5.2 Results of the Study at Kashan Velvet & Rayon Mills

5.2.1 Outline of the Plant

(1) Plant name

Kashan Velvet & Rayon Mills LTD.

(2) Plant address

Amirkabir Ave. Kashan, Iran

(3) Number of employees

6,073

(4) Major products

Cloths, velvet and carpets

(5) Production capacity

Cloths: 10,000,000 m/y
Velvet: 4,460,000 m/y
Carpet: 1,235,000 m^2/y

(6) Production process

The plant is divided into the rayon factory for spinning, weaving, and dyeing and the velvet factory that receives the raw yarn from the rayon factory.
Major processes are outlined below. Figure 5.2.1 shows the process flow chart.

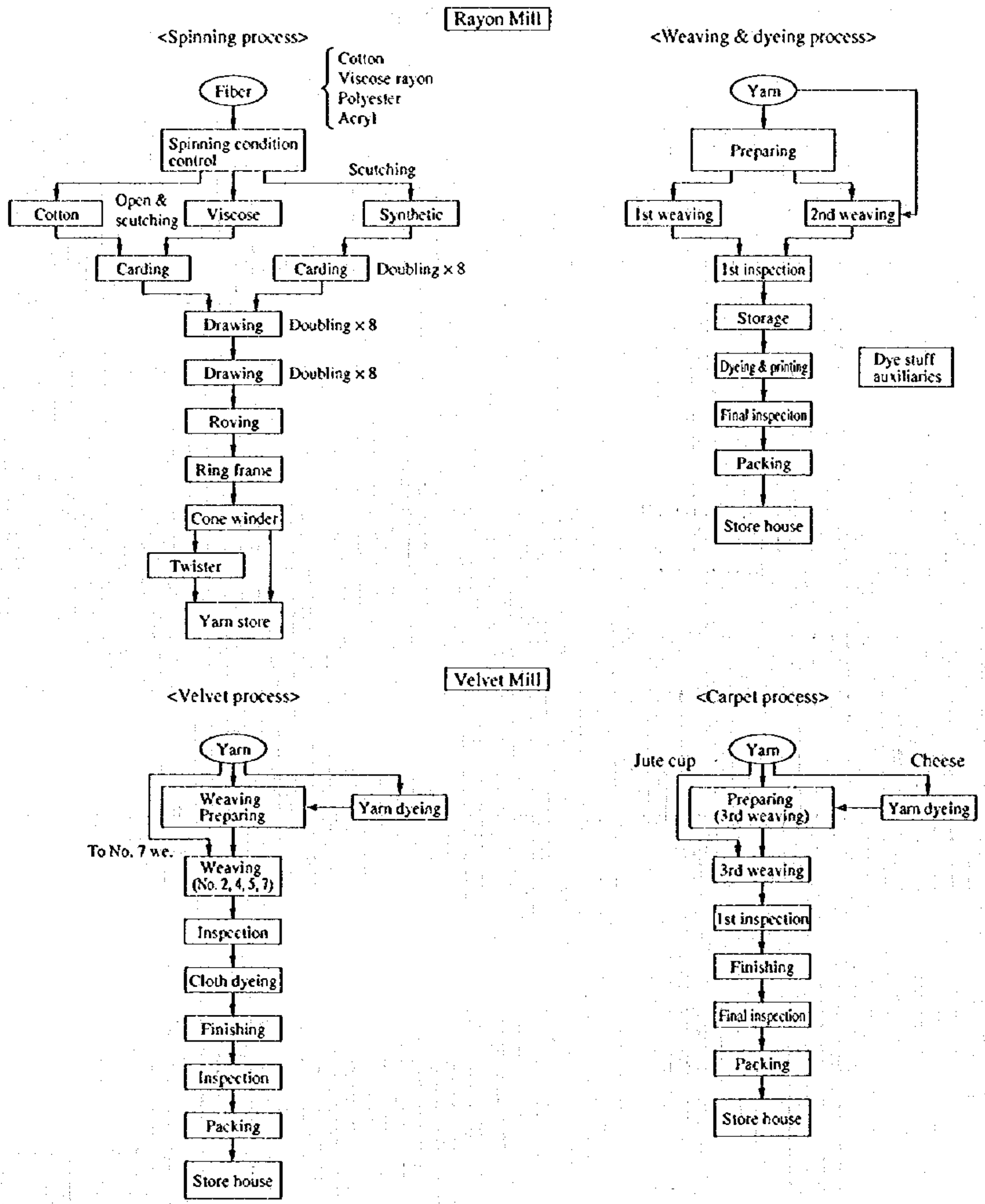
a. Rayon factory

1) Spinning process

In the spinning process, raw material fibers such as cotton, rayon, polyester, and acryl are spinned individually or in a mixed mode.

After having foreign matters removed in raw cotton through each process, cotton fibers are repeatedly made paralled and uniform along with synthetic resin, and turned into yarn of a specified yarn count number by the spinning machine.

Figure 5.2.1 Process Flow



The bobbin yarn taken out from the spinning machine is wound into cheese shape by the automatic winder and then twisted by the double twister. This twisted yarn is used as the raw yarn for velvet, carpet, and gray fabric along with a part of the bobbin yarn.

Temperature and humidity control in the spinning process is an important control factor, for which the air conditioner in each process maintains the specific temperature and humidity in a stable manner.

Power consumption by the air conditioners is high, accounting for 10 % to 20 % of the electricity consumption for production.

2) Weaving process

The received raw yarn is treated by warping and winding to prepare for the warp and weft, and then woven into a gray fabric by a weaving machine.

The gray fabric for general textiles is fed to the dyeing and finishing processes.

As with the spinning process described above, temperature and humidity control in the weaving machine room is important. A dedicated air-conditioning system controls the temperature and humidity.

3) Dyeing and finishing processes

For dyeing and finishing the gray fabric, there are various and versatile processing types depending on the use of the finished product.

The short-fiber woven fabric is processed in the following three sets of processes:

① Preparation processes

The major processes are singeing, desizing, scouring, and bleaching. The mercerization and heat setting processes are performed as required.

② Dyeing processes

These processes are classified into dipping as plain dyeing and textile printing. Dip dyeing is performed in a batch system using the liquid flow dyeing machine, the wince and jigger dyeing machines.

Also, pattern printing by a printing machine is available.

③ Finishing process

For resin finish which is performed according to each specific use and purpose of the product, the finishing technology is getting increasingly upgraded and diversified, which includes crease-preventive finish, flexibility-adding finish etc.

A heat medium is provided as the heat source for two heat setting machines used for finishing.

A large amount of heat and water is used in the dyeing and finishing processes. Hence, energy management focused on specific important areas is essential.

b. Velvet factory

In the velvet factroy, in addition to the raw yarn supplied from the spinning process, carpet weft and pile yarn of a large yarn count are supplied by the subcontractor.

Velvet and carpet are woven and finished by using these raw yarns.

1) Velvet processes

A part of raw yarns supplied from the rayon factory and subcontractor are dyed by the yarn dyeing machine.

The raw gray fabric woven by twining the pile thread with the warp and the weft is, also in the final finish process, subjected to fluffing, shearing, glazing, and then sheeping, to be made into a product, though additional processing operation may somewhat differ depending on the yarn dyeing or piece dyeing.

A large amount of steam and washing water is used in the yarn and fabric dyeing processes.

2) Carpet processes

For the carpet warp raw yarn, spun yarn is supplied, while the thicker warp and pile are subcontracted. After yarn dyeing, the carpet raw yarns have the pile inserted into the base fabric by the tufting machine to form the pile. Then, after raising, polishing and shearing, a product is made by the lining process.

As with velvet, a large amount of steam and washing water is used in the yarn dyeing process. Therefore, energy management is essential. In the shearing process, the electric facility capacity for the dust collecting blower is large.

(7) History of the plant

Forty years ago, this factory was founded as a private enterprise with the capital provided by banks (50 %) and private companies (50 %).

At the initial stage, the item produced was velvet. Then, raw materials such as silk and viscose rayon have been added to cotton.

Presently, carpets as well as velvet are produced. As new raw materials, polyester and acryl have been introduced to be used in various ways (i.e. individually or in a mixed mode with traditional fibers).

Although a part of raw materials for such as rayon is imported, polyester and acryl are supplied from domestic manufacturers as raw material.

The products are exported to Russia, Czecho, and nations within the former Soviet Union.

As other manufacturers engaged in the same business in I. R. Iran, there are three rayon plants and one velvet plant. There is no competition in silk velvet.

The scale of this plant ranks high among all Iran's fiber companies.

The production in the entire country is now greatly reduced due to economical depression and an increase in exports by adjoining countries.

For the renovation of facilities, their replacement to hi-tech weaving machines is currently in progress in the No. 3 fabric weaving shop of the rayon factory.

(8) Plant layout

Figure 5.2.2 shows the plant layout.

(9) One line diagram

Figure 5.2.3 shows one line diagram.

(10) Outline of major facilities

Table 5.2.1 shows the major utility facilities and production machines in the rayon factory and velvet factory.

Figure 5.2.2 Plant layout

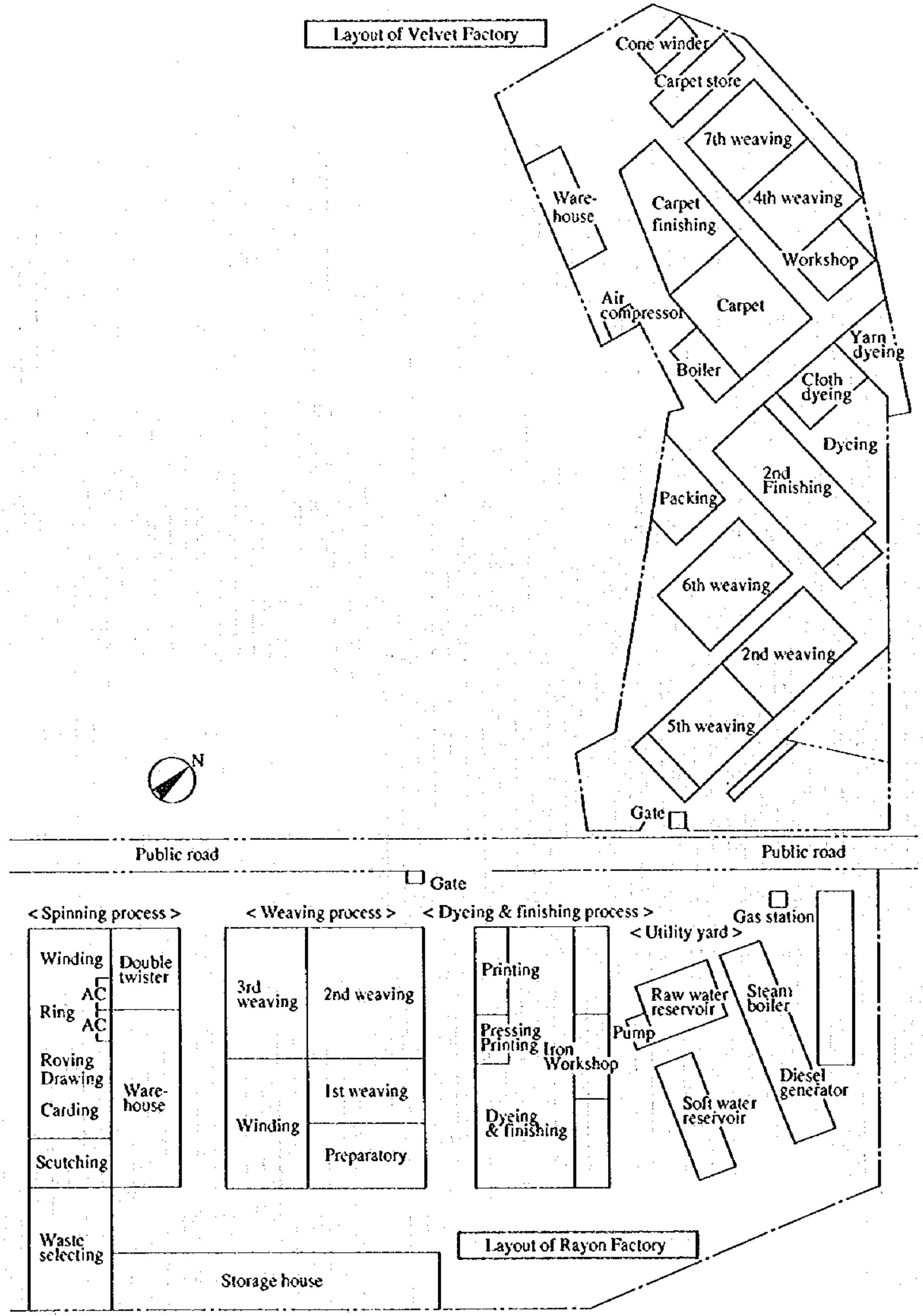


Figure 5.2.3 One Line Diagram

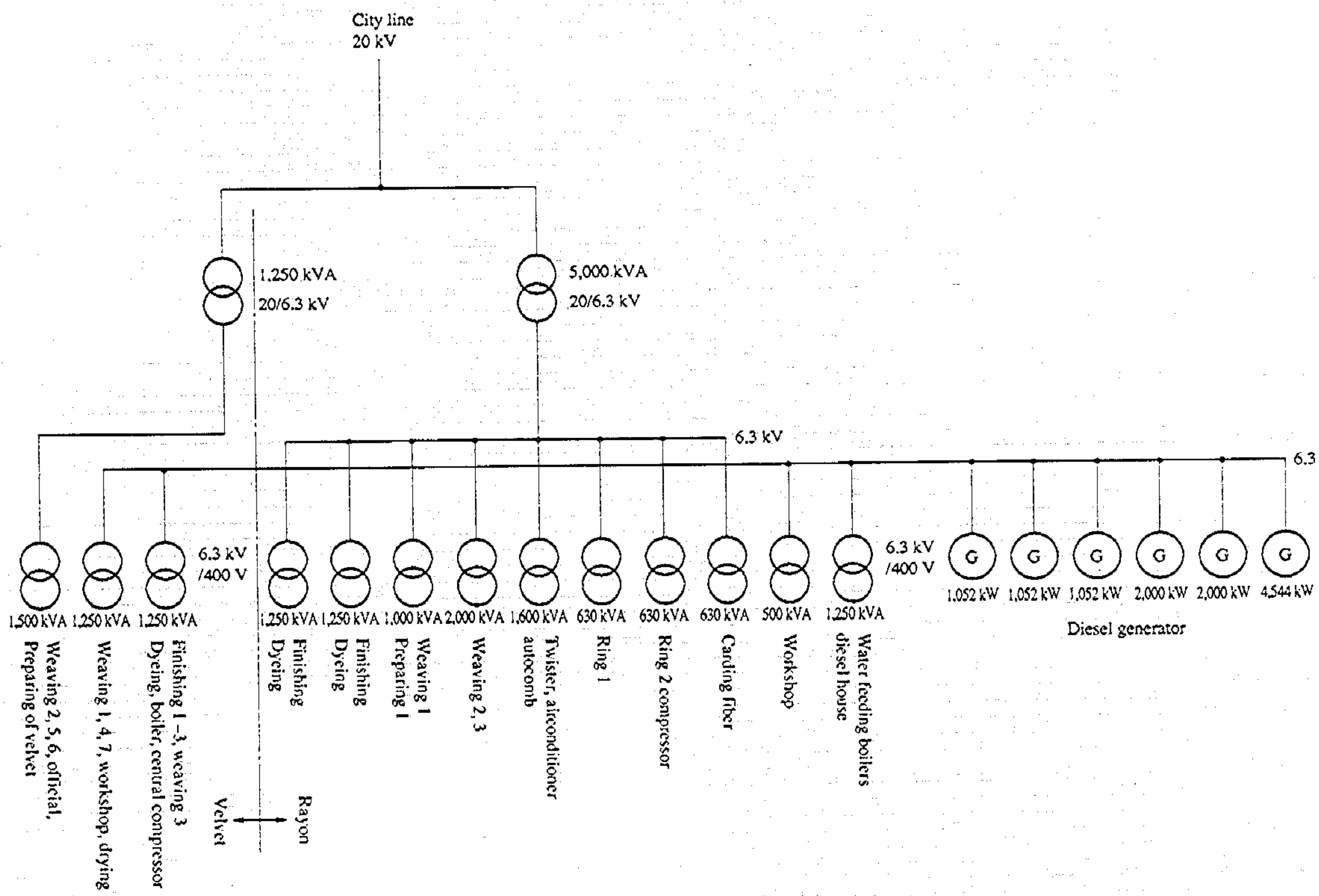


Table 5.2.1 Main Equipment

Factory	Process	Equipment	Number	Specification
Rayon	Utilities	Diesel generator	6	(3 × 1,315 + 2 × 2,500 + 1 × 5,680) kVA
		Steam boiler	5	smoke tube (1 × 20 + 4 × 10) t/h
		Raw water treatment	1	4 × deepwell, water softener
	Spinning	Preparation	1	Blending and scutching, carding, drawing and prespinning
		Spinning	48	400 sps × ring frame
		Winder	7	50 drums × autocorner
		Double twister	28	
		Air conditioner	3	Air washer type
		Air compressor	3	2 × screw / 1 × reciprocate
	Weaving	Preparation	1	Sizer, warper, winder
		Shuttle looms	325	No. 1, 2 weaving
		Shuttleless looms	47	No. 4 weaving
		Air conditioner	3	Airwasher system
		Air compressor	3	2 × screw / 1 × reciprocate
	Dyeing and finishing	Preparation	1	Singeing, desizing, scouring, bleaching,
		Continuous dyeing	1	1 × thermosol
		Batch dyeing	22	6 × jet
				9 × jigger
				7 × wince
		Print dyeing	2	1 × rotary
				1 × frame
		Finishing	1	Tenter, resin, etc.
		Heat media boiler	2	Once through 26.7 m²
		Air compressor	3	2 × screw / 1 × reciprocate
Velvet	Utilities	Steam boiler	4	smoke tube (3 × 10 + 2 × 7) t/h
		Air compressor	6	3 × screw / 3 × reciprocate
		Vacuum cleaner	1	2 × 55 kW reciprocate
	Velvet	Yarn dyeing	4	Overmiyer type
		Yarn dryer	2	Hot air circulate
		Preparation	1	Warper, winder, etc.
		Weaving	1	Looms for velvet
		Continuous dyeing	1	for cloth
		Batch dyeing	12	9 × vertical
				3 × horizontal
		Finishing	1	Shearing, glazing, etc.
		Air conditioner	1	Evaporation system
	Carpet	Yarn dyeing	1	Common use velvet
		Preparation	1	Basefabric, and pile, etc.
		Weaving	1	for carpet
		Finishing	1	Shearing, brushing, etc.
		Air conditioner	1	Evaporation system

(11) Energy cost

Electric power and fuel costs are as follows:

Power : 42 to 43.5 Rial/kWh (1995)
Fuel oil: 10 Rial/L (1995)
Gas oil : 20 Rial/L (1995)

Natural gas: Rayon factory 29 Rial/m^3 (1996)
Velvet factory 26 Rial/m^3 (1996)

(12) Study period

a. Preliminary study: October 14, 1995

b. Plenary study : August 17 to 19, 1996

(13) Members of the study team

a. JICA team

Leader	: Norio Fukushima (Preliminary study)
Leader and heat management technology	: Jiro Konishi
Process management technology	: Takashige Taniguchi
Electricity management technology	: Kazuo Usui
Economic evaluation	: Shigeaki Kato (Preliminary study)

b. PBO team

Energy conservation	: Mr. Mianji
Energy conservation	: Mr. Akhavan (Preliminary study)
Factory management	: Mr. Sajadifar
Macro level energy management	: Mr. Moosavi

(14) Interviewees

a. Preliminary study

Mr. Mossavar	: Deputy General Manager
Mr. Shojaee	: Manager of Spinning Factory
Mr. Javad-Dashtizadeh	: Manager of Velvet Factory
Mr. Rokni	: Manager of Dyeing Room
Mr. Ghattan	: Manager of Utility Section

b. Plenary study

Mr. Khayatian: Technical Manager
Mr. Kamali : Supervisor of Power House
Mr. Ansari : Supervisor of Technical Office
Mr. Hemsian : Supervisor of Factory Office
Mr. Sanayia : Supervisor of Industrial Management

5.2.2 Current Situation of Energy Consumption

(1) Transition of the production

Table 5.2.2 shows the production by product type for each year of 1990 through 1995.

For the fabric production, the weight values converted from the length, area, and weight for square meter are shown in addition to the unit that is usually in use.

Table 5.2.2 Production

Name of Product		1990	1991	1992	1993	1994	1995
Spinning Yarn (R + V)	t	1,551	1,414	1,353	1,318	1,290	1,250
Weaving	km	10,032.8	10,183.3	9,203.3	9,448.7	7,334.1	5,038.1
Fab (R + V)	t	1,091	1,107	1,001	1,028	798	548
Velvet	km	3,897.7	3,618.7	3,351.3	2,885.8	2,821.6	1,851.2
	t	1,964	1,824	1,689	1,454	1,422	933
Carpet	m^2	824,442	901,044	899,887	843,465	759,568	423,181
	t	1,855	2,024	2,026	1,898	1,709	952

Note: The weight was calculated based on the assumption that the specific weights are as follows:
Fabric: Average 1.45 m Width, 75 g/m^2
Velvet: Average 1.4 m Width, 504 g/m
Carpet: Average 2,250 g/m^2

(2) Transition of the energy consumption

Table 5.2.3 shows the energy consumption for each year of 1990 through 1995.

Table 5.2.3 Energy Consumption

		1990	1991	1992	1993	1994	1995	Note
Electricity								
Purchased		–	–	–	–	–	–	
In-house		17,071.1	17,103.9	16,840.1	8,814.1	7,415.6	–	
Total	MWh	–	–	–	–	–	–	
Diesel oil	kL	4,260	4,280	4,210	2,220	1,860	–	8,900 kcal/L
Kerosine	kL	270	235	220	310	235	–	8,320 kcal/L
Fuel oil	kL	3,250	2,750	2,700	1,300	1,250	1,280	9,300 kcal/L
Natural Gas	1,000 m^3	6,922.3	6,931.6	6,932.5	6,941.5	6,942.7	6,327.7	9,500 kcal/m^3
Soft water	1,000 m^3	580	595	580	580	567	589	
Boiler fuel	Gcal	95,987	91,425	90,969	78,034	77,581	69,797	

Since both natural gas and fuel oil are used for the steam boiler, the sum of these values converted into calories is shown as the boiler fuel.

Table 5.2.4 shows the electricity balance in the factory at the point of this study.

Table 5.2.4 Electric Power Balance

Measuring date: 18 August-19 August

	Diesel kW	Diesel Weight (%)	Diesel Capacity (kW, kVA)	City line kW	City line Weight (%)	City line Capacity (kW, kVA)	Total kW	Total Weight (%)
Supply								
Diesel engine No. 1			1,052					
Diesel engine No. 2			1,052					
Diesel total	1,160	30.4	2,104					
City line				2,650	69.6	6,250		
Total							3,810	100.0
Consumption								
Velvet								
Weaving No. 1, 4, 7	400	10.5	1,250					
Workshop								
Drying								
Weaving No. 3	410	10.8	1,250					
Dyeing								
Finishing No. 1–3								
Boiler, Central, Compressor								
Diesel total	810	21.3						
Weaving No. 2, 5, 6				450	11.8	1,500		
Velvet preperation								
Official								
City line total				450	11.8	1,500		
Velvet total							1,260	33.1
Rayon								
Water feeding boiler	280	7.4	1,250					
Diesel house								
Workshop	70	1.8	500					
Diesel total	350	9.2						
Finishing & Dyeing				420	11.0	1,250 × 2		
Weaving No. 1 & Preparing				180	4.7	1,000		
Weaving No. 2, 3				330	8.7	2,000		
Twister, A. C. auto-comb				420	11.0	1,600		
Ring No. 1				130	3.4	630		
Ring No. 2, Compressor				420	11.0	630		
Carding, flyer				300	7.9			
City line total				2,200	57.7			
Rayon total							2,250	66.9
Total	1,160	30.4		2,650	69.6		3,810	100.0

Table 5.2.5 shows the status of power generation by the diesel power generation facility at the point of this study.

Table 5.2.5 Diesel Engine Power Generation

Measuring date: 18 August 1996, 13:00 – 19 August 1996, 12:00

	Diesel Engine No. 1		Diesel Engine No. 2		Total	
	kW	p. f.	kW	p. f.	kW	p. f.
Average	581.2	0.977	488.6	0.951	1,069.8	0.967
Maximum	716.7	0.991	655.1	0.975	1,316.7	0.977
Minimum	433.6	0.958	310.9	0.910	844.5	0.956

(3) Energy intensity

a. Energy Intensity

Table 5.2.6 shows energy intensity.

Since no tabulated data on purchased power for each year is available for electricity intensity, it is difficult to grasp the accurate electricity intensity in each process. The electricity intensity was derived from data in July, September, and November, 1995.

Table 5.2.6 Energy Intensity (1995)

			Spinning	Weaving (R + V)	Dyeing and Finishing	Velvet Processing	Carpet Processing	Velvet + Carpet
Production		t	1,250	–	–	933	952	1,885
		km	–	5,038	3,187	1,851	–	
		10^3 m^2	–	7,053	4,462	2,591	423	
Consumption	Electricity	MWh/y	7,286	11,194	2,645	816	2,010	–
	Fuel	Gcal/y[1]	–	–	41,878	–	–	27,919[2]
Energy intensity	Electricity	MWh/t	5.83	–	–	–	–	–
		MWh/km	–	2.22	0.83	0.44	–	–
		MWh/10^3 m^2	–	1.59	0.59	0.31	4.75	–
	Fuel	Gcal/t	–	–	–	–	–	14.66
		Gcal/km	–	–	13.1	–	–	–
		Gcal/10^3 m^2	–	–	9.39	–	–	–

Note 1): Fuel ratio of rayon and velvet was assumed to be 0.6:0.4 based on the boiler capacity.
2): Total fuel intensity for velvet and carpet.

b. Evaluation on the fuel intensity of diesel power generation

The fuel intensity and heat efficiency are calculated based on the fuel consumption and actual power generation result of diesel power generator, and shown in Table 5.2.7.

Table 5.2.7 Fuel Economy of Diesel Generation

		1990	1991	1992	1993	1994	Total	Average
Fuel consumption	kL	4,260	4,280	4,210	2,220	1,860	16,830	-
Power generation	MWh	17,071	17,104	16,840	8,814	7,416	67,245	-
Fuel intensity	L/MWh	250	250	250	252	251	-	250
	g/Ps·h	172	172	172	176	175	-	172
Thermal efficiency	%	38.7	38.7	38.7	38.3	38.5	-	38.7

For comparison with the standard fuel intensity, the result value is converted by the following formula:

(kg/L)		(L/kWh)		(kWh/Hp·h)				(g/PS·h)
0.92	×	0.25	×	0.76	×	1,000	=	172

Fuel intensity, 172 g/PS·h is within the standard range of diesel power generators with the equivalent scale; therefore the operation status is identified to be good.

(4) Heat energy flow

Figure 5.2.4 shows energy flow of major processes in the rayon factory and velvet factory.

Figure 5.2.4 Heat Energy Flow

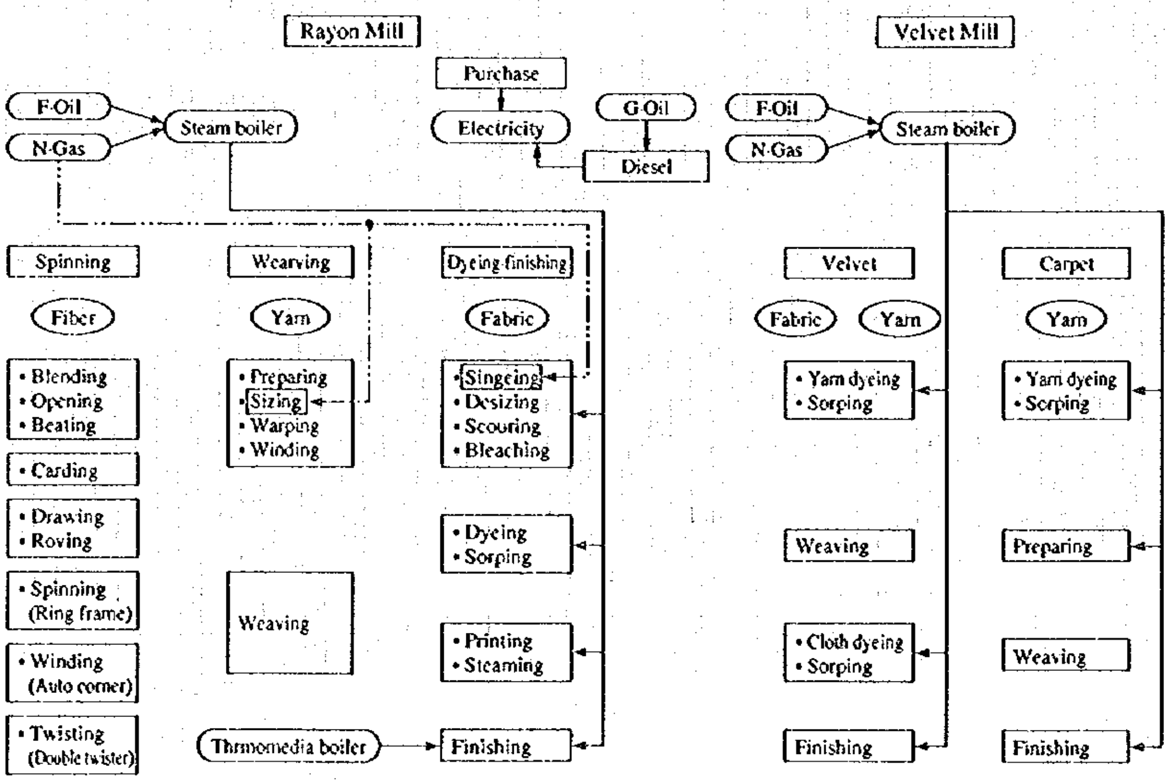


Figure 5.2.5 shows the system flows of steam and boiler feed water in the rayon factory and velvet factory.

In both factories, the rayon factory is placed as the main base for energy supply, which supplies power and raw water to the velvet factory across the public road. Although the interconnecting piping for steam is provided for any emergency case in either factory, it is usually closed by valves.

Natural gas as the boiler fuel is individually supplied to each factory and the billing system is individually provided for each factory.

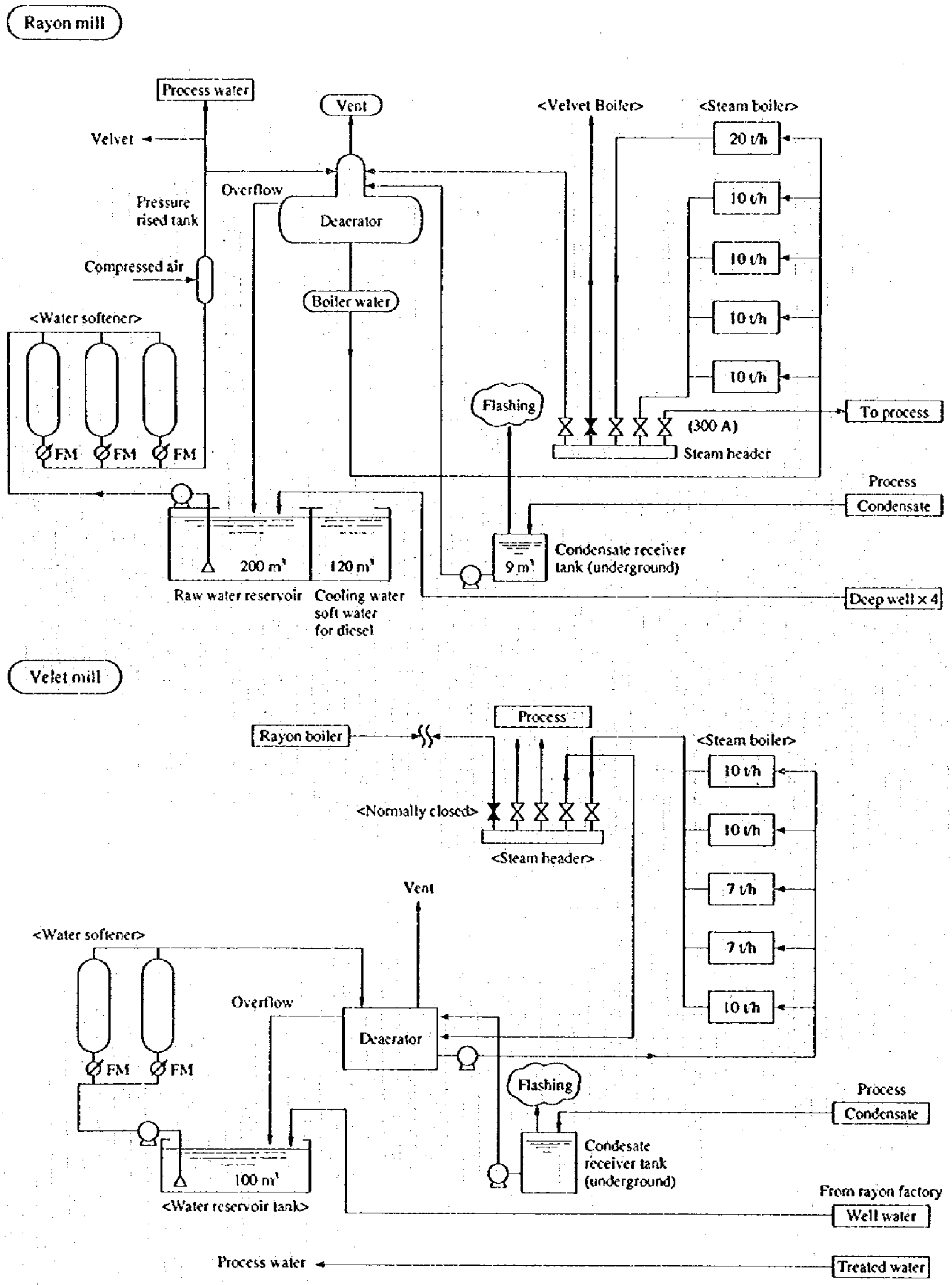
(5) Electric power supply and demand

Electric power is supplied by the purchased power line and the private power generating plant, which are completely separated. Hence, there is no flexibility in electricity supply and demand. In terms of the contracted power, the maximum power is adjusted by the load only, and an advantage of suppressing the maximum power by adjusting private power generation is not utilized. Since the unit price of private power generation is higher than that of purchased power when supply price of diesel engine parts is taken into account, only two diesel power generators are in service. The ratio of the purchased power is 70 %. Power failures in purchased power occur approximately 30 times a year, and each time is several minutes to 20 minutes.

At the point of this study, the facility utilization factor (= Average power/generator rating output) of the power generators is 55 % for the No. 1 generator and 46 % for the No. 2 generator, which are low. However, the light-load operation is performed to avoid accidents in terms of the problem in supplying spare parts.

For the power factor, many condensers are placed in each substation in the factory for power factor adjustment. The power factor throughout the factory is more than 90 %, which indicates a good state.

Figure 5.2.5 Steam Flow and Feed Water Flow



5.2.3 Current Situation of Energy Management

(1) Setting the energy conservation target

Presently, the specific target values for energy conservation have not been set yet.

The reasons are as follows:

- The energy price is low and the cost advantages derived from energy conservation actions cannot be expected.

- The production has gradually reduced since 1990. The production in 1995 is a half of that in 1990.

Setting the target and promoting activities to achieve it is a management technique common to any plant management and it is indispensable to high-efficiency operation of facilities as well as improvement of facility reliability. Even though the cost advantages are low, the cumulative profit in long period resulting from energy saving will be large.

Setting the target and promoting activities promises not only the cost reduction effect by energy conservation but also improvement of the overall management level. Therefore, many synergetic effects can be expected.

(2) Organized activities

Technical Service Department is responsible for energy management. It is the only organization that checks and manages all utilities in a centralized manner on a company-wide basis. This Department is allowed to promote cross-over activities as required.

However, organized activities for energy conservation are not yet performed for the reasons described in (1) above.

To bring synergetic effects as a result of energy conservation, a system should be created so that all employees will be aware of the problem and promote small-group activities sub-divided in each workshop.

We firmly believe that Technical Service Department will take the lead in the energy conservation to make it a company-wide campaign.

(3) Data-based management

Energy intensity management, as the basis for energy management, is not yet performed.

As the prerequisites for energy intensity management, measurement/metering of electric power, fuel, steam, and utility water is essential but measuring meters for utilities other than electric power are insufficient. It is therefore necessary to install measuring meters to check the energy consumption by plant and by process.

Metering control is required as the basis for calculation of the product cost, and it is useful for evaluation of equipment efficiency and for judgment of the limit and allowance of the energy generation and consumption capability.

It is also necessary to prepare the layout of overall metering equipment and then promote new installation or renovation of metering instrumentation individually or together with the modification of production facilities, in a scheduled manner.

Particularly, for calculation of the contamination load used to plan the dyeing process waste water treatment equipment, it is necessary to grasp the washing water volume. Upon selection of measuring meters, it is desirable that high-accuracy, long-life, and maintenance-free meters should be selected even though the initial cost is high.

Presently, data management is possible for the following:

a. ELectricity management

- Electricity generated by each power generator
- Purchased electricity
- Electricity consumption by plant and by process

b. Fuel management

- Purchased gas amount (for each of the rayon and velvet factories)
- Purchased fuel oil for power generation
- Purchased fuel oil for boiler (for each of the rayon and velvet factories)
- Purchased kerosene for heat-medium boiler

c. Water management

- Soft water quantity manufactured

By tabulating these data monthly, the energy intensity per production unit can be obtained. Graphing the data and the monthly follow-up management will be an effective energy management technique.

(4) Education and training of employees

Although the necessary skill training is of course being implemented through OJT (on-the-job training), systematic company-wide training is not yet started.

Basic concepts on training of employees in Japan are as follows:

a. Management attempts to renovate and activate the employees' awareness to allow the employees themselves "to recognize how bad the situation is". The intent is productivity improvement, product quality stabilization and improvement, safety, and working circumstance improvement, including, of course, energy conservation.

b. As specific activities:

- Promotion of small-group activities by each workshop and presentation of the performance inside/outside the company

- Establishment of a work improvement proposal system, and encouragement and enlightenment of employees for participation in the proposals

These are positively promoted on a company-wide basis. For a remarkable performance in these activities, an individual or small-group circle is awarded and a bonus is supplied.

As a characteristic of the textile factory, stains on the intermediate product and final product result in the production loss and energy loss; therefore the drastic "Keep it tidy, neat and clean!" campaign is being carried out.

As a traditional spirit in the Japanese textile industry, the motto "Do not drop a cotton fly! Pick it up." has been inherited.

QC circle activities (i.e. small-group activities) positioned in TQC (Total Quality Control) in Japanese companies are introduced into many companies, bringing satisfactory results as a powerful tool for revitalizing the company and enhancing cost competitiveness.

Also, through the small-group activities, standardization of operation and plant maintenance can be reviewed, thus allowing technology transfer from experts to beginners. In this way, vigorous activities are continued on a long-term basis every year.

(5) Equipment maintenance

Technical Service Department has established the maintenance system by purpose and by function. The production equipment and major utility facilities such as the diesel power generators, and boilers are checked periodically, overhauled, and replaced on the part basis according to the preventive maintenance method. Auxiliary equipment such as pumps and steam traps are maintained with breakdown maintenance.

The equipment maintenance status totally has no problem but we found inadequate points in steam leak, steam trap maintenance, and heat insulation for piping. Power consumption by blowers and pumps sometimes accounts for 20 to 30 % of total power consumption, and large reduction in power consumption may be possible by promotion of the streamlined equipment maintenance system.

After the present process requirements are grasped, matching of blowers and pumps to the optimum operation point and allowance of component specifications should be studied and thereafter correction actions should be taken upon overhauling or renovation.

Since these do not require particular energy conservation cost, the actions can be taken with the normal facility maintenance cost.

Establishment of the streamlined equipment maintenance system will improve total reliability of the facilities along with the remarkable energy conservation cost advantage.

A master file for major facilities and individual components should be prepared thereby to make the maintenance record each time. Thus, the master file will become a powerful tool for supporting equipment maintenance system.

At least, the following drawings are required for equipment maintenance:

- Electric power facility
    - One line diagram
    - Plant wiring route diagram
    - Power load layout
- Steam and service water
    - Piping schematic diagram
    - Piping route diagram
    - Steam trap layout diagram and drain recovery piping schematic diagram

Equipment maintenance described above should be implemented as a part of jobs in Technical Service Department.

5.2.4 Problems and Measures in Utilization of Energy

(1) Comparison with an excellent plant

a. There is not sufficient data on energy consumption for each type of production. Therefore, the energy intensity of fiscal year 1995 was estimated by supplementing it with spot data. Table 5.2.8 shows comparison between the energy intensity of this company and that of an energy conservation type plant in Japan.

Table 5.2.8 Comparison of Energy Intensity

		Spinning	Weaving (R + V)	Dyeing and Finishing	Carpet Processing	
		MWh/t	MWh/10^3 m^2	MWh/10^3 m^2	MWh/10^3 m^2	
Electricity intensity	Kashan	5.83	1.58	0.59	4.75	Electric power only for production and boiler. Including the fixed amount for water and waste water facilities.
	Japan	3.06	0.26	0.13	7.61	
		Gcal/t	Gcal/10^3 m^2	Gcal/10^3 m^2	Gcal/t	
Fuel intensity	Kashan	–	–	9.39	14.66	
	Japan	–	–	0.94	9.44	

Note 1): The energy intensities for I. R. Iran are based on Table 5.2.6. Fuel consumption for the carpet processing covers also that for velvet processing. (weight ratio).

2): The intensities for Japan were based on the data quoted from large-scale textile companies. The intensities for carpet processing were based on the data quoted from the companies exclusively engaged in carpet processing. The intensity per unit area was calculated using the specific weight of 2,250 g/m^2.

b. Evaluation of energy intensity

The energy intensity for spinning, weaving, dyeing, and finishing processes at this company (excluding carpets) is 2 to 10 times that of the plant in Japan.

The energy consumption measurement for each process is necessary as a prerequisite for comparison of energy intensity. The lack of this data significantly lowers the accuracy and reliability of the measured energy intensity. The possible factors for the fluctuation in the energy intensity are as follows.

1) Spinning process

- Raw material in the process and blending ratio
- Spinning yarn count number and spinning process conditions
- Spinning equipment productivity
- Production yield
- Operation conditions and operation rate
- Load factor of air conditioner, dust collector, cotton collector, etc.
- Management of daily operation

2) Weaving process

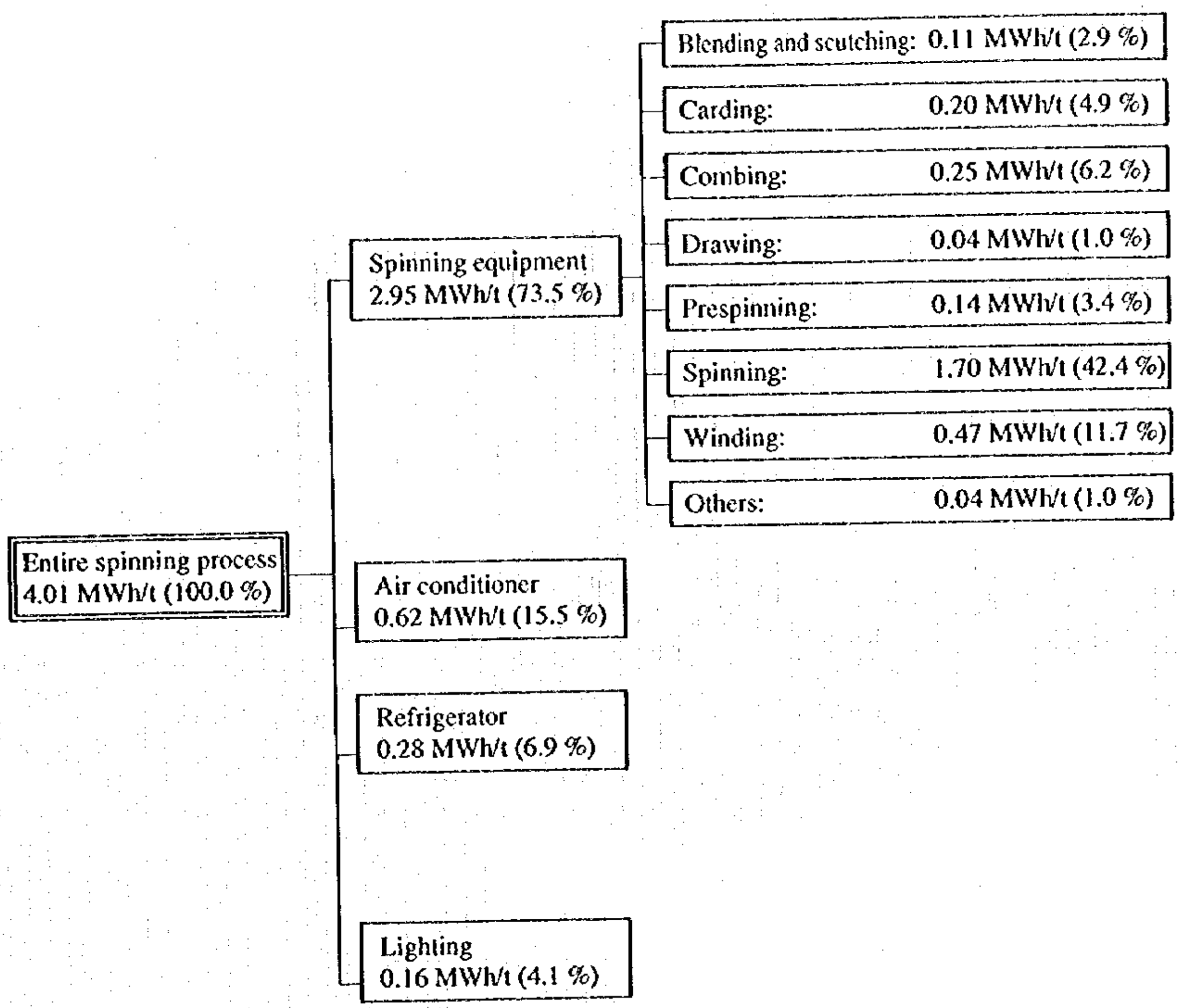
- Material and weight per square meter of work in process
- Production performance of weaving machine
- Weaving degree
- Performance of auxilary equipment such as an air conditioner and compressor
- Operating conditions and rate of operation
- Rate of defective fabric occurrence

3) Dyeing process

- Material and weight per square meter of work in process
- Finishing conditions
- Dyeing density
- Dyeing system (batch, continuous) and performance
- Re-processing rate
- Difference in terms of management
- Difference in water supply and waste water treatment system and scale of the equipment
- Availability of a waste heat recovery system

Figure 5.2.6 gives an example of individual electricity intensities in a typical spinning process in Japan.

Figure 5.2.6 Electricity Intensity of a Spinning Mill (an example)

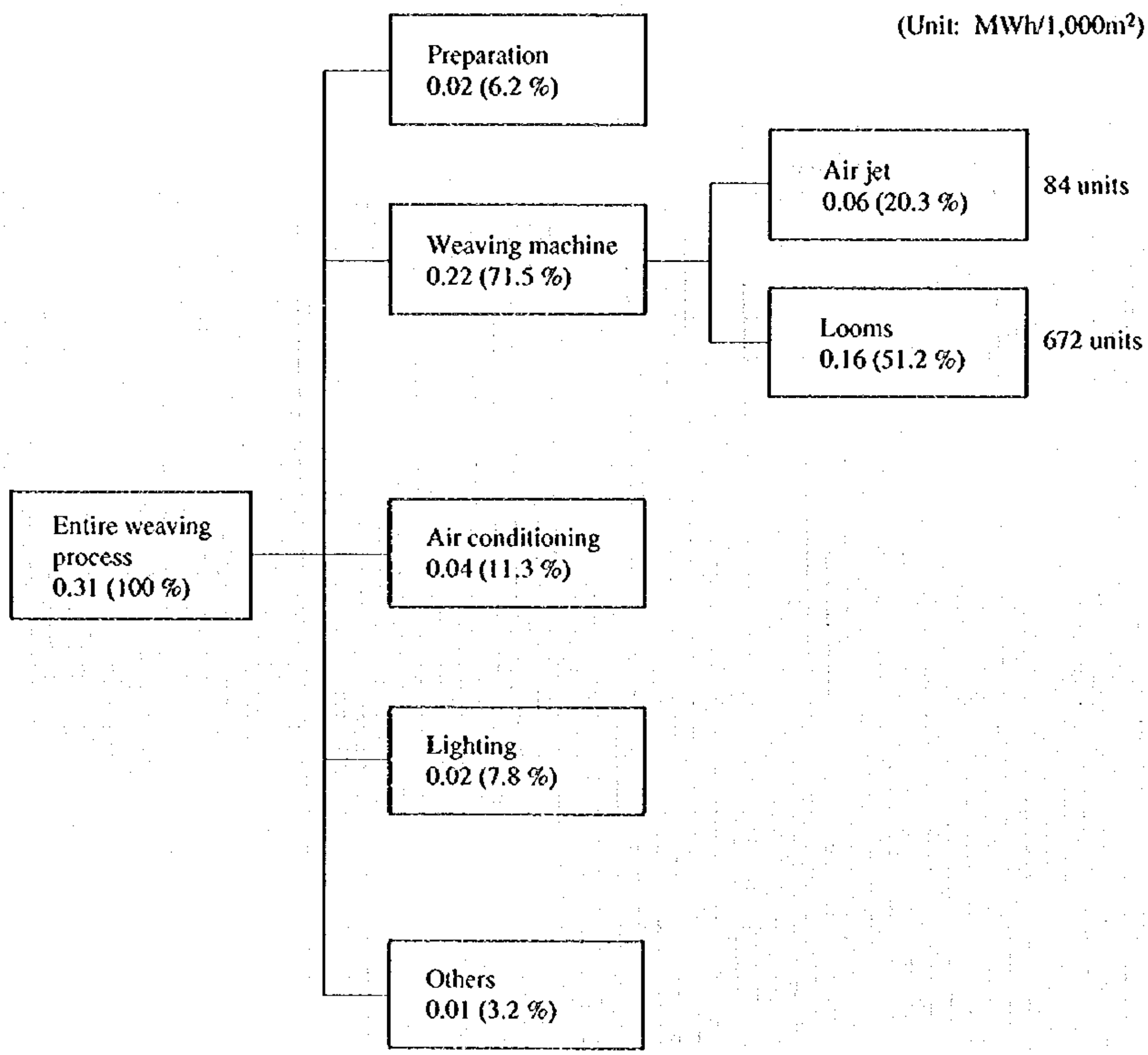


Source: Data from Japan Spinners' Association

The energy intensity is estimated based on the model data obtained by calculating the electricity consumption of the 40 s, comber yarn, 50,000 spindle plant.

Figure 5.2.7 indicates the actual result value of electricity intensity for each unit of a typical weaving plant in Japan.

Figure 5.2.7 Electricity Intensity for a Weaving Factory (an example)



Data on the present consumption of electricity, fuel oil, natural gas, and steam is a precondition for the evaluation of the energy intensity in every factor.

As mentioned above, there are a great many factors which influence the energy intensity, thus making it difficult to compare the plant with an excellent plant under the same conditions. It is not so difficult, however, to improve energy intensity by at least 30 % through reinforcement of the daily management.

Items which contribute to the improvement of the energy intensity in each process are outlined below.

(2) Increasing the productivity of the spinning process

a. Current problems

1) Large amounts of pneuma waste produced on the spinning machine as a result of yarn breaking

The amount of pneumatic waste produced each month in fiscal 1995 was approximately 8.0 %, as shown in Table 5.2.9.

Table 5.2.9 Pneuma Waste Generated on Spinning Machine

Year Month	Pure Product (kg)	Waste (kg)	Rate of Waste (%)
1995. 4	75,954	7,719	9.2
5	116,911	10,828	8.5
6	108,082	10,041	8.5
7	125,842	12,682	9.1
8	70,155	6,582	8.6
9	107,518	4,629	4.1
10	107,818	6,472	5.7
11	123,506	10,319	7.7
12	106,869	11,012	9.3
1996. 1	110,435	10,176	8.4
2	111,932	10,196	8.3
3	84,768	7,897	8.5
Total	1,249,790	108,553	8.0

The pneuma waste amount in Japan is as follows:

- Cotton 100 % (Card yarn) 1.5 to 2.0 %
- Cotton 100 % (Comber yarn) 1.0 to 1.50 %
- Polyester/Cotton 1.0 % or less

The above difference is caused by a large amount of yarn breaking on the spinning machine, as outlined below.

2) A large amount of yarn breaking

The yarn breaking at this plant is as follows:

- Polyester/Rayon (yarn count 30) 40 pieces/1,000 sp/h
- Cotton (yarn count 28) 110 pieces/1,000 sp/h
- Cotton (yarn count 20) 160 pieces/1,000 sp/h
- Polyester/Cotton (yarn count 20) 140 pieces/1,000 sp/h

In comparison with the above plant, the yarn breaking at the plant in Japan is as follows:

- Under average management conditions 25 pieces/1,000 sp/h
- Under well-managed conditions 10 pieces to 15 pieces/1,000 sp/h

This lower rate of yarn breaking is directly linked to the reduction of pneumatic waste.

b. Measures

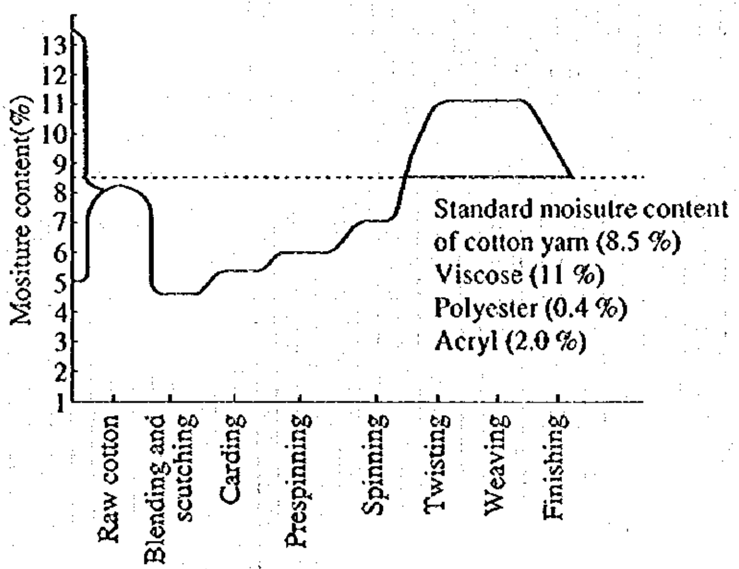
A drastic measure is required for checking the maintenance of factors such as the spinning conditions and spinning machine. This report, however, studies the measures which can be adopted at the present time.

1) Improvement measures with the air-conditioning system

① Reviewing the room temperature and humidity standards

The moisture content of cotton and yarn of the work in each process is adjusted by the air blowing conditions and the amount of the blown air of the air conditioner. The moisture content of yarn is closely related to yarn breaking and the amount of cotton fly produced. The control index of moisture content is decided for each process unit. Figure 5.2.8 indicates the standard moisture content of in-process product in each cotton spinning process.

Figure 5.2.8 Standard Moisture Content of In-process Product in Each Spinning Process



Data by Mr. Haven

Table 5.2.10 indicates the measurement values of temperature and humidity and the control standard values of each process at this plant by spot measurement. Table 5.2.11 indicates the general standard temperature and humidity in each rayon mix spinning and cotton mix spinning process.

According to these data, the relative humidity generally tends to show a low trend. In particular, the humidity of pretreatment and post process of the spinning process is extremely low.

Table 5.2.10 Measured Values of Temperature and Humidity in the Spinning Process

Unit	Data Item		DB (°C)	RH (%)
Scutching	STD		–	–
	Spot		29.5	41.2
Carding	STD		25.1 ~ 27.8	50 ~ 55
	Spot	①	30.8	50.2
		②	28.9	51.2
Flier	STD		25.5 ~ 27.8	50 ~ 55
	Spot	①	30.9	52.2
		②	31.2	49.8
		③	30.5	52
	Sensor		28.9	57
Ring	STD		30.0 ~ 33.3	48 ~ 52
	Spot	①	32.0	45.2
		②	32.0	50.9
		③	31.5	54.4
Twister	STD		25.5 ~ 27.8	60 ~ 65
	Spot	①	32.8	43.8
		②	33.7	41.1
Ambient			35.6	18.6

Note: STD : Standard value
Spot : Spot measurement value
Sensor: Values indicated by temperature and humidity regulator and sensor

Table 5.2.11 Standard Temperature and Humidity for Each Process

Process / Product Type		Blending and Scutching	Carding	Drawing	Pre-Spinning	Spinning	Winding
Rayon mix spinning	Temperature (°C)	20 ~ 30	20 ~ 30	20 ~ 30	20 ~ 30	20 ~ 30	20 ~ 30
	Humidity (%)	70 ~ 75	60 ~ 65	60 ~ 65	60 ~ 65	55 ~ 60	65 ~ 70
Cotton mix spinning	Temperature (°C)	20 ~ 30	20 ~ 30	20 ~ 30	20 ~ 30	20 ~ 30	20 ~ 30
	Humidity (%)	55 ~ 60	55 ~ 60	55 ~ 60	55 ~ 60	55	65 ~ 70

② Correcting the relative humidity standard value

The moisture content of yarn under the current operating conditions is measured and the attempt is made to raise the humidity standard values for each process according to Figure 5.2.8 and Table 5.2.11.

③ Correcting the installation position of the temperature and humidity automatic control sensor

The sensor in use at present is installed rather high, at approximately 2 m from the floor. Therefore, the sensor can be directly affected by air flow from the ceiling discharge opening.

A reconsideration of the sensor position and its relocation to a place suitable to process is recommended.

④ Improving the spray efficiency

Since there are air conditioner spray nozzles that are not mounted in the same direction, a uniform spray effect cannot be expected in the current state.

Also, the nozzle caps are repaired by welding and drilled to make holes every time they wear out, making it difficult to obtain a uniform spray pattern.

The standard spray specifications of the air conditioner are as follows:

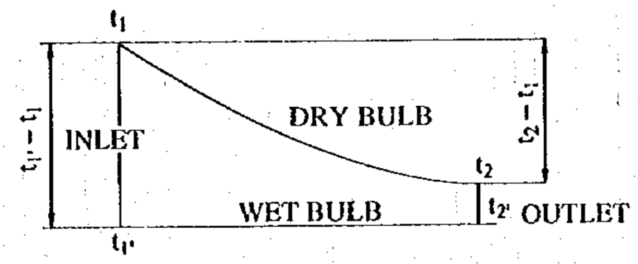
- One spray nozzle is installed per 25 cm^2 of cross-sectional area.
- The diameter of nozzle hole is 3 mm.
- The spraying pressure is 1.5 to 2 kg/cm^2 (G).
- The spraying angle is 80 °.

Polycarbonate resin is favorable as spray nozzle cap material because of its wear resistance.

The spraying efficiency is evaluated by the saturation of the air at the air conditioner outlet. Figure 5.2.9 indicates the difference in blown air saturation efficiency according to the spray bank arrangement of an air conditioner. The dry-bulb temperature (DB) and wet-bulb temperature (WB) are measured periodically, and the saturation efficiency is calculated using the formula of ηs given in the figure.

The saturation efficiency will be 90 to 98 % by a 2 bank back current.

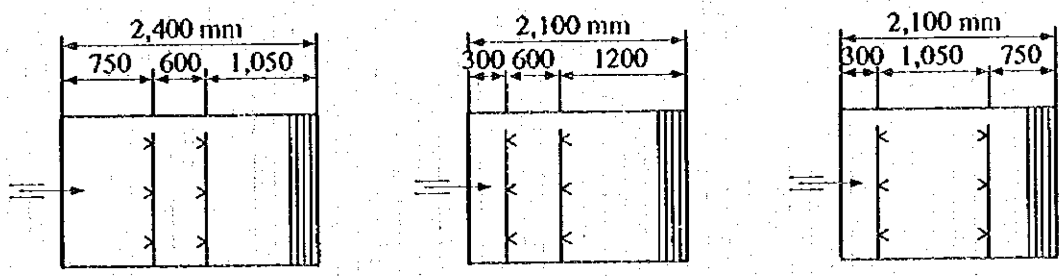
Figure 5.2.9 Saturation Efficiency by Spray Direction



$$\eta_s = \frac{t_2 - t_1}{t_{1'} - t_1} = \frac{t_2 - t_1}{t_{2'} - t_1}$$

η_s = Saturation efficiency

Adiabatic saturation change



2 bank back current
η_s = 90 ~ 98 %

2 bank parallel current
η_s = 80 ~ 90 %

2 bank back & parallel current
η_s = 85 ~ 95 %

⑤ Spinning operation control

The stable quality and productivity are maintained by operation control which can provide matching control for operation, temperature and humidity, and equipment. Table 5.2.12 gives the operation control items used in Japan.

Table 5.2.12 Operation Control Items in the Spinning Process

Operation control	1. Running control	Prevention of the occurrence of a defective product due to a trouble in spinning operation.	1. Checking the spinning condition To detect an abnormal spinning at an earlier stage by an operator's patrolling 2. Checking the working of operator To check the standard working of the operator by the person in charge	1. Removing a defective product. 2. Repair and adjustment of a malfunctioning machine. Re-training of employees with regard to running operation.
	2. Temperature and humidity control	To control the temperature and humidity so that the optimum spinning environment can be obtained in each spinning process.	1. Controlling temperature and humidity To measure and record the temperature and humidity for each process and control the temperature and humidity by means of air-conditioning equipment.	To adjust the equipment if it is out of the proper range.
			2. To examine the moisture content in all the processes.	To humidify using an auxiliary device when humidity is still insufficient even by temperature/humidity control.
	3. Mechanical control	To control the maintenance condition of the machine in order to maintain and improve the product quality and spinning-out condition.	To surely perform the periodical maintenance of the machine and strictly observe the replacement cycle for parts and devices for operation by using the maintenance book or check sheet.	1. To carry out a preparatory plan to observe the maintenance or replacement cycle. 2. To replace or adjust a defective part, etc. at the time of periodical maintenance.

The control cycle of important operation control items is as follows:

- Moisture content control by each process: Once/month
- Pneumatic waste volume control: Every day (for each material and yarn count)
- Spinning machine yarn breaking control: Once/month (for each yarn count)
- Temperature and humidity record for each process: Every day (by a person in charge of operation)

Stable operation is enabled by recording these control data in the control diagram and performing follow-up control.

The operating conditions can be stabilized further through detection and correction of uneven temperature and humidity by measuring the distribution of temperature and humidity, and studying the air flow in the spinning yard once a year.

c. Estimated effects by adoption of the measures

1) Reduction of pneuma waste rate

The pneuma waste rate in September and October 1995 was approximately 50 % of the yearly maximum value. It is necessary to confirm whether this is accidental or recurrent by analyzing past data.

The target value (3 %) of yearly average pneuma waste rate is expected to be attained. The improvement effects of this measure on electricity intensity is calculated as follows.

Reduction of pneuma waste rate: 8 % → 3 %
Amount of input : 1,249,790 + 108,553 = 1,358,343 kg/y
Reduced pnuema waste amount : 1,358,343 × (8−3) / 100 = 67,917 kg/y

Since the yield will improve from 92 % to 97 %, the electricity intensity, which will be as follows, is improved by 0.3 MWh/t.
5.83 × 0.92 / 0.97 = 5.53 MWh/t

Besides the above, a 68 t/y of productivity improvement and reduction of cotton flies loss in overall processes can be expected.

(3) Electric power conservation by stopping the return fan of air conditioner

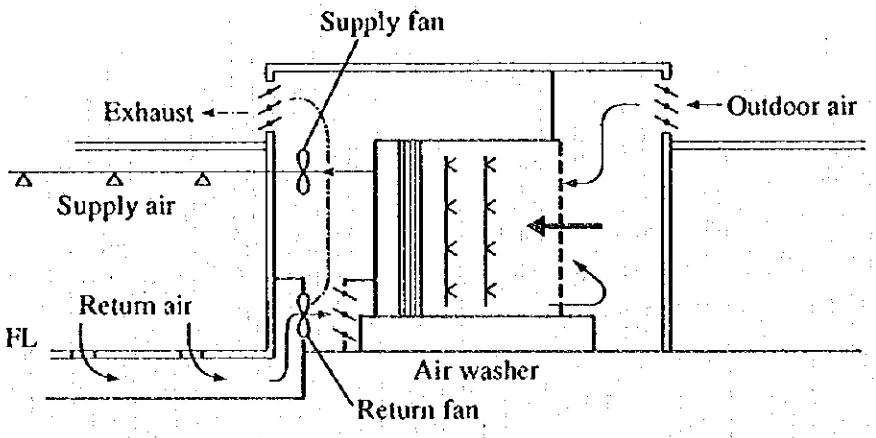
a. Present situation

Table 5.2.13 shows the air conditioner setting conditions and electric power load for each process at present. Figure 5.2.10 shows the structure of the air conditioner.

Table 5.2.13 Air Conditioner Setting Condition

Spinning			Other		
Process	No. of Units	kW	Process	No. of Units	kW
Twister	1	92	Weaving	7	188
Ring	1	97	Finishing	3	27
Card	1	105	Dyeing	1	9
			Velvet and preparation	1	19
Total	3	294	Total	12	243

Figure 5.2.10 Configuration of Air Conditioner



In summer, the intake of outdoor air will be 100 %. On the other hand, 100 % of the return air is discharged outdoors. The heat load is high due to power equipment in the room for the spinning and weaving processes, and the intake volume of outdoor air is high for quite a long period.

b. Problems

Although the return fan is used for discharging the return air outdoors, it need not be used in some portions. The electric power consumption of the return fan is estimated to be approximately 20 % of the entire air conditioning system.

c. Measures

It is possible to stop the return fans at a point where this will do not affect the production quality and when there are no scattered waste yarn and flies. The twister air conditioner and about half of the other air conditioners in the spinning process may be stopped. After confirming the outcome, it is advisable to increase the number of return fans to be stopped one by one.

When the intake volume of outdoor air is 50 % or more, it is preferable to stop the return fan and have only the required return air volume taken to the air conditioner using the suction static pressure of a supply fan.

When the return fan is stopped, it will be necessary to discharge the room air to the outside. The existing entrance/exit can be used as the opening for this forced air exhaust. Ohterwise, a forced exhaust by ventilation fan system on the wall is commonly used.

Although there is basically no problem in the measures for automatic control of the existing air conditioning system, a test should be done first. For, a dynamic characteristic check of the automatic controller. Any problem that might occur can be corrected by setting the static pressure difference at the damper of outdoor air intake or by some other method.

d. Estimated effects

1) Effects of stopping the return fans

- Electric power of return fans which can be stopped

Rayon:	92 kW × 0.2	= 18 kW
Others:	243 kW × 0.5 × 0.2	= 24 kW
Total :		42 kW

- Number of days for which the return fans can be stopped: 100 d/y

2) Along with the reduction of the air feed volume from summer to mid-season, consideration should be given to whether it will be possible to forcibly stop one of the two return fans.

(4) Reducing the heating load during winter

There is a possibility of reducing 25 to 30 % of the heating steam load by preventing the leakage of air through the gaps between vanes and the gaps between the vanes and casing of the open air intake and discharge damper. The problems of the equipment can be determined by oiling and inspection of the open/close of dampers periodically.

(5) Waste heat recovery

a. Current problems

1) Flash steam is produced from the condensate recovery junction tanks installed in all locations. Condensates of two sizing dryers of the weaving machine in rayon factory are wasted.

2) The dye and washing hot waste water produced during the dyeing process are directly discharged to the drain.

3) The 400 °C of exhaust gas from a diesel generator is discharged to the atmosphere and the hot waste water of cylinder jacket cooling is returned naturally to the pool and cooled.

b. Improvement measures

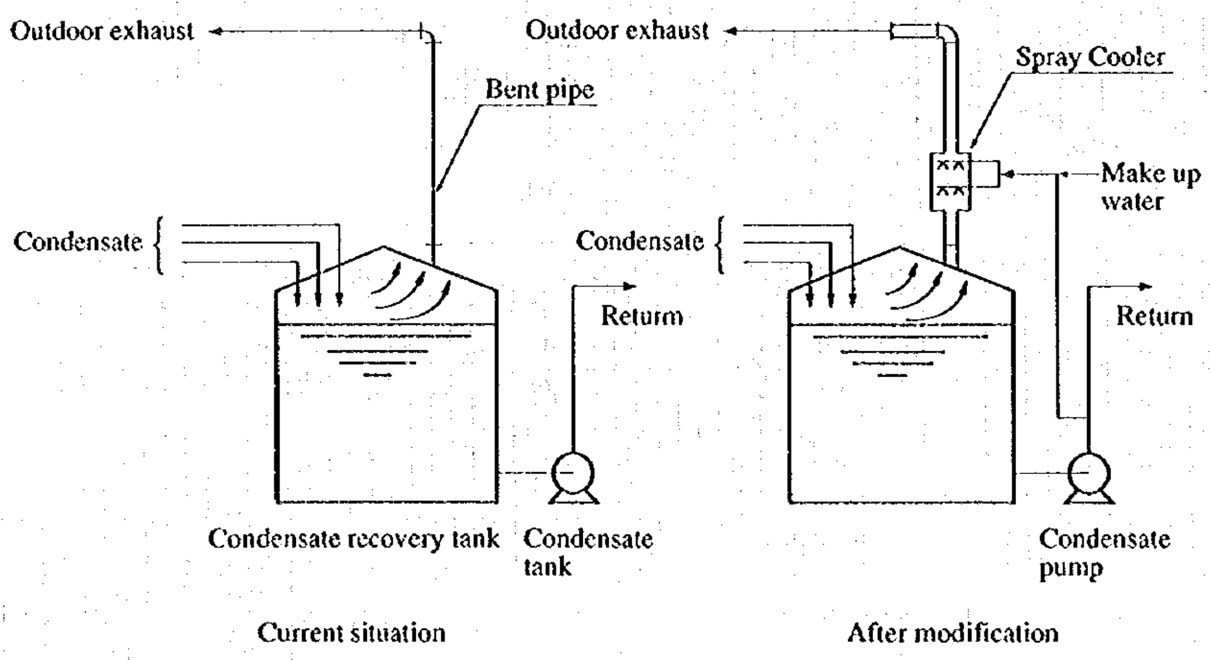
1) Effective use of the recovered condensate heat

① The flash steam of the junction tank in the current state must be caused by sheet leakage of the steam trap and leakage of the steam trap bypass valve of the dyeing process machine.

It is advisable to replace the defective steam trap by daily maintenance in the early stage, perform maintenance of the bypass valve, and, if possible, to remove the bypass valve. In this case, proper treatment capacity of the steam trap is necessary.

② There are cases of steam flashing caused by damage or falling-off of the condensate injection pipe in the condensate recovery tank or by defects in the system design. Figure 5.2.11 shows the standard condensate flash suppressing method.

Figure 5.2.11 Recovery of Flash Steam



③ The amount of condensate generated by the sizing dryers of weaving machine in the rayon factory is approximately 0.4 t/h (0.2 t/h × 2 units = 0.4 t/h) per unit. It is advisable to connect it to the recovery main pipe at the earliest opportunity.

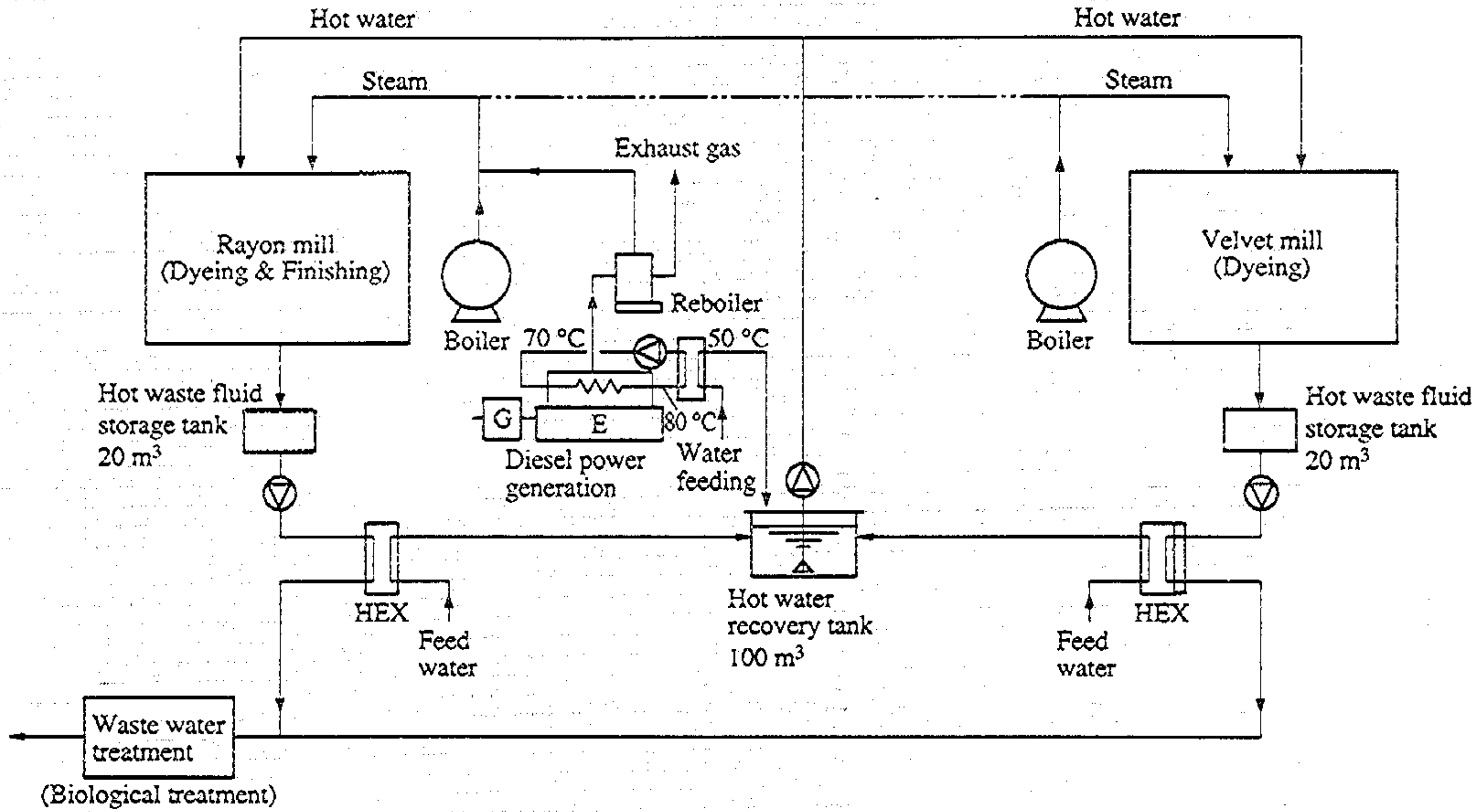
2) Waste heat recovery from hot waste water in the dyeing process

Hot waste water is produced at the desizing machine, scouring machine, and dyeing machine during the dyeing finishing process at the rayon factory. A large amount of hot exhaust heat is produced by the desizing, scouring, and dyeing operations from the yarn- and roll-dyeing machines in the velvet factory.

The waste heat discharged during a standard operation amounts to 25 to 30 % of the entire amount of steam used. It is possible to recover 50 % of the waste heat by a heat exchanger.

The greatest concern in waste heat recovery is to procure a system that provides a 100 % effective use of the recovery heat. Figure 5.2.12 shows the conceptual diagram of a system for recovering and using the waste heat.

Figure 5.2.12 Concept of Waste Heat Recovery Flow Sheet

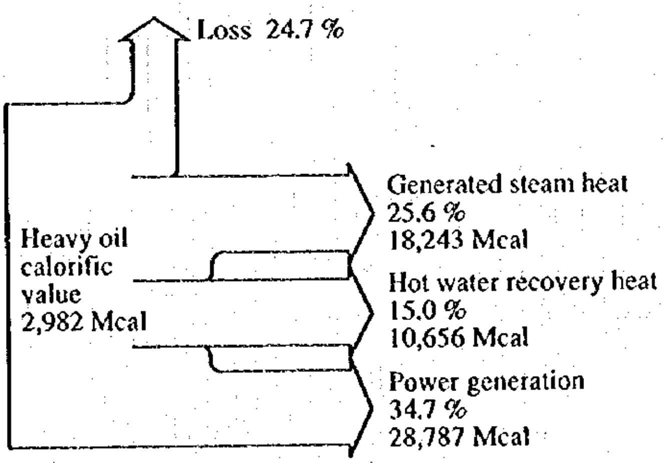


3) Recovery and utilization of diesel engine exhaust heat

Of late, there is a global trend of introducing cogeneration into diesel generator, and the overall efficiency including the use of exhaust heat in this arrangement exceeds 75 %.

Figure 5.2.13 gives an example of the heat balance when the exhaust heat is recovered from the diesel engine.

Figure 5.2.13 Heat Balance of Cogeneration



The most popular method of using the exhaust heat of a diesel engine is implemented in the following manner. At first, steam is taken out from the exhaust gas by the exhaust heat boiler. Then, the exhaust heat of cooling water of the cylinder jacket is taken out as hot water of 50 °C by a heat exchanger.

c. Estimated effects

Table 5.2.14 summarizes the estimated effects to be achieved by efficient use of the heat loss.

Table 5.2.14 Summary of Estimated Effects by Waste Heat Recovery

No.	Item	Calculation Basis	Recovery Heat	Effect	Consumer of Recovery Heat
①	Enhancement of condensate recovery rate	• Fuel 69,797 Gcal/y • Condensate generation rate 30 % • Flashing rate 20 % • Boiler efficiency 80 %	69,797 × 0.3 × 0.2 × 0.8 = 3,350 Gcal	Natural gas 352.6 × 10^3 m^3/y or Fuel oil 360.2 kL/y	Boiler feedwater
②	Recovery of waste heat of washing water in the dyeing process	• Fuel heat value 69,797 Gcal/y • Retained heat of waste fluid: of the total calorific value 30 % • Recovery efficiency of heat exchanger 50 %	69,797 × 0.3 × 0.5 = 10,470 Gcal	Natural gas 1,102 × 10^3 m^3/y or Fuel oil 1,126 kL/y	Process hot water supply
③	Recovery and utilization of diesel engine waste heat	• Power generation 3,162 MWh/y • Fuel for power generation 1,860 kL	1,860 × 0.25 × 8,900 × 10^6 = 4,139 Gcal	Natural gas 435 × 10^3 m^3/y or Fuel oil 445.0 kL/y	Steam generation
		• Waste gas recovery heat 25 % • Jacket recovery heat 15 %	1,860 × 0.15 × 8,900 × 10^6 = 2,483 Gcal	Natural gas 261.4 × 10^3 m^3/y or Fuel oil 267.0 kL/y	Process hot water supply
			20,442 Gcal/y	Natural gas 2.15 × 10^6 m^3/y or Fuel oil 2,198.2 kL/y	

1) Effective use of the recovered condensate heat

In the calculation given in Table 5.2.14, only the amount produced by re-evaporation of condensate is counted from flash steam from tank. Actually, however, there is a strong possibility that the steam will be discharged as it is due to trap defects. If this happens, the heat loss is even greater.

A tie-up networking between the rayon and velvet factories will be necessary to establish the system for both recovery and use.

2) Waste heat recovery from hot waste water in the dyeing process

Reducing the waste water temperature by waste heat recovery is also convenient to perform biochemical treatment for the dyeing waste water.

3) Recovery and utilization of diesel engine exhaust heat

If the hot water is to be recovered, the pipes must be installed up to the site of use. Therefore, the recovery and use of the diesel engine exhaust heat should be implemented after studying the cost efficiency.

(6) Improving the boiler combustion

Table 5.2.15 indicates the measurement results of the exhaust gas temperature and oxygen content in exhaust gas of the rayon plant's No. 1 boiler (20 t/h) and the velvet plant's No. 5 boiler (10 t/h).

Table 5.2.15 Exhaust Gas Temperature and Oxygen Content in Exhaust Gas of No. 1 Boiler at Rayon Plant and No. 5 Boiler at Velvet Plant

	Rayon Factory	Velvet Factory
Exhaust gas temperature	182 °C	200 °C
Oxygen content in exhaust gas	8.8 %	6.8 %

When the measured oxygen content in the exhaust gas of rayon plant (8.8 %) and velvet factory (6.8 %) is expressed by air ratio, it is equivalent to 1.65 and 1.43 respectively. The air ratio for boilers of this type is specified between 1.2 and 1.3 according to the standards in Japan, and this value is equivalent to 4.5 % in terms of oxygen content in exhaust gas. If the air ratio of this plant is adjusted to the standards of Japan, fuel can be saved by 2.3 % and 1.2 % respectively. If this saving ratio applied to all boilers during operation at both plants, the calculation result will be a total of 1,340 Gcal/y. In this formula, the annual natural gas consumption of the plants is allotted according to the capacity of boilers during the operation of both rayon and velvet plants. In other words, 72,017 Gcal/y × 0.6 × 0.023 = 994 Gcal/y is obtained for the rayon plant and 72,017 Gcal/y × 0.4 × 0.012 = 346 Gcal/y for the velvet plant; the total is 1,340 Gcal/y.

(7) Reinforcing the heat insulation

The steam pipes are provided with heat insulation in the plant. The accessory valves, however, are not heat-insulated. The amount of heat emission will be significantly reduced with the increase in insulation thickness if insulation is provided on these non-insulated portions. Figure 5.2.14 shows example of this calculation.

Figure 5.2.14 Insulation Thickness and Heat Emission (an example)

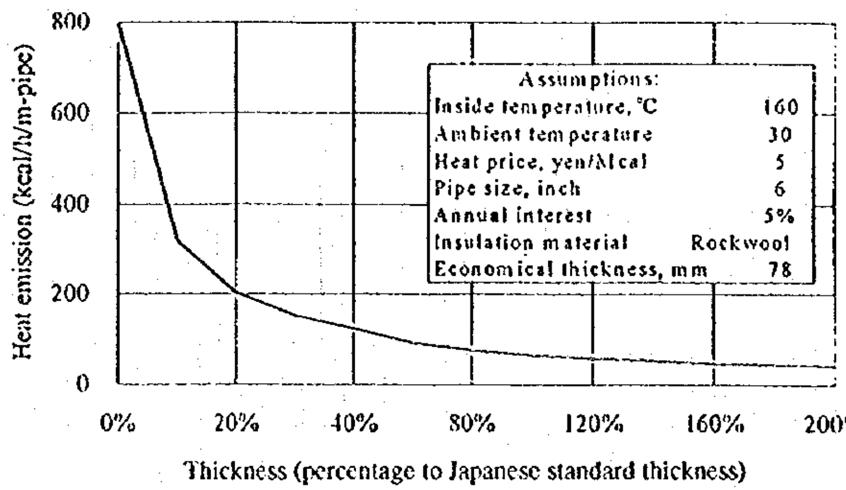


Table 5.2.16 and Table 5.2.17 show the results of the heat emission calculation by assuming the number of steam valves installed in this plant. These tables assume the heat emission from non-insulated portions around a valve to be 50 %.

Table 5.2.16 Assumed Number of Bare Valves

No.	Size (Pipe diameter) Nominal	Actual	Equivalent Length, FG10	Number of Valves Boiler House	Lines	Length for Calculation
1	300	318.5	1.91	4		7.62
2	250	267.4	1.76	10		17.63
3	200	216.3	1.68		10	16.80
4	150	165.2	1.50	30	20	75.00
5	100	114.3	1.27		50	63.50
6	80	89.1	1.25		100	125.00

Table 5.2.17 Calculated Heat Emission from Bare Valve Surface

No.	Ambient Temperature	Surface Temperature	Emissivity	Pipe diameter	Area Length	Heat Transfer Coefficient Convection	Radiation	Unit Heat	Total Heat
1	30	128	0.9	0.3185	7.6	4.880	7.820	1,245	9,493
2	30	128	0.9	0.2674	17.6	4.880	7.820	1,046	18,429
3	30	128	0.9	0.2163	16.8	4.880	7.820	846	14,209
4	30	128	0.9	0.1652	75.0	4.880	7.820	646	48,447
5	30	128	0.9	0.1143	63.5	4.880	7.820	447	28,380
6	30	128	0.9	0.0891	125.0	4.880	7.820	348	43,550
	Subtotal								162,508
		Bare pipes around these valves are assumed to be 50 %.							81,254
	Grand total								243,762
								kcal/h/m	kcal/h

Since the valve has a complicated shape, the straight pipe length equivalent to the valve surface area is used. The fuel reduction amount of boiler resulting from providing insulation will be 2,162 Gcal/year (= 243.762 kcal/h × 0.9 × 8,760 × 0.9 × 0.8) based on the heat emission calculation given earlier (under conditions where: heat emission reduction rate is 90 %, annual operating rate is 90 %, and boiler efficiency is 80 %). Moreover, this effect is equivalent to 0.4 t/h in terms of steam amount.

(8) Air compressor

Table 5.2.18 upper section shows the result of electric power measurement of the air compressor at the velvet plant. This measurement was conducted from August 18 (16:00) to August 19 (10:40). The air compressor operation condition during this period is as follows: Capacity control by simultaneous unload of three screw type compressors from August 18, 16:00 to August 19, 10:40; capacity control by simultaneous unload by the above three compressors and an additional reciprocating compressor after August 19, 10:40. The capacity control is performed by pressure, and 5 kg/cm² (G) is used for on-load and 6 kg/cm² (G) for unload. According to the measurement results, the load per one screw type compressor is 41 kW during on-load and 17 kW during unload.

The method of controlling the number of compressors is suggested as an improvement measure. This method divides the compressors into base operation machines and load adjustment machines and increases the number of base operation machines as the load increases. The load fluctuation is adjusted by the load adjustment machines. Table 5.2.18 lower section indicates the results of this trial calculation.

Table 5.2.18 Power Measurement Result of Air Compressor at Velvet Plant and Trial Calculation for Improvement Plan

Measuring date: 18 August 1996, 17:00 – 19 August 1996, 12:00

Before Improvement

Time	Maximum Power (kW)	Mean Power (kW)	Minimum Power (kW)	Start Frequency	Operating Time (min)
17:00–18:00	120.3	88.7	50.6	23	32.6
18:00–19:00	121.9	80.9	51	25	25.3
19:00–20:00	121.5	73.6	51.5	27	18.9
20:00–21:00	121.9	69.6	50.5	21	16.1
21:00–22:00	122	70.3	51.2	21	16.2
22:00–23:00	123.2	69.3	51.2	23	15.1
23:00–24:00	124.1	69.9	51.2	21	15.4
00:00–01:00	123.3	69.5	50.8	22	15.5
01:00–02:00	122.8	72.5	51.2	27	17.9
02:00–03:00	123.2	68.8	51.2	24	14.7
03:00–04:00	123.2	69.2	50.4	24	15.5
04:00–05:00	122.8	71.1	50.8	23	16.9
05:00–06:00	122.9	67.2	50.8	19	13.7
06:00–07:00	123.1	66.8	50.6	19	13.4
07:00–08:00	125.6	72.3	53.2	24	15.8
08:00–09:00	125.5	88.2	53.3	23	27
09:00–10:00	123.8	99.9	52.6	29	39.9
10:00–10:40	123.2	92.6	52.4	16	20.8
10:40–11:00	143.3	108	58.9	6	11.6
11:00–12:00	143.9	102.2	58.9	19	30.6
Average*	123.0		51.3		

After Improvement

Time	No. of Base Units	On-off Units	Operating Time (min)	Mean Power (kW)	Saving Power (kWh)
17:00–18:00	1	2	37.7	88.7	0.0
18:00–19:00	1	1	15.9	63.9	17.0
19:00–20:00	0	2	56.8	56.4	17.2
20:00–21:00	0	2	48.2	52.8	16.8
21:00–22:00	0	2	48.6	53.2	17.1
22:00–23:00	0	2	45	52.1	17.2
23:00–24:00	0	2	46.2	52.8	17.1
00:00–01:00	0	2	46.4	52.6	16.9
01:00–02:00	0	2	53.6	55.5	17.0
02:00–03:00	0	2	44	51.7	17.1
03:00–04:00	0	2	46.5	52.4	16.8
04:00–05:00	0	2	50.8	54.2	16.9
05:00–06:00	0	2	40.9	50.2	17.0
06:00–07:00	0	2	40.2	49.9	16.9
07:00–08:00	0	2	47.5	54.6	17.7
08:00–09:00	1	1	27	70.4	17.8
09:00–10:00	1	2	59.6	99.9	0.0
10:00–10:40	1	2	22.5	89.3	2.2
10:40–11:00	2	1	1.87	99.7	2.8
11:00–12:00	1	2	50	95.0	7.2
Total					268.5

Note: Average from 18 August 1996, 17:00 to 19 August 1996, 10:00

This improvement can reduce the electric power consumption by approximately 270 kWh per day. This is a reduction of 64,800 kWh assuming the operations days per year are 240 days. The improvement expense is only for the order control device, and almost no cost is required. The future subject of study is the compressor on/off control. If there are not too many start and stop operations, the electric power consumption during unload operation can be reduced by simply performing a complete stop of compressor itself.

Before carrying out this measure, it is necessary to supply compressed air at the appropriate air pressure and flow rate by performing the following items:

- Review of air blow cleaning
- Air leak check
- Appropriate pressure setting

The air volume for air blow cleaning is especially high at this plant. The method applied here is the use of air pressure just for moving dust, which is a wastage and degrades the working environment. We strongly suggest an improvement of this cleaning method.

The same items should also be studied for the air compressor of the rayon plant.

(9) Integration of utility supply system

The supply energy cost will be reduced by integrating the utility supply systems at the rayon and velvet plants. In addition, the following merits can be expected.

- Reduction of personnel due to a centralized daily operation control
- Improvement of allowance of equipment capacity and maintenance cost
- High efficiency operation of equipment and machines

To achieve the above, the following measures are required:

- Establishment of backup system for trouble situations
- Addition of measurement system for production cost management

This study will be useful for rationalization measures when the plant is modified or expanded in the future.

(10) Summary of proposals

Table 5.2.19 gives the summary of the above proposals.

Table 5.2.19 Summary of Proposals

(Japanese Yen base)

Item	Expected Saving: Fuel kL/y	Fuel Million yen/y	Fuel %	Electricity MWh/y	Electricity Million yen/y	Electricity %	Total Million yen/y	Investment Million yen	Payback Period Year
Reduction of pneumatic waste rate	–			375*8	3.8	1.6*10	3.8	0	0
Stopping of the return fan	–			101*9	1.0	0.4*11	1.0	0	0
Recovery of waste heat									
Enhancement of condensate recovery rate	360	6.1	4.5*3	–			6.1	6.0	1.0
Recovery of waste heat of washing water in the dyeing process	1,126	19.1	14.2*4	–			19.1	40.0	2.1
Recovery & utilization of diesel engine waste heat	712	12.1	9.0*5	–			12.1	50.0	4.1
Improvement of boiler air ratio	147*1	2.5	1.9*6	–			2.5	0	0
Enhancement of heat insulation	238*2	4.1	3.0*7	–			4.1	15.8	3.9
Control of the number of air compressors	–			65	0.7	0.3*12	0.7	0	0
Total	2,583	43.9	32.6	541	5.5	2.3	49.4	111.8	2.3

(Iran Rial base)

Item	Expected Saving: Fuel F.oil kL/y	Fuel Million Rial/y	Fuel %	Electricity MWh/y	Electricity Million Rial/y	Electricity %	Total Million Rial/y	Investment Million Rial	Payback Period Year
Reduction of pneumatic waste rate	–			375*8	38	1.6*10	38	0	0
Stopping of the return fan	–			101*9	10	0.4*11	10	0	0
Recovery of waste heat									
Enhancement of condensate recovery rate	360	27	4.5*3	–			27	105	3.9
Recovery of waste heat of washing water in the dyeing process	1,126	84	14.2*4	–			84	700	8.3
Recovery & utilization of diesel engine waste heat	(712)	(53)	(9.0)*5	–			(53)	(875)	(16.5)
Improvement of boiler air ratio	147*1	11	1.9*6	–			11	0	0
Enhancement of heat insulation	(238)*2	(18)	(3.0)*7	–			(18)	(277)	(15.4)
Control of the number of air compressors	–			65	7	0.3*12	7	0	0
Total	1,633	122	20.6	541	55	2.3	177	805	4.5

*1 $1,340 \times 10^6 / (9,100 \times 10^3) = 147$ kL/y

*2 $2,162 \times 10^6 / (9,100 \times 10^3) = 238$ kL/y

*3 $$\frac{1,280 \text{ kL/y} \times 9,300 \times 10^3 \text{ kcal/kL} + 6,327.7 \times 10^3 \text{ m}^3\text{/y} \times 9,500 \text{ kcal/m}^3}{9,100 \times 10^3 \text{ kcal/kL}} = 7,914 \text{ kL/y}$$

$360 / 7,914 \times 100 = 4.5$ %

*4 $1,126 / 7,914 \times 100 = 14.2$ %

*5 $712 / 7,914 \times 100 = 9.0$ %

*6 $147 / 7,914 \times 100 = 1.9$ %

*7 $238 / 7,914 \times 100 = 3.0$ %

*8 0.3 MWh/t × 1,250 t/y = 375 MWh/y

*9 42 kW × 24 h × 100 d/y = 101 MWh/y

*10 $375 / (7,286 + 11,194 + 2,645 + 816 + 2,010) \times 100 = 1.6$ %

*11 $101 / (7,286 + 11,194 + 2,645 + 816 + 2,010) \times 100 = 0.4$ %

*12 $65 / (7,286 + 11,194 + 2,645 + 816 + 2,010) \times 100 = 0.3$ %

Energy price in Japan:
- Fuel price: 17,000 yen/kL
- Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
- Fuel oil: 75 Rial/L
- Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen

Investment cost is based on that in Japan.

6. RESULTS OF THE STUDY ON THE FOOD INDUSTRY

6. RESULTS OF THE STUDY ON THE FOOD INDUSTRY

6.1 Results of the Study at Behshahr Industry Company

6.1.1 Outline of the Plant

(1) Plant name

Behshahr Industry Company

(2) Plant address

7 km Karaj, Old Road, Teheran

(3) Number of employees

Approximately 1000 including:

6 process engineers

1 heat management engineer

3 electrical engineers

(4) Major products

Soybean oil, sunflower oil and cotton seed oil.

Their types comprise 90 % of hydrogenated oil and 10 % of refined oil.

(5) Production capacity

1,000 t/d

200,000 t/y

(6) Production process

Raw oil is imported from Brasil or Argentine and refined at this company where no oil extraction from the seed is conducted.

The imported raw oil is heated without any degumming, and neutralized by caustic soda solution in the continuous neutralization process where free fatty acid, gums, trace elements, coloring matters are partly removed.

For their removal, a Westfalia type centrifugal separator is used. The oil is, after being removed of the water content, transferred to the vertical type bleaching tank. Acid clay is added to the oil to adsorb and remove coloring matters such as chlorophyll, and residual soap from the preceding neutralization process. The neutralization, drying and bleaching processes are conducted in vacuum at a temperature from 65 to 110 °C.

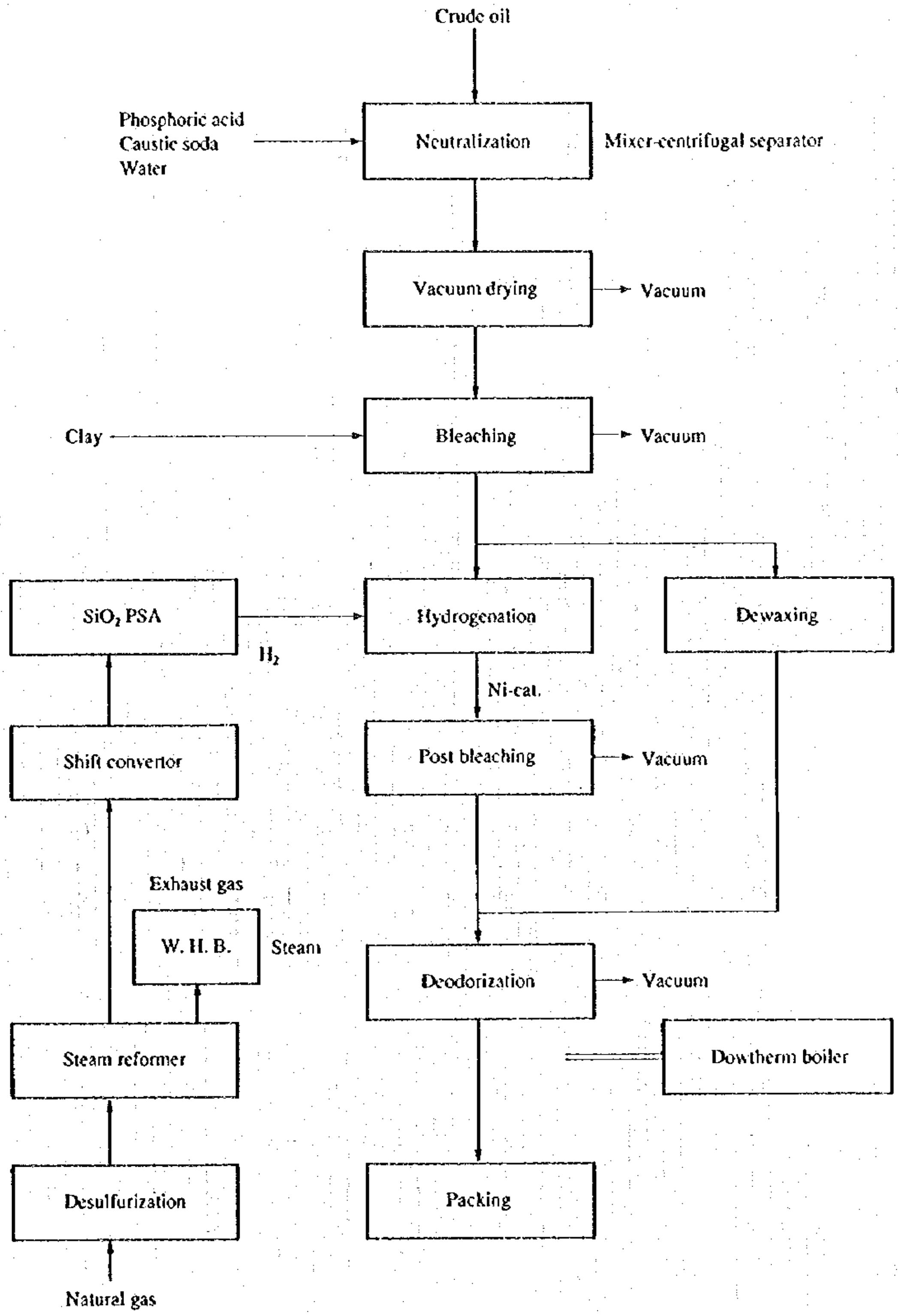
At this plant where hydrogenated oil is mainly produced, the oil after the decolorization process is fed to the hydrogenation reactor. The hydrogenated oil, from which the catalyst is removed, is then sent to the new and old two lines of the deodorization processes. At the deodorizer, the oil is heated to 260 °C and gets steam to be blown in under vacuum, thereby to make odorant substances, etc. evaporate together with water vapor.

The oil after passing through the deodorizing tower is subjected to a filtering finish in the post-bleaching process. After being cooled, it is applied to the votator and filled into the packer to come out as a product.

At this factory, 10 % of the bleached oil is deodored after the dewaxing process and subjected to filtering finish in the post-bleaching process. Thereafter the oil is cooled to be salad oil, which will be packed as a final product.

Figure 6.1.1 shows the process flow.

Figure 6.1.1 Process Flow



(7) History of the plant

a. History

Based on the 1st Economic, Social and Educational Development Plan, this factory was transferred to the private sector from Iran National Industrial Organization in 1992, which management was commissioned to Behshahr Industrial Development Group and a board of directors of stockholder federation.

Behshahr Industrial Private Joint-Stock Co. was founded in 1953 with a capital of 55 million Rial. Since then, it has gradually segregated the business until it has 14 companies affiliated with it, which are each engaged in refining of vegetable oil, manufacture of detergent, can manufacture, chemicals (medicine) manufacture, oxygen manufacture, and sales. In 1969 the production was increased from 170 t/d to 250 t/d in 1969, and furthermore in 1979 equipment for 400 t/d was additionally installed. In 1993, the hydrogen manufacturing method was changed from the hydrogen electrolysis process to the natural gas reforming process.

In 1995, a deodorizing tower was additionally installed, and a hydrogenerating equipment now is under construction. After completion, it will ensure a capacity of 1,000 t/d.

This factory is the largest of 15 vegetable oil factories in the country, occupying about 30 % market share. The factory area is 280,000 m^2.

b. Current situation of the industry

There are 15 vegetable oil factories in I.R. Iran, which produced 675,000 t/y in 1994. Raw oil production by the oil expression and extraction process acounts for only 7 %, while for the remaining 93 %, raw oil is imported to be refined.

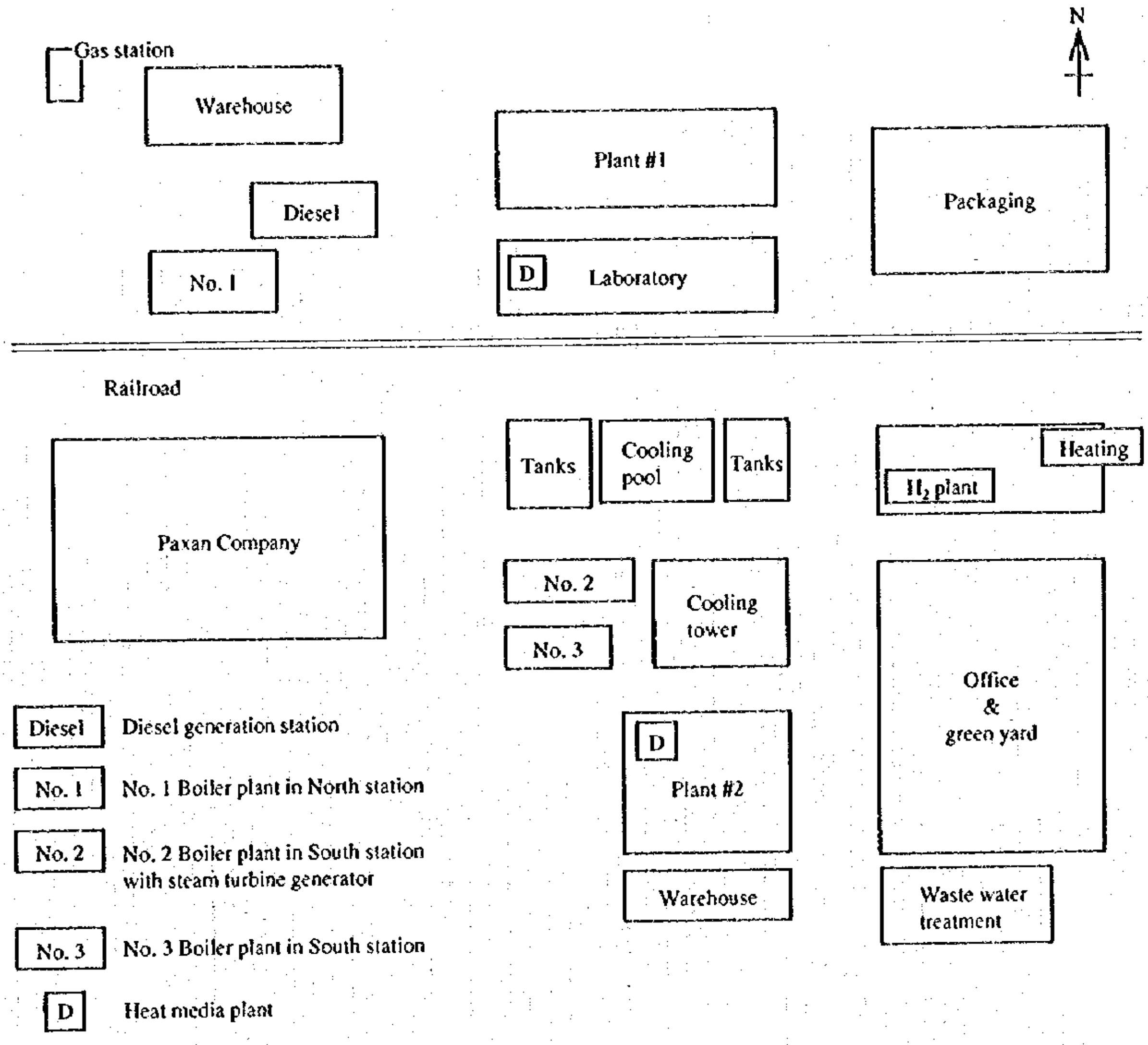
The demand for vegetable oil registers an annual increase rate of 3%, currently amounting to 800,000 t/y. Although at present the insufficiency is supplemented by products imported, the country is expected to be self-sufficient 10 years later.

There is an industrial association, where information exchange is available.

(8) Plant layout

Figure 6.1.2 illustrates the plant layout.

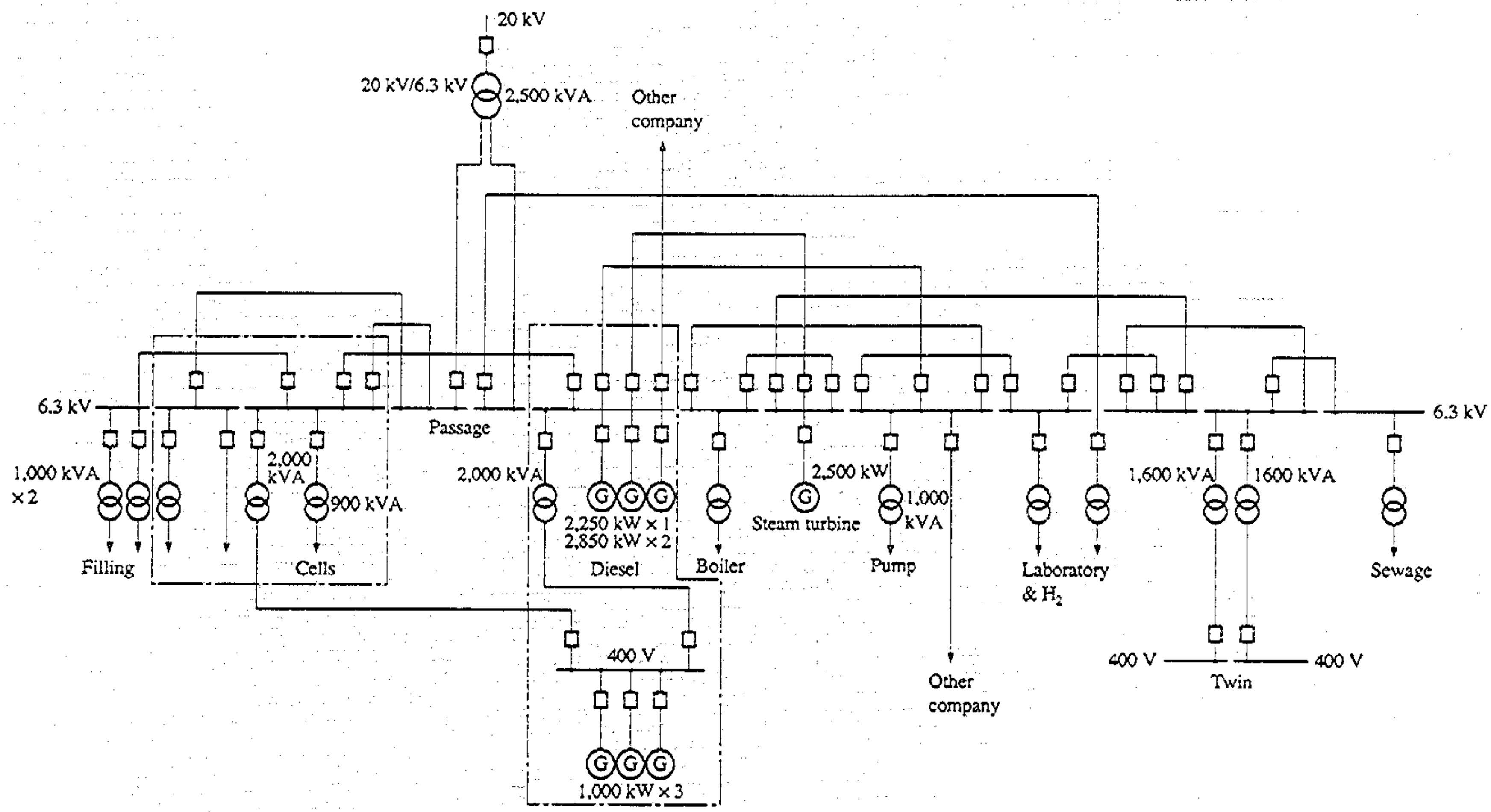
Figure 6.1.2 Plant Layout



(9) One line diagram

Figure 6.1.3 shows the electric power one line diagram.

Figure 6.1.3 One Line Diagram



(10) Outline of major equipment

Table 6.1.1 shows the outline of the major equipment

Table 6.1.1 Major Equipment of No.2 Plant

Name	Number	Specification
Neutralization		
Centrifuge	3	Westfalia 300t/d × 3
Dryer	2	
Bleaching		
Tank	1	Continuous vertical type with an agitator. 40 to 60 Torr
Hydrogenation		
Reactor	4	38 m³, 500 t/d, 6-8 h/batch
	4	Now under additional construction with the same specifications as above. 500 t/d
Deodorization		
Deodorizer	2	Continuous, 300 t/d × 2, 3 Torr
	1	Continuous, 400 t/d, 3 Torr, Double shell DESMET type, with an economizer
Packaging		
Emulsifier	1	Votator
Hydrogen Plant	1	Natural gas water vapor reforming process, PSA separation, 1676 m³/h Hydrogen purity 5-nine
Waste Water Treatment	1	200 m³/h processing Air floatation, Chemical treatment Activated sludge treatment
Utility		
Diesel Generator	6	1,000 kW × 3 Voltage: 400 V 2,250 kW × 1 Voltage: 6.3 kV 2,850 kW × 2 Voltage: 6.3 kV
Boiler	10	Firing by natural gas 43 kg/cm², 45 t/h × 2 11 kg/cm², 22 t/h × 3 11 kg/cm², 13 t/h × 3 11 kg/cm², 10 t/h × 2
Steam turbine	1	Condensing extraction method: 2,500 kW Steam pressure 42.18/11.25 kg/cm²

(11) Energy price

Electric power: 40 Rial/kWh

Natural gas : 26 Rial/m^3, 9,800 kcal/m^3

Gas oil : 30 Rial/L, 9,800 kcal/L

(12) Study period

a. Preliminary study: September 23, 1995

b. Plenary study: August 10 to 14, 1996

(13) Members of the study group

a. JICA team

Leader	: Mitsuo Iguchi (Preliminary study)
Leader	: Norio Fukushima
Process management technology	: Shiro Honda
Heat management technology	: Jiro Konishi
Heat management technology	: Takashige Taniguchi
Electricity management technology	: Kazuo Usui
Energy policy	: Toru Kimura (Preliminary study)
Energy policy	: Shin-ya Udo (Preliminary study)
Database and energy utilization plan	: Kaoru Yamaguchi (Preliminary study)
Economic evaluation	: Shigeaki Kato (Preliminary study)

b. PBO team

Energy conservation	: Mr. Mazhari
Micro level energy management	: Mr. Mianji
Macro level energy management	: Mr. Azizi (Preliminary study)
Factory management	: Mr. Sajadifar
Macro level energy management	: Mr. Mohamadzadeh (Preliminary study)

(14) Interviewees

Mr. Mirmortazavi	: Managing Director (Preliminary study)
Mr. Alavizadeh	: Power Generation & Distribution Manager
Mr. Givard	: Deputy of Managing Director
Mr. Fazel	: Production Manager
Mr. Harirchi	: Electric & Instrument Manager
Mr. Nourai	: Head of Mechanical Maintenance Department
Mr. Yousef Pour	: Head of Packing Department
Mr. Fahiminiya	: Chemical Engineer
Mr. Hatefi	: Process Engineer (Preliminary study)
Mr. Berenji	: Chief of Boiler Department
Mr. Fathi	: Promotion Method Engineer (Preliminary study)

6.1.2 Enegy consumption

(1) Trend of production amount, energy consumption and energy intensity

a. Production

Table 6.1.2 shows the trend of production amount.

Table 6.1.2 Production

Fiscal Year	1989	1990	1991	1992	1993	1994	1995
Production (t)	117,907	143,020	155,389	158,244	167,000	200,000	245,100

b. Energy consumption

Table 6.1.3 shows the trend of energy consumption.

Table 6.1.3 Energy Consumption

	1989	1990	1991	1992	1993	1994	1995
Gas oil (L)		10,475,726	8,636,990	7,816,648	7,191,214	6,459,972	
Natural gas (m^3)	22,000,000	45,090,000	39,710,000	40,670,000	65,460,000	70,620,000	
Electricity (kWh)	37,240,000	47,440,000	53,270,000	43,057,000	48,042,000	46,510,000	36,983,260
For Behshahr		41,046,740	36,671,804	35,288,412	33,734,000	33,400,000	27,451,260
Steam (t)							453,491

According to the actual results in 1995 the annual electric power balance is as shown in Table 6.1.4.

Table 6.1.4 Electric Power Balance (1995)

Supply unit: kWh/y

Privately Generated			Purchased	Total
Engine House	Turbine	Total		
22,413,760	12,127,500	34,541,260	2,442,000	36,983,260

Consumption unit: kWh/y

Paxan	Behshahr	Total
9,532,000	27,451,260	36,983,260

Table 6.1.5 shows the results of measuring the electric power supply and demand. The electric power on the load side measured by the integrating power meter of the distribution board, and the power factor measured at a different time is used. The power consumed in the entire factory is 3,200 kW, with the power factor 76%, at which time no power was received from the external power line.

Table 6.1.5 Measurement Results of Electric Power Balance (11 August 1996)

Equipment Name		Electric power (kW)	Power factor
(Supply side)			
Steam turbine power generator		1,860	0.80
Diesel power generator	No.1	380	0.85
	No.2	530	0.57
	No.4	1,480	0.72
In-house power generation meter		4,250	0.74
Purchased electric power		0	
Total		4,250	0.74
(Load side)			
Refinery No.1		970	
Refinery No.2		1,010	
Turbine house		220	
Pump house		410	
Diesel house		70	
Well		280	
Others		260	
Behshahr total		3,220	0.76
PAXAN		1,030	

Table 6.1.6 shows the actual results of private power generation in 1990.

Table 6.1.6 Annual Private Power Generation and Annual Utilization Factor

Generator	Capacity (kW)	Power Production (MWh/y)	Utilization Factor (%)
Diesel No.1	1,000	1,702.7	19.4
Diesel No.2	1,000	1,220.7	13.9
Diesel No.4	2,850	5,975.0	23.9
Diesel No.5	2,850	7,356.0	29.5
Diesel No.6	1,000	1,834.8	20.9
Diesel No.7	2,250	2,581.3	13.1
Diesel total	10,950	20,670.4	21.5
Turbine	2,500	12,744.0	58.2
Generation total	13,450	33,414.4	28.4

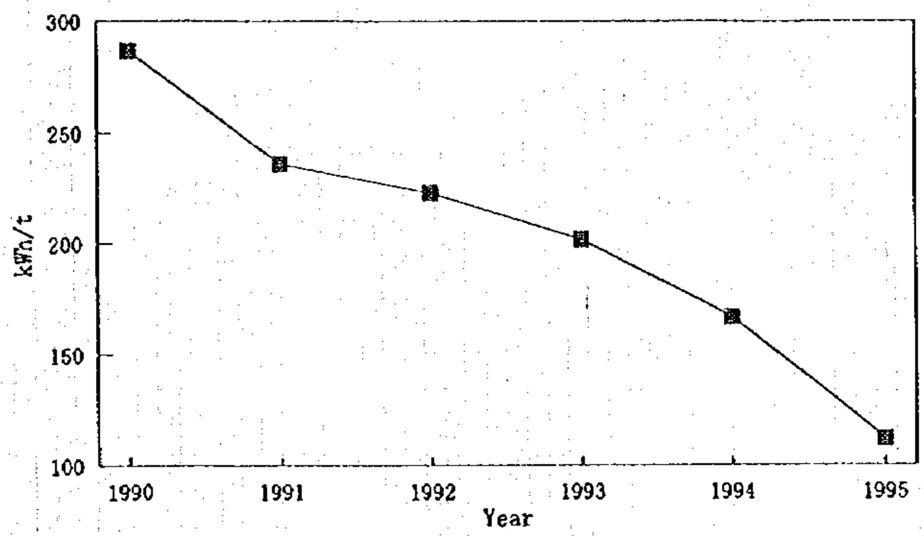
c. Energy intensity

Table 6.1.7 shows the trend of consumption each of electricity, natural gas, steam and water, while Figure 6.1.4 illustrates the trend of electric power intensity.

Table 6.1.7 Electricity, Natural Gas, Steam and Water Intensity

Fiscal Year	1990	1991	1992	1993	1994	1995
Electric power (kWh/t)	287	236	223	202	167	112
Natural gas (m^3/t)	315	256	257	392	353	
Steam (t/t)						1.85
Water (t/t)						2.60

Figure 6.1.4 Electricity Intensity



The result of electricity intensity reveals that it decreased remarkably in 1995 as shown in Figure 6.1.4. According to the explanation of the factory side, this drop is due to the increase of production amount. Natural gas intensity is as shown in Table 6.1.7, where it is found to have increased since 1993 when the hydrogen manufacturing method was switched to the natural gas reforming process. Gas oil intensity has been decreasing since 1990, which is because of the decrease in diesel engine operating hours and the first preference for the use of more efficient diesel.

(2) Energy flow by process

Figure 6.1.5 shows the energy flow. Figure 6.1.8 shows the steam consumption design value for production of 500 t/d and 1,000 t/d.

Figure 6.1.5 Energy Flow

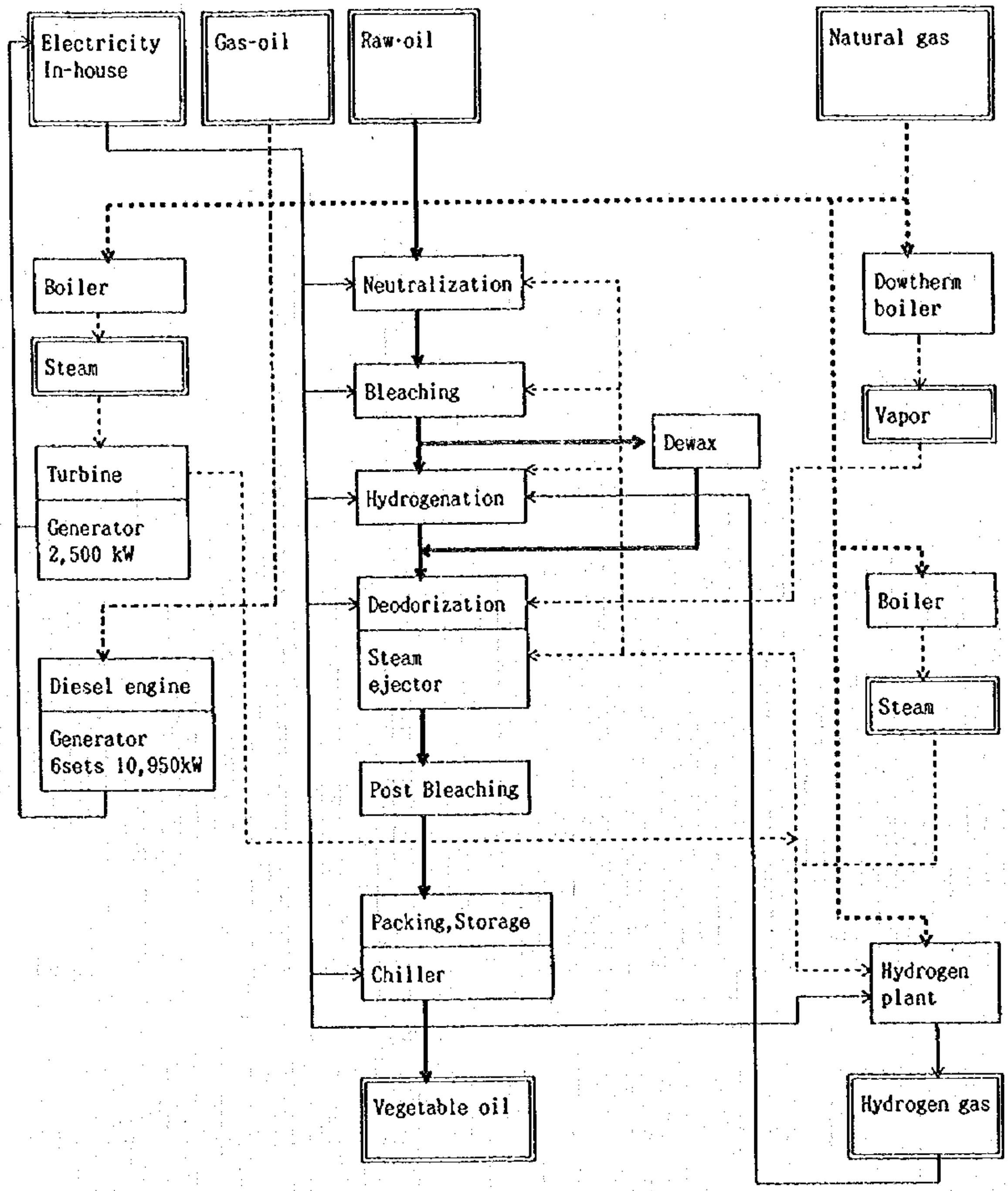


Table 6.1.8 Steam Consumption and Steam Intensity

Production	500 t/d		1,000 t/d	
	Average (kg/h)	Intensity (kg/t)	Average (kg/h)	Intensity (kg/t)
Deodorization	3,600	173	5,400	130
Post bleaching	100	5	200	5
Hydrogenation	2,300	110	4,600	110
Bleaching	3,140	151	6,280	151
Alkali refining	2,070	100	4,140	99
Total	11,210	539	20,620	495

(Design value)

6.1.3 Situation of Energy Management

(1) Setting the target for energy conservation

To start energy conservation activities, the top management of the company must define energy conservation as one of major management targets, demonstrating serious attitude and enthusiasm for energy conservation to the employees. This will convince the employees that making efforts for energy conservation will conform to the policy of the company, and will motivate them for positive efforts.

When policy is shown by these top management, mere abstract instruction for energy conservation is not sufficient; specific target values and the deadline for achieving the goal must be shown to the workers. In response to these instructions, each section of the factory should set up the concrete targets for individual items which can be taken charge of within the scope of the responsibility, so that the overall target can be achieved. Only after the target has been set, concrete action plans to achieve the target can be worked out, including study of various approaches, preparation of the programs, and assignment of the works.

However, setting the target requires correct information on the current energy consumption in the factory. This factory has no concrete plan set up yet.

Before setting up the target, it is necessary to have a correct understanding of the energy consumption of the factory.

(2) Systematic actions

At present, no committee for promoting energy conservation has been set up. Energy conservation activities should be systematically performed. The approaches for energy conservation include company-wide efforts, technical development by the staff, and a combination of these two methods, that is, a systematized way of actions.

In order to push forward with the systematic activities, in many cases, a committee is set up where representatives of each division and engineers have lateral communication with one another to make studies. This close tie-up system allows them to thoroughly understand and verify annual energy consumption, so that they will proceed with various efforts such as analysis of numerical values to achieve the target, system modification, equipment investment, setting of the test plan, systematized cooperation of related departments, etc. Thus, they can be kept fully informed of annual projects and the priority plan to offer a prompt cooperation. In this system, it is recommended that the accounting system should also provide data. The effect of energy conservation is, in many cases, evaluated in terms of cost reduction. Hence, these energy conservation activities should be implemented systematically. In this regard, the current situation needs to be further reviewed.

ISO 9000 series is an international standard for quality control system, whose implementation method is recommendable as well for energy conservation. Based on the policy of the top management, each division's operation activities are coordinated, thus permitting improvements to be made.

(3) Data-based management

The first step of energy conservation starts with an accurate understanding of the energy utilization situation for each process. To this end, energy consumption should be first measured. Without measured values, neither data control can be performed, nor will any good idea on improvement occur.

In this factory, they perform technical control for individual processes, and have many experienced engineers, who proceed successively with improvements of equipment. The equipment management is also in good condition. As a future theme, it is recommended for them to make further data analysis, and thereby implement a systematic management based on data.

(4) Education and training of employees

For education and training of employees on energy conservation, it is important to start with education of the management class and gradually spread it down to the employees. It is vitally important to make every one understand that energy conservation leads to cost reduction. It is equally necessary to raise their consciousness concerning the fact that energy conservation efforts are getting increasingly important in terms of global environmental protection. In this plant, a training center is provided, which demonstrates their great interest in the education of the employees.

It may be also recommendable to award commendation to employees who offered effective proposals.

In addition, it is advisable to collect information on the latest energy conservation technology as well as to offer opportunities for their studies.

(5) Equipment management

Equipment are comparatively well maintained. Since heat insulation of equipment is necessary for energy conservation, vessels and steam pipings with much heat radiation should be insulated.

6.1.4 Problems in Use of Energy and Countermeasures

(1) Comparison with a Japanese excellent plant

Energy intensities of a Japanese refinery by process are roughly as shown in Table 6.1.9.

Table 6.1.9 Energy Intensity by Process in a Japanese Oil Refinery

	Steam kg/t-oil	Electricity kWh/t-oil
Neutralization	200 to 250	15 to 20
Bleaching	50 to 70	5
Deodorization	80 to 120	30 to 50
Total	330 to 440	50 to 70

By contrast with this, the energy intensity of Behshahr Industry in 1995 is 1,850 kg/t for steam, and 112 kWh/t for electricity respectively as shown in Table 6.1.7. Of these, the electricity intensity for the refining process is estimated at approximately 69 kWh/t, which is at a level nearly equal to that in Japan. Since steam consumption by process is not available, the consumption in the refining process is unknown. Even if it includes steam consumption each for power generation and hydrogen manufacture, which may be supposedly only about 64 kg/t-oil and 42 kg/t-oil respectively, the steam consumption from which these values are subtracted is estimated to be still as large as 1,744 kg/t-oil. This value is 3.6 times larger than that in Japan, even assuming the steam consumption for other auxiliary facilities to be 20 %.

Moreover in this plant, a Dowtherm boiler is employed to preheat oil in the deodorizing process. On the other hand in Japanese plants, where no Dowtherm boiler is employed, heating is performed by steam, which is also included in the figure. The steam consumption is, however, not so high in Japanese plants due to the advanced techniques of recovering heat of the deodorized oil.

The design values of steam consumption at this plant are as shown in Table 6.1.8, and the design intensity excluding that for the hydrogenation process is 385 to 429 kg/t-oil, which is nearly identical to the standard value in Japan. Therefore it may as well be said that there is no difference due to the process or equipment.

As for the scale, the capacity of Japanese hydrogenation plants is about 500 t/d, which is not so significantly different from that of this plant. The difference in the material does not influence so much the energy intensity either.

In Japan, hydrogenated oil as a product is mainly for margarine with a melting point nearly identical to that of this plant's product, which makes no significant difference either. Rather in Japan, active carbon is used and the refining degree is higher.

The steam intensity in the refining process is greatly influenced by factors such as the performance and operation of the vacuum equipment and the heat recovery from treated oil. Therefore, these factors are considered to make such a significant difference in energy intensity. In Japanese plants, an energy conservation committee is set up to proceed with company-wide energy conservation activities, presenting many improvement case examples.

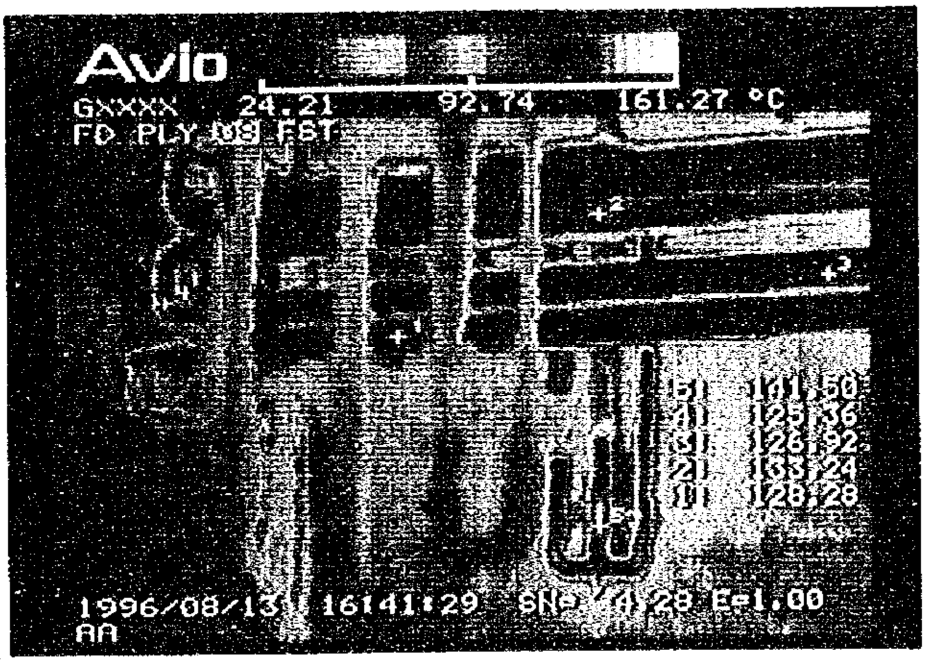
(2) Heat insulation

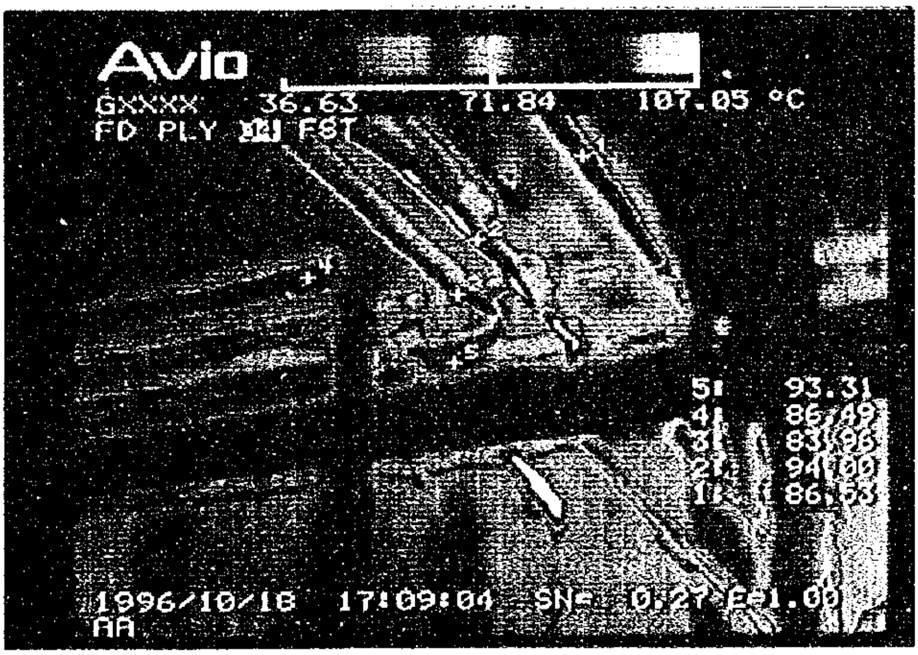
The Thermal Video System is available for measuring the surface temperature of an object without having to contact it. This measuring instrument receives the infrared ray radiation from the object's surface with a camera and displays this received image on the CRT screen in color showing the temperature distribution. It can also record the image as a still picture on a floppy disk.

The infrared visual display allows one to view dynamically and facially the surface temperature of the equipment and steam pipe. It is also capable of showing the temperature distribution of any section in a graph.

When we visited the company this time, we used the Thermal Video System to capture the external appearance of the bleaching process pipes. Figure 6.1.6 is an example of the images. The red portion is the steam pipe and its temperature is between 90 and 130 °C.

Figure 6.1.6 Surface Temperature of Steam Pipe by Infrared Visual Display





It was observed that in the boiler plant of this factory, no heat insulation was provided to the steam valves and flanges. Based on our observation of these valves with no heat insulation, we calculated the heat emission. Table 6.1.10 shows the calculation results, adding 50 % loss of heat from the uninsulated part near the valves.

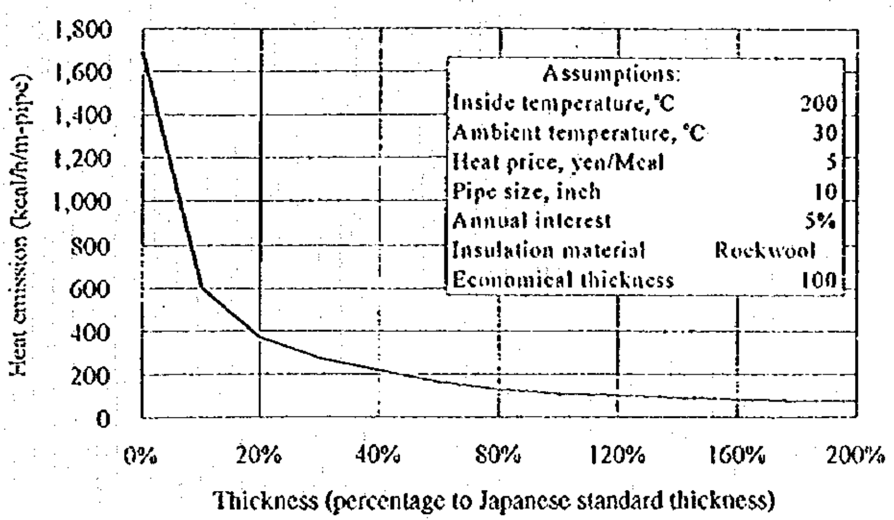
Table 6.1.10 Heat Emission from Power Plant

		Boiler-1	Boiler-2	Boiler-3	Total	
Valves						
	Number	15	10	6		
	Size range	3 – 6	3 – 8	4 – 8		Diameter, inches
	Emission loss	25,587	39,455	8,190	73,233	kcal/h, total
Bare pipes around these valves are assumed as 50 % of valves.					36,616	
Total of valves & bare pipes:					109,849	
Tank surface						
	Number		2			
	Emission loss		184,069		184,069	kcal/h, total
Grand total					293,918	kcal/h

Notes: Surface temperature of valves & pipes was taken as steam temperature.
Ambient temperature was taken as 40 °C.

Providing heat insulation on these parts will sharply decrease the heat loss in accordance with the increase of heat insulation thickness. Figure 6.1.7 shows the calculation example.

Figure 6.1.7 Insulation Thickness and Heat Emission (An example)



An annual reduction in boiler fuel by providing heat insulation, which is obtained from the above-mentioned heat emission calculation, will be 2,607 Gcal (= 293,918 × 0.9 × 8,760 × 0.9/0.8) (assuming that heat emission reduction is 90 %, annual operating ratio is 90 %, and boiler efficiency is 80 %). This reduction effect will be equivalent to 0.5 t/h of steam.

(3) Adjustment of the vacuuming level of the deodorizing process

The steam ejector is used for vacuuming in both neutralization and deodorizing processes. As indicated in Table 6.1.8 Steam Flow, the consumption is particularly high in the deodorizing process.

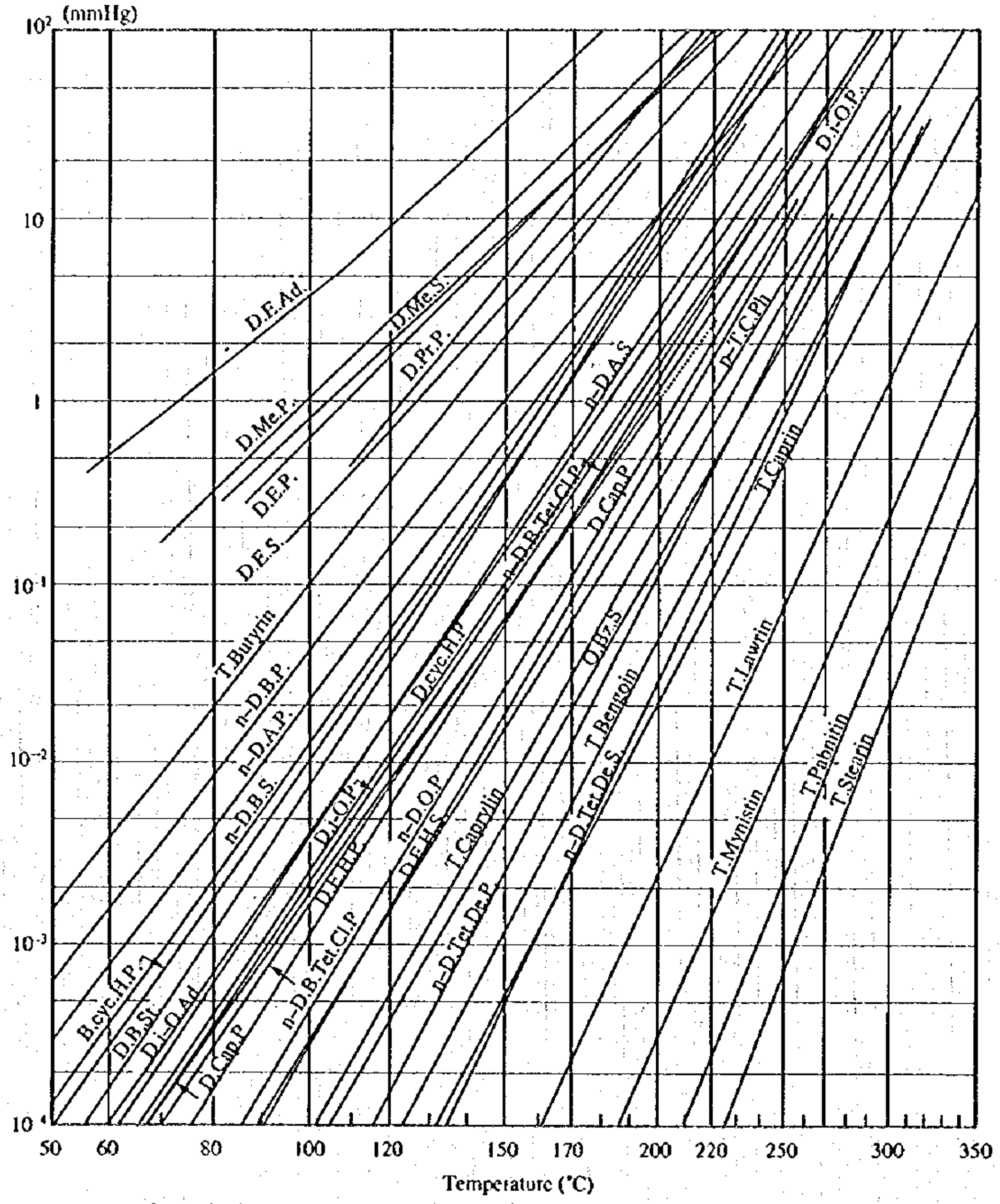
Since coloring is used for hydrogenated oil in this company, the color value cannot be compared between its products and the products in Japan. However, we did not find much difference in the smell.

Under the deodorizing conditions at this company, the vacuuming level was 3 Torr at our investigation. The vacuuming level of a hydrogenated oil plant in Japan is 6 to 8 Torr. Therefore, we believe that the potential for energy conservation is high if the vacuuming level during deodorizing is reduced to 6 Torr. Figures 6.1.8 and 6.1.9 prove that most of the substances which smell can be eliminated on an equal level in both the cases of 3 mmHg (Torr) at 260 °C and 8 mmHg (Torr) at 265 °C for the ester group, hydrocarbon, chlorine hydrocarbon, and organic silicon compounds. The level of coloring caused by the 5 °C increase in temperature can be ignored. It will not present a major problem in terms of quality.

If the vacuuming level is reduced from 3 Torr to 6 Torr, the steam volume to be used by the steam ejector can be cut down by 60 % to 80 %. The steam blowing volume will not change much even if the vacuuming level is changed to 6 Torr.

In the case of salad oils, deodorizing is performed at 2 Torr in Japanese plants, and thus a separate study is necessary.

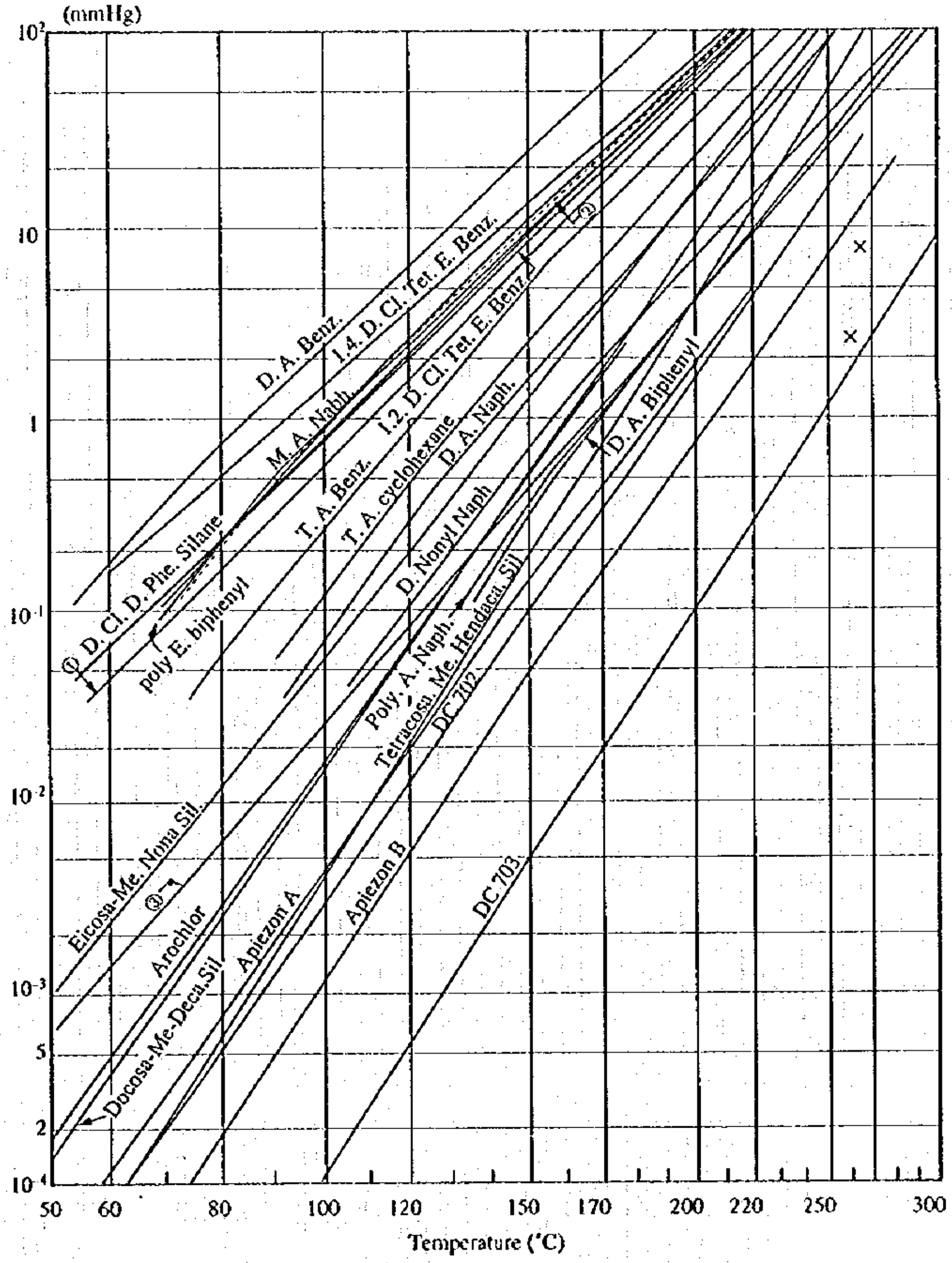
Figure 6.1.8 Vapor Pressure of Organic Compounds (Esters)



Symbols:

A.	Amyl	D.	Di	P.	Phthalate
Ad.	Adipate	E.	Ethyl	Ph.	Phosphate
B.	Butyl	H.	Hexyl	S.	Sebacate
Bg.	Benzyl	i-	iso-	St.	Stearate
C.	Cresyl	Me.	Methyl	T.	Tri
Cap.	Capryl	n-	normal	Tet.	Tetra
cyc.	cyclo	O.	Octyl		

Figure 6.1.9 Vapor Pressure of Organic Compounds
(Hydrocarbon, Chlorinated Hydrocarbon and Organic Silicon Compound)



A.	Amyl	E.	Ethyl
Benz.	Benzene	Naph.	Naphthalene
Cl.	Chloro	Sil.	Siloxane
D.	Di	T	Tri
M.	Mono	Phe	Phenyl

② Chlor. Me. D. phe. Silane   Broken line: Dodecyl Benz.

③ D. Phe. Silicon D. isothio cyanate

(4) Adjustment of ejector steam pressure

At present, steam of 10 kg/cm² (G) is used, while in Japan, steam of 7 kg/cm² (G) is used.

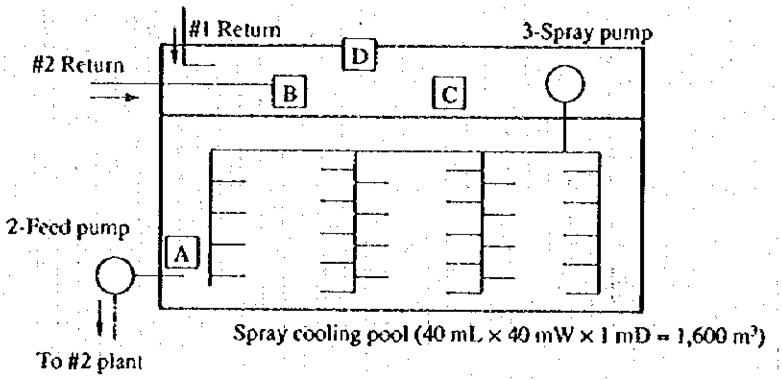
An ejector is often extravagantly designed. Therefore, it is recommendable to perform tests to reduce the steam pressure in successive phases by monitoring the vacuum level after making the effort to reduce as much leakage air as possible.

If the steam pressure is dropped from 10 kg/cm² (G) to 7 kg/cm² (G), approximately 30 % of the steam flowrate can be reduced as shown by some actual example records.

(5) Barometric condenser water temperature control

The cooling water (barometric condenser cooling water) of the steam ejector used in the deodorizing process is sprayed to the spray pool, cooled, and then supplied again. Figure 6.1.10 shows the layout of the spray pool and water temperature measurement result.

Figure 6.1.10 Spray Cooling for Barometric Condenser Coolant



Temperature measurement:

Point	Content	Temperature	
A	#2 Feed	24	
B	#2 Return	24	
C	#2 & #1 Return mixed	31	
D	Ambient	34	24 % Humidity

Approximately half of the spray pool sprinkler nozzles are clogged. The temperature of the water from the pool was 24 °C (atmospheric temperature 34 °C) at the time of measurement. The temperature can be adjusted closer to the wet bulb temperature by using a cooling tower equipped with a ventilation fan. For example, the condenser cooling water of the turbine is controlled at 21 °C.

The driving steam volume of a booster is greatly affected by the cooling water temperature of the No. 1 barometric condenser. In other words, the vapor should be compressed by a booster to vapor pressure of the water under the water temperature of the barometric condenser. It is necessary to use the lowest possible cooling water temperature to reduce the use volume of driving steam. The ejector vapor can be reduced by approximately 15 % as indicated in Table 6.1.11 by lowering the cooling water temperature from 24 °C to 21 °C in the barometric condenser. When the cooling tower is used, it is necessary to select packing which is not easily clogged since the cooling water becomes very dirty.

Table 6.1.11 Relationship between Barometric Condenser Cooling Water Temperature and Ejector Steam Amount

Temperature	°C	10	15	20	25	30	34
Steam Amount for Drive	kg/h	200	250	330	425	585	720

150 t/d for the deodorizing equipment

The steam consumption in the refining mill is not grasped yet. However, taking the measures mentioned in the above items (3) to (5) can reduce steam for the ejector to 83 kg/t-oil, saving 267 kg/t-oil of steam assuming that the steam consumption for the ejector is 25 %, or 350 kg/t-oil of the estimated steam intensity of the refining process (1,400 kg/t-oil).

$$350 \times (1 - 0.6) \times (1 - 0.3) \times (1 - 0.15) = 83 \text{ kg/t-oil}$$

There are a number of actual cases in Japan where the final ejector is replaced by the vacuum pump. Whether or not the vacuum pump should be adopted instead of final ejector must be determined by comparing the electric power and steam unit price rates. The water sealing type Nash Hytor pump may be suitable as a vacuum pump.

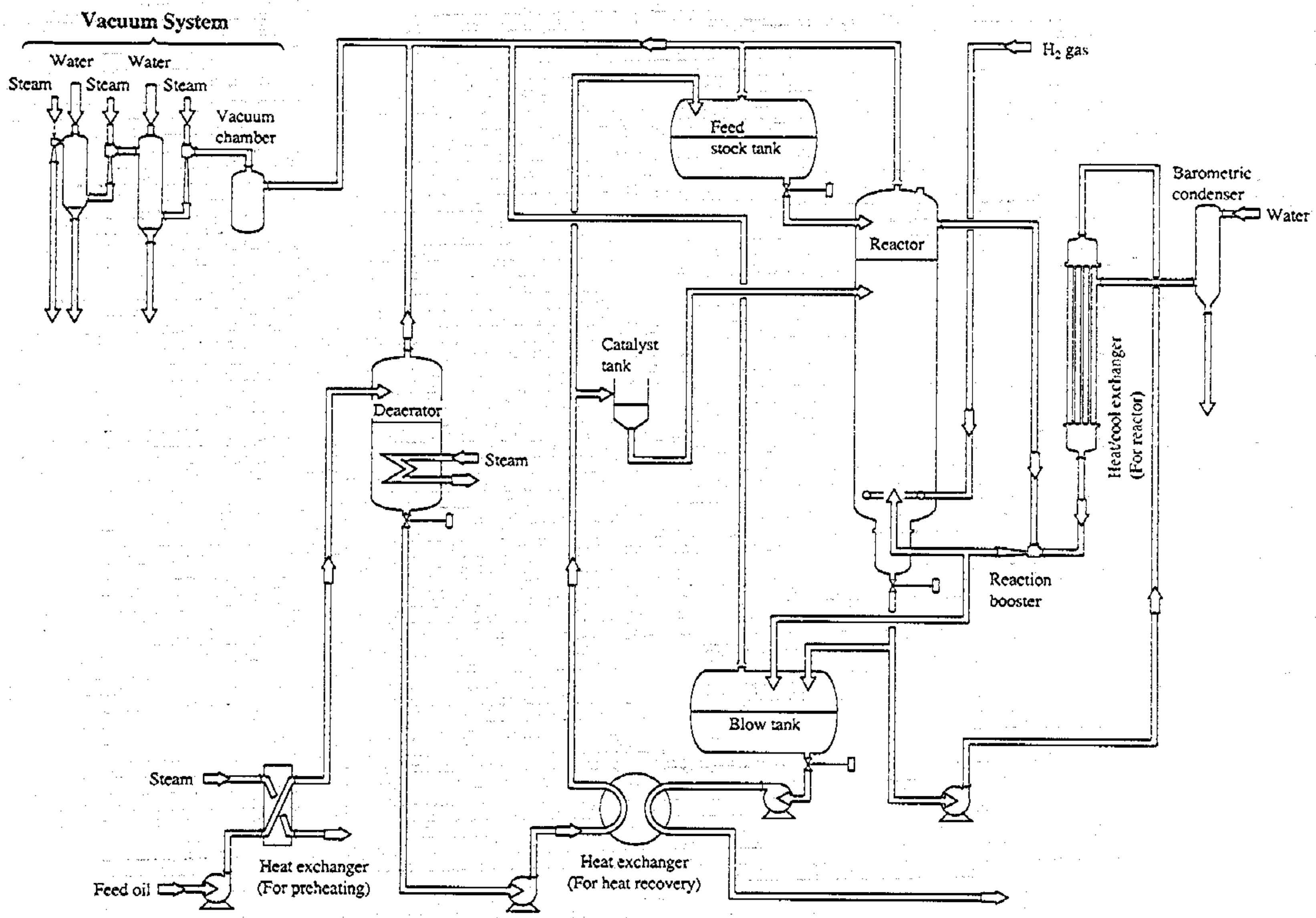
(6) H_2 circulation of hydrogenation process

The circulation of hydrogen is carried out in the hydrogenation reaction tank of hardened oil manufacturing in Japan. As shown in Figure 6.1.11, the important technique is to use the reaction booster for preventing a fire hazard during non-reacted hydrogen circulation and for improving the mixing effect.

The reaction time will be about half and the steam consumption will be reduced by approximately 65 kg/t-oil compared with conventional type hydrogenation equipment.

In the case of batch process, energy consumption by de-aerating at every initial stage is high. However, it is expected to be reduced by continuing the process. The continuous hydrogenation process is not performed in Japan at present because the reaction completion control method is not yet finished and apparently it is difficult to obtain a constant quality. We should consider this matter according to the trends of global technological development in a future long-term plan.

Figure 6.1.11 Hydrogenation Equipment



(7) Heat exchange of deodorizing tower refined oil and raw material oil

Normally, treated oil of 260 °C, which was deodorized in the tray in the deodorizing tower, first exchanges heat with the bleached oil in the tower to cool it down. Then, it exchanges heat with the refined oil outside the tower, and it is further cooled down there by water.

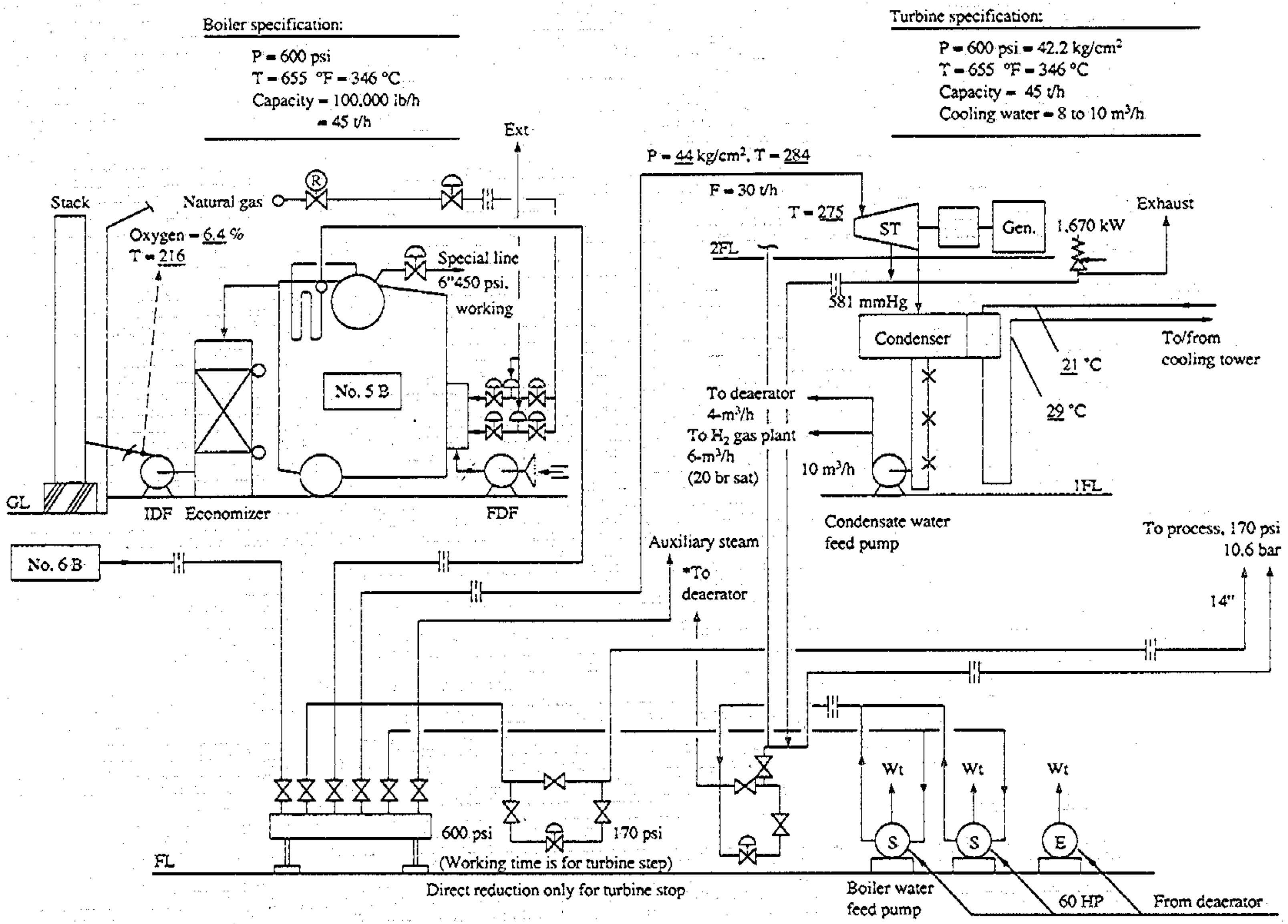
The heat utilization is accomplished through heat exchange using deodorized oil and bleached oil outside the tower in the new deodorizing tower. The old system does not have the heat exchange equipment of raw material oil. Since there is a plan for replacement of the old deodorizing tower, the heat exchange equipment can be introduced at the time of this replacement.

Also, the Dowtherm boiler is used for coil heating of the deodorizing tower. In Japan, however, a high-pressure superheated steam system is used instead to prevent health hazards due to mixing of dangerous substances.

(8) Boiler turbine system

Two high-pressure 45 kg/cm² type boilers are installed and connected to the condensing extraction turbine. Figure 6.1.12 shows the flow and measurement results of this boiler turbine system.

Figure 6.1.12 Steam Line for Boiler No. 5



Note: The values underlined are those observed on August 12, 1996.

a. Improvement of steam temperature of steam turbine

The designed value of the steam temperature at the turbine inlet of the power plant is 346 °C as indicated in Figure 6.1.12. It has dropped to around 310 °C due to a trouble in the superheater in November 1996 and was 275 °C when we measured it in August 1996. If this steam temperature is increased, the turbine output will increase.

If the steam temperature is increased to 346 °C, the turbine output will increase by 12 % at the base in November and 31 % at the base in August although this is based on various assumed conditions. The comparison table using this example is given in Table 6.1.12.

Table 6.1.12 Steam Temperature on Turbine Output Power

			Actual/August	Actual/November	Studied
Main steam					
	Pressure	kg/cm²	45	45	45
	Temperature	°C	275	310	316
	Flow	t/h	30	30	30
Extraction steam					
	Pressure	kg/cm²	11.6	11.6	11.6
	Ratio	%	85 %	85 %	85 %
Power output					
	Output	kW	1,530	1,787	2,001
	% increase to August		Base	–	31 %
	% increase to November		–	Base	12 %

Notes: Actual/August for steam temperature at field survey on August
Actual/November for steam temperature at November
Studied for steam temperature designed

The thermal efficiency at the high-pressure portion of the turbine is about 50 % including the boiler efficiency, and this is higher than the Diesel generator. Therefore, the energy conservation can be achieved by reducing the Diesel output corresponding to the increased amount of turbine output.

b. Boiler heat balance

We have attempted to calculate the boiler heat balance based on the measured values of the boiler exhaust gas. Since we could not obtain the boiler fuel flow rate, we set the fuel volume so that the value in "Other losses" in the heat balance result table would not be an extreme value. Table 6.1.13 indicates the heat balance assumption value and Table 6.1.14 indicates the heat balance result. It should be, however, noted that the superheated steam temperature at that time was extremely low: 284 °C.

Table 6.1.13 Data for Boiler Heat Balance Calculation (Boiler No.5)

Natural gas

Time, begin	1100	(set in	Emission option	c
Time, close	1200	four digits)	d:JIS formula	0.73%
Time, hour	1		c:Calculated	0.17%
Boiler capa t/h	45	(Rated)	m:Manually	1.4%
Base temperature	30		Adopted	0.17%

Item	Unit	Amount	/hour	Pressure abs	Temperature	Unit heat
Fuel combustion heat	m^3_N	2,100	2,100	-	-	9,491
Fuel sensible heat	kcal	2,100	2,100	-	38	3.18
Burner air	m^3_N wet	31,439	31,439	-	38	2.48
Invasion air	m^3_N wet	0	0	-	38	2.48
Exhaust gas	m^3_N wet	33,695	33,695	-	216	60.92
CO loss	m^3_N wet	0	0	-	-	3,018
Economizer inlet feed	kg	-	-	50	115	116.1
Boiler-in feed	kg	30,000	30,000		115	116.0
Drum blow	kg	0	0		-	171.5
Outlet steam	kg	30,000	30,000	44.0	284	692.5
	Dryness%		Superheated			

Fuel amount was selected to get suitable miscellaneous loss in heat balance.

Table 6.1.14 Boiler Heat Balance (net heat value based) (Boiler No. 5)

Heat-in

	$kcal/m^3_N$	kcal/h	%
Fuel calorie	9,490.5	19,930,071	99.58
Fuel sensible heat	3.2	6,673	0.03
Air sensible heat	37.2	78,020	0.39
Total	9,530.8	20,014,765	100.00

Boiler efficiency

In/out method	86.40 %
Heat loss method	89.58 %

Heat-out — Natural gas

	$kcal/m^3_N$	kcal/h	%
Steam generated	8,234.5	17,292,447	86.40
Exhaust gas loss	977.4	2,052,601	10.26
CO loss	0.0	0	0.00
Emission loss	15.7	32,903	0.16
Sub total	9,227.6	19,377,952	96.82
Miscellaneous	303.2	636,813	3.18
Total	9,530.8	20,014,765	100.00

The oxygen content in the exhaust gas of this boiler is 6.4 % and the exhaust gas temperature is 216 °C, suggesting that the thermal efficiency is not bad. The Japanese standard value of exhaust gas oxygen content is 5 % and that of the exhaust gas temperature is 170 °C.

Figure 6.1.13 shows the measured results of the exhaust gas and water feed volume of the low-pressure boiler No. 11. Table 6.1.15 indicates the boiler heat balance of boiler No. 11.

Figure 6.1.13 Boiler No. 11 for Process Steam

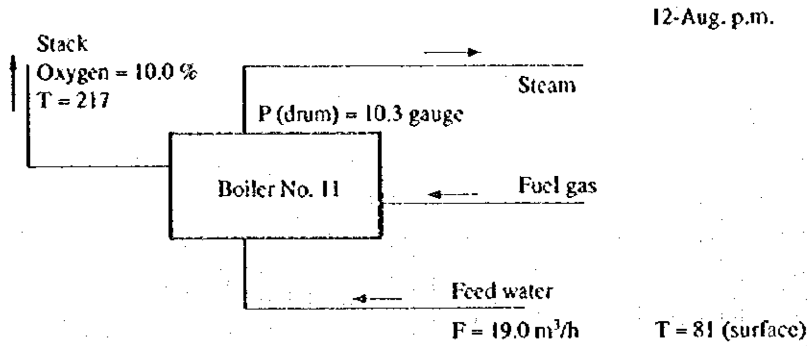


Table 6.1.15 Boiler Heat Balance (net heat value based) (Boiler No. 11)

Heat-in	$kcal/m^3_N$	kcal/h	%
Fuel caloric	9,490.5	13,286,714	99.46
Fuel sensible heat	3.2	4,449	0.03
Air sensible heat	48.4	67,805	0.51
Total	9,542.1	13,358,968	100.00

Boiler efficiency	
In/out method	81.50 %
Heat loss method	86.65 %

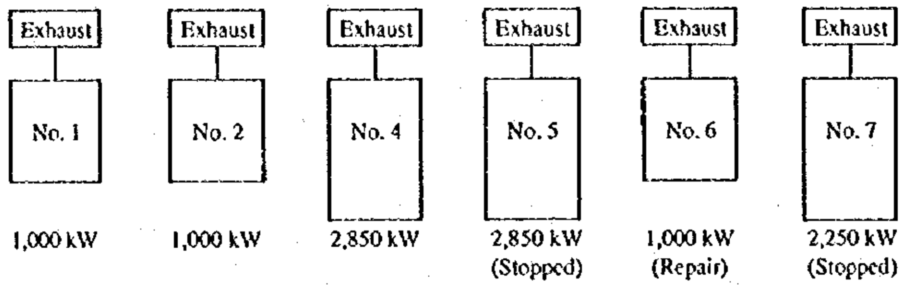
Heat-out (Natural gas)	$kcal/m^3_N$	kcal/h	%
Steam generated	7,776.5	10,887,070	81.50
Exhaust gas loss	1,250.6	1,750,823	13.11
CO loss	0.0	0	0.00
Emission loss	23.5	32,903	0.25
Sub total	9,050.6	12,670,796	94.85
Miscellaneous	491.6	688,172	5.15
Total	9,542.1	13,358,968	100.00

The oxygen content in the exhaust gas of this boiler is high. If the oxygen content in exhaust gas is reduced to 5 % which is the Japanese standard value, the fuel can be saved by approximately 3.5 %.

(9) Heat recovery from diesel power plant exhaust gas

Six middle-size Diesel engines for electric power generation are installed in this plant as shown in Figure 6.1.14.

Figure 6.1.14 Diesel Generators



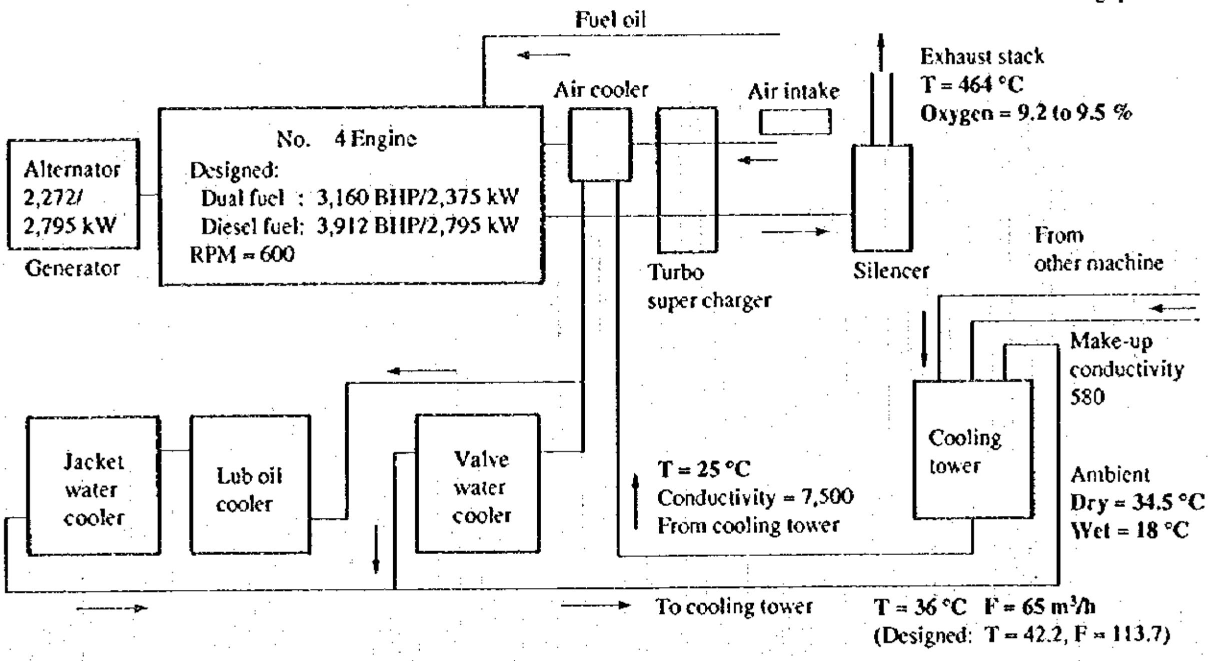
Field measured for:

No.2	No.4
Exhaust gas	Exhaust gas
	Fuel flow
	Cooling water

Among these 6 Diesel engines, we measured the exhaust gas oxygen content, temperature, fuel flowrate, and cooling water volume of the No. 4 Diesel generator which is a large-scale machine, and the measurement results are indicated in Figure 6.1.15. We also measured the exhaust gas for Diesel No. 2 and its results are indicated in the same diagram.

Figure 6.1.15 Simplified Flow Diagram and Measurement of Diesel No. 4

11-Aug. pm



Valve coolant and jacket coolant have independent cooling circuit respectively.

Jacket coolant: Cooler in T = 76 °C by surface contact thermo — 12-Aug. 10:40
Cooler out T = 70 °C — Power
F = 11.7 m^3/h by U.S flow meter — 1,640 kW

Air-in and -out to air cooler (surface contact thermo)
-in T = 89 °C (after supercharger)
-out T = 48 °C
Super charger inlet air T = 43 °C

Exhaust gas (surface contact thermo)
Expansion turbine-in T = 483 °C
Expansion turbine-out T = 371 °C

Exhaust gas temperature (panel reading)

No. 1	560 °C	No. 5	553 °C
No. 2	565 °C	No. 6	555 °C
No. 3	530 °C	No. 7	520 °C
No. 4	530 °C	No. 8	520 °C

Power-out, 15:10
1,520 to 1,560 kW

No. 2 engine stack gas, as reference
T = 335 °C
Oxygen = 14.0 %

Remark: Block letters for field measured value.

This engine has the closed circuit cooling system for cooling the cylinder and valve. Figures 6.1.16 and 6.1.17 show the cooling water around the engine and the fuel system. Since there is no demand of hot water near the engine, only the steam recovery from the exhaust gas was investigated.

Figure 6.1.16 Water Line for Diesel No. 4

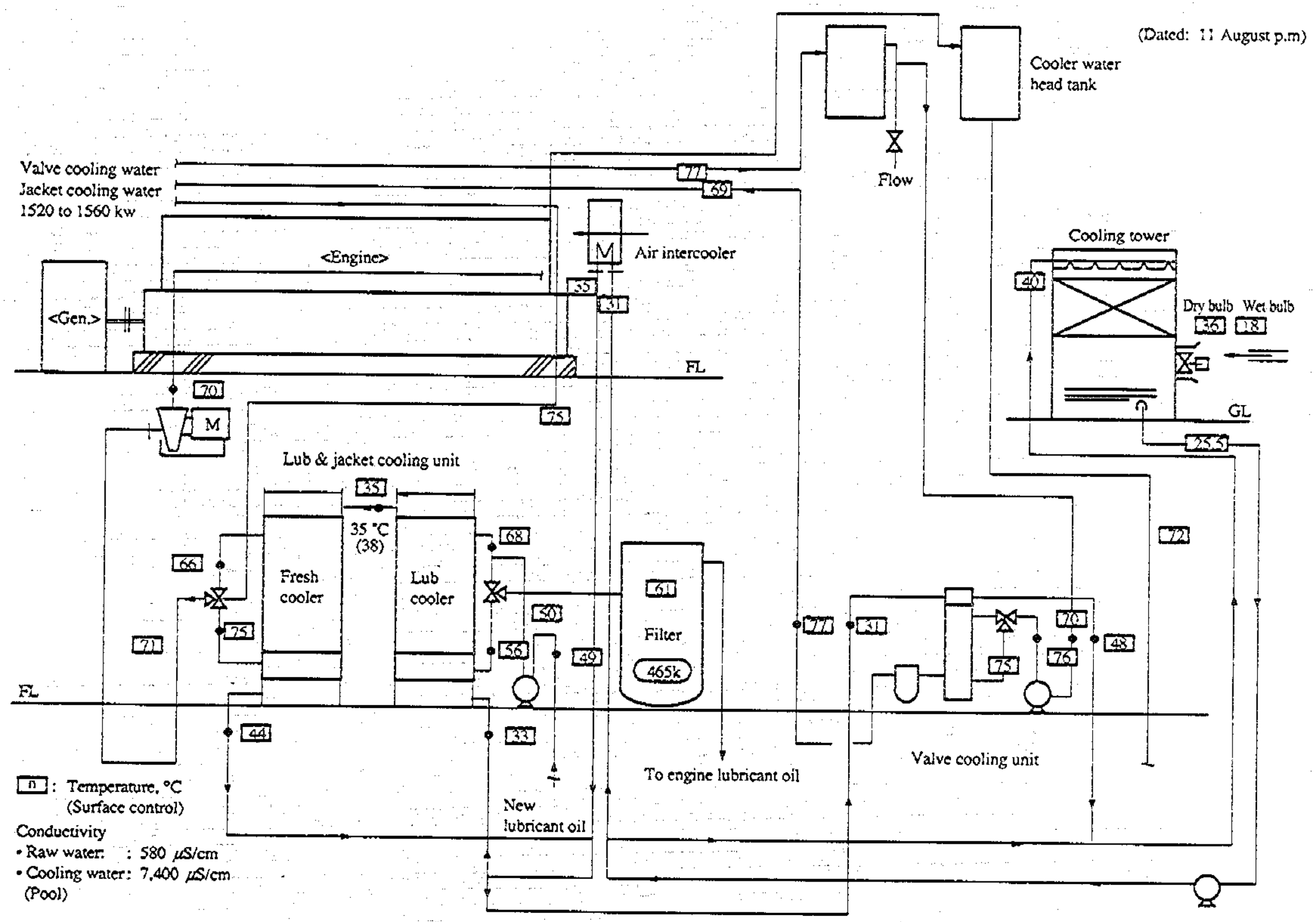


Figure 6.1.17 Fuel and Exhaust Gas Flow for Diesel No. 4

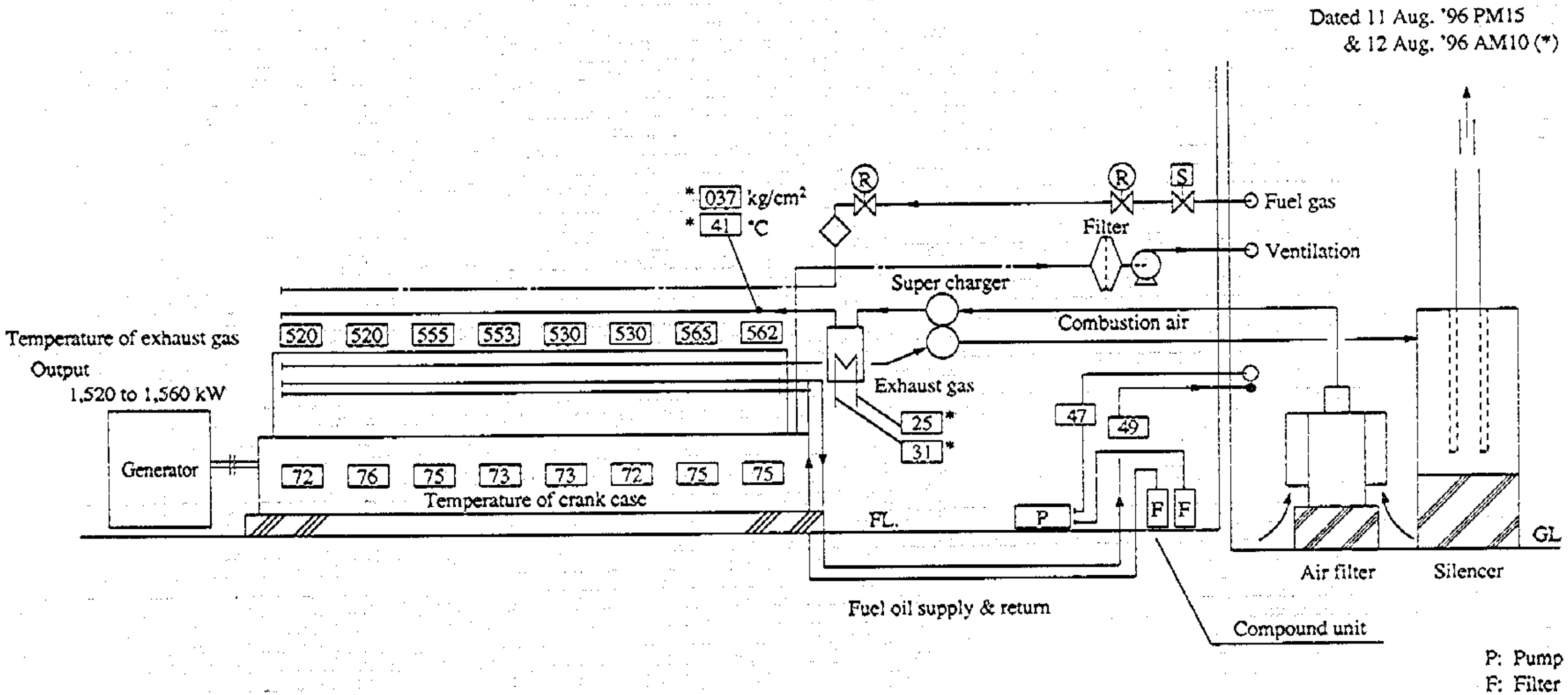


Table 6.1.16 gives the result of a case study of recovering the exhaust gas heat volume as steam. The steam volume which can be recovered from a large-sized Diesel engine is approximately 1.3 t/h. If this recovered heat can be utilized effectively, the thermal efficiency will improve to approximately 50 % from about 30 % by power generation only. In addition, 7,823 Gcal/y can be reduced for the boiler.

Table 6.1.16 Exhaust Heat Analysis (No. 4 Engine)

Exhaust gas temperature, °C	464
Unit exhaust gas (Oxygen = 9.3 %), m^3/kg-fuel	19.5
Specific heat, kcal/(°C·m^3)	0.338
Temperature after heat recovery	150
Available heat per fuel, kcal/kg-fuel	2,070
Annual power generation, kWh/y	10,862,400
Assumed generating efficiency	30 %
Fuel heat requirement, Gcal/y	31,139
Fuel consumption, t/y	3,023
Fuel combustion heat, kcal/kg	10,300
Annual heat recovery, Gcal/y	6,257
Assumed boiler efficiency	80 %
Fuel saving, annually, Gcal/y	7,821
10 bar steam heat, (kcal/kg)	663
Engine running ratio	85 %
Recovered steam, kg/h	1,267

(10) Electric power supply and demand

The electric power of this plant is supplied by the in-house power plant and the external power system. The purchased electricity is supplied by one 20 kV line and the maximum demand is 2,500 kW.

Total of 13,450 kW is generated as an in-house power plant by the condensing extraction turbine power generator and 6 Diesel generators. Among these, however, one 2,250 kW and three 1,000 kW Diesel generators have been operating for more than 30 years. Therefore, for stable operation, the power generation of the 2,250 kW Diesel generator is kept to 1,500 kW maximum, and that of 1,000 kW Diesel generator is kept to 700 kW maximum.

The maximum output of two 2,850 kW Diesel generators are kept to 1,800 kW due to a high exhaust gas temperature. Therefore, the actual total power generation capacity is 9,700 kW. As the electric power operation method, the steam turbine generator is used for base operation and the Diesel generator is used for absorbing the load fluctuation at the plant.

The utilization factor (= average electric power/generator rating output) of the generator in 1994 was 13 to 29 % for the Diesel generator and 58 % for the turbine generator as indicated in Table 6.1.6. These values indicate that there is a sufficient allowance. However, considering the bottleneck in the way of parts supply for aged equipment, a light-load operation may be unavoidable in order to reduce the chance of accidents.

For the electric power supply, the purchased power system and private power generating plant are completely separated from each other, and there is no flexibility in the supply and demand of electric power. In other words, even from standpoint of the contracted power, the maximum power adjustment is performed by only controlling the load. No advantage is taken to reduce the maximum power by adjusting the power output of the private power generating plant.

At the time of our investigation, no electric power was supplied from the purchased power system. The ratio of the private power generating plant supply to purchased electric power in 1994 (March 1994 to March 1995) was approximately 4 to 1.

There are no synchronous motor and power condenser for the plant load, and no measures for improving the power factor have been taken either. Although the power factor of the plant at the time of our investigation was 76 %, which does not seem to be satisfactory, now one cannot expect to benefit from the merits of condenser installation by reduction of electric tariff. Therefore, this problem should be solved together with the utilization factor mentioned earlier at the same time when the purchased power system is reinforced and becomes reliable in the future.

(11) Pump

The plant water is supplied by 4 submergible pumps from the well. Three pumps are fully operational in summer and 2 pumps are fully operational in other seasons. In all seasons, the No. 3 machine controls the water volume with water pressure. Table 6.1.17 indicates the electric power measurement results of each pump.

Table 6.1.17 Measurement Result of Electric Power for Well Pump and Calculation Result of Pump Efficiency

	No. 2	No. 3	No. 4	No. 5
P (kg/cm²)	13.5	13.5	13.5	13.5
Q (m³/h)	99	112	115	118
Efficiency of motor (%)	0.9	0.9	0.9	0.9
W (kW)	61	69.7	75.7	72.4
Efficiency of pump (%)	66	66	62	67

According to this table, the pump efficiency is 62 % to 67 %, which is rather low for a large-size pump. However, this value may be unavoidable considering that these are submergible pumps. Table 6.1.18 indicates the electric power measurement results of other large-size pump motors.

Table 6.1.18 Measurement Result of Electric Power for Large Pump Motor

Time	kW	kvar	kVA	p. f	U. F
Turbine condenser pump (13 Aug. 1996) 60 HP					
16:34	54.77	37.22	66.22	0.827	124.2
16:36	54.61	37.18	66.07	0.827	123.8
16:38	61.19	41.83	74.12	0.826	138.8
16:40	68.03	45.82	82.02	0.829	154.3
16:42	60.31	41	72.93	0.827	136.8
Cooling tower pump for Refinery No. 1 & No. 2 110 HP					
16:22	56.17	41.94	70.10	0.801	69.4
16:24	56.23	41.88	70.11	0.802	69.5
16:26	56.2	41.87	70.08	0.802	69.5
16:28	56.25	41.86	70.12	0.802	69.5
16:30	56.22	42.01	70.18	0.801	69.5
Cooling pond pump for Refinery No. 2 90 kW					
15:28	71.07	33.92	78.75	0.902	79.0
15:30	71.03	33.9	78.70	0.902	78.9
15:32	71.1	33.97	78.80	0.902	79.0
15:34	71.14	34.05	78.87	0.902	79.0
15:36	71.21	34.1	78.95	0.902	79.1

We could not measure the water volume of these pumps. However, it can be assumed that there is no problem regarding the motor load in view of the equipment utilization factor and power factor.

The first thing that must be done to improve the energy efficiency of a pump is to check whether the present water volume is appropriate. It is necessary to check the volume of water used by the plant by considering the regulations of subterranean water in the future particularly for the well pumps, and to study the possibility of recycling the water.

(12) Transformer

We investigated whether it would be possible to shut down one of the two 1,000 kVA transformers used for the Filling Substation, which are operating in parallel. The measurement results we obtained during our study of the plant are indicated in Table 6.1.19. Since the test records of these transformers were not available, we compared the operations between one transformer and two transformers for the following two cases: (1) iron loss 2.5 kW and full load copper loss 12.5 kW and (2) iron loss 3.5 kW and full load copper loss 14.8 kW using the typical example in Japan. The trial calculation results are indicated on the right side of Table 6.1.19.

In the case of (1), the transformer loss can be reduced by 10 kWh/day (= 3,650 kWh/year) by operating one transformer during the night (22:00 to 6:00). In the case of (2), the transformer loss can be reduced by 20.9 kWh/day (= 7,640 kWh/year) by operating one transformer all day.

It is necessary to know the characteristics of the transformer in either case, and the number of transformers to be operated should be determined in accordance with the load situation in the future.

(13) Summary of effects by application of the proposals

Table 6.1.20 gives the above energy conservation measures.

Table 6.1.19 Measurement Result of Filling Substation Transformers (1/2)

Filling transformer measurement

	Transformer No. 1				Transformer No. 2				Transformer total			
Time	kW	kvar	kVA	p. f	kW	kvar	kVA	p. f	kW	kvar	kVA	p. f
14:00	235.3	205.2	312.2	0.754	231.1	210.3	312.5	0.740	466.4	415.5	624.6	0.747
15:00	259.4	225.6	343.8	0.755	254.6	231.4	344.0	0.740	514	457	687.8	0.747
16:00	262.8	222	344.0	0.764	258	228	344.3	0.749	520.8	450	688.3	0.757
17:00	255.9	216.5	335.2	0.763	251.2	222.3	335.4	0.749	507.1	438.8	670.6	0.756
18:00	256.3	219.1	337.2	0.760	251.4	224.9	337.3	0.745	507.7	444	674.5	0.753
19:00	257.6	213.5	334.6	0.770	252.7	219.3	334.6	0.755	510.3	432.8	669.1	0.763
20:00	260.6	217.7	339.6	0.767	255.6	223.6	339.6	0.753	516.2	441.3	679.1	0.760
21:00	248.9	213	327.6	0.760	244.2	218.7	327.8	0.745	493.1	431.7	655.4	0.752
22:00	200.8	166.6	260.9	0.770	197.3	171.2	261.2	0.755	398.1	337.8	522.1	0.762
23:00	183.7	149	236.5	0.777	180.7	153.3	237.0	0.763	364.4	302.3	473.5	0.770
00:00	177.7	143.3	228.3	0.778	174.6	147.5	228.6	0.764	352.3	290.8	456.8	0.771
01:00	173.4	138.7	222.0	0.781	170.5	142.8	222.4	0.767	343.9	281.5	444.4	0.774
02:00	171	136.3	218.7	0.782	168.2	140.3	219.0	0.768	339.2	276.6	437.7	0.775
03:00	168.8	135.6	216.5	0.780	166	139.4	216.8	0.766	334.8	275	433.3	0.773
04:00	166.9	135.7	215.1	0.776	164.1	139.5	215.4	0.762	331	275.2	430.5	0.769
05:00	166.3	135.8	214.7	0.775	163.5	139.5	214.9	0.761	329.8	275.3	429.6	0.768
06:00	175.9	153.1	233.2	0.754	172.7	156.8	233.3	0.740	348.6	309.9	466.4	0.747
07:00	238.5	212.4	319.4	0.747	234.1	217.2	319.3	0.733	472.6	429.6	638.7	0.740
08:00	251.3	223.5	336.3	0.747	246.7	228.8	336.5	0.733	498	452.3	672.7	0.740
09:00	261.9	232.5	350.2	0.748	257.3	238.2	350.6	0.734	519.2	470.7	700.8	0.741
10:00	261.6	236.4	352.6	0.742	256.8	242.2	353.0	0.727	518.4	478.6	705.5	0.735
11:00	260.8	234.6	350.8	0.743	256.3	240.3	351.3	0.730	517.1	474.9	702.1	0.737
12:00	237.8	211.3	318.1	0.748	233.8	216.2	318.4	0.734	471.6	427.5	636.5	0.741
13:00	212	193.4	287.0	0.739	208.2	197.7	287.1	0.725	420.2	391.1	574.0	0.732
Average	222.7	190.5	293.0	0.760	218.7	195.4	293.3	0.746	441.5	385.8	586.3	0.753
Maximum	262.8	236.4	352.6	0.782	258	242.2	353.0	0.768	520.8	478.6	705.5	0.775
Minimum	166.3	135.6	214.7	0.739	163.5	139.4	214.9	0.725	329.8	275	429.6	0.732

Table 6.1.19 Measurement Result of Filling Substation Transformers (2/2)

Transformer loss	Iron loss = 2.5 kW Copper loss = 12.5 kW				Transformer loss	Iron loss = 3.5 kW Copper loss = 14.8 kW			
Tr1 (kW)	Tr2 (kW)	Tr1 + Tr2	Only Tr1	Difference	Tr1 (kW)	Tr2 (kW)	Tr1 + Tr2	Only Tr1	Difference
3.72	3.72	7.44	7.38	0.06	4.94	4.94	9.89	9.27	0.61
3.98	3.98	7.96	8.41	-0.46	5.25	5.25	10.50	10.50	0.00
3.98	3.98	7.96	8.42	-0.46	5.25	5.25	10.51	10.51	-0.01
3.90	3.91	7.81	8.12	-0.31	5.16	5.17	10.33	10.16	0.17
3.92	3.92	7.84	8.19	-0.34	5.18	5.18	10.37	10.23	0.13
3.90	3.90	7.80	8.10	-0.30	5.16	5.16	10.31	10.13	0.19
3.94	3.94	7.88	8.27	-0.38	5.21	5.21	10.41	10.33	0.09
3.84	3.84	7.68	7.87	-0.18	5.09	5.09	10.18	9.86	0.32
3.35	3.35	6.70	5.91	0.80	4.51	4.51	9.02	7.53	1.48
3.20	3.20	6.40	5.30	1.10	4.33	4.33	8.66	6.82	1.84
3.15	3.15	6.30	5.11	1.20	4.27	4.27	8.54	6.59	1.96
3.12	3.12	6.23	4.97	1.27	4.23	4.23	8.46	6.42	2.04
3.10	3.10	6.20	4.89	1.30	4.21	4.21	8.42	6.34	2.08
3.09	3.09	6.17	4.85	1.33	4.19	4.20	8.39	6.28	2.11
3.08	3.08	6.16	4.82	1.34	4.18	4.19	8.37	6.24	2.13
3.08	3.08	6.15	4.81	1.35	4.18	4.18	8.37	6.23	2.13
3.18	3.18	6.36	5.22	1.14	4.30	4.31	8.61	6.72	1.89
3.77	3.77	7.55	7.60	-0.05	5.01	5.01	10.02	9.54	0.48
3.91	3.92	7.83	8.16	-0.33	5.17	5.18	10.35	10.20	0.15
4.03	4.04	8.07	8.64	-0.57	5.32	5.32	10.63	10.77	-0.13
4.05	4.06	8.11	8.72	-0.61	5.34	5.34	10.68	10.87	-0.18
4.04	4.04	8.08	8.66	-0.58	5.32	5.33	10.65	10.80	-0.15
3.76	3.77	7.53	7.56	-0.03	5.00	5.00	10.00	9.50	0.50
3.53	3.53	7.06	6.62	0.44	4.72	4.72	9.44	8.38	1.06
				6.71					20.91

Table 6.1.20 Summary of Proposals

(Japanese Yen base)

Item	Expected Saving						Total	Investment	Payback
	Fuel			Electricity			Million	Million	Period
	10^3 m³/y	Million yen/y	%	MWh/y	Million yen/y	%	yen/y	yen	Year
Heat insulation of steam valves and flanges	266*1	4.9	0.7*5	–			4.9	19	3.9
Adjustment of the vacuum degree in the deodorizing process Adjustment of ejector steam pressure Reduction of the cooling water temperature for the barometric condenser	5,534*2	101.3	14.4*6	–			101.3	0	0
Boiler combustion control	1,342*3	24.6	3.5	–			24.6	30	1.2
Recovery of exhaust gas heat from diesel power generation	798*4	14.6	2.1*7	–			14.6	50	3.4
Total	7,940	145.4	20.7	–			145.4	99	0.7

(Iran Rial base)

Item	Expected Saving						Total	Investment	Payback
	Fuel			Electricity			Million	Million	Period
	N.gas 10^3 m³/y	Million Rial/y	%	MWh/y	Million Rial/y	%	Rial/y	Rial	Year
Heat insulation of steam valves and flanges	(266)*1	(33)	(0.7)*5	–			(33)	(333)	(10.1)
Adjustment of the vacuum degree in the deodorizing process Adjustment of ejector steam pressure Reduction of the cooling water temperature for the barometric condenser	5,534*2	681	14.4*6	–			681	0	0
Boiler combustion control	1,342*3	165	3.5	–			165	525	3.2
Recovery of exhaust gas heat from diesel power generation	798*4	98	2.1*7	–			98	875	8.9
Total	7,674	944	20.0	–			944	1,400	1.5

*1 $2{,}607 \times 10^6$ kcal/y / 9,800 kcal/m³ = 266×10^3 m³/y

*2 $\dfrac{245{,}100 \text{ t/y} \times 267 \text{ kg/t} \times 663 \text{ kcal/kg}}{9{,}800 \text{ kcal/m}^3 \times 0.8} = 5{,}534 \times 10^3 \text{ m}^3\text{/y}$

*3 $\dfrac{453{,}491 \text{ t/y} \times 663 \text{ kg/t} \times 10^3 \text{ kcal/t}}{9{,}800 \text{ kcal/m}^3 \times 0.8} = 38{,}350 \times 10^3 \text{ m}^3\text{/y}$

$38{,}350 \times 10^3 \text{ m}^3\text{/y} \times 0.035 = 1{,}342 \times 10^3 \text{ m}^3\text{/y}$

*4 $7{,}823 \times 10^6$ kcal/y / 9,800 kcal/m³ = 798×10^3 m³/y

*5 $266 \times 10^3 / (38{,}350 \times 10^3) \times 100 = 0.7$ %

*6 $5{,}534 \times 10^3 / (38{,}350 \times 10^3) \times 100 = 14.4$ %

*7 $798 \times 10^3 / (38{,}350 \times 10^3) \times 100 = 2.1$ %

Energy price in Japan:
- Fuel price: 17,000 yen × 9.8 / 9,100 = 18.31 yen/m³
- Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
- Natural gas: 123 Rial/m³
- Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japnaese Yen

Investment cost is based on that in Japan.

6.2 Results of the Study at Karun Cane Company

6.2.1 Outline of the factory

(1) Plant name

Karun Cane Company

(2) Plant address

Khuzestan Shushtar

(3) Number of employees

1,150 (including seasonal workers) consisting of

9 process engineers,
1 heat engineer, and
2 electrical engineers.

(4) Major products

Cane sugar

(5) Production capacity

200,000 t/y

(6) Production process

Sugarcane cultivated in the adjacent farm is received as the raw material for producing sugar. This sugar cane is first made into raw sugar, which is then remelted and refined into white sugar.

Sugarcane is finely cut by a cane cutter, and then applied on the cane crusher instead of a cane shredder, which is not available in this plant, and pressed by the mill to extract juice. There are 3 lines of mill, which consists of 6 units, thus reducing the water content of the bagasses.

Since bagasse is sold to a paper manufacturing company as the raw material for paper, it is not used as fuel at this plant. The sugar juice coming out from the clarifier is concentrated by the quadruple-effect evaporator, then made into massecuite by the crystallizer with an agitator, and centrifuged into raw sugar.

Before the raw sugar is stored, it is applied on the dryer.

The raw sugar is then fed to the sugar refinery, where it is applied on the washed sugar separator and thereafter melted by the melter.

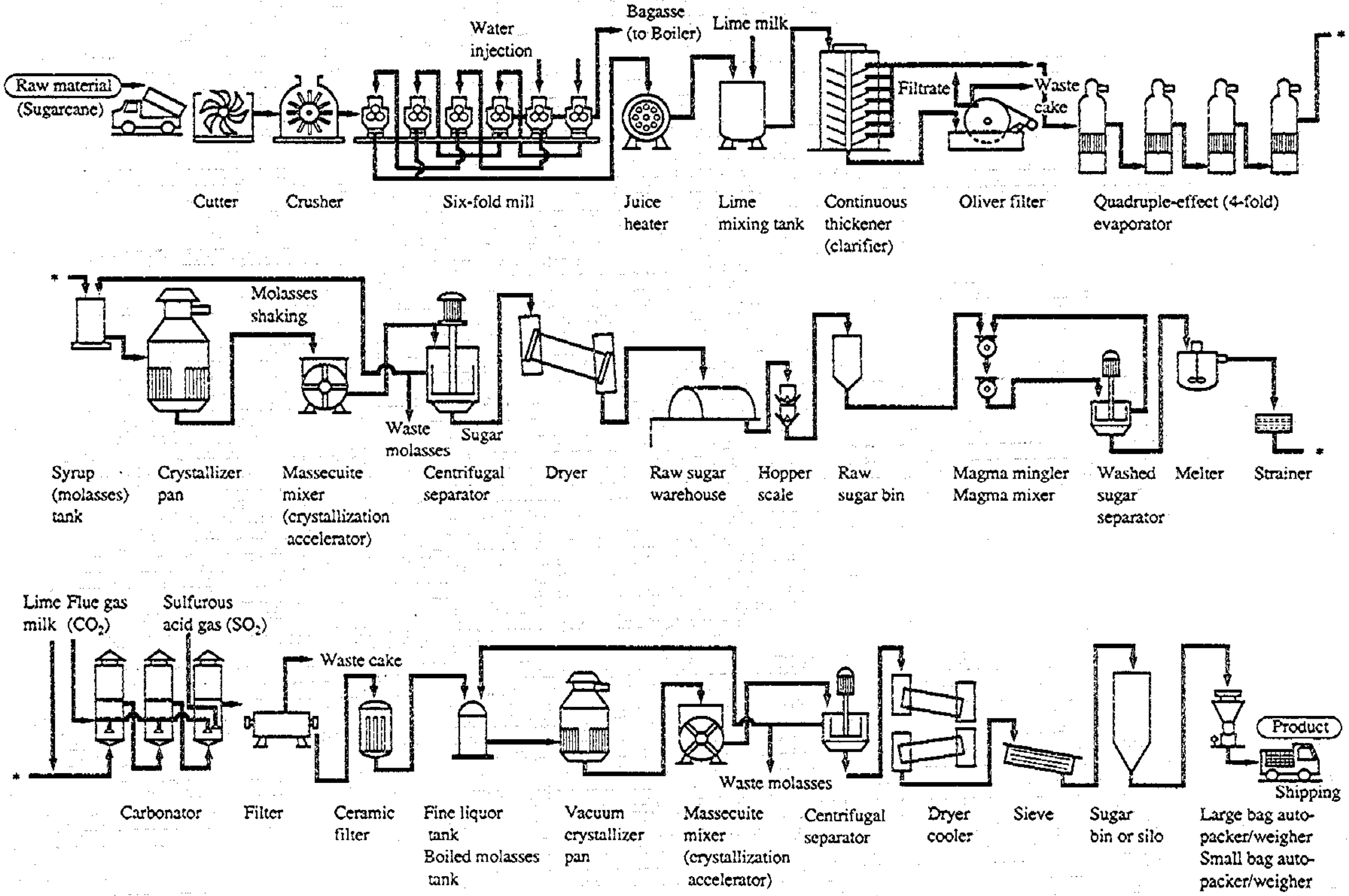
The melted sugar is, after carbonation, bleached by sulfurous acid gas instead of ion exchange resin, and boiled by the crystallizer.

The crystallizer is equipped with an agitator. The massecuite is placed on the centrifugal separator, and mixed with the second sugar to be made into a final product.

The molasses of first sugar is mixed and boiled in second sugar, and the molasses of second sugar is mixed and boiled in third sugar. Third sugar is returned to the process and the molasses of third sugar is made waste molasses.

Figure 6.2.1 shows the process flow.

Figure 6.2.1 Process Flow



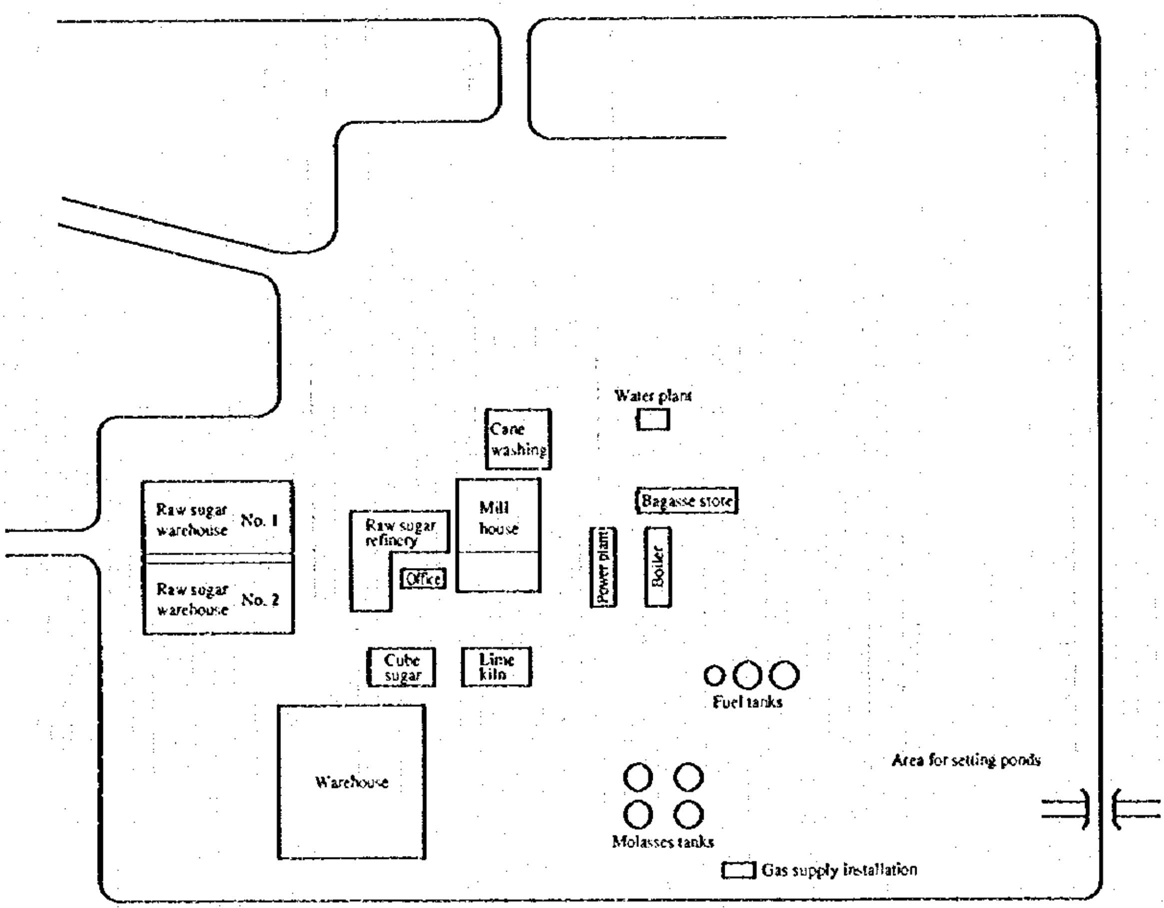
(7) History of the plant

This factory was established under the financial support by the state-run Agriculture Development Bank in 1975. It started operation in 1976.

(8) Plant layout

Figure 6.2.2 shows the plant layout.

Figure 6.2.2 Plant Layout



(9) One line diagram

Figure 6.2.3 shows electric power one line diagram.

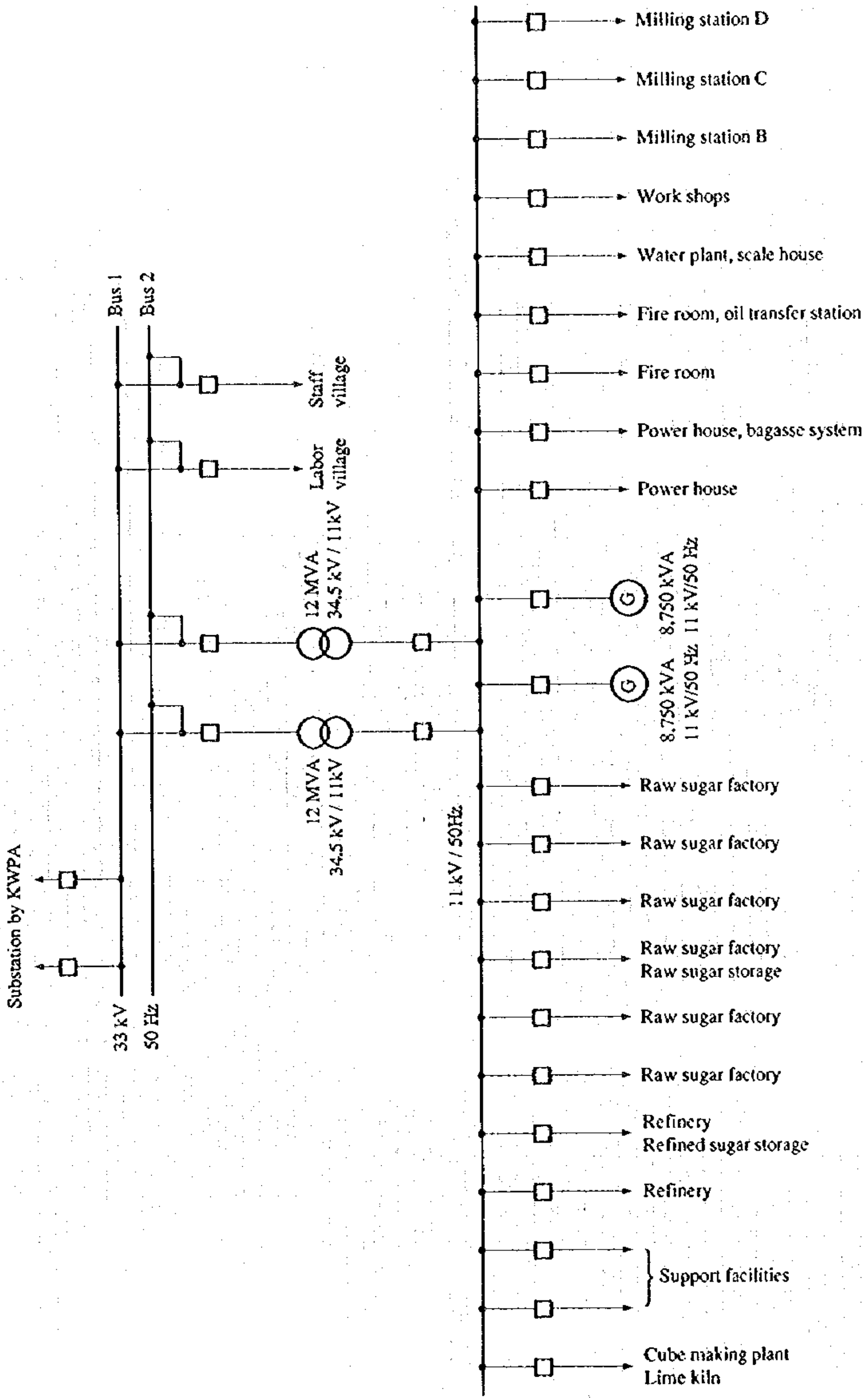


Figure 6.2.3 One Line Diagram

(10) Outline of major equipment

Table 6.2.1 shows the outline of the major equipment.

Table 6.2.1 Major Equipment

Name	Number	Specification
Cutter	3 lines	Diameter 400 mm, 600 RPM
Mill	3 lines	18,000 t/d 6 stands
Raw sugar line		
Evaporator	1	Quadruple effect 1st 125 °C
Boiling pan	12	60 kL/set
Centrifugal separator	38	ϕ48 ~ ϕ53 inch, 1,200 to 1,500 RPM
Refined sugar line		
Melter	1	49 kL
Boiling pan	3	60 kL/set
Centrifugal separator	25	ϕ48 ~ ϕ53 inch, 1,200 to 1,500 RPM
In-house power generation		
Steam turbine generator	2	Back pressure turbine 7,000 kW
		Inlet 31 kg/cm^2 (G), Outlet 4 kg/cm^2 (G)
		11 kV, 8,750 kVA
Receiving transformer	2	34.5 kV/11 kV, 12 MVA
Vacuum pump	6	5,000 m^3/h
Boiler	3	31 kg/cm^2 (G), 380 °C, 180 t/h, Babcock
		Fuel: Bagasse, Natural gas, Oil
Lime kiln	2	Shaft type

(11) Energy prices

Fuel : 30 Rial/L
Electric power: 38.42 Rial/kWh
Water : 30 Rial/m^3

(12) Study period

a. Preliminary study: October 17 and 18, 1995

b. Plenary study: August 17 to 19, 1996

(13) Members of the study group

a. JICA team

Leader : Norio Fukushima
Process management technology
and heat management technology: Shiro Honda
Electric management technology : Kazuo Usui (Preliminary study)
Economic evaluation : Shigeaki Kato (Preliminary study)

b. PBO Team

Energy conservation : Mr. Mazhari
Instrumentation : Mr. Shayesteh (Preliminary study)
Macro level energy management : Mr. Moosavi (Preliminary study)

(14) Interviewees

Mr. Alizadegan: Deputy of Managing Director
Mr. Bavarsad : General Manager of the Factory
Mr. Ayati : Consultant, Director Manager (Pleriminary study)
Mr. Madnoli : Head of Electric Section
Mr. Noorzadeh : Head of Refining Section
Mr. Afshar : Head of Raw Sugar Section
Mr. Shademan : Head of Mechanical Maintenance Section
Mr. Noroozi : Head of Laboratory
Mr. Poure : Advisor (Preliminary study)

6.2.2 Stituation of Energy Consumption

(1) Trend of production, energy consumption and energy intensity

a. Production

Table 6.2.2 shows the trend of production.
The actual result for the year 1994 reveals that 10.0 % of raw sugar, 9.9 % of refined sugar, 35.6 % of bagasse and 4.7 % of molasses are produced from cane (Pol = 15)

Table 6.2.2 Production

		1989*	1990	1991	1992	1993	1994	1995
Cane	t						1,087,411	
Raw sugar	t						108,197	
Refined sugar	t	72,670	104,759	88,145	76,153	93,113	107,000	106,590
Bagasse	t	367,036	427,107	431,291	346,085	334,811	383,845	384,932
Molasses	t	38,406	40,753	59,404	32,462	35,707	54,000	51,087

*: October 1989 to March 1990: This period (from October to March in the next year) also applies to the other years.

b. Energy consumption

Table 6.2.3 shows the trend of energy consumption.

Table 6.2.3 Energy Consumption

		1990*	1991	1992	1993	1994	1995
Natural gas	m^3		56,737,464	67,863,020	85,749,140	66,116,113	95,796,210
Electricity	MWh	23,303	26,948	24,032	25,594	17,602	32,105
Fuel oil	L	47,748					
Steam	t						1,119,722
Water	m^3	976,320	1,019,520	1,022,976	1,002,240	972,864	1,322,474

*: October 1990 to March 1991: This period (from October to March in the next year) also applies to the other years.

c. Energy intensity

Energy intensity for 1995 is as follows:

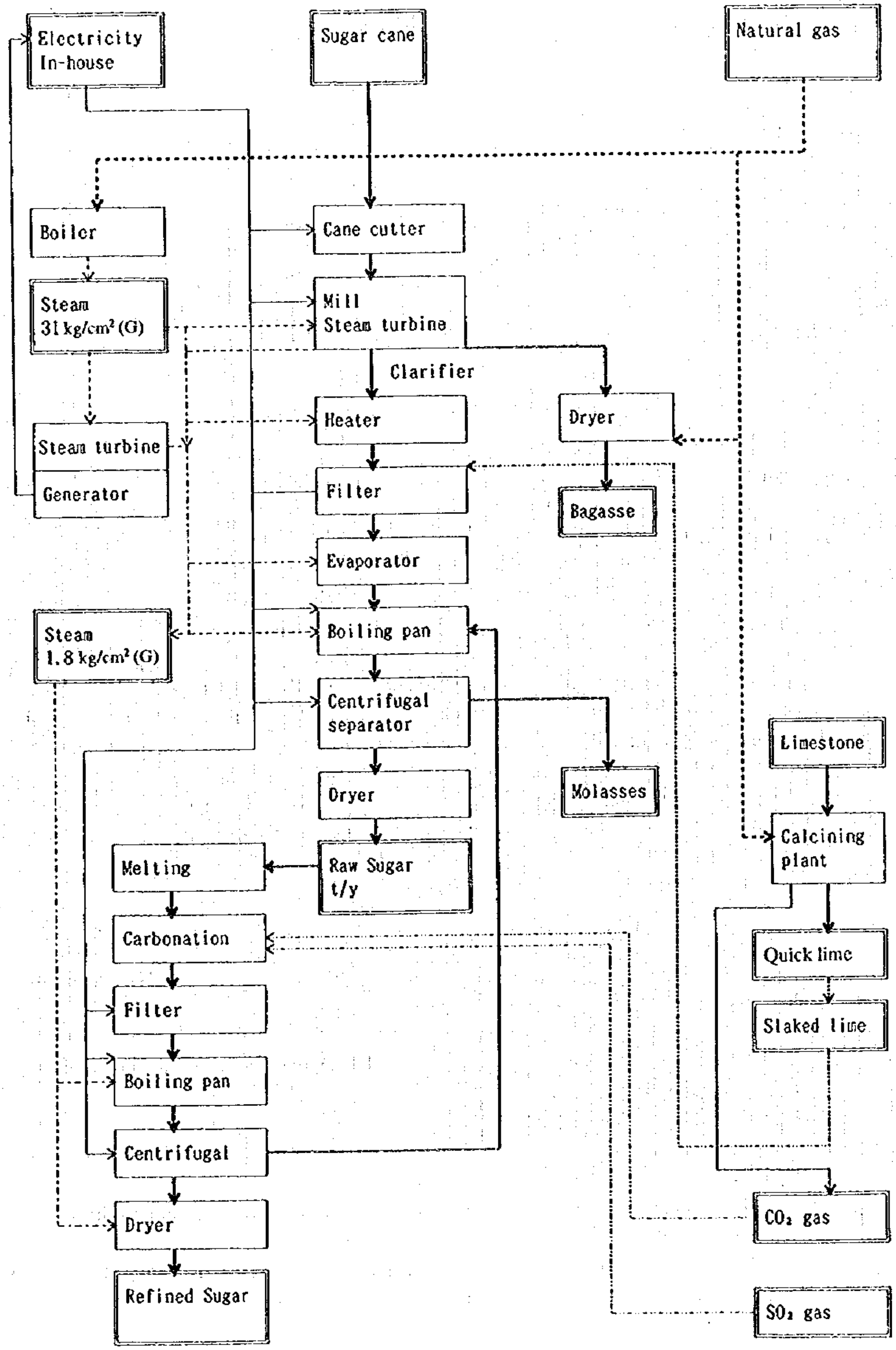
Natural gas : 899 m^3/t 8,541 Mcal/t
Electric power: 301 kWh/t
Steam : 10.5 t/t

(2) Energy flow at normal operation

Figure 6.2.4 shows the energy flow.

Natural gas is used as fuel for the boiler, and electric power is supplied by the steam turbine.

Figure 6.2.4 Energy Flow



(3) Energy intensity by process

Table 6.2.4 shows energy allotment by process.

Table 6.2.4 Energy Allotment by Process

Process	Sugar Factory (%)	Raw Sugar Shop (%)	Refined Sugar Shop (%)
Heater	9	9	–
Melter	3	–	3
Evaporator	49.25	41.25	8
Pan boiling	34.5	22.5	12
Centrifuge	2.25	2.25	–
Dryer	2	–	2
Total	100	75	25

6.2.3 Situation of Energy Management

(1) Setting the target for energy conservation

No target for energy conservation has been set yet. The management should demonstrate their specific policy.

The chief of each department of the workshop is a well-experienced engineer, who is expected to work out a target for energy conservation, future development and a maintenance plan, and thereby to improve energy efficiency.

Since the price of natural gas also tends to increase, a company-wide consensus should be obtained concerning the importance of energy conservation.

(2) Systematic actions

To implement energy conservation, systematic inter-department cooperation is required. An energy conservation committee should be started to obtain a close lateral communication between departments.

This factory has a plenty of competent staffs, and this will enable a lateral communication to be obtained rather easily.

(3) Data-based management

Data-based management is necessary to promote energy conservation activities.

This plant has many operation records of utility generating departments, and analytical records in the product analysis room.

The personnel in charge of quality control creates monthly and annual statistics regarding the production, the yield and the product quality (process analysis and product analysis).

In sugar-manufacturing companies, persons in charge of manufacture are supposed to afford time for data analysis during the non-manufacturing period.

Data from each department should be collected to manage energy conservation effectively. If the target for energy conservation efforts is focused on the crystallizer, it will be equally necessary to enhance measuring instruments. This will make it easier to control the flow rate according to the data on steam, sugar juice and water.

(4) Education and training of employees

Each person in charge of manufacture (raw sugar, refined sugar or utility) has a thorough knowledge of control standards (temperature, time, capacity), etc. through their long-accumulated experiences.

It is noteworthy that they are making every effort to improve the technology by means of exchanging technical data with other sugar-manufacturing companies, joint studies, etc. They employ the same operators every year, who are expected to keep their technological level.

(5) Equipment management

This factory has many old equipment, which are, however, well maintained.

The maintenance of equipment seems to be frequently conducted, because they have plenty of time during the non sugar-manufacturing period and also because heat exchangers, etc. require disassembly-cleaning because of their liability to clogging due to the characteristic of the process.

Mild steel is used for the heat transfer surface of the crystallizer, and this allows scales to occur more easily. To cope with this problem, such measure as softening of juice by means of ion exchange resin will be considered.

We could hardly detect any bare piping or parts where heat-insulating work is left undone. However, boiler measuring instruments and stokers do not seem to be well maintained.

6.2.4 Problems in the Energy Utilization and the Countermeasures

(1) Comparison with a Japanese excellent plant

Table 6.2.5 shows the result of comparing the energy intensity of Karun Cane Company with that of a Japanese average cane sugar plant.

Table 6.2.5 Comparison of Energy Intensity

	Karun Cane		Japan	
	Raw Sugar	Refined Sugar	Raw Sugar	Refined Sugar
For thermal energy	75 %	25 %		
Steam	7.9 t	2.7 t	5.1 t	1.41 t
Fuel	5,056 Mcal	1,728 Mcal	3,264 Mcal	903 Mcal
Total	6,784 Mcal		4,167 Mcal	
Electricity	301 kWh		205 kWh	95 kWh
	259 Mcal		176 Mcal	82 Mcal
Total	259 Mcal		258 Mcal	
Total of steam and Electricity	7,043 Mcal		4,425 Mcal	

Setting conditions:	Natural gas	9,400 kcal/m^3
	Steam	2 kg/cm^2 (G)
		640 kcal/kg
	Electricity	860 kcal/kWh
	Fuel	9,500 kcal/fuel-L

As shown in Table 6.2.5, the fuel intensity of this plant is approximately 1.6 times higher than that of the Japanese plant, but the electricity intensity is nearly equal to that of the Japanese plant.

The possible reasons for this difference may be as follows:

a. Difference in the yield

The yield of this plant remains 9.9 %, as compared with 12 % yield of the Japanese plant where the sugar cane similar to that used in I.R Iran is used. This is because the sugar cane storage time is longer, deteriorating the sugar content and increasing waste molasses. Moreover, the low level of purity in the production process increases molasses, thus reducing the yield. This difference in yield makes an approximately 20 % difference in energy intensity.

b. Operating conditions

Table 6.2.6 shows the comparisons of operating conditions in the refining process between this plant and a Japanese plant.

Table 6.2.6 Comparisons of Operating Conditions between Refineries

Refined Sugar		Karun Cane	Japan
Melter	in	Bx 65	Bx 68
	out	Bx 45	Bx 60
Refined sugar evaporator	in	Bx 60	Bx 65
		Vacuum 65 to 70 mmHg	Vacuum 72 to 73 mmHg
Boiling pan		With a stirrer	With a stirrer
Boiling hour		1st 2 h/batch	1st 1.8 h/batch
		2nd 2.5 h/batch	2nd 2.2 h/batch
		3rd 3 h/batch	3rd 3 h/batch
Charge		1st 55 kL	1st 61 kL
		2nd 55 kL	2nd 61 kL
		3rd 55 kL	3rd 61 kL
Remarks		Active carbon method and sulfurous acid method	Active carbon method and ion exchange resin

Bx45 at the inlet of the refined sugar evaporator is low. This is probably due to the difference in Bx at the melter and much mixture of water in the subsequent processes of filtering, etc.

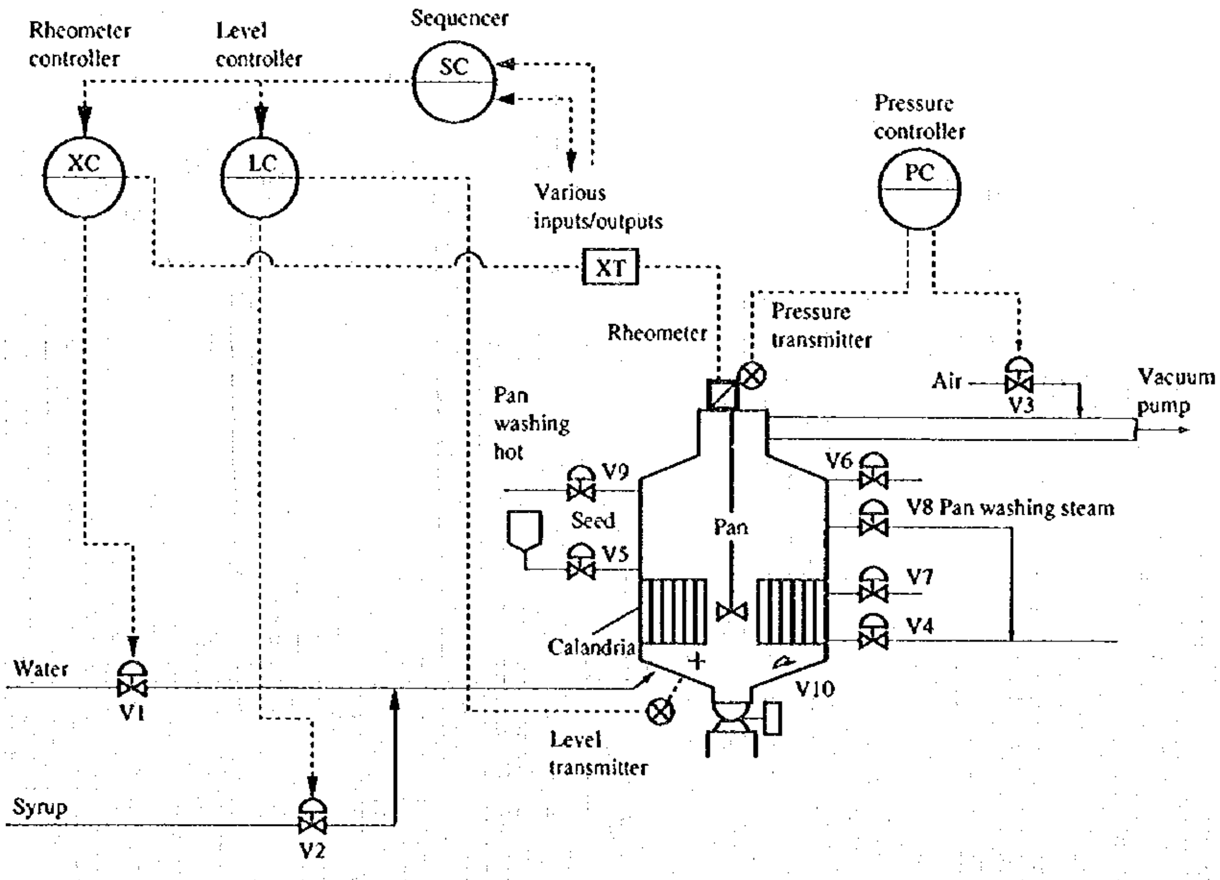
In Japan, the sugar boiling time is shorter because the vacuum of the crystallizer pan is high. The availability of low-temperature cold water for the condenser water contributes to raising the vacuum.

When water addition and concentration/crystallization at the crystallizer pan are not thoroughly controlled, uneveness and disparity of crystal will occur even if an agitator is installed. This increases the volume of water to be added and makes the sugar boiling time longer.

(2) Reduction of the sugar boiling time by automatic control of the crystallizer pan

The first sugar boiling time is 3 hours for raw sugar and 2 hours for refined sugar. The crystallizer pan has an agitator installed, but further to shorten the sugar boiling time, it will be advisable to adopt an automatic control system employed in recent plants. Figure 6.2.5 shows the general system.

Figure 6.2.5 Automatic Control System Diagram



It is vitally important for the pan boiling to control the concentration of the sugar liquor in the pan during sugar boiling. The sugar boiling operation is conducted in the following procedure.

a. The crystallizer pan is made vacuum.

b. The sugar liquor (syrup) or molasses is suctioned up to the level enough to fill the calandria (heat transfer surface).

c. Steam is introduced.

d. For the first sugar, the syrup is boiled until it becomes supersaturated (Bx84) suitable to start crystallization (Supersaturation degree 84/75 = 1.12).

e. The seed sugar is suctioned to produce a base crystal. To grow this base crystal, the liquor continues to be boiled until the specified massecuite amount can be obtained while keeping the supersaturation degree of the liquor in the pan at 1.1 to 1.2 by suction of the syrup.

f. The mobility is measured, and the vacuum in the pan is relieved to make the pressure normal. Then massecuite is let to drop on the massecuite mixer.

g. The pan is cleaned to return to normal.

Excessive supersaturation of the mother liquor surrounding a base crystal causes secondary crystallization to occur, interfering with the molasses separating operation. Moreover, crystals sticking together form false crystal, and make the crystal size uneven, thus degrading the product value. In recent years, the proper control of liqour concentration has become available through the combined use of a mobility controller and a level controller. The product grain size can be made uniform and the water addition can be reduced by automatically controlling syrup concentration and water addition while measuring the mobility of the liquor in the crystallizing pan so as to obtain a proper crystal concentration in the sugar being boiled.

The reduction effects of water addition are as follows:

First sugar massecuite	4 kL → 2 kL/batch
Second sugar massecuite	6 kL → 3 kL/batch
Third sugar massecuite	10 kL → 5 kL/batch

The energy conservation effect is estimated to be 5 %.

Furthermore, the effect by reducing the sugar boiling time in the crystallizer pan can be seen in the first massecuite. The sugar boiling time in the crystallizer pan can be reduced to 1.8 hours from 2 hours (10 % reduction), leading to 3 % energy conservation.

(3) Ion exchange

In the raw sugar process, it is preferable to install a cation exchange resin softener in the preceding process of the evaporator. This can prevent the scale sticking on the heat transfer surface, leading to energy conservation for the evaporator. Two units of ion exchange resin towers are required, which costs 100 million yen for equipment investment including ion-exchange resin.

The use of a softening equipment requires one more tower, that is, two towers. As the result of this measure, steam consumption is expected to be reduced by 5 %, including the effect on the crystallizing pan.

In Japan, where acid sulfitation is prohibited, decolorization by active carbon is performed after carbonation to produce plantation white sugar. Coloring matters and a part of calcium are absorbed by decolorization by active carbon, which can decrease the occurrence of scale in the evaporator.

For the refined sugar, a coloring matter in the juice is exchanged with Cl ion through R-Cl type strong basic anion exchange resin. A part of sulfate is exchanged with Cl and the treated liquor forms relatively less scales, thus eliminating the pan washing operation in the crystallizer pan. The use of ion exchange resin (R-Cl type) contributes to the improvement of both quality and yield of the refined sugar.

An energy conservation effect by the improvement of yield is estimated at 3 %.

The investment for a plant using an ion exchange resin refining method costs approximately 200 million yen, which will be a future consideration.

(4) Maintenance of bagasse boilers

In this plant, steam is used for steam turbines, the mill driving steam turbines, and evaporation-concentraion of sugar juice.

The boiler plant is equipped with 3 boilers and 2 back pressure turbines. The boilers are operated with bagasse, heavy oil and natural gas as fuel; two of them running, and one stand-by.

Since boilers were under repair at our plant investigation, we could not study the burner combustion status nor could measure the exhaust gas temperature and the oxygen content. Thus, based on the boiler operation log data dated December 23, 1995, the boiler efficiency is estimated to be as follows:

No. 2 boiler: 83.57 %
No. 3 boiler: 88.47 %

Table 6.2.7 and Table 6.2.8 show No. 2 and No. 3 boiler efficiency calculation results respectively.

Table 6.2.7 Boiler No. 2 Heat Balance (net heat value based)

Operation condition

Fuel flow	8,898 m^3_N/h
Steam	105 t/h
	32 kg/cm² (G)
	370 °C
	755 kcal/kg
Exhaust gas	200 °C

Heat-in

	kcal/m^3_N	kcal/h	%
Fuel calorie	10,081	89,704,742	98.56
Air sensible heat	148	1,312,981	1.44
Total	10,229	91,017,723	100.00

Boiler efficiency: 83.57 %
(In/out method)

Heat-out — Natural gas

	kcal/m^3_N	kcal/h	%
Steam generated	8,549	76,067,428	83.57
Exhaust gas loss	1,603	14,266,468	15.67
Emission loss	4	32,903	0.04
Sub total	10,156	90,366,799	99.28
Miscellaneous	73	950,924	0.72
Total	10,230	91,017,723	100.00

Utilized heat detail

	kcal/m^3_N	kcal/h	%
Main body of boiler	6,532	58,123,513	63.86
Economizer	1,005	8,938,395	9.82
Super heater	1,012	9,005,520	9.89
Total	8,549	76,067,428	83.57

Table 6.2.8 Boiler No. 3 Heat Balance (net heat value based)

Operation condition

Fuel flow	8,490 m^3_N/h
Steam	106 t/h
	32 kg/cm² (G)
	369 °C
	755 kcal/kg
Exhaust gas	200 °C

Heat-in

	kcal/m^3_N	kcal/h	%
Fuel calorie	10,081	85,591,511	98.69
Air sensible heat	134	1,137,601	1.31
Total	10,215	86,729,111	100.00

Boiler efficiency: 88.47 %
(In/out method)

Heat-out — Natural gas

	kcal/m^3_N	kcal/h	%
Steam generated	9,038	76,733,225	88.47
Exhaust gas loss	1,014	8,611,234	9.93
Emission loss	4	32,903	0.04
Sub total	10,056	85,377,362	98.44
Miscellaneous	159	1,351,749	1.56
Total	10,215	86,729,111	100.00

Utilized heat detail

	kcal/m^3_N	kcal/h	%
Main body of boiler	6,975	59,214,683	68.28
Economizer	1,000	8,485,910	9.78
Super heater	1,064	9,032,633	10.41
Total	9,038	76,733,225	88.47

The boiler efficiency of this plant is low, considering that the efficiency of the large water tube boiler using natural gas combustion is usually 90 % to 92 %. Air may invade from the stoker for discharging bagasse ash and the stoker inspection door, possibly making the loss of exhaust gas large. Hence, it is necessary to repair it for too much air not to invade into the boiler at combustion of natural gas alone. From the preheated air temperature of 280 °C, the exhaust gas temperature is supposed to be 300 °C or more. An economizer should be installed to improve the waste heat recovery rate and thereby to lower the exhaust gas temperature.

At present, the bagasse can not be used since the stoker for the bagasse boiler remains unrepaired, and thus natural gas alone is used for combustion.

Since the mill is equipped (six-fold), the water content of bagasse is well compressed to as much as 38 %, thus making the bagasse fully available as a fuel. The water content and the combustible standard are as follows.

Water content of bagasse 48 % – requires an auxiliary fuel.
Water content of bagasse 40 % – requires no auxiliary fuel.
Water content of bagasse 38 % – allows a sugar manufacturing plant to be purchased fuel-free and 10 to 20 % of the bagasse to be sold to external companies.

The use of bagasse for fuel is supposed to bring about a remarkable reduction of natural gas. There are many actual cases in the world where bagasse is utilized as fuel.

As the result of our inspecting the furnace inside, a large amount of distortion was found on the stoker. Since tear-off of the inner wall mortar results in clogging in the chain, possibly having damaged the stoker. For the stoker, there seems to be a problem with the material and the structure. After a good consideration of sales of the bagasse to external companies as a material for paper manufacture as well as its economical factor, the stoker should be improved or repaired.

(5) Summary of proposals

The energy conservation measures mentioned above are shown in Table 6.2.9.

Table 6.2.9 Summary of Proposals

(Japanese Yen base)

Item	Expected Saving: Fuel 10^3 m³/y	Fuel Million yen/y	Fuel %	Electricity MWh/y	Electricity Million yen/y	Electricity %	Total Million yen/y	Investment Million yen	Payback Period Year
Automatic control of the crystallizing pan / Decreasing of water addition / Reduction of sugar boiling type	2,594*1	45.6	2.7	-			45.6	30*4	0.7
Adoption of a softening type ion exchange resin	4,790*2	84.1	5.0	-			84.1	100	1.2
Adoption of R-Cl type ion exchange resin	(2,874)*3	(50.5)	(3.0)	-			(50.5)	(200)	(4.0) in the future
Total	7,384	129.7	7.7	-			129.7	130	1.0

(Iran Rial base)

Item	Expected Saving: Fuel N.gas 10^3 m³/y	Fuel Million Rial/y	Fuel %	Electricity MWh/y	Electricity Million Rial/y	Electricity %	Total Million Rial/y	Investment Million Rial	Payback Period Year
Automatic control of the crystallizing pan / Decreasing of water addition / Reduction of sugar boiling type	2,594*1	319	2.7	-			319	525*4	1.6
Adoption of a softening type ion exchange resin	4,790*2	589	5.0	-			589	1,750	3.0
Adoption of R-Cl type ion exchange resin	(2,874)*3	(354)	(3.0)	-			(354)	(3,500)	(9.9) in the future
Total	7,384	908	7.7	-			908	2,275	2.5

Remarks: The items to be implemented in the future are not included in the total column.

*1 95,786,210 m³/y × 0.345 × (1 − 0.95 × 0.97) = 2,594 × 10³ m³/y
*2 95,796,210 m³/y × 0.05 = 4,790 × 10³ m³/y
*3 95,796,210 m³/y × 0.03 = 2,874 × 10³ m³/y
*4 Semi auto controller

Energy price in Japan:
Fuel price: 17,000 yen × 9.4 / 9,100 = 17.56 yen/m³
Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
Natural gas: 123 Rial/m³
Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Investment cost is based on that in Japan.