand and supply shall be prepared in advance; and a water supply development plan shall be established based on the water source provided under the multi-purpose dam project. It is also important to make a trial computation on the water balance in advance and allocation of the cost obtaining detailed data on the contents of the dam project.

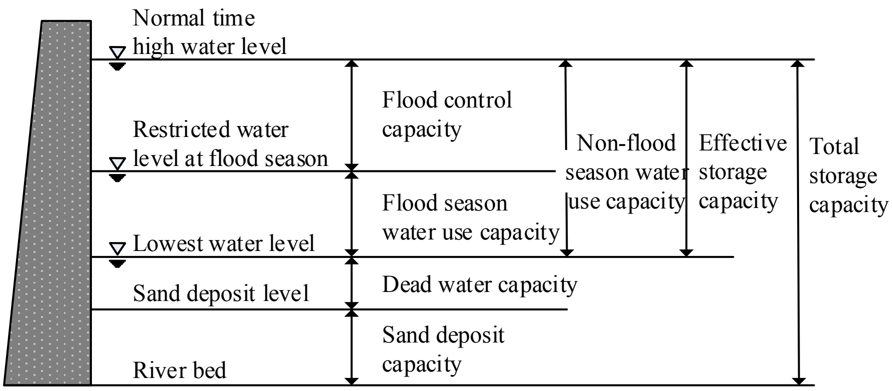
In the final year of the implementation plan study, in general, such basic matters as master plan, basic agreement etc. of the construction plan are fixed, in which the users and their water use to be developed, allocations of the yield from the storage facilities, cost allocation, the total project cost, the term of construction etc. are determined. At the time of fixing the master plan etc., as the opinions of the concerned entities are heard, the intention of the water supply utility shall be reflected based on the preceding study and its examination on the allocation, water intake plan etc.

The respective utilities will bear the cost of dam construction based on the respective rates of allocation in accordance with the master plan, the basic agreement etc.

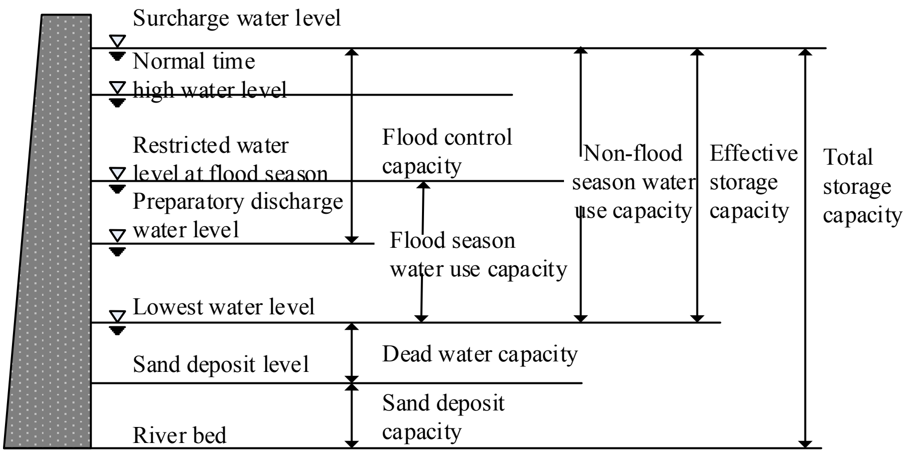
**On the item 3.;**

For planning the multi-purpose water storage facilities, since the plan is established combining more than two purposes into one, it is the basis to incorporate the necessary and sufficient conditions into the plan with precise understanding of their respective purposes. The capacity of the multi-purpose storage facilities is classified into the water use volume (for water supply, irrigation, industrial water supply and the volume required for discharging water to maintain the normal flow in the river), the flood control volume (the volume required for flood control), the volume necessary for hydraulic power generation (the volume required for power generation) and the sand deposit (the volume required for the deposit of earth and sand entering the reservoir). As the types of uses of these volumes are different from each other, competitive relationship may arise between some of them.

Especially, since the reservoir needs to be vacant during the flood season for the flood control project whereas it needs to be filled with water for water users, the concepts of operation fundamentality conflict between flood control and water use. Even between water users, as the time of use and the required storage volume are different depending on purpose, competition may occur. To avoid such conflicts, after separately computing respective storage volumes necessary for the users, they shall synthetically be adjusted to determine the allocation of the storage capacity. Given this, the water utilities need to properly determine their storage volumes in reference to 3.2.4 Determination of required storage capacity. An example of the allotment of the storage capacity of a multi-purpose dam reservoir is illustrated in Figure 3.3.1.




(1)Reservoir which performs relatively low-level control




(2)Reservoir which performs relatively high-level control

Note) 1. The water use capacity shall only be used for the need for water use, and not be used for other purposes. However, in case the water use flow is discharged via a power generation plant and abstracted downstream, the water can be used for power generation without affecting the purpose of the water use.

2. The dead water capacity can be omitted depending on the situation of sand deposit.

3. The surcharge water level denotes the water level up to which water is artificially, systematically and temporarily stored over the normal time high water level at the time of a flood.

**Figure 3.3.1 Example of allotment of the capacity of a multi-purpose dam reservoir**

**On the item 4.;**

Towards the completion of the dam, it is needed for the water supply utility to enter into a management agreement, which stipulates specific items of management, with the executing body and other offices after coordination with them. The items to be stipulated in the agreement shall be the primary body of management, handling of the joint-use facilities, consultation on enactment or alteration of the rules etc. for operation of the dam, consultation on the year-by-year implementation plans, allocation and charging method of the operating cost, indemnity concerned with the dam and so forth.

**On the item 5.;**

The securement of water sources by means of construction of a new dam etc. is becoming difficult in the recent years due to rethinking of public undertakings, consideration to the environment etc. Effective use of water sources by means of mutual transfer of water uses so as to cope with the water demand with limited water resources.

# 8. Mechanical, Electrical and Instrumentation Equipment
# 8.1. Introduction

### 8.1.1. Basic matters

#### 1. Roles of mechanical, electrical and instrumentation equipment

Since the mechanical, electrical and instrumentation equipment used for water supply (Hereinafter referred to as "the equipment") are related to the majority of water supply facilities from water intake through water distribution, their apparatus and devices are highly diversified. What's more, their conformance with the water supply facilities will give a heavy impact to the reliability and economy of water service due to the importance of the roles they are playing.

Therefore, safety and efficiency of the equipment shall be assured in their operation, and a simple and highly reliable composition shall be their basis. When selecting apparatus and devices, while securing required functions and credibility, the procurement of proven, standardized and general-purpose products shall be considered, and, at the same time, their life-cycle cost, reduction in load on the environment etc. shall also be taken into consideration. The possession of a water source, from which the design water intake volume can be abstracted all year round, is the basic matter.

#### 2. Securement of safety and items of requirement

From the view points of risk management and preparedness for disasters and accidents, backup capacity shall be provided for the water supply facilities as a whole so that water service in the same manner as in the normal times can be made even on the occasion of breakdown, inspection or replacement of equipment. Additionally, the composition of the equipment shall make the water supply facilities enable to maintain a necessary minimum function even at the times of such natural disaster as earthquake, typhoon etc, and regional power failure.

What's more, to raise the safety of operation, monitoring and protection devices shall be installed so that any anomaly in the equipment shall be detected when it occurs, and that the equipment shall be shut down, or alarming or display of heavy or light failures shall be made according to the situation.

Besides, the measures to prevent the erroneous operation committed by the operator are also important. Although automation of the facilities and extent of its application are advancing to carry out efficient operation, operational errors by operator's judgment are not non-existent. Therefore, to suppress accidents caused by wrong judgment of the operator and his improper operation, the equipment shall be planned to be simple and safe. To this end, it is desirable to adopt apparatus and devices in consideration of ease and safety of operation as much as possible while avoiding to immoderately add functions so as to lessen the burden on the operator.

#### 3. Replacement of equipment in the water supply system and its procedure

The equipment plays an important role in water treatment and water management, and works in close cooperation with other facilities. For this reason, when planning and designing the equipment, the composition and functions of the entire water supply facilities and the operational status of the equipment shall be fully understood, and at the same time it shall be rational and flexible and in harmony with such a future plan for replacement, expansion, demolition and regionalization of water supplies.

As illustrated in Figure 8.1.1, the procedure of planning shall be as follows: the purpose of the plan is clarified as much as possible; such basic condition as the environment of installation or human factors is taken into consideration; the basic policy for operation and management is established; and the basic plan is prepared. In the basic plan, evaluation standards shall be established for reliability, safety, economic benefits, integrity, and measures for environmental preservation in accordance with the orientation of the facilities; and evaluation is to be carried out based on them; and the most optimum plan is determined.

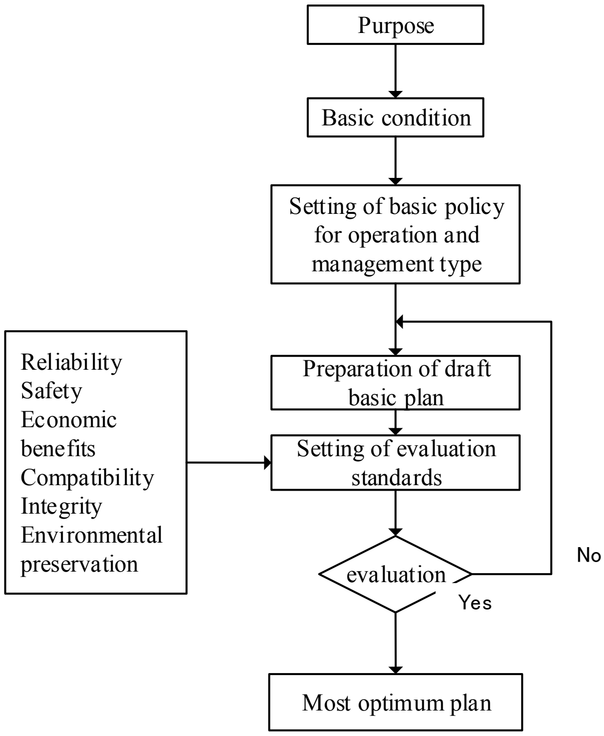



**Figure 8.1.1 Procedure of planning**

### 4. Plan for replacement and asset management

For preparing a replacement plan, it is effective to introduce the method of asset management so as to level off the peaks of the entire facilities and to reduce the cost.

As to the specific method of utilization of asset management, by clearly understanding the dates of installation of apparatus and devices and the magnitude of deterioration from aging, the lives of apparatus and devices are estimated judging from the speed of deterioration; and leveling-off of timing of replacement and lengthening of lives of the apparatus and devices by means of implementing replacement or repair to prevent incidences of breakdown etc. in advance.

On the occasion of preparing a replacement plan, the numbers of units, rating and capacity of equipment need to carefully be reexamined.

### 8.1.2. Related laws and regulations

For designing the equipment, the matters stipulated in related laws and regulations shall be abided by.

### 8.1.3. Improvement and replacement of the equipment

Improvement and replacement of the equipment shall be in conformity with the following:

1. A mid- to long-term plan suitable to the respective water supply utility shall be prepared using such a method as asset management etc., and improvement and replacement shall be implemented at an appropriate point of time.

2. At the time of improvement and replacement, the most rational technique shall be employed so that operation and maintenance (O&M) will become easy and economical with reference to the status of deterioration of related facilities and equipment and their replacement plans.
3. Such an installation plan shall be prepared that the operation of the related facilities is not interrupted during replacement of the equipment.

**[Interpretation]**

**On the item 1.;**

The timing of improvement and replacement of the equipment shall synthetically be determined by means of the asset management etc. based on the increase in the O&M cost and decline in function due to deterioration, the replacement plan for the related facilities and equipment and so forth.

As these determining conditions, there are the experience of operation, legal life, the situation of supply of repair parts by the manufacturers, possibility of life extension, such scientific method as the technique for judging deterioration in equipment shall be determined based on these conditions.

**On the item 2.;**

At the time of replacement of the equipment, the record of operation and upkeep of the objective equipment shall be examined, the points of inconvenience for O&M shall be identified, and such inconvenient points shall be remedied by the replacement. Postponement of the time for replacement along with a replacement plan for other equipment shall be examined as required. When adopting new technologies for apparatus and devices, those with high reliability and safety and the ease of maintenance shall be adopted, and the economic advantage of employing standardized and general-purpose products with record of successful use shall also be reviewed.

**On the item 3.;**

In case reduction in function or shutdown is inevitable due to the composition of the facilities, the replacement work shall be executed at night or in winter when the water demand is small, or the supply from other system shall be considered so that water treatment and water management are not interrupted as much as possible.

### 8.1.4. Risk management

Measures for risk management for planning and designing of equipment shall be determined in consideration of the following items:

1. The equipment shall be a system, which can unerringly manage the items for management based on a water safety plan etc. of each water utility, and can respond immediately when the values of the items for management exceed their thresholds.
2. The equipment with a high priority shall be composed of duplicated units or two systems in parallel; and a backup system shall be considered if needed.
3. The supervisory and control system becomes a target for cyber-terrorism, so it shall be so composed that its damage can be contained to a localized one and minimized.
4. For unmanned facilities, its monitoring system shall be able to immediately detect and confirm the intrusion of suspicious persons and the abnormal performance of the facilities.
5. The equipment shall be constructed in a simple form with unitized components within a feasible scope; and the space for installation of equipment, the routes for cabling and piping etc. shall be laid out in consideration of the work of restoration.
6. Installation location of the equipment, structure and materials of devices, installation of

lightning arresters as measures against a flood, fire, lightning, power failure and tsunami shall be considered.

7. For installation of the apparatus and devices, strengthening of fixing by anchor bolts, prevention of a tumble etc. shall be considered against an earthquake.

**[Interpretation]**

On the occasion of planning and designing the equipment, security measures against natural disasters (earthquake, flood, lightning and ensuing power failure, fire etc.) shall be determined in accordance with the actual condition of the water utility. Equipment with high priority shall be structured and of composition with high safety and reliability in consideration of the influence of an earthquake etc.

Besides, even when part of the equipment is damaged by a great earthquake, terrorism etc., water service shall be maintained as much as possible by the water supply system as a whole.

#### 8.1.5. Measures for environmental conservation

As measures for environmental conservation, the following matters shall be examined:

1. It shall be examined that over sized and superannuated apparatus and devices with low efficiency are to be reformed to ones with proper capacity or replaced with energy-efficient ones at an early date.
2. The introduction of such new energy facilities as small-scale hydraulic power generation, solar power etc. shall be examined.

## 8.2. Pump Facilities

#### 8.2.1. General

As pump facilities in water supply facilities, many various pumps are used such as pumps for the intake of raw water from a river, pumps for raw water transmission, pumps used in water treatment, pumps for treated water transmission, pumps to serve water from the service reservoir etc.

When designing pump facilities, such pumps need to be selected as to achieve the design discharge and water pressure, to aim at operation with high reliability, safety and stability, and pumps suitable to the purpose and use.

Furthermore, to operate pumps efficiently, a proper control type needs to be adopted for pump motors and its operating method, proper measures shall be provided against such hydraulic phenomenon as cavitation, water hammer etc., and at the same time consideration shall be made for the pump well, the structure of the foundation of installation.

In consideration of O&M, the equipment shall be able to safely operate even during the work of repair and replacement.

#### 8.2.2. Planning of pump facilities

On the occasion of planning pump facilities, they shall be examined from a comprehensive point of view including respective fields of technologies in civil, architectural, mechanical, electrical engineering and so forth with an aim for reliable water service.

**[Interpretation]**

Pump facilities shall be planned as a system including water mains so as to have high reliability and safety, and achieve the design discharge and water pressure.

Such parameters as number of units, discharge, lift, output and rotational speed of the motor etc. of the pumps shall be determined to satisfy the design discharge and required delivery pressure. Additionally, review of water hammer is needed depending on the situation of the water mains, so, as the provision of a surge tank is needed on the water mains in some cases, the pump facilities need to be studied as a system including the water mains.

Since the operating cost of pumps varies depending on their control type, and the composition of such equipment related to control as the switchboard etc. is different, the pump facilities shall be rational and efficient in consideration of their life cost. Moreover, measures for prevention of nuisance to the neighborhood caused by noise and vibration shall be provided.

### 8.2.3. Capacity and the number of units of pumps

The capacity and the number of units of pumps shall be determined in accordance with the following items:

1. The capacity and the number of units of raw water intake pumps and treated water transmission pumps shall be determined so as to enable their operation at the point of high efficiency.
2. The capacity and the number of units of treated water transmission pumps shall be determined to be suitable for hourly fluctuation of discharge.
3. The capacity and the number of units of pumps shall be determined in consideration of the design discharge (maximum, minimum and average) and the occasion of breakdown.
4. Spare units of pumps shall be provided according to the importance of the facilities and the condition of operation.

**[Interpretation]**

The definitions of pumps by use in this chapter are as follows:

- Raw water intake pump: a pump for the intake of raw water from a river, groundwater etc.
- Treated water transmission pump: a pump for the transmission of treated water from a clear well (service reservoir) to a service reservoir
- Water distribution pump: a pump for the distribution of water directly form a service reservoir
- Booster pump: a pump to be installed on a distribution main to supplement insufficient water pressure in part of service area

**On the item 1.;**

Although the volumes of raw water intake and treated water transmission change by season of year (summer to winter), their hourly change is smaller than that of the volume of water distribution. Therefore, the hourly volume to determine the hourly discharge of the raw water intake and treated water transmission pumps shall be the hourly average of the design daily maximum treated water transmission volume, and the pumps shall be able to be operated at as high efficiency as possible.

**On the item 2.;**

Although the design hourly volume to determine the capacity of the water distribution pump shall be the design hourly maximum distribution volume, such hourly minimum volume as one at night needs to also be taken into consideration.

The water distribution volume not only changes hourly but also largely changes by season of year, day of the week and weather. The range of the annual fluctuation in water volume is, in many cases, largely different from that of the hourly maximum distribution volume in summer to that of the hourly minimum distribution volume in winter. Thus, the capacity and the number of units of water distribution pumps shall be determined so as to adapt to these conditions.

As for water distribution pumps, in addition to the decision of their capacity and the number of units, the type of pump control (control by number of units, valve control, and rotational speed control) shall also be examined in consideration of the size of the water distribution volume and the change in the volume.

Although the type of control of booster pumps shall be in conformity with the water distribution pump, it shall specially be cautioned not to cause too much pressure decline in the suction side of the pump.

**On the item 3.;**

The number of units of pumps to be installed shall be determined synthetically examining the safety and the life cycle cost after preparing scenarios with different number of units as the method of control in consideration of the characteristics of the water demand.

The number of units of water distribution pumps is, in many cases, determined to be 3 to 5 including the spare units so as to minimize the influence of breakdown and inspection to water service in consideration of the space for installation and so on.

The points to be considered on the occasion to determine the number of units are as follows:

(1) The trend of water demand for the period through to the terminal design year

(2) The pumps shall be of the same capacity as much as possible to aim at providing the compatibility of the consumables and spare parts.

(3) In case the change in discharge is large, two sizes of pumps with small and large discharges shall be installed, or the discharge shall be controlled by the rotational speed control (See 8.2.10 Control of pumps).

(4) Where the change in the lift between day and night, seasons etc. is large, provision of two types of pumps with high and low lift shall be considered.

**On the item 4.;**

Spare units of pumps shall be installed so that water service is not to be interrupted in the case of stop of a pump due to breakdown, repair etc. The number of units in case spare units are required shall generally be one with the same capacity if the same type of pumps are installed; and a larger one shall be installed as the spare if different sizes are installed.

Spare units of pumps will not be required in some cases if water service is not interrupted even when the pump stops because backup can immediately be made from the upstream side or other system.

The optimum capacity and number of unit of pumps shall be determined with reference to the above. The detailed flow diagram for making an optimum plan is presented in Figure 8.2.1.

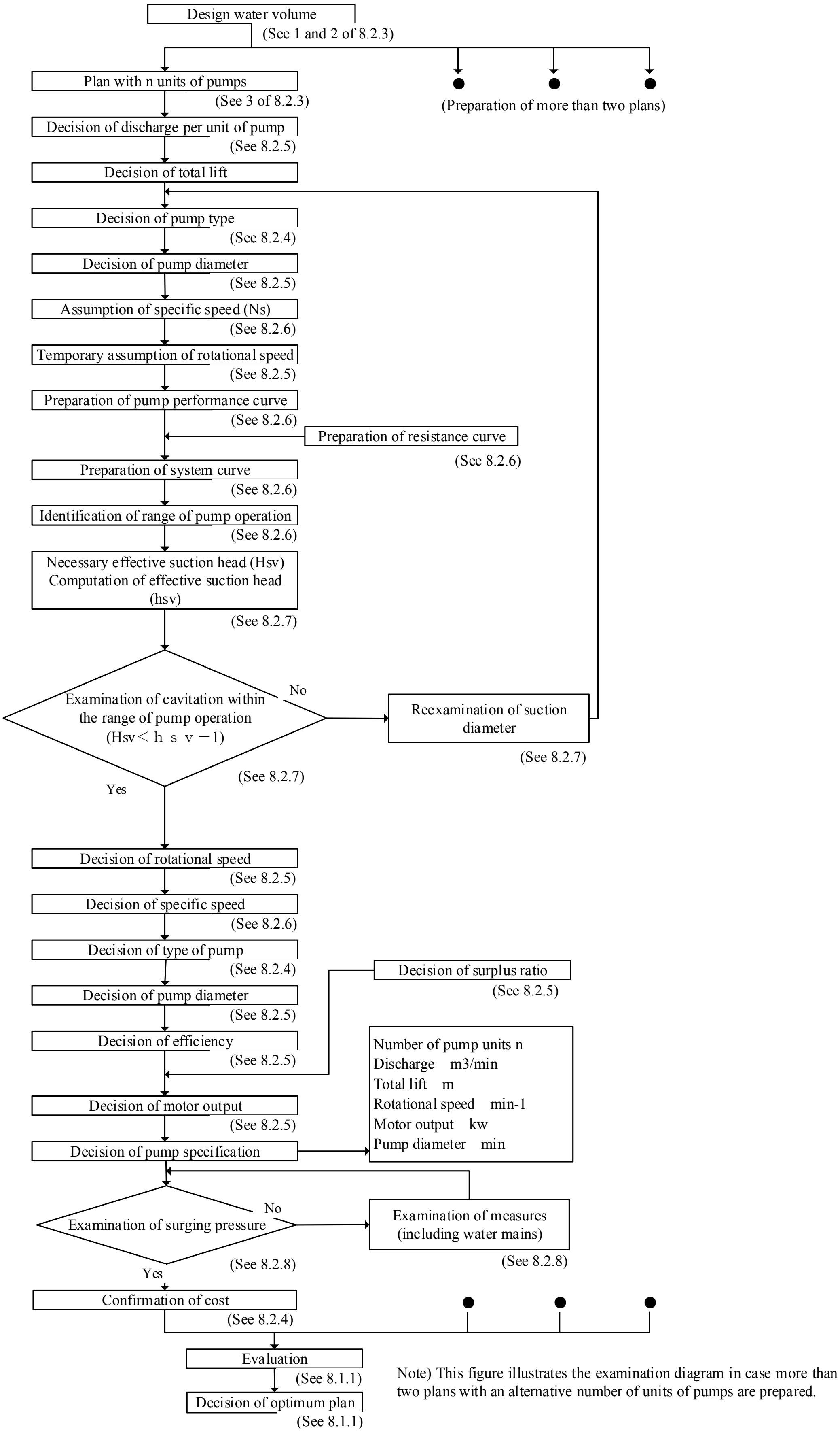



**Figure 8.2.1 Flow diagram for preparation of the optimum plan**

## 8.2.4. Selection of pump type

> The type of the pump shall be in conformity with the following:
>
> 1. The type of the pump shall satisfy the design discharge and the total lift, and exert high efficiency within the operational range.
> 2. No cavitation shall occur at the design suction head.
> 3. The type of the pump shall be determined examining the method of operation, and merits and demerits related to maintenance, dismantling and servicing etc. of the pump.

**[Interpretation]**

Pumps used for water supply are mostly volute pumps.

Types of pumps are classified into the centrifugal pump, mixed flow pump, axial flow pump, submersible motor pump and variable runner blade pump as a special pump etc. by principle of performance. An example of classification of pumps used mainly for water supply is illustrated in Figure 8.2.2.

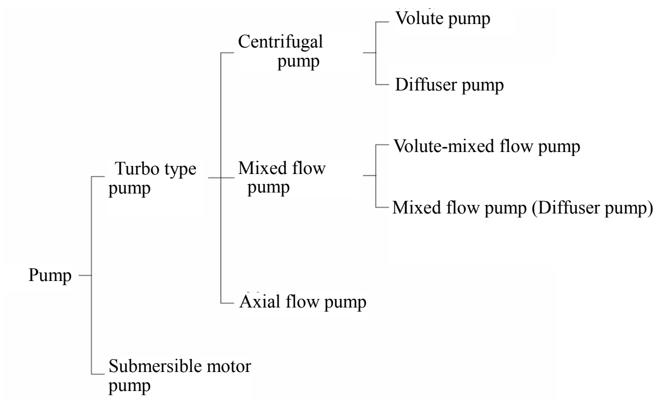



**Figure 8.2.2 Example of classification of pumps**

### 1) Centrifugal pump

It is a pump, of which centrifugal force produced by the pump runner gives pressure and velocity to water in the wheel, and part of the velocity energy is converted to pressure for pumping.

The pump, in which pressure conversion is made in the volute casing, is called a volute pump; and the one, in which conversion of pressure is made by the guide vanes, is called a diffuser pump (Figure 8.2.3).

### 2) Mixed flow pump

It has characteristics in between the centrifugal pump and the axial flow pump; the centrifugal force and lifting action of the blades give pressure and velocity energy to water in the impeller casing, and part of velocity energy is converted to pressure by the volute casing or the diffuser casing, which does pumping (Figure 8.2.4).

### 3) Axial flow pump

The lifting action of the blades gives pressure and velocity energy to water in the impeller wheel; and the guide vanes convert part of the velocity energy to pressure, which performs pumping (Figure 8.2.5).

### 4) Submersible motor pump

The submersible motor pump is composed of the pump unit and the motor unit in one body; the pump and the motor are set in water and run; and it is used as raw water intake, treated water transmission or water distribution equipment of relatively small water supply facilities.

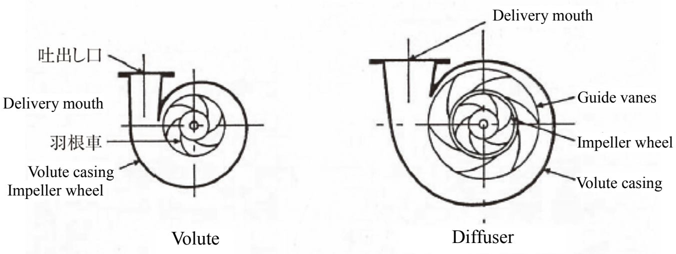



**Figure 8.2.3 Centrifugal pump**

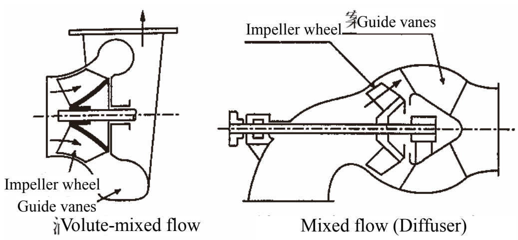



**Figure 8.2.4 Mixed flow pump**

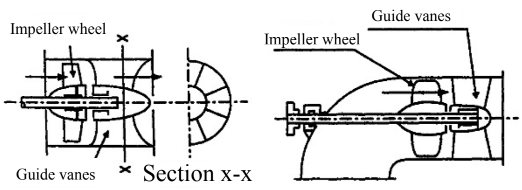
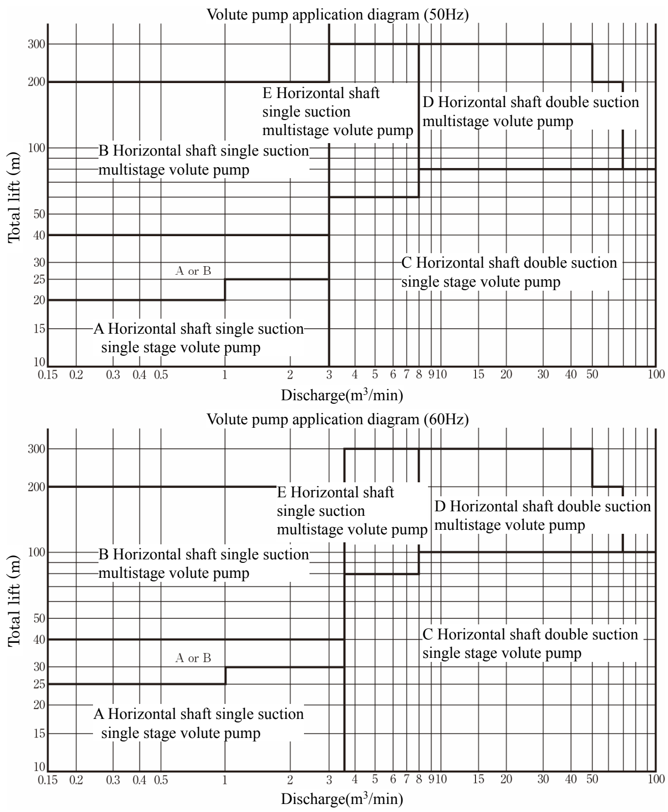



**Figure 8.2.5 Axial flow pump**

**On the item 1.;**

For selection of pump types, 8.2.6 Pump type and operating point shall be referenced. If the discharge, total lift, and rotational speed are determined, the specific speed is given and the proper pump type is determined. The range for the selection of the typical type of volute pumps for water supply shall be in accordance with Figure 8.2.12.




Note 1. The boundary between the pump types indicate rough criterion.
2. In case a high rotational speed can be set with forced pump suction, the C zone may expand towards the direction of high lift.

**Figure 8.2.12 Example of Volute pump application diagram**

**On the item 2.;**

On the relationship between the suction head and cavitation, 8.2.7 Cavitation shall be referred to.

**On the item 3.;**

The horizontal shaft pump, of which upkeep is easy, is often used for water supply.

Besides, as the phase blade type impeller, which can reduce pulsation as the cause of noise etc., is effective as a measure to lower pulsation relatively cheaply, the horizontal shaft double suction volute pump shall be reviewed for its adoption according to the need.

As the vertical shaft pump has a structure to set its motor on top of the pump unit, and the pump can be dismantled after removing the motor, its disassembling and maintenance are difficult compared with the horizontal shaft pump.

Since the installment space of the vertical shaft pump is smaller than the horizontal shaft pump, and the pump unit is placed in water, the device of priming water is unnecessary, and has an advantage in terms of cavitation characteristics (See 8.2.7 cavitation).

In case groundwater is pumped, and the water level is low, the submersible motor pump is used. The submersible motor pump is composed of the pump unit and the motor unit in one body, which is operated with its pump unit and motor unit placed in water, and used for raw water intake, treated water transmission or water distribution of relatively small water supply facilities.

### 8.2.5. Parameters of the pump

For determining the parameters of the pump, the following items shall be examined:

1. Total lift
2. Discharge
3. Pump diameter
4. Motor output
5. Rotational speed

**[Interpretation]**

**On the item 1.;**

To pump up the prescribed flow from the suction water level to the delivery water level, larger energy than the sum of the difference between two water levels and the resistance of pipe, valve etc. is needed.

The value of water level, resistance and energy represented by the height of water pillar is called water head; and the water head generated by pumping is named lift.

As water head, there are actual lift, velocity head, pressure head, and friction loss of water mains, and their sum is called the total lift.

**1) The method of computation of the total lift is as follows: See Figure 8.2.13.**

$$H = h_a + h_l + \frac{{v_d}^2}{2g}$$

where,

H: total lift (m)

H = $H_d$ + $H_s$ (- in the case of pressurized suction)

$H_d$ : total delivery head (m)

$H_s$ : total suction head (m)

$H_a$ : actual lift (m)

$h_a$ = $h_{ad}$ + $h_{as}$ (- in the case of pressurized suction)

$h_{ad}$ : delivery head (m)

$h_{as}$ : suction head (m)

$h_l$ : head loss in water mains (m)

$h_l$ = $h_{ld}$ + $h_{ls}$

$h_{ld}$ : head loss in delivery water mains (m)

(The head loss includes friction loss of water mains, and head losses of valves, short pipes, bends etc.)

$h_{ls}$ : head loss of suction pipe (m)

(The head loss includes friction loss of water mains, and head losses of short pipes, bends etc.)

$v_d$ : flow velocity at the head of delivery pipe (m/s)

g : gravity constant (9.8m/$s^2$)

**2) For computation of the total lift for a booster pump, the velocity head is omitted since it is very small, and the difference between the two hydraulic gradient lines is set as the deficit head (total lift) H as shown in Figure 8.2.14.**

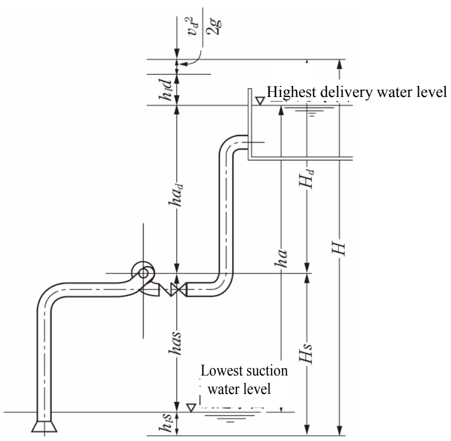



**Figure 8.2.13 Total lift of the horizontal shaft pump (suction)**

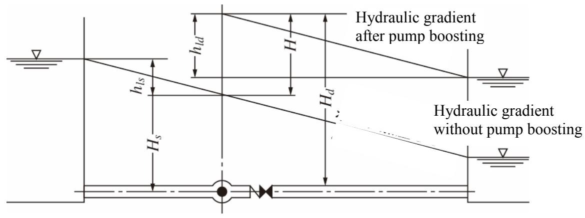



**Figure 8.2.14 Total lift of the booster pump (suction)**

**3) In the case of the water distribution pump, the sum of the minimum necessary dynamic water head at the end of distribution mains, the difference of ground levels between the distribution pump and the fringe of the distribution mains, and the head loss of the water mains is the total lift.**

**On the item 2.;**

The design discharge of the pump is determined based on the design water flow and the number of pump units (See Capacity and number of units of pump).

**On the item 3.;**

The size of the pump is represented by the pump diameter. In the cases of the vertical shaft axial flow pump, the vertical shaft mixed flow pump, and the submersible motor pump, the size is represented by the delivery diameter and, in other cases, it is represented by the suction diameter and the delivery diameter. The rough diameter is presented by the following formula:

$$D = 146\sqrt{\frac{Q}{v}}$$

where,

D: pump diameter (mm)

Q: discharge of the pump ($m^3$/min)

v: velocity at suction mouth or delivery mouth (m/s)

The standard velocity at suction mouth or delivery mouth shall be 2m/s.

**On the item 4.;**

The output of the motor shall be computed by the following formula:

$$P = \frac{0.163 \cdot \gamma \cdot Q \cdot H}{\eta_p}(1+\alpha)$$

where,

P : output of the motor (kW)

$\gamma$ : mass of liquid per unit volume (kg/L)

Q : discharge of the pump ($m^3$/min)

H : total lift of the pump (m)

$\eta_p$: pump efficiency (See Figure 8.2.15)

$\alpha$ : ratio of allowance 0.1 to 0.15 (in the case of electric motor)

※0.163=g/60 g: gravity constant (9.8 m/s$^2$)

Figure 8.2.15 shows the reference values in respect to the highest efficiency.

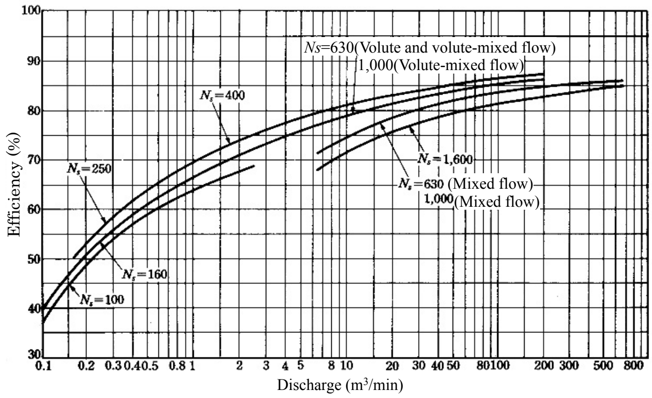



**Figure 8.2.15 Discharge and pump efficiency**

**On the item 5.;**

The higher the rotational speed of the pump, the smaller and lighter the motor and its cost. However, as the rotational speed becomes high, the occurrence of cavitation and the attrition of sliding parts are accelerated, so the rotational speed shall synthetically be judged.

### 8.2.6. Type and operating point of the pump

The pump shall be of a type suitable for the design discharge, dynamic water pressure, the characteristics of the water main, and able to be efficiently operated.

1. The type of the pump shall achieve the specific speed (Ns) which is most suitable to the condition of operation.
2. After finding the operating range based on the design water service volume, dynamic water pressure and the characteristics of the water main, and examining the possibility of the occurrence of cavitation, the most suitable control method shall be adopted.

**[Interpretation]**

**On the item 1.;**

**1) Specific speed (Ns) of the pump**

The specific speed (Ns) stands for the value which shows the shape of the runner of the pump, and is presented by the following formula:

$$N_S = N \times \frac{Q^{\frac{1}{2}}}{H^{\frac{3}{4}}} \quad \cdots\cdots\cdots\cdots \quad (8.1)$$

where,

N: Rotational speed ($min^{-1}$) (N=120 × frequency (of power source)/number of poles)

Q: Discharge ($m^3$/min) (In the case of double suction, Q/2 since computation is made by the flow on the one side only)

H: Total lift (m) (The total lift per stage in the case of a multistage pump)

Concerning the relationship between Ns and the shape of the pump, the relative width of the runner blade to the diameter of the runner decreases as Ns become small; and it increases as Ns become large. In addition, as Ns further increases, the pump becomes a mixed flow type, and the axial flow type as Ns increases further.

As indicated by Formula 8.1, small Ns generally means a high-lift pump with small discharge; and large Ns stands for a low-lift pump with large discharge.

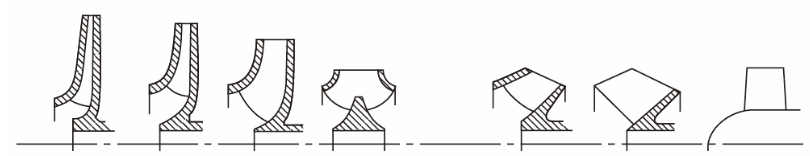
| | |
|---|---|
| Shape of runner |  |
| Approximate value of Ns | 100 200 300 400 800 1000 >1200 |
| Type of pump | Single suction volute pump (100–300); Double suction volute pump (400); Mixed flow pump (800–1000); Axial flow pump (>1200) |

**Figure 8.2.16 Relationship between shape of runner, Ns and type of pump**

**On the item 2.;**

As shown in Figure 8.2.18, the operating point of the pump is found as the intersection of the head-capacity curve and the curve of water mains resistance. The curve of water main resistance is drawn as the curve with the actual lift and the addition of the head loss in the water mains system in accordance with the discharge.

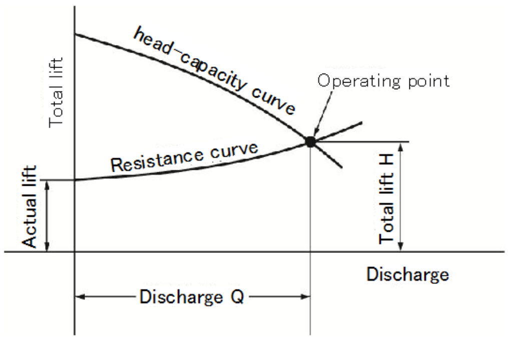



**Figure 8.2.18 Operating point of the pump**

**1) Operating point for the main control methods**

**(1) Control by number of units**

In case more than two pumps with the same performance are operated in parallel for the common water mains lines as shown in Figure 8.2.19, the intersection a of the composite curve, which is obtained by the head-capacity curve with the discharge of the pump multiplied by the number of units, and the resistance curve R, becomes the operating point of the pumps.

The operating point of the pump when 3 units are in service becomes Point b at the same lift as the point a. Besides, when operating two pumps for the same resistance curve, the operating point of each pump likely becomes Point b'; and it becomes b'' in the case of one pump. As shown in the Figure, assuming Point b as the specified point of the pump, as Point b'' means the excessive discharge region, there is possibility of cavitation and overloading, so caution shall be practiced when planning the installation of pump facilities. Especially, in case there is fluctuations in the intake water level from a river etc., and the actual lift is lowered, i.e., in the case of b'', such operation as throttling of the valve and so forth shall be considered.

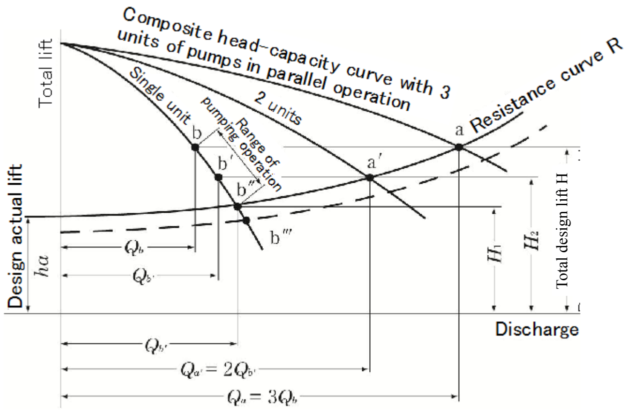



**Figure 8.2.19 Parallel operation of pumps with the same performance**

**(2) Control by throttling the valve**

As shown in Figure 8.2.20, while a pump is operated with a valve full-open at the intersection $A_1$ on the head-capacity curve and resistance curve $R_1$, the resistance curve moves from $R_1$ to $R_2$ if the valve is throttled and the operating point becomes $A_2$.

Although the apparent efficiency at Point $A_2$ is $\eta_2$, it is actually $\eta_3$. For as the power at Point $A_2$ and $A_3$ is the same,

$$\eta_2 = 0.163\gamma \frac{Q_2 H_2}{P}$$

$$\eta_3 = 0.163\gamma \frac{Q_2 H_3}{P}$$

from the above relationship, the following equations are obtained.

$$\frac{\eta_2}{\eta_3} = \frac{H_2}{H_3}$$

$$\eta_3 = \eta_2 \times \frac{H_2}{H_3}$$

Since $H_3 < H_2$, $\eta_3 < \eta_2$ in the Figure, the efficiency of the system as a whole decreases to $\eta_3$.

**(3) Rotational speed control**

As to the operating point, see (1) Change in the rotational speed in 1. above.

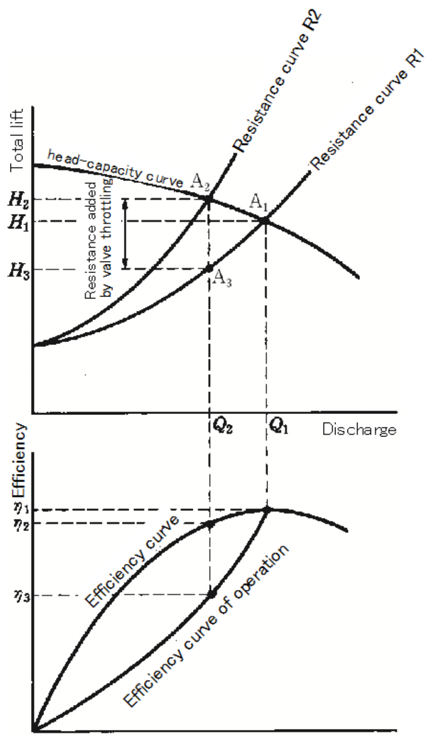



**Figure 8.2.20 Control by valve throttling**

**2) Operating point in the automatic control method**

**(1) Constant delivery pressure control (in the case of rotational speed control)**

As the water consumption by consumers decreases, the resistance curve R transforms to a curve with a steep slope according to the water consumption. In case the rotational speed is constant, if the flow decrease from $Q_0$, the operating point moves from A to the left along the curve $N_0$. On the other hand, in case the delivery pressure is kept constant by rotational speed control, and the flow declines to $Q_0$, $Q_1$, $Q_2$, and $Q_3$, the rotational speed changes to $N_0$, $N_1$, $N_2$ and $N_3$, the operating point shifts to A, B, C, and D, and the total lift is maintained at H. At the same time, the shaft power alters from $L_0$ to $L_1$, $L_2$, which indicates that there is an energy saving effect (Figure 8.2.21).

**(2) Constant terminal pressure control (in the case of rotational speed control)**

In this method, the water pressure at the end of the water mains is maintained constant even if the flow changes. There are the actual measurement method (constant terminal pressure control) and the computing method (estimated constant terminal pressure control) (See 8.3.4 Pressure control).

As shown in Figure 8.2.22, to keep the terminal pressure constant, the pump operating point moves along the resistance curve according to the change in the water consumption. If the change in the shaft power is compared with the constant delivery pressure control, it is understood that there is further saving in energy.

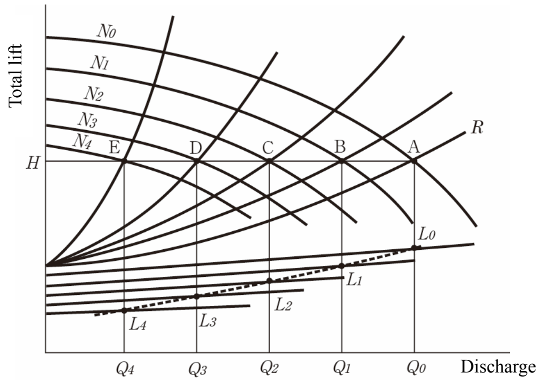



**Figure 8.2.21 Constant delivery pressure control**

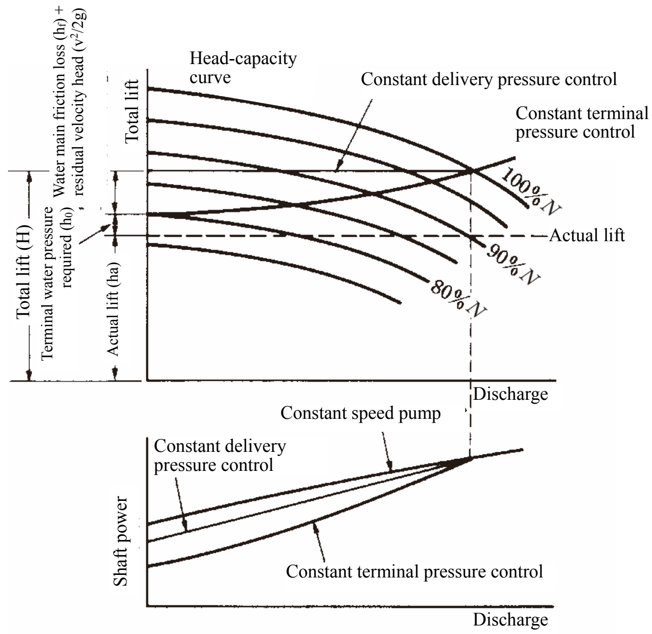



**Figure 8.2.22 Constant terminal pressure control**

### 8.2.7. Cavitation

Since cavitation causes vibration, noise and erosion on the pump, and will give such a lethal effect as inability of pumping, the following matters shall be examined:

1. Effective suction head
2. Necessary effective suction head
3. Measures against cavitation

**[Interpretation]**

In case the pressure of fluid inside the pump decreases due to abrupt change in flow velocity, occurrence of eddy current, obstacles in flow channel etc. and it becomes close to the pressure of saturated vapor, the gas dissolved in water starts to separates from water to form bubbles. Furthermore, as the pressure become lower than the pressure of saturated vapor, the water evaporates, and cavity is produced; this phenomenon called cavitation.

Cavitation tends to occur at the entrance to the runner. This bubble moves together with the stream, gets to the high pressure zone, is squashed, and crashes instantaneously. If this phenomenon continues, the performance of the pump declines, generates vibration and nose, and makes pumping impossible in some cases. What's more, if cavitation continues for a long time, the runner, casing etc. gets eroded by the partial impact pressure caused when the bubble crashes, and, in some cases, gets damaged in a short period of time. In the treated water transmission and distribution pump facilities, the cavitation, which occurs in the region where the discharge largely exceeds the prescribed discharge, and that occurring in the too small flow region depending on the pump type, is the problem.

**On the item 1.;**

For the pump not to be operated without the occurrence of cavitation, the usable effective suction head needs to be larger than the required effective suction head (mentioned later), which is needed by the pump. The usable effective suction head (hsv) is given by the following formula (See Figure 8.2.24).

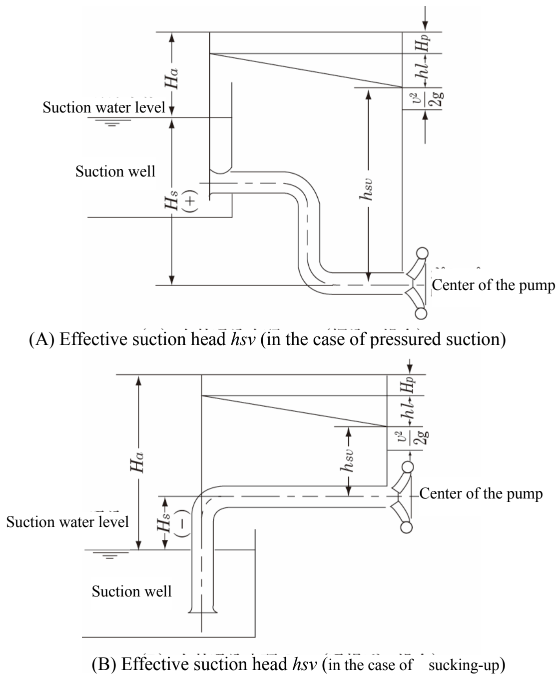



**Figure 8.2.24 Effective suction head of the pump (hsv)**

hsv＝Ha−Hp＋Hs−hl

where,

hsv : usable effective suction head (m)

Ha : atmospheric pressure expressed in water head (m) (See Table 8.2.3)

Hp : pressure of saturated vapor at the current temperature expressed in water head (m) (See Table 8.2.4)

Hs : actual suction head (m)

In the case of sucking-up: (-) symbol

In the case of pressurized suction: (+) symbol

hl : head loss of the suction pipe (m)

**Table 8.2.3 Elevation and atmospheric pressure expressed in water head (Ha)**

| Sea level altitude (m) | 0 | 50 | 100 | 150 | 200 | 300 |
|---|---|---|---|---|---|---|
| Ha (m) | 10.33 | 10.27 | 10.21 | 10.15 | 10.09 | 9.97 |

**Table 8.2.4 Saturated vapor pressure corresponding to water temperature (Hp)**

| Temperature (℃) | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|
| Hp (m) | 0.089 | 0.125 | 0.174 | 0.238 | 0.323 | 0.432 |

**On the item 2.;**

For respective different total lifts, discharges and rotational speed of the pump, there are limits in the effective suction head required for its operation, which is named the required NPSH (Hsv). It is the minimum limit of water head at the standard suction plane of the pump required for the runner to suck water without causing cavitation, and indigenous to each pump.

The required effective suction head (Hsv) is obtained by the following formula using the suction capacity and the specific speed for suction (S):

$$H_{SV} = \left( \frac{N\sqrt{Q}}{S} \right)^{\frac{4}{3}}$$

where,

$H_{sv}$ : Effective suction head required by the pump (m)

N : Rotational speed of the pump ($min^{-1}$)

Q : Discharge of the pump ($m^3$/min) (In the case of double suction, use Q/2 as computation is made with the flow at one side only.)

S : Suction specific speed

This formula is derived from the concept that, if the shape of entrance of the runner is the same, cavitation occurs at the same discharge point despite of changing the diameter of the runner. The value of suction specific speed of the volute pump is shown in Figure 8.2.25.

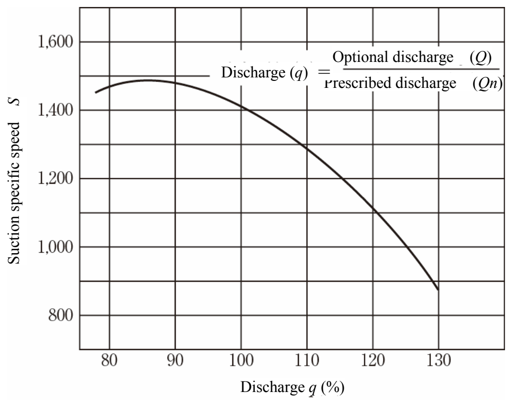



**Figure 8.2.25 Suction specific speed of the volute pump**

**On the item 3.;**

As to prevention of cavitation, the following measures are useful:

(1) To make hsv as big as possible by lowering the location of the pump.

(2) To make hsv as big as possible by reducing the head loss of the suction pipe.

(3) To make Hsv small selecting low rotational speed of the pump.

(4) In case the lift becomes low as the operating point changes, as Hsv increases with increased discharge, sufficient hsv shall be given in reflection of such situation, or the valve shall be throttled so that the discharge does not become excessive. Besides, it is cautioned that, if the total lift has too much allowance as the design, actual operation is made at an excessive discharge, and Hsv becomes large.

(5) If the discharge is the same, and the rotational speed is the same, in general, the double suction pump is less likely to develop cavitation.

(6) In case the pump is operated in a severe condition, materials, which have strong anti-corrosiveness, shall be used to avoid erosion.

(7) The valve on the suction pipe shall not be throttled.

### 8.2.8. Water hammer

> As to water hammer in a pumping system, the following matters shall be taken into consideration:
>
> 1. The occurrence of water hammer at the time of sudden stop of the pump shall be examined.
> 2. In case a possibility of water hammer, measures to relieve it shall be considered.

**[Interpretation]**

**On the item 1.;**

In case the velocity of flow of water filled in a pipe changes abruptly, violent change in water pressure is brought about. This phenomenon is called water hammer, and it often causes water column separation.

In case the pump suddenly loses the driving force during transmitting water by such an accident as power failure, the delivery force is lost, and the pressure in the transmission main rapidly declines. As a result, in the case of such a water main as Figure 8.2.26, there is a point around Point A of negative pressure; if the pressure decreases down to about – (minus) 10 m, cavity breaks out in water causing water column separation.

Over some time after water column separation, the water upstream collides with that downstream, and abnormally high surging pressure occurs when the water columns reunite.

Since these phenomena occur as easily as the length of the water main becomes long, and there is a possibility to cause an accident of burst of the water main etc., it is important to provide measures for it in advance.

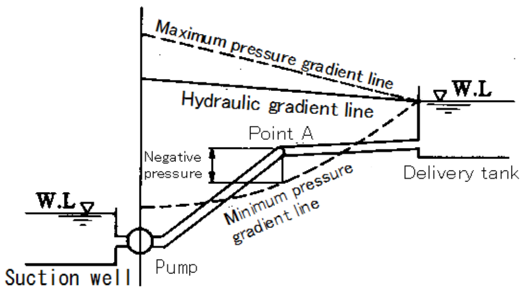



**Figure 8.2.26 Water hammer phenomenon**

**On the item 2.;**

The main measures to prevent the water hammer are as follows:

**1) Method to prevent negative pressure (water column separation)**

**(1) To set a flywheel on the pump**

Obtaining a large inertial effect by setting a flywheel on the pump, the rapid decline in pump delivery pressure is relieved. On the occasion of employing the flywheel, the bearings in consideration of its weight and the starting method need to be examined.

**(2) To provide a surge tank (a conventional surge tank) on the water main on the delivery side**

The water main downstream of the surge tank is isolated from the surging phenomenon. In other words, it absorbs the rise in pressure, and prevents the negative pressure by feeding water from it.

The surge tank is the most safe and reliable means to prevent the water hammer. See Figure 8.2.27. The following conditions shall be examined when employing it:

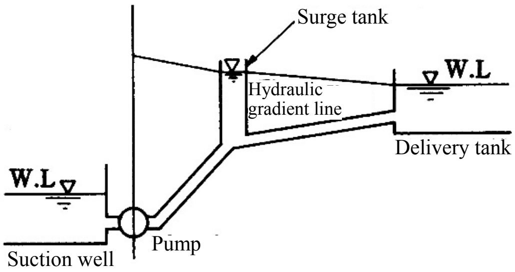



**Figure 8.2.27 Conventional surge tank**

(i) To absorb the fluctuation in water level in the surge tank accompanied by the change in flow at the time of normal start and stop of the pump, adequate water surface shall be designed for the surge tank.

(ii) The tank will generally be tall when the pump lift is large.

(iii) Although the surge tank is normally located near the pump, it is placed at the point of the highest negative pressure depending on the water main.

### (3) To provide a one-way surge tank on the delivery water main

The purpose of the one-way surge tank is only to feed necessary and sufficient water at the time of drop in pressure to prevent negative pressure; and it is isolated from the water main by a check valve at normal times.

Admitting its size is generally smaller than the normal surge tank, more than two units are required in some cases. Examination shall be made on its construction and maintenance in that its height needs to be lower than the static water head to fill water in it; that it shall be protected from freezing in a cold district; and that provision needs to be made for replacing water to maintain water quality in the case of treated water. See Figure 8.2.28.

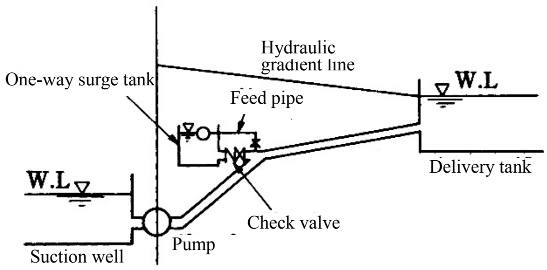



**Figure 8.2.28 Piping diagram of one-way surge tank**

### (4) To provide a pressure tank (air-chamber)

To prevent the pressure drop brought about after sudden stop of the pump, water in the pressure tank is fed into the water main by the air pressure in the tank.

**2) Methods to mitigate the rise in pressure**

Right after the flow in the water main starts to reverse, the check valve close slowly so that the reverse flow is gradually stopped and relieve the rise in pressure.

**(1) Method by means of a slow-closing check valve**

Right after the flow in the water main starts to reverse, the check valve close slowly so that the reverse flow is gradually stopped and relieve the rise in pressure.

**(2) Method by means of rapid-closing check valve**

Since large pressure increase occurs when reverse flow grows and then stops suddenly, the flow is stopped right before the flow slows down and the reverse flow starts; and the method is used for a water main in which the reverse flow starts rapidly.

**(3) Method by means of the cone valve or the needle valve**

Right on the occasion of power failure, the opening of the valve is automatically and slowly closed by its hydraulic control mechanism so that the rise in pressure can be suppressed by making the change in the flow velocity small.

### 8.2.9. Installation of the pump and ancillary apparatus

The installation of the pump and its ancillary apparatus shall be in conformity with the following:

1. The suction pipe of the pump shall be so designed that air does not gather in the pipe.
2. The delivery pipe of the pump shall be considered to have small friction head loss; and a check valve and a delivery valve shall be installed on the delivery pipe.
3. The pump suction well shall be constructed as close to the location of the pump as possible, and so shaped that turbulent flow or eddy current does not occur easily.
4. The foundation of the pump shall have enough strength against the load of the pump and vibration.
5. A vacuum pump for priming shall be provided for a pump with a sucking-up pipe.
6. Apparatus to know the operating condition of the pump shall be equipped.
7. Joints shall be fit in the piping for shaft-sealing, cooling, lubrication etc.

**[Interpretation]**

**On the item 1.;**

The joints of the suction pipe shall be of a flange joint, and so sealed that no air is to be sucked. The suction pipe shall be as short as possible, laid with a slope, and so structured as not to gather air. See Figure 8.2.29. Besides, in the case of a pump with pressurized suction, a isolation valve (manually operated) shall be fit on the suction pipe.

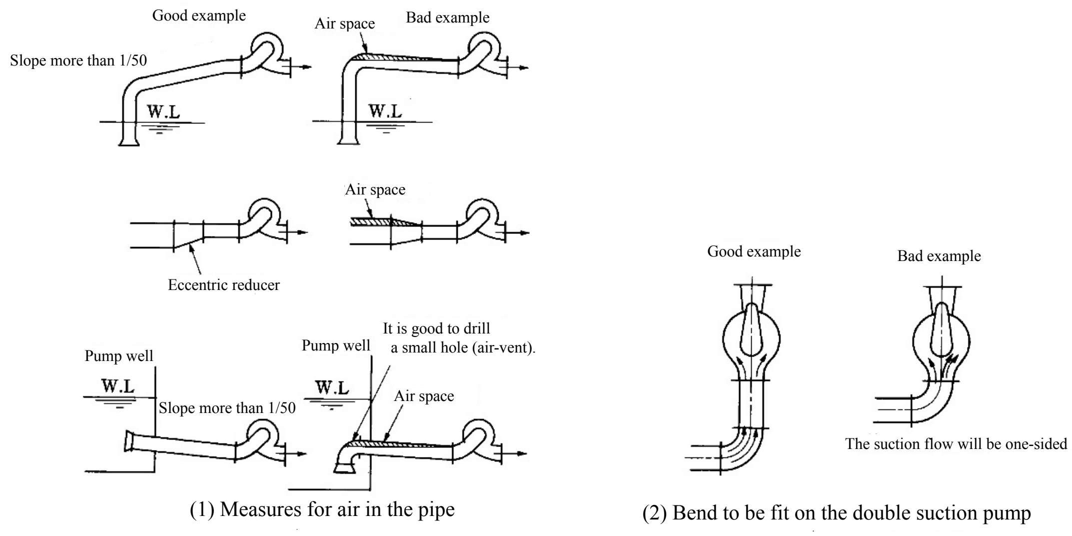



**Figure 8.2.29 Pump suction pipe and good and bad examples**

**On the item 2.;**

In case the flow velocity at the delivery mouth of a pump is large, an expander pipe with gentle expansion shall be fit to make the velocity at the outlet of the delivery pipe at smaller than 3 m/s. The check valve and the delivery valve are usually fit at the downstream end of the expander pipe. On this occasion, a flexible joint, expansion-contraction joint or expansion-contraction pipe and an isolation valve (manually operated) shall be installed.

What's more, in case more than two units of pumps are installed, at the points in the header pipe where delivery pipes concentrate, the pipe diameter shall be expanded, where the flow become large, so as to reduce the friction loss. See Figure 8.2.30 and Figure 8.2.31.

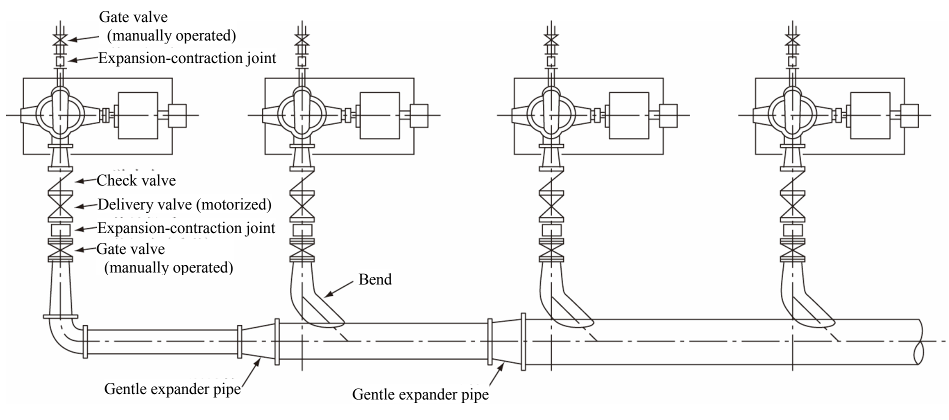



**Figure 8.2.30 Example of pump delivery pipe**

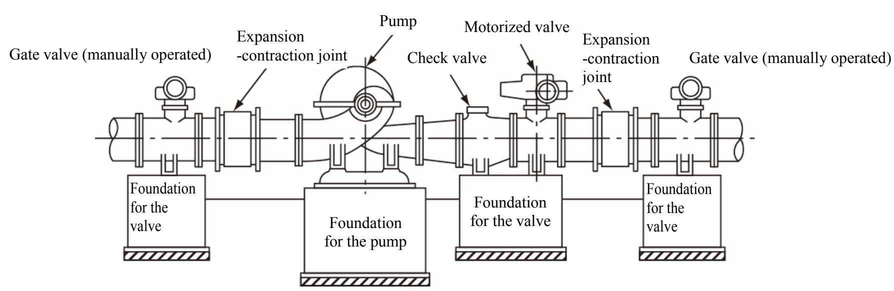



**Figure 8.2.31 Example of the use of expansion-contraction joints**

**On the item 3.;**

If the suction well is divided into more than two cells, it is convenient at the time of such O&M work as cleaning, repair etc.

It shall be considered that no one-sided flow shall occur in the suction well, and that the condition of suction shall be the same for each pump in case more than two pumps are installed. Guide walls, baffle walls etc. set in the suction well are effective for prevention of one-sided flow. Reference Figure 8.2.32.

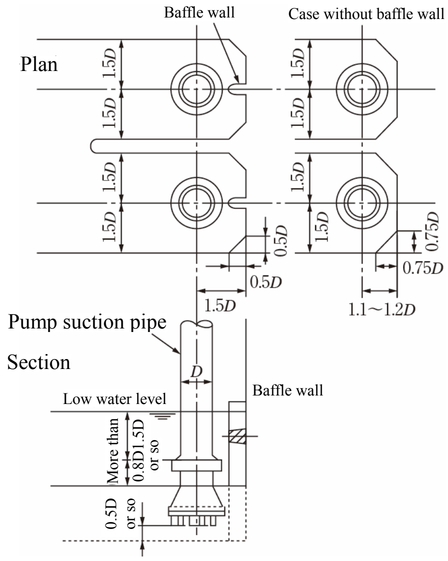



**Figure 8.2.32 Example of the size of suction well and its structure**

**On the item 4.;**

The foundation of the pump shall in principle be of a concrete structure, and it shall make one body structure together with the foundation for the motor.

**On the item 5.;**

The vacuum pumps shall be installed for the regular use and the spare unit. The time required to prime a main pump is generally 3 to 10 minutes or so.

**On the item 6.;**

To know the operating condition of the pump, a vacuum gauge or compound pressure gauge on the suction side of the pump, and a pressure gauge on its delivery side at a position to be seen easily shall be installed.

**On the item 7.;**

Joints shall be fit at appropriate positions in the pipe so that dismantling and upkeep can easily be undertaken.

### 8.2.10. Control of the pump

The control of the pump shall be in conformity with the following:

1. The control of the pump facilities shall be determined synthetically in consideration of the

location, where control is performed with the priority, the circuits for the automatic-manual operation and response to abnormal incidences.

2. Flow control shall be performed by the combination of the methods to change the number of pumps in operation, speed control, valve throttling, and control by variable impeller blades.
3. Pressure control shall be performed by the rotational speed of the pump, throttling of valve opening etc. with an aim to maintain the pump delivery pressure constant or keep the pressure at the fringe of distribution network constant

**[Interpretation]**

**On the item 1.;**

**1) Switching of the location of control**

Operation shall only be possible at the selected location, and the priority for switching shall be as higher as the location is lower (the site).

**2) Method of control**

As the method of pump operation, there are manual operation and automation, and manual operation can be performed at the pump room, and both manual and automation can be executed at the electric room and the supervisory room.

**3) Collective switching**

Switching of the location of control shall collectively be made for the pump facilities as a whole. Switching of control method (automation or manual) shall be made for respective areas of control (pump control, operation of the inflow valve of the service reservoir, control of inflow bypass valve, and switching of power source).

**4) Maintenance of the status quo**

The pump control circuits shall maintain the preceding status of pumps (in operation or shutdown) even after the switching the location (remote – site), or the operation mode (automation – manual). Additionally, when the operation mode is “Auto”, the current status of the pump shall in principle be maintained even at the time of the following abnormal incidences:

(1) Abnormal status of the pump unit number control itself

(2) Malfunction of the control (The designated pump does not run; or the designated pump does not stop.)

(3) At the time of abnormal flow signal

(4) At the time of abnormal pressure signal

**5) Prevention of simultaneous start of pumps**

If pumps are simultaneously started, it is probable for a trip to occur on the power receiving breaker by the inrush current. Besides, as the flow rapidly increases when the power is restored from power failure and so on, it is apprehended that the rise in turbidity occurs. Therefore, a circuit to prevent simultaneous start of pumps shall be provided.

**On the item 2.;**

To control the pump discharge during operation, there are the following methods:

(1) The method to control the number of pumps

(2) The method to control the rotational speed of pumps

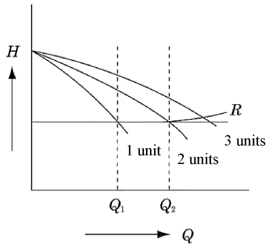
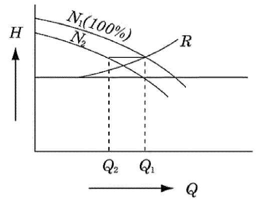
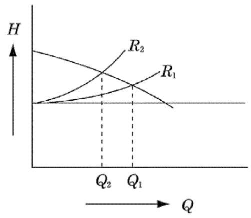
(3) The method to throttle the opening of the valve

(4) The method to control by changing the angle of the runner vanes

(5) The method to combine (1) to (4) above

As the apparatus to be installed and their operational efficiency have their respective characteristics, the method of control shall be determined taking advantage of these characteristics. Comparison of (1) to (3) above is tabulated in Table 8.2.5.

**Table 8.2.5 Comparison of pump control methods**

| Control method | Diagram | Annotation | System to be applied | Merit | Demerit |
|---|---|---|---|---|---|
| Control by number of units |   | Number of units is controlled depending on flow.<br>$Q<Q_1$……1 unit<br>$Q_1<Q<Q_2$….2 units<br>$Q>Q_2$..........3 units | · System in which relatively large changes in delivery pressure are permitted<br>· Pipe system in which head loss of pipe is small compared with actual lift, and which has a reservoir. | · Control is relatively easy.<br>· Spread of risk can be made by dividing units of pumps | · The range of pressure fluctuation is large.<br>· Only applicable for step-wise change of specific property. |
| Rotational speed control |   | When flow changes from $Q_1$ to $Q_2$, pressure is controlled constant by setting rotational speed from $N_1$ to $N_2$. | · System in which head loss of pipe is large compared with actual lift<br>· In case flow largely fluctuates and operation is continuous. | · Elaborate control can be made.<br>· High efficiency and low cost | · Cost of the system is expensive.<br>· High level of technology is needed for O&M. |
| Control by valve throttling |   | Control is made by valve throttling responding to detected pressure and flow. | · Pipe system in which head loss of pipe is small compared with actual lift<br>· Common method of discharge control for small-to-medium pumps | · Control is simple<br>· Installation cost is small. | · Low efficiency<br>· Operating cost is expensive.<br>· Noise is generated.<br>· Cavitation may occur in case the pressure downstream side of valve is low. |

**On the item 3.;**

Although, as pressure control methods, there are the control by rotational speed of the pump, and the one by throttling of the valve, they are commonly used in combination with the control by number of units of pumps.

**1) Control with constant delivery pressure**

Under the control with constant delivery pressure, the delivery pressure is maintained constant by increasing or decreasing the rotational speed or the opening of the valve to fill the gap between the target value of the delivery pressure to be set by the controller and the actual one.

**2) Control with constant terminal pressure**

Under the control with constant pressure at the fringe of distribution network (terminal pressure), the pump delivery pressure is controlled so as to maintain the terminal pressure constant even if the flow changes. This method is suitable in case the head loss of water mains is large, or the fluctuation in water demand is large.

#### 8.2.11. Ancillary apparatus for pump control

In case pumps are controlled by automation or remote control, the following apparatus shall be installed:

1. A priming detector to detect that the pump casing has been filled with water
2. A pressure gauge to detect the delivery pressure of the pump
3. A water current detector to check the flow of sealing water, cooling water, lubrication water etc.
4. Motorized or solenoid valves for opening or closing flow of priming water, sealing water, cooling water, lubrication water etc. to be fit in required locations in the small piping for such water.
5. Limit switches etc. for confirmation of operation of the delivery valve and its protection.

**[Interpretation]**

In case start and shutdown of pumps are controlled by automation or remote control, ancillary apparatus shall be installed as required to automatically and smoothly set forward a series of starting process of water priming, starting the pump, opening the delivery valve etc. or the steps of reverse actions, i.e., the shutdown process.

#### 8.2.12. Protective gears

Proper protective gears shall be installed to detect anomalies, which occur during pumping, and generate an alarm or display them.

**[Interpretation]**

In case such an anomaly as a failure occurs during operation of the pump, there is a need to notify the operator of the anomaly by an alarm, or shut down the pump depending on the magnitude of the failure to protect the pump and the motor.

## 8.3. Motor

#### 8.3.1. General

A motor fit for the purpose of use shall be selected in consideration of reliability, controllability, the cost of operation etc.

The types of the motor are largely classified into the induction motor, the synchronous motor, the direct-current motor, and the alternating current commutator motor. For water supply, the induction motor is often used; and the high efficiency three-phase squirrel-cage induction motor has also been developed as the motor for pump as an energy-saving measure.

For selection of the motor, it shall be excellent in reliability, durability, controllability and the ease in maintenance and suitable to the load characteristics and the method of pump operation. Additionally, energy-saving equipment, with which saving in the life-cycle cost can be expected owing to its energy-saving effect, shall be examined for adoption even though the initial cost is high.

### 8.3.2. Selection of the motor

The selection of the motor shall be in conformity with the following items:

1. The standard motor shall be the three-phase induction motor.
2. Among various types of the motors classified by the method of protection, cooling etc., its selection shall be made by the environment of the location of installation and the purpose of use.

**[Interpretation]**

**On the item 1.;**

Although there are many types of motors, the three-phase induction motor shall be the standard as the motor for the pump since it is sturdy and simple in its structure, inexpensive, and easy to operate and maintain. The three-phase induction motors are classified into the squirrel-cage type and the wound-rotor type by the structure of the rotor.

**1) Squirrel-cage induction motor**

It has a structure with a rotor composed of rod-like conductors set in slots in the iron core and the end rings, which short-circuit the conductors. Although it is simple and solid of its structure, inexpensive and easy to maintain, a starter to reduce the big starting current is needed except for ones of small size.

**2) Wound-rotor type induction motor**

It has a motor, which has three-phase windings on the rotor as same as the stator, and can be started without reduction in the starting torque by regulating the resistance of the secondary rotor-resistor connected to the rotor winding through the slip rings. Besides, speed control can be made by regulating the secondary resistance, or secondary excitation.

**3) Motor for the submersible motor pump**

Since the motor for the submersible motor pump has various restrictions for its external diameter, connecting pipe, applied voltage etc., its shape, structure etc. are prescribed in JIS B 8324 (Submersible motor pump for deep well).

### 8.3.3. Method for starting

The starting method for the three-phase induction motor the most suitable to the capacity of power source, the type and use of the motor shall be selected.

**[Interpretation]**

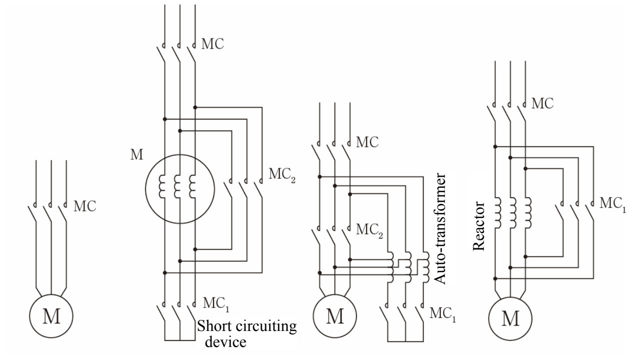
There are the types of starting for three-phase induction motor as presented in Table 8.3.3.

**Table 8.3.3 Starting methods**

| Type of motor | Starting method |
|---|---|
| Squirrel-cage induction motor | Full voltage starting<br>Star-delta starting<br>Korndorfer starting<br>Reactor starting |
| Wound-rotor type induction motor | Secondary resistor starting |

**1. Starting of the squirrel-cage induction motor**

The method of starting of the squirrel-cage induction motor shall be selected based on the restricted upper limit of the starting current, and required starting torque. Figure 8.3.1 shows the connecting diagrams of the respective methods.




(1) Full voltage starting (2) Y- Δ starting (3) Korndorfer starting (4) Reactor starting

**Figure 8.3.1 Starting methods of the three-phase squirrel-cage induction motor**

**1) Full voltage starting (line starting)**

In this method, the source voltage is directly applied to the winding of the stator. This method is used for motors with a rated power of smaller than 3.7 kW, and the special squirrel-cage motor with a rated power of smaller than 11 kW, or the one with that of larger than 11 kW in case no remarkable change is imposed to the source voltage. The starting current is 450 % to 700 % of the full load current.

**2) Star-delta (Y-Δ starting)**

Connecting the winding of the motor in the Y (star) mode at starting, and making the voltage to be applied to each phase $\frac{1}{\sqrt{3}}$ of the source voltage, the starting current becomes $\frac{1}{3}$ of the current of full voltage starting (The starting torque also becomes $\frac{1}{3}$.). When the rotation speed almost reaches the full speed, the connection is changed to the Δ (delta) mode, and the normal operation starts with the rated voltage.

**3) Korndorfer starting**

It is a method to start the motor using a three-phase auto-transformer only at starting to lower the voltage of the motor terminals to 60% to 80% or so of the rated voltage. As, in this method, a large inrush current may arise, starting is made in the reduced voltage mode using the auto-transformer by means of opening the neutral point of the auto-transformer after the acceleration of speed to restrict the current, making part of the winding of the transformer a reactor and then short-circuiting the reactors.

**4) Reactor starting**

At starting, the starting current is restricted by means of setting reactors in the stator windings in series, and short-circuiting them after the acceleration. The starting current is larger than the above methods whereas the starting torque is smaller.

**2. Starting of the wound-rotor type induction motor**

In this method, starting is made by means of putting resistors in rotor windings via slip rings to reduce the starting current in a certain range, and at the same time to make the starting torque relatively large.

Figure 8.3.2 shows the connection diagram of secondary resistor starting method in that the rotor windings are connected to the rotor-resistors via slip rings and brushes, and the motor can be accelerated from the start to the full speed by reducing the resistance. Besides, in case the motor is continuously operated for a long time, the slip rings are short-circuited, and the brushes are lifted to avoid their wear.

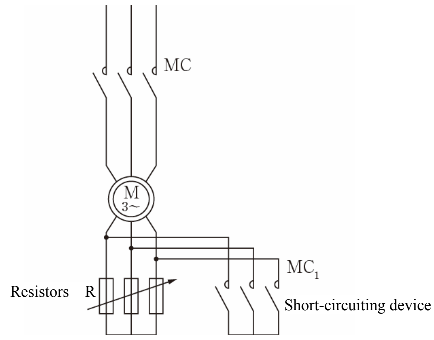



**Figure 8.3.2 Connection diagram of rotor-resistance starting method**

### 3. Comparison of the starting methods

Table 8.3.4 presents comparison of the stating current and the torque of the starting methods. These characteristics shall fully be considered for the selection of the starting method.

**Table 8.3.4 Comparison of the current and the torque of the starting methods**

| Starting method | | Starting voltage (%) (Ratio to the source voltage) | Starting current (%) (Ration to that of direct application) | Starting torque (%) (Ration to that of direct application) |
|---|---|---|---|---|
| Squirrel-cage type motor | Full voltage (Direct application) | 100 | 100 | 100 |
| | Y- Δ | 57.7 | 33.3 | 33.3 |
| | Korndorfer | 50 | 25 | 25 |
| | | 65 | 42 | 42 |
| | | 80 | 64 | 64 |
| | Reactor | 50 | 50 | 25 |
| | | 65 | 65 | 42 |
| | | 80 | 80 | 64 |
| Wound-rotor type motor | Rotor-resistor | 100 | Starting possible with full load current | 100 |

Note) 1. The starting current with the full voltage starting is 450% to 700% of the full load.
2. The starting torque with the full voltage starting is 100% to 150% of the full load.

### 8.3.4. Rotational speed control

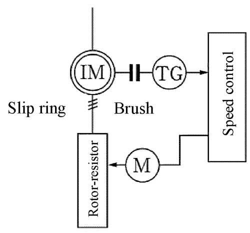
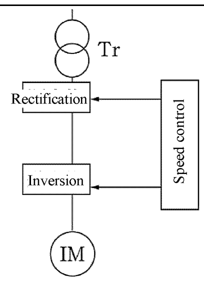
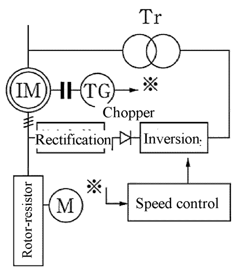
In case the rotational speed control of the motor is adopted, a method suitable to the pump facilities shall be selected in synthetic consideration of the control range, ease of control, efficiency, life-cycle cost, reliability, ease of maintenance etc.

**[Interpretation]**

### 1. Rotational speed control method

The main rotational speed control methods are compared as shown in Table 8.3.5.

**Table 8.3.5 Comparison of rotational speed control methods**

| Method of control | Rotor-resistance control | Primary frequency control (Inverter) | Secondary excitation control (Static Scherbius) |
|---|---|---|---|
| Motor | Wound-rotor type motor | Squirrel-cage type motor | Wound-rotor type motor |
| Principle | Control by regulating the rotor—resistance. The secondary slipping power becomes heat and is not salvaged as a loss. | Source voltage is rectified to DC voltage, and inverted to be applied as the primary voltage with constant voltage-frequency ratio (V/F) to control the motor. | Secondary slipping power is rectified into DC current, inverted to the AC power with frequency of the power source and returned to the source. Speed control is made by controlling the chopper and inverter element. |
| Basic block schematic |  |  |  |
| Synthetic efficiency | 55～90% | 80～90% | 80～90% |
| Control range | 60～100% | 60～100% | 60～100% |
| Main control equipment | Metal resistor +controller or liquid resistor + controller | Controller, rectifier, and inverter | Controller, rectifier, transformer, inverter, and chopper |
| Characteristics | 1. Simple as the controller is a mechanical one. But upkeep needed for brushes and resistors.<br>2. Efficiency is low at low speed range because the secondary power of motor is lost as heat.<br>3. Bad in response to control.<br>4. Large in speed fluctuation.<br>5. Narrow range of control | 1. Owing to the inverter control, the lower harmonic wave contained in the output voltage is eliminated.<br>2. An existing induction motor can be operated in variable speed.<br>3. Measures needed for abrupt power failure.<br>4. Power factor is good except for exceptional low speed.<br>5. Measures for higher harmonic wave needed.<br>6. Space for installation is big. | 1. The narrow the range of control, the smaller the capacity of rectifier and transformer.<br>2. Efficiency is high as secondary power is returned to the power source at a low speed.<br>3. Even at breakdown of the control unit, normal operation is possible by short-circuiting the secondary terminals.<br>4. Measures needed for abrupt power failure. |

**2. Selection of the control method**

Table 8.3.6 presents an example of comparison of control methods taking into consideration of the above. The control methods shall synthetically be compared based on not only the superiority or inferiority of the methods but also the organization for their maintenance (personnel, technical level, and setup for emergency at night), water management in the case of shutdown of pumps (switching of water service systems, backup by the capacity of the service reservoir etc.), economic benefits etc. multiplied by weight for the respective items depending on their importance.

**Table 8.3.6 Example of comparison of control methods**

| | | Rotational speed control (Rotational speed control of motor) | | | Control by valve opening | Control by angle of blades |
|---|---|---|---|---|---|---|
| Control method | | Rotor-resistance control (Liquid resistor) | Primary frequency control (Inverter) | Secondary excitation control (Static Scherbius) | Delivery valve | Variable angle impeller blades |
| Ability of flow control | | ○ | ◎ | ◎ | △ | ◎ |
| Maintenance | | ◎ | △ | △ | ◎ | △ |
| Energy saving | | ○ | ◎ | ◎ | △ | ◎ |
| Initial cost | | ○ | △ | △ | ◎ | △ |
| Running cost | Basic cost | ○ | ◎ | ◎ | △ | ◎ |
| | Repair cost | ◎ | △ | △ | ◎ | △ |
| Life of control equipment | | ◎ | △ | △ | ◎ | ○ |
| Applicable capacity | | Medium-large | Small-medium | Medium-large | Small-large | Medium-large |

◎Good ○Relatively good △Relatively bad

### 8.3.5. Protective gear

The protective gear of the motor shall be in conformity with the following:

1. A protective gear shall be installed for overloading, short-circuiting, grounding fault, low voltage, open phase, and prevention of accidents at the time of restoration of power.
2. An interlock between the electromagnetic switch of the motor and the starter and the short-circuiting device to prevent operational errors shall be installed.

# 8.4. Valve

## 8.4.1. General

### 1.Role and function of the valve

Valves for water supply bear important roles for effective and safe operation of water supply facilities for isolation of water flow, its control, adjustment of its pressure etc. The following functions are required for valves.

(1) Control of flow, pressure and water level

(2) Starting and shutting off the flow in water mains

(3) Reducing potential of water or controlling its flow when water is introduced from a pressurized water main to a grit chamber, service reservoir etc.

(4) Prevention of back-flow in water mains

(5) Reducing pressure in water mains

### 2. Selection of the valve

When selecting a valve, the one with the property compatible with the characteristics of the conduit or water main in adequate consideration of its use and role. It shall be installed where its upkeep and management are easy so that its function is maintained for a long time.

As to material and coating of the valve, it is important that, in addition to strength and resistance to corrosion, the one, which does not adversely affect the water quality, shall be selected.

## 8.4.2. Use and type of the valve

> The valve shall be selected by such a use as for flow control, isolation, discharging, back-flow prevention, reduction of pressure etc. and by such characteristics as water stopping, handling, durability etc.

**[Interpretation]**

### 1. Control valve

Although the control valves are classified into flow control valve, pressure control valve, and water level control valve for their purpose of use, the butterfly valve for water supply is widely used since its structure is simple; it is light in weight; its torque for operation is small; and its flow characteristics are relatively good.

The valves used for control are presented in Figure 8.4.1. Examples of the structure of the butterfly valve, cone valve and variable multi-holes orifice valve commonly used for water supply are shown in Figures 8.4.2 to 8.4.4.

- Control valve
  - Butterfly valve
    - Butterfly valve for water supply [*1]
      - Concentric axis type
      - Eccentric axis type
      - Slanted disc type
    - Metal seat butterfly valve
    - Valve body removable butterfly valve
    - Short face-to-face butterfly valve
    - Flange-less butterfly valve
    - Sub-valve embodied butterfly valve
    - Cavitation curbing type butterfly valve
  - Cone valve
  - Ball valve
  - Auto-valve
    - Direct-drive auto-valve
    - Pilot type auto-valve
  - Needle valve
  - Sleeve valve
    - Discharge type sleeve valve
    - Inline type sleeve valve
  - variable multi-holes orifice valve
  - Float valve
    - Direct action type float valve
    - Pilot type float valve
  - Eccentric valve

[*1] JWWA B 138 Butterfly valve for water supply

**Figure 8.4.1 Types of control valves**

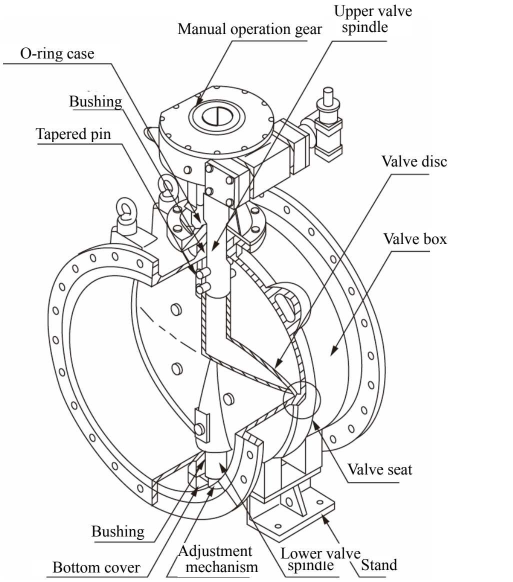



**Figure 8.4.2 Example of the structure of a butterfly valve for water supply**

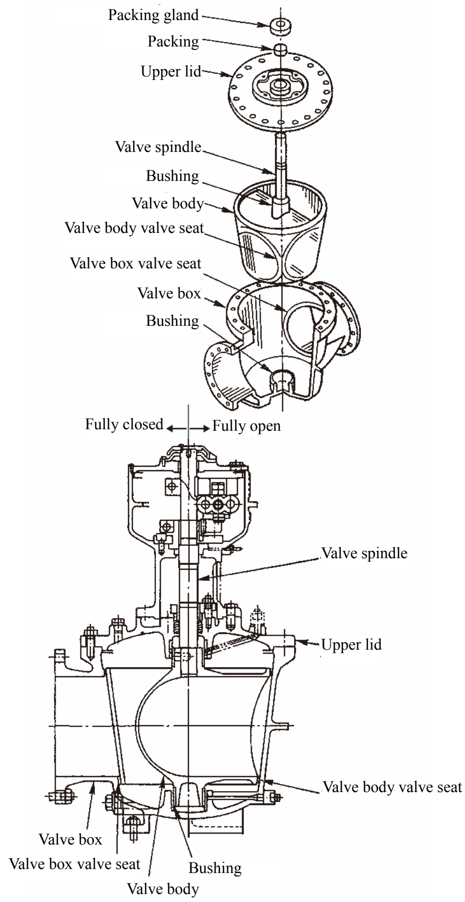



**Figure 8.4.3 Example of the structure of a cone valve**

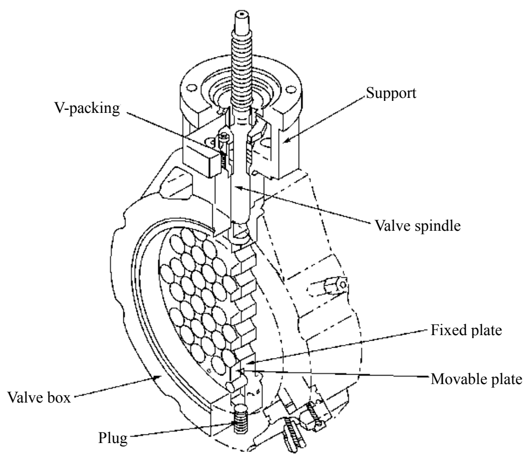



**Figure 8.4.4 Example of the structure of a variable multi-holes orifice valve**

**2. Isolation valve**

The valve used for isolation is presented in Figure 8.4.5.

**3. Valve for discharge**

The valve for discharge is used for not only discharging water from a dam but also drawing off from pressurized water main to the open surface of a grit chamber, receiving well etc. to reduce the pressure or control the flow. With this valve, continuous discharge for a long time is often carried out under high water pressure and high velocity, so one with a relatively large diameter is required.

- Isolation valve
  - Gate valve
    - Gate valve for water supply *1
    - Soft-seal gate valve for water supply *2
    - Ductile gate valve for water supply *3
    - Geared gate valve for water supply *4
    - Gate valve *5
  - Butterfly valve
  - Globe valve *5
  - Cone valve
  - Ball valve
  - Sluice valve gate
  - Sluice gate
  - Emergency isolation valve
    - Butterfly valve type emergency isolation valve
    - Sluice gate type emergency isolation valve
    - Auto-type emergency isolation valve
  - Siphon valve

*1 JIS B 2062 Gate valve for water supply
*2 JWWA B 120 Soft seal gate valve for water supply
*3 JWWA B 122 Ductile gate valve for water supply
*4 JWWA B 131 Geared gate valve for water supply
*5 In case the gate valve according to JIS B 2011, JIS B 2031 (JIS 2031: 1994 (Gray cast iron valve) is used, its elution property shall be tested.

**Figure 8.4.5 Types of isolation valves**

### 4.Valves for back-flow prevention

Unlike other valves, all of which are operated by electric power, pneumatics or manually, as a significant difference, the valves for back-flow prevention are actuated by the hydraulic force of forward or reverse flow. The types of the valves for back-flow prevention are presented in Figure 8.4.6.

- Valve for back-flow prevention
  - Check valve
    - Swing type check valve
      - Swing type check valve
      - Rapid-closing check valve
      - Slow-closing check valve
      - Bypass slow-closing check valve
    - Lift type check valve
      - Lift type check valve
      - Spring-operated rapid-closing check valve
      - Ball type check valve
    - Butterfly check valve
  - Foot valve
  - Flap valve

**Figure 8.4.6 Types of valves for back-flow prevention**

### 1) Check valve

For the prevention of back-flow for a pump and a surge tank, a swing check valve, of which valve body is supported by a hinge, and can turn around the spindle freely, is used (See Figure 8.4.7).

The slow-closing check valve closes very slowly right before its complete close to lessen the rise in pressure caused by the back-flow current, and there are the one type with the slow-closing main body, and the other type with slow-closing bypass valve (See Figure 8.4.8). In case the actual lift is relatively high, the swing type with slow-closing bypass valve is used. In this instance, more than 10 m of actual lift is needed. This valve is composed of a swing check valve with a bypass pipe embodied with a slow-closing valve, and its structure is complex (Figure 8.4.9).

**2) Foot valve**

The foot valve is installed at the front end of the vertical suction pipe of pump facilities, and works to maintain the suction side of the pump filled with water when the pump is stopped.

**5. Valve for reducing water pressure**

Although there are the butterfly valve, cone valve, ball valve etc., the auto valve is used in the distribution mains since power source or control equipment is needed for the former. Figure 8.4.10 presents the structure of a commonly used auto-valve.

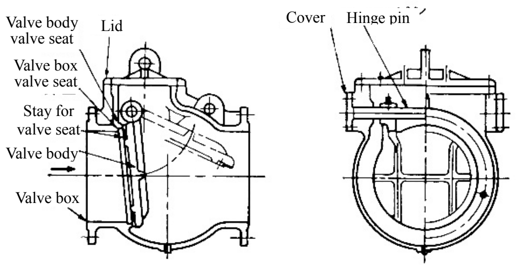



**Figure 8.4.7 Example of the structure of the swing check valve**

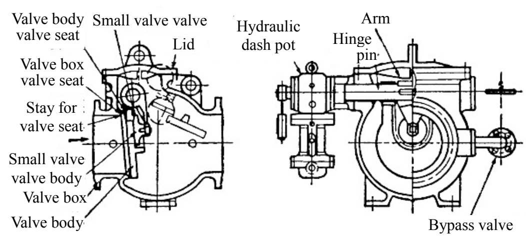



**Figure 8.4.8 Example of the structure of the slow-closing swing check valve**

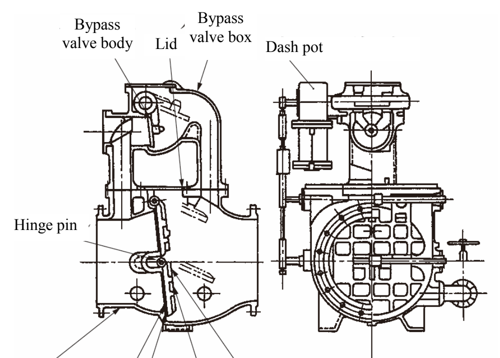



**Figure 8.4.9 Example of the structure of the bypass slow-closing swing check valve**

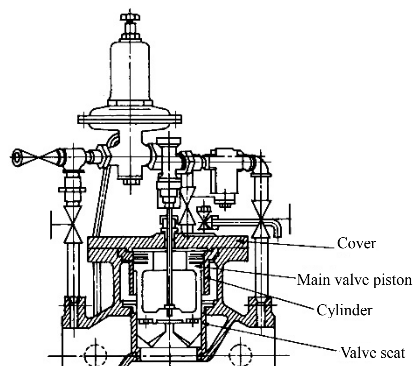



**Figure 8.4.10 Example of the structure of the auto-valve**

**6. Valve for protection of water mains**

The following are air valves for water supply used for exhaust and intake of air in water mains:

(1) The rapid action air valve, which rapidly inhale or exhaust a large amount of air and discharge air under pressure by the action of the flying valve body actuated by the buoyancy of the float in valve body.

(2) The single mouth air valve, which opens or closes by the float valve to inhale or exhaust air and discharge air under pressure.

(3) The double-mouth air valve, which opens or closes by the float valve to inhale or exhaust a large amount of air and discharge air under pressure.

The structure of the air valve is shown in Figures 8.4.11 to 8.4.13.

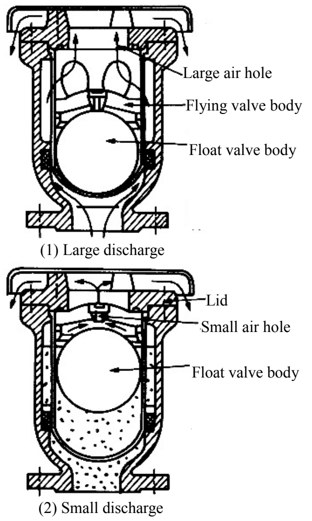



**Figure 8.4.11 Example of the structure of a rapid air valve for water supply**

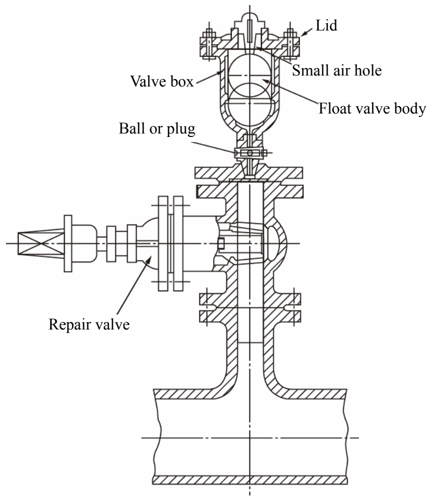



**Figure 8.4.12 Example of the structure of a single-mouth air valve for water supply**

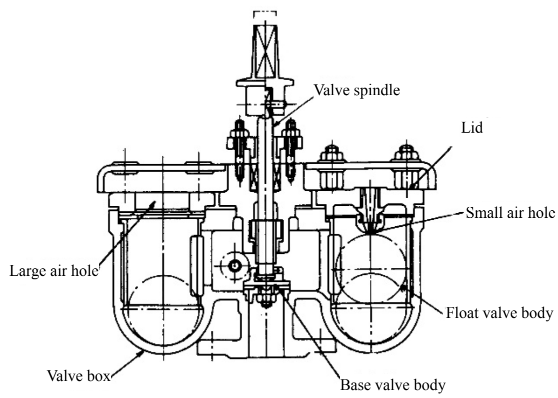



**Figure 8.4.13 Example of the structure of a double-mouth air valve for water supply**

**7. Valve for desludging and chemical dosing**

1) Since the valve for desludging is used for control and isolation of sludge drainage of the chemical sedimentation basin, the sludge disposal facilities etc., the diaphragm valve, eccentric valve, the

pinch valve etc. are used, the shape of which gives only small resistance to the flow to be formed when the valve is fully open.

2) The valve for chemical dosing needs to be of corrosion-resistant materials, which are the most suitable for the chemical in use. The diaphragm valve, the pinch valve and the ball valve are used for isolation, and the ball valve is used for back-flow prevention. As the flow control valve, one with not only corrosion-resistant materials but the suitable capacity coefficient, diameter, structure etc. shall be adopted.

### 8.4.3. Selection of the valve

The valve shall be selected in accordance with the following:

1. A valve, which has characteristics to satisfy the hydraulic condition, the purpose of installation etc., shall be selected.
2. A control valve, with which smooth control can be made, shall be employed after examining the flow to be controlled, the threshold velocity, the capacity coefficient etc.

**[Interpretation]**

**On the item 1.;**

Valves have their particular characteristics. For a valve to exert its capacity, based on a study on hydraulic and working conditions required for respective purposes of use for isolation, control etc., it is important to select a valve which possesses such basic properties as head loss coefficient, capacity coefficient, flow characteristics etc. to satisfy those conditions. The common items to be examined for the selection of the valve are the following:

(1) Flow and pressure

(2) Adaptability to the hydraulic conditions of the pipeline

(3) Adaptability to the location of installation and environmental condition etc.

(4) Cavitation

(5) Water hammer

(6) Type of operation and the driving gear

(7) Economic comparison

**On the item 2.;**

The selection of the valve shall be carried out according to the following steps, and their detailed steps are presented in Figure 8.4.15 Selection diagram for control valves.

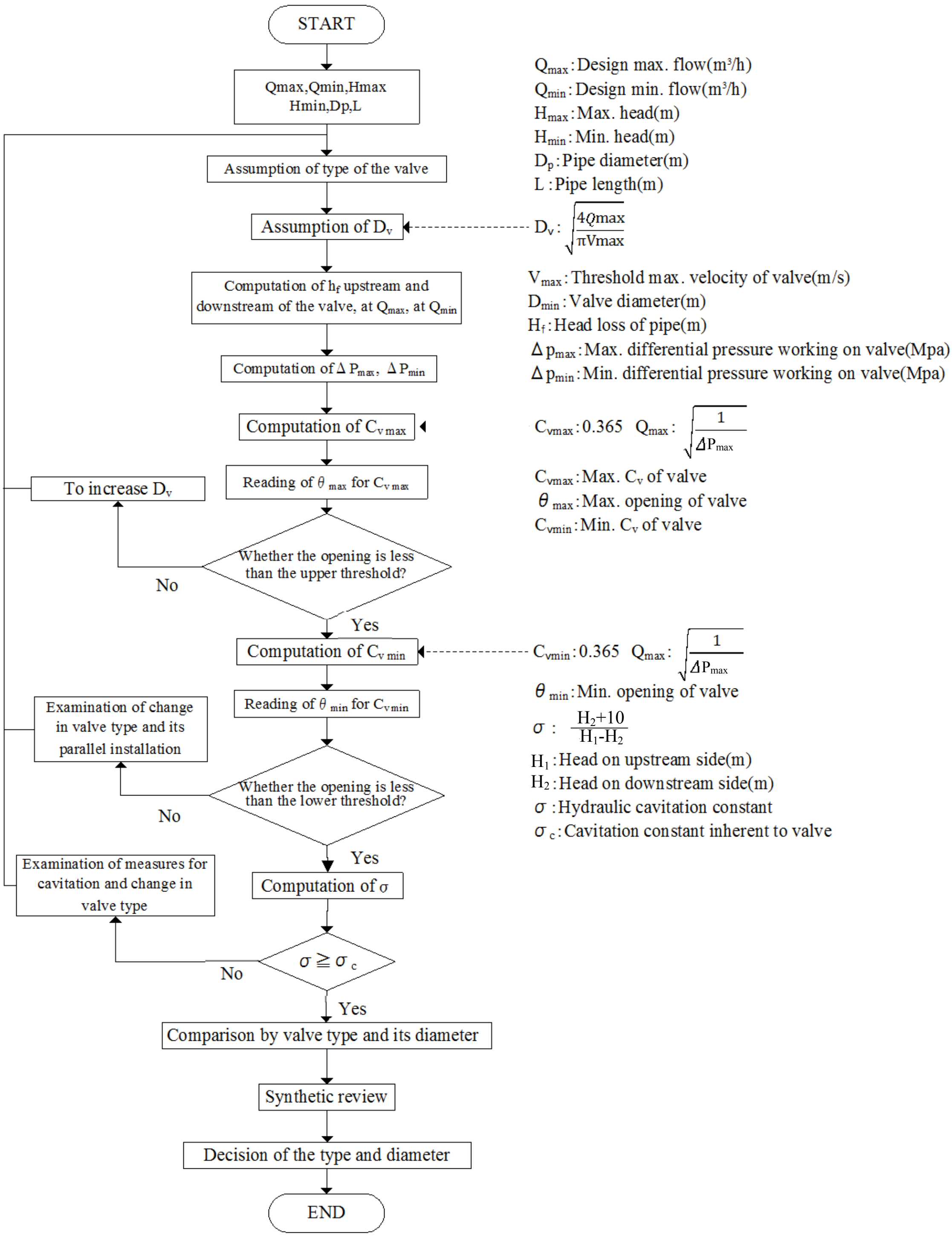



**Figure 8.4.15 Selection diagram for control valves**

(1) Find the flow velocity assuming the maximum flow to be controlled by the valve and its diameter.

(2) Confirm the above values are smaller than the threshold maximum velocity of the valve to be used (a value particular to the valve; 6m/s in the case of the butterfly valve)

(3) Compute the various head losses, maximum and minimum pressures upstream and downstream of the valve etc. at the maximum and minimum flows.

(4) Compute the maximum and minimum capacity coefficients required for the valve, read the maximum and minimum openings from the flow characteristic chart, and confirm that these openings are within the controllable range.

(5) Examine the possibility of cavitation.

(6) During above computation processes, in case the conditions of (2), (4) and (5) above are not met, change the valve diameter or the type, redo the computation, and select the type and diameter of the valve which meet the above conditions.

### 8.4.4. Driving gear of the valve

| |
|---|
| A proper driving gear of the valve shall be selected in consideration of the type, the use, the environment of installation, the method of control etc. of the valve. |

**[Interpretation]**

The manual, motorized or pneumatic driving gear is commonly used.

Additionally, as the driving gear for the control valve, the motorized and pneumatic types are often used, so a proper driving gear shall be chosen taking into account its control range, the precision of control and frequency of operation.

**1. Manual driving gear**

In the case of the small diameter gate valve, butterfly valve etc., for which only small force is needed for operation, a direct-connection handle type is used.

**2. Motorized driving gear**

The motorized driving gear is widely used since the commercial power supply can be used, with which strong driving force can easily be obtained, and remotely operated.

The motorized driving gear consists of a motor and reduction gears, and is equipped with a stroke-limit switch, a torque-limit switch, a circular manual handle and a selection device for manual or motorized mode.

**3. Pneumatic type driving gear**

Since the pneumatic type driving gear can simply obtain its power source, i.e., compressed air by an air-compressor, possesses good response as a driving gear, and can be operated for a certain period of time even at the time of power failure, it is often used for valves for chemical dosing, desludging and valves which needs to be operated at such an emergency as power failure.

## 8.5. Chemical dosing equipment and water sampling equipment

### 8.5.1. General

Since the chemical dosing equipment is one of the most important water treatment facilities, to obtain the most optimum water quality, adequate examination is required on such various matters as the nature and safety of chemicals, their dosing method, control method etc. The chemical dosing equipment has such purposes of uses as coagulation, pH control, and disinfection, and their type and consistency are largely different from each other. Therefore, proper dosing methods and equipment to be used and suitable to these purposes need to be selected. Furthermore, detailed specifications for them shall be determined in consideration of their size, the shape of the site of their installation, their required functions etc. The chemicals commonly used for water supply are presented in Table 8.5.1.

As items to be examined for the chemical dosing equipment, there are the dosing quantity, method of dosing, control method, materials used etc. Since the type, the property and the dosing rate of chemicals are the most important factors for designing, sufficient examination on the water quality for treatment, the size of the facilities and the condition of use shall be made in advance.

What's more, as to chemical dosing equipment, see 5.3 Dosing equipment for coagulation chemicals and 5.10 Disinfection facilities.

The water sampling equipment is the equipment to obtain precise information on water quality, which is indispensable for reliable and proper control of the dosing equipment and monitoring of water quality, so proper sampling location and the required quantity of water shall be adequately be examined.

**Table 8.5.1 Chemicals used for water supply**

| Name of chemical | Abbreviation (Common name) | Use |
|---|---|---|
| Sodium hypochlorite | Hypochlorite of soda, antiformin | Chlorine agent |
| Polyaluminum chloride | PAC | Coagulant |
| Aluminum sulfate | Alum, | Coagulant |
| Polysilicate iron | PSI | Acid agent |
| Concentrated sulfuric acid | Sulfuric acid | Alkaline agent |
| Sodium hydroxide | Caustic soda, lye | Alkaline agent |
| Calcium hydroxide | Slaked lime | Alkaline agent |
| Sodium carbonate | Soda ash | Removal of taste and odor |
| Powdered activated carbon | PAC | Coagulant |

### 8.5.2. Chemical dosing equipment

Chemical dosing equipment shall be in conformity with the following:

1. The dosing equipment shall always possess capacity to reliably dose from the maximum quantity through the minimum quantity with high precision.
2. The method of dosing shall be the one the most suitable to the purpose of use, the size of the facilities, the type and consistency of chemicals and condition of use.
3. The dosing equipment shall be constructed into two systems in parallel, and have spare units.
4. The control method of dosing shall be capable of dealing with the change in water quality in consideration of the size of the facilities, the situation of water quality, operation and maintenance etc,
5. For the apparatus, valves, piping etc., their materials shall be adequately corrosion-resistant to the nature (acid, alkaline etc.) of chemicals, and they shall have proper structure and piping.
6. The dosing equipment shall have a structure and layout in consideration of safety in respect to the handling and management of chemicals.

**[Interpretation]**

**On the item 1.;**

An example of examination diagram for chemical dosing equipment is presented in Figure 8.5.1.

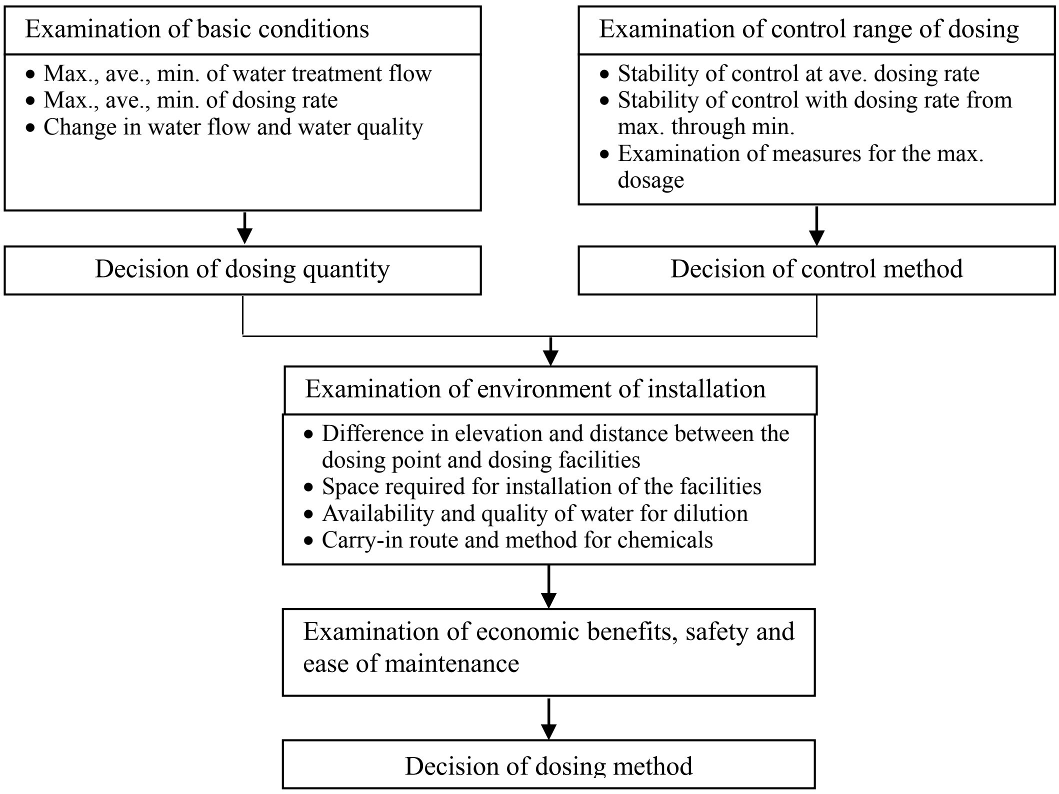



**Figure 8.5.1 Example of examination diagram for chemical dosing equipment**

**On the item 2.;**

**1) Classification of dosing methods**

Reference Figure 8.5.2 for the classification of methods of chemical dosing.

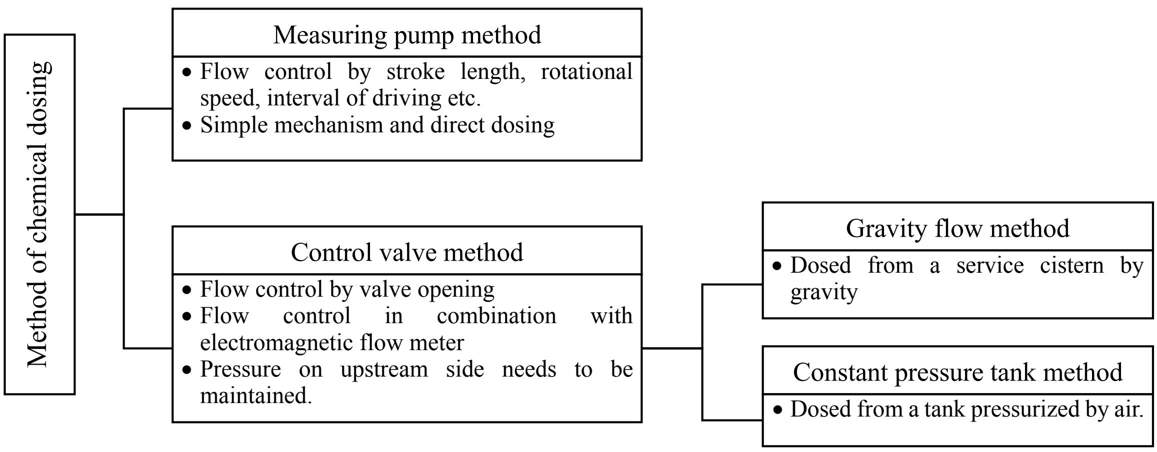



**Figure 8.5.2 Example of classification of methods of chemical dosing**

## 2) Characteristics of dosing methods

### (1) Measuring pump method

In a method, the stroke length or its frequency of the diaphragm pump or the measuring pump is regarded as the dose; and in another method, a computed value of the rotational speed of the single-axis screw type pump is considered the dose. See Figure 8.5.3.

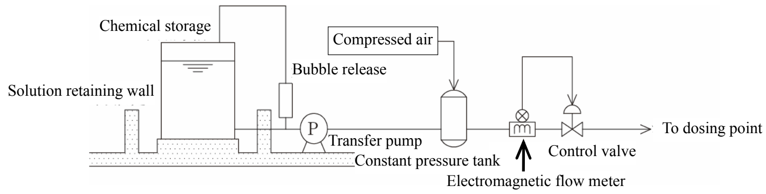



**Figure 8.5.3 Measuring pump method**

### (2) Gravity flow method

In this method, a storage tank or a service cistern is placed near the dosing point, and dosing is made from the cistern by gravity. As the feeder is installed near the dosing point, and dosing is made by the original chemical solution in this method, response is quick with a very little delay when the dosage is changed. Although location of installation is restricted, it is the most simple dosing method, has very little trouble with air bubbles in the dosing pipe, and can reliably perform dosing. See Figure 8.5.4.

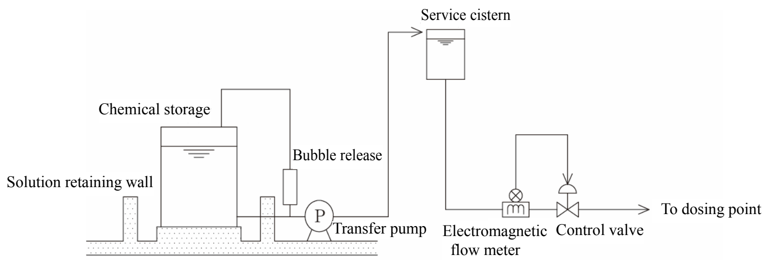



**Figure 8.5.4 Gravity flow method**

### (3) Constant pressure tank method

In this method, dosing is made by the pressure in a tank, to which air is fed with required pressure, and dosing can be carried out with all the equipment situated on the same floor similar to the measuring pump method whereas the condition for installation with sufficient difference in elevations is needed in the gravity flow method. See Figure 8.5.5.

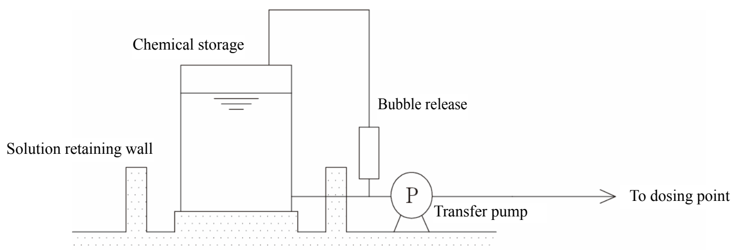



**Figure 8.5.5 Constant pressure tank method**

**(4) Injector method**

The injector is used together with the measuring pump method, the control valve method or independently in case the distance from the dosing equipment and the dosing point is large, or the mixing effect needs to be raised; and pressurized water is fed to the injector to dilute the chemical with water and transfer it to the dosing point. Its mixing effect at the dosing point is good. See Figure 8.5.6.

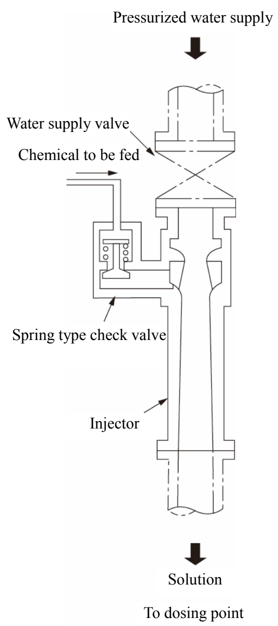



**Figure 8.5.6 Injector method**

**3) Dosing method of powdered chemicals**

In this method, such a chemical as slaked lime and powdered activated carbon (PAC) is dosed as powder, and transferred to the dosing point as its solution or slurry.

**On the item 3.;**

The dosing equipment need to be provided with a spare unit to cope with breakdown and repair and inspection. More than one spare unit shall be provided for each dosing system, and it can be shared in case there are many systems depending on the situation. The dosing pipelines shall also be duplicated so as to cope with such a trouble as leakage of liquid or clogging.

**On the item 4.;**

The general matters of the control method of chemical dosing as follows:

For the control of chemical dosing, it is common to perform the control by automation. The objectives of control for respective methods are shown below:

(1) Measuring pump method: Rotational speed of the pump, stroke length and interval of driving

(2) Control valve method: Valve opening

**1) Manual control**

In this method, the control valve or the measuring pump is operated manually, and the operation is manually made directly on site in a case; or manually handled remotely from the central control room etc.

**2) Fixed command control**

The fixed command control is a control method to maintain the dosing quantity of chemical at a constant value as a target. The control valve or the measuring pump is so controlled that the dosage gets to the prescribed value, the value measured by the flow meter is fed back to the flow controller, and flow is adjusted according to the differential value. This method is used in case the changes in treatment water flow and raw water quality are small, and the required water quality (turbidity, alkalinity, pH, residual chlorine etc.) can be sustained with almost constant dosage of the chemical.

**3) Flow-paced control**

In this method, the quantity of chemical is controlled so that the dosing rate is constant at the prescribed rate. It is applied in case the change in the raw water quality is almost level, and the water treatment flow changes.

**4) Feed-back control**

In the feed-back control method, control is made so that the quality (turbidity, alkalinity, pH, residual chlorine etc.) of treated water is held constant in case the water treatment flow as well as the raw water quality changes. The signals from the water quality measurement apparatus as the object of flow-paced control are fed back to compensate the dosing quantity of the chemical. See Figure 8.5.7.

**5) Feed-forward control**

In this control method, setting the dose of chemicals based on the measurement values of the water quality apparatus (residual chlorine meter, chlorine demand meter etc.) in advance, the dosage of chemicals is controlled before the deviation in the value of water quality occurs. It is in general employed for additional dosing of chlorine in the water transmission and distribution systems in many cases. The residual chlorine in the incoming water is measured, and the dose of chlorine is computed from the residual chlorine required in the service area based on the corresponding chlorine dosage and the incoming water flow. See Figure 8.5.8.

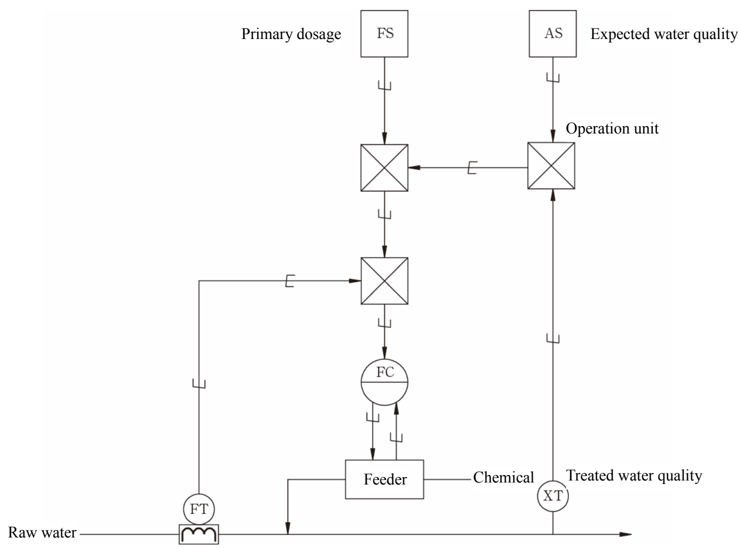



**Figure 8.5.7 Feed-back control**

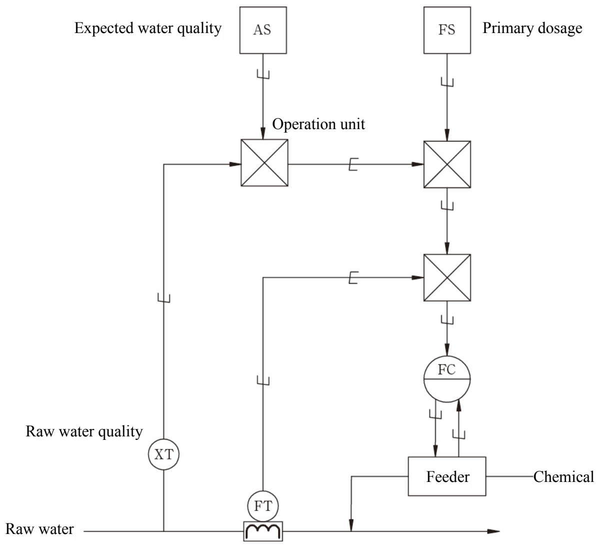



**Figure 8.5.8 Feed-forward control**

### 6) Cascade control

In this control method, in combination with the water quality apparatus, the dosing rate signals are supplemented by the factors of target value, delays etc. so that the target water quality is held constant, in which the supplemental signals are produced by the pacing control system based on the signals obtained by the water quality apparatus.

## 8.5.3. Water sampling equipment

The water sampling equipment shall be in conformity with the following:

1. Water sampling equipment, which can fully satisfy their purpose, shall be installed.
2. The locations of sampling shall be where the objective water quality can be obtained.
3. Ease of O&M shall be taken into consideration for the structure of the equipment.

**[Interpretation]**

The water sampling equipment is the equipment to convey water for testing to water quality apparatus, and needed for precise and reliable control of the chemical dosing equipment. As such, their capacity, environment of installation, structure required as the sampling apparatus shall adequately be studied in advance.

## 8.6. Mechanical facilities for water treatment

### 8.6.1. General

Such mechanical facilities for water treatment as a screen, mixing equipment, sludge raking equipment etc. are installed in water supply facilities.

On the occasion of designing these mechanical facilities for water treatment, their structure, materials etc., which can withstand continuous operation, shall be selected in consideration of their operating condition, environmental condition etc. As to the mechanical facilities used for water treatment, wastewater treatment etc., materials, which are fully compatible with the water quality to be treated, shall be selected, their structure shall be simple, and they shall have certain allowance in their capacity, mechanical strength etc.

Especially, as to the equipment, which travels in water, since not all construction work can be carried out at the same time, a development plan for the respective years shall be drawn, and an appropriate design shall be prepared to divide the facilities by unit of system or block so that the upkeep work can be carried out in an appropriate period when the operation of water treatment will not be interrupted. Additionally, since corrosion and attrition become extensive depending on water quality and the life is shortened, the decision of the structure, selection of materials and painting shall be examined, and as for the replacement of consumables, inspection of equipment and so forth, they shall be so designed that their O&M are easy.

### 8.6.2. Screening equipment

> As for the screening equipment, a proper model and type shall be selected in consideration of the raw water quality, the shape of the water channel, the environment of installation, the method of operation.

**[Interpretation]**

The screening equipment is installed to prevent the inflow of floating matters etc. contained in the raw water, and remove them so as not to cause troubles in the work of water treatment; and there are the rake type and the rotary type.

The rake type screen is installed at the intake mouth of river water (surface water) to remove such coarse matters as wooden blocks, garbage etc.

The rotary type screen in general removes by its net-screen such garbage as algae, leaves, wooden blocks etc. which have not been removed by the raking type screen.

When the screening equipment is installed, the provision of a bypass conduit shall be considered to prevent flooding caused by breakdown of the equipment.

As the ancillary equipment, there are a belt conveyer, a running water trough, a draining pit, a hopper, water service equipment etc.

An example of the raking-type screen is presented in Figure 8.6.1. An example of the rotary type screen is presented in Figure 8.6.2.

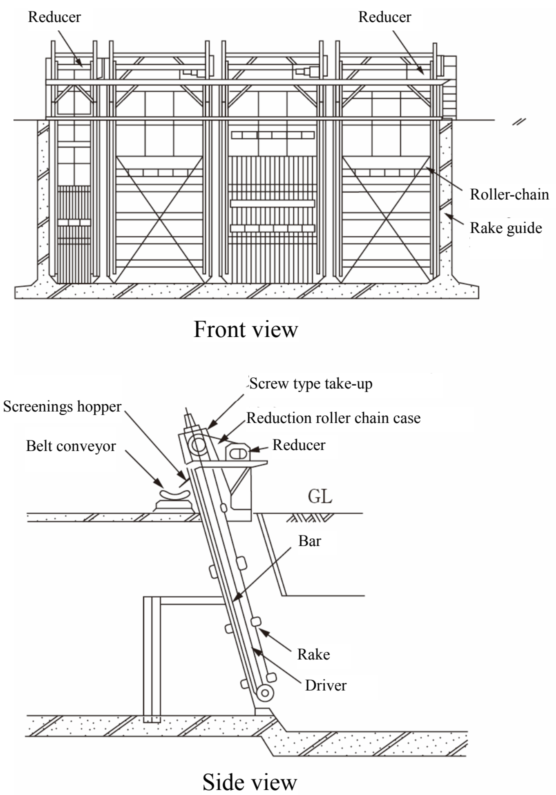



**Figure 8.6.1 Example of the raking-type screen**

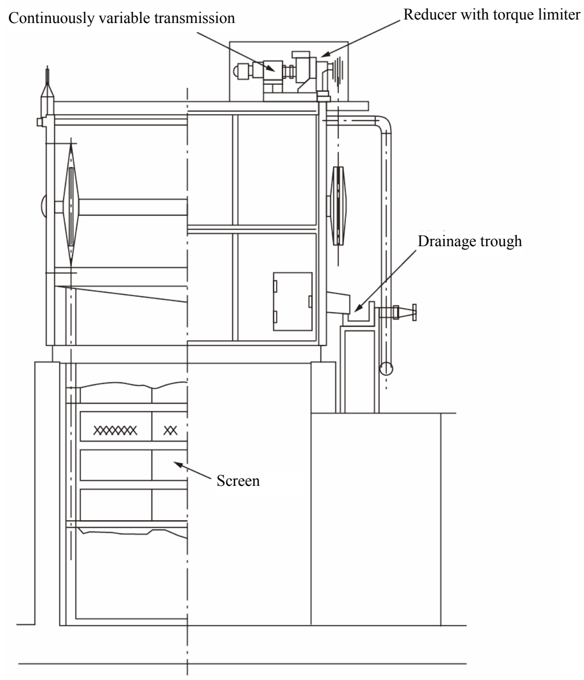



**Figure 8.6.2 Example of the rotary type screen**

### 8.6.3. Mixing equipment

> As mixing facilities, there are a flush mixer to be fit in the mixing chamber, a flocculator to be fit in the flocculation basin etc., so the type, for which the mixing capacity, efficiency, O&M etc. are taken into consideration to fit the conditions of the facilities, shall be selected.

**[Interpretation]**

The flush mixer mechanically and rapidly mixes a coagulant with raw water in a mixing chamber, and there are the paddle type with paddles fit parallel with the axis, the turbine type with a disk and blades fit perpendicular to the disk etc.

The flocculator, which has paddles fit parallel with the axis, gently rotates, brings about smaller head loss than the zigzag flow type flocculator, which has a channel with baffle plates, and has an advantage to be able to change the intensity of mixing depending on the situation of water treatment. On the other hand, such regular maintenance as replacement of consumable parts is required.

### 8.6.4. Sludge scraper

> A proper sludge scraper shall be selected in consideration of the structure, size, sludge volume, and allowance in capacity of the sedimentation basin, the reliability, O&M etc. of the machinery.

**[Interpretation]**

The characteristics of the desludging equipment in the sedimentation basin etc. and the points to be considered for their design are presented below (See Table 8.6.1).

**Table 8.6.1 Comparison of sludge scrapers**

| Type | Link-belt type | Submerged towing type | Meeda type | Rotating type |
|---|---|---|---|---|
| Working mechanism | Flights (raking blades) fit on the endless chain travel and collect sludge. | A raking blade mounted on a carriage set on rails travels and rakes sludge as it is towed by wire. | A movable raking blade mounted on a carriage, which travels on the basin, travels and collects sludge. | The rake rotates and collects sludge toward the center of the basin to drain it to the hopper. |
| Composition of machinery | Driving unit, chain transmission, raking blades, rails etc. | Driving unit, wire reel, carriage, rails etc. | Traveling vehicle, elevator, movable arms, raking blade, rails etc. | Driving unit, hanging axis, rakes, raking blades etc.. |
| Characteristics | The structure is simple; and continuous raking is possible. If the long side is very long, it is unsuitable as the load becomes too big. | As the structure is simple, and few moving parts in water, it is advantageous in case the long side is long. Positioning control necessary since there are the processes of forward and backward strokes. | One unit of equipment can work for more than two basins. Its size is big, and its structure is complex since there many components. | It is only applicable to a round sedimentation basin because of a rotary type of rake. It is advantageous in case a device for settling accelerating device is set in the basin. |

Respective examples of sludge scraping equipment are shown in Figures 8.6.4 to 8.6.7.

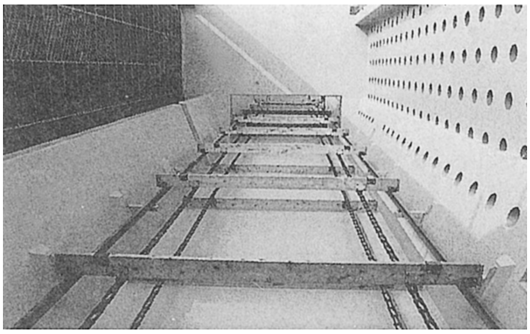


**Figure 8.6.3 Example of a link-belt type sludge scraper.**

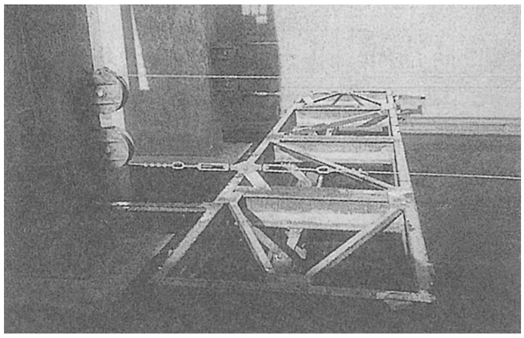


**Figure 8.6.4 Example of a submerged towing type sludge scraper.**

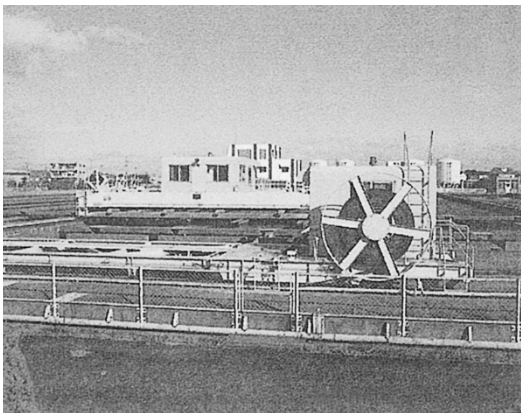


**Figure 8.6.5 Example of a Meeda type sludge scraper.**

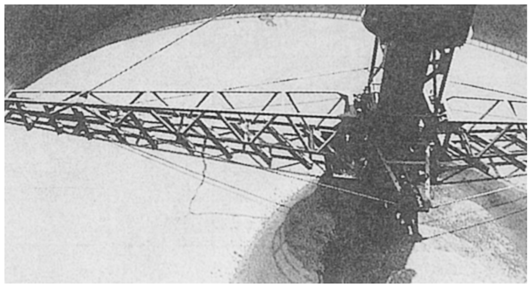


**Figure 8.6.6 Example of a rotating type sludge scraper.**

## 8.7. Ancillary facilities

### 8.7.1. General

As ancillary facilities of water supply facilities, there are the air source equipment to drive valves, cranes to lift and move machinery and goods, the ventilation and air-conditioning equipment for the purpose of the control of room temperature and ventilation etc. On the occasion of designing these facilities, a type of equipment shall be selected suitable to its required capacity and purpose of use, and their structure and composition shall be able to withstand continuous operation in consideration of the operational and the environmental conditions. In addition, respective related laws and regulations shall be abided by.

### 8.7.2. Ancillary equipment

The points of consideration for the ancillary facilities shall be the following:

1. Air source equipment suitable to the purpose of use with high reliability shall be adopted equipped with various safety measures.
2. Such loading equipment as cranes shall be of a model for which the safety and accuracy are

considered important.

3. The ventilation and air-conditioning equipment shall be installed for securing the safety at the location of various apparatus, and ensuring the normal functions of the apparatus.

**[Interpretation]**

**On the item 1.;**

The air source equipment is composed of an air tank, dehumidifier etc. in addition to an air-compressor, and used for instrumentation, driving of valves, starting engines and so forth. Its spare unit shall be provided in consideration of decline in its capacity and influence of breakdown. An example of air source equipment is presented in Figure 8.7.1.

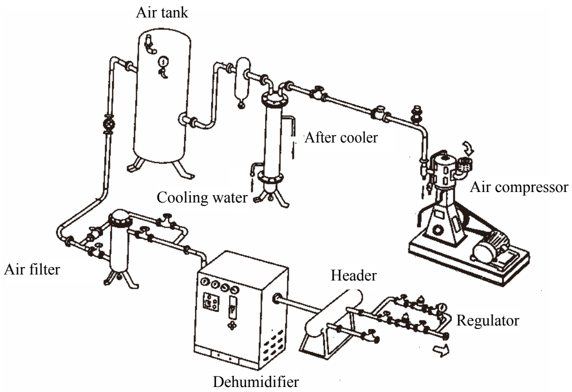



**Figure 8.7.1 Example of an air source**

**On the item 2.;**

The tall ceiling crane often used in water supply can travel both lengthwise and widthwise while carrying goods horizontally, and one with one traveling girder, which can only move one direction, is called telpher.

**1) Type**

**(1) Ceiling crane**

The ceiling crane consists of a girder mounted on saddles on rails, which are fixed upper both sides of the house, a crab on the girder, and a winch set on the crab. It is installed to be used for carrying-in and carrying-out of such large machinery as pumps, motor etc., their installation, dismantling and so on.

**(2) Telpher**

The telpher moves along the rails and lifts goods up and down only. In many cases its structure is simple, and used for small scale loading and unloading of materials and small machinery etc.

**On the item 3.;**

In water supply facilities, there are such heat-generating equipment as the machinery room, electric room, chemical room etc., and chemicals, which possibly emit a toxic gas. For securing safety or ensuring normal function, lengthening life of machinery, ventilation and air-conditioning equipment shall be installed in such places.

## 8.8. Power facilities

### 8.8.1. General

Power facilities consist of power receiving equipment, to which power is supplied by a power company, transforming equipment, which deals with the type and voltage for the loads, distribution equipment for serving power to loads, loading apparatus etc.

Electric power in water supply facilities is widely used for power, lighting, heating, communications, instrumentation, and an energy source for other facilities, so it is the most closely related to other equipment. Therefore, since its failure may bring about direct and grave influence to water supply, the condition with highest priority for designing them is to make the facilities with high reliability so that the damage by an accident can be contained to a minimum, and restoration can be made in a short period of time.

Since water supply facilities are used for a long time, power facilities, which have a long life and excellent durability, shall be adopted, and consideration shall also be paid to their replacement. In addition, they need to be assured to safely work even at the times of such natural disasters as an earthquake, typhoon, flood, tsunami, snow damage, lightning damage, salt damage etc.

Furthermore, as the power cost accounts for the largest weight among operating costs of the facilities, consideration to rational use of power shall be given for the power facilities.

In the recent years, technological development has been realized in the direction of high reliability and safety, excellent serviceability, resistance to the environment, miniaturization, and energy saving owing to the advancement in electronic apparatus, and electric materials. When employing these technologies, in addition to consideration to the above, the power facilities need to be made suitable for the purpose of respective water supply facilities after examining all such conditions as measures for power failure, the quality of power source, environmental conservation etc.

What's more, as various legislative regulations apply to the installation, maintenance and operation of power facilities, related laws and regulations shall be abided by. Especially, sufficient consideration needs to be paid to security.

### 8.8.2. Basic design

The design of power facilities shall be in conformity with the following items:

1. Related laws and regulations shall be abided by.
2. They shall be suitable to the importance of water supply facilities with sufficient reliability and consideration to energy saving.
3. They shall be flexible facilities, for which replacement and reconstruction can be implemented without difficulty in consideration of the future plan.
4. Their operation and maintenance (O&M) shall be easy, and at the same time they shall possess high safety taking into account prevention of accidents.
5. Sufficient strength, reliability, and the ease of restoration against an earthquake and other natural disasters shall be considered.
6. Coordination with related offices and divisions and sections responsible for O&M shall be made in addition to consultation with related government offices and power companies.

**[Interpretation]**

**On the item 2.;**

(1) Adequate preliminary survey shall be conducted on the purpose of use of the facilities in question and other related facilities, and the coordination of the system as a whole shall be made.

(2) The reliability of apparatus of power receiving through loads shall be prioritized, and the reliability shall be accorded with the economic benefits.

(3) The apparatus shall be composed of standard products with high reliability and a long life.

(4) As for apparatus, circuits, sequence etc. they shall be simplified, unless there is an obstacle, and a backup system as well as a failsafe system shall be introduced.

(5) A rational layout shall be made, and collateral damage by an accident shall be localized and minimized.

Furthermore, consideration to the environment shall be practiced by the adoption of such energy-saving equipment as the top-runner transformer etc.

**On the item 3.;**

Water supply facilities are regularly replaced, and there is a possibility for them to be reconstructed for expansion or downsizing in accordance with water demand etc. On the occasion of designing, the following matters shall be taken into consideration so that construction work can be carried out without difficulty even at the time of replacement or reconstruction:

(1) The layout of apparatus shall be rational, and adequate space shall be provided to be used during construction for replacement etc.

(2) Power distribution shall be appropriate, and stable operation can be made even during construction of replacement etc.

(3) To reduce as much time as possible for suspension of operation due to construction of replacement etc., the division of facilities for power-cut shall properly be set.

**On the item 4.;**

Since failure of power facilities directly results in suspension of water service or drop in water pressure, it shall be avoided as much as possible.

Accidents are in general divided into an accident of facilities and that by human causes. Hence, prevention of accidents of facilities shall be aimed by the use of apparatus with high reliability, and, at the same time, for prevention of accidents by human causes a system of failsafe or error-proof shall be incorporated at the time of designing taking the following into consideration:

(1) Necessary and sufficient work space shall be secured for inspection and upkeep; a layout of apparatus shall be considered to make maintenance easy; and a cover for prevention of an electric shock shall be fit where electric shock may occur.

(2) The pattern of personnel's movements shall be reflected to the operating switches, lamps etc. and a harmonious layout of apparatus, which wards off operational errors and misjudgment, shall be considered. Double-action switches shall be employed for important operation, and interlock circuits shall be provided if required.

(3) Switching from an apparatus to the other shall be automated or interlocked to ward off factors of operational errors.

**On the item 5.;**

If the power receiving and transforming facilities are damaged even if the main structures are not damaged in the case of an earthquake, the function of the water supply facilities is paralyzed.

It is desirable to aim at making the earthquake resistance of power facilities to be at the same level as that of the main structure.

The location, structure and protective measures of power facilities shall be determined to sustain as small damage as possible from a typhoon, flood, tsunami, heavy snow, lightning and salt.

**On the item 6.;**

At the time of designing power facilities, consultation shall be made with related government offices and power companies in regard to the above laws and regulations.

Coordination shall be made with related offices responsible for civil work, architecture, power, machinery, water quality etc. It is important to hear the opinion of offices in charge of O&M at the time of designing to reflect the practicable technologies which cannot be understood in theoretical discussions.

### 8.8.3. Power receiving, transforming and distribution plan

The plan for power receiving, transforming and distribution shall be in conformity with the following:

1. The maximum power demand (kW) shall be determined based on the load facilities plan in respect to water demand and adequate study on loads from the existing facilities.
2. Adequate consultation with the power company shall be made and necessary matters shall be determined based on the power supply provisions of the company.
3. The type of power receiving shall be selected in accordance with the importance of the facilities.
4. The type of transformation shall be chosen depending on the surroundings and the condition of the installation location.
5. The type of distribution shall be selected in association with the priority of the loads.
6. To secure the high credibility, duplex power supply, non-utility generation etc. shall be considered.

**[Interpretation]**

**On the item 1.;**

The maximum power demand is the maximum power required when the load facilities (contract load facilities) are in commission at the same time; so a survey on loads as the basis is needed to obtain it.

As the load facilities change in many cases from the present to the future, on the occasion of designing power facilities, such terminal objective as the size of facilities and its year-by-year development plans up to the design year need to be clarified.

**On the item 3.;**

Admitting it is desirable for a water utility to receive electric power by an exclusive power line to avoid power outage caused by a collateral accident brought about by an accident of other power user, it cannot be provided in some cases due to the routing of power distribution by the power company.

In consideration of scheduled power-cut for electric work of the Power Company, and power outage caused by a collateral accident etc., it is advisable to receive power from two sources and so forth for high-priority facilities so that power can be supplied from another source even in the case of failure of one source.

The steps of examination on the occasion of designing power facilities are presented in Table 8.8.2 for a plan for a large scale; Table 8.8.3 for a plan for a small scale high tension receiving facilities; and Table 8.8.4 for an example of a single-line diagram.

**Table 8.8.2 Steps of examination for designing power facilities (Planning of large scale)**

| | Item | Particulars | Items for examination |
|---|---|---|---|
| 1 | Decision of basic policy | ･To decide basic policy on level of credibility, type of O&M, plan for expansion etc. | ･Purpose of the plant<br>･Outline and size of facilities<br>･Location of installation, existence of house<br>･Coordination with other facilities, life-cycle<br>･Final plan or expansion/year-by-year plan |
| 2 | Preliminary survey | ･ Implementation of preliminary survey on weather, topography, example of similar design, example of accident, laws and regulations etc. | ･ Damage from storm, flood, snow, heat and cold-weather, atmospheric pressure, high tide, and lightning<br>･Damage from salt, earthquake, land subsidence, dust, groundwater, galvanic corrosion,<br>･Example of operation of a similar plant<br>･ Examples of human casualties, damaged facilities, accident in operation, fire etc.<br>･Land use area related to construction site<br>･Laws and regulations related to noise, vibration etc. |
| 3 | Survey on loads.<br>Decision of capacity of facilities. | ･To study on loads, prepare load list, and decide capacity of facilities<br>･In case contents of load cannot be determined, estimate from consumption rate, actual example etc. | ･Category, use, capacity and number of units of loads<br>･Condition of operation, load factor, spare units, power factor, operation at emergency<br>･Timing of installation, layout, priority |
| 4 | Decision of receiving power.<br>Decision of method of receiving.<br>Relationship with non-utility generation. | ･To estimate max. power demand, and contract demand from capacity of facilities, and consult with power company.<br>･To compare merits and demerits of methods of receiving, and decide the receiving method through consultation with power company.<br>･To examine the role of non-utility generation, clarify its purpose (emergency use, regular use for peak-cut), and examine coordination with the commercial supply. | ･ Max. power demand, contract demand, receiving voltage, contract type, burden charges<br>･Exclusive line or common line<br>･Receiving method (Limitation possible depending on local condition)<br>･Lead-in method, boundary of responsibility, boundary of property ownerships, power safety communications<br>･ Regular use or emergency use, for operation of facilities or security, relationship with commercial supply, voltage, method of switching, restriction in load, load for fire-fighting |
| 5 | Preparation of main circuit single-line diagram:<br>･ Transformer capacity<br>･Composition of bus<br>･ Method of distribution<br>･ Distribution voltage | ･ To determine capacity of transformer reliability and economy as well as facility capacity<br>･To determine bus composition and method of distribution considering size of facilities, their layout, method of operation.<br>･ To decide type of power, distribution voltage (6kV, 3kV, 400V, 200V, 100V) from economic and safety points of view | ･ By use, allowance, power factor, starting current, impedance, max. power demand, load factor, over loading<br>･Future plan, past experience<br>･Bus type, method of distribution, division of loads into groups, demarcation of distribution, unbalance ratio, main machinery, auxiliaries, facilities attached to architecture, lighting fixtures, plug sockets, power source for work<br>･Examination of grounding fault |

| | | | |
|---|---|---|---|
| 6 | Examination of condition of main circuit<br>・Rated current<br>・Computation of breakdown<br>・Improvement of power factor | ・To prepare impedance map, carry out respective computation, and select main machinery and spec of cables.<br>・To examine capacity of capacitors, number of banks. | ・Rated current, impedance, short-circuit current, fluctuation in voltage, allowable current, voltage drop,<br>・Points to connect capacitors, method for power factor control, capacitor capacity, reactor capacity, measures for harmonics |
| 7 | Computation of various capacities | ・Decision of capacity of non-utility generator, uninterruptible power supply (DC, AC) etc. | ・Model, generator output (4 types), motor output (3 types), type of fuel, stock of fuel, noise, flow of air inhalation and exhaust<br>・Compensation time, required condition on loading side, parallel operation, non-short-break switching, measures for harmonics<br>・Type of rechargeable batteries, number of cells, method of recharging. |
| 8 | Examination of types of measurement and protection | ・Detailed examination of type of protection, type of measurement, and measures for harmonics | ・Overcurrent, short-circuiting, grounding fault, power failure, open-phase, negative-phase, rise in temperature, internal breakdown of machinery<br>・Selective type of isolation, coordinated curve of operation, relay setting value, coordination of insulation, interlock<br>・CT, ZCT, VT, ZPD, EVT<br>・Current, voltage, power factor, power, power consumption, pulse abstraction |
| 9 | Decision of equipment layout | ・To decide layout based on examination of future plan | ・Measures for expansion, measures for replacement, free space, inspection pathway, work space, carry-in space, wiring route, floor load, ceiling height<br>・Ventilation apparatus, lighting fixtures, fire retarding division, firefighting equipment, emergency lighting<br>・Maneuverability, visibility |
| 10 | Examination of control method | ・To examine automatic control method of receiving and transforming equipment, and select necessary equipment | ・Manned, unmanned, location of control, items of inspection and control (site, remote), communication channel, items of automation (switching of power source, shifting of load, switching of in-house transformer, power factor control), demand inspection<br>・Monitoring panel |
| 11 | Selection of type of receiving and transforming Selection of equipment | ・Decision of type of power receiving, and type of equipment (transformer, breaker), and their spec.<br>・Examination of power source for control | ・GIS, C-GIS, breaker, disconnector, switch, contactor, power fuze, lightning arrester, transformer, capacitor, reactor, transformer, protective relay, meters, cables<br>・Rating, method of insulation, heat resistance class, protection class<br>・Indoor, closed space, multi-layer piling, type of latch<br>・Power source for control (division, type, voltage) |
| 12 | Examination of related laws and regulations | Reexamination of such regulation as Electric installation engineering standards | Legislative checking needed for facilities as a whole. |
| 13 | Others | Consultation with related government offices at all times | Ministry of Economy, Trade and Industry, power companies, and fire department, and telecommunication carriers |

**Preliminary survey**

=>Site survey and preliminary consultation with the power company

Receiving voltage, voltage fluctuation, lead-in wire (aerial, underground),lead-in route and receiving point, boundary of responsibility and that of property ownership, frequency of power failure, frequency fluctuation, need for lightning arrester, disconnecting capacity of disconnector for receiving, burden charge for lead-in.

**Decision of capacity of transforming equipment**

=>Obtained from loading factor, demand ratio, and unbalance ratio

**Decision of distribution voltage**

=>Determined by contents of the load

There are common load (lighting, power apparatus etc.), which are not related to the use of the building, and special loads with different uses.

**Decision of connection type of main circuit**

=>Preparation of single-wire diagram

Receiving method (1 circuit, 2 circuits), main breaker, contract demand, transformer bank composition, capacitor bank composition, switches for capacitors, protective method, meters, distribution method, number of diversions on the secondary side and their capacity,

**Decision of control method & method of protection**

=>・Monitoring & control method (Upkeep & management system, items for upkeep & management), remote monitoring and control method, data logger, computer etc.

・Protection method (Selection of relay, coordination of protection etc.),

**Decision of type of transforming equipment**

=>Transformers are roughly divided into cubicle type and open-air type.
They are grouped into B type, PF・CB type, PF・S type by method of protection.

**Decision of apparatus to be used**

=>・Transformer, breaker, power fuze, load switch, metal closed type switchgear and control gear, power capacitor, lightning arrester, UPS etc.

・AC current meter & voltage meter, power meter, frequency indicator, power factor meter, reactive-power meter, CT, PT, VCT, overcurrent relay, grounding fault overcurrent relay, short voltage relay etc.

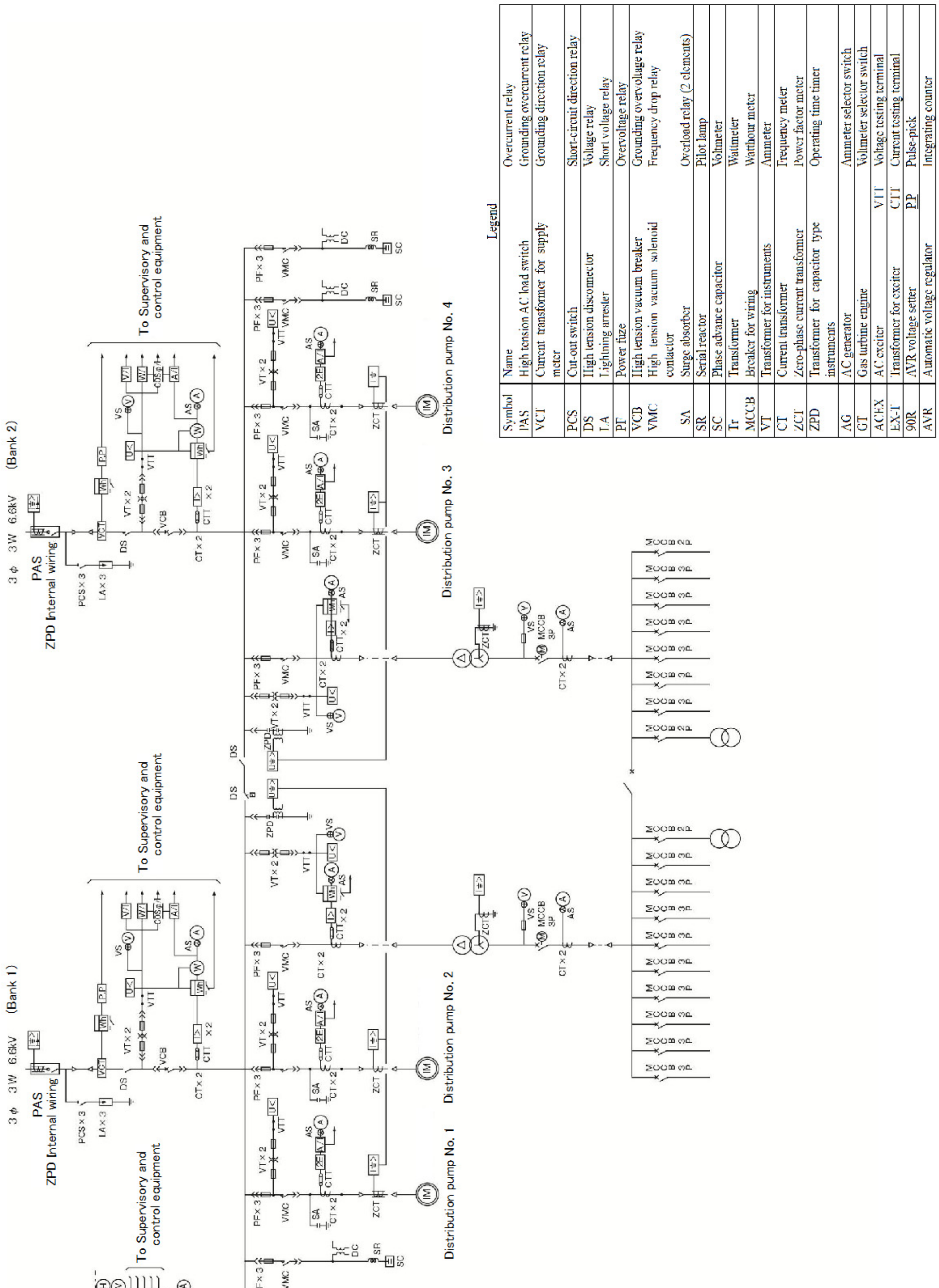
**Decision of location of substation and its area**

=>Location of substation shall desirably be in the center of loads from cost point of view. Location may be indoor/outdoor, roof, underground etc. depending on the surroundings and use of the building.
The area needed for the substation largely varies depending on the capacity of transformer. Additionally, space for replacement or expansion, carry-in and –out of equipment and maintenance etc.

**Layout of apparatus**

=>Layout in consideration of traffic line for safe upkeep & inspection and route of carry-in and –out of equipment and maintenance etc. at times of replacement or expansion.

**Figure 8.8.3 Diagram of planning process of high tension receiving and transforming facilities (Planning of small scale)**




| Symbol | Name | | |
|---|---|---|---|
| | | | Overcurrent relay |
| PAS | High tension AC load switch | | Grounding overcurrent relay |
| VCT | Current transformer for supply meter | | Grounding direction relay |
| PCS | Cut-out switch | | Short-circuit direction relay |
| DS | High tension disconnector | | Voltage relay |
| LA | Lightning arrester | | Short voltage relay |
| PF | Power fuze | | Overvoltage relay |
| VCB | High tension vacuum breaker | | Grounding overvoltage relay |
| VMC | High tension vacuum solenoid contactor | | Frequency drop relay |
| SA | Surge absorber | | Overload relay (2 elements) |
| SR | Serial reactor | | Pilot lamp |
| SC | Phase advance capacitor | | Voltmeter |
| Tr | Transformer | | Wattmeter |
| MCCB | Breaker for wiring | | Watthour meter |
| VT | Transformer for instruments | | Ammeter |
| CT | Current transformer | | Frequency meter |
| ZCT | Zero-phase current transformer | | Power factor meter |
| ZPD | Transformer for capacitor type instruments | | Operating time timer |
| AG | AC generator | | Ammeter selector switch |
| GT | Gas turbine engine | | Voltmeter selector switch |
| ACEX | AC exciter | VTT | Voltage testing terminal |
| EX-T | Transformer for exciter | CTT | Current testing terminal |
| 90R | AVR voltage setter | PP | Pulse-pick |
| AVR | Automatic voltage regulator | | Integrating counter |

**Figure 8.8.4 Example of single wire diagram of a water treatment plant (distribution center)**

**On the item 4.;**

In water supply utilities, high voltage motors for 3.3 kV and 6.6 kV and low voltage apparatus for 100 V ~ 400 V are used. Since power is generally received from the power company in high tension or extra-high tension, transforming equipment is necessary to lower the voltage suitable for loads.

Although the transforming equipment is represented by the transformer, it is not unrelated to the receiving equipment and the distribution equipment, and consists of many such apparatus as breakers, lightning arresters, protection devices etc.

As the type of the transforming equipment, there are the outdoor type, the indoor type, semi-indoor type etc.

**On the item 5.;**

The distribution type shall be ranked according to the priority of the load, so important distribution main lines shall be structured with duplicated systems or loop systems so that power outage does not occur at the time of an accident or replacement. In this case, it is required to prevent total shutdown of water treatment due to power outage caused by inspection and upkeep etc. of power facilities by means of coordinating the power distribution system with the water treatment system.

As for the capacity of the main lines, it shall be determined in consideration of the occasion of shutdown of one of the systems as well as the economic benefits related to the capacity of the cables.

**On the item 6;**

Important main lines shall be formed in duplicated systems, and it is desirable to install non-utility generation equipment so that power supply for a prolonged period is possible even at the time of a large disaster.

Although there are such various forms of linkage between the generator and the commercial power source as power lines, types of apparatus of linkage, the bus type etc., a proper type suitable to the load facilities, for which such maintenance as inspection of equipment etc. is taken into account, shall be selected.

### 8.8.4. Power receiving-transforming equipment

The power receiving-transforming equipment shall be in conformity with the following:

1. The main circuit structure of the power receiving-transforming equipment shall be so designed that total power failure can be avoided as much possible at the time of inspection and upkeep, and that they are simplified to the extent possible.
2. The installed capacity (kVA) shall be for the maximum power demand (kW).
3. A disconnector or load switch (with a grounding fault protection device) as the dividing switch shall be installed at the demarcation point of responsibility for security.
4. A main breaker, which can firmly disconnect the accidental current, in the circuit on the loading side of the demarcation point of responsibility.
5. A lightning arrester shall be installed to effectively protect from an external lightning.
6. The transformer shall possess proper surplus ratio; and the principal transformer shall be composed of more than two banks of equipment so that operation is not interrupted even at the time of failure.

7. The standard high tension switch shall be the closed type switch board; and the extra-high tension switch device shall be a gas isolation type or a switch board of other closed type.
8. For the selection of equipment and materials, their reliability shall be high and they shall be standardized products conforming to the standards in consideration to the purpose of the use and the site of installation.
9. The power receiving-transforming equipment shall be rationally designed and their maintenance is easy; and at the same time they shall possess sufficient safety at the time of installation and wiring, and high resistivity to an earthquake.

**[Interpretation]**

**On the item 1.;**

Admitting the power receiving-transforming equipment is the most important one of power facilities, it is desirable to make their reliability so high as economically permitted. The main circuit of the receiving-transforming equipment shall be divided into blocks, to which the area subject to power-cut is restricted for maintenance, so that total power outage can be avoided as much as possible at the time of regular inspection.

Especially, as for the transformer for the supply meter (VCT), it shall desirably be of the 2CB + 2VCT type to avoid total power failure at the time of regular inspection in accordance with laws and regulations in consultation with the power company. Furthermore, it needs to be as much simple a circuit as possible assuming a case of an accident and restoration from it.

Figure 8.8.6 presents an example of a composition of power receiving facilities. However, it is cautioned that the layout of apparatus etc. is different from the actual single-line diagram since this example contains not only the high tension one but the extra-high tension one.

**On the item 4.;**

The vacuum type or the gas type breaker shall in general be selected. Table 8.8.3 presents characteristics of breakers.

**Table 8.8.3 Types and characteristics of breakers**

| Item | Vacuum circuit-breaker (VCB) | Gas circuit-breaker (GCB) |
|---|---|---|
| Arc-extinguishing type | Arc diffusion in vacuum | Blow of chilled SP6 gas |
| Breaking ability | Excellent. Easily causes abnormal voltage | Excellent. Good ability owing to short breaking time |
| Standard working voltage | 3.6 to 84 kV | 12 to 84 kV |
| Noise | Small | Small |
| Influence of atmospheric temperature | Not affected | Not affected |
| Maintenance | Easy | Easy |
| Safety | Incombustible | SF6 gas is non-toxic, odorless and incombustible |
| Life of contact | Excellent | Excellent |

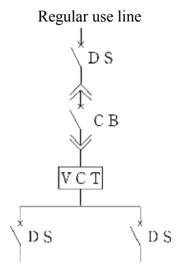
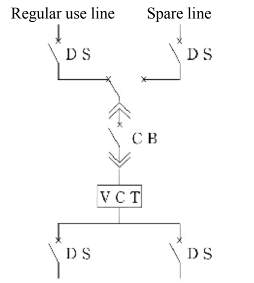
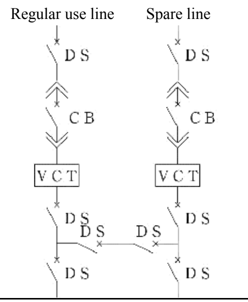
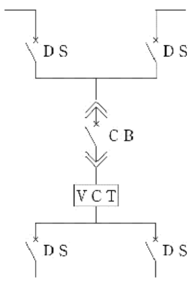
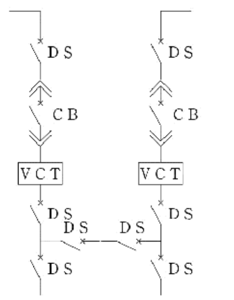
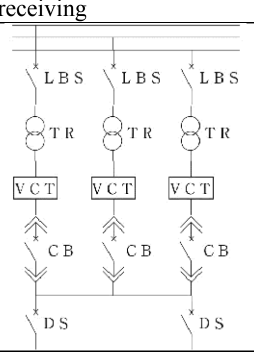
| Receiving type | | 1Circuit receiving | Regular・spareReceiving (1VCT) | Regular・spareReceiving (2VCT) |
|---|---|---|---|---|
| Distribution type | |   |   |   |
| Reliability of supply | At system fault | Total power outage | After temporary outage, Then switching | After temporary outage, Then switching |
| | At 1 circuit fault | Total power outage | After temporary outage, Then switching | After temporary outage, Then switching |
| | At power cut at upkeep | Total power outage for the work upstream of VCT | Total outage during work for VCT | No need for power cut |
| Economy · space | | Most economical · saving space | Cheap · saving space | Slightly expensive · saving space |
| Receiving type | | Loop type receiving (1 VCT) | Loop type receiving (2 VCT) | 3-circuit spot-network receiving |
| Distribution type | |   |   |   |
| Reliability of supply | At system fault | Uninterrupted power supply | Uninterrupted power supply | Uninterrupted power supply |
| | At 1 circuit fault | Uninterrupted power supply | Uninterrupted power supply | Uninterrupted power supply |
| | At power cut at upkeep | Total outage during work for VCT | No need for power cut | No need for power cut |
| Economy · space | | Cheap · saving space | Slightly expensive · saving space | Expensive · large space needed |

**Figure 8.8.6 Example of composition of power receiving facilities**

**On the item 6.;**

Although there are various types of transformers, the molded type or the gas-insulated type shall desirably be selected from the disaster prevention and security points of view. The matters to be designated on the occasion of adopting a transformer are shown in Table 8.8.4.

**Table 8.8.4 Matters to be designated for the transformer**

Rating & common specification: Matters stated here are mandatory. JEC 2200 (1995)

| | Matters to be designated | | Matters to be designated |
|---|---|---|---|
| 1 | Rating to be applied | 13 | Existence of tap-switching device<br>In the case of existence<br>· Designate no-voltage tap-changing device, and tap-changing device with load. And indicate method of operation.<br>· Designate the winding to which the tap belongs.<br>· Designate the standard tap voltage and all the tap voltages.<br>· Designate the existence of reduced tap voltage (If existing, designate its capacity.) |
| 2 | Model name | | |
| 3 | Number of units | | |
| 4 | Number of phases | | |
| 5 | Type of transformer (oil-immersed transformer, dry type transformer, gas-filled transformer)<br>· Oil-immersed transformer (Select mineral oil or synthetic oil)<br>· Gas-filled transformer (Type of gas)<br>· Dry type transformer (Designate type)<br>· Dry type transformer, gas-filled transformer (Designate the heat-resistance class) | | |
| 6 | Location of installation (Outdoor, indoor) | 14 | Connection method of the system |
| 7 | Cooling type | 15 | Short-circuiting capacity of the system |
| 8 | Cooling unit (Designate mounted on the body or placed separately) | 16 | Value of lightning pulse resistance testing voltage, and value of AC resistance voltage |
| 9 | Rated capacity<br>· In the case of multiple winding transformer (Designate capacity for each winding and the ratio of capacity of each winding to be used.) | 17 | Connection symbol or connection and polarity |
| | | 18 | Pulling-out of terminals |
| | | 19 | Condition of fabrication (Designate allowable max. size, weight etc.) |
| 10 | Line capacity (Designate in the case of series transformers and voltage regulator when loaded.) | 20 | Condition of transportation (Designate allowable max. size, weight etc.) |
| 11 | Rated voltage | 21 | Power source for auxiliary apparatus and protection circuits<br>· Designate the power source for oil pump, cooling fan, gas blower, tap switching device etc. |
| 12 | Rated frequency | 22 | Method of preventing deterioration of oil (Open air type, sealed type) |

### 8.8.5. Distribution equipment

The Distribution equipment shall be in conformity with the following matters:

1. The distribution voltage shall be determined in adequate consideration of the purpose of its use and the characteristics of the load side.
2. The type of distribution shall be selected in accordance with the load.
3. In each distribution line, breakers etc. which can safely close and break the load current flowing in the line and accidental current, shall be installed.
4. The switches for distribution shall be of the enclosed type switchboard.
5. Cable shall be used as the line. The line shall have a structure of which maintenance is easy.

**[Interpretation]**

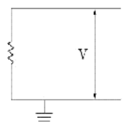
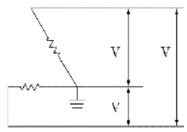
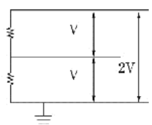
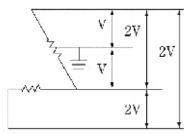
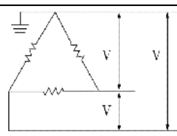
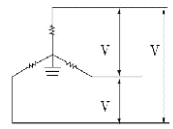
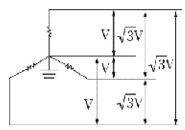
**On the item 1.;**

The distribution voltage shall be determined according to such condition as the capacity of the loads, the voltage drop of the distribution line etc. From the entire distribution system point of view, however, it is desirable for the types of voltage to be reduced to a few. In case the distribution equipment is divided into several groups, the same voltage shall be used in the respective group.

**On the item 2.;**

As, shown in Table 8,8.6, there are different types of voltage, the number of lines used as the type of distribution, the type shall properly be selected in accordance with the uses and loads since it affects the cost and reliability.

**Table 8.8.6 Types of distribution**

| | | | |
|---|---|---|---|
| [Single phase two-wire type (1 $\phi$ 2W)]<br>Generally used in case load capacity is less than 30kW. Often used when obtaining single phase 100V from 3-phase 200V, generated by an emergency generator, through Scott transformer. |  | [V-connection 3-phase 3-wire type (3 $\phi$ 3W)]<br>Output is 57.7% of that of type Y connection. Capacity factor is 86.6% of capacity of the transformer. |  |
| [Single phase three-wire type (1 $\phi$ 3W)]<br>Often used in case single-phase load density is high. Voltage between both sides of lines is 200V, and that between the side line and the neutral line is 100V. As a merit, it can feed fluorescent lamp with 200V, so widely used. |  | [Different capacity V-connection 3-phase 4-wire type]<br>A combination of single phase three-wire type of 100/200V and V-connection 3-phase 3-wire type. |  |
| [3-phase 3-wire type (3 $\phi$ 3W)]<br>Widely used as power source for loads for 3-phase induction motor etc. Voltages of 200V and 400V are often used. But the low voltage line of 400V circuit is of Y-connection (neutral point grounding). | <br>Or<br> | [3-phase 4-wire type (3 $\phi$ 4W)]<br>Used for 240/415V and 220/380V. If single phase load is uniformly connected to the outside and neutral lines, no current occurs in neutral line. Besides, voltage is often directly stepped down from extra-high tension to 400V, so as a merit high-tension transformer, breaker etc. can be omitted. |  |

**On the item 5.;**

If the distribution lines to main facilities are cables, there will be fewer cases of deterioration in insulation and breakage by wind and snow, and their arrangement is easy. For their selection, it is needed to examine conditions for installation etc. Figure 8.8.10 presents the steps for selection of the cable.

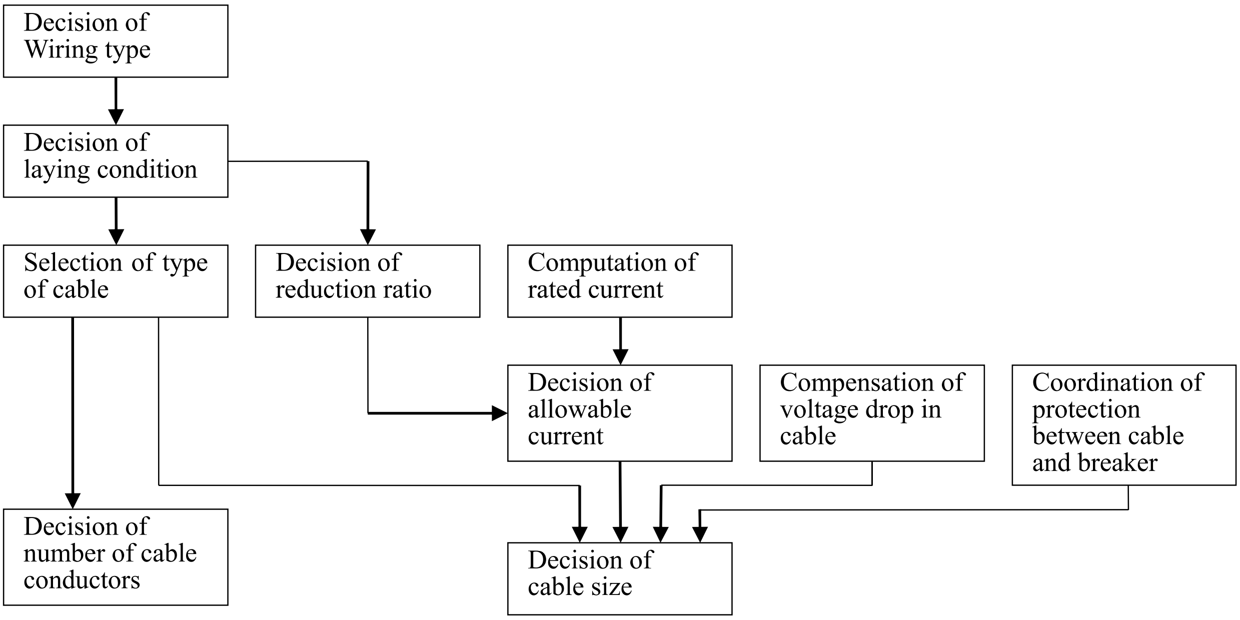



**Figure 8.8.10 Steps for selection of the cable**

### 8.8.6. Power plant

The power plant shall be in conformity with the following:

1. It shall be situated in the vicinity of load groups, and be of an enclosed type switchboard.
2. Breakers or fuzes, which can not only turn on and off the load current but safely disconnect an accident current, shall be installed.

**[Interpretation]**

**On the item 1.;**

It is desirable for the power plant to be situated as much close to the loads and their center as possible.

Although only one power plant will suffice in a pumping station etc. where loads are concentrated, power plants shall preferably be collected into several groups. In this case, it is desirable to divide the plants in consideration of the systems of the water treatment processes. Additionally, a bus, which has important and large loads, shall desirably be divided into two systems so as to minimize the power outage as much as possible due to an accident or maintenance.

The loads need to be divided into groups in consideration of the voltage suitable to the capacity of the respective loads.

The lines laid to the loads shall be cables, which possess proper allowable current in consideration of voltage drop, rise in temperature, and short-circuiting current.

**On the item 2.;**

As the load switch for high tension, there are the high tension combination starter units, which are divided into the vacuum type, the atmospheric type and the gas-filled type.

### 8.8.7. Protection and security equipment

> The protection and security equipment of the power plant shall be in conformity with the following:
>
> 1. Assuming that abnormal current occurs in the circuit, adequate coordination of protection shall be provided between apparatus for the prevention of a collateral accident, and the containment of power outage to a small local area at the time of an accident.
> 2. Sufficient coordination of insulation between apparatus shall be provided against abnormal voltage in the circuit.
> 3. Respective apparatus shall be guarded by proper protective devices.
> 4. Grounding shall effectively be made by each of groups of apparatus.
> 5. Respective apparatus shall possess sufficient provision for prevention of electric shock as well as an interlocking mechanism to avoid operational errors.

**[Interpretation]**

**On the item 1.;**

As abnormal currents occurring in the circuit, there are overload current, short-circuiting current and grounding current. These abnormal currents may give electric, mechanical and thermal stresses to apparatus, and so break or burn them. Therefore, when such abnormal current occurs, the lines need to be able to withstand such abnormal current, and such current shall quickly be eliminated to prevent spread of the accident.

The device, which detects such anomaly and gives instruction, is the protective relay; and the devices, which eliminate it, are breakers, load switches, fuzes etc.

Since the basis of such operation is the failure current at the receiving point, the incidence shall be confirmed with the power company, and then the failure current (short-circuiting and grounding fault) needs to be computed with an assumption.

Based on this, the respective types of protection downstream of the receiving point shall be examined, and coordinated measures shall be implemented to prevent the spread of the incidence to the system of the power company, and minimize the section and time of power outage.

**On the item 2.;**

Abnormal voltages occurring in the circuit are classified into the lightning surge (lightning pulse) as the external abnormal voltage, the switching surge as the internal abnormal voltage, and the continuous abnormal voltage.

Coordination of insulation means that, setting the dielectric strength of the line, the line can withstand the internal abnormal voltage, and it is protected from the external abnormal voltage by means of making the lightning surge voltage lower than the dielectric strength of the line by a lightning arrester.

**On the item 3.;**

The respective apparatus shall possess sufficient short time resistance (short-circuiting strength) and a withstand voltage to resist the abnormal current or voltage during an accident.

The measures for protection of apparatus shall be in conformity with the "Electric installation engineering standards", and the following matters shall be taken into consideration:

(1) As breakdown of the main body of such oil-immersed apparatus as the capacitor etc. brings about serious influence, it shall embody a detecting device for internal malfunction, and its

protection shall be able to be made by breaking by itself.

(2) As for the distribution line in trouble with an accident, the related circuit shall be able to be selectively cut off.

(3) The current transformer shall be of the molded type, and compatible to the overcurrent strength (withstand current) and overcurrent coefficient (saturation ratio of magnetic flux density).

(4) Cables connecting the apparatus shall not only sufficiently be able to withstand the short-circuiting current but coordinated with the breaking characteristics.

**On the item 4.;**

The purpose of grounding is to aim at the prevention of electric shock, avoidance of damage of apparatus, and evasion of fire and explosion. In addition, as the damage of electronic parts by the wraparound of the accident current from the grounding at the high-tension side is a problem, caution shall be paid to separate the grounding of the high-tension side from that of the weak current side, and keep distance between them.

The installation of grounding is prescribed in the four types, namely, Type A, Type B, Type C and Type D in accordance with the “Electric installation engineering standards”, and classified by purpose into the system grounding, apparatus grounding, lightning grounding, static grounding, electronic grounding etc. The types of grounding is presented in Table 8.8.9.

In case the thickness of the grounding line is determined, although it shall be determined from (1) mechanical strength, (2) corrosion resistance, (3) current capacity, it is mainly decided with emphasis on (3) current capacity based on the allowable temperature (150℃) of copper wire according to the regulation on internal wiring.

The following matters shall be considered for grounding:

(1) Against surge by induced lightning, the reverse voltage shall be prevented by range-rods grounding etc.

(2) The grounding point for lightning and that for weak current apparatus shall be placed apart from each other to avoid interference.

(3) The grounding resistance for such electronic equipment as communication apparatus and computers shall be less than 10Ω

(4) The grounding line and the earth rod for apparatus connected to the lines protected by an earth leakage breaker, and those not protected shall as a general rule not be shared.

(5) A grounding terminal panel for the purpose of testing the grounding resistance shall be provided at such a location as the electric room suitable for its maintenance.

**Table 8.8.9 Types of grounding**

| Type of installation | Grounding resistance | Thickness of earthing line | Location of connection |
|---|---|---|---|
| Type A | Less than 10 Ω | Dia.>2.6mm | Arresting equipment (arrester, lightning rod), metal rack or case of high-tension and extra-high-tension apparatus |
| Type B | Less than 150/I Ω (300/I: When voltage of low voltage line exceeds 150V due to mixed touch, automatic breaking within 1 to 2 sec., 600/I: breaking within 1 sec. under the same status.) | Dia.>4.0mm | Neutral node of the low voltage side of coupling transformer between the high-tension or extra-high-tension line and the low voltage line (In case there is no neutral node, use one terminal of low voltage end.) |
| Type C | Less than 10 Ω (500 Ω : Automatic breaking within 0.5 sec. at grounding fault.) | Dia.>1.6mm | Metal rack or case of low voltage apparatus. (In case >300V) |
| Type D | Less than 100 Ω (Automatic breaking within 0.5 sec. at grounding fault.) | Dia.>1.6mm | Metal rack or case of low voltage apparatus. (In case <300V, and installed in a DC line and AC line with <150V) |

### 8.8.8. Equipment for improvement of power factor

The equipment for improvement of the power factor shall be in conformity with the following:

1. Improvement of the general power factor of the receiving-transforming equipment shall be aimed.
2. It is desirable to set phase advance capacitors directly in parallel in the motor circuits, and, at the same time, groups of high-tension phase advance capacitors for the improvement of the general power factor in the high-tension bus.
3. Current-limiting fuzes etc. shall be set in the main circuits of the capacitors to protect them from internal failures individually and prevent collateral accidents.
4. Such discharge devices as serial reactors, discharge coils etc. shall be fit on the phase advance capacitors according to needs.
5. The high-tension phase advance capacitors shall be divided into more than two groups so that they can be controlled separately.

**[Interpretation]**

**On the item 1.;**

Many of such power loads as motors, transformers etc. used in water supply reduce their power factor because of increase in reactive power due to their nature as an inductive load. Since the loading current increases as the power factor declines, the load current increase bringing about the rise in power loss and voltage drop, improvement of the power factor needs to be made by phase advance capacitors which are capacitive loads. If the power factor is improved, energy saving and decrease in power bills can be achieved by reduction in power losses.

The effects of the improvement in the power factor are as follows:

**(1) Reduction in power charges**

a. The basic charge is discounted according to the rate of improvement in the power factor after the installation of phase advance capacitors based on the rate schedule stipulated by respective power companies.
b. Since, as stated later, the line loss and transformer loss (copper loss) in the facilities of customers are reduced by the installation of phase advance capacitors, the commodity charges can be

discounted according to the reduction in such losses.

**(2) Increase in allowance in facilities**

An allowance in the capacity of the receiving and distribution equipment can be obtained as much as the reduction in apparent current owing to improvement in the power factor, and so the expansion of the facilities or the augmentation in loads will become possible.

**(3) Decrease in the loss in the line**

The loss caused by the resistance from the point of the installation of the phase advance capacitor to the power source side is reduced owing to the decrease of current in the line (apparent current) as a result of the improvement in the power factor.

**(4) Reduction in the loss in the transformer**

The copper loss from the point of the installation of the phase advance capacitor to the transformer is reduced by the decline in the line current (apparent current) because of improvement in the power factor.

**(5) Reduction in the voltage drop in the line**

As the voltage drop in line attributable to the impedance of the line from the point of the installation of the phase advance capacitor to the power source side is reduced by the decline in the line current (apparent current) because of improvement in the power factor, operational efficiency of loads is increased. It is cautioned, however, that the line voltage may increase in some cases if the power factor extremely advances.

### 8.8.9. Uninterruptible power supply

The uninterruptible power supply shall be in conformity with the following:

1. Its composition shall have reliability coordinated with the priority of the loads.
2. The capacity of the equipment shall be determined based on an adequate study on loads in consideration of the capacity required in the normal, power outage and instantaneous time (at the time of start).
3. The equipment shall be of a closed type stowed in a switchboard with provisions for an earthquake and temperature control.
4. Distribution to the loads shall be systematized and divided into blocks; and breakers for wiring shall be installed in each circuit to avoid the spread of an accident.

**[Interpretation]**

**On the item 1.;**

For the operation of water supply facilities, it is required that reliable control and supervision can be carried out at not only the normal time but such emergency as power failure etc. As such, the uninterruptible power supply (UPS), which feeds power required for the above facilities, needs to have even higher reliability.

On the other hand, due to the loading situation, it is often not allowed to stop supply once loading is started. Therefore, consideration needs to be taken so that regular inspection and expansion and improvement can be undertaken without power-cut.

The UPSs are divided into the DC power supply and the AC UPS.

**1) DC power supply**

The DC power supply consists of a rectifier and rechargeable batteries. It is mainly used for the control circuits for the receiving-transforming, distribution equipment etc. and the circuits for indicator lamps, and possesses rechargeable batteries except for small facilities.

**2) AC uninterruptible power supply (UPS)**

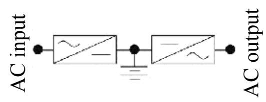
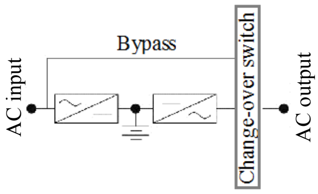
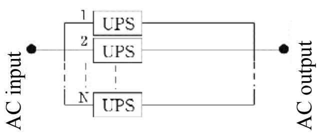
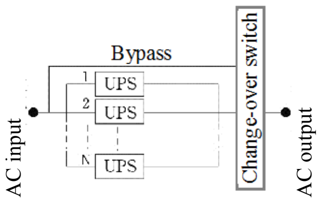
The AC UPS is composed of a rectifier, batteries and an inverter device. It is used as the power source for instrumentation apparatus, supervisory and control equipment, communication equipment, and required to supply quality AC power at all the time without power failure.

When choosing the UPS, the form of its use, redundancy needed at the time of assumed breakdown of the main body, and the ease of O&M shall be considered, and attention shall also be paid to the reduction in its lifecycle cost. The adoption of batteries of long life and reduced need for maintenance is desirable.

Although the compensation time for power outage is various depending on the objective loads and the use of the UPS, they are roughly divided into two cases: the case to deal with the time needed only for saving data, and another case to sustain for time up to the power supply restoration. A general use UPS for ten minutes will suffice for the former whereas, in the latter case, it shall be determined in respect to such condition as the priority of the loads, the existence of a non-utility generator etc. Types and characteristics of the UPS are presented in Table 8.8.10.

## Table 8.8.10 Types and characteristics of the UPS

JEM-TR185 (1993)

| System | Item | Type name | | Block diagram | Outline of the type | Features |
|---|---|---|---|---|---|---|
| Single UPS | With no commercial bypass | Operation by a single unit | |  | One unit operation. Often used together with bypass type except for different input frequency from that of output. | Can be a compact system, but power source is cut off in the case of failure. |
| | With commercial bypass | Regular supply from commercial source | Cold standby operation type |  | Commercial source supplies power to loads at normal times. When power failure occurs, inverter is turned on and feeds power. | Power is cut at the time of change-over from commercial source to inverter, vice versa. In case the input to bypass is non-utility generator, caution is to be paid for coordination with loads. |
| | | | Hot standby operation type | | Commercial source supplies power to loads at normal times. When power failure occurs, power is fed from inverter which is always in standby operation with no lead. | |
| | | Regular supply from inverter | Asyn-chro-nous operation type | | Power is fed from inverter to loads in normal times. | As change-over switch is mechanical, power supply is temporarily cut at the time of change-over. |
| | | | Commercial synchronous operation type | | Power is fed from inverter to loads in normal times. Inverter is synchronized with commercial source within an allowable range. | As change-over switch is semiconductor, power supply is changed without temporary cut-off at the time of change-over. |
| Parallel Redundant UPS | With no commercial bypass | Parallel redundant operation without bypass | |  | In case 1 unit fails with system capacity of UPS parallel redundant units (N-1), the failed unit is separated, and power is fed from the remaining unit without impediment. | UPSs are mutually synchronized and their load allocation is controlled, degree of redundancy is raised. |
| | With commercial bypass | Parallel redundant operation with bypass | |  | In case 2 units fail with system capacity of UPS parallel redundant units (N-1), or overloading, change-over switch is turned from UPS to bypass with no temporary cut-off | Since it is a combination of synchronization with commercial source and UPS parallel redundant units, reliability of power supply is high. |

# 8.9. Non-utility generation equipment

## 8.9.1. General

As non-utility generation equipment, there are the emergency use generation equipment to secure a power source required at the time of power failure, and the common use generation equipment installed for the purpose of leveling-off of loads, peak-shaving of power etc.

The emergency use generation equipment is installed to reduce impediments of curtailed or suspension of water service caused by power failure as much as possible. To this end, it can safely and quickly generate power at the time of power failure; change-over of power sources in a short period of time is possible; and the storage of fuel for the internal-combustion engine for driving the equipment and its day-to-day upkeep are easy. Additionally, it shall be considered that the equipment is to be installed preferentially in the main water treatment plant, that it can operate continuously to deal with the assumed risk and is secured with sufficient fuel, and that the location of its installation is selected so as to be safe from storm and flood damages etc.

The common use generation equipment shall be examined for its introduction in case the improvement of the general efficiency can be achieved and so forth.

### 8.9.2. Basic design

The design of the non-utility generation equipment shall be in conformity with the following:

1. Emergency use generation equipment shall be installed in main facilities if required. Its capacity shall be determined by summing up the capacity of powered facilities to be secured.
2. The non-utility generation equipment shall be high in reliability, and its starting shall be infallible.
3. In case the utilization of thermal energy can be applied, the installation of common use generation by means of a cogeneration system shall be examined.

**[Interpretation]**

**On the item 1.;**

As for the emergency use generation equipment, its need and capacity shall be determined based on the examination of the operational condition etc. of the facilities at the time of the failure of the commercial power source. The need and capacity shall be decided in accordance with the sum of the capacity of powered equipment to be secured at an emergency based on the water management plan for the entire water supply system during power outage, which covers the situation of power failure of the commercial source, state of reduction and suspension of water service and so on. The specification, continuous operation time and stockpile of fuel shall be determined based on the sum of the capacity.

The power required as the emergency power source is divided into the one for security of facilities and the other one for their operation.

**(1) Power for security of facilities**

Power for security is for emergency lighting, instrumentation, driving of part of valves, neutralization equipment for chlorination facilities, communications, firefighting etc., all whose capacity shall desirably be secured.

**(2) Power for operation of facilities**

Power for facilities operation is for power for the operation of water treatment processes and the other one for main pumps; and the former is for the sedimentation basins, chemical dosing equipment, the filters etc.

In case raw water intake and water distribution systems are performed by gravity, the capacity of generation, with which almost normal operation can be made, shall desirably be secured.

In case water transmission and distribution are carried out by pumping, the capacity of generation shall be so much as to restrict the influence of power outage to a minimum based on the provision of mutual supply from and to other water utilities, the capacity of service reservoirs, the reliability of the power sources, economic benefits etc.

**On the item 2.;**

Since the non-utility generation equipment needs to rapidly supply power to important loads at the time of failure of the commercial power source, it shall possess high reliability so that the start of the generator is infallible. In addition, starting of the generator shall be automatic, and its handling, operation and maintenance shall be easy.

### 8.9.3. Type

In case emergency generation equipment is installed, the generator shall be a synchronous generator; the type of its excitation shall be brushless excitation or static excitation; and the standard engine shall be a gas turbine or diesel engine.

**[Interpretation]**

**1. Generator**

As the generator for the emergency use generation, 3-phase synchronous generator is mainly used.

**2. Engine**

A comparison of the gas turbine generation equipment and the diesel engine generation equipment is presented in Table 8.9.2.

**Table 8.9.2 Comparison of gas turbine generation equipment and diesel engine generation equipment**

| Item | Gas turbine generation equipment | Diesel engine generation equipment |
|---|---|---|
| Principle of function | Thermal energy is directly converted to rotational movement (rotational engine) | Thermal energy is converted to reciprocal movement (reciprocal engine) |
| Starting ability | After power failure, time up to establishment of voltage is relatively long (20 to 40 sec). Warming up not needed in a cold district. | After power failure, time up to establishment of voltage is short (5 to 40 sec). Warming up needed in a cold district (Starting in low temperature is relatively difficult.) |
| Casting of load | Instant casting of all loads possible after voltage establishment. | Instant casting of all loads impossible after voltage establishment. (One with supercharger is especially a problem) |
| No-load operation | Possible. | Undesirable due to imperfect combustion and carbon stain. |
| Fuel consumption | Little difference between low speed operation and high speed. So disadvantageous in low speed range 190 ~500g/PS･hr. | 15 0~230 g/PS･hr. |
| Fuel to be used | Natural gas, kerosene (A diesel oil, B diesel oil,C diesel oil, kerosene, propane gas) | A diesel oil (B diesel oil,C diesel oil, kerosene) |
| Cooling water | Because of air-cooling, no cooling water needed, so no influence of water supply suspension | Cooling water needed. (No need in the case of radiator) |
| Quantity of air needed | As large quantity of air needed for combustion and cooling, big size of air intake & exhaust needed (2.5 to 4 times that for diesel engine). | Small amount needed for combustion and room cooling |
| Vibration | Owing to small vibration, vibration isolation not needed. | Due to large vibration, vibration isolation needed. |
| Noise | Because of high frequency sound source, silencer needed. | Silencing is difficult (Low frequency, big vibration) |
| Mass and weight | Owing to small size and light weight, small installation space and simple foundation | Due to large size and heavy weight, large installation space and large foundation |
| Earthquake resistance | Anti-earthquake measure needed for the duct and piping | Such a measure as stopper of vibration isolation device needed. |
| Others | Much regular upkeep work consuming time and cost. Unsuitable to cases of frequent start-stop and change in rotation speed. | Because unsuitable for light load operation, capacity to run with nearly full load shall be selected. |

### 8.9.4. Output

> The capacity and output of the non-utility generation equipment require sufficient continuous rating values for the general power of loads.

**[Interpretation]**

The capacity of the generator and the engine shall be selected from the standard products of their manufactures. When computing them, the largest one shall be selected of the regularly required load capacity, the capacity required from the allowable voltage drop at the time of start of a motor, temporary overload capacity, capacity required from the allowable antiphase current etc.

### 8.9.5. Ancillary equipment

> The ancillary facilities of the non-utility generation equipment shall be in accordance with the following:
>
> 1. Refueling equipment shall be provided for the generator, and fuel in sufficient quantity to deal with an accident and a disaster shall be stored.
> 2. For the refueling equipment, a control switchboard, a switcher from the commercial source, and various protective devices shall be installed.
> 3. Such auxiliary equipment as starting apparatus etc. shall be furnished with motors.
> 4. A ventilation apparatus shall be equipped with the motors.
> 5. Measures for ventilation, noise, exhaust gas, resistance to an earthquake shall be provided for motors; and measures for anti-freezing shall be added in a cold region.

**[Interpretation]**

**On the item 1.;**

Since the generator for an emergency is required to soundly be operated in response to sudden power failure as the purpose for its installation, fuel of good quality shall always be stored. When examining the quantity of fuel to be stored, considered shall be mutual cooperative operation of water supplies, appropriateness of operation with reduced output, the importance of the equipment, the ease of the O&M of the refueling tank, fuel consumption at the time of its test run, deterioration in the quality of the fuel, time required for refueling etc.

In general, it is desirable that the storage of fuel shall be at minimum for ten hours of operation to correspond to the accident of the power company; and for more the 24 hours for such a disaster as an earthquake.

As refueling equipment, there are a fuel tank situated 2 to 3 m above the crown of the generator to directly feed the main body of the generator by gravity (fuel tank); and a fuel storage tank which store fuel required for generation for a long time.

## 8.10. Supervisory and control system

### 8.10.1. General

The supervisory and control system plays an important role to reliably serve safe and good quality water in a cheap price working in the entire water supply system from the raw water intake facilities and the water treatment facilities to water distribution facilities. Before the establishment of the supervisory and control system, direct supervisory and control of facilities by operators were commonplace. However, the supervisory and control system has been introduced in all the processes accompanied with the advancement of instrumentation technologies so as to properly control water quantity, pressure and quality, to raise the reliability and safety, and to save cost. It can safely be said that no water supply facilities can run without the supervisory and control system today.

The structure of the supervisory and control system is the combination of (1) the supervisory and control equipment for monitoring of respective processes of water supply facilities and control of water pressure, flow etc., (2) the equipment for data collection, analysis and service for proper management of water supply facilities and their maintenance, and (3) the equipment for transmission of required information between facilities etc., which systematize supervisory and control of the entire water supply facilities.

Therefore, the supervisory and control system shall be compatible with the size of the water supply facilities and the type of their operation and maintenance so as to precisely grasp the operational condition of the facilities. In case an abnormal incidence occurs due to a disaster, failure of equipment etc., it is afraid that resultant suspension of water service, reduced service quantity, bad water quality etc. may give severe impact to the society. As such, the reliability of the supervisory and control system needs to be improved so that the operational condition of water supply facilities can precisely be judged even at an emergency, and that they are properly operated.

### 8.10.2. Planning of the supervisory and control system

Planning of the supervisory and control system shall be in conformity with the following:

1. The supervisory and control system shall be compatible with the size of the water supply facilities, the method of water treatment, and the type of their management.
2. The composition of the system and installed equipment shall be provided with measures for its high reliability so that the influence of obstacles, when they occur, can be contained to a minimum, and that they can withstand the use for a long time.
3. The system shall possess extensibility to flexibly cope with the changes in functions of water supply facilities along with their improvement and replacement, and at the same time shall be equipped with standard models of equipment.
4. Consideration shall be paid that the life cycle cost of the system for installation, operation, maintenance and disposal is the lowest.
5. As to the location for installation of the equipment, which comprises the system, such environmental conditions as temperature, humidity, corrosive gases, dust, vibration etc. shall be taken into consideration.

### 8.10.3. Equipment for supervisory and control

The equipment for supervisory and control shall be in conformity with the following items:

1. Since there are various types of monitoring and control equipment, a proper system and equipment, which are compatible with the size, the range of monitoring and control, the system of operation and maintenance of the water supply facilities, shall be selected.
2. As for the operational function of the system, it not only can precisely indicate, record and store the information on the operation of the water supply facilities, but also shall be excellent in visual performance and maneuverability.
3. The system shall possess function required for the control of the objective facilities, and also be able to reliably perform communication and input-output of data with the apparatuses which comprise the system.

4. Safety measures to guaranty reliable water service, even when an abnormal incidence occurs on the facilities as the object of the monitoring and control system, shall be provided, and, in addition, containment of human errors shall be taken into consideration.

5. A monitoring TV apparatus shall be installed if required for raising the efficiency and safety of the operation of the water supply facilities.

**[Interpretation]**

**On the item 1.;**

The types of supervisory and control are classified into the one with the use of a computer, and the other one without it. The types with the use of a computer for control are classified into the centralized control type and the localized control type.

**1) The control type without the use of a computer for control**

The control type without the use of a computer for control is a type which directly controls the local equipment by means of relay circuits, controllers etc. installed in the central control panel and local panels. As its control type is simple, it is used in the case of relatively small size of objective equipment, and can bring large economic benefits. The sequential control and loop control are the core, so not suitable to the control, for which high level operation is needed, or the control in combination of the sequential control and the loop control. Although relay circuits are easy to inspect and maintain, it somewhat lacks in flexibility since parts and wiring need to be added and/or removed at the time of changing the contents of control. An example of its composition is shown in Figure 8.10.1.

**2) Centralized control type**

The centralized control type is a type, which performs the control and supervisory functions by means of the computer for control installed in the center, and suitable to supervision and control of relatively small facilities. Not only sequential control and loop control but also control, for which complex control and high-tech operation are required, can be performed. It possesses such flexibility as the contents of control can be changed by the replacement of the software, so the change is easier than the case of the change of such parts as relay circuits in the panel. However, it is cautioned that the change in the software is costly and that the software is affected by the discontinuation of its production and the termination of its support. An example of its composition is illustrated in Figure 8.10.2.

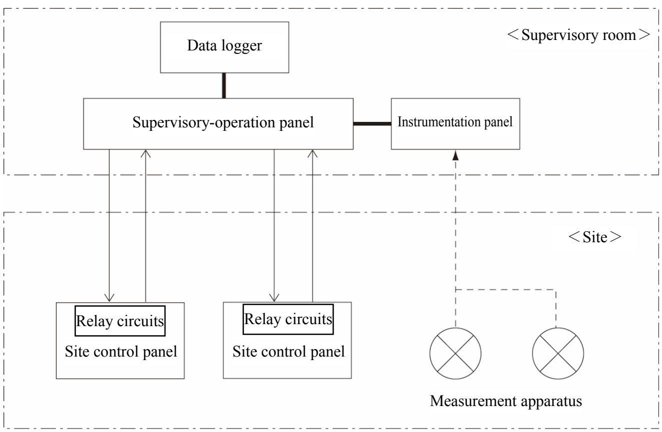



**Figure 8.10.1 Example of composition of a system without use of a computer for control**

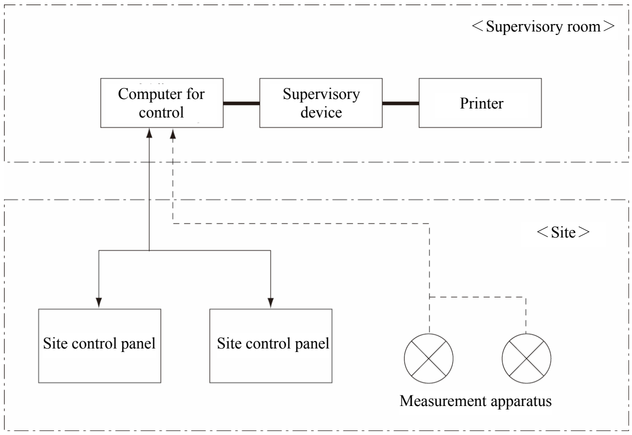



**Figure 8.10.2 Example of composition of a system of centralized control type**

### 3) Decentralized control type

The decentralized control type makes more than two computers perform control, which are installed at each water treatment process or division of facilities, to perform the control function separately. It is suitable to such facilities as a relatively large water treatment plant which possesses more than two processes of raw water intake, coagulation and sedimentation, filtration, chemical dosing, treated water transmission and distribution etc. Similar control to the one by the centralized control type is possible by it, between the centralized supervisory and control equipment and the site control devices, and between respective site control devices are connected with the control LAN etc. It has excellent extensibility in that it can contain the extent of failure of devices to its part, so the reliability of the system as a whole can be raised, and, in addition, the expansion of equipment and change in the contents of control can be dealt with by means of an addition of the computer or change in the software. However, it is cautioned that the change in the software is costly and that the software is affected by the discontinuation of its production and the termination of its support. Examples of its composition are illustrated in Figure 8.10.3 and Figure 8.10.4.

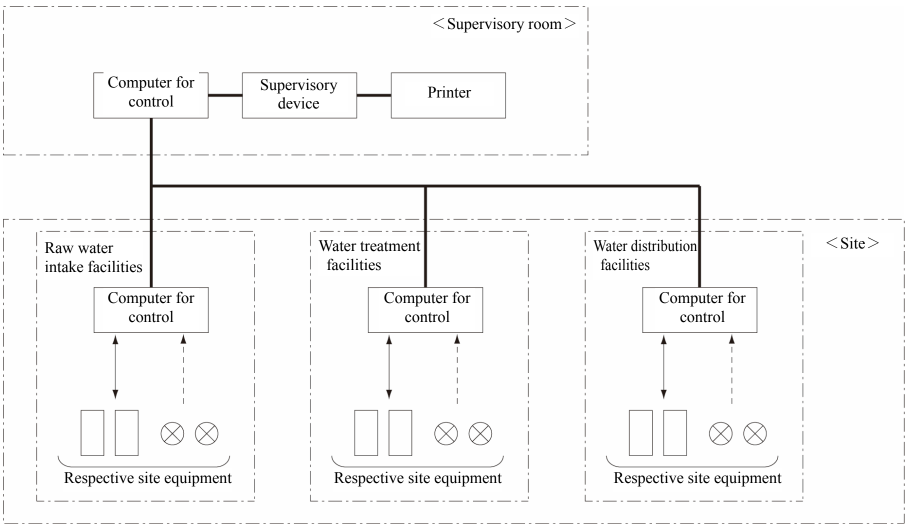



**Figure 8.10.3 Example of decentralized control type system (mid-size)**

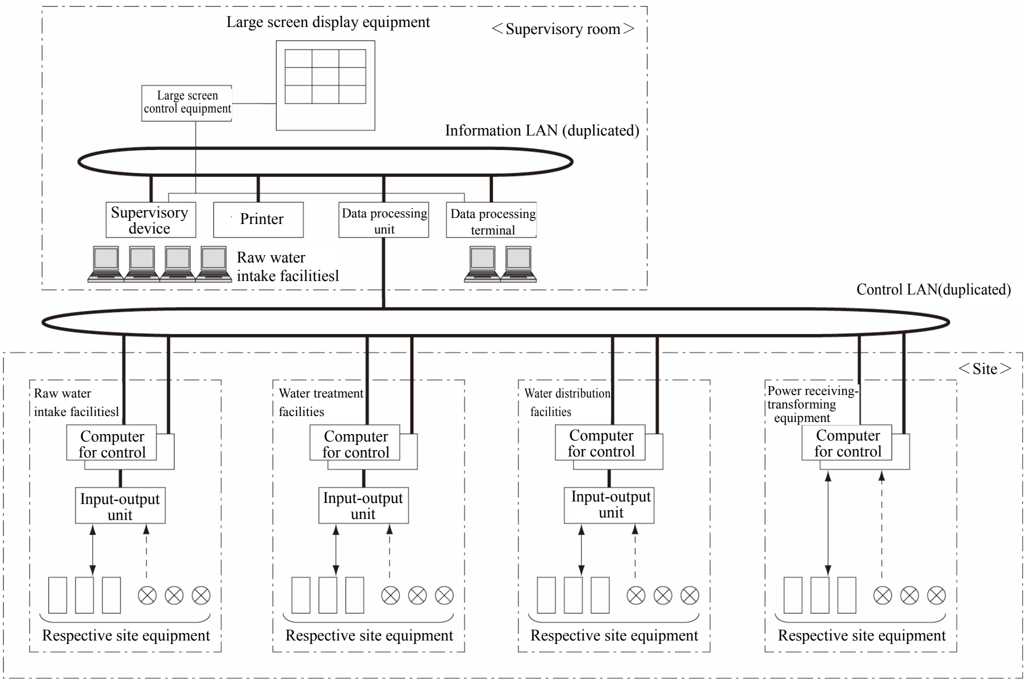



**Figure 8.10.4 Example of decentralized control type system (large size)**

**On the item 2.;**

The basic function of the monitoring and operating equipment is to monitor the operating condition of the water supply facilities, measure water flow, pressure, quality etc., indicate, record and store such information, and yield warning without fail whenever an anomaly is detected. Outline of the monitoring and operating equipment and its functions are presented hereunder.

**1) Supervisory and operating equipment**

A supervisory control panel, instrumentation panel, mini-graphic panel, visual display panel (VDP), large screen display unit, monitoring TV device etc. or their combination comprise the supervisory and operating equipment.

The supervisory and operating equipment sorts information of the operating condition of equipment and apparatus and their status of malfunction, measurement values in the water treatment processes by their purpose and use, and is required to accurately serve them to the operator in a prerequisite form in time of need. The supervisory and operating equipment shall be excellent in supervisory ability so that the operator can expeditiously and precisely recognize the operational condition.

**2) Supervisory and operating function**

**(1) Display of the status**

The status of the operation of equipment and devices and the treatment processes etc. shall be displayed on the indicator lamps and indicators of the monitoring panel and the VDT equipment so that the condition can be known by the operator of the water supply facilities.

**(2) Warning**

Failure of the equipment and devices and the occurrence and restoration of upper and lower limits of measured values shall be detected and indicated by the breakdown lamps and the VDT equipment with warning sound to report to the operator.

### (3) Recording and storing

The measured values of the processes and the history of performance of the equipment and devices shall be stored for a certain period of time, and preparation shall be made to serve them for use according to the need. Such information will be useful as the basic data for preparation of daily, monthly, yearly reports as the record of the operation of the water supply facilities, and they will also be useful for the improvement of the method of operation and the analysis of a trouble when it occurs.

**On the item 3.;**

The computer for control consists of the control function, communication function, input and output functions. The outline of the respective equipment and its functions are presented as follows:

### 1) Control function

As the type, which realizes the control function of the decentralized control type, it is largely classified into the DCS (decentralized control system) and the PLC (programmable logic controller or sequential controller).

### 2) Communication function

As the means of communication of information used in the monitoring and control system in water supply facilities, the LAN (local area network), which enables rapid transmission of large data of monitoring and control information, is the most common.

### 3) Input-output function

The input-output to and from the computer for control shall be carried out in accordance with a definite normalized standards due to the need to handle signals to be generated by various equipment and devices.

**On the item 4.;**

The technologies for safety measures aim at preventing various risks when operating the supervisory and control equipment in advance, or containing the influence of the risk to a harmless level in case it gets actualized. Typical examples of a safety measure are fail-safe, interlocking, and error-proof; and their outlines are presented below (See Table 8.10.4).

**Table 8.10.4 Example of application of safety technologies**

| | Failsafe | Interlock | Error-proof |
|---|---|---|---|
| Definition | A property given by design to be set to the safe status prescribed in advance in case one item fails. | A technology to prevent operational error, or automatically control the operation of the equipment in question in case operation deviates from the normal operating condition. | A technology to improve the job, which induces an error, to the one compatible with the nature of man so that a human error does not apt to occur and that it shall not cause a big accident even if it happens. |
| Application example | In case the input signal gets erroneous by disconnection of a cable, the present status of equipment is held without going out of control, or stopping. | Provision is made in that the disconnector shall not be actuated unless the breaker is open in the receiving-distribution equipment. | The operation of change-over of pump units is automated so that no failure shall take place. And a warning is yielded when an anomaly occurs. |

**(1) Failsafe**

Although, with the failsafe system, the facilities are generally halted in many cases to sustain the safe status in a case of failure, the “in-commission” mode is in principle held since continuous water service is important, and then the operator often judges the need for a halt.

**(2) Interlock**

With the interlock system, the operation cannot be initiated in wrong procedure so that wrong operation will not adversely affect the equipment and personnel as one of measures against human errors.

**(3) Error-proof**

The error-proof system consists of the measure to prevent human errors and that to ward off expansion of the accident. As the measure to prevent human errors, the fundamental idea is to prohibit the operator from performing the operation, or make the operation easy on precondition that human being commits an error. A typical example is automation by supervisory and control equipment. As the measure for prevention of spread of accident, even a trouble occurs, the anomaly is detected in an early stage so as to contain the damage to a minimum and prevent lethal effect of the accident. An example is an operation guidance function to assist the operator when a warning has been issued. An outline of error-proof is shown in Figure 8.10.7.

**On the item 5.;**

For the purpose of quick information gathering and efficient operation and management when an anomaly occurs in water supply facilities, the introduction of a monitoring TV system shall be considered. It possesses a function to monitor the status of water treatment processes from raw water intake through water treatment, the operating condition of such equipment as pumps, incidences of the intrusion of unidentified persons etc. Especially, at remote unmanned facilities, it is to be installed for the purpose to know the status of operation and supervise the facilities. For monitoring of intrusions, a tension sensor, an infrared sensor, a loudspeaker, a light projector etc. shall be used together.

<table>
<tr><th>Work process</th><th>Classification</th><th colspan="2">Principle</th></tr>
<tr><td>Purpose/Risk</td><td rowspan="3">Measures to prevent occurrence</td><td>Removal</td><td>Eliminate the need for a jog and attention<br><Example><br>･Removal of job ･Removal of risk</td></tr>
<tr><td>Memory<br>Sense/judgment<br>Action</td><td>Alternative actor</td><td>To replace “memory””sense/judgment””action” to be performed by man by a mechanism other than man.<br><Example> ･Automation ･Support system</td></tr>
<tr><td>Human error</td><td>Facilitation</td><td>To make easy<br>“memory” ”sense/judgment” ”action” to be performed by man<br><Example> ･Communization ･specialization<br>･Adaptation</td></tr>
<tr><td>Anomaly</td><td rowspan="2">Measures to prevent spread</td><td>Detection of anomalies</td><td>To detect errors<br><Example> ･Record of actions ･Restriction of actions ･Confirmation of result (Issuing of warning)</td></tr>
<tr><td>Influence</td><td>Mitigation</td><td>To mitigate influence of error<br><Example> ･Redundancy ･Failsafe<br>･Protection</td></tr>
</table>

**Figure 8.10.7 Outline of error-proof**

### 8.10.4. Information processing equipment

The information processing equipment shall be in conformity with the following:

1. Since the purpose of information processing equipment is to aim at optimizing the operation of water supply facilities based on the information on operation, O&M etc., a system, which is excellent in cost effectiveness, shall be constructed making clear the purpose and need for their installation.
2. Hardware and software shall be introduced depending on the contents of information processing such as the plan on water management, operation assistance etc.
3. As the constructed software and accumulated data are important assets, their utilization for the improvement of operation of water supply facilities and the replacement plan for them shall be considered.
4. Security measure shall thoroughly be implemented to reduce the risk related to information such as leak of information and intrusion of viruses.
5. Monitoring TV devices shall be installed so as to enhance the efficiency and safety of the operation of water supply facilities as required.

### 8.10.5. Transmission equipment

The transmission equipment shall be in conformity with the following:

1. The purpose of the transmission equipment is to mutually connect the remote supervisory and control equipment, the information processing equipment etc. by means of communication, so it shall be compatible with the required quantity and speed of transmission.
2. The communication channel shall be selected in consideration of the form of operation of water supply facilities, their operating method and the influence of a disaster when it occurs, whose duplication and backup shall be considered according to the priority of communication.

### 8.10.6. Provision for regionalization

1. On the occasion of constructing a regional supervisory and control system, the layout of water supply facilities, water management and risk management shall adequately be examined so that balanced operational reliability and efficiency of the facilities are considered to be realized.
2. In case existing supervisory and control systems are integrated, they shall be integrated in stages, or all at once based on the recognition of the functions to be performed by respective systems and their economic lives.

# 8.11. Instrumentation devices

## 8.11.1. General

### 1. Definition of instrumentation

The role of instrumentation apparatus for water supply is to smoothly operate water supply facilities, and it is equipment to expeditiously and unerringly acquire information required for operation and management of facilities so as to reflect them to the operation. Given this, instrumentation is defined as not only the equipment for supervision and control of facilities but rather a mechanism including the technology to effectively utilize information in a broad sense.

What's more, although instrumentation is of late regarded as the technology and equipment which handle supervision, control and information processing of facilities in many cases, instrumentation devices, in this chapter, denote such measuring apparatus as flow meter, level gauge, pressure gauge, water quality meters etc., indicator, recorder, controller, signal converter, lightning devices, simplified telemeter devices etc., so the equipment consisting of such devices for instrumentation is annotated as the instrumentation apparatus.

### 2. Purpose of installation of devices for instrumentation

The purposes of installation of devices for instrumentation are to secure the ease, reliability and safety of operation through measurement of facilities for raw water intake, raw water transmission, water treatment, treated water transmission, distribution etc., and automation and centralized management of control; as well as to optimize operation and O&M of the water supply facilities as a whole through proper information management. Therefore, at the time of installation of instrumentation devices, they shall be selected for their ability to fully exert functions required. The effects of the proper installation of instrumentation devices are expected as follows:

(1) Improvement in quality control (QC) such as water quality, flow, water pressure etc.

(2) Recognition of the operating status of facilities, and securement of reliability and safety of operation by means of rational control

(3) Expeditious and appropriate response at the time of an anomaly

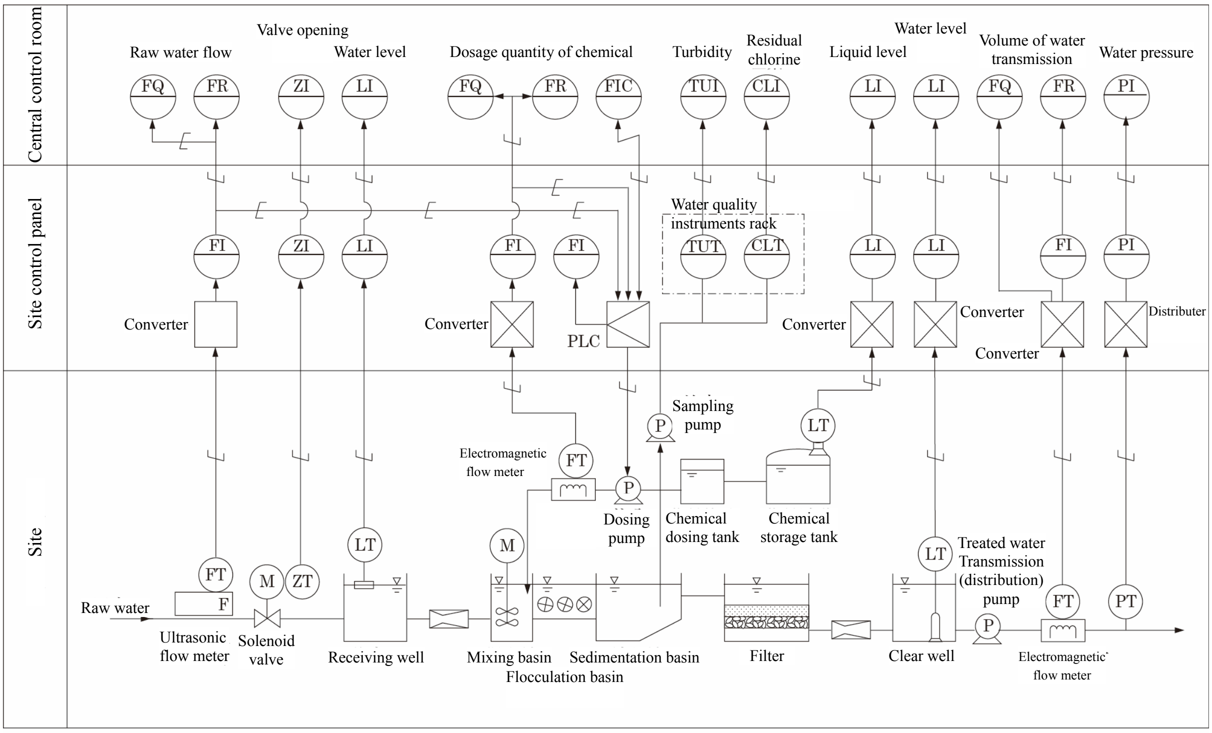
(4) Improvement in labor condition by means of reduction in labor, maintenance of safety and sanitation etc.

(5) Improvement in productivity through proper use of chemicals, power etc.

(6) Improvement in operation and management of water supply facilities as a whole and the function of facilities management by means of proper information management.

### 3. Composition of instrumentation devices

The composition of instrumentation devices is determined by the items and their number required for management and control, the safety and priority of facilities etc. As main types of measurement in water supply facilities, there are measurements of flow, water level, water pressure, and water quality, and as other measurements, meteorological measurement of temperature, humidity, precipitation etc., the electric measurements of voltage, current, power etc. An example of the composition of instrumentation devices is presented in Figure 8.11.1.




Legend

| Symbol | Name | Symbol | Name | Symbol | Name |
|---|---|---|---|---|---|
| FT | Flow meter | ZT | Potentiometer converter | TUI | Turbidity indicator |
| FI | Flow indicator | ZI | Valve opening indicator | CLT | Residual chlorine meter |
| FR | Flow recorder | LT | Level gauge | CLI | Residual chlorine indicator |
| FQ | Flow integrating meter | LI | Level indicator | PT | Pressure converter |
| FIC | Flow indicator controller | TUT | Turbidimeter | PI | Pressure indicator |

**Figure 8.11.1 Example of the composition of instrumentation devices**

**1) When determining the composition and size of instrumentation devices, points of attention are as follows:**

(1) Clearly recognizing the purposes of supervision and control, necessary minimum devices shall be laid out in a well-balanced manner in accordance with the size of the utility and the size of facilities to make equipment in good coordination with the entire facilities.

(2) The instrumentation devices often cooperate with such superior equipment as the central supervisory and control equipment, the remote supervisory and control equipment etc. As such, consideration shall be given to the network of respective facilities and that of respective equipment from stable supervisory and control point of view.

(3) Devices with high reliability and safety shall be selected, and their backup units shall be provided depending on their priority.

(4) As to items of measurement and supervision and their number, some of them need to be always supervised at the central control room whereas others need not; and likewise as to their expression, some of them only need to give direction and display whereas the other need to be recorded, integrated and give warning. As such, the priority of each item needs to be clarified in accordance with their purpose and needs. In consideration of such situation, the items and their number shall be set to the necessary minimum limit so as to be simplified.

(5) As for control, as one style, control is limited to be manually performed by the operator based on

the measured value; or, in another style, a control loop is formed using such control device as a one-loop controller based on the measured displacement and variant. Thus, the composition of the devices shall be determined by the type and the priority of control.

**2) As for the selection and the condition for installation and environment, points of attention are as follows:**

(1) There are many models of the devices for the same purpose of use with different structure, principle, material, shape, dimensions etc., and they respectively have merits and demerits. Given this, the models, which are the most suitable to condition of use, measurement range, accuracy, condition of installation, environmental condition etc. and high in reliability, shall be selected. Furthermore, their life-cycle cost as well as the ease in their calibration and maintenance shall be taken into consideration. In addition, the selection shall be made in consideration of not only their function but also their mounting and appearance.

(2) Since the condition of installation and environmental condition largely affect the reliability, durability and stability, and cause a problem about assurance of their accuracy, devices compatible with such conditions shall be selected. Besides, measures to prevent inductive interferences and lightning troubles shall be undertaken for communication lines for transmission of signals between the devices.

(3) The model and its signal shall be unified, desirably as much as possible, from view points of the ease of planning, simple upkeep, compatibility of the devices and the commonality of parts etc.

(4) Devices are day after day advancing owing to the technological innovation. Efforts shall be made to collect contemporary information; and function, maneuverability, credibility, safety, economic benefits etc. shall be synthetically be judged; and introduction of new technologies shall be examined.

### 8.11.2. Installation plan for instrumentation apparatus

> At the time of planning installation of instrumentation apparatus, its purpose shall be clarified, and installation shall be planned with devices compatible with the size of facilities, and the characteristics of the region in consideration of the organization of facilities management and their replacement in future.

**[Interpretation]**

An example of the steps of installation planning of instrumentation apparatus is presented in Figure 8.11.2.

### 8.11.3. Safety measures for instrumentation equipment

> To maintain the reliability and safety of the instrumentation apparatus, sufficient safety measures such as protective devices and backup devices and so forth shall be provided.

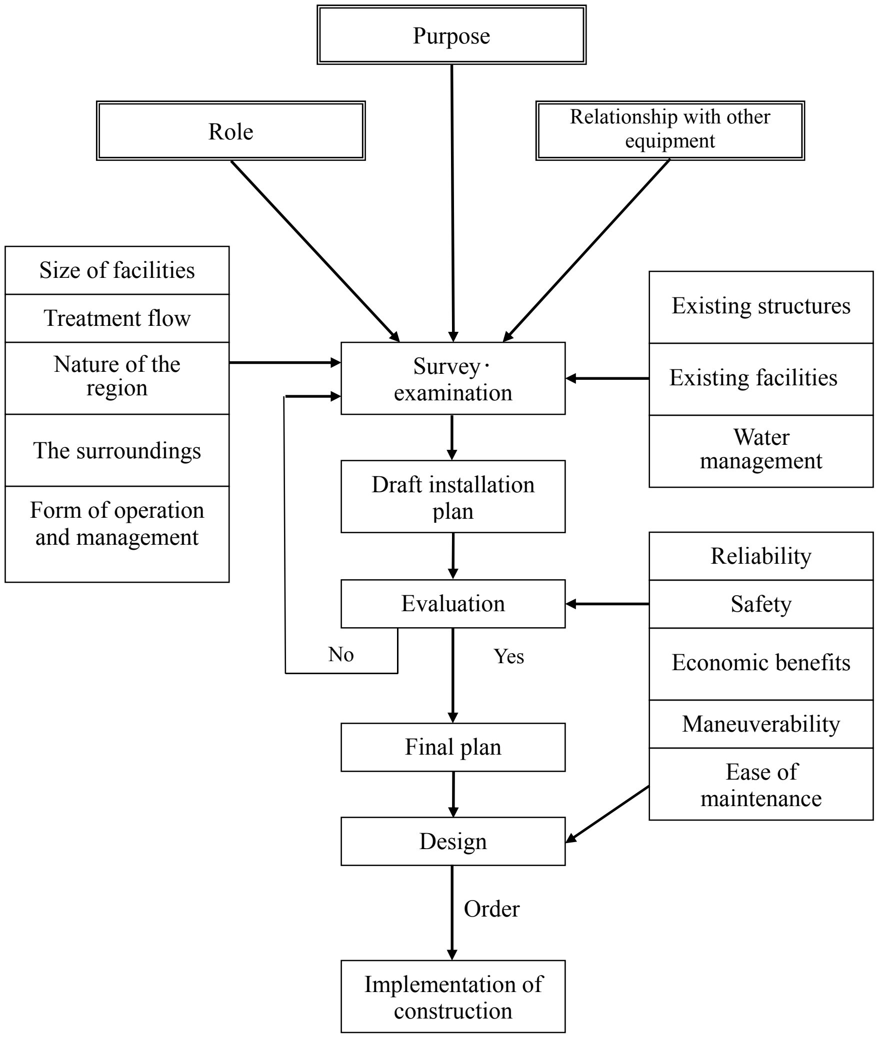



**Figure 8.11.2 Example of steps of installation planning of instrumentation apparatus**

### 8.11.4. Measurement of flow

Measurement of flow shall be in conformity with the following:

1. Measuring instrument for the measurement of flow shall be selected in consideration of condition of measurement, measurement range, accuracy etc. Especially, the flow meter for commercial supply and the one related to revenue water ratio shall be selected from ones with high accuracy.
2. On the occasion of installing a flow meter, condition of installation and environmental condition shall be taken into account.

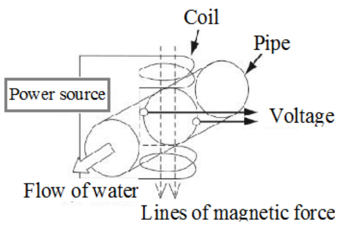
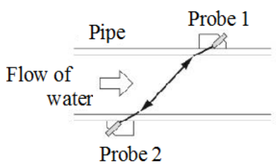
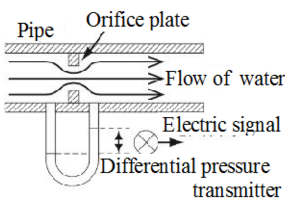
**[Interpretation]**

Flow meters are used not only for recognition of quantities in water treatment processes and control of chemical dosing but also the measurement of treated water transmission flow, receiving quantity, volume of water distribution etc., so those measurement values affect the identification of the ratio of revenue water and the quantity of balk water supply. Therefore, high accuracy is required for these flow measurement instruments.

Since the accuracy of flow meters is different depending on the model and the diameter and flow velocity even for the same model, and also affected by the environment of use, condition of installation, measurement range etc., the one, that can satisfy these conditions, shall be selected.

As types of the flow meter, there are the electromagnetic flow meter, which applies the electromagnetic induction principle, the ultrasonic flow meter, which uses ultrasonic waves, the differential pressure type flow meter, which utilize the pressure difference caused by such a throttling mechanism as Venturi tube, orifice etc., the wheel type flow meter, which utilizes rotation of wheel run by the flow and so on. In addition, there are weir type flow meter for open channels, the area type flow meter used for measurement of small flow for chemical dosing etc. Table 8.11.1 presents the main types of flow meters.

**Table 8.11.1 Table Main types of flow meters**

| Type | Structure schematic example | Principle | Merit | Demerit | Required length of straight pipe |
|---|---|---|---|---|---|
| Electromagnetic flow meter |  | ･Applying Faraday's law of electromagnetic induction, output relative to flow is obtained. Composed of a probe fit on pipe to convert flow to electric signal, and another converter to receive signal from probe, calculate and output instrumentation signals.<br>･Measurement method by JIS B7554 is standard.<br>Dia.: 25-3000mm or so<br>Accuracy: ±0.1-0.5% or so<br>Use: Raw water, treated water, wastewater, chemicals | ･No influence of liquid temperature, pressure, density, viscosity. High precision measurement possible for wide range with rapid response.<br>･Can deal with corrosive liquid, too.<br>･No moving part, so no head loss.<br>･Both-way, forward and reverse, measurement possible.<br>･Can handle slurry by selection of lining. | ･Relatively expensive compared with other types. For larger dia., this tendency is higher.<br>･Unsuitable for low inductance liquid<br>･Accuracy affected in case inductance changes, and electrodes stained with incrustation.<br>･Bypass pipe needed in case flow cannot be cut off. | ･Upstream: 5D. In case pump and valves are upstream,<br>･Upstream: 10D<br>See JIS B 7554 for more details. |
| Ultrasonic flow meter (Differential travel time type) |  | ･Output relative to flow is obtained applying the property of traveling speed of ultrasonic waves to change according to flow velocity. Composed of probe to emit and receive ultrasonic waves and converter to receive signal from probe, calculate, output instrumentation signals. ･In addition to differential travel time type, there are types using measuring principles of Doppler type, pulse Doppler type etc.<br>Dia.: 25-3000mm or so<br>Accuracy: ±1% or so<br>Use: Raw water, treated water, wastewater, chemicals | ･Measurement possible irrespective of inductive or non-inductive.<br>･Like electromagnetic flow meter, no head loss.<br>･Cost is not relative to pipe dia. Cheaper than electromagnetic flow meter for large pipe dia.<br>･Calibration possible irrespective of real flow. | ･Long straight section needed.<br>･Bubbles in liquid cause error. Unless thickness of pipe wall and lining known precisely, accuracy of measurement declines.<br>･Easy to be affected by turbulent flow. | ･Upstream: 10D<br>･Downstream: 5D<br>In case pump and valves are upstream,<br>･Upstream: 30D<br>･Downstream: 10D<br>See JEMIS 032 1987 for more details. |
| Differential pressure type flow meter (orifice) |  | ･Composed of aperture mechanism in pipe to produce pressure difference, differential pressure transmitter to convert the differential pressure to electric signals, and switching operator to output the signals as flow.<br>･In addition to orifice type, there are Venturi pipe type and nozzle type.<br>･Measurement method by JIS Z8762 is standard.<br>Dia.: >15-1500mm<br>Accuracy: ±1~2% or so<br>Use: Raw water, treated water, chemicals | ･Measurement possible for any of gas, liquid or vapor.<br>･Less easily to have failure as the structure is simple with no moving parts.<br>･Relatively cheap, and more economical as dia. increases. | ･Range of measurement is narrow compared with other types.<br>･Accuracy is also low.<br>･Head loss is large, and tends to have failure due to clogging of pipes for conducting differential pressure.<br>･Vulnerable to pulsating flow. Compensation for temperature difference needed. | ･Upstream: 10~40D<br>･Downstream: 5D<br>*Methods of drawing differential pressure are as follows:<br>Flange tap<br>Corner tap<br>Penner tap etc.<br>There are respective rules for position of tapping. See JIS Z8762 for more details. |

### 8.11.5. Measurement of water level

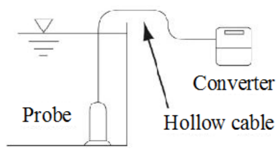
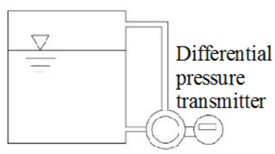
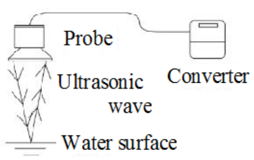
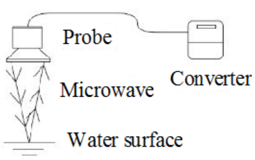
> Measurement of water level shall be in conformity with the following:
>
> 1. Apparatus for measurement of water level shall be selected in consideration of the condition of measurement, its range, accuracy etc.
> 2. For installation of the level gauge, condition of installation and environmental condition shall be taken into consideration.

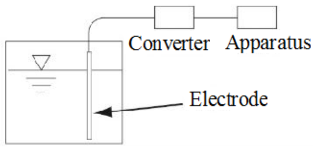
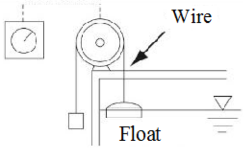
**[Interpretation]**

Measurement of water level as well as measurement of flow and pressure is one of important factors for operation and management of water supply facilities, and used for not only monitoring and control of water level in the water treatment processes but also management of stockpile of chemicals, control of water level in the pumping system and so forth. It is desirable for the apparatus to be duplicated in case it is used for important monitoring and control of water level etc.

As the level gauge used for monitoring and control of water supply facilities, there are the throw-in type, differential pressure type, ultrasonic wave type, electric wave type, static capacitance type, float type, electrode type etc. Table 8.11.2 tabulates main types of level gauges.

**Table 8.11.2 Main types of level gauges**

| | Schematic of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Throw-in type |  | Introducing atmospheric pressure to the probe set in liquid through hollow cable, water level is measured by difference between atmospheric pressure and liquid pressure.<br>Accuracy: ±0.2%<br>Measurement range: 0~40m | Required action is only to throw the probe hanging on chain etc. in water, so no installation work needed. | Caution shall be paid when installing it where flow is rapid. |
| Differential pressure type |  | Water column pressure by liquid surface is measured by means of differential pressure transmitter. As differential pressure transmitter, there are electrostatic capacitance type and diaphragm type<br>Accuracy: ±0.2%<br>Measurement range: 0~50m | Wide range of change in liquid level can be measured continuously. Suitable for measurement of liquid level in an airtight container. | Cannot be used for a river, well, underground tank etc. Use is limited to chemical tanks etc. |
| Ultrasonic wave type |  | Time needed for sound wave pulse to be emitted from probe, reflected on surface and return to it, is measured and converted to distance.<br>Measurement range: 0~45m<br>Accuracy: ±4~6mm (±0.25%) | Contactless measurement possible. No influence from viscosity and density. There is no moving part. | Becomes unstable in case there are splash of water, ripples etc. Error is caused if exposed under direct sun. |
| Electric wave type |  | Time, needed for microwaves emitting from the probe to get to the surface and reflect back to it, is measured, and converted to distance.<br>Accuracy: ±10~20mm<br>Measurement range: 0~30m | Contactless measurement possible. No influence from viscosity and density. There is no moving part. | Becomes unstable in case there are splash of water, ripples etc. Leakage of electric wave to outside shall be cautioned. |

| | | | | |
|---|---|---|---|---|
| Electrostatic capacitance type |  | Inserting electrode in liquid, change in capacitance between electrode and tank wall is converted as change in the level.<br>Accuracy: ±0.25%<br>Measurement range: 0~10m | Structure is sturdy. With no moving part, easy upkeep. Can be used irrespective of inductive or non-inductive property, and for not only liquid but powder. | Attention shall be paid to the incrustation on the electrode which changes permittivity causing errors. Easy to be affected by external noises. |
| Float type |  | Movement of float is taken out by wire and pulley, and measured electrically or mechanically.<br>Accuracy: ±1%<br>Measurement range: 0~15m | Suitable for measurement of such large water surface as impounding reservoir and service reservoir. Can be used without power source. | Relatively low accuracy due to friction etc. Unsuitable for outdoor use in cold regions. |

### 8.11.6. Measurement of water pressure

> Measurement of water pressure shall be in conformity with the following:
>
> 1. Apparatus for measurement of water pressure with proper purpose of use, condition of measurement, measurement range, accuracy and response shall be selected.
> 2. For installation of the pressure gauge, condition of installation and environmental condition shall be taken into consideration.

**[Interpretation]**

Measurement of water pressure is one of the important measurement items in water supply facilities, and widely used in facilities from raw water transmission to water distribution for confirmation of pressure of pumps, pressure control of treated water transmission and distribution mains, control of water pressure for prevention of water leakage.

As the type of the pressure gauge, there are such mechanical pressure gauge as Bourdon tube type, diaphragm type and bellows type.

### 8.11.7. Measurement of water quality

> Measurement of water quality shall be performed in accordance with the following;
>
> 1. The measurement apparatus for water quality shall be selected from the ones with high reliability, good responsiveness, and the ease of calibration and upkeep. Additionally, the one suitable to such environmental condition as humidity-resistance, and anti-corrosiveness depending on the situation of its installation.
> 2. The environment of installation of the apparatus, and the method of water sampling shall be taken into consideration.

**[Interpretation]**

There are two types of water quality measurement apparatus, namely, the one used for monitoring of water quality in the processes from raw water intake through water treatment and in the treated water transmission and distribution; and the other one used for control of dosage of such chemicals as coagulants, alkaline agents and disinfectants, for which high precision, stability and reliability are required.

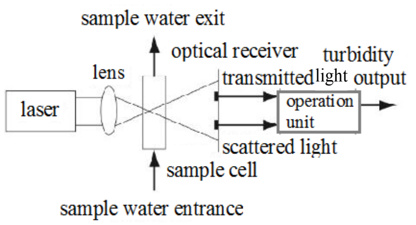
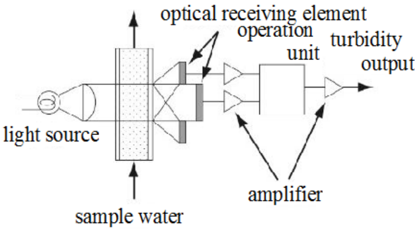
Unlike other industrial instruments, the precision of the water quality measurement apparatus differs depending on the difference in the principle of measurement, the type of the product, or the difference in the range of measurement even between the same types.

For the dosage control of coagulants, the turbidimeter, pH meter, alkalinity meter, water thermometer are used; pH meter and alkalinity meter for the dosage control of alkaline agents for pH control; and chlorine demand meter, ammonia meter, residual chlorine meter etc. for dosage control of chlorine agents. Dissolved ozone concentration (liquid phase) meter and spent ozone concentration meter are used for the control of ozonation.

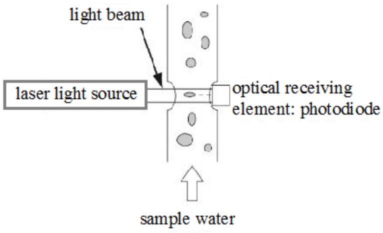
As monitoring instruments, there are the VOC (micro-volatile organic compounds) meter, oil film meter, oil contents meter, low level turbidimeter, colorimeter, trihalomethanes meter, conductance meter, UV (ultra-violet ray absorbance) meter, ORP (oxidation-reduction potential) meter, cyan meter etc., which are installed if required. The structure, principle and characteristics of main water quality measurement apparatus are presented in Table 8.11.3, and an example of installation of the ones for the water treatment plant are shown in Table 8.11.4.

**Table 8.11.3 Structure, principle and characteristics of main water quality measurement apparatus**

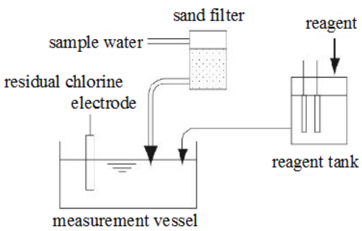
**(1) Low level turbidimeter**

| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Transmitted-scattered light method (Semi-conductor laser method) |  | Converging semi-conductor laser to one point and aiming at the sample water, interference occurs by the scattered light from the micro-particles in the solution. Detecting this signal by an optical receiver, signal proportional to the turbidity is obtained.<br><br>Reproducibility: ±3%FS<br>Measurement range:<br>0.0000~2.0000 units (mg/L) | Owing to high sensitivity, low level turbidity can be measured. | Constant flow of sample water is needed. Fouling of cell window shall be watched. |
| Transmitted-scattered light method (Tungsten lamp) |  | Light emitting from the light source splits into transmitted light and scattered light by the suspended matters. Measuring them by optical receivers, turbidity is obtained by the operation unit.<br><br>Reproducibility:±2%FS<br>Measurement range:<br>0~0.2 units (mg/L)<br>~<br>0~2 units (mg/L) | Owing to high sensitivity, low level turbidity can be measured.<br><br>Not influenced by fluctuation in power source and deterioration in light source. | Constant flow of sample water is needed. Fouling of cell window shall be watched. |

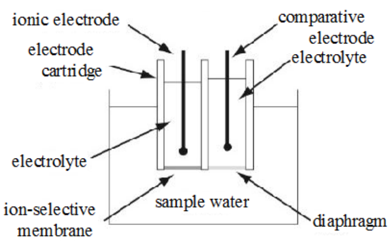
## (2) Particle counter

| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Particle counting method (Semi-conductor laser type) |  | Irradiating laser light on the sample water, the intensity of light diminishes as it is intercepted by suspended matters. The size of the particle is detected by amount of reduction in light. As one light pulse is generated by one particle, the number of particles is measured by the number of the pulses.<br>Reproducibility:<br>±2%FS (0.0000~0.5000 units)<br>±5%FS (0.5000~2.0000 units)<br>Micro-particle number density :<br>0~$10^5$/mL<br>Measurement range:<br>0.0000~2.0000 units (mg/L) | Since the number of particles can be measured by particle diameter, the distribution of particles can be known, so the performance of filtration can be confirmed. | Constant flow of sample water is needed to maintain the accuracy of measurement.<br><br>As the density of particles becomes high, the measured number is smaller than the actual one. |

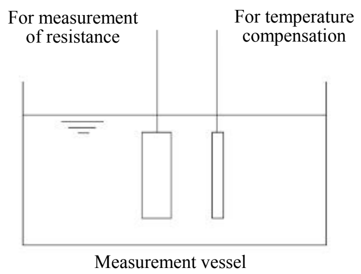
## (3) Chlorine demand meter

| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Electrolysis current control method |  | The quantity of generated chlorine to be dosed in sample water is controlled by the electrolysis current so that the concentration of chlorine at the point of measurement of chlorine is always maintained constant.<br>Reproducibility: ±3% FS<br>Linearity: ±3% FS<br>Measurement range:<br>0~5 mg/L<br>～<br>0~20 mg/L | Since the reaction takes place for all the substances, which consume chlorine, in addition to ammoniac nitrogen, precise dose of chlorine can be estimated. | As sodium hydroxide separates out on the electrode of the chlorine generator, the reaction vessel gets tainted by organic matters etc., such proper regular maintenance as cleaning is needed. |

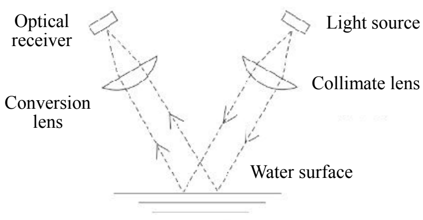
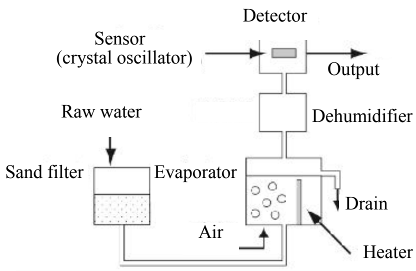
## (4) Ammoniac nitrogen meter

| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Ionic electrode method |  | Ammoniac nitrogen is measured by the ammonium ionic electrode. There is the high-performance one which automatically compensates the influence of such interfering elements as potassium, water temperature etc. Other measurement methods are ion chromatography, absorption photometry etc.<br><br>Precision: 5% ± 0.2mg/L (measured value)<br>Measurement range:<br>0.2~20 mg/L<br>～<br>0.2~1000 mg/L | Replacement of electrolyte and reagent are unnecessary.<br>Handling is easy; and high-precision measurement is possible. | Replacement and calibration of the cartridge are needed every one half year.<br><br>To stabilize the operation, an air cleaning device shall be installed. |

## (5) Conductance meter

| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Electrode method |  | Electric resistance between the electrodes dipped in sample water is measured, and conductance is obtained. Its principle is simple, and it can withstand dirt. There is an electromagnetic induction type with high precision.<br><br>Reproducibility: ±0.2% FS<br>Linearity: ±0.5% FS<br>(measured value)<br>Measurement range:<br>0~0.2 μ S/cm<br>~<br>0~2000 mS/cm | Its principle is simple, and it can work even when turbidity is high. Its maintenance is easy. | As the electrode for measurement gets deteriorated in its property, its regular inspection is required.<br>Since the performance become unstable if air bubbles permeate into electrodes, caution shall be paid when installed. |

## (6) Detection of oil

| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Oil film detector |  | Installing above water surface of river etc., light emitting from LED or laser is thrown on the film formed by oil. As the reflectance of oil is larger than water, the existence of oil is detected by measuring the intensity of reflected light.<br><br>Reproducibility: ±2% FS | The device is small and light; does not have consumable parts; and its maintenance is easy. | In case rain drops or strong wind hit the water surface, it works erroneously, or stops to function.<br>It is unsuitable to a channel where water surface largely changes or where the flow is fast. |
| Oil monitor・oil odor sensor |  | The filtered raw water is heated by the heater, and oil is evaporated by air blow. The air containing evaporated oil is dehumidified; oil is then detected by the crystal oscillator sensor.<br><br>Reproducibility:±5%FS<br>Sensitivity: 10μg/L for kerosene (approximate) | Oil, which coming into raw water, can be detected at as high sensitivity as human's sense of smell. | Such peripheral equipment as sampling piping, sampling pump, and compressor need to be of oil-less products. |

**(7) VOC meter**

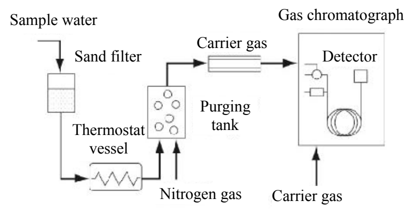
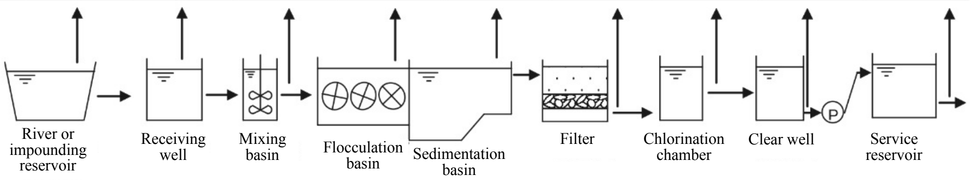
| Type | Example of structure | Principle | Merit | Demerit |
|---|---|---|---|---|
| Gas chromatography type |  | Continuously injecting sample water into the thermostat vessel while making bubbles by air, the VOC constituents evaporate; and sample gas is obtained. Respective constituents are measured by the gas chromatograph.<br><br>Reproducibility: ±1% FS<br>Measurement range:<br>1ppm~100% (TCD. FID)<br>1ppm~0.1% (FPD)<br><br>TCD: Thermal conductivity detector<br>FID; : Flame ionization detector<br>FPD: Flame photometric detector | Simultaneous multi-constituent analysis is possible. | Same Testing environment as a laboratory is required, so nitrogen gas etc. is needed for analysis.<br><br>High level upkeep and management are required as the analytical instrument. |

**Table 8.11.4 Example of installation of water quality instruments in a water treatment plant**

◎ Needed at least
○ To be installed depending on size of facilities and condition of water quality

| Water quality instrument \ Location | Water intake site | Receiving well | Mixing basin | Flocculation basin | Sedimentation basin | Filter | Chlorination chamber | Clear well | Service reservoir |
|---|---|---|---|---|---|---|---|---|---|
| Turbidimeter | ◎ | ◎ | | | ○ | ○ | | ○ | ○ |
| Low level turbidimeter | | | | | | ◎ | | ○ | ○ |
| Particle counter | | | | | | ○ | | | |
| Colorimeter | | | | | | ○ | | ○ | ○ |
| pH meter | ◎ | ◎ | ○ | ○ | ○ | ○ | ○ | ◎ | ○ |
| Residual chlorine meter | | | ○ | | | ◎ | ○ | ◎ | ◎ |
| Chlorine demand meter | ○ | ○ | | | | | | | |
| Alkalinity meter | ○ | ○ | | | | | | | |
| Ammonia meter | ○ | ○ | | | | | | | |
| Conductance meter | ○ | ○ | | | | | | | |
| Oil film･oil constituent meter | ◎ | | | | | | | | |
| Water thermometer | ○ | ○ | | | | | | | |




※In case the marking are set for both the water intake site and the receiving well, either one of them will do.

**On the item 1.;**

**1) Turbidimeter**

The turbidimeter is the most important water quality instrument in water treatment facilities together with the residual chlorine meter. Especially, in a water treatment plant, it is indispensable for treatment processes of river water as raw water, settled water, filtered water etc.

**2) Colorimeter**

The colorimeter measures the degree of light yellow to yellowish brown color of water caused by dissolved and colloidal matters mainly in treated water; and for its method of measurement, the transmitted light measurement method is applied. There is a turbid-colorimeter, which can measure both turbidity and color.

**3) pH meter**

The pH meter is used for the pH control at the respective processes of water treatment and the dosage control of coagulants, and confirmation of pH at the final stage of water treatment.

**4) Residual chlorine meter**

The residual chlorine meter is the most important water quality instrument to maintain the safety of tap water.

**5) Chlorine demand meter**

Such a control system is formed as the quantity of chlorine to be dosed in sample water is controlled by the electrolysis current so that the concentration of residual chlorine in the measurement vessel is always maintained constant. When residual chlorine declines as chlorine is consumed by ammoniac nitrogen, iron, manganese, organic matters etc., the dosage of chlorine is added by increasing the electrolysis current to restore the prescribed value. As the replenished quantity of chlorine in this case is the chlorine demand, the chlorine demand is obtained by measuring the electrolysis current.

**6) Alkalinity meter**

The alkalinity meter is a device to measure the alkalinity in sample water by means of neutralizing titration, and used for the dosage control of coagulants and prevention of corrosion of water distribution mains.

**7) Ammoniac nitrogen meter**

Ammoniac nitrogen is formed in the decomposition process of such organic nitrogen as protein, urea, and uric acid contained in household wastewater, industrial wastewater, sewage, fertilizer etc. Since ammoniac nitrogen consumes a lot of chlorine, it gives significant influence to the dosage of disinfectant. By the ammoniac nitrogen meter, ammoniac nitrogen in water is continuously measured by the ammonium ionic electrodes.

**8) Conductance meter**

The conductance meter is an instrument to measure the conductance of water, and sometimes used as an indicator for water quality control in a water treatment plant and water distribution facilities.

**9) Detection of oil**

Among accidents of raw water (river water), there are many accidents of such drained oil as kerosene and gas oil. As the instrument for measurement of oil in raw water, there are the oil film detector and the oil detector.

**10) Micro-volatile organic compound (VOC) meter**

To prepare for an accident of raw water pollution, a VOC meter, which can detect volatile organic compounds by the order of $\mu$ g/L, is sometimes installed in the water treatment plant.

**11) Ozone concentration meter**

For continuous measurement of the concentration of ozone, there are the UV absorbance method, the diaphragm electrode method, the polarograph method, semi-conductor sensor method etc.

**12) UV (ultra-violet ray absorbance) meter**

The UV meter is used to measure the approximate total amount of organic matters.

**13) Trihalomethane meter**

The trihalomethane meter is an instrument to measure trihalomethanes formed in the process of disinfection by a chlorine agent. The instrument applying the membrane separation fluorescence quantitative method possesses high correlation with the gas chromatography, and can be used for continuous monitoring.

**14) TOC (total organic carbon) meter**

The TOC meter is an instrument to measure the amount of carbon (TOC) to be derived from organic matters in water, and at times installed for monitoring of water quality of raw water.

**15) ORP (oxidation-reduction potential) meter**

The oxidation-reduction potential is used as the indicator of oxidation-reduction potential matters dissolved in water, and its measurement principle is almost as same as the pH meter. At a seawater desalination plant, it is at times used as a management indicator to know the situation of pollution by cyan, chromium etc.

**16) FI meter (SDI meter)**

In case an RO membrane and an NF membrane are used for seawater desalination etc., the transmission velocity declines as a cake layer is formed by suspended matters including colloids in water. The FI meter is an instrument to measure suspended matters which cannot be measured by a turbidimeter.

**17) Automatic water quality monitoring device**

The automatic water quality monitoring device is used for water quality control at the fringe of distribution network, early detection of malfunction of the distribution system and so forth. Some of devices can measure color, turbidity, residual chlorine, pH, water temperature, conductivity etc.

**18) Water quality monitoring device by fish**

The water quality monitoring device by fish is a continuous water monitoring device by means of bioassay in that fish are kept in an aquarium, in which sample water always flows, and abnormal water quality is detected from unusual behavior of fish.

**On the item 2.;**

**1) Type of installation**

As the type of water quality measurement, there are the site installation type, for which the instrument is set in the close vicinity of the sampling point, and the centralized installation type set at the laboratory etc. by means of collective sampling. A comparison of locations of water quality instruments is presented in Table 8.11.5.

**Table 8.11.5 Comparison of locations of water quality instruments**

| Item of comparison | Site installation | Centralized installation |
|---|---|---|
| Time lag in measurement data | Small time lag. No problem for control of chemical dosing | In case the site is distant from the central lab, time lag is a problem. Caution shall be paid for control of the chemical feeding system. |
| Influence of sampling pipe to water quality | Almost none. | Yes. Regular cleaning of pipe needed. |
| Environmental condition to water quality instruments | Condition is bad. Measures for water-proofing, dehumidification, frost prevention, ventilation etc. needed. | Environmental condition is good. |
| Maintenance of water quality instruments | Efficiency is low as instruments are sparsely situated. | Efficient as instruments are centralized. |

### 8.11.8. Other measurement instruments

Such instruments as the chlorine gas leak detector, sludge concentration meter, apparatus for electric measurements, apparatus for supervision of equipment, apparatus for meteorological observation etc. shall be suitable for their respective uses, and shall be selected from models compatible with the purpose of use, the condition of installation and the environmental condition.

**[Interpretation]**

**1. Chlorine gas leak detector**

(1) The detector, which continuously detects leak of chlorine gas and gives a warming, shall be used.

(2) Control equipment, to automatically actuate the neutralizing facilities with interlock with the above detector, shall be installed.

(3) A sampling device shall be set at an appropriate location so as to immediately detect the leak.

(4) Sufficient space for such maintenance work as refilling of reaction liquid, cleaning of electrodes etc. shall be secured, and lighting fixtures shall be installed.

(5) Hard PVC or the equivalent material shall be used for sample sucking pipe, and a valve for regulation of air flow shall be set at the entrance mouth of the detector.

**2. Sludge concentration meter**

The sludge concentration meter is used for measurement of sludge concentration, when discharged from the sedimentation basin, sludge in the sludge basin, sludge, when it is transferred from the thickening tank, etc. There are the scattered light type, transmitted light type, laser light type, micro-wave type, defoaming type etc. as the type of sludge concentration meters.

**3. Instruments for electric measurement**

They are instruments to measure voltage, current, power, power factor etc. at the receiving-transforming equipment, power plant etc., and there are mainly indicators set at site, current transformer to convert high tension voltage or large current to the measurement range for instruments in the cases of high tension and large current, the transducer (converter) to output to outside as measurement signals and so on.

**4. Monitoring devices for facilities**

For pump facilities etc., thermometers and vibration meters shall be installed, as required, for continuous monitoring of temperature and vibration of bearings of the motor and pump.

**5. Apparatus for meteorological observation**

Various meteorological observations are required for forecast of river flow, prediction of water demand, and solar power. There are the rain gauge, anemoscope, anemometer, pyrheliometer, thermometer, hygrometer etc. as meteorological observation apparatus.

### 8.11.9. Devices for indication and recording

> Devices for indication and recording shall be suitable for recognition and data management of measurement values and operating condition of facilities, and the purpose of use and the condition of installation shall be taken into account for their selection and installation.

**[Interpretation]**

As devices for indication and recording, there are indicators and recorders deployed in the control panel at site and the monitoring panel etc. of the central supervisory panel.

### 8.11.10. Controllers

> 1. Controllers shall function reliably and unerringly.
> 2. The characteristics of action and type of controllers shall be compatible with the control system in their charge.

**[Interpretation]**

The controllers compare, by its operational unit, the values set originally and the actually measured signals of flow, water level, water quality etc., detect deviations between them, and then output control signals to the operating section so that the deviations become zero.

### 8.11.11. Signal converters

> Signal converters compatible with the use and the condition of installation shall be selected.

**[Interpretation]**

To perform supervision, control and information processing of water supply facilities, communication of various signals takes place between miscellaneous units of equipment. These signals need to be converted into other signals suitable for the purpose of use.

There are resistance-current, voltage-current, pneumatic pressure-current conversions etc. as the types of conversion.

### 8.11.12. Lightning arresters

> Lightning arresters compatible with the use and the condition of installation shall be selected.

**[Interpretation]**

Although lightning rods are installed as a measure against lightning damage in many cases, protection from damage by induced lightning, which intrudes inside the building, cannot be expected since the protection by the lightning rods is only useful against direct lightning outside the building. Lightning arresters shall be installed as the measure against the lightning surge by the induced lightning.

### 8.11.13. Simplified telemetry

> Proper simplified telemetry shall be selected in consideration of the size, priority, management system of facilities etc.

**[Interpretation]**

Simplified telemetry is used for a remote supervisory device for small-scale facilities which have only a few items of transmission.

## 8.12. Instrumentation for respective facilities

### 8.12.1. General

Instrumentation in water supply is roughly divided into the one for plant control for individual facilities of the raw water intake station, the water treatment plant, the water distribution center etc., and the other one for system operation control of the entire water supply facilities from the water source through water distribution facilities which are synthetically integrated. As such, instrumentation apparatus suitable to the respective facilities needs to be installed to perform efficient supervision and control. An example of items for measurement and control of water supply facilities is presented in Figure 8.12.1. In addition, an example of items for measurement and control of small scale water supply facilities is shown in Figure 8.12.2. Although some of these items may be curtailed or supplemented according to quality of raw water, the method of water treatment, the method of raw water intake, the methods of water transmission and distribution, they are in general measurement and control items required in the processes from raw water intake through water distribution irrespective of the size of the facilities.

On the occasion of determining the size and components of instrumentation apparatus, such fundamental matters as clarification of the purpose and effect of instrumentation, its reliability and safety, its initial and running costs etc. shall be examined.

### 8.12.2. Water storage and raw water intake facilities

> Instrumentation of water storage and raw water intake facilities shall be in conformity with the following:
>
> 1. It is desirable to install a level gauge and a flow meter suitable for the type of water source and its O&M, and water quality instrument, an aquarium for water quality monitoring according to the need.
> 2. Such proper protection device as a lightning arrester shall be installed on respective input and output terminals of instrumentation apparatus in the water storage and raw water intake facilities.

### 8.12.3. Raw water transmission facilities

Instrumentation for raw water transmission facilities shall be in conformity with the following:

1. It is desirable to install a flow meter in raw water transmission facilities suitable for the type of raw water transmission and its O&M.
2. See “8.2.10 Control of the pump” for control of the flow of raw water transmission.
3. Protection devices for instrumentation apparatus in raw water transmission facilities shall be in conformity with 8.12.2 Water storage and raw water intake facilities.

### 8.12.4. Receiving well

Instrumentation for the receiving well shall be in conformity with the following:

1. A level gauge and a flow meter suitable for its size and purpose shall be installed in the receiving well, and additionally water quality instrument shall be installed as required.
2. In case the flow in the receiving well is to be controlled, a reliable and sound control method for the fluctuation of water level shall be adopted.

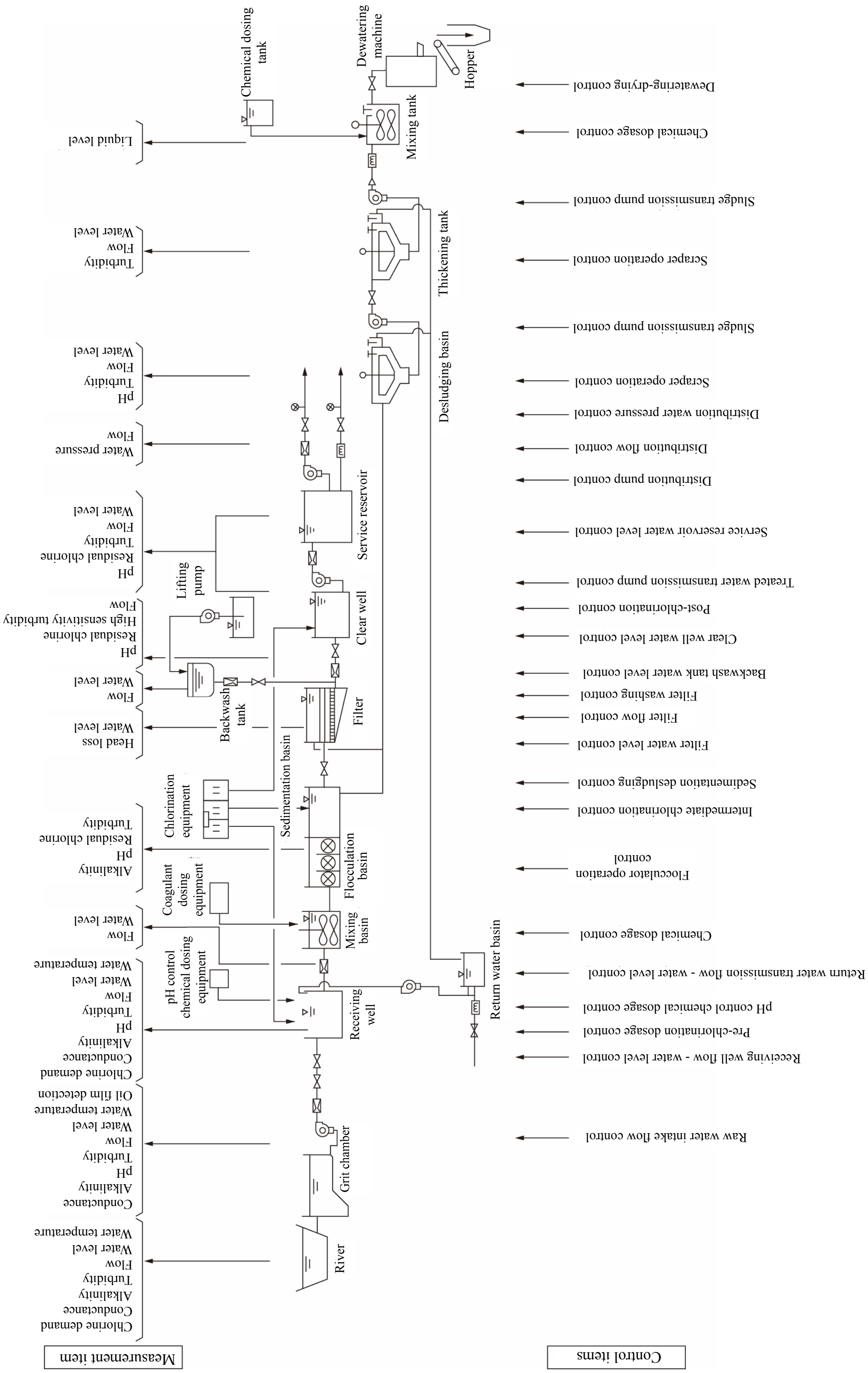



**Figure 8.12.1 Example of measurement and control items for water supply facilities**

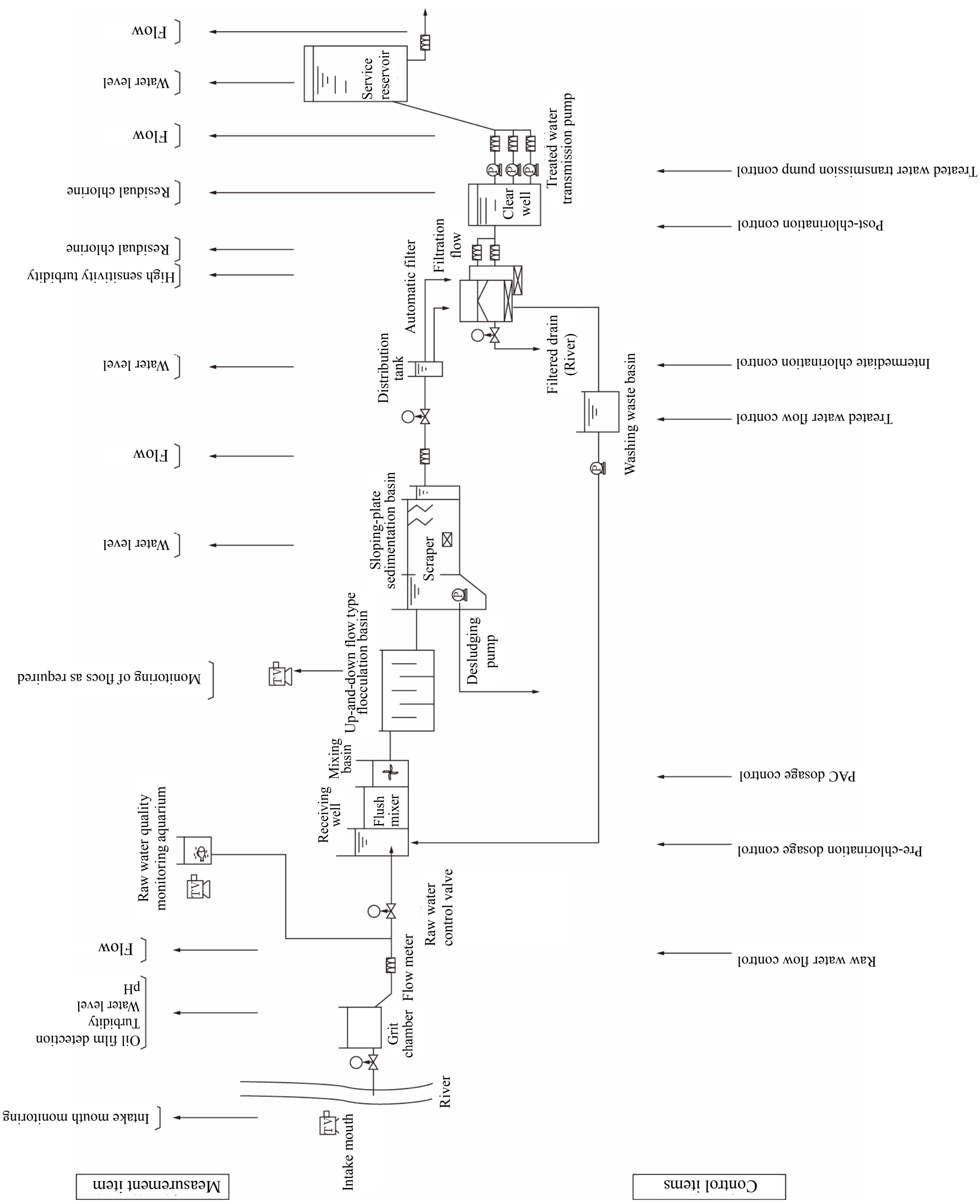



**Figure 8.12.2 Example of measurement and control items for small water supply facilities**

### 8.12.5. Flocculation basin and suspended solid contact clarifier

Instrumentation of the flocculation basin and the suspended solid contact clarifier shall be in conformity with the following:

1. Water quality instruments etc. shall be installed in the flocculation basin and the suspended solid contact clarifier as required.
2. Water quality instruments suitable to the surroundings shall be selected.
3. Desludging control of the suspended solid contact clarifier shall be performed by equipment, which can be operated safely and soundly, in consideration of the condition etc. of the sludge basin.

### 8.12.6. Filter

Instrumentation of the filter shall be in conformity with the following:

1. A filtered water flow meter and a head loss meter shall be installed on the filter; and, in addition, water quality instruments etc. shall be installed there as required.
2. In case the filtered water flow is controlled, it is desirable for the total filtered water flow can arbitrarily be controlled.
3. In case filter washing operation is undertaken by a sequential control method, respective apparatus with secure performance and high safety and reliability shall be selected.
4. A level gauge shall be installed in the washing tank, which is interlocked with the lifting pump etc., and display water level warning and indication.

### 8.12.7. Clear well

Instrumentation of the clear well shall be in conformity with the following:

1. A level gauge shall be installed in the clear well; and, in addition, water quality instruments etc. shall be installed there as required.
2. For water quality instruments, such environmental condition as resistance to chlorine gas and humidity etc. shall be taken into account.

### 8.12.8. Coagulation chemical dosing equipment

Instrumentation of the coagulation chemical dosing equipment shall be in conformity with the following:

1. A flow meter, liquid level gauge, control valve etc. suitable to the type of chemical, method of dosing and their O&M shall be installed.
2. Instrumentation of the chemical dosing equipment shall be high in accuracy and reliability, and can deal with the change in water quality.
3. The structural materials of instrumentation apparatus shall be resistant to corrosion etc. by chemicals.

### 8.12.9. Disinfection equipment

Instrumentation of the disinfection equipment shall be in conformity with the following:

1. A flow meter, pressure gauge, control valve, residual chlorine meter etc. suitable to dosing of disinfectant and their O&M shall be installed.
2. Instrumentation apparatus shall be fit to the environmental condition, and, additionally, its required part shall be corrosion-resistant.
3. As security for the disinfection equipment, a chlorine gas leak detector shall be installed in the chlorine gas store and the chlorinator room.

#### 8.12.10. Chlorination equipment

Instrumentation of the chlorination equipment shall be in conformity with the following:

1. The Instrumentation apparatus shall be able to be controlled and perform measurement dealing with the change in the raw water flow and quality.
2. As a security measure for the disinfection equipment, chlorine leak detectors shall be installed in the chlorine store and the chlorination room.

#### 8.12.11. Acid agent and alkaline agent dosing equipment

Instrumentation of the acid agent and alkaline agent dosing equipment shall be in conformity with the following:

1. The instrumentation apparatus shall be suitable to the condition of the use of the chemicals and the environment of the surroundings, and have a structure to be handled safely.
2. The flow meter, the pressure gauge, level gauge etc. suitable to dissolution and dosing of chemicals shall be installed, and a control valve etc. suitable for control shall be installed.
3. The Instrumentation of the chemical dosing equipment shall be high in accuracy and reliability, and able to deal with the change in water quality.

#### 8.12.12. Activated carbon adsorption equipment

Instrumentation of the activated carbon adsorption equipment shall be in conformity with the following:

1. Dust-proofing, explosion-proofing, abrasion resistance etc. shall be considered for the instrumentation apparatus for and the feeder of powdered activated carbon adsorption equipment.
2. For the granular activated carbon adsorption equipment, instrumentation apparatus required for control of the carbon layer (fixed bed type, and fluidized type) shall be installed.

#### 8.12.13. Ozone treatment equipment

Instrumentation of the ozone treatment equipment shall be in conformity with the following:

1. The instrumentation apparatus shall be suitable to the nature of ozone and the surroundings, and its structure shall be easy of O&M and safe of handling.
2. Generation and dosing of ozone shall be safe and efficient, and able to be properly controlled.
3. The Instrumentation of ozone treatment shall be high in accuracy and reliability, and able to deal with the change in water quality.

#### 8.12.14. Membrane filtration equipment

Instrumentation of the membrane filtration equipment shall be in conformity with the following:

1. The operation of the membrane filtration equipment shall be by automation in consideration of its characteristics, O&M etc.
2. As instruments for the membrane filtration equipment, a flow meter, a pressure gauge, a level gauge, a turbidimeter and a thermometer shall be installed, and, additionally, a particle counter, a detector of compromised membrane etc. shall also be installed as required.
3. The equipment shall possess a control device to quickly and automatically shutdown the equipment and perform such required action as warning at such abnormal occasion of the damage in membrane, the rise in filtered water turbidity etc.

**8.12.15. UV treatment equipment**

The instrumentation of the UV treatment facilities shall be in conformity with the following:

1. The UV radiation device can at all times not only stably radiate UV but also be of a structure to always monitor its intensity.
2. Such instrumentation apparatus as a UV intensity meter, turbidimeter, thermometer, and flow meter shall be installed on the UV treatment facilities.

**8.12.16. Wastewater treatment facilities**

The instrumentation of the wastewater treatment facilities shall be in conformity with the following:

1. The discharge of sludge shall in principle be controlled by automatic sludge discharging equipment so that its equalized discharge is possible.
2. Along with the instrumentation for the sludge preparation and thickening facilities, water quality measurement apparatus shall be installed.
3. The instrumentation for dewatering facilities shall be of the safest and most reliable instrument and the control method which conform to the method of treatment in question.
4. The environment of installation, the condition of measurement etc. shall be taken into consideration.

**8.12.17. Treated water transmission facilities**

The instrumentation of the treated water transmission facilities shall be in conformity with the following:

1. A flow meter and a water pressure gauge suitable for monitoring and control of the treated water transmission facilities shall be installed.
2. The control of treated water transmission flow shall secure safe, reliable and economic operation of the treated water transmission facilities through the utilization of water storage in the clear well and the service reservoir.
3. The protection equipment for instrumentation of the treated water transmission facilities shall be in conformity with 8.12.2 Water storage and intake facilities.

**[Interpretation]**

**On the item 1.;**

Since in the treated water transmission and distribution facilities, the water pressure gauge is often required in the case of booster pumping, the surroundings, such condition of installation as air entrainment etc. and upkeep and inspection shall be examined at the time of its installation. As the flow meter in the treated water transmission facilities, the electromagnetic type, the ultrasonic type and the differential pressure type, and as the pressure gauge, the Bourdon tube type and the bellows type are used in many cases. Besides, as the water level gauge, the float type, the capacitance type, the electrode type, and the throw-in type are mainly used.

### 8.12.18. Water distribution facilities

The instrumentation of the water distribution facilities shall be in conformity with the following:

1. A flow meter, level gauge and water pressure gauge suitable for monitoring, control and water management of the water distribution facilities shall be installed. Water quality measurement instruments shall be installed if required.
2. The control of distribution water flow shall secure safe and efficient operation of the water distribution facilities, and proper water volume and pressure in the service area.
3. It is desirable for the measurement and control signals suitable for the operation and management of the water distribution facilities to be transmitted to the water treatment plant or the treated water transmission-water distribution center.
4. The protection equipment for instrumentation of the water distribution facilities shall be in conformity with 2. of 8.12.2 Water storage and intake facilities.

**[Interpretation]**

For the instrumentation of the water distribution facilities, such special property of the facilities as the hourly change in the water distribution flow is large, and as the location of the service reservoir, stand pipe, or elevated tank is far away or on an elevated site need to be considered.

**On the item 2.;**

The purpose of the control of water distribution flow is to aim at proper water distribution in the service area, and leveling of water pressure there. Especially, the control of water pressure aims to prevent burst of water mains and water leakage caused by unnecessarily high water pressure at night, or eliminate areas of inadequate water service due to low water pressure.

On the other hand, to undertake smooth water distribution compatible with the demand, while the hourly change of water demand in the service area shall precisely be understood, the service reservoir shall efficiently be operated in coordination with the control of treated water transmission such as feeding of necessary volume of water to the service reservoir.

An example of an instrumentation diagram for treated water transmission and water distribution facilities is presented in Figure 8.12.14. As the water is distributed by gravity in the low-lying area, no special control is made, and an emergency isolation valve is installed to prevent an accident at the time of such an emergency as burst of water mains.

Water distribution in the high and medium service areas is made by pumping, and pumps with the same lift is used, for which the constant pump delivery pressure control or the constant water mains end pressure control are employed while the control method is commonly the pump unit number control or the rotational speed control.

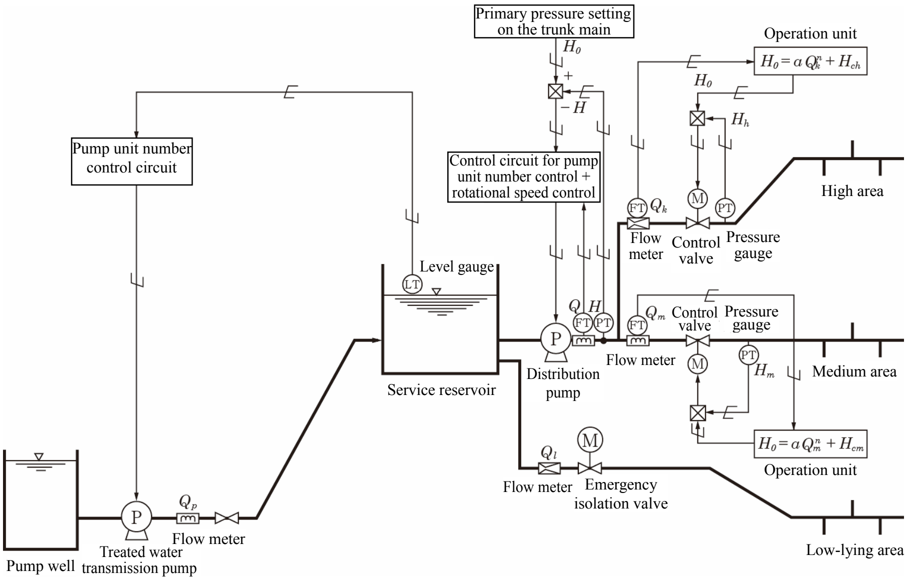



**Figure 8.12.14 Example of an instrumentation diagram for treated water transmission and water distribution facilities**

**On the item 3.;**

As the location of the service reservoir, stand pipe, or elevated tank is far away in many cases, there is a tendency for such facilities to be unmanned. For safe and economic operation of facilities, it is desirable for the measurement and control signals to be transmitted to the water treatment plant or the treated water transmission-water distribution center.

### 8.12.19. Pump facilities

The instrumentation of the pump facilities shall be in conformity with the following:

1. A level gauge, pressure gauge and flow meter suitable for the operation, monitoring and control of pumps shall be installed, and a rotation speed meter shall be installed if required.
2. The power source for the instrumentation of the pump facilities shall be separated from the one for the circuit for electric power facilities, and it is desirable that they are supplied from the UPS.
3. The type of pump control shall be in conformity with the safety, reliability and economic benefits of pump operation in accordance with the purpose of pump control.

### 8.12.20. Seawater desalination facilities (Reverse osmosis facilities)

The reverse osmosis facilities consist of the protective filter, high lift pump, membrane module, suck-back tank, membrane cleaning equipment etc., and their instrumentation shall be a system suitable for the type of membrane, composition etc.

1. The control of operation of the reverse osmosis facilities shall in principle be of automation, and can synthetically be interlocked with the raw water preparation and adjustment facilities etc.

2. The instrumentation devices of the reverse osmosis facilities are the level gauge, flow meter, pressure gauge etc.; and pH meter, turbidimeter, thermometer, residual chlorine meter, ORP meter, conductivity meter, FI (SDI) meter and alkalinity meter shall properly be deployed so as to fit the condition of the surroundings with a structure which can be replaced safely.

## 8.13. Machinery room, electric room and supervisory room

### 8.13.1. General

When designing the machinery room, electric room and supervisory room, attention shall be paid in that the installed facilities can fully work for their functions. The respective rooms shall be protected from inundation, collateral damage caused by the leak from water service and drainage piping, gas piping, oil piping etc.

As heavy articles and rotating machines are placed in the machinery room, it needs to have enough space so that the upkeep work, inspection etc. can be performed safely.

For electric equipment to be accommodated in the electric room and the supervisory and control system to be installed in the supervisory room, there needs to be environment to maintain their reliability as required by their advancement, conversion to an electronic form and complication. In addition, for operation and management, and upkeep, adequate safety and convenience of work shall be fully considered.

What's more, as these rooms are in some cases subject to regulation by the law, attention shall be paid accordingly. Furthermore, sufficient security and crime prevention measures shall be provided since the machinery room and the electric room are often absent with personnel.

### 8.13.2. Machinery room

The machinery room shall be in conformity with the following:

1. The machinery room shall possess necessary space for the inspection and upkeep and dismantling of installed facilities, and be secured with a necessary passage for carry-in and –out for machinery together with provision of a crane etc. as needed.
2. The machinery room situated underground shall have sufficient drainage capacity to deal with inundation and leakage, there shall be more than two entrances.
3. A ventilation device shall be equipped with the room to maintain the room temperature and humidity constant, and security shall be provided for the lighting window and the doors.

### 8.13.3. Electric room

The electric room shall be in conformity with the following:

1. Although it is desirable that the location of the electric room is at the central position of loads, it shall be selected in consideration of the condition of the location of installation, layout of loads, the routes of wiring etc.
2. The space and the height of the electric room shall be sufficient with some allowance for carry-in and –out of equipment, inspection and upkeep, dismantling and repair, and future replacement of facilities. There shall be more than two entrances.
3. As to the environment of the room, ventilation, air-conditioning equipment etc. shall be fully provided, and, at the same time, the room shall adequately be isolated from corrosive gas, combustible gas etc.
4. The electric room shall be structured in conformity with the fire law and the building standards law. Besides, security shall be provided for lighting windows and doors; and, at the same time, protective measures shall be arranged against the invasion of animals, insects etc.

**[Interpretation]**

**On the item 2.;**

A design with an assumption for facilities to be replaced is essential, and so the space in the same room for carrying out the replacement work shall be considered (See Table 8.13.1).

**Table 8.13.1 Space required around the receiving-distribution equipment**

(m)

| By location<br>By apparatus | Front face or operating panel | Rear or inspection panel | Between rows (panels for inspection) | Other faces |
|---|---|---|---|---|
| High tension switchboard | 1.0 | 0.6 | 1.2 | — |
| Low tension switchboard | 1.0 | 0.6 | 1.2 | — |
| Transformer etc. | 0.6 | 0.6 | 1.2 | 0.2 |

(Source: High voltage power receiving equipment rules 2008)

### 8.13.4. Supervisory room

The supervisory room shall be so planned as to possess the function as the mainstay of facilities management as well as to provide work environment for safe operation and management. Besides, it needs to have the environment to become an emergency operation base at the time of a disaster.

### 8.13.5. Lighting fixtures

The lighting fixtures shall be in conformity with the following:

1. Lighting shall have illumination to allow pleasant performance of activities compatible to the purpose of use, and efforts shall be made for energy saving by means of using a light source with high efficiency.
2. Emergency lighting shall be provided at points required for operation and management.
3. The lighting fixtures shall be considered in that they are so laid out as to make their maintenance easy.

### 8.13.6. Prevention of noise and other measures

Prevention of noise and other measures shall be in conformity with the following:

1. Measures shall be implemented to prevent noise and vibration to spread beyond the boundary of the premises.
2. It shall be considered for noise and vibration not to spread to the supervisory room, the office etc.
3. Communication equipment, with which effective contact can be made in an emergency, shall be installed.

**[Interpretation]**

**On the item 1.;**

In such water supply facilities as pump facilities built close to residences, preventive measures for noise and vibration emitting from pumps, motors, combustible engines, power plant etc. to spread to the residences shall be implemented. What's more, even if there are no residences etc. in the neighborhood at the time of construction, in case residential area is expected to approach the premises, it is desirable to provide such measures in advance, or prepare to make it possible to implement soundproofing and vibration-proofing measures in future.

## 8.14. New energy

### 8.14.1. General

Water supply utilities have a facet as an energy consuming industry, and use approximately 0.8 % (in 2010) of the power consumption of the country as a whole. Hence, it is required for the water utility to positively tackle the preservation of the environment. These criteria deal with small-scale hydraulic generation and solar power which have been introduced by many water utilities.

### 8.14.2. Small-scale hydraulic generation

Small-scale hydraulic generation shall be in conformity with the following:

1. Synthetic examination shall be conducted on usable water flow, effective head (difference in elevation), facilities to consume generated power, condition of location for installation etc.
2. The effect of the introduction of generation shall be examined, and the clarification of the purpose and economic benefits shall be confirmed.
3. A model, which can effectively generate power, shall be chosen.

**[Interpretation]**

The largest untapped energy source in water supply is considered to be the residual head in the processes of raw water transmission, treated water transmission, and water distribution. Although the water pressure in raw water transmission, and treated water transmission is traditionally regulated by pressure reducing valves, the residual head can be effectively used converting the head into electric energy by means of installing a generator in the pipe.

### 8.14.3. Solar power

Solar power shall be in conformity with the following:

1. Solar cells with an excellent conversion factor and the ease of maintenance shall be selected.
2. The effect of the introduction of solar power shall be examined, and the clarification of the purpose and economic benefits shall be confirmed.
3. It shall be composed of solar cells, racks, connecting box, power conditioner etc.
4. The type of operation, systems interconnection method, data measurement method etc. shall be studied.

**[Interpretation]**

As the introduction of solar power has been in progress in water supply facilities since around 2000, it is installed on the cover of sedimentation basins and filters, on service reservoirs etc. in many cases.