5.5.10 Code No. of Factory: C-10

(1.) Outline of Factory

Capital (M฿): -

Annual Amount of Shipment: 900 t/M
(Latex 300 t/M)
(Resins 600 t/M)

Total Area (m^2): 17,000

Total No. of Employees: 100

Main Products: Latex, Alkyd Resin and Amino Resin

(2.) Present Situation of the Use of Industrial Water

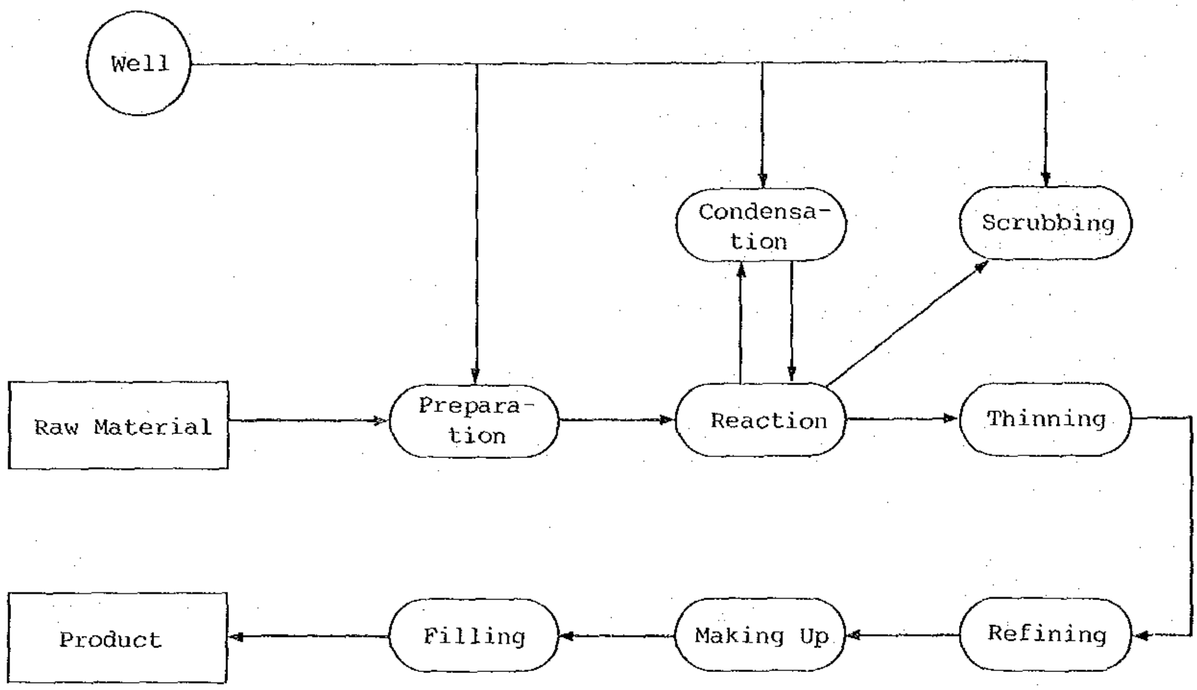
(2.1) Water Consumption

Unit: m^3/d

Use \ Source	Well Water	MWA	Others	Sub Total	Recovered Water	Total
Boiler	26			26		26
Material	10			10		10
Processing & Washing	135			135		135
Cooling	60			60	2,000	2,060
Air Conditioning						
Others	69			69		69
Sub Total	300			300	2,000	2,300
Outside						
Total	300			300	2,000	2,300

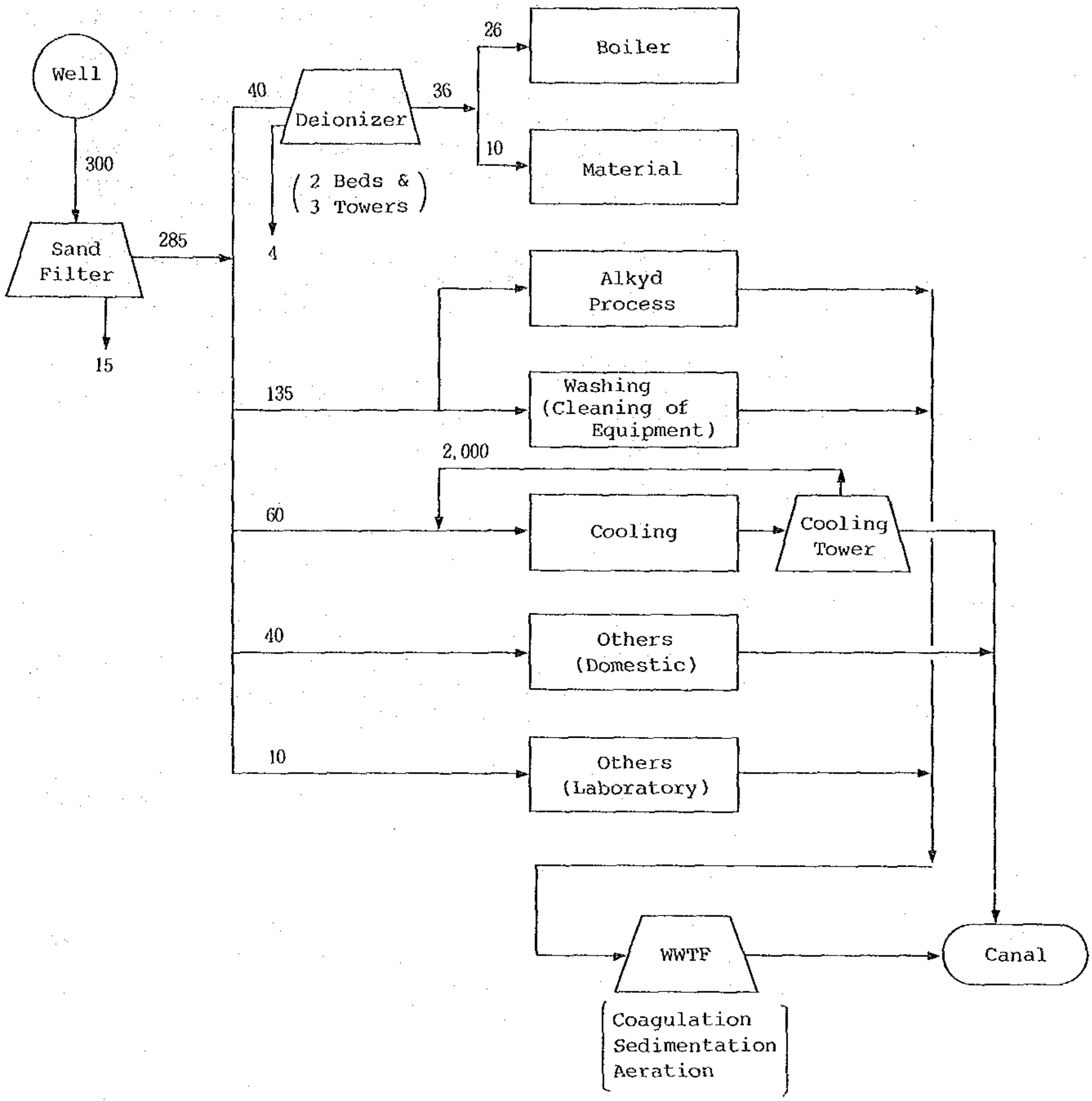
Recovery Rate (%): 87.0

(2.2) Process Diagram of Production Line



(2.3) Flow Diagram of Water Supply and Waste Water Discharge

(Unit: m^3/d)



Legend: WWTF = Waste Water Treatment Facility

(2.4) Explanation of Present Situation

(2.4.1) Sources and Uses

All water (including drinking water) used in this factory is supplied from a single well. The well is rather shallow (34 m deep).

Well water is fed to storage tank through an integrating flow meter. From the storage tank, well water flows into a water tank through a sand filter before being pumped out to a pressure tank. Thus, well water is supplied to each use from the pressure tank. On the whole, the use of water is well controlled.

All well water is treated by sand filter before being used. It is used mainly for the washing of machine and equipment (45% of the total) and as make-up water for the cooling tower (20%).

The recycle of cooling water is estimated at around 4,900 m^3/d. The degree of concentration is 1.4. The supply of make-up water is automatically controlled by water level of pit. Its volume is measured by the integrating flow meter.

The production facility of this factory is now being expanded, so the water consumption is expected to increase twice in the near future.

(2.4.2) Water Treatment

Well water is treated by a 2-bed-3-tower type demineralizer and mixed-bed polisher before being used for processing and the boiler.

Water treated by sand filter is used as make-up water for the cooling tower. The supply of make-up water is automatically regulated, and degree of concentration of recycled water is 1.4.

(2.4.3) Waste Water Treatment

Washing water for the equipment, waste water from laboratory and waste water from reactor (around 170 m^3/d in total) are treated by the coagulation, sedimentation and simple aeration processes.

Waste water from the regeneration operation of the demineralizer is neutralized before being discharged.

Blow down water from the cooling tower, blow down water from boiler and domestic waste water are discharged without any treatment.

(3.) Plans of Effective Use of Industrial Water

(3.1) General

On the whole, the water control of this factory seems to be good.

Cooling water for the monomer storage tank is recycled after collecting sprinkling water by receiving plate. Moreover, a sunshade is provided on the top of the tank.

The supply of make-up water for the cooling tower is measured by using integrating flow meter, and automatically regulated in accordance with the water level. Nonetheless, it is still possible to raise the degree of concentration from the present 1.4 to around 2 by chemical injection.

Washing water of machine and equipment takes up a large of water consumption, but it is very difficult to find water saving measures in this respect.

Instead of the once-through system which uses a lot of water, the water saving type system is adopted for the scrubber of reactor.

The water recovery rate of this factory reaches 94.3%.

(3.2) Details

a. Raising of degree of concentration through improvement of operation control of cooling tower

If the degree of concentration is raised to about 2, the required quantity of make-up water would be reduced to 34 m^3/d.

Thus 26 m^3 of water would be saved.

(4.) Cost Estimation

Number	1
Method for Effective Use Method Item	 Improvement of operation control Improvement of operation and maintenance of cooling tower to raise degree of concentration
Water Saving Use Quantity (m^3/d)	 Cooling 26
Apparatus for Effective Use Apparatus Cost (10^3฿)	
Unit Cost (฿/m^3) Fixed Operating Total	 - 0.5 0.5

5.5.11 Code No. of Factory: C-11

(1.) Outline of Factory

Capital (M฿): 80

Annual Amount of Shipment (M฿): Ca. 180

Total Area (m^2): 80,000

Total No. of Employees: 240

Main Products: Plasticizer and Plastics

(2.) Present Situation of the Use of Industrial Water

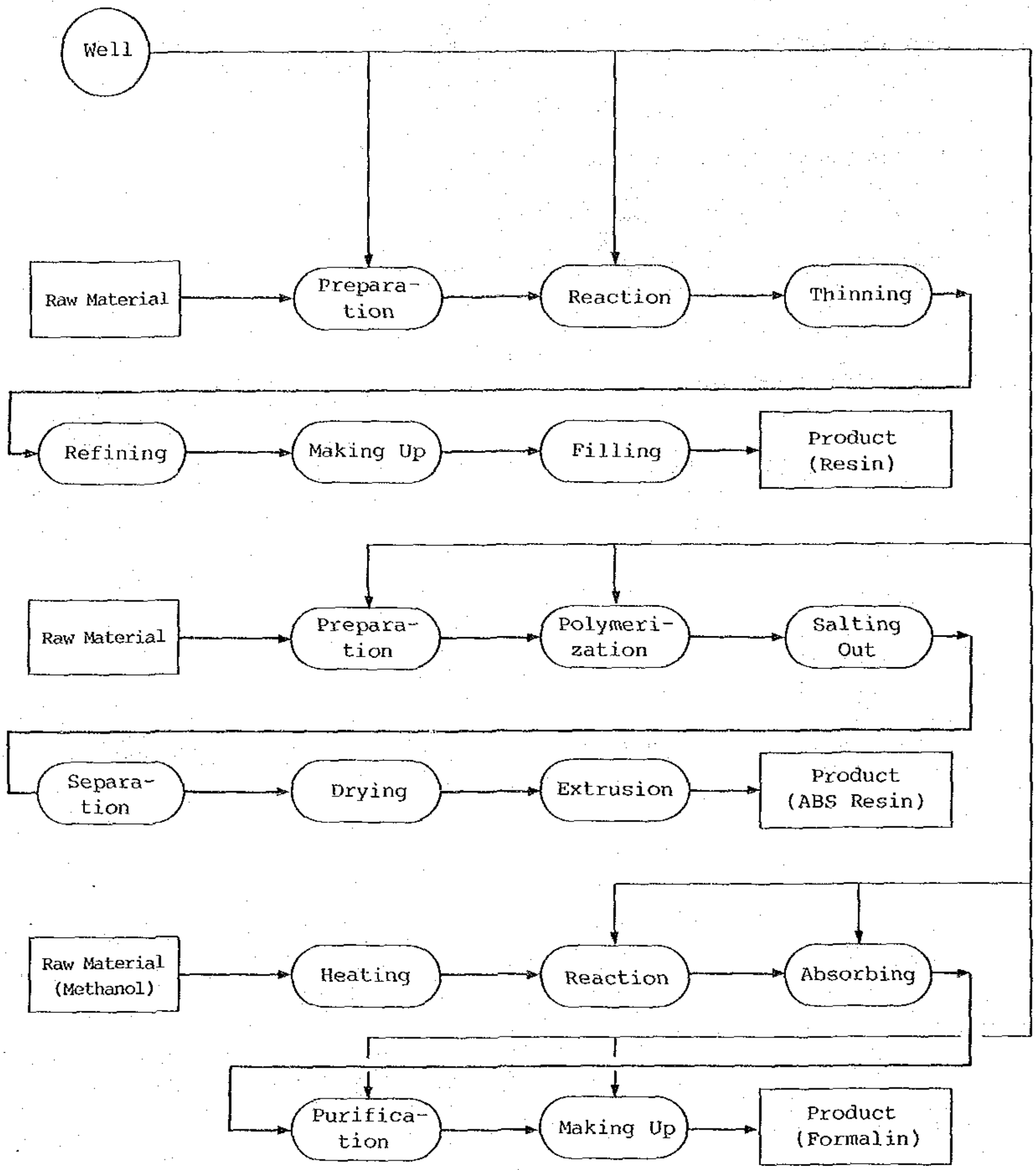
(2.1) Water Consumption

Unit: m^3/d

Use \ Source	Well Water	MWA	Others	Sub Total	Recovered Water	Total
Boiler	100			100		100
Material	30			30		30
Processing & Washing	190			190		190
Cooling	450			450	14,400	14,850
Air Conditioning						
Others	50			50		50
Sub Total	820			820	14,400	15,220
Outside	200			200		200
Total	1,020			1,020	14,400	15,420

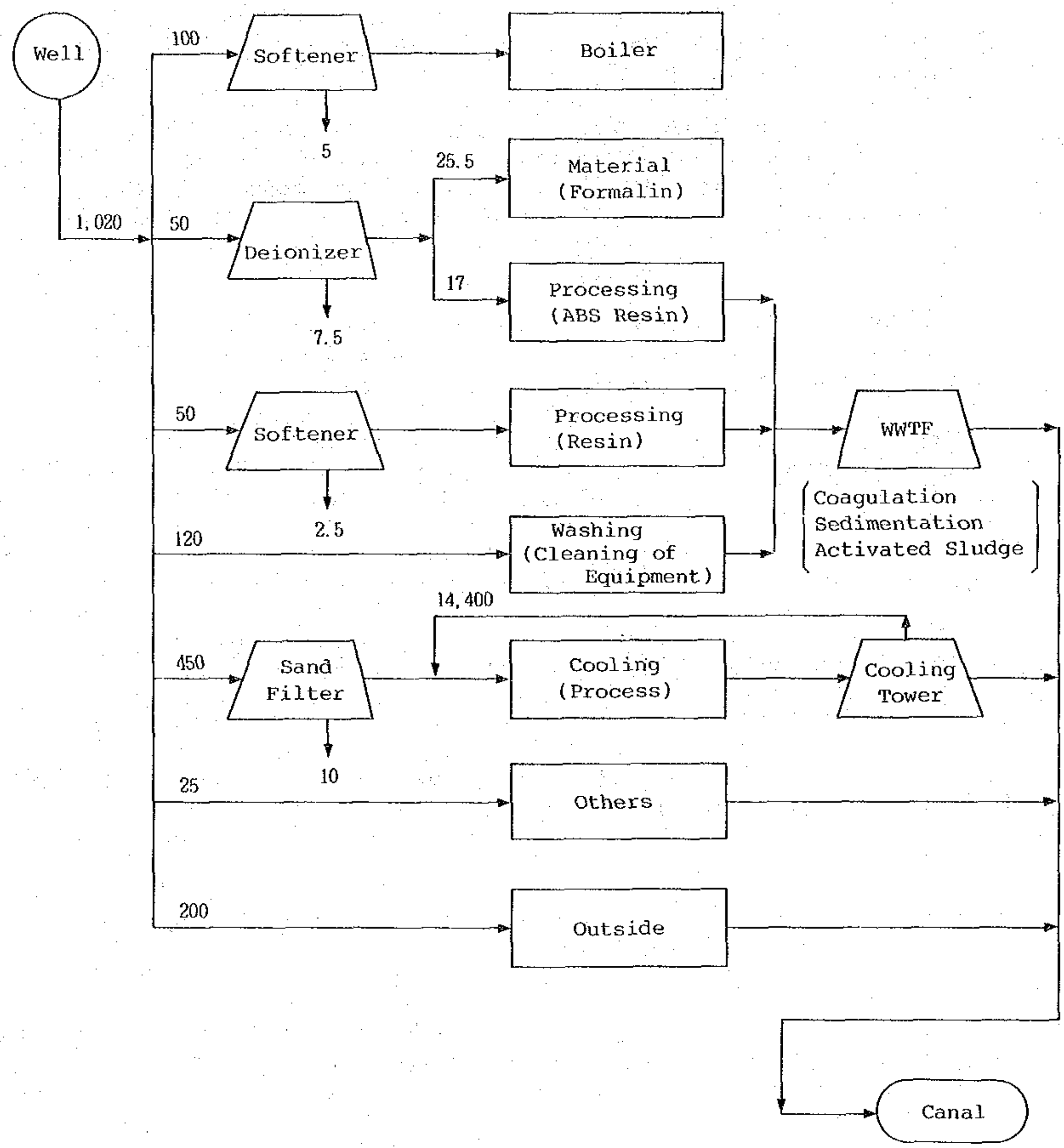
Recovery Rate (%): 93.4

(2. 2) Process Diagram of Production Line



(2.3) Flow Diagram of Water Supply and Waste Water Discharge

(Unit: m^3/d)



Legend: WWTF = Waste Water Treatment Facility

(2.4) Explanation of Present Situation

(2.4.1) Sources and Uses

In this factory, water is supplied from two wells.

Water is used for the cooling (44%), the boiler (10%) and the employees' dormitory (200 m^3/d, 20%).

On the basis of the specifications of the cooling towers, the quantity of recycling water is estimated 1,500 m^3/h by the staff of factory. On the assumption that around 1% of it is evaporation loss and that blow down water is 80 m^3/d, it is estimated that the make-up water for the cooling towers may be 440 m^3/d.

However, judging from the pipe diameters of water supply line (one 8 inches and two 6 inches), the actual quantity of recycled water should be around 600 m^3/h.

Owing to the batch-type production system, the load of the cooling tower fluctuates in accordance with the operation condition. Because the degree of concentration of the recycled water is quite low (1.04), it seems that the actual heat load to the cooling tower and quantity of recycled water are substantially lower than the values estimated by the factory.

For formalin absorption/refining and for ABS resin reaction, pure water treated by the ion exchanger is used.

For reaction of other resins, softened water is used.

For the washing of machine and equipment, the office and the dormitory, well water is used without any treatment.

(2.4.2) Water Treatment

Make-up water for the cooling towers is treated by the sand filter provided exclusively.

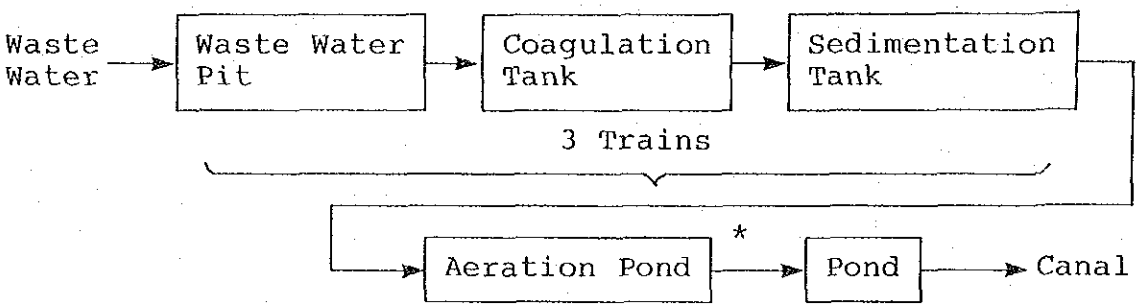
There are four cooling towers. The return water is sent to a hot water tank, from which it is pumped out to the top of cooling towers. Cooled water is supplied to each production process through a cool water pit. Make-up water is sprayed to the cool water pit.

A demineralizer is installed to supply pure water for ABS resin and formalin productions.

A softener is installed to supply softened water for various types of resin production.

(2.4.3) Waste Water Treatment

Waste water from processing and washing is treated and discharged as shown below.



*(3-stage aeration, total detention time is 3 days)

On the whole, the waste water treatment system of this factory is working well.

(3.) Plans of Effective Use of Industrial Water

(3.1) General

Integrating flow meters at the outlets of two wells measure the pumping up quantity of water.

The degree of concentration of cooling tower is very low. Therefore, the use of make-up water could be reduced by raising the degree of concentration.

Water leakage was observed at some pipings and valves on the water supply system. To save the water consumption, these leakage parts should be promptly repaired.

(3.2) Details

a. Raising of degree of concentration through improvement of operation control of cooling tower

According to the water balance data provided by the factory, the degree of concentration of the cooling water is 5.5 and the temperature difference is a little less than 6 °C, both of which seem to be impracticable.

The survey revealed that the temperature difference between the outlet and inlet is 3.5 °C and the degree of concentration is 1.05. Also, judging from the piping diameters of the recycling line, the quantity of recycled water for cooling towers seems to be nearly 600 m^3/h. On the basis of these data, the evaporation loss is likely to be about 90 m^3/d.

Therefore, 440 m^3/d of make-up water will be divided into 80 m^3/d of evaporation loss and 360 m^3/d of blow-down. Based on the above estimate, the degree of concentration is calculated at 1.2, which seems to agree with the actual state.

With the evaporation loss of 90 m^3/d, water saving measures for cooling system could be summarized as the following table.

Unit: m^3/d

Case	Degree of Concentra-tion	Make-up Qt.	Required Pre-treatment	Pre-treatment Loss	Total Required Water Qt.	Comparison with Present Level
1	1.2	540	Sand fil-tration	16	556	+ 106
2	1.5	270	"	8	278	- 172
3	2.0	180	Sand fil-tration/ softening	24	204	- 246
4	2.5	150	"	20	170	- 280
5	3.	135	"	18	153	- 297

Among the various cases shown above, the case 3 (with the degree of concentration of 2) seems to be reasonable. Taking the measures of the case 3, 246 m^3/d of water would be saved.

(4.) Cost Estimation

Number	1
Method for Effective Use Method Item	 Improvement of operation control Improvement of operation and maintenance of cooling tower to raise degree of concentration
Water Saving Use Quantity (m^3/d)	 Cooling 246
Apparatus for Effective Use Apparatus Cost (10^3฿)	
Unit Cost (฿/m^3) Fixed Operating Total	 - 0.5 0.5

5.5.12 Code No. of Factory: C-12

(1.) Outline of Factory

Capital (M฿): -

Annual Amount of Shipment (M฿): -

Total Area (m^2): 20,000

Total No. of Employees: 109

Main Products: Sorbitol and Dextrose Monohydrate

(2.) Present Situation of the Use of Industrial Water

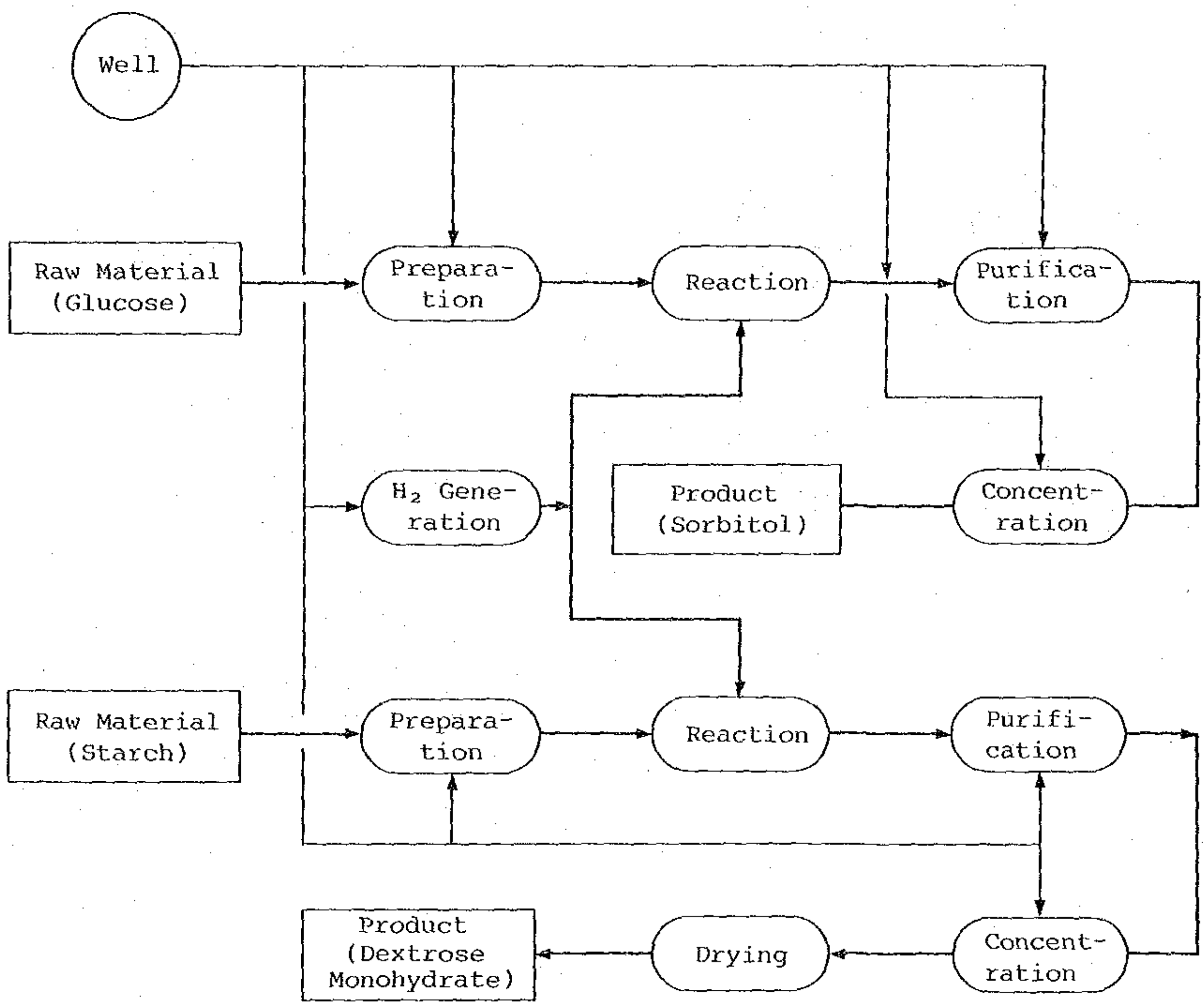
(2.1) Water Consumption

Unit: m^3/d

Use \ Source	Well Water	MWA	Others	Sub Total	Recovered Water	Total
Boiler					67	67
Material						
Processing & Washing	130			130		130
Cooling	43			43	2,160	2,203
Air Conditioning						
Others	77			77		77
Sub Total	250			250	2,227	2,477
Outside						
Total	250			250	2,227	2,477

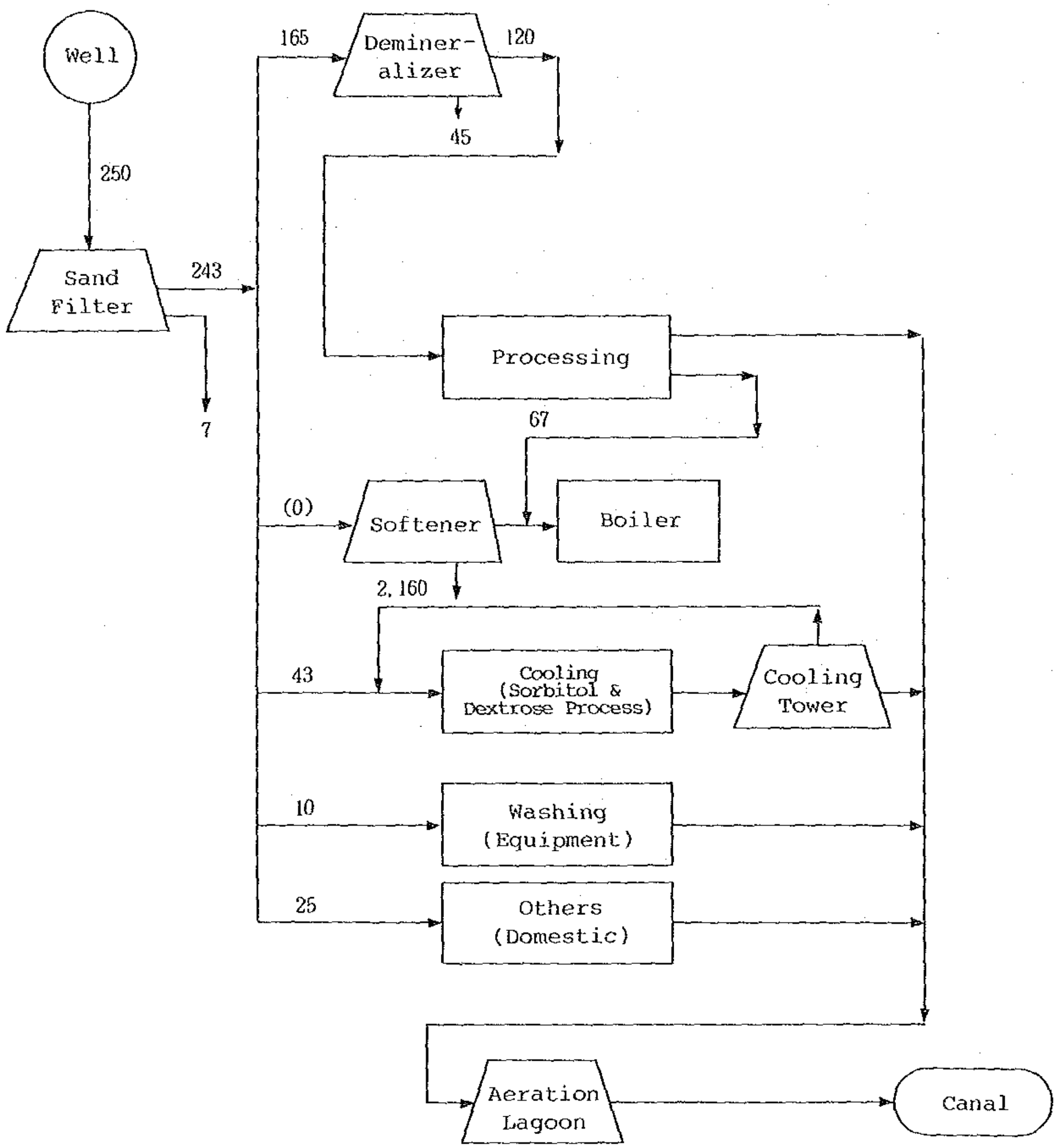
Recovery Rate (%): 89.9

(2.2) Process Diagram of Production Line



(2.3) Flow Diagram of Water Supply and Waste Water Discharge

(Unit: m^3/d)



(2.4) Explanation of Present Situation

(2.4.1) Sources and Uses

In this factory, water is supplied from two wells.

The main use of water is for processing (about 120 m^3/d of pure water). For the boiler, almost all water comes from the condensate recovered from the process plant. Thus virtually no make-up water is used for the boiler.

The recycled water of the cooling tower is estimated at approximately 2,200 m^3/d. Judging from the temperature difference of 2 ℃ and the degree of concentration of 1.2, the make-up water for the cooling tower is estimated at 43 m^3.

No flow meter is installed at the well outlets. Well water consumption is estimated at 200 m^3/d in this factory. Yet, judging from the measurement on the day of this survey, (16.2 to 17.1 m^3/h, i.e. 390 to 410 m^3/d), the actual pumping up quantity is likely to exceed the factory's estimate.

(2.4.2) Water Treatment

Although a sand filter is installed at the inlet of the head tank, it is for emergency use and is normally out of operation.

A 2-bed-3-tower type demineralizer is provided for process water treatment.

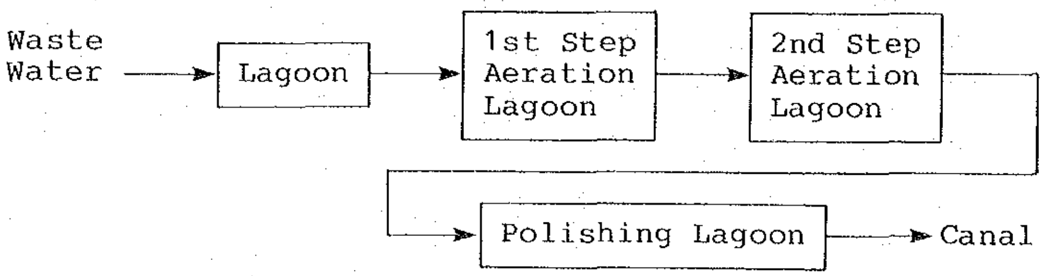
Although two softeners are installed for the treatment of boiler water, normally recovered condensate from the production process is used for the boiler.

There is one cooling tower. Its make-up water is supplied directly from the head tank.

No flow meter is installed for any of the water supply line.

(2.4.3) Waste Water Treatment

Waste water from processing and washing is treated and discharged as shown below.



At each step of the aerated lagoon, water is treated once a day batch wise.

(3.) Plans of Effective Use of Industrial Water

(3.1) General

In order to carry out effective control of water use, appropriate flow meters should be installed to record the accurate quantity of water consumption.

The consumption of pure water for processing seems to be too large. If the consumption of pure water is decreased, the operation cost of the factory will be also reduced. However, since the actual state of water use is to be known, it is difficult to study possible water saving measures in detail.

The softener for boiler water is usually out of operation. So, if it is used to produce softened water for the cooling tower, the quantity of make-up water required for the cooling tower would be reduced.

(3.2) Details

a. Raising of degree of concentration by using softened water as make-up water of cooling tower

If softened water is supplied to the cooling tower and the degree of concentration is raised up to about 2, the quantity of make-up water would be 15.4 m^3/d (16 m^3/d including discharged water from softener). Thus, about 7 m^3/d of water would be saved.

(4.) Cost Estimation

Number	1
Method for Effective Use Method Item	 Recycle use Supply of soft water as make-up water to cooling tower to raise degree of concentration
Water Saving Use Quantity (m^3/d)	 Cooling 27
Apparatus for Effective Use Apparatus Cost (10^3฿)	 Piping 4
Unit Cost (฿/m^3) Fixed Operating Total	 0.1 1.2 1.3

5.5.13 Code No. of Factory: C-13

(1.) Outline of Factory

Capital (M฿): 24.5

Annual Amount of Shipment (M฿): 18.8

Total Area (m^2): 25,600

Total No. of Employees: 94

Main Products: Medicines (Tablet, Cream, Sore Mouth Gel, etc.)

(2.) Present Situation of the Use of Industrial Water

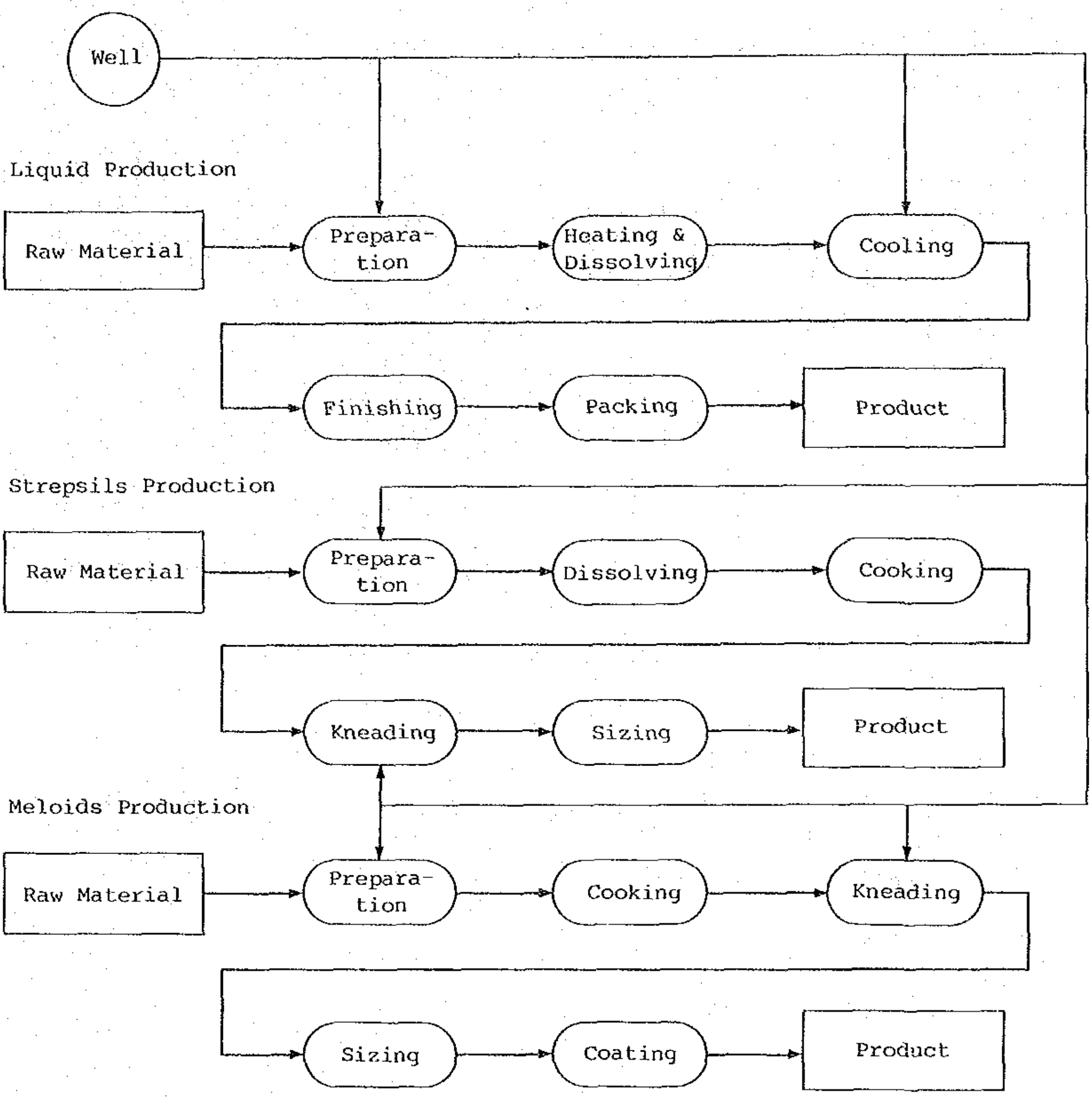
(2.1) Water Consumption

Unit: m^3/d

Use \ Source	Well Water	MWA	Others	Sub Total	Recovered Water	Total
Boiler	1			1	2	3
Material Processing & Washing	34			34		34
Cooling	2			2	30	32
Air Conditioning						
Others	8			8		8
Sub Total	45			45	32	77
Outside						
Total	45			45	32	77

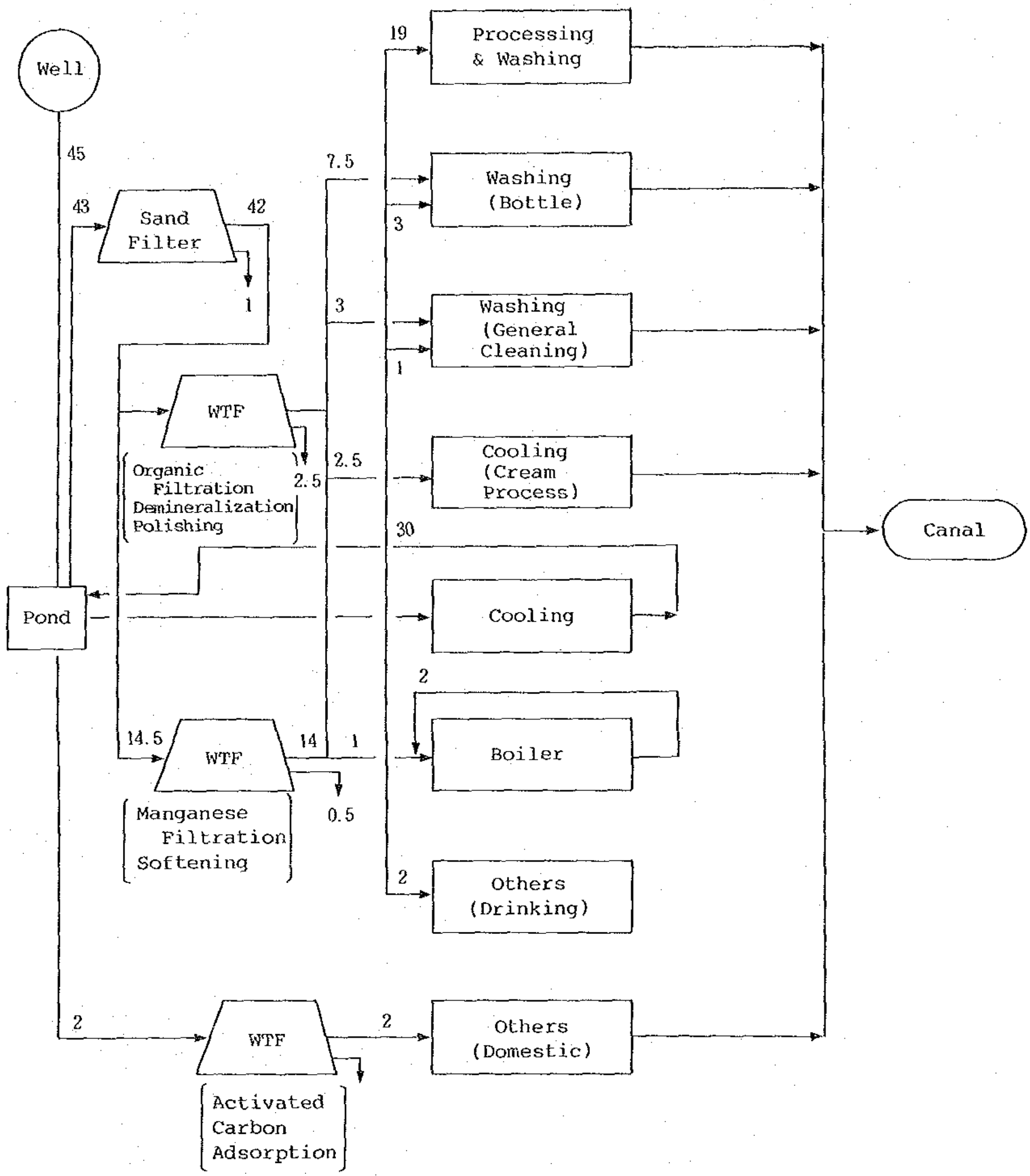
Recovery Rate (%): 41.6

(2.2) Process Diagram of Production Line



(2.3) Flow Diagram of Water Supply and Waste Water Discharge

(Unit: m^3/d)



Legend: WTF = Water Treatment Facility

(2.4) Explanation of Present Situation

(2.4.1) Sources and Uses

In this factory, water is supplied from a single well. An integrating flow meter is installed at the well outlet to measure the pumping up quantity.

Although the well water has a relatively low electrical conductivity, it contains a large quantity of iron, which has to be removed before being used.

According to the requirement of the production process, the use of pure water and softened water takes up significant percentage of the total water consumption.

Cooling water is recycled to a well water pond. This way is possible because the cooling load is small.

For drinking, pure water is used.

(2.4.2) Water Treatment

Through a tower-type aerator, well water is sent to a well water receiving tank where chlorine (soda hypochlorite) is injected.

Office water is supplied after being treated by activated carbon adsorption tower.

Processing water is first sent from the well water receiving tank to a sand filter. Then some of it is treated by a manganese filter and a softener.

Main use of the treated water is for cleaning or washing of bottle. *It is also supplied to the boiler.*

Most of sand filtered water is further treated by the organic filter, 2-bed-3-tower type demineralizer, mixed-bed polisher, and ultraviolet sterilizer. Thus treated water (pure water) is used for drinking as well as for processing and washing.

(2.4.3) Waste Water Treatment

Waste water treatment facility is not installed in this factory. After being sent to a pond inside the factory, waste water is discharged to the outside.

(3.) Plans of Effective Use of Industrial Water

(3.1) General

Well water consumption is measured by the flow meter which is installed at the well outlet.

A flow meter is also installed at the purifier. Yet, it shows unusually small quantity of pure water consumption. The flow meter does not seem to be accurate enough.

Since well water consumption is small and the use of water is reasonably well controlled, there is little room for further improvement.

Chapter 6

Guideline for Effective Use of Industrial Water Classified by Use

6 Guideline for Effective Use of Industrial Water Classified by Use

6.1 Outline

In this Chapter, general methods for effective use of industrial water are explained being classified by the purpose of use, in addition to those for each factory which have been described in the previous Chapter 5.

Purpose of industrial water use are as follows:

(1) Boiler water
(2) Product processing and washing water
(3) Cooling and air conditioning water
(4) Others

For industrial water included in above-mentioned (1), (3) and (4), there seems to be no difference on the characteristics of feed water and drainage and also water usage between each type of industry, and general methods for effective use are explained.

The water for processing and washing of products (2), on the other hand, the applications and the characteristics of feed water and drainage can be divided into two categories, those which are pertaining to each type of industry and common ones.

In this Chapter, therefore, the methods for effective use of water are provided mainly for the latter case.

To clarify the effective use of water, the method for each purpose of water use are detailed as follows:

(1) Characteristics of feed water and drainage,

(2) Standard methods for effective use of water,

(3) Cost estimation, and

(4) Notes and problems in effective use of water.

In addition to the above, a theoretical explanation are partly given.

The conditions for cost estimation are as follows, unless otherwise specified:

Depreciation period:	10 years
Average interest:	10% per year
Annual operating days:	300 days
Water cost:	10 &/m³

Incidentally, effective use of industrial water is not employed in pursuit of economic merit, but should be applied as pollution control measures which is not basically connected with economic features. Therefore, cost estimation in this report is one of reference value.

6.2 Industrial water for boilers

6.2.1 Characteristics of Feed Water and Drainage

The water for boiler feed is used, in general, after removing hardness components by means of water softeners. The steam generated in the boiler is used mainly for the various purpose of heating. The heating methods can be roughly divided into two types--direct heating and indirect heating.

Steam which is used for direct heating of products cannot be a subject of the study of effective use because the recovery of condensate is impossible.

However, in the case of indirect heating, steam condensate can be recovered in principle. Condensate should be recovered as much as possible because the effect of the increase in heat efficiency is largely expected in addition to the effective use of water.

The flow diagram for boiler water used for both direct and indirect heating is shown in Fig. 6.1. Condensate generated by the indirect heating is nearly pure water containing no impurities except only a little corrosion products from piping material.

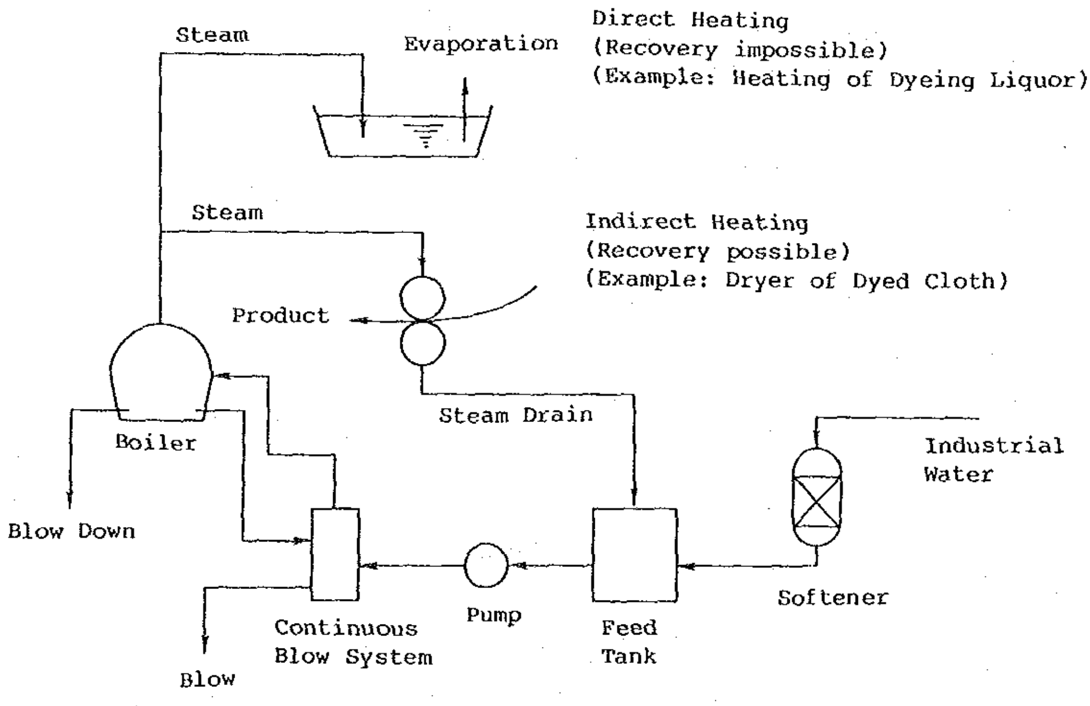


Fig. 6.1: Flow Diagram of Boiler Water

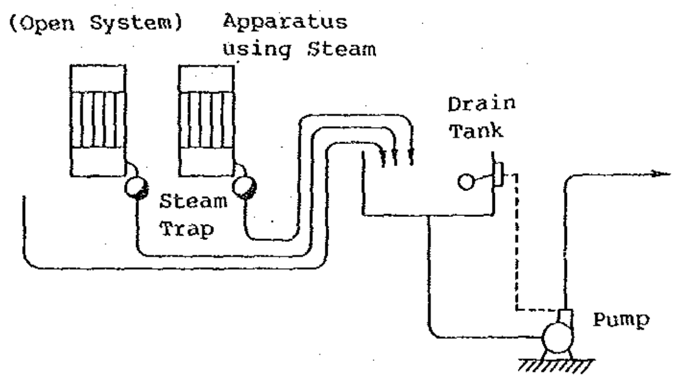
6.2.2 Standard Methods for Effective Use of Water

As condensate has a good quality, it can be re-used for boilers without treatment or after the removal of contained suspended solid utilizing a simple condensate filter.

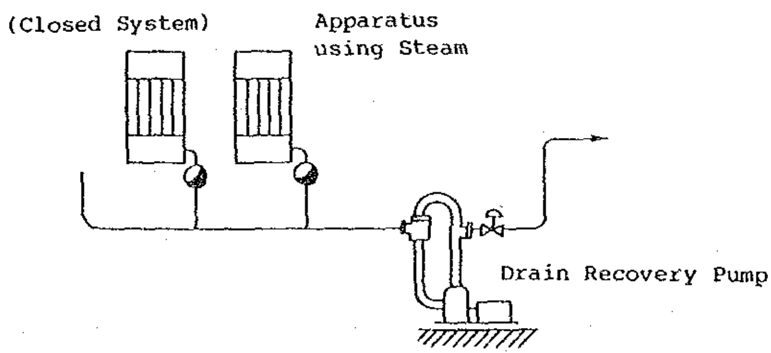
To recover condensate, there are two systems in general, open system and closed system. In the open system, the condensate is once released into an open-type tank during the recovering process.

This system is currently employed at most factories, however in this system, a large quantity of heat which corresponds to nearly 50% of the thermal energy of the condensate is radiated in the atmosphere and several percent to around 20% of the condensate is lost in the atmosphere as re-evaporating steam. To make the recovery of condensate more effective covering the weak point of open system, a closed system was recently developed and is gradually becoming popular.

In the closed system, the condensate is recovered directly to a boiler without contacting the air. A high temperature more than 100 °C, causes few corrosions on pipes and allows the recovered condensate be used widely. Each drain recovering system for open and closed systems is shown in Fig. 6.2.



Drain Recovery Combined with Centrifugal Pump



Combined with Drain Recovery Pump Drain Recovery

Fig. 6.2: Example of Steam Drain Recovery Apparatus

6.2.3 Cost Estimation

Required cost for effective use should be calculated for each case of such drain recovering systems as follows;

(1) current system (steam condensate is not recovered)
(2) open recovering system, and
(3) closed recovering system.

(a) Conditions

Boiler capacity: 10 t/d (1 t/h)
Cost of water (softened water): 50 ฿/m^3
Type of fuel: Heavy oil (65 ฿/lit)

(b) Cost estimation

Table 6.1: Cost Estimation for Condensate Recovery

Item \ Case	Current System	Open System	Closed System
1. Condensate recovery rate (%)	0	20	50
2. Amount of make up water (m^3/d)	10	8	5
3. Cost of supply water (A) (¥/d)	500	400	250
4. Cost of facilities for condensate recovery (¥)	-	10,000	800,000
5. Depreciation including interest (B) (¥/d)		7	530
6. Fuel consumption (lit/d)	700	630	420
7. Fuel cost (C) (¥/d)	45,500	40,950	27,300
8. Total cost (A)+(B)+(C) (¥/d)	46,000	41,357	28,080
9. Cost saving rate (%)	–	10%	39%

6.2.4 Notes and Problems in Effective Use of Water

Excessive iron contained in the recovered condensate accelerates the corrosion of the boiler tube, so an appropriate anti-corrosive treatment is required for steam and condensate lines to reduce the iron contents.

Particularly, it should be noted that a frequent use of recycled water by means of the condensate recovery gradually increases the concentration of iron in the boiler water even if it is initially low in the recovered condensate.

In addition, make-up water should be always softened, because an excessive quantity of hardness components in the make-up water makes, as explained above, scales on the inside surface of the boiler tubes. And the thick scale reduces the heat transfer rate of the boiler tubes extremely.

A pump applied for condensate recovery system should have enough capacity to suck the steam condensate and deliver it to a condensate re-using unit. Both units, recovery and re-using units, should be balanced in capacity in order not to give a bad influence upon the performance of each of them.

Moreover, because the steam condensate is recovered and re-used at high temperature and pressure, equipments and materials in this system should be of made of suitable material for such conditions.

6.3 Industrial Water for Processing and Washing of Products

6.3.1 Characteristics of Supply Water and Drainage Water

Industrial water for processing and washing of products should usually be comparatively good in quality, corresponding to the quality of material water as much as possible, because it often contacts directly with the products.

And a large quantity of water is often consumed in all industries, though the quantity used at each production process depends on the type of processing line. As for the quality of waste water discharged from the washing process, on the other hand, the concentration of pollutant is relatively high and it determines in many cases the characteristics of waste water for a factory.

6.3.2 Standard Methods for Effective Use of Water

The following standard methods have been applied for effective use of product processing and washing water:

(1) Counter-current and multistage washing system
(2) Cascade system
(3) Water saving apparatus

The principle, water saving rate and etc. for each method are as follows:

(1) Counter-current and multistage washing system

(a) General concept

In this system, materials to be washed and washing water flow counter-currently to each other. With a single washing tank system, the washing of product is not effective. Thus a multistage washing system should be selected. An outline drawing of this counter-current and multistage system is shown in Fig. 6.3.

This system is widely applied. For examples, metal-plated products washing in the metal industry and cans and bottles washing for canned foods and refreshing drinks in the food industry.

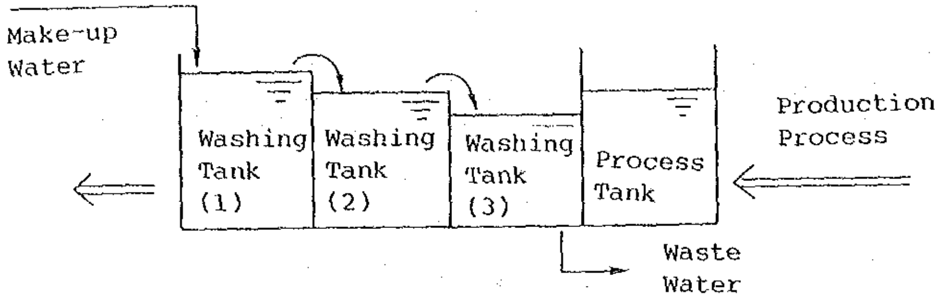


Fig. 6.3: Example of Counter-Current Multistage Washing System

(b) Water consumption for counter-current washing system

In the washing process for metal-plated products, washing water is used to wash out residual chemicals on the surface of products delivered from a plating bath. In this case, any chemicals are not required to be absolutely removed, however, they should be diluted to an acceptable concentration.

Assuming that the concentration of a chemical adhered on a product should be diluted to a hundredth with two-stage washing system instead of the single stage system.

In the two-stage washing system, a chemical should be diluted to one tenth of concentration at the first stage and should be diluted once more to one tenth at the second stage.

That is, a chemical diluted to one tenth of concentration at the first stage is diluted once more to one tenth, finally obtaining the concentration of one hundredth $(1/10 \times 1/10 = 1/100)$.

The water consumption of the two-stage is one tenth of that at the single stage system (assuming quantity of feed water as A, $1/100 = A/100 \times A/100$ resulting $A = \sqrt{100}/100$).

Similarly, water supply at the three stage reduces to $\sqrt[3]{100}/100 = 1/22$. Consequently, water consumption can be reduced proportionally to the increase of the diluting effect obtained according to the increased number of washing times (stages).

The relationship between the number of stages and the water consumption is shown in Fig. 6.4. As seen in this figure, the increasing of the washing stage over the third is not so effective for water saving.

In the counter-current and multistage washing with a bottle washing machine, bottles are dipped in a caustic soda solution and washed by means of water jet for five to six times as shown in Fig. 6.5.

For example, make-up fresh water is used only at the third washing stage as shown in Fig. 6.5. Its waste is used at the second stage washing then the waste water from this stage is re-used at the first stage washing. This system assures the almost same washing effect as that to be obtained under any stage washing systems.

The water consumption, different from that for the washing of plated products as described above, is inversely proportional to the number of washing stages. With a three-stage washing system, for example, the total quantity of water use is one third of that by supplying fresh water to all washing stages.

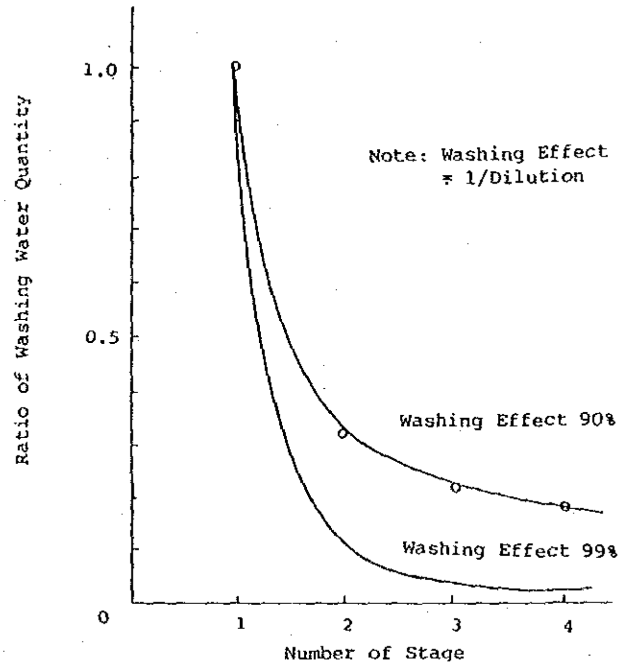


Fig. 6.4: Number of Stage and Ratio of Washing Water Quantity in Counter-Current Multistage Washing System

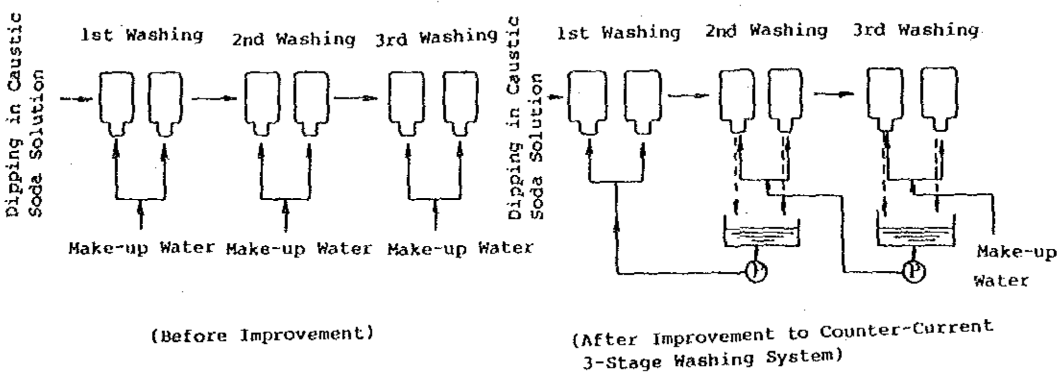


Fig. 6.5: Counter-Current Multistage Type Bottle Washing Machine

(2) Cascade system

With a cascade system, waste water used for a certain process is re-used for another process without treatment. Because it does not require any expensive facilities flow re-use and the operation cost is small, this cascade system can be a highly effective method of washing if it is practically available.

In most cases, indirect cooling water is re-used as a cascade in a washing process. To introduce this system, however, there are a lot of restrictions as described below.

(a) The quality and the temperature of waste water from the preceding process should be kept a level acceptable for the succeeding process.

(b) The quantity of waste water from the preceding process and the water consumption at the succeeding process should be nearly balanced.

(c) Operating conditions such as operating time and so on of both preceding and succeeding processes should be similar to each other.

In the effective use of water with a cascade system, water consumption can be saved by 50% at most even if all the requirements as stated above have been satisfied.

(3) Use of water saving apparatus

The following washing equipment and devices are available to save the water consumption.

(a) Hand control valve
(b) Flow control valve
(c) Automatic water supply system for washing tank
(d) High pressure jet washer
(e) Hot water jet washer
(f) Bottle washer
(g) CIP (cleaning in place)
(h) Washing machine for finishing
(j) Jet dyeing machine with low liquor ratio

Among the above-mentioned machines and devices, (a) through (e) are used widely in all industry, while (f) and (g) are limited to use for food processing plants mainly and (h) and (j) are to the textile industry. These equipment and devices from (f) through (j) will be explained in the next Chapter.

In addition to the above, the following water saving apparatus are available.

(k) Automatic urinal washer
(l) Water saving type closet

Details of these two apparatus are described in "6.5 Industrial Water for Miscellaneous Use".

(a) Hand Control Valve

(Function and Structure)

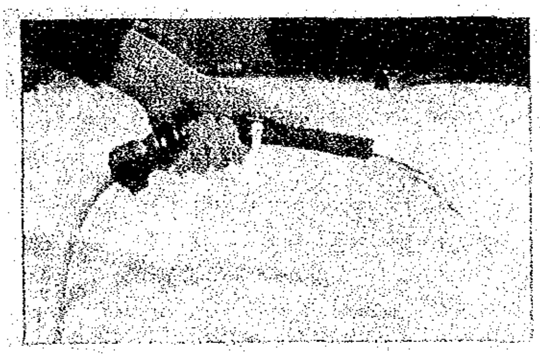
Hand control valve is mounted at the nose of a water hose to allow an operator to freely control the water discharge at hand (hand control valves for high pressure washers which will be explained later are excluded here).

When washing is carried out by using a water hose, water is discharged wastefully for a certain time from the opening of the main valve to the washing work as well as from the finishing of the washing work to the closing of the main valve. *In addition, the operator often moves to another* work for a while without closing the main valve.

By utilizing a hand control valve therefore, it is expected to achieve a considerably high rate of water saving (more than 20%).

A hand control valve is composed of a valve element, a grip section, a hose adapter and other parts. There are several types of valves according to their appearance, operating method, etc.. Two types of hand control valves are shown in Figs. 6.6 and 6.7.

Cylinder-type Thumb Touch Control



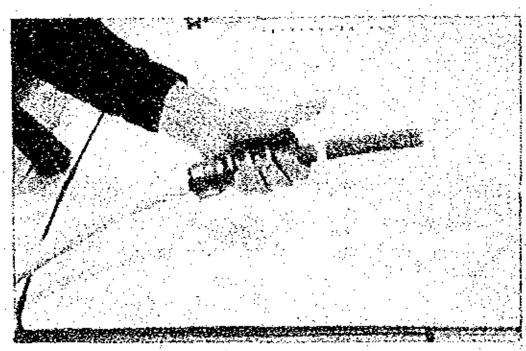


Fig. 6.6: Hand Control Valve (No. 1)

Gun-type Front Lever Operation

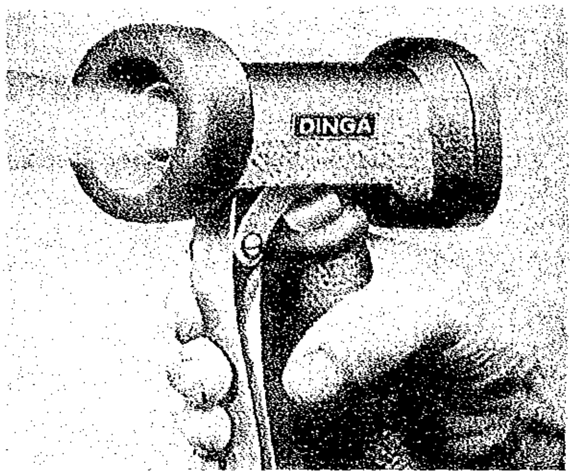


Fig. 6.7: Hand Control Valve (No.2)

Hand control valve should be of light weight for easy operation because it is used being equipped at the nose of a water hose as explained above. Rough handling after use may easily damage the apparatus, however, with a rigid structure which could bear such a rough handling, the weight should increase making the operation difficult and raising its cost. The water hose to which a hand control valve is mounted should also be of pressure proof.

(Cost of equipment)

Prices of hand control valves varies from 3,000 to 30,000 yen according to the type and the material.

(b) Flow Control Valve

(Function and Structure)

Flow control valve is used to supply a required and adequate quantity of water. This valve is mounted on the way of a supply water piping led from a water source or a hydrant in a factory to a machine or a device which uses water.

Since the water supply for machines and devices is previously set with this flow control valve at optimum flow rate, excessive spillover will be prevented.

Flow control valve is composed of a valve part, a flow control system, inlet and outlet connections, etc. There are two types of the control system, constant flow control type and integrated flow control type.

(Water Saving Rate)

The water saving rate with a flow control valve is considered to be 10 through 20%, though it depends on the control level. Fig. 6.8 shows a sample of flow control valve.

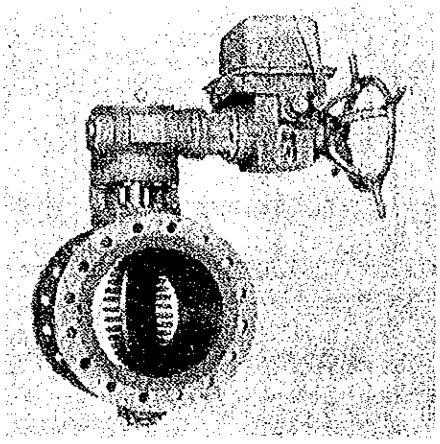


Fig. 6.8: Example of Flow Control Valve

(Cost of Equipment)

Price of flow control valves largely varies depending on specification including nominal bore size. The average price of the usual use is within the range from 2,000 yen to 50,000 yen per unit.

(c) Automatic Water Supply System for Washing Tank

(Function and Structure)

Automatic water supply system for washing tank (hereinafter called "Water supply system") is used to automatic control for the water supply to a washing tank to keep quality of water in the washing tank at a constant level.

To control the water supply for maintaining washing water quality, the system detects the change in quality of water in the washing tank. This unit is composed of detecting section, control section which transfers the detected signal to the driving section, and driving section which controls the water supply responding to the signal from the control section.

When it is used in various processes in the chemical industry including metal plating, alumite and semiconductor washing process as well as in the washing process before coating and painting, conductivity meter is provided as the detector. A model flow of a water supply system is shown in Fig. 6.9.

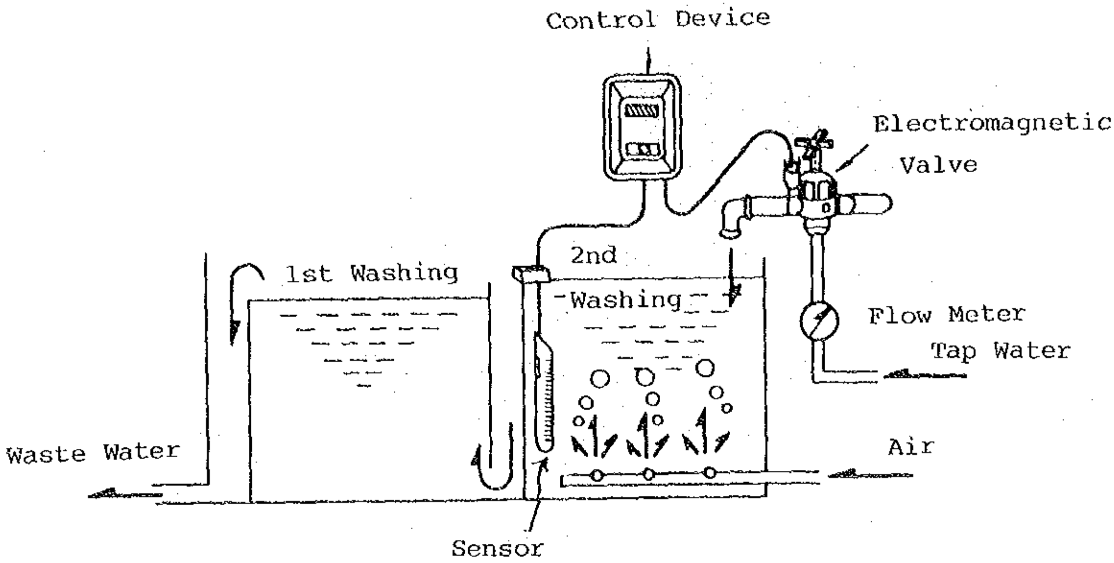


Fig. 6.9: Automatic Water Supply System for Washing Tank

Fig. 6.9: Automatic Water Supply System for Washing Tank

(Water Saving Rate)

The water saving rate with a water supply system varies depending on the type and the shape of products to be washed, however, the saving of 50 to 80% of the water consumption can be expected if a water supply system is installed for the case of one through washing.

(Cost of Equipment)

The price for a water supply system, including detector, control and drive sections, will be 100,000 to 200,000 yen.

(d) High Pressure Washer

(Function and Structure)

High pressure jet washer is a machine used to wash out oil, grease and dirt adhered on the surface of products utilizing the impact of high pressure water which jetted from a nozzle at a high speed.

Since the impact of high pressure water is used, any narrow gaps, meshes, small holes and other inaccessible parts can be cleaned effectively without damages on the products' surface.

For this reason, high pressure jet washers are used to wash many kinds of products in all kinds of industrial fields.

A high pressure jet washer is composed of a high pressure pump, a pressure control device to control the water pressure, and such accessories as high pressure water hose and jet nozzle. It has also a structure which allows a hand control valve and other apparatus to be equipped. An outline of this equipment is shown in Fig. 6.10.

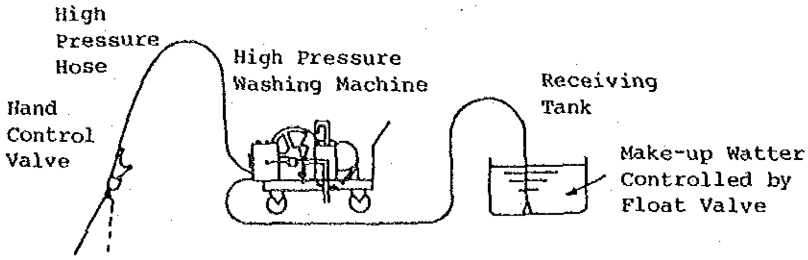


Fig. 6.10: High Pressure Jet Type Washing Machine

To control the water jet at hand, a hand control valve should be mounted at the nose of a high pressure hose. A nozzle for pipe to clean the inside of the pipe and a rotating nozzle for tank to wash the tank's inside can be equipped.

There are also such other cleaning methods as washing with chemicals and washing by high pressure water with sand.

(Water Saving Rate)

The impact of water jet in the washing with a high pressure jet washer is proportional to the quantity of jetted water and its speed. That is,

$F = KQ\sqrt{P}$
F: Impact (kg)
Q: Quantity of jetted water (m^3/h)
P: Jetting pressure (kg/cm^2)
K: Coefficient

From this formula, it is understood that the water consumption can be largely saved by increasing the jetting pressure.

As a result of a model test of the water saving of a high pressure jet washer, the following saving rates were obtained when compared to the normal washing way with a hose.

1) Water saving rate based on the effect of high pressure jet water : 33 to 75%.
2) Water saving rate based on the effect of hand control valve : 45%.

The total water saving rate considering the above-mentioned effects will be:

$$100 - \left[\left\{ 1 - (0.33 \text{ to } 0.75) \right\} \times (1 - 0.45) \right] \times 100 = 63 \text{ to } 86\%$$

This water saving rate cannot always be expected because a high pressure jet washer is used to wash various kinds of products, however it is evident that a significant water saving can be obtained when compared to the normal washing with a hose.

(Cost of Equipment)

Although the equipment cost may vary in wide range depending on the specifications including the working pressure (20 through 1,000 kg/cm^2), the price of a machine of popular type (150 kg/cm^2 of working pressure) is around 400,000 yen.

(e) Hot water washer

(Function and Structure)

Hot water jet washer is widely used in such various fields as motor repair shops, general machine shop, construction machine shop, rolling stock manufacturing and repair shops, food processing plants, ship, fishing and agriculture. The washing efficiency against oil and grease in particular, is high because a high pressure hot water of 60 to 80 ℃ is jetted.

A hot water jet washer is composed of a hot water generating unit, a high pressure water pump, a hose to transfer high pressure water, a jet nozzle and other accessories. It has a structure to allow a hand control valve or other devices to be equipped.

This washer is one of the high pressure jet washer with a hot water generating unit. Most of hot water generating unit currently used are lamp oil boilers, however, electric heater type units are also available. In most cases, the temperature of hot water is below 100 ℃.

By using this hot water jet washer, a very large water saving effect can be obtained when compared to the traditional spray washing with tap water from a hose. The advantages of this type of washer are as follows:

1) Improvement of washing effect given by the impact of high-speed injecting water.

2) Improvement of washing effect given by the high temperature of high-speed injecting water.

3) Cutting of unwanted water by use of a hand control valve.

(Water Saving Rate)

The water saving rate is almost the same as that for the above-mentioned high pressure jet washer.

(Cost of Equipment)

The working pressure for hot water jet washers is within 50 to 80 kg/cm² in general which is a little lower than that for high pressure jet washers. The equipment cost is around 500,000 yen.

6.3.3 Cost Estimation

The methods for effective use of water explained in the previous section are as follows:

(1) Counter-current multistage washing system

(2) Cascade system

(3) Use of water saving apparatus

(a) Hand control valve
(b) Flow control valve
(c) Automatic water supply system for washing tank
(d) High pressure washer
(e) Hot water pressure

Among these methods, (1) and (2) require only a very small cost of equipment and the water saving rate directly corresponds to the cost saving rate of water.

As for (3), there is a certain variation of both cost of equipment and water saving rate, so it is difficult to exactly calculate the required cost.

Table 6.2 shows the water saving cost for each system or apparatus calculated on the basis of appropriate assumptions. Judging from this Table, it is clear that the application of water saving apparatus should save the washing cost by 9 to 40%.

6.3.4 Notes and problems in Effective Use of Water

Since each factory is using industrial water for processing and washing of products in various ways, appropriate methods may be found by thinking out the ideas to satisfy the effective use of water.

Therefore each factory is expected to make its own effort for the effective use of water not sticking to any method proposed here.

It is important to avoid wasting water, however, excessive water savings should also be avoided in order not to give any bad influence to products, because the use of industrial water for processing and washing of products is closely related to the quality of products.

Table 6.2: Cost Saving Rate when Water Saving Apparatus is Adopted

Item \ Apparatus	Hand Control Valve	Flow Control Valve	Automatic Water Supply System for Washing Tank	High Pressure Washer	Hot Water Washer
Condition					
Initial Cost (¥)	30,000	50,000	150,000	400,000	500,000
Amount of Water Saving (m^3/d)	10 30% saving of 50 m^3/d consumption	50 10% saving of 500 m^3/d consumption	50 50% saving of 100 m^3/d consumption	150 30% saving of 500 m^3/d consumption	150 30% saving of 500 m^3/d consumption
Present Water Cost (¥/d)*	500	5,000	1,000	5,000	5,000
Cost Estimation					
Depreciation of Apparatus (¥/d) (including Interest)	20	33	100	267	333
Water Cost after Adoption of Water Saving Apparatus (¥/d)	400	4,500	500	3,500	3,500
Total Water Cost after Improvement of System (¥/d)	420	4,533	600	3,767	3,833
Cost Saving Rate (%)	16	9	40	25	23

Note: * Water cost is 10 ¥/m^3 in this cost estimation.

Remarks: Water saving rates after installations of these apparatuses vary in large extent in accordance to conditions of water use before installations, and standard rates are difficult to set up. Saving rates which are deemed to be attained are assumed here in order to figure out cost saving rates.

6.4 Industrial Water for Cooling and for Air Conditioning

6.4.1 Characteristics of Water

Industrial water for cooling ("Cooling water") can be classified into the following three categories:

(1) Indirect cooling water
(2) Direct cooling water
(3) Indirect cooling water to be used at a low temperature

In general, cooling water means indirect cooling water which is the most part of cooling water . However in some industrial fields such as food industry, machine and apparatus manufacturing industry, direct cooling water is often used and also indirect cooling water at a low temperature is used in food and chemical industries.

Indirect cooling water is scarcely polluted while its temperature may rise (usually 5 to 10°C) during the use, so that it can be easily recycled for re-use through cooling towers as brought into practice in industrial fields generally.

Direct cooling water is similar to washing water in utilization and all methods for effective use of washing water (counter-current multistage washing system, cascade washing system and utilization of water saving apparatus) are applicable.

A detecting system of the water temperature can also be employed as a detecting section of an automatic water supply system for washing tank as stated in the previous section.

For indirect cooling water to be used at a low temperature, a refrigerator is required. However, costs of both equipment and operation is high in this system, and for this reason, the application of this system should be studied taking such conditions into account.

General method for effective use of indirect cooling water are explained as follows.

6.4.2 Standard Methods for Effective Use of Water

(1) Cooling Tower

(Function and Structure)

Cooling tower is the popular equipment used for the effective use of indirect cooling water. However, the cooling tower system is effective only under the conditions where the inlet water temperature is below 50 °C and the maximum allowable temperature of outlet water is more than 30 °C, and a refrigerator should be used as stated below if cooling water of lower temperature is required.

Cooling tower is used in order to lower the water temperature by latent heat of water evaporation obtained after the contact of warm water with cold air (exactly, air with lower wet bulb temperature than temperature of water to be cooled).

Fig. 6.11 shows a model flow for recycling use of water through a cooling tower. If effective use of water could be realized as shown in this figure by using a cooling tower, the water consumption is reduced from 100 to 5.

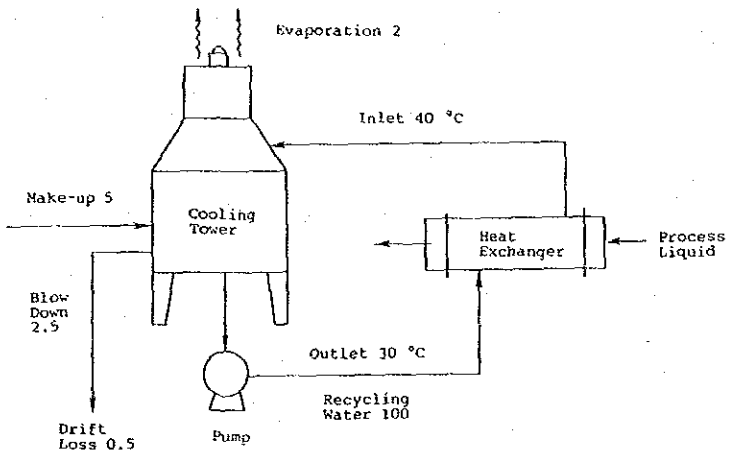
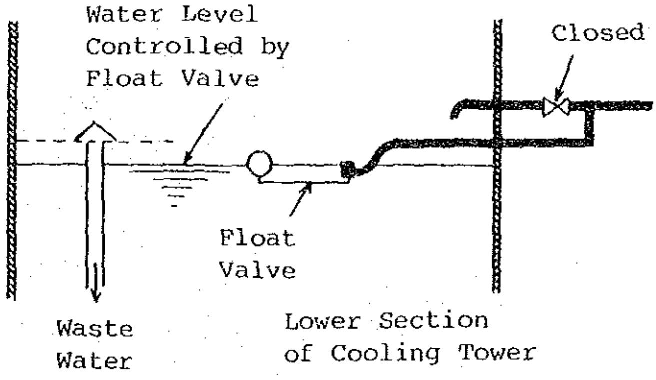


Fig. 6.11: Recycling System of Cooling Tower

(Control of supply water by float valve)

Although most cooling towers are equipped with a float valve, supply water is usually controlled by a another valve on a different piping system and the float valve is used only at the time when the water level lowers abnormally.

In a case as shown below, the float valve is used for water supply at the time of non-blow operation. The valve is set at a lower place than the over flow port in order to feed water only to cover the water level which has been lowered due to the evaporation and mist loss.



(Water balance for open circulating-type cooling water system)

Water balance for an open recirculating cooling water system (refer to Fig. 6.11) is explained below.

(a) Evaporation loss (E)

When the total heat quantity transferred from a process (heat exchanger in Fig. 6.12) to a cooling water and the total heat quantity released from the cooling tower due to the evaporation is equivalent, the following equation is satisfied:

$$Q = R \times 10^3 \times \Delta T \times C = E \times 10^3 \times HL \;.....\; (1)$$

R: Flow rate of circulating water (m^3/h)
C: Specific heat of water at constant pressure
(kcal/kg °C, 0.998 kcal/kg °C at 40 °C)
HL: Latent heat of water evaporation
(kcal/kg, about 578 kcal/kg at 40 °C)
ΔT: Temperature drop through cooling tower (°C)
E: Evaporation loss (m^3/h)

Then, equation (2) is derived from the equation (1);

$$E = \frac{(R \times 1/100) \times \Delta T}{5.8} \quad (m^3/h) \;........\; (2)$$

Therefore, when 1% of the circulating water evaporates, the temperature difference becomes approximately 5.8°C.

(b) Drift loss (W)

The quantity of drift loss from a cooling tower depends on the type of cooling tower. Usually the drift loss amounts to 0.05% to 0.2% of the circulating cooling water in the forced draft cooling tower.

(c) Blow down (B)

Blow down rate is determined with consideration of corrosion and scales prevention as well as available make-up water.

(d) Make-up water (M)

In cooling water system, the total system volume is kept constant under the normal operating conditions.

Therefore, the quantity of make-up water is equivalent to the total volume of water lost due to evaporation (E), drift loss (W) and blow down (B). Then, the following equation is obtained.

$$M = E + B + W \;.........\; (3)$$

(e) Degree of concentration (N)

Degree of concentration is an index to show the ratio of dissolved solids concentration in the circuiting water to that of the make-up water, and is defined by the following equation:

$N = C_R / C_M$ .... (4)

C_R : Dissolved solids concentration in circulating water
C_M : Dissolved solids concentration in make-up water

When the system is operated at steady-state, the quantity of dissolved solids which is added to the system in the make-up water is equivalent to the quantity of dissolved solids which is lost from the system by blow down and drift loss. So, the following equation (5) is formed :

$C_M \times M = C_R \times (B + W)$ .... (5)

Equation (6) is derived from equations (4) and (5) ;

$$N = \frac{C_R}{C_M} = \frac{M}{B + W} \quad .... (6)$$

Equation (7) is obtained by substitution of the equation (3) into equation (6) ;

$$N = \frac{E + B + W}{B + W} = 1 + \frac{E}{B + W} \quad ....(7)$$

Since both the evaporation loss (E) and the drift loss (W) are constant if the operating conditions of a cooling tower are constant, the dissolved solids concentration in the cooling water can be controlled by adjusting of the blow down rate (B).

Assuming E = 2% and W = 0% (both are percentages to the flow rate of circulating cooling water) in the equation (7), the relationship between N and B can be illustrated as in Fig. 6.12.

As seen in this figure, the reduction of blow down is large when the degree of concentration increase within 5 or so, however, it becomes considerably smaller when degree of concentration exceeds such a level.

That is, since M = 2 + B + 0 is found from the equation (3), it is understood that a considerable saving of make-up water (M) is possible until the degree of concentration reaches 5.

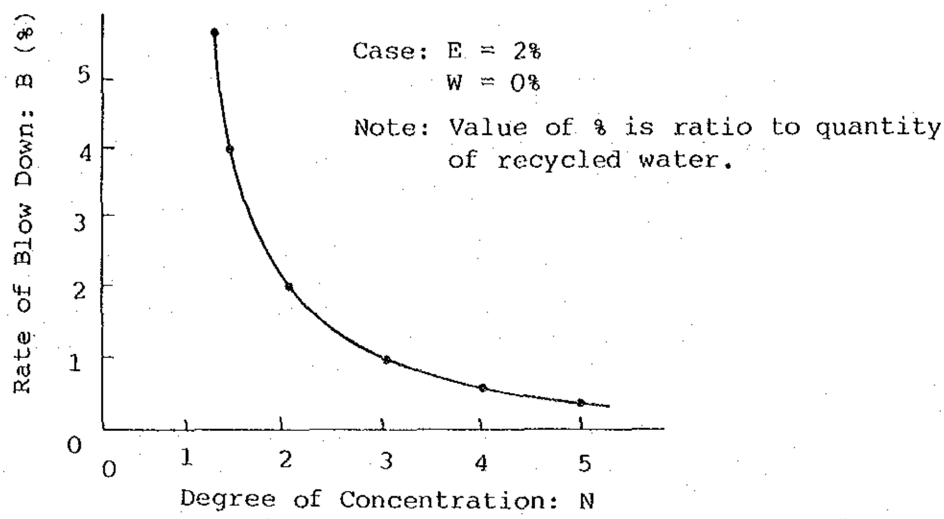


Fig. 6.12: Degree of Concentration and Rate of Blow Down

(Capacity of cooling tower)

The total heat quantity released from the cooling tower due to the evaporation is as shown in the equation (1)

$Q = R \times 10^3 \times \Delta T \times C$ (kcal/h)

The capacity of a cooling tower is usually indicated in refrigerated tons of water (RT). Since 1 RT = 3,900 kcal/h, the required capacity of a cooling tower is calculated by the following formulation:

$$RT = \frac{Q}{3{,}900} = \frac{R \times \Delta T \times C}{3.9} \quad \ldots\ldots(8)$$

As seen in this equation, a large capacity of cooling tower is required when the temperature difference (ΔT) is large even if the flow rate of circulating water (R) is small.

However, every cooling tower is usually operated at a temperature difference within 5 to 10 °C because the temperature difference (ΔT) is limited by the functions of the cooling tower.

(2) Refrigerator

When the required temperature of cooling water is lower than the wet bulb temperature, a refrigerator should additionally be used, because a cooling tower cannot cool water to a temperature level lower than the external wet bulb temperature and a large-sized cooling tower is required to cool water down to near the wet bulb temperature.

That is, the capacity of a cooling tower can be reduced by making a refrigerator supplement. These procedure, however, cannot save cooling water.

Tables 6.3 and 6.4 respectively show types and major characteristics of refrigerators.

A refrigerator itself is an equipment to lower the temperature of water, and not for the effective use nor saving of water. For such a refrigerator, because the temperature of refrigerant in the machine increases in return for generated cold water, cooling water for cooling media is required.

Such cooling water is recycled to use through the above-mentioned cooling tower. Then, the water flow in a cooling system utilizing a refrigerator is as shown in Fig. 6.13.

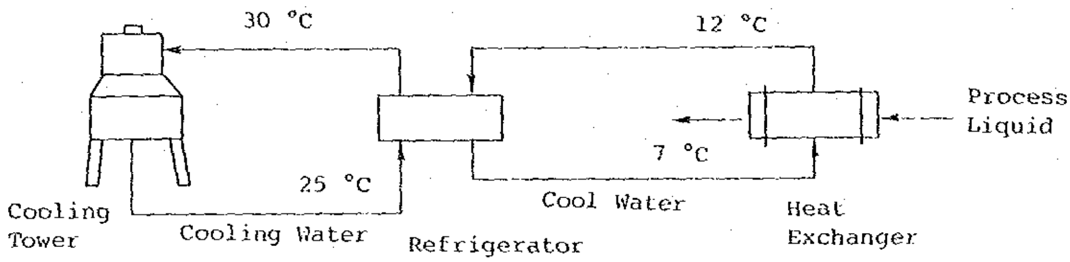


Fig. 6.13: Concept of Cooling System Employing Refrigerator

6.4.3 Cost estimation

(1) Cooling tower

Fig. 6.14 shows relationship of capacity (RT), price and power of cooling tower. The price for a 50 RT cooling tower is about 0.9 million yen and about 7 million yen for a 500 RT cooling tower.

In addition to the above, the installation of pumps, reservoirs, pipings and other equipment is also required in the actual cooling water facilities, thus about double of the unit cost of a cooling tower system is required as a whole construction cost.

The followings are comparison of running costs of cooling system before and after the installation of a cooling tower.

(a) Before the installation of cooling tower

Cooling water consumption : 312 m^3/d
Cost of make-up water : 3,120 ¥/d

Table 6.3: Types of Refrigerator

Type	Power per Unit (kW)	Capacity per Unit (kcal/h)	Main Application
Mechanical Compression Type			
Reciprocating Type			
Small Type	0.065 - 1.5	40 - 500	Food Freezing Air Conditioning
High Speed Multi-Cylinder Type	0.2 - 290	200 - 1,800,000	"
Vertical Type	0.2 - 100	200 - 530,000	"
Horizontal Type			Gas Compression
Rotating Type	40 - 160	7,500 - 435,000	Food Freezing Skate Rink Ship
Turbo Type	40 - 200	133,000 - 3,320,000	Air Conditioning
Non-Mechanical Compression Type			
Absorption Type		50 - 2,125,000	Air Conditioning Food Freezing
Steam Jet Type		166,000 - 1,992,000	Water Cooling

Table 6.4: Features of Refrigerator

Type	Features
Compression Type High Speed Multi-Cylinder Type (Reciprocating Compression)	1) Cost of machine with a capacity of around 200 JRT (0 °C of freezing temperature) is cheap. 2) It is necessary to check valve, piston ring and seal after operation of 3,000 to 5,000 hours. 3) It is necessary to overhaul at least once a year.
Turbo Type (Centrifugal Compression)	1) As it is operated at high speed, its weight is light and its dimension is small for its capacity. It is suitable for large capacity. 2) As it is assmbled in a unit, it requires smaller space. 3) It is maily used for indirect cooling.
Absorption Type	1) Operating cost would be reduce if waste steam is available. 2) Absorption solusion pump is the only moving part. Therefore, its noise level is low and suitable for continuous operation

(b) After the installation of cooling tower

Capacity of cooling water	: 50 RT
Quantity of circulating water	: 312 m³/d (39 m³/h x 8 h)
Quantity of make-up water	: 6.2 m³/d (2% of circulating water)
Cost of make-up water (A)	: 62 ¥/d
Price of cooling tower	: 0.9 million yen (refer to Fig. 6.14)
Total construction cost	: 1.8 million yen (Double of cooling tower's price)
Depreciation (including interests) (B)	: 1,200 ¥/d
Cost of electricity and chemicals (C)	: 624 ¥/d (2 ¥/m³)
Total cost (A) + (B) + (C)	: 1,886 ¥/d

(c) Cost saving rate

Consequently, the cost saving rate attained by the installation of a cooling tower is 40%.

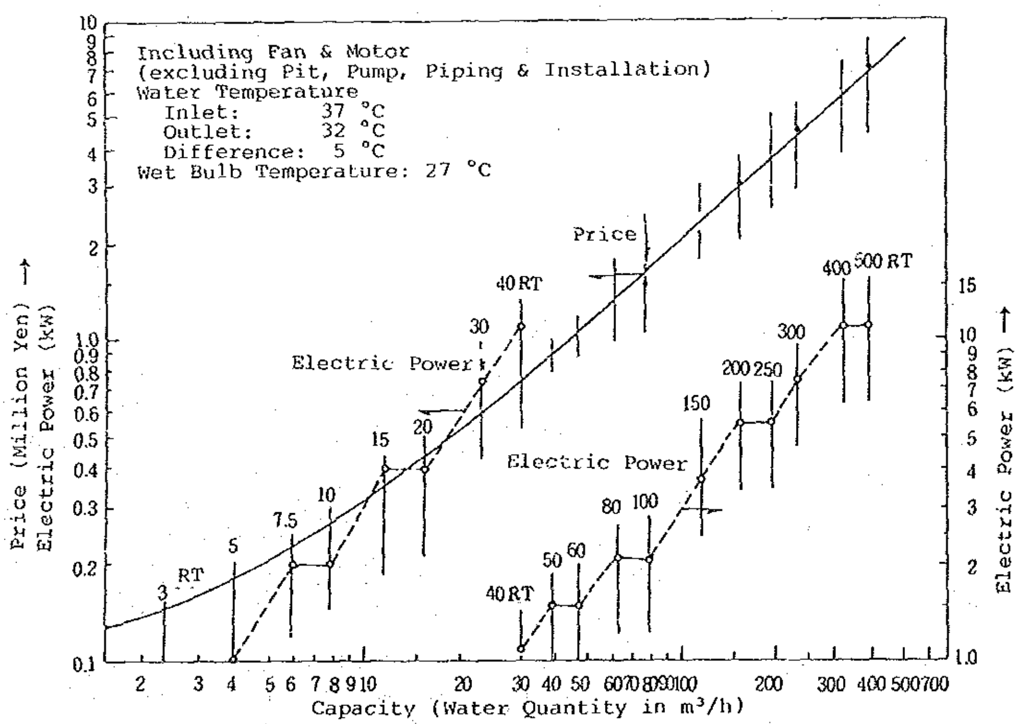


Fig. 6.14: Price and Capacity of Cooling Tower

(2) Refrigerator

Fig. 6.15 shows relationship between the capacity of a refrigerator to be used in a cooling system as shown in Fig. 6.13 and the price and required power of the whole system.

6.4.4 Notes and Problems in Effective Use of Water

Though the increase of the degree of concentration reduces the quantity of make-up water and saves the water consumption as explained above, the dissolved solids concentration accelerates the increasing of scales and slime in the tubes of a heat exchanger.

In order to prevent these troubles, a chemical is often injected into circulating water. In such a case, however, both the control of the concentration and the dosage of a chemical are required based on the economical view point.

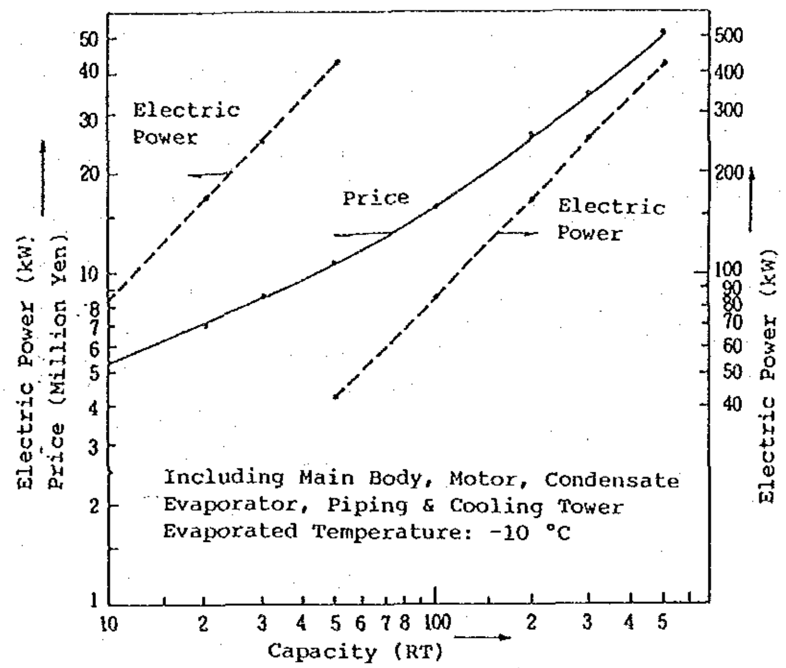


Fig. 6.15: Price and Required Electric Power in Refrigerating System

6.5 Industrial Water for Miscellaneous Use

6.5.1 Characteristics of Water Supply and Waste Water Discharge

Industrial water for miscellaneous use includes the following:

(1) Bath water
(2) Kitchen water (for cooking and dish washing)
(3) Water for garden
(4) Toilet water (for toilet washing and hand washing)

Among the above, water quality for bath water, kitchen water and water for hand washing should be potable, water for garden and for toilet washing should not necessarily be of high quality. For these purposes, reclaimed water may be applicable.

Generally, the estimation of the water consumption for each miscellaneous use is impossible in a factory. So, it is calculated by the difference of the total water consumption for other uses and the total water consumption in the factory, or by an approximate value of water consumption per capita (200 lit/capita/d to 500 lit/capita/d) and the number of employees. Living water consumption of each surveyed factory shall be refer to 3.4 and Fig. 3.7.

6.5.2 Standard Methods for Effective Use of Water

(1) Outline of methods

The following are methods not described previously.

(a) Implantation of water saving consciousness to employees

(b) Use of water saving apparatus

(c) Reclamation of waste water

Although the implantation of water saving consciousness is often apt to be made light for the reason that its water saving effect is hardly be measured in an actual value, it is one of the important methods to largely contribute to the effective use of water.

The following two types of water saving apparatus are available other than those mentioned in the above section (6.3 Industrial water for Processing and Washing of Products).

1) Automatic urinal washer
2) Water saving type toilet

Among these apparatus, 2) water saving type toilet is omitted here because it is not familiar with in any factories in Thailand where different types of toilets are used. Therefore, only 1) automatic urinal washer is explained here.

With regard to the reclamation of waste water for toilet washing, on the other hand, while it is now popular in buildings, it is still rare in factories even though reclaimed water is often used to garden water. A high distribution cost is the main factor which disturbs the use of reclaimed water.

(2) Automatic urinal washer

Automatic urinal washer is an apparatus which automatically wash a urinal in response to the using situation. There are following automatic washing systems:

(a) System to wash by detecting a person who uses a urinal

(b) System to wash by linking with switches (start to wash when a light or a ventilating fan is switched on).

(c) System to wash by the signal from timer in which a using time of a urinal has previously been set.

(d) System to wash by detecting the electric conductivity of the urine by means of an electronode placed in the trap of a urinal.

In the past, high-tank automatic siphon type has been widely used to each urinals for the interval washing during the night regardless of the use of urinals.

Thus a considerably large quantity of water used being not utilized to wash urinals. To save such wasted water, automatic urinal washers with above-mentioned various systems have been developed.

The following is an explanation of an automatic system to wash a urinal by detecting, by means of infrared rays, a person when he leaves the urinal. This is a typical automatic urinal washing system.

This system is composed of detecting section which detects a person by means of infrared rays, control section which transfer the signal from the detecting section to the driving section and driving section which opens or shuts the water flow valve responding to a signal from the control section.

There are two types of automatic urinal washer. The individual type is equipped with this system for each urinal, while the collective type covers several urinals by automatic washer.

The individual type washer is excellent in water saving as well as in sanitation because it washes only one urinal used. As for the collective type washer, on the other hand, one washer is installed to cover several urinals and it washes all urinals including unused ones even when only one urinal is used. For such a reason, the collective type washer is a little bit inferior to the individual type one in water saving effect.

Fig. 6.16 illustrates an example of use of an individual type washer, and Table 6.5 shows an example of a water saving effect.

6.5.3 Cost Estimation

The following is unit price for each type of automatic urinal washers.

(1) Detecting type (Individual):	60,000	¥/unit
(Collective):	150,000	¥/unit
(2) Linking type (Door switch) :	150,000	¥/unit
(3) Time-switch type	70,000	¥/unit

Total cost of installing automatic urinal washer of detecting type for the case shown in Table 6.5 is ¥1,320,000 (¥60,000 x 22 units) and required cost for saving 1 m^3 of washing water is 60 ¥/m^3. Therefore, this system is feasible when water cost is higher than 60 ¥/m^3.

6.5.4 *Notes and Problems in Effective Use of Water*

For automatic urinal washers, an excessive water saving may cause bad smell, clogging of pipings and deterioration in capacity of final waste water treatment system (troubles in waste water treatment systems due to the high concentration of impurities in raw waste water).

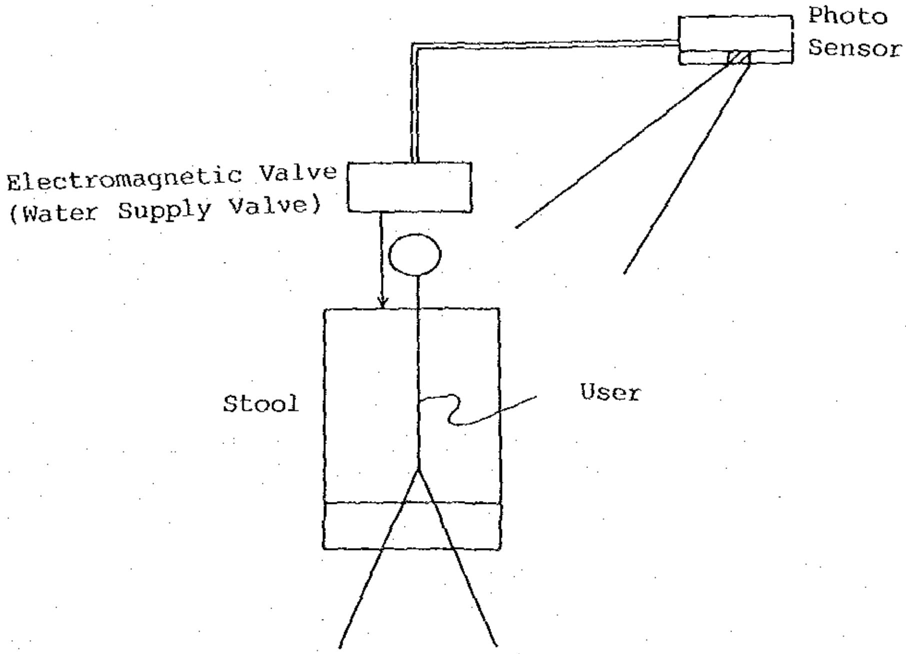


Fig. 6.16: Water Saving in Lavatory

Table 6.5: Water Saving in Lavatory

Total Water Consumption before Installation	549 m^3/mon
Total Water Consumption after Installation	270 m^3/mon
Monthly Quantity of Water Saving	279 m^3/mon
Saving Rate	50.8%

RemarkS:
Number of Stool: 22
Number of High Tank: 13
Hour: 07:00 to 20:00

Chapter 7

Guideline for Effective Use of Industrial Water Classified by Industry

Chapter 7 Guideline for Effective Use of Industrial Water Classified by Industry

7.1 Outline

Following on Chapter 6 which describes common methods for effective use of water classified by use, methods for effective use of water classified by industry are described in this Chapter. The industries have been divided into the following six:

(1) Food industry
(2) Paper industry
(3) Textile industry (Dyeing)
(4) Metal manufacturing industry
(5) Machine industry
(6) Chemical industry

The metal industry has been divided into the metal manufacturing industry and machine industry due to the difference in the product and the processing stages.

As stated at the beginning of Chapter 6, differences in water usage are especially apparent in the areas of processing and washing water *when divided by the type of industry. Therefore, the methods of* effective use will be mainly focused on those uses.

The methods of effective use for the individual industries are contained the following four headings:

(1) Outline of process and water use,

(2) Standard methods for effective use of water,

(3) Cost estimation, and

(4) Notes and problems in effective use of water.

The estimation costs shown in this chapter are based on the following conditions except in cases where otherwise indicated (same as Chapter 6):

Depreciation period	10 years
Average interest	10% per year
Annual operating day	300 days
Unit cost of make-up water	&10 per cubic meter

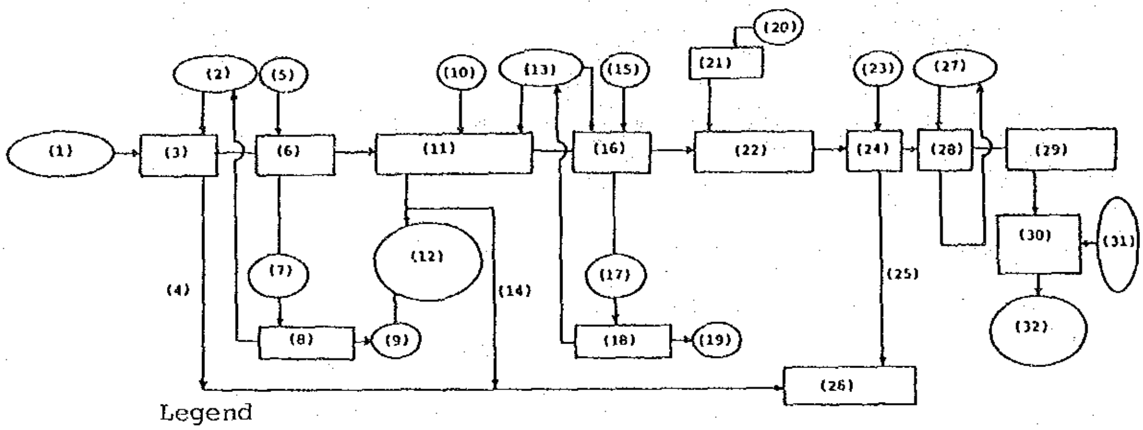
7.2 Food industry

7.2.1 Outline of Process and Water Use

Because wide variety of items is produced by the food industry and also different raw materials, production systems etc., are used according to the quality required for the various food products, the characteristics of water use within the whole food industry cannot be shown in one production flow chart. Consequently, the production flow chart shown in Fig. 7.1 has been drawn up from the most common production processes.

(1) Washing of raw materials

As most raw materials are agricultural or marine primary products such as fish, rice and beans as is shown in Fig. 7.1, it is popular to employ two stage washing for raw materials in order to completely get rid of substances such as soil and sand in the raw materials and which can lead to a deterioration in the quality of the materials during processing. The process for washing raw material, therefore, uses a large quantity of water.



Legend

(1) Material
(2) Recovered water
(3) Washing (Material)
(4) Waste water
(5) Water
(6) Washing (Material)
(7) Waste water
(8) Filtrating
(9) Refuse
(10) Water
(11) Cutting & separating
(12) Removed matter other than food
(13) Recovered water
(14) Waste water
(15) Water
(16) Washing
(17) Waste water
(18) Filtrating
(19) Refuse
(20) Water
(21) Boiler
(22) Heating
(23) Water
(24) Dehydrating
(25) Thick waste water
(26) Waste water treatment facility
(27) Recycled water
(28) Cooling
(29) Sterilizing & packing
(30) Storaging
(31) Air conditioning
(32) Shipping

Fig. 7.1: Production Process of Food Industry

(2) Washing as a part of raw material processing (soaking raw materials)

This process corresponds to the process of cutting up fish and the subsequent washing process used in marine product processing plants. In such cases, the substances unsuitable for food such as skin, blood and internal organs are removed and washed out in this process.

It therefore generates heavily polluted waste water and unusable solid matter. As this process is used in order to get rid of such solid matter, very large quantity of waste water is discharged and this waste water is heavily polluted.

(3) Washing water and waste water generated in heating and other processing

This water corresponds to waste water delivered from the process for removing astringency and bleaching during the bean jam paste manufacturing, waste water discharged at the time of canning in canned sea food factories, and the waste water derived after chemical treatment in orange canning factories.

Because this process is very important in determining the quality of the product, a large quantity of water with high quality is used.

(4) Water for cooling

As this water is supplied to cool processed products, water with required quality are used depending on the type of processing. However, in most cases the greater part of the industrial water is used just for cooling.

In many instances, such as canning plants, the food containers are cooled indirectly, and in such cases despite the large quantity of water is used it is possible to recycle the water. Moreover, as in most cases the water need not be of high quality there are factories which use recycling water.

(5) Washing containers and machinery

The processed raw materials sticked to machines and containers are composed of carbohydrates and/or high proteins which have a high nutritional value. Therefore, the machines and containers are easily contaminated.

As a result, washing with good quality water is undertaken immediately after finishing operations and a large volume of water is used for the complete removal of residue. It is not uncommon to use more water for these washing than water required for product processing.

(6) Washing floors

Because food processing plants is operated batchwise commonly, and also because manual operations are involved, it is easy to leak processing materials from machines. Floors are usually washed with water at the end of the daily operations. In cases where there is no clear rules for washing the floors, in some operations wasteful water is consumed than should be necessary.

7.2.2 Standard Methods for Effective Use of Water

In the food industry, water is used for extraction of high nutritional food from agricultural and marine products. Consequently, the water can be classified into two categories;

a. Water with a higher quality than that generally used for industrial purposes of treating raw materials, soaking, thawing, processing, and washing machines and containers;

b. Water with not so high quality for cooling water.

The methods described below are used for the effective use of water.

a. Water for product processing and washing

1) Counter-current multistage washing system (washing raw materials)

2) Use of water saving apparatus

* hand control valve (floor clearing)
* high pressure jet washer (washing machines and containers)
* bottle washer (washing containers)
* cleaning in place (CIP) (washing machines and containers)

b. Water for cooling
- use of recycled water for indirect cooling using a cooling tower

c. Other uses of water
- foot switch

Some of these apparatus and devices were shown in Chapter 6. Those which were not shown in Chapter 6 will be described here. They are:

1) Bottle washer (washing containers);
2) CIP;
3) Foot switch.

(1) Bottle washer

(a) Function and structure

Bottle washers are machines, using detergent and warm water, for cleaning of empty bottles for milk products, savory sauces, cold drinks and alcoholic beverages, etc.

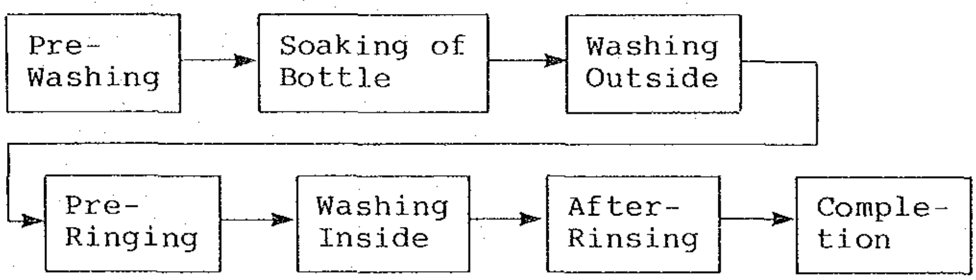
While the bottle washer itself can save a certain quantity of water, if mechanisms for 1) counter-current washing system (multistage use of recovered water from the final rinsing stage for washing to the preceding washing stage to the preceding washing stages),

and 2) stopping the water supply to the final washing stage *in synchronization with the stopping of the bottle washer* operation, are additionally equipped much quantity of water can be saved.

The bottle washer is consisted of a prewashing section, washing section, rinsing section, transportation device, pump device, heating device for washing liquid, washing tank and a device for filtering the remains of labels.

They can be classified into two main types according to the type of washing system used: one uses a jet system and another uses a soaking jet system. The jet system washes by spraying washing liquid (caustic solution, warm water etc.) through the washing nozzle with a jet effect, and the soaking jet system has an improved washing effect which is achieved by washing using a nozzle for jet spraying and also soaking in a caustic solution tank.

The process for the bottle washer can be summarized as follows:



1) Prewashing

This section is at the upper end of the bottle feed part of the bottle washer and dirt is removed here mainly by spraying water recovered from preceding washing section. The purpose of this process is to prevent the soaking tank from becoming dirty and to preheat the bottles.

2) Bottle soaking

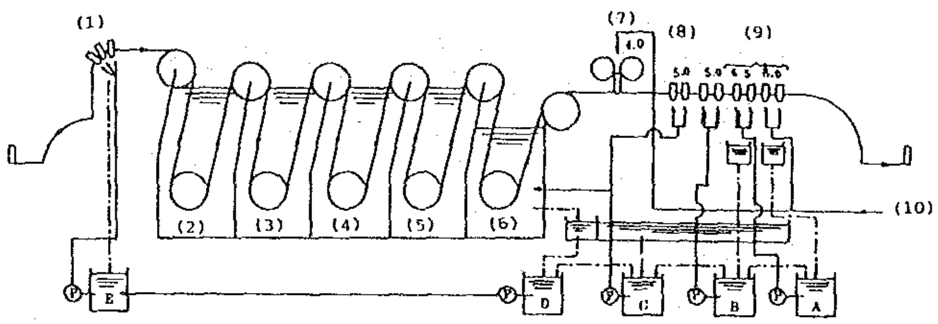
Bottles are soaked by putting them through a number of soaking tanks. While the bottles pass through the tanks they are sterilized by a warm (40 to 65 °C) caustic solution. Sometimes, an agitating device or a jet device of hot caustic solution has been incorporated for removing labels from the bottles.

3) Inside and outside washing and rinsing

The washing of the inside and outside of bottles is undertaken by brush washing and by jet washing. Also, pre-rinsing and after-rinsing takes place before and after the washing of the inside of the bottles.

Fig. 7.2 shows outline of the various bottle washing stages using the brush system.

Fig. 7.3 shows the relationship between the capacity of a bottle washer and the appropriate water consumption. The term appropriate water consumption used here refers to the quantity of water used in case where the rationalizing functions mentioned earlier (counter-current washing system and a synchronized water supply) have been applied to the machine.



Legend

(1) Prewashing	(6) Final dipping tank	A - E: Recovery tank
(2) No.1 Tank	(7) Outside washing brush	
(3) No.2 Tank	(8) Inside washing brush & rinsing	
(4) No.3 Tank	(9) Inside rinsing	
(5) No.4 Tank	(10) Make-up water	

Fig. 7.2: Process Flow of Brush Type Bottle Washing Machine

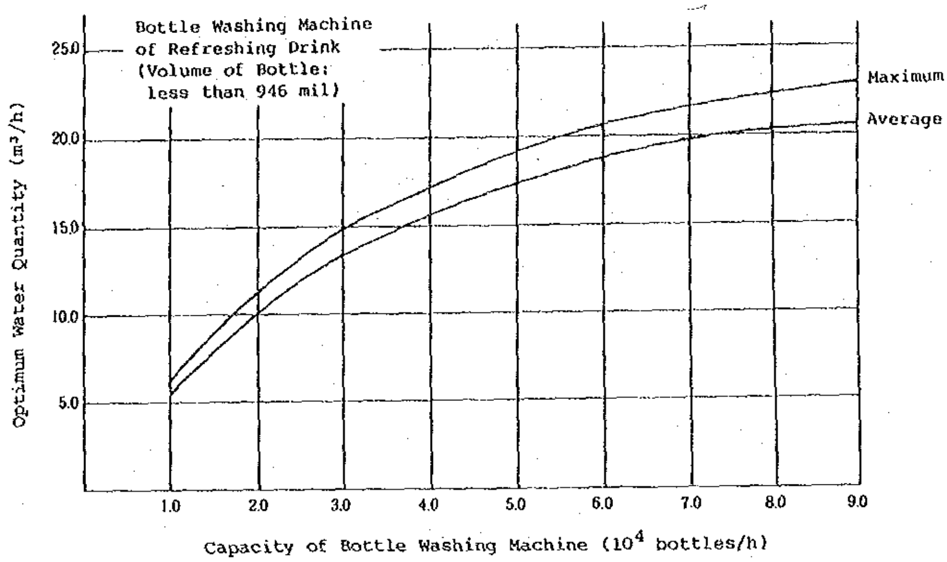


Fig. 7.3: Capacity and Optimum Water Quantity of Bottle Washing Machine

(b) Cost estimation

The cost of a bottle washer is related to the capacity for bottle washing and it ranges from 2.5 million yen to 60 million yen.

The cost comparison of a general bottle washer and one attacked above mentioned rationalizing functions are shown in Table 7.1

(c) Notes and problems related to effective use of water

A wide variety of bottle washers have been developed and they are greatly evaluated as energy conserving machines as well as for their water saving functions.

However, high performance machinery of bottle washer is introduced only in cases of renewing, expansion or new establishment. They are not used very widely. Also, the emergence of one-way containers such as paper packs as a substitute for bottles has hindered the application of bottle washers.

(2) CIP

(a) Function and structure

Cleaning in place equipment (referred to hereafter as "CIP") carry out washing by automatically supplying of washing media such as acid, alkali and warm water to the place being washed. Thus they wash the tanks and pipes used in plants which produce milk products, cold drinks and beer etc., without having to disassemble or move the plant.

Table 7.1: Cost Estimation for Improvement of Bottle Washing Machine

Item \ Stage	Before Improvement	After Improvement
Capacity Bottle Volume	24,000 bottles/h 180 mlit	
Water Consumption (m^3/h) Electric Power (kW)	27 30	12.7 64.8
Installation Cost (¥) Piping Pump Water Tank Total	- 	 100,400 355,000 2,400,000 2,855,400
Depreciation including Interest (¥/y)		571,000
Operating Cost (¥/y) Electric Power Water Total	 1,440,000 648,000 2,088,000	 3,114,000 304,800 3,415,200
Total Annual Cost (¥/Y)	2,088,000	3,986,200
Daily Cost (¥/d)	6,960	13,287
Lower Limit of Water Cost in which Benefit will be taken ($¥/m^3$)	68	

Remarks: Electric Power = 20 ¥/kWh

Annual Operating Time = 2,400 hours

Source: Report on Effective Use of Industrial Water in Food Industry, Chiyoda D&M, 1978

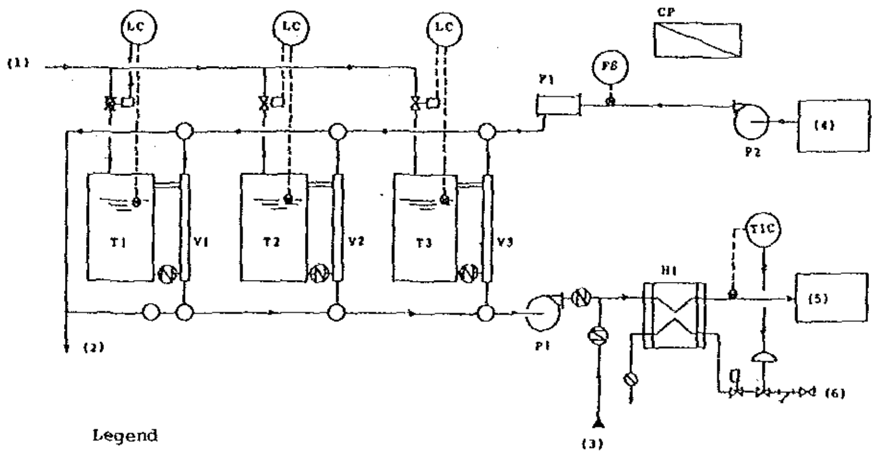
The CIP is comprised of a washing tank, pump, heat exchanger, automatic valve, control board and instrumentation. A CIP usually has 2 or 3 tanks (acid solution tank, alkali solution tank and warm water tank).

The CIP can automatically carry out the supply of washing media and the circulation of recovered water by program controller. These functions have resulted in labor cuts, improved productivity and an improvement in operational capacity and a reduction in unnecessary water use due to *the standardization of the washing effect in comparison* with the traditional system of manual washing.

Recently, CIP is introduced rapidly in this field.

Although the CIP itself is not a water saving equipment, it can save water if the counter-current washing system is introduced into the system for the use of washing water.

Fig. 7.4 is an example of flow diagram for a CIP and Fig. 7.5 shows the optimum water quantity required by a CIP. As shown Table 7.2, the optimum water quantity is the water consumption after water saving has been made due to the introduction of the counter-current washing system.



Legend

T1: Clean Water Tank
T2: Alkali Tank
T3: Acid Tank
V1: Recycle Vessel
V2: Recycle Vessel
V3: Recycle Vessel
P1: CIP Delivery Pump
P2: CIP Recovery Pump
H1: CIP Plate Heater
F1: Tube-Type Filter
CP: CIP Control Panel

(1) Make-up Water
(2) Drain
(3) Air
(4) from Washing Machine
(5) to Washing Machine
(6) Steam

Fig. 7.4: Flow Diagram of CIP

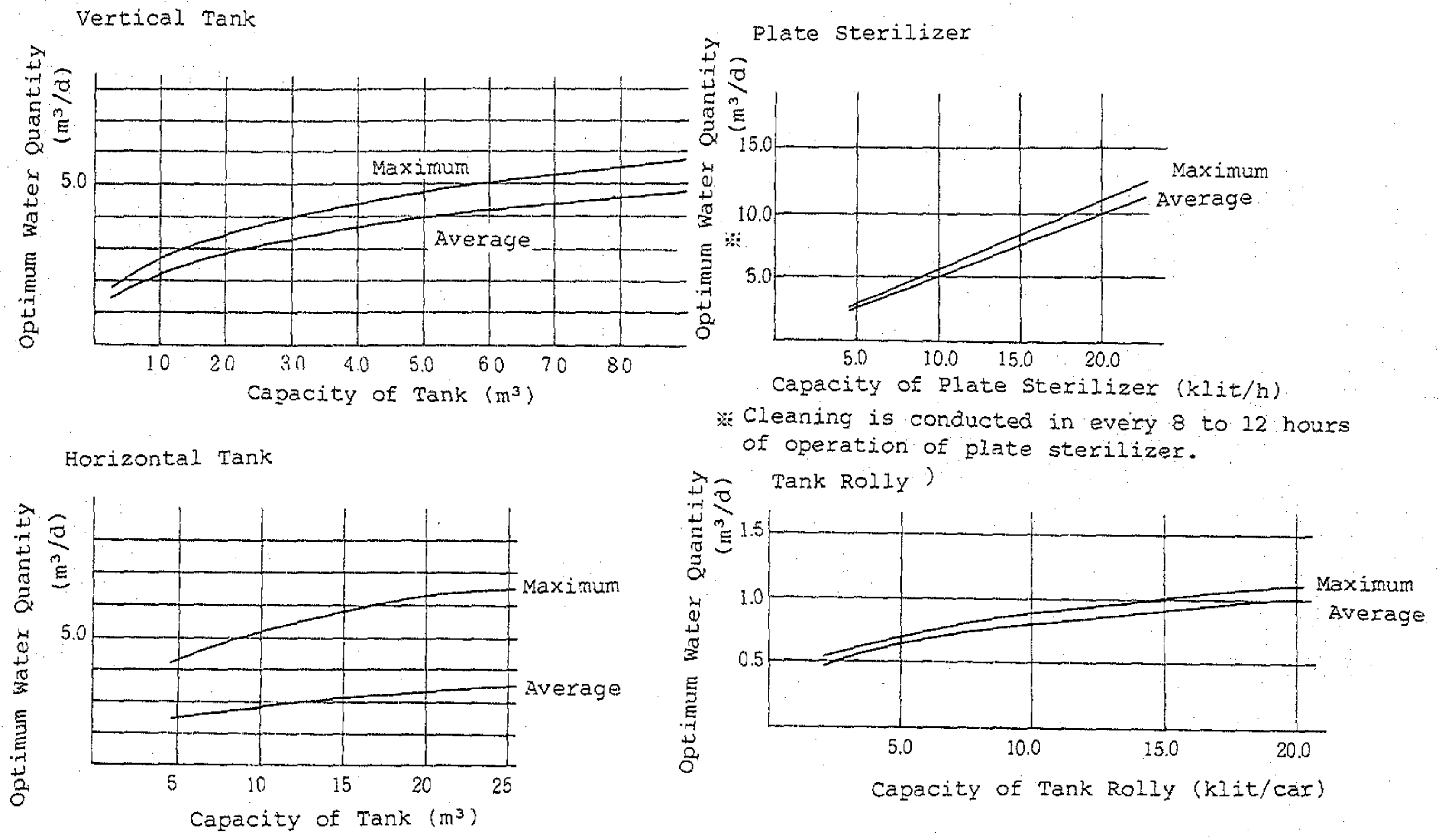


Fig. 7.5: Optimum Water Quantity of CIP

(b) Cost estimation

The cost of a CIP with a washing tank with a capacity of 1,000 lit is approximately 20 million yen. As for its economy, though this differs according to the location of the equipment in the plant, an approximate cost comparison for CIP system in case of, with and without above-mentioned counter-current washing system is shown in Table 7.2.

Cost after improvement is fairly high, because reduction of operation man-hour and advancements of sanitation condition and working ratio are not included in cost estimation.

(c) Notes and problems relating to effective use of water

Because in the case of the CIP equipment, the washing media including water and the warm water are controlled by a program which has been set beforehand, the setting of the optimum quantity of water is decisive in determining the water which can be saved. Therefore, as long as the setting of the time for the washing system has been done correctly there are no other problems requiring attention.

(3) Foot switch

In cases where washing is undertaken in sinks the water is often left running. In addition, a fair quantity of water is lost before and after operations if the faucet is of the general type. Not only is the training of employees required in such cases, but with the introduction of a foot switch it is possible to reduce the loss of water used by turning the water on only when required.

There are two types of foot switch; one which uses a combination of an electrical switch and an electro-magnetic valve, and one which works on a mechanical system. Price of foot switch varies between 50,000 yen and 60,000 yen. One example is shown in Fig. 7.6.

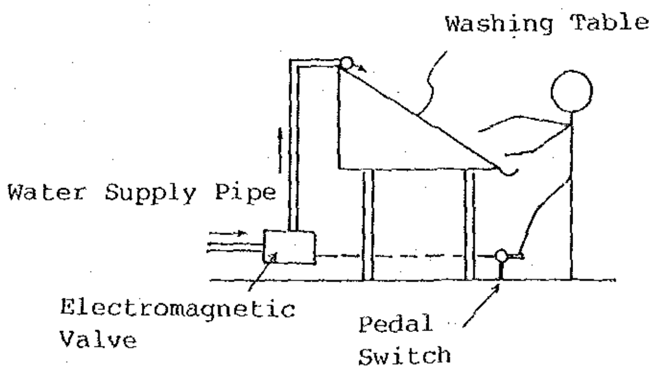
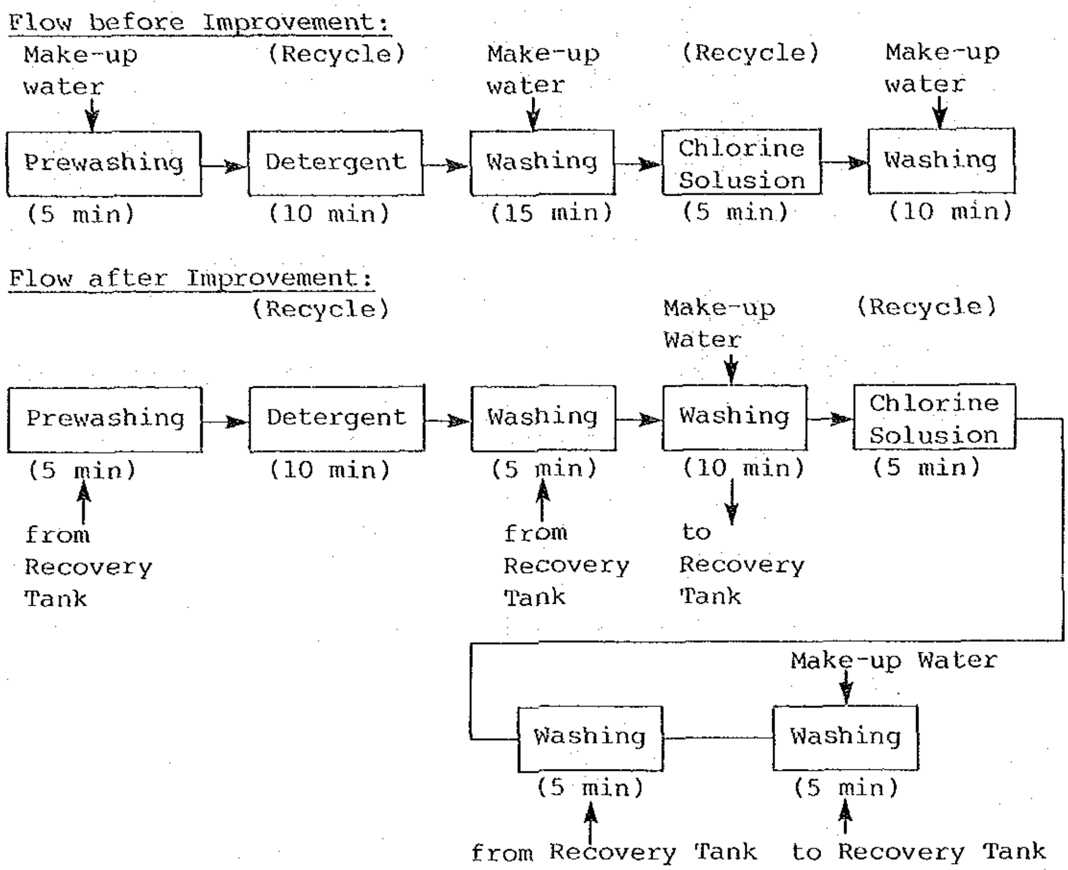


Fig. 7.6: Foot Switch

Table 7.2: Cost Estimation for Improvement of CIP



Item \ Stage	Before Improvement	After Improvement
Water Supply Quantity	200 lit/min x 30 min = 6 m^3	200 lit/min x 15 min = 3 m^3
Recovery Tank	-	3 m^3
Valve	-	25mm, Auto Valve
Piping		25mm x 10 m
Installation Cost (¥)		
Recovery Tank	-	500,000
Valve & Piping	-	200,000
Total	-	700,000
Depreciation including Interest (¥/y)	-	140,000
Operating & Water Cost (¥/y)	18,000	9,000
Total Annual Cost (¥/y)	18,000	149,000
Total Daily Cost (¥/d)	60	490
Lower Limit of Water Cost in which Benefit will be Taken	56	

Source: Report on Effective Use of Industrial Water in Food Industry, Chiyoda D&M, 1978

7.3 Paper Industry

7.3.1 Outline of Process and Water Use

The manufacture of pulp and paper involves the process for separating the cellulose fibers from the wood chip (pulping process) and to the process for arranging the separated fibers uniformly (paper making process).

Because the pulping process and the paper making process are production systems which require the repeated washing of the cellulose fibers within a number of stages they use extremely large volumes of industrial water. The manufacture of 1 ton of paper requires 100 to 200 times weight of water.

Also, most of the water is used for the processing and washing process where water contacts directly with raw materials and intermediate product. The processes are therefore different from many other industrial processes in that it is difficult to use recovered water.

Nevertheless, in order to raise the yield of cellulose fiber from raw material, efforts are being undertaken to keep the quantity of discharged waste water to an absolute minimum and fairly high rate of recycle use of white water is undertaken.

Pulp is either virgin pulp which is made from wood chips or used paper pulp made from recovered used paper. Generally, paper is made from a mixture of virgin pulp and used paper pulp.

A high proportion of virgin pulp is used for high quality paper and tissue paper, and a high proportion of used paper pulp is used for making toilet paper and corrugated cardboard.

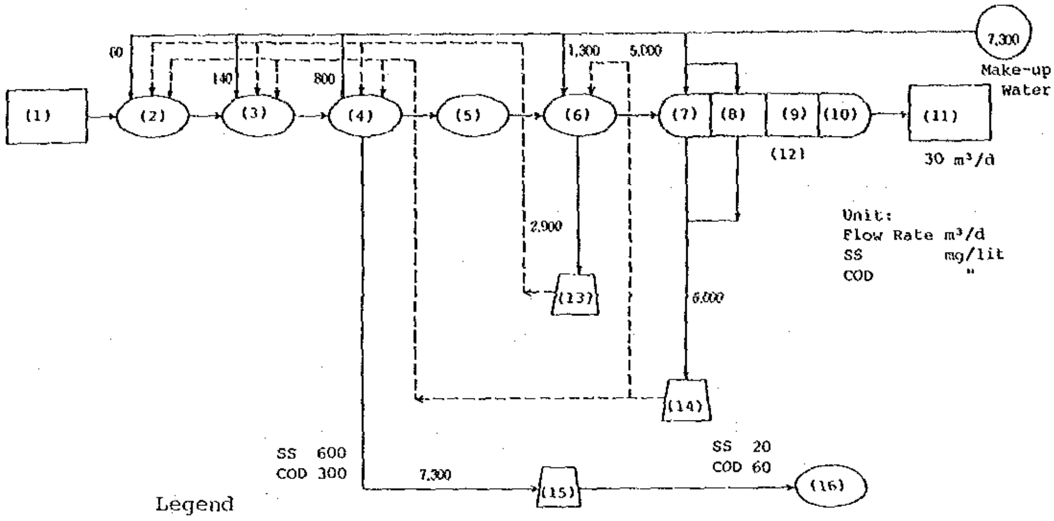
On the whole, it is only the large companies which have production processes for manufacturing virgin pulp, and this restricts the number of companies dealing with this process.

Therefore, the processing stages and water use described below relate mainly to used paper pulp which is more common and they have been based on companies which possess process for manufacturing used paper pulp through to those for paper manufacture.

A flow chart of the processing stages is provided in Fig. 7.7. A general explanation of the various processes involved is also provided below.

(1) Processing of used paper

The processing of used paper involves the processes of selection and separation, pulping, screening and de-inking. The selection and separation process is undertaken by used paper collectors and by the factories which receive the used paper.



Legend

(1) Used Paper
(2) Pulping
(3) Screening
(4) Washing
(5) Bleaching
(6) Washing
(7) Wire Part
(8) Press Part
(9) Dry Part
(10) Winding
(11) Product (Toilet Paper)
(12) Paper Machine
(13) White Water Recovery Tank
(14) White Water Recovery Tank
(15) Coagulation/Sedimentation Tank
(16) Discharge Gate

Fig. 7.7: Production Process of Toilet Paper

The dust screening is performed roughly in this stage. The training and instruction for employees are important because the performance of screening is relied on human skills mainly.

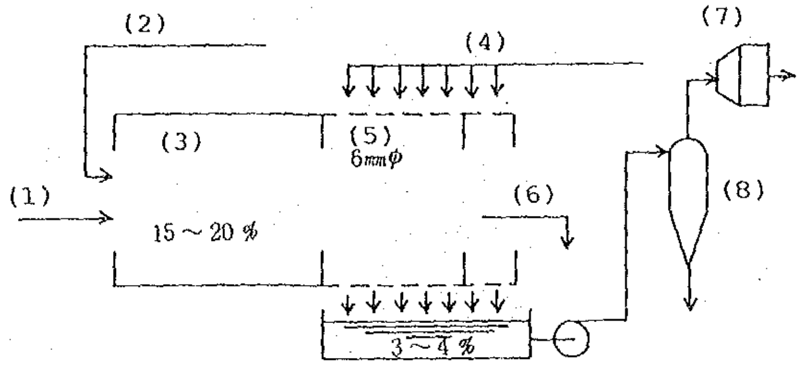
During the processing of used paper, it is common for pulping and screening to take place at the same time, and many machines which have the capacity to perform both of these functions have been developed.

Though either the flotation or the washing with water can be used for de-inking, it is common for both of these methods to be used in combination.

(2) Pulper

The pulper carries out the pulping and screening of used paper, and the pulping is done mechanically in the tank with agitator. The pulp content in a diluted defibered pulper is 3.5 to 5.5%, and in a concentrated defibered pulper it is 15 to 18%.

Water is used for the liquefying in the pulper, A diluted pulper uses strainers and ragger for screening, but because a concentrated pulper cannot undertake screening a supplementary pulper is used to remove various kinds of foreign matter. Devices which have combined a pulper, supplementary pulper, high concentration cleaner and a rough selection machine into a single system have recently been developed. One example is shown in Fig. 7.8.



Legend

(1) Used Paper
(2) Chemicals & Water
(3) High Concentration Pulper
(4) Water
(5) Screen (Rough Selection)
(6) Foreign Matter
(7) Defraker
(8) High Concentration Cleaner

Fig. 7. 8: Combined Process of Pulping, Screening and Rough Selecting

(3) De-inking and bleaching

After screening and washing, the used paper pulp is bleached or de-inking through the use of chemicals. De-inking is achieved by adding alkali and detergent to used paper which then undergoes heat and mechanical treatment.

As well as defibering the used paper into single fibers, this process disperses the ink into water. Also, in some cases organic pigments and dyes are contained in the inks. Because these pigments are eluted and stain the pulp during the de-inking stage, bleaching becomes necessary.

Oxidizing agents and/or reducing agents are used for bleaching and the chemical reaction makes impurities decompose. Because it is necessary to remove substances at before and after bleaching, washing machine is installed for thorough washing.

(4) Conditioning process

After the bleaching and washing processes have been completed sizing material, aluminum sulfate, starch and fillers are added. Paper will be added to enhance smoothness to improve the quality of writing and printability.

(5) Paper making process

After the conditioning process has been completed screening and the removal of foreign matter takes place one more time using cleaners and screens, after which the refined paper stock is fed into the paper machine.

After adjust of the paper stock concentration in the the stock inlet of the paper machine, the accepted stock is fed to the wire part and paper layers are formed.

After dehydration takes place in the wire part to reduce the water content to 80%, the water is further reduced to 65% by compressed dehydration. Drying then takes place in the drying part to reduce the water level between 5 and 7%.

High quality water are required for the wire part and the press part of the paper machine and the bleaching of the pulp in pulp and paper making processes.

As has already been mentioned the purpose of bleaching is to wash the material, and in the case of the paper machine the good quality water is required to wash the wire and blankets. Therefore, the use of fresh water (make-up water) is concentrated around the bleaching and paper making stages.

7.3.2 Standard Methods for Effective Use of Water

The following procedures can be achieved in the paper industry;

a. Recycle use of white water

b. Reclamation of waste water

(1) Recycle use of white water

(a) Outline

The recycle use of white water has been carried out for some time in pulp and paper factories. This involves using the waste water (white water) which is discharged from the wire part or the press part of the paper making machine in the screening and the conditioning stage which take place beforehand, and then once again using waste water derived from that stage for the bleaching process which takes place one stage earlier. In addition to saving water, this is widely carried out in all factories with consideration for recovering raw material fiber and for economizing on steam used for warming.

(b) Cost estimation

When raising the recovery rate of white water it becomes necessary to add further recovery tanks and recovery pumps to meet the increase of recovered water. Table 7.3 shows calculations on the approximate cost of water saving based on an example where 200 m^3/d of white water is recycled.

Table 7.3: Water Cost Before and After White Water Recycle

Item \ Stage	Before Recycle	After Recycle	Remarks
Quantity of Make-up Water (m^3/d)	200	0	
Cost of Make-up Water (¥/d)	2,000	-	10 ¥/m^3
Quantity of Recycled White Water (m^3/d)	0	200	
Cost of White Water Recycle System (¥)	-	800,000	Including installation
Depreciation including Interest (¥/d): (a)	-	530	
Operating Cost (¥/d): (b)	-	360	0.75 kW
Total Cost (¥/d): (a)+(b)	0	800	
Cost Saving Rate (%)	-	55	

The table shows that by recycling white water a cost saving of 55% is achieved. This also has the added advantages of recovering raw material (increase in yield) and recovering energy. However, if the recovery rate for white water is raised too high it will have an effect on quality as described below. Consequently, the recovery rate is determined on the base of experience.

(c) Notes and problems related to the effective use of water

The criterion for evaluation whether effective use are being made is the recovery rate of white water. On the other hand, if effective use is excessive and recovery rate for white water is too high, unacceptable components in the raw material fiber will also be recovered and this will have bad effect on the quality of the product.

Also, a problem which often occurs with the use of recovered water is the lowering of whiteness due to coloring substances in the water. It is also necessary to take methods to prevent the forming of scale, slime, foaming and pitch, and also the corrosion of machinery and equipment.

(2) Reclamation of waste water

(a) Outline

Although in pulp and paper manufacturing factories it is usual for waste water to be discharged after coagulation and sedimentation, the method for effective use shown here consists of waste water reclamation after slight additional treatment, and reclaimed water is used as a substitute for fresh water in process.

This method is also used in Japan in regions which are liable to suffer from water shortages. While the method has not yet been adopted widely, it will be shown here because it was included as a method for effective use in some factories in Chapter 5.

The reclamation treatment system composes of the biological treatment and sand filtration, and it is presumed that the reclaimed water is used in the wire part and press part of the paper machine.

(b) Conditions for cost estimation

1) Types of raw water

Water from waste water discharged from pulp and paper factories which has been treated by a coagulator

2) Quality of raw water and treated water

	Raw Water	Treated Water
SS (mg/lit)	20	5
COD (mg/lit)	100	25
Electrical Conductivity (μS/cm)	500	500

3) Reclamation system

Biological treatment - Sand filtration

4) Quantity of treated water

1,000 m^3/d

5) Processes for re-use

Wire part and press part

(c) Cost estimation

Table 7.4: Cost Comparison of Re-Use of Reclaimed Water (Pulp and Paper Industry)

Item \ Stage	Before Re-Use	After Re-Use	Remarks
Quantity of Make-up Water (m^3/d)	1,000	0	
Cost of Make-up Water (¥/d)	10,000	0	10 ¥/m^3
Quantity of Reclaimed Water (m^3/d)		1,000	
Cost of Reclamation Facility (10^3¥)		125,000	
Depreciation including Interest (¥/d)		83,000	
Operating Cost (¥/d)		4,000	Electric power & chemicals
Total Cost (¥/d)		87,000	
Cost Comparison	1	8.7	
Lower Limit of Water Cost in which Benefint will be taken (¥/m^3)	87		

(d) Notes and problems related to effective use of water

This system has of the disadvantage of the high cost of water in comparison to water normally used for industrial purposes. This system is a final option which can be used after it has been ascertained that there are no prospects for finding new water sources.

As a point requiring attention, particular care must be paid to maintenance control for the reclamation treatment device and the processes where the water is re-used because the same problem as described in the case of the recycle use of white water can be expected to arise.

7.4 Textile Industry (Dyeing)

7.4.1 Outline of Process and Water Use

The production line of textile industry can be generally divided into a physical processing, such as spinning and weaving, and a chemical processing such as dyeing. The former entails a rapid motion of textile which is sensitive to temperature and humidity, and requires conditioning of the temperature and humidity of the atmosphere of factory in order to improve and stabilize the workability and quality. Therefore, a large quantity of water is consumed to for air conditioning.

On the other hand, the latter is a chemical treatment with water and a repeat of washing and drying. Consequently, the dyeing industry is considered to be an water and energy consuming industry. Details of water for air conditioning are given in the foregoing chapter. In this chapter, therefore, only use of water in the dyeing industry is mentioned.

Dyeing is mainly divided into the following four processes:

a. Scouring and bleaching--Washing and removing the impurity of textile and the oil, adhesive and dirt sticked in the previous process, besides bleaching if necessary.

b. Dyeing--Coloring by dyeing

c. Printing--Pattern printing by dyeing

d. Finishing--Enhancing textile goods and giving new function by the chemical and physical treatment using resin, processing aid and finishing agent

The dyeing processes vary according to the types and configurations of textiles and the purposes and contents of processing, and there are numerous types of such processes. Here, the dyeing process of cotton and hemp cloth is given below as an example.

Flow chart of the process is shown in Fig. 7.9.

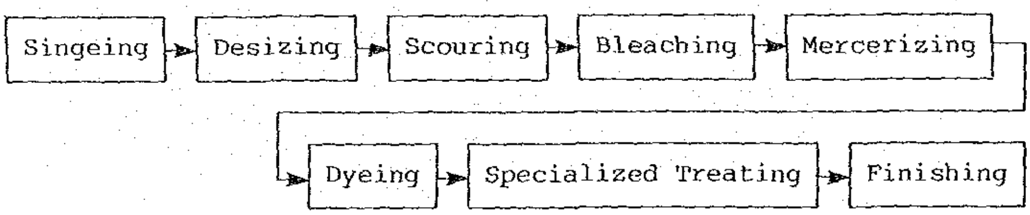


Fig. 7.9: Dyeing Process of Cotton and Hemp Cloth

General explanation of each process is given below.

(1) Singeing

Nap of cotton and hemp is burnt with gas burner and digested in water tank.

(2) Desizing

Process to remove adhesive of warp, such as starch and PVA sticked at the time of weaving, by steaming and by washing after being steeped into desizing agent.

(3) Scouring and bleaching

Impurity in textile is boiled in caustic soda or detergent and washed out. This is called scouring.

Cotton and hemp refined by scouring are bleached once or twice with sodium hypochlorite or hydrogen peroxide. After bleaching they are washed to remove agent. Generally, the process from desizing through bleaching is carried out in a continuous system.

(4) Dyeing (Dipping)

Most of the textile products are colored by printing and dipping although a part of them is directly sent to the stages of processing and finishing after being bleached.

There are two types of dipping. One is a batch type dyeing to be carried out in dyeing agent whose weight is ten to fifty times as much as that of the textile.

The other is a pad-roll type continuous dyeing by steaming and dyeing of textile wrung out after being steeped into dyestuff. In both dipping processes, these dyestuff and agent are washed out with water the weight of which is twenty to eighty times as much as that of the textile.

(5) Printing

Pattern is printed on textile with printing adhesive and block prepared for every color and dyed by steaming and drying. Then the adhesive, dyestuff and agent are removed with washing machine. In case of printing, it is hard to remove them. Therefore, a larger quantity of water is consumed compared with dipping.

7.4.2 Standard Methods for Effective Use of Water

In a dyeing works, the washing machine consumes a large quantity of water. Various types of washing machines are used according to the application and purpose, and the applying system varies in each factory. However, it is in common that a quantity of water to be used for washing a texture is twenty liters per one kilograms of cloth.

Recently research and development has been promoted to satisfy the demand for improving such a water consuming washing machine in terms of energy and resource saving. The followings are actual methods for effective use:

a. Application of water saving machine

- Washing machine for finishing
- Dyeing machine with low liquor ratio

b. Reclamation of waste water

Outline of each method is given below.

(1) Washing machine for finishing

(a) Function and structure

The washing machine for finishing means a washing machine to be used in the finishing processes of texture or texture product, such as desizing, scouring, bleaching and resin treatment.

To be qualified as a water saving machine, its make-up water consumption has to be less than two thirds of that of conventional type washing machine for finishing. In addition, the water saving machine has to have one of the following five washing systems or structures.

1) Counter-current type

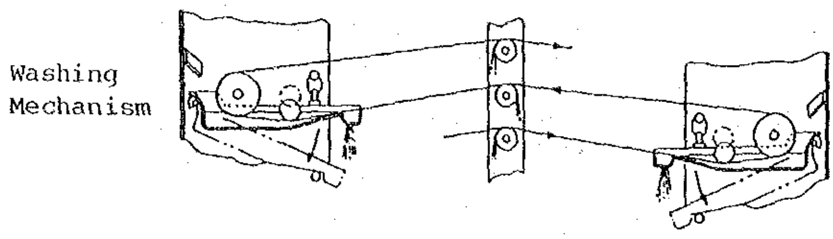
This is a system to enhance saving efficiency by repeating dipping and dehydration of textile or textile product which the textile or textile product and water are moving toward reverse directions, respectively.

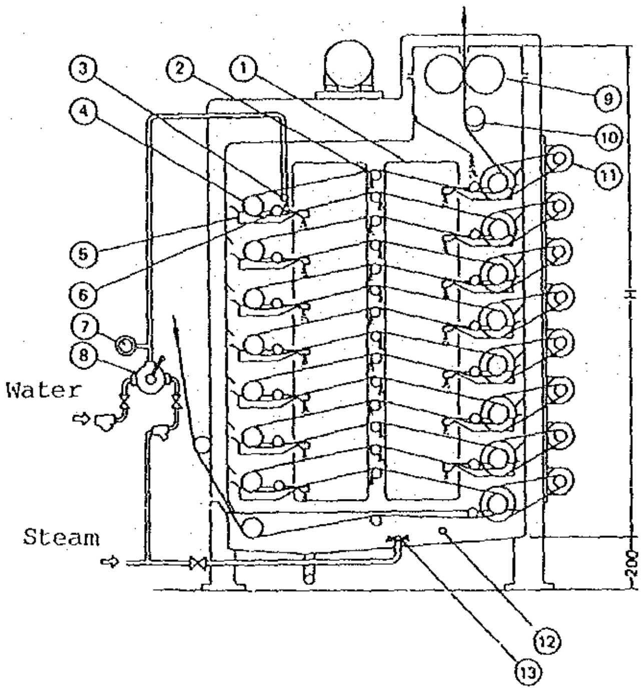
The washing system of this machine is as follows: (Refer to Fig. 7.10)

Cloth moves upward. On the contrary, water flows downward. Meanwhile, the cloth is repeatedly dipped and wrung, receiving with counter flow washing water at each step. Shallow tanks are installed beneath the guide rollers in order for a part of each guide rollers to be able to be soaked in the tank.

While the cloth passes, dipping and wringing are repeated. Bars in these tanks perform dehydration and prevent the cloth from wrinkling.

At this stage, water transferred with the cloth moving upward, is stopped by the intermediate roller and returns to the tank. The cloth is washed with the fresh water at the upper part of the washing room. The horizontal wringer installed at the upper part of the room enables the perfect counter-flow.





Legend

(1) Door
(2) 50ϕ (75ϕ) Guide Roller
(3) Water Supply Pipe
(4) 100ϕ (125ϕ) Guide Roller
(5) Small Tank
(6) 48.6ϕ Bar
(7) Thermometer
(8) Water Heater
(9) Pneumatic Squeezing Apparatus
(10) Rubber Curve Expander
(11) Tolque Motor
(12) Thermometer (Option)
(13) Steam Heater

Fig. 7.10: Counter-Current Type Washing Machine

2) Vibration type

This is a system to enhance water saving efficiency by vibrating textile or textile product and bringing it into contact with water with a physical and mechanical force. Outline drawing of the washing machine for vibration type finishing is shown in Fig. 7.11.

The washing system of the said washing machine is as follows:

As shown in the drawing, washing efficiency is enhanced by the pressure wave resulting from the rotation of a runner and continuous compression and expansion of water.

Due to the pressure wave arising 3,000 times per minute, the textile is vibrated while passing in the washer. As water is continuously circulating around the basket rotor, the contaminated water does not stay in the same place. This facilitates the effective use of fresh make-up water.

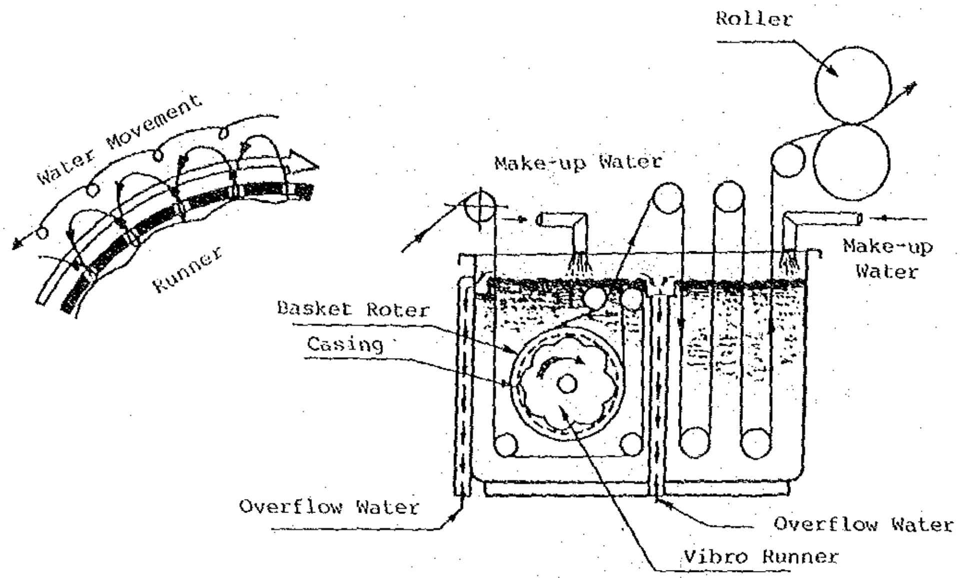


Fig. 7.11: Vibration Type Washing Machine

3) Through flow type

This is a system to enhance water saving efficiency by forcing water penetrate the textile or textile product.

The structural drawing and washing system of the washing machine for through flow type finishing are shown in Fig. 7.12.

As shown in the drawing, the cloth transferred on the rotating drum is thrust into the mesh of a wire net welded on the drum by the soft rubber roller.

As the cloth rubs against the mesh, the contaminant separates from it, and flows into the drum together with water.

4) Wringing type

This is a system to enhance water saving efficiency by repeating dipping and wringing with a roller. Washing system and outline drawing of the washing machine for wringing type finishing are shown in Fig. 7.13.

As shown in the drawing, an open soaper roller is replaced with a wringing roller, and contaminated water contained in the cloth is efficiently replaced with fresh water by repeating dipping and wringing.

For reference, the most popular washing machine for conventional type finishing is shown in Fig. 7.14.

In this system, the textile or textile product is washed while being transferred in the dipping tank with a roller.

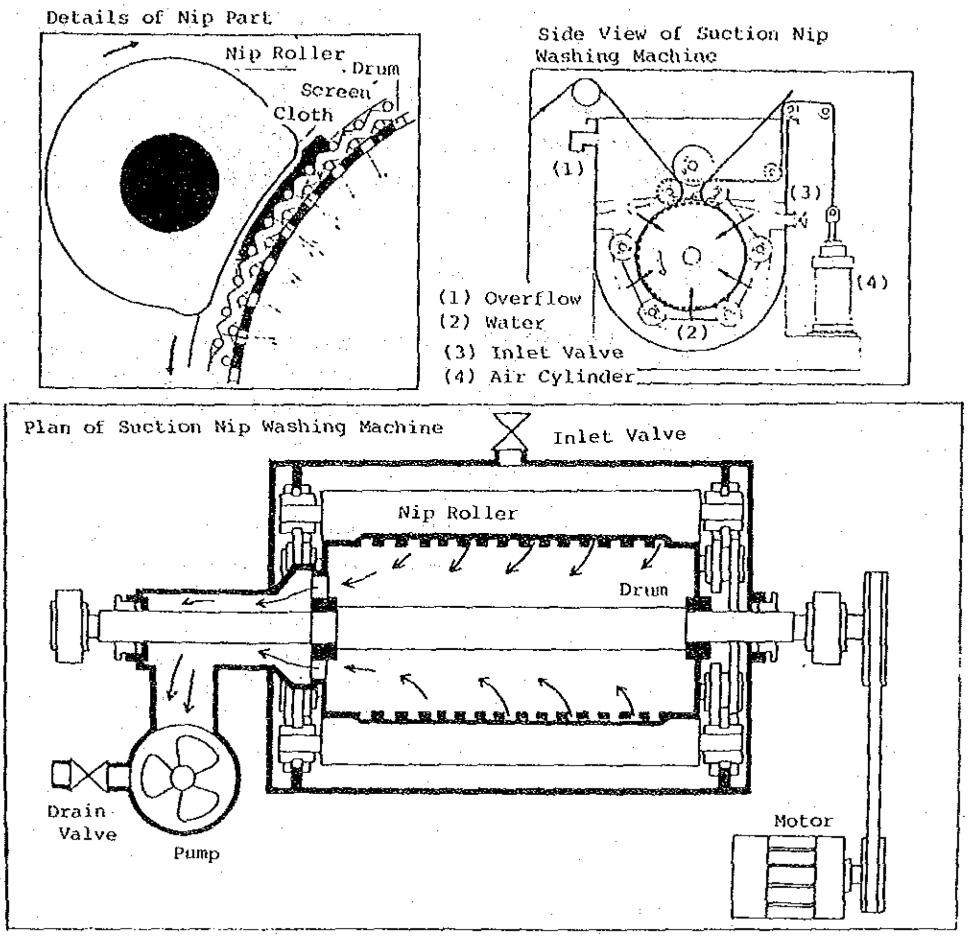


Fig. 7.12: Through Flow Type Washing Machine

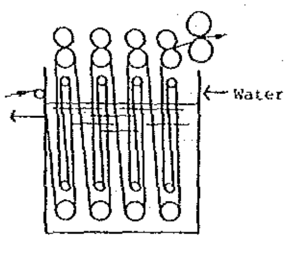


Fig. 7.13: Wriging Type Washing Machine

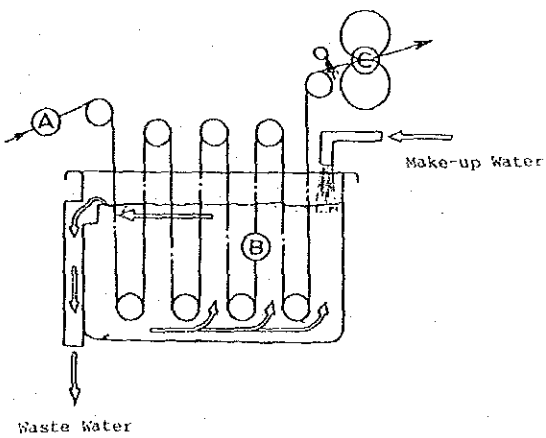


Fig. 7.14: Conventional Type Washing Machine

5) Powerful spray shower type

In this system, textile is washed by jet water. This system consists of drive unit to transfer textile, fresh water supply unit, water jet equipment, dipping tank to bring textile into contact with water, wringing device, and heating system.

(b) Comparison system

The following example shows an average fresh water consumption of the water saving type and conventional type washing machines every materials to be washed.

1) Polyester

Process	Fresh Water Consumption (lit/kg cloth)		Saving Rate
	Conventional Type	Water Saving Type	(%)
After Scouring	43	22	49
After Dyeing	57	30	47
After Printing	86	30	65

2) Wool fabric

Fresh Water Consumption (lit/kg cloth)		Saving Rate
Conventional Type	Water saving Type	(%)
120 - 150	80 - 85	33 - 43

3) Cotton

In case of cotton, the fresh water consumption is approximately twice as much as that of polyester, but the saving rate is almost the same (50%).

(c) Cost Estimation

In case of the water saving washing machine for counter-current type finishing, the unit cost is approximately 5 to 10 million yen, although it varies depending on the capacity. The following is an estimated cost for water in this system:

According to Table 7.5, the cost saving rate is comparatively small (6.7%) due to the large cost of installation. However, there is a discrepancy between actual comparison of the cost and data given in the said table because the water saving washing is generally installed when a renewal of equipment is required.

In this table, the estimation is base on the assumption that a water consumption is 2,000 cubic meters per day. When the water consumption is larger than the said figure, however, the economic efficiency increases more and more if such water saving washing machine is introduced.

Table 7.5: Comparison of Water Cost Before and After Installation of Water Saving Machine

Item \ Stage	Before Installation	After Installation	Remarks
Quantity of Make-Up Water (m^3/d)	2,000	1,000	Water Saving Rate: 50%
Cost of Make-up Water (¥/d): (a)	20,000	10,000	10 ¥/m^3
Cost of Washing Machine (¥)	-	8,000,000	Including installation
Depreciation including Interest (¥/d): (b)	-	5,330	
Operating Cost (¥/d): (c)	20,000	22,000	Electric power & chemicals
Total Cost (¥/d): (a)+(b)+(c)	40,000	37,330	
Cost Saving Rate (%)	-	6.7	

(d) Notes and problems related to effective use of water

Water consumption of the water saving washing machine, which varies in type from single tank type to multi-tank type, is said to be 30 to 50% of that of the conventional washing machine regardless of its type.

However, water consumption per unit quantity of cloth varies with the site because difficulty of removal of contamination, feeding speed of cloth and quantity of make-up water are different in each site. Therefore, water saving efficiency depends on software rather than hardware.

(2) Jet dyeing machine with low liquor ratio

(a) Function and structure

Jet dyeing machine with low liquor ratio is a machine to dye textile or knitting under recycling condition by spraying dyeing liquor whose weight is less than eleven times as that of the textile.

It has the advantage of saving water, for example, low liquor ratio, curtailment of dyeing time, control of liquor level and structural advantage suitable for batchwise rinse.

There are two types of the jet dyeing machine with low liquor ratio as follows:

1) Atmospheric jet dyeing machine

The atmospheric jet dyeing machine is used for dyeing cotton, acrylic, nylon and wool at atmospheric pressure. It consists of dyeing tank, heat exchanger, liquor spray unit, pump, reel, dyestuff feed tank, motor, liquor level controller, water feeding and discharging system and electrical control unit.

2) High-pressure jet dyeing machine

The high-pressure jet dyeing machine is used for dyeing polyester and cotton under the pressure of maximum working temperature of 130 to 140 ℃. Component of the high-pressure jet dyeing machine is similar to that of the atmospheric jet dyeing machine.

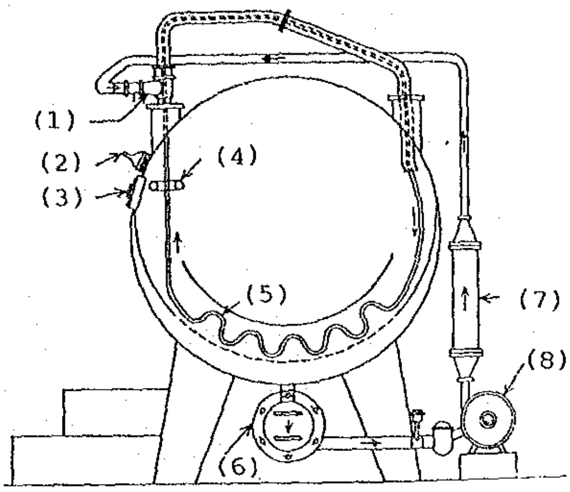
Schematic diagram of the jet dyeing machine is shown in Fig. 7.15.

Low liquor ratio is a fundamental factor for saving water. The liquor ratio of conventional wince dyeing machine is about 1 to 20 (weight of textile to weight of liquor).

On the other hand, the liquor ratio of the jet dyeing machine is about 1 to 10. In another word, its water saving rate is approximately 50%. This value is applicable not only to dyeing process but also to processes of water bath, washing and soaping. It means that water saving rate of all the processes is 50%.

(b) Cost estimation

Unit cost of the jet dyeing machine with low liquor ratio is 10 to 40 million yen, although it depends on capacity of the machine. Comparison of the costs is omitted here.



Legend

(1) Ventury Jet
(2) Light
(3) Cloth Inlet
(4) Pot Eye
(5) Cloth
(6) Filter
(7) Heat Exchanger
(8) Pump

Fig. 7.15: Jet Type Dyeing Machine

(c) Notes and Problems related to effective use of water

The jet dyeing machines with low liquor ratio are spread and there is no particular problem. However, all the possible care shall be taken in operation not to cause wrinkle nap, fray and dyeing speck.

(3) Reclamation of waste water

(a) Outline

In a dyeing factory, type and quantity of dyestuff and agent vary according to how and what kind of textile is processed, and quality of waste water vary time to time.

Therefore, it is very difficult to control and treat waste water of the dyeing industry, and treatment of the waste water is carried out with the combination of biochemical treatment, coagulating treatment, oxidation and adsorption to meet the discharge regulation.

Like a paper mill, the dyeing factory consumes a large quantity of washing water although it is a small and middle-sized business. Therefore, possibility of reclaiming waste water, which is discharged at present, is under studying in many different fields. However, reclamation of waste water has not been put to practical use because high quality washing water are required.

Estimate of reclaiming based on the results of the past experiments is shown here.

(b) Conditions for cost estimation

1) Raw water

Biologically treated waste water from dyeing factory of synthetic fiber

2) Quality of raw water and treated water

	Raw water	Treated water
SS (mg/lit)	30	1
BOD (mg/lit)	100	2
COD (mg/lit)	200	5
Electrical Conductivity (μS/cm)	1,200	1,200

3) Reclaiming system

Coagulation - Sand filtration - Activated carbon absorption

4) Quantity of treated water

1,000 m^3/d

5) Process to re-use

Washing process of various types of dyeing

(c) Cost estimation

According to Table 7.6, cost for water after reclaiming is 14 times as much as cost for water without reclamation. According to Table 7.4 which shows the similar comparison in a paper mill, cost for water after reclaiming is 8.7 times as much as cost for water no reclaiming.

The difference in comparison of cost between the dyeing factory and the paper mill is due to the fact that high quality wash water and activated carbon absorption are required for dyeing process.

Table 7.6: Cost Comparison of Re-Use of Reclaimed Water (Dyeing Industry)

Item \ Stage	Before Re-Use	After Re-Use	Remarks
Quantity of Make-Up Water Water (m^3/d)	1,000	0	
Cost of Make-up Water (¥/d)	10,000	0	10 ¥/m^3
Quantity of Reclaimed Water (m^3/d)		1,000	
Cost of Reclamation Facility (10^3¥)		175,000	
Depreciation including Interest (¥/d)		116,700	
Operating Cost (¥/d)		20,000	Electric power, chemicals, & activated carbon
Total Cost (¥/d)		136,700	
Cost Comparison	1	13.7	
Lower Limit of Water Cost in which Benefit will be taken (¥/m^3)	137		

7.5 Metal Manufacturing Industry

7.5.1 Outline of Process and Water Use

Products of a metal manufacturing industry can be divided into the material product, such as steel bar and aluminum die casting, and the surface treated product, such as tin plate, galvanized wire and alumite product.

Production process of typical products of each group are shown in Figs 7.16 and 7.17.

The following types of waters are used in the processing of the steel bar shown in Fig. 7.16.

a. Indirect cooling water for electric arc furnace (EAF)

b. Direct cooling water for rolling process

Cooling water hardly becomes dirty for the indirect use. On the other hand, effluent of direct cooling water almost becomes dirty. Because, scales of raw material come off and get mixed with the direct cooling water due to the direct contact with it. But, quality of water is not important for the direct cooling use, as water is repeatedly used without removing contaminant excluding a part of precipitate.

In case of surface treatment such as processing of tin plate shown in Fig. 7.17, the following types of waters are used:

a. Washing water for products chemically treated, such as scrubbing after dewaxing and washing after plating.

b. Direct cooling water such as quenching water

c. Indirect cooling water such as mill cooling water

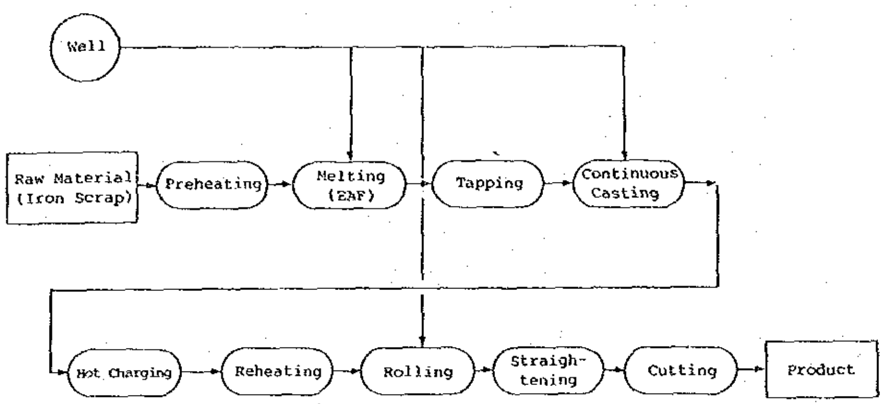


Fig. 7.16: Production Process of Steel Bars

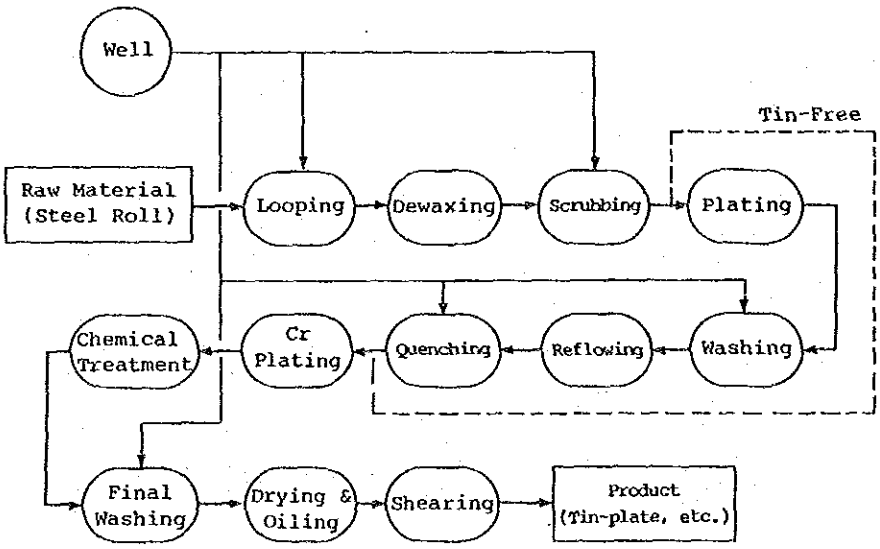


Fig. 7.17: Production Process of Tin-plate

Large quantity of make-up water is used for wash water given in item "a". Quality of water given in items "b" and "c" is similar to that of water to be used for processing of steel bar. Wash water for products chemically treated slightly varies according to configuration of processed product and way of washing. In case of metal plating, wash water is as shown in Fig. 7.18.

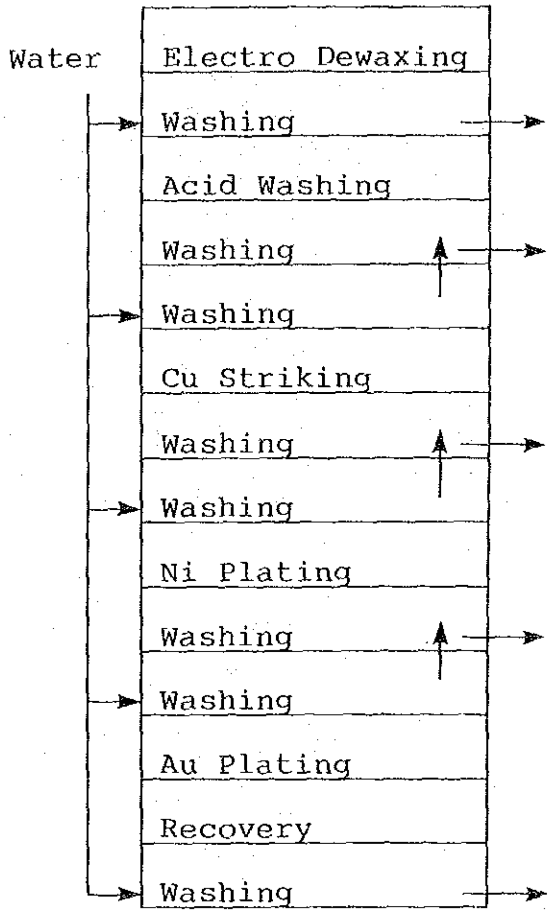


Fig. 7.18: Processing and Washing Water of Metal Electro-Plating

7.5.2 Standard Methods for Effective Use of Water

In metal manufacturing industry, standard methods for effective use of water are as follows :

(1) Processing and wash water

(a) Counter-current multistage washing system (refer to Fig. 7.18)

(b) Use of water saving apparatus

Flow control valve
Automatic water supply system for washing tank

(2) Cooling water

Recycling of indirect cooling water through the cooling tower:

Explanation of the above subject is omitted here because it is already given in 6.3 and 6.4.

7.6 Machine Industry

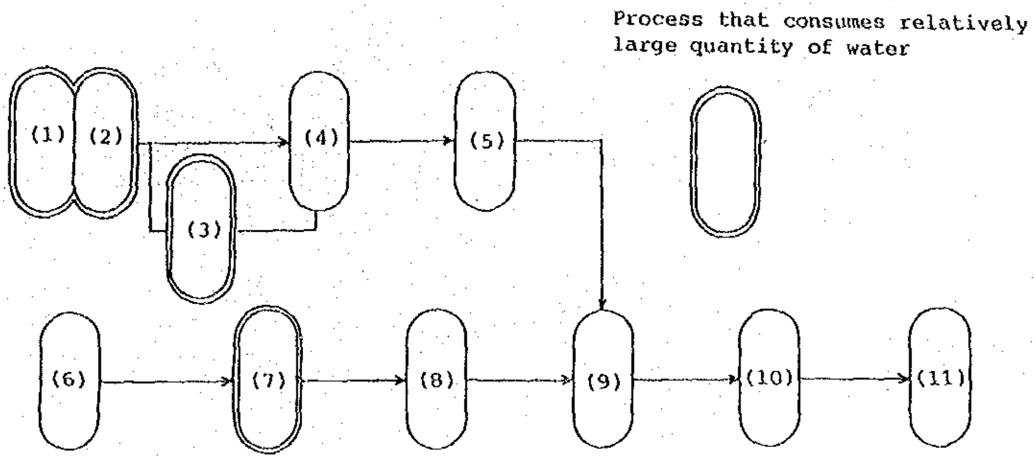
7.6.1 Outline of Process and Water Use

The machine industry involves the manufacture of automobiles and their parts, electrical machinery and machinery for other industries, and water consumption varies considerably according to the different processing stages adopted by the various kinds of manufacturing plants.

Some typical examples of processes used within the industry are the painting, plating, degreasing, pickling, and casting slag cooling processes. These processes mainly use cooling water, washing water and processing water. The machine industry uses a small quantity of water and is therefore unlike industries such as the chemical, steel, and pulp and paper industries which consume large quantities of water.

Nevertheless, automobile manufacturing plants have a high level of water consumption. For this reason and also because they incorporate a range of different processing stages the automobile manufacturing industry will be used as an example here for explaining the various processes involved.

Fig. 7.19 shows an outline of the general manufacturing process of the automobile industry. The process which consumes the largest volume of water is the painting process, and here water is used mainly in the pretreatment process which takes place before painting and in the electro-static coating process. This is followed by the casting process where water is used for cooling the furnaces and also for cooling welding machines used during the body assembly process.



Legend

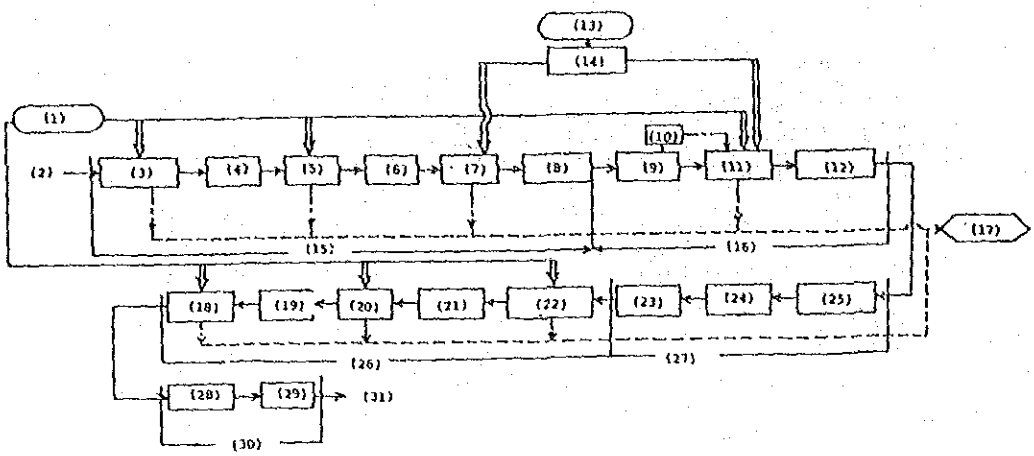
(1) Casting
(2) Forging
(3) Heat Treating
(4) Mechanical Treating
(5) Unit Assembling
(6) Pressing
(7) Body Assembling
(8) Painting
(9) Final Assembling
(10) Inspecting
(11) Shipping

Fig. 7.19: Production Process of Automobiles

The features of water consumption focusing into the painting process is described as follows.

(1) Painting process

As shown in Fig. 7.20, the painting process for the body of automobiles can be divided into the pretreatment process, electro-static coating process and the interim and final coating processes. The larger part of water consumption occurs during the pretreatment and electro-static coating processes.



Legend

(1) Industrial Water
(2) Metal Plate
(3) Prewashing
(4) Degreasing
(5) Washing
(6) Chemical Treating
(7) Washing
(8) Drying
(9) Electro Plating
(10) Ultrafiltration
(11) Washing
(12) Drying
(13) Industrial Water
(14) Pure Water Producing
(15) Pretreatment Process
(16) Electro-static Coating & Painting Process
(17) Waste Water Treatment
(18) Final Painting
(19) Drying
(20) Water Polishing
(21) Interim Drying
(22) Interim Painting
(23) Dryer Furnace
(24) Sealer Painting
(25) Undercoating
(26) Interim & Final Painting Process
(27) Floor backside Painting & Sealer Process
(28) Final Drying
(29) Inspecting
(30) Final Drying & Inspecting Process
(31) Assembling

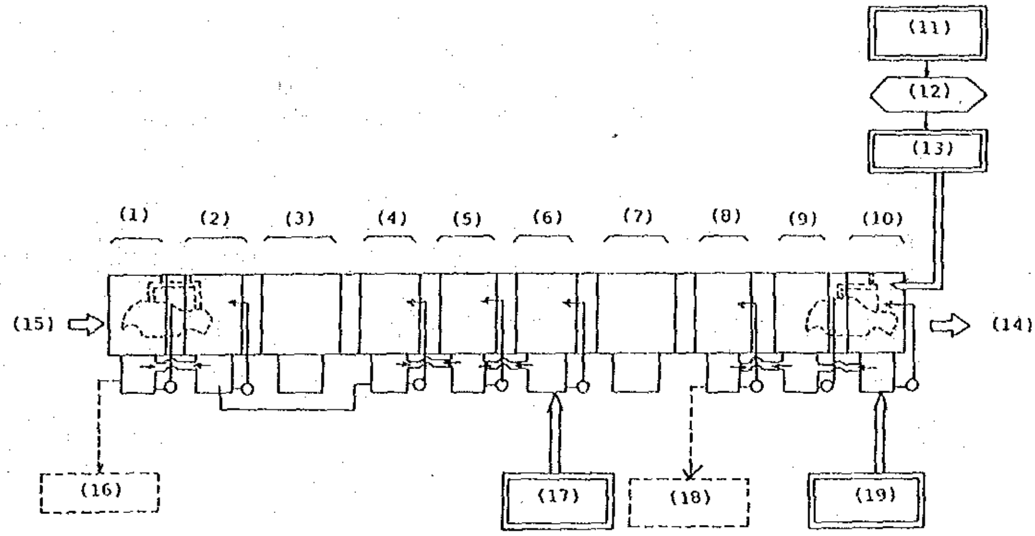
——> Flow of Production Process
===> Make-up Water
---> Waste Water

Fig. 7.20: Flow Diagram of Automobile Painting Process

(a) Pretreatment process

A flow chart for the pretreatment process is provided in Fig. 7.21.

The pretreatment process comprises of removing dirt from the car body and chemical coating as the primer coating. It is undertaken to improve the adhesiveness and anti-corrosiveness of the steel plates and electro-static coating and a large volume of water is consumed for washing. Because painting requires the adequate removal of the small quantity of inorganic ions which result from chemical coating, washing is carried out using pure water.



Legend

(1) Washing by Hot Water
(2) Predegreasing
(3) Degreasing
(4) No.1 Washing
(5) No.2 Washing
(6) No.3 Washing
(7) Chemical Treatment
(8) No.4 Washing
(9) No.5 Washing
(10) No.6 Washing
(11) Industrial Water
(12) Pure Water Producing
(13) Pure Water
(14) to Dryer
(15) Metal Plate
(16) Waste Water
(17) Industrial Water
(18) Waste Water
(19) Industrial Water

<—— Cascade Water
<=== Make-up Water
<--- Waste Water

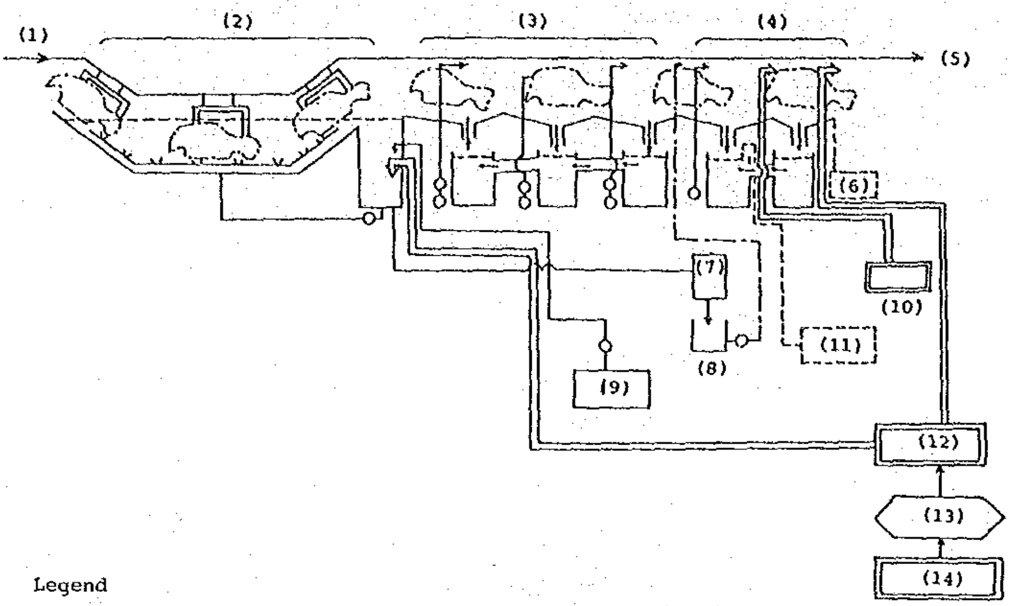
Fig. 7.21: Flow Diagram of Pretreatment

(b) Electro-static coating

Electro-static coating takes place immediately after the pretreatment process for the car body has been completed. Electro-static coating is a method of painting which entails soaking the car body in a solution of paint diluted in water and with this acting as one kind of electrode a direct current is run through the solution between this electrode and an electrode with an opposite potential. By doing this the coating material is precipitated onto the surface of the car body which is then baked.

The water consumed during the electro-static coating process is shown in Fig. 7.22. In the washing stage for coated bodies, washing water is used to wash out residual chemicals adhered on the surface of products which are lifted up from a coating bath.

Drips and globules are formed if washing is insufficient. In order to prevent from these troubles, after shower washing has been carried out a number of times a final shower washing using pure water is carried out, as shown in



Legend

(1) from Dryer
(2) Electro-static Coating Tank
(3) Washing by Ultrafiltrated Water
(4) Submerged Washing by Industrial Water and Pure Water
(5) to Dryer
(6) Waste Water
(7) Ultrafiltration Apparatus
(8) Filtrated Water Tank
(9) Electro-static Coating Paint
(10) Industrial Water
(11) Waste Water
(12) Pure Water
(13) Pure Water Producing Apparatus
(14) Industrial Water

<—— Cascade Water
<=== Make-up Water
<--- Waste Water

Fig. 7.22: Flow Diagram of Electro-Static Coating

(2) Casting process

Casting automobile parts are used for the engine, transmission, etc. , and they comprise approximately 15% of the weight of the vehicle. Classified according to type of material they are separated into either cast iron or light alloy parts.

Cast iron parts are made by melting the materials usually in a cupola or a low frequency induction furnace. Casts of a fixed shape are then made by pouring the resulting molten metal into cast molds for which silica sand, caking agents and water have been used.

As for alloy casting (mainly aluminum alloy), the materials which have been melted in a reverberating furnace or a quick melting furnace are cast into shapes using a die casting machine or a low pressure casting machine.

The casting process is one in which high temperatures are required for melting metals, and it therefore consumes a large quantity of water such as that used for cooling. A flow chart for the casting process is shown in Fig. 7.23.

(a) Melting process

The water used in the melting process for cast iron comprises of water for cooling the furnace and slag cooling water used treating the slag. For instance, approximately 15 m^3/h of cooling water is used for cupola having a capacity of 5 tons and a similar quantity is used for slag cooling. Following the removal of suspending solids after the water has been used, the water is cooled and then circulated for re-use.

Cooling water is important for the low frequency induction furnace, and a high quality of water is required so that scale, etc., does not form.

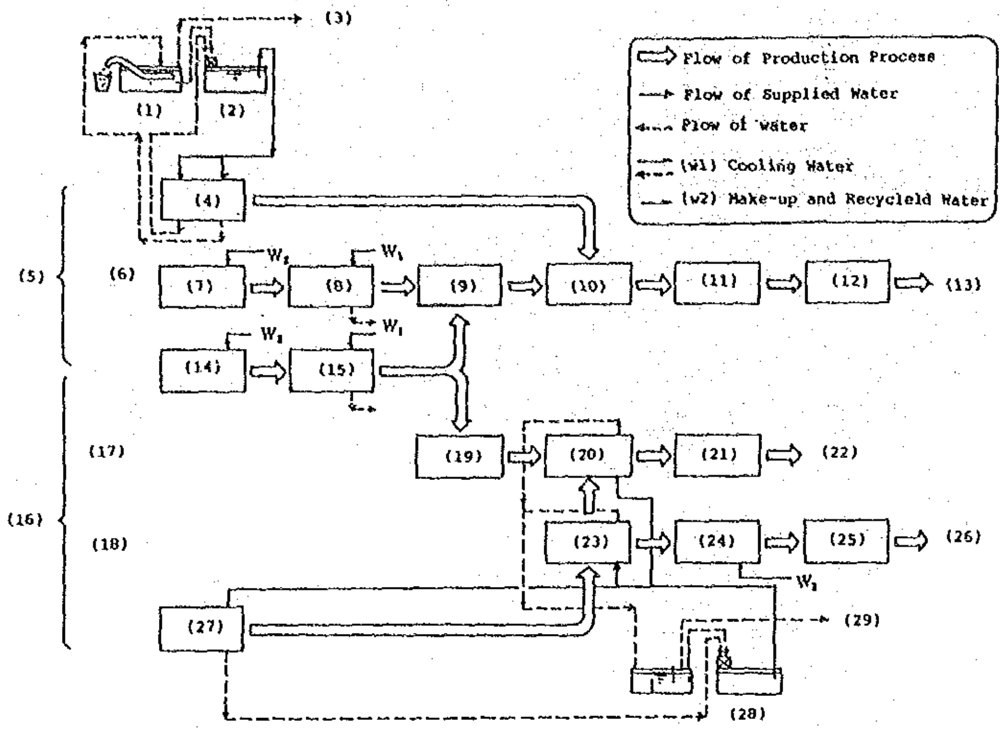
(b) Sand treatment process

A large quantity of silica sand is used for cast molds. This is a conditioning process undertaken to enable the circulated use of cast molds, and the 2% or so of moisture which was lost during casting is replenished. Approximately 8 to 10 tons of sand are required in order to produce 1 ton of cast iron parts.

(c) Molding process (Pourling process)

A large quantity of water is used for die casting in the molding process. In order to carry out production which is of a consistent quality by maintaining the mold at an appropriate temperature forced cooling is carried out by feeding cooling water into the inner part of the mold.

This cooling water and the water solution of mold release agents for the products and the molds which has leaked from the molds are recovered for re-use after suspending solids and oil have been removed.



Legend

(1) Slug Separating Tank	(15) Core Molding
(2) Tank	(16) Al Casting Process
(3) Overflow	(17) Low Pressure Casting & Gravity Casting Line
(4) Melting	(18) Die Casting Line
(5) Iron Casting Process	(19) Core Setting
(6) Mold Product Line	(20) Pouring
(7) Sand Treatment	(21) Finishing
(8) Mold Producing	(22) to Processing
(9) Core Setting	(23) Pourling
(10) Pouring	(24) Cooling
(11) Cooling	(25) Settling
(12) Break Up of Frame	(26) to Processing
(13) to Processing	(27) Melting
(14) Treatment of Shell Sand	(28) Water Reservoir

Fig. 7.23: Flow Diagram of Casting Process

7.6.2 Standard Methods for Effective Use of Water

As has been shown above, much water is used in product treatment and for washing during the manufacturing processes. However, as is shown in Figs. 7.21 and 7.22, the recovery of used water is carried out in the automobile industry to a much greater extent than in other industries. The following provides some details on methods which have been widely adopted for the effective use of water.

(1) Water for processing and washing

(a) Counter-current multistage washing system

- the adoption of the water washing process and spraying between the tanks as part of in the pretreatment process
- washing using water in the electro-static coating process

(b) Cascade system

- use of waste water discharged from degreasing process in the preparatory degreasing and then in the hot water washing process
- use of waste water discharged from pure water spraying in the pretreatment process in processes which use industrial water for washing
- use of waste water discharged from pure water used in the electro-static coating process, for industrial washing water

(c) Reclamation of waste water

- re-use of waste water discharged from electro-static coating and recovered by ultra filtration in washing processes (recovered paint is also re-used)
- circulation of waste water discharged from the water polishing stage after the separation of solid matter

(d) Recycle use

- recycle of washing water in the painting booth

(e) Use of water saving apparatus

- automatic water supply system (setting to an appropriate level the volume of fresh water to be sprayed during the painting pretreatment process)

(2) Cooling water

Recycle of indirect cooling water by using a cooling tower.

As most of the methods described above have already been explained in Chapter 6 or in the sections on other types of industry, only the following two methods are to be outlined here: (i) re-use of waste water reclaimed from electro-static coating by using ultra filtration; and (ii) recycle use of washing water in the painting booth.

(a) As is shown in Fig. 7.22, most of the substances contained in the waste water resulting from electro-static coating are paint chemicals. Therefore, it is possible to re-use the water and the paint chemicals by using ultra filtration to separate the paint chemicals. By doing this it is possible to decrease a significant load for waste water treatment. The quantity of water re-used in this process ranges from 0.01 to 0.1 m^3/unit of vehicle.

(b) Between 20 and 80 percent of the paint sprayed in the painting booth misses the object being painted and is mixed in the exhaust. In order to remove this paint from the exhaust the exhaust is washed in water.

If this water is circulated its effectiveness in washing exhaust is decreased due to the accumulation of paint scum in the water. By removing the paint scum by some means or other and adopting the method of complete recirculation the water supply can be reduced by renewing the water once every three weeks to a month.

7.6.3 Cost Estimation

Of the two methods for effective use of water which have been outlined above, the re-use of water by using ultra filtration to treat waste water discharged from the electro-static coating process will be used here for the purpose of cost estimation.

An ultra filtration device which can filter 20 liters of water per minute costs around 20 million yen. Fig. 7.24 is a flow diagram showing a process which incorporates ultra filtration.

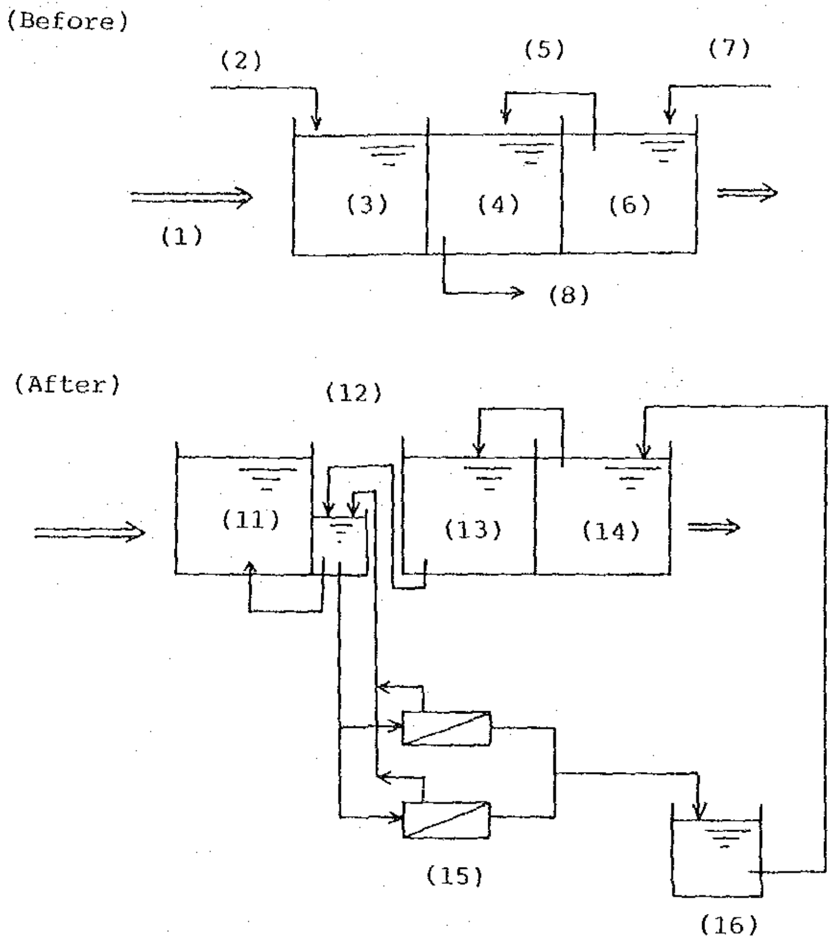
According to Table 7.7, by using reclaimed water the saving rate for costs is estimated at 52%, and this shows that the method is a fairly effective one.

7.6.4 Notes and Problems Related to Effective Use of Water

The automobile industry is ahead of other industries in the effective use of water. There is no particular problem related to this.

But it should be noted that due to the relationship between water quantity and the number of stages in counter-current multistage washing system the effectiveness decrease if system is carried out in more than 3 stages. (Refer to Chapter 6 and Fig. 6.4.)

Also, as for the use of recycled cooling water, in the case of water used for cooling spot welding machines care should be taken to prevent blockages from occurring in the cooling coils and small tubes of the spot chips as a means of preventing the cooling water from becoming dirty and the formation of scale and slime.



Legend

(1) Production Process
(2) Supply of Paint
(3) Electro Coating Tank
(4) No.1 Washing Tank
(5) Cascade
(6) No.2 Washing Tank
(7) Make-up Water
(8) Discharge

(11) Electro Dipping Tank
(12) Sub Tank
(13) No.1 Washing Tank
(14) No.2 Washing Tank
(15) Ultrafiltration Apparatus
(16) Treated Water Tank

Fig. 7.24: Flow Diagram of Before and After Installation of of Ultrafiltration Apparatus

Table 7.7: Comparison of Water Cost Before and After Installation of Ultrafiltration System

Item \ Stage	Before Installation	After Installation	Remarks
Quantity of Make-up Water (m^3/d)	10	1	
Quantity of Paint (kg/d)	20	2	
Cost of Water & Paint (¥/d): (a)	70,100	7,010	Water Cost = 10 ¥/m^3 Paint Cost = 3,500 ¥/kg
Quantity of Ultrafiltrated Water	-	10	20 lit/min x 60 min x 8 h
Cost of Ultrafiltration System (¥)	-	40,000	Including installation
Depreciation including Interest (¥/d): (b)	-	26,700	
Operating Cost (¥/d): (c)	-	200	
Total Cost (¥/d): (a)+(b)+(c)	-	33,910	
Cost Saving Rate (%)	-	52	

7.7 Chemical Industry

7.7.1 Outline of Process and Water Use

In the chemical industry, various categories of businesses are included; inorganic industry, organic industry, photograph, electrolysis, petrochemical industry, polymer industry, fats and oils, medicine, perfume, coating material, etc. Processes are different depending on each category of business and there is also a large difference of use of water.

It is naturally very difficult to profile the characteristics of use of water for the whole of chemical industry by sampling a manufacturing process. In summarizing production processes, however, typical processes are; adjustment of raw materials, reaction, separation and purification, filling and packaging. In this section, the use of water in the polymer industry will be outlined as shown in Fig. 7.25. Types of water used for production processes are as follows:

a. Process water
b. Washing water (including cooling water for polymer)
c. Cleaning water
d. Cooling water
e. Boiler water

Process water is used as a solvent or a mother liquor to directly contact with polymer at the time of polymerization reaction in the polymer manufacturing process. Usually pure water is used in order to prevent a bad influence on the polymatization reaction or the quality of products due to grains of salt, impurities or pH contained in water used.

Washing water is used to wash out unnecessary components from the generated polymer or to directly cool the melt polymer. For such purposes, pure water or soft water is used.

In the polymatization process, polymer adhered on the inside wall of reactors and pipings should be washed out at regular intervals, and all the system should also be cleaned before manufacturing a different type of polymer in order to avoid any influences from the components previously used.

Even in other processes, the cleaning of process equipment, including the replacement of filters, is required. For such cleaning purposes, general service water, soft water and pure water are used according to the requirements. High pressure jet washings or hot water jet washings are also used.

Cooling water is used for the temperature control of reactors or solvent condensers attached to reactors. Usually, cooling water is used and re-used being recycled through cooling towers. In a special case where cooling water is used at around 200 °C, pure water is sometimes cooled and recycled to use through heat exchangers.

Boiler water is used for boilers which generate steam to control the reaction temperature or other purposes. Indirectly used steam is recovered as condensate and pure water or soft water is used as feed water.

7.7.2 Standard Methods for Effective Use of Water

In the chemical industry, the following methods for the effective use of water are available.

(1) Process water

Water of required quality should always be supplied and there is almost no room for the effective use of water.

(2) Washing water

(a) Use of water saving apparatus

- High pressure jet washer
- Hot water jet washer

Used to cleaning of tanks, pipings and filters.

(3) Boiler water

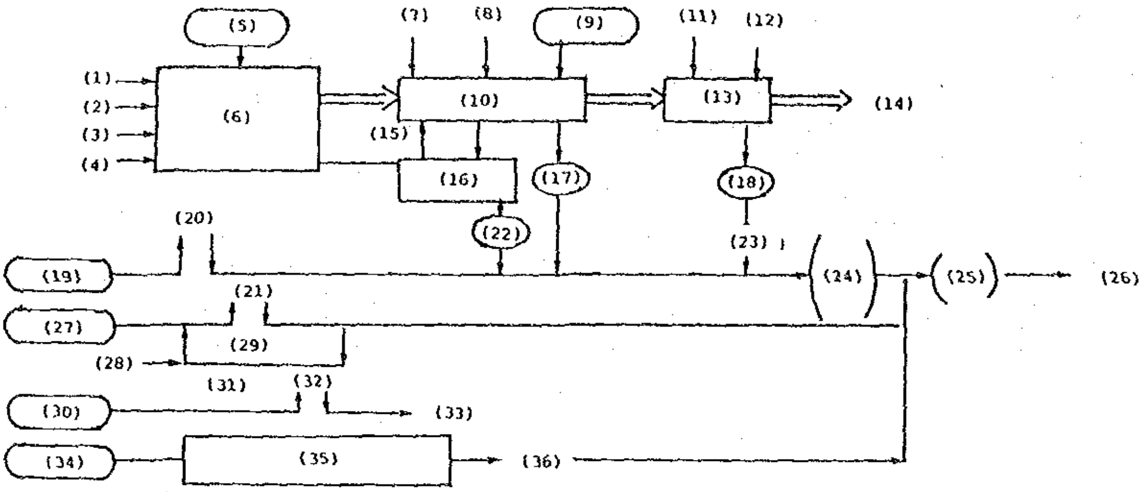
- Recycle use of recovered condensate

(4) Cooling water

Recycle use through cooling towers for indirect cooling water

For further details, refer to the description in Chapter 6.

Washing water can be saved by means of an effective production control, for example, successive manufacturing of identical products which reduces the number of washing stages.



Legend

(1) Monomer
(2) Solvent
(3) Catalysis
(4) Additives
(5) Process Water
(6) Polymerzation
(7) Cleanser
(8) Additives
(9) Washing Water
(10) Washing & Separating Process
(11) Additives
(12) Polymer Cooling Water
(13) Finishing Process
(14) Polymer Product
(15) Cleanser
(16) Recovery Processing
(17) Dehydrating
(18) Waste Water
(19) Washing Water
(20) Process
(21) Process
(22) Waste Water
(23) Treating
(24) Secondary Treating
(25) Overall Treating
(26) Discharge
(27) Cooling Water
(28) Additives
(29) Re-Use
(30) Boiler Water
(31) Steam
(32) Process
(33) to Waste Water Treatment
(34) Tap Water
(35) Water for Office, Dinning Roon & Domestic Use
(36) Treating

Fig. 7.25: Production Process of Polymer

Chapter 8

Problems in Implementing Water Saving Measures

Chapter 8 Problems in Implementing Water Saving Measures

8.1 Outline of Countermeasures Against Land Subsidence

In the previous sections of this report, the results of field study were summed up, and analyzed from various points of view, with some suggestions made. In this Chapter, the study will be reviewed again. Also, some of the problems encountered in implementing the measures against land subsidence in Thailand will be discussed.

As both the nation's population and industrial activities grow sharply, the Bangkok Metropolitan area (including its surrounding areas) has recently seen various problems caused by excessive pumping up of groundwater.

In addition to lowering of the water level and the intrusion of saline water to groundwater, the subsidence of land has become so serious that it often triggers floods during the rainy season.

Though the excessive pumping up of groundwater may not be the sole cause of land subsidence, it is undoubtedly the main one. Thus, effective measures are urgently called for.

The Government of Thailand has been making strenuous efforts to prevent the subsidence of land by implementing various laws (i.e. the Groundwater Act, the Factory Act and the Metropolitan Waterworks Authority Act). The Government's objective is to switch water sources in the area--from wells to rivers.

However, even today a large quantity of water is daily pumped up in the Bangkok Metropolitan area. For example, the pumping up quantity in 1986 reached more than 1,200,000 m^3/d (Fig. 8.1).

According to a study made by the Thai Government, the safe yield (i.e. limit of pumping up quantity that does not cause land subsidence) in the Bangkok Metropolitan area amounts to between 600,000 and 800,000 m^3/d. Thus, the present pumping up amount is nearly twice as much as the safe yield.

In order to stop the subsidence of land, it is necessary to reduce the pumping up quantity by more than 400,000 to 600,000 m^3/d. However, the reduction of groundwater consumption by this quantity cannot be done at one stroke as this would halt all industrial activities in the area.

Rather, measures for the prevention of land subsidence should be coordinated with the area's economic/industrial development plans. Moreover, future increases in the demand for industrial water must also be taken into account.

On the basis of the above considerations, the measures listed in Fig. 8.1 will be reviewed one by one.

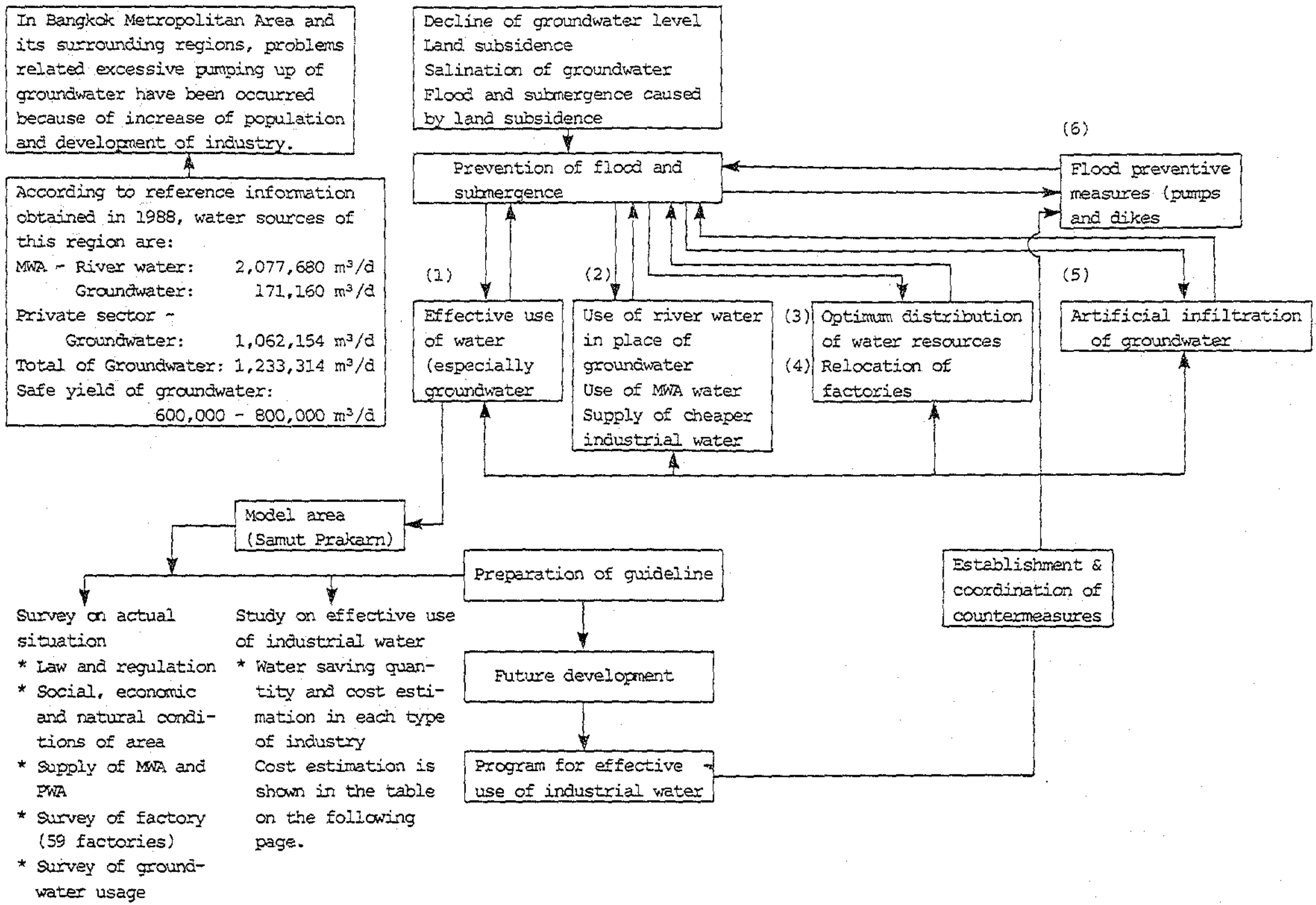


Fig. 8.1: Study Results and Relations to Plan for Effective Use of Industrial Water

Industry	No. of Surveyed Factory	Make-up Water (m^3/d)	Recycled Water (m^3/d)	Total (m^3/d)	Possible Saving Amount of Water (m^3/d)	Unit Cost for Effective Use (฿/m^3)
Food	14	7,025	39,301	46,326	969	3.4
Paper	5	18,845	11,009	29,854	1,560 5,260	0.8 3.3
Textile	7	13,632	53,535	67,167	636 2,636	0.8 10.1
Metal	20	8,594	26,565	35,159	1,603	1.4
Chemical	13	4,799	43,693	48,492	694	0.3
Total	59	52,895	174,103	266,998	5,462 11,162	1.4 4.7

Fig. 8.1: Continued, Part 2

8.1.1 Effective Use of Water (Groundwater)

This is the aim of the study. On the basis of the detailed survey of 59 factories in Samut Prakarn area, the technical guidelines were prepared for the reduction of groundwater consumption. To reduce the pumping up of well water, the guidelines should be effectively implemented.

Furthermore, in light of the future increase in the number of factories, the guidelines should be revised whenever necessary. In the future, the guidelines should cover the water demand in the north, particularly up-stream of the Chao Phraya River, of Samut Prakarn area as well.

8.1.2 Use of River Water (Water Supplied by MWA or New Public Industrial Waterworks System)

In addition to the efforts to reduce groundwater consumption, some measures should be taken to switch water sources from wells to rivers, accompanied by each factory's effort. With this purpose in mind, MWA is gradually switching its water source (from underground to river) while enlarging its supply area.

To stop the use of groundwater, individual factories will have to rely on either MWA or newly planned public industrial water works system. As the study shows, MWA water costs about 8.0 ฿/m^3 (depending on the volume consumed), whereas the present cost of pumping up is only 1.0 to 1.5 ฿/m^3 (2.0 to 2.5 ฿/m^3, if the groundwater rate is included). This difference is important for individual factories. For them, using MWA water instead of well water is economically disadvantageous.

It is in this context that the construction of public industrial water works emerges as an alternative to the use of river water. Such waterworks should (1) supply industrial water at much lower prices than MWA, and (2) hold the leakage ratio to a minimum. To achieve these purposes, some governmental support (subsidizing or favorable tax treatment) may be required.

8.1.3 Optimum Distribution of Water Resources

In the Bangkok Metropolitan area, the main source of river water is the Chao Phraya, the largest river in Thailand. The Chao Phraya River provide water not only for agriculture in the upstream areas, but also for potable water systems of MWA and PWA.

As the demand for river water increases in the downstream areas, it becomes increasingly important to secure balanced utilization of surface water so that the flow rate of the Chao Phraya River be kept safe for diversified demand (particularly, during the drought period).

Generally, river water is distributed (or its use is adjusted) by reserving water in dams or diverting the water of nearby rivers. These measures, however, are difficult to apply to the Chao Phraya River, as it runs through the vast central plain.

To cope with this situation, the public industrial waterworks project includes the construction of a giant reservoir that will serve to adjust the flow of the Chao Phraya River. In spite of some difficulties such as the securing of an adequate site, adoption of this plan is expected.

The flow rate of the Chao Phraya River reaches its lowest level in February. To supply river water even in this drought period (for agricultural, industrial and household uses), an effective plan for the utilization of surface water of the Chao Phraya River should be established, taking into account the increase in water demands in the future. Without such a plan, "switching water sources from wells to rivers" will have little meaning.

8.1.4 Relocation of Factories

Factories are naturally attracted to areas which have advantageous infrastructures. Besides harbors and roads, the supply of water is an important element of the infrastructure. To operate a factory properly, abundant water must be constantly supplied at a reasonable cost.

Thus, the water supply capacity is an essential factor in deciding the location of a factory. Conversely speaking, the plan for factory site may be determined by the limit of water supply.

The use of groundwater in the Bangkok Metropolitan area is closely related to that in the upper reaches of the Chao Phraya River. This fact taken into account, programs mat have to be established to prevent the concentration of factories.

8.1.5 Artificial Infiltration

It is technically possible to inject the surface water of the upstream of the Chao Phraya River into the groundwater aquifer. (This technique is called "artificial infiltration".)

In this case, water to be injected comes from the Chao Phraya River, so that due attention should be paid to its flow rate. Furthermore, since the injection of untreated river water will lead to clogging in the long run, the cost for water treatment should be taken into consideration.

8.1.6 Flood Preventive Measures (Pumps and Dikes)

In the Bangkok Metropolitan area, dikes and pumps have been already installed to prevent floods or to drain off flood water. By furnishing a giant reservoir, it may become possible to utilize stopped or drained flood water. On the basis of hydrological studies, this possibility should be further studied.

In addition to the above measures, sea water may be utilized for cooling. However, this method can be applied only to the costal areas, and hence, is not listed in Fig. 8.1.

8.2 Effects of Water Saving Measures

Among the measures listed in Fig. 8.1, measure (1)--effective use of industrial water--is less cost-demanding than other ones. The study pursued the possibilities of this measure in 59 factories in Samut Prakarn area, indicating the potential water saving quantity as shown in Part 2 of Fig. 8.1.

In the followings, on the basis of the study estimations are given for both the potential quantity of groundwater saving for the entirety of Samut Prakarn Province and in the Bangkok Metropolitan Area.

According to the survey conducted in 1986, the number of factories in Samut Prakarn Province amounts to 2,631. The total quantity of groundwater consumption in these factories reaches 286,070 m^3/d (refer to Table 2.2).

Thus, the study covered 2.2% (59) of the factories in Samut Prakarn Province and 17.6% of the total pumping up quantity. Although some of the surveyed factories use water from various sources (MWA, river, klongs or rainwater) besides wells, the aggregate quantity of such water is negligible.

As stated in Chapter 4 of this report, the groundwater cost in the surveyed area is somewhere between 2.0 and 2.5 ฿/m^3, while the cost of MWA water is about 8.0 ฿/m^3.

As shown in 4.8.3, if the average unit cost of improvement is set at 1.4 ฿/m^3, about 10% of the make-up water currently consumed in the surveyed factories can be saved. If the average unit cost of improvement is set at 4.7 ฿/m^3, the saving rate will be raised to 20% (refer to Fig. 8.1).

The improvement cost equivalent to 4.7 ฿/m^3 is not unduly high. Though the situation may be different from factory to factory, this amount of cost increase is unlikely to have any serious effects on the surveyed factories.

As far as the surveyed factories are concerned, the recovery rate of industrial water is already fairly high. In addition to the awareness of the graveness of land subsidence on the factories' side, certain governmental measures (the groundwater rate based on the Groundwater Act, the regulations on waste water, etc.) seem to have been effective in this respect.

The quantity of make-up water in the surveyed factories reaches 52,895 m^3/d (Fig. 8.1), of which well water accounts for 50,295 m^3/d. As mentioned above, the total quantity of well water consumed in Samut Prakarn Province is 286,070 m^3/d.

Also, the study showed that about 10% (i.e. 5,462 m^3/d for the surveyed factories) of well water could be saved at 1.4 ฿/m^3 of the average unit cost of improvement. Therefore, on the assumption that the same conditions apply in other factories in Samut Prakarn Province as in the surveyed ones, the average unit cost of 1.4 ฿/m^3 will bring the saving of well water in Samut Prakarn Province as follows:

286,070 x 5,462/50,295 = 31,067 (m^3/d)

Similarly, if the average unit cost is set at 4.7 ฿/m^3 (i.e. if the saving rate is set at 20%), the saving of well water in Samut Prakan Province will be:

286,070 x 11,162/50,295 = 63,488 (m^3/d)

Then, on the basis of the comparison of gross area, the potential saving quantity of well water in the Bangkok Groundwater Area (7,923 km^2) and the Groundwater Critical Area (2.285 km^2) can be estimated.

Since Samut Prakarn Province has an area of 934 km^2, the potential saving quantity in the both Areas are calculated as follows:

(1) The average unit cost of improvement is 1.4 ฿/m^3 (i.e. the saving rate is 10%)

    Groundwater Critical Area
    31,067 x 2,285/934 = 76,004 (m^3/d)
    Bangkok Groundwater Area
    31,067 x 7,923/934 = 263,537 (m^3/d)