4. RESULTS OF THE STUDY ON THE NON-METALLIC MATERIALS INDUSTRY

4. NON-METALLIC MATERIALS INDUSTRY

4.1 Results of the Study at Wolomin Plant

(1) Study period: August 12 to 14, 1997

(2) Members of the study team

a. JICA Team

Mr. Yozu Takemura : Leader
Mr. Norio Fukushima : Leader of energy audit & Heat management
Mr. Masami Kato : Process management
Mr. Jiro Konishi : Heat management
Mr. Masashi Miyake : Heat management
Mr. Toshio Sugimoto : Electricity management
Mr. Akihiro Koyamada: Measuring engineerring

b. KAPE and local consultants

KAPE
Mr. Dariusz Koc: Manager of Energy Audit

Research Center of Warsaw University of Technology
Dr. Krzysztof Wojdyga: Heat management in 1997 and 1998
Mr. Maciey Chorzelski : Heat management in 1997
Mr. Wrobel Waldemar : Electricity management in 1997
Dr. Jozef Lastowiecki : Electricity management in 1998
Dr. Tomas Wisiniewski: Heat management in 1998

(3) Interviewees

Mgr inz. Zdzisław Kowalczyk : Technical Director
Mgr inz. Jerzy Kolinski : Production Director, Factory Manager
Mgr inz. Mieczysław Ponichtera: Technical Manager, Process Department
Mgr inz. Jerzy Lutynski : General Manager, Energy Department
Inz. Jozef Skup : Deputy Manager, Technical Department
Mr. Sielewicr Miroslaw : Power Engineering Master
Mgr. inz. Waldemar Pokropski : Technical deputy manager
Inz. Zdzisław Wisiniewski : Technical engineer

4.1.1 Profile of the Plant

(1) Plant name: Huta Szkła Wolomin

(2) Plant address: ul. Wilenska 49/51 05-200 Wolomin

(3) No. of employees: 1,300 (1997), 1,164 (1998)

(4) Major products: Bottle for drink, heat-proof glassware, laboratory glassware, vacuum flask

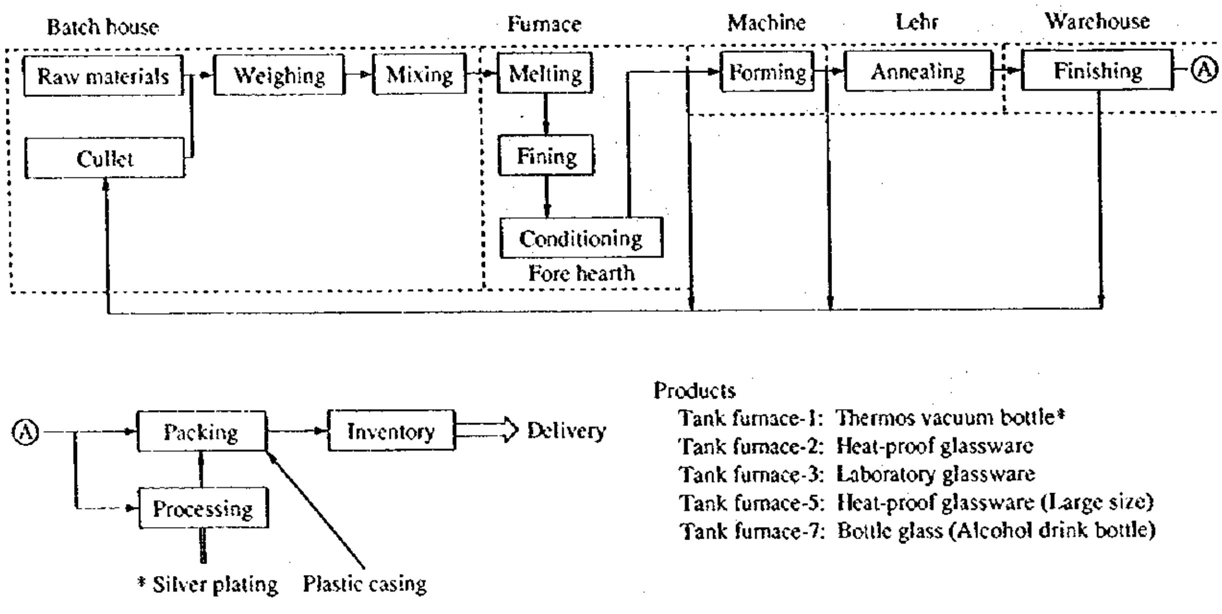
(5) Production capacity: 50,000 t/y

(6) Overview of process

Wolomin Plant consists of a general bottle production line, a heat-proof glassware (large and small) production line, a laboratory glassware production line, and a vacuum bottle production line. After raw materials and cullets are weighed and mixed, they are melted in the melting furnace and thereafter subjected to forming and annealing. A part of them are processed and made into products. Natural gas is used as fuel for the melting furnace, and the boiler is operated only for heating during the winter season.

Figure 4.1.1 shows the process flow.

Figure 4.1.1 Process Flow



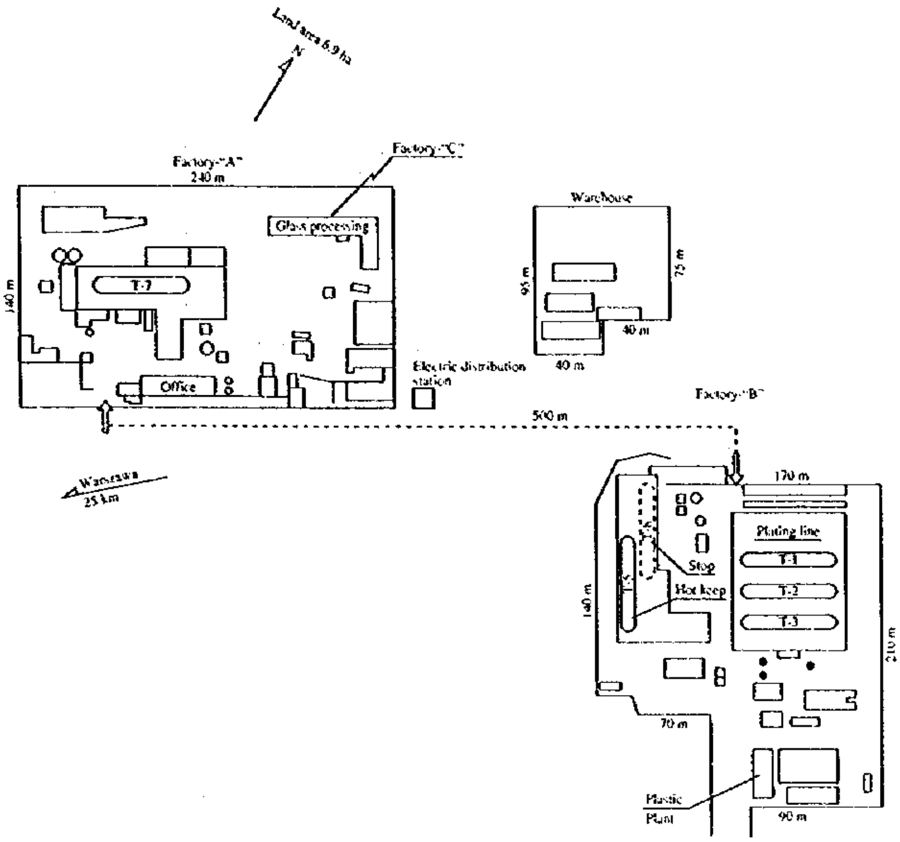
(7) History of the plant

In 1905, Wolomin was established as a private company, and thereafter in 1940 it started bottle production, while its operation was shifted to the government in the same year. In 1960, the company started the second factory, producing heat-proof glassware "Telmisil". The company introduced the automatic bottle forming machine "IS Machine" and the thermos bottle production technique in 1972 and 1982, respectively. It has been moving toward privatization since 1997, and bids for the management right are scheduled to be called for in November, 1998.

(8) Plant layout

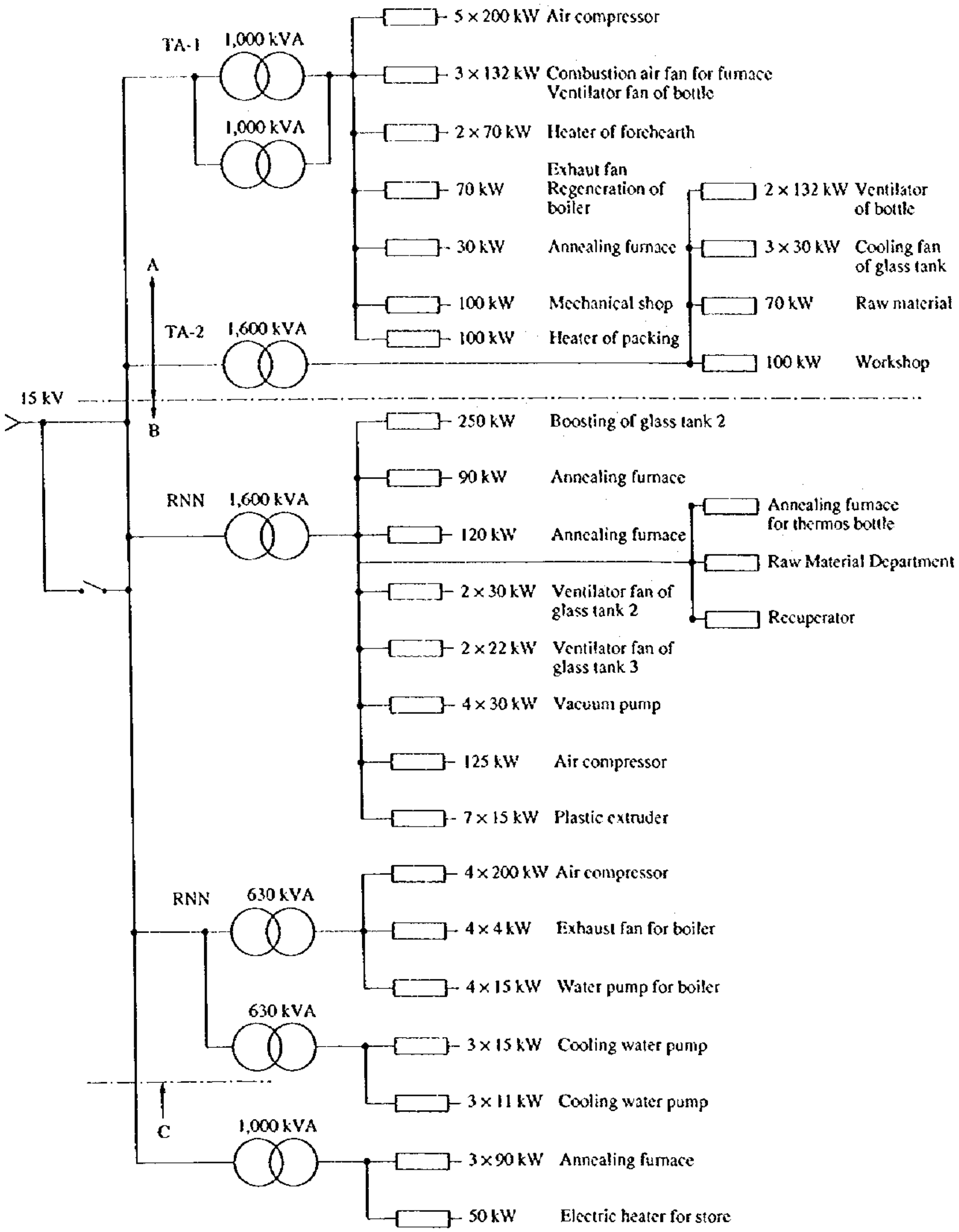
The factory location falls into two major areas: Factory A for the general bottle producing factories, and Factory B 500 m away from Factory A. Factory A includes Factory C where the assembling shop of laboratory glassware is located. Figure 4.1.2 shows the plant layout.

Figure 4.1.2 Plant Layout



(9) One line diagram

Figure 4.1.3 One Line Diagram



(10) Outline of major equipment

Table 4.1.1 shows the design values of the glass melting furnace as the major equipment and the forming machine.

Table 4.1.1 Major Equipment

Factory	Equipment	Quantity	Specificaitions
T-1 line	Melting furnace	1	End port type 7.6 t/d
			Products: Thermos vacuum bottle
	Forming machine	2	Lindner
T-2 line	Melting furnace	1	Side port type (3-port) 10 t/d
			Products: Heat-proof ware
	Forming machine	1	Gerome Bonefoil
T-3 line	Melting furnace	1	End port type 7.5 t/d
			Products: Laboratory flask
	Forming machine	1	Hand blowing
T-5 line	Melting furnace	1	Unit melter: 8.0 t/d
	(Under heat holding)		Products: Heat-proof ware
	Forming machine	1	Walter
T-7 line	Melting furnace	1	Side port type (5 ports) 150 t/d
			Products: Bottle for drink
	Forming machine		Hart Ford IS machine
T-8 line	Melting furnace	1	Unit melter. 30 t/d
	(Operation stopped)	1	Products: Heat-resistant ware
	Forming machine	2 and 1	Olivotto and NEG
Utility	Water boiler	4	5 atm. 950,000 kcal/h Coal
			Installation in 1975
	Water boiler	1	1.0 Mpa. 2.2 Gcal/h
			Waste heat recovery: Started in 1985
	Air compressor	10	Reciprocating type 200 kW × 9 sets
			125 kW × 1 set

(11) Energy price and heat value

Table 4.1.2 Energy Price and Heat Value in 1997 and 1998

	Energy price		Heat value
	1997	1998	
Coal	0.150 PLN/kg	0.150 PLN/kg	22,598 kJ/kg
Natural gas	0.328 PLN/m^3	0.522 PLN/m^3	35,900 kJ/m^3
Electricity	0.112 PLN/kWh	0.139 PLN/kWh	10,258 kJ/kWh
Liquid oxygen	0.260 PLN/kg	0.290 PLN/kg	

4.1.2 Energy Consumption Status

(1) Trend of production

Table 4.1.3 Trend of Production

Plant	Design capacity (MG t/d)	Production (t)				
		1993	1994	1995	1996	1997
T-1	7.6	334.8	407.3	366.9	448.2	560.0
T-2	10.0	790.9	877.2	808.0	813.4	887.4
T-3	7.5	355.6	336.0	307.1	352.4	372.6
T-5	8.0	932.3	950.1	1,053.9	1,075.0	1,251.3
T-7	150.0	21,964.4	17,488.2	30,424.9	20,320.0	18,550.9
Total	183.1	24,378.0	20,058.8	32,960.8	23,009.0	21,622.2

(2) Trend of energy consumption

Table 4.1.4 Trend of Energy Consumption

	Unit	1993	1994	1995	1996	1997
Coal	(t)	2,420	2,787	2,154	2,554	1,774
	(GJ)	54,687	62,981	48,676	57,715	40,089
Natural gas	(10^3 m^3_N)	22,375	25,125	23,927	20,943	20,963
	(GJ)	803,263	901,988	858,979	751,854	752,572
Electricity	(MWh)	19,636	21,257	21,016	19,623	19,380
	(GJ)	201,426	218,054	215,582	201,293	198,800
Consumption of liquid oxygen	(t)	1,050	920	1,050	950	922
Total	(GJ)	1,059,376	1,183,023	1,123,237	1,010,862	991,461

(3) Trend of energy intensity

Table 4.1.5 Trend of Energy Intensity

	Unit	1993	1994	1995	1996	1997
Energy intensity	(GJ/t)	43.5	59.0	34.1	43.9	45.9

(4) Energy intensity of each furnace

Table 4.1.6 Energy Intensity of Each Furnace in 1996 and 1997

1996

	Product (t)	MG (t)	Cullet (%)	MGS (t)	Natural Gas (10^3 m^3)	Electricity (MWh)	Coal (t)	Energy Intensity (GJ/t-MG)	(GJ/t-product)
T-1	448.2	1,527.5	31.4	1,485	1,751	1,511	–	51	172
T-2	813.4	2,688.2	51.4	2,373	3,500	2,257	–	55	180
T-3	352.4	1,209.5	59.7	1,027	2,375	1,511	–	82	282
T-5	1,075.0	1,227.1	34.2	1,175	3,669	1,315	–	117	133
T-7	20,320.0	37,418.8	32.8	36,074	9,514	9,438	–	12	21
Common	–	–	–	–	134	3,591	2,554.2	–	–
			Average					Average	Average
Total	23,009.0	44,071.1	34.6	42,134	20,943	19,623	2,554.2	23	44

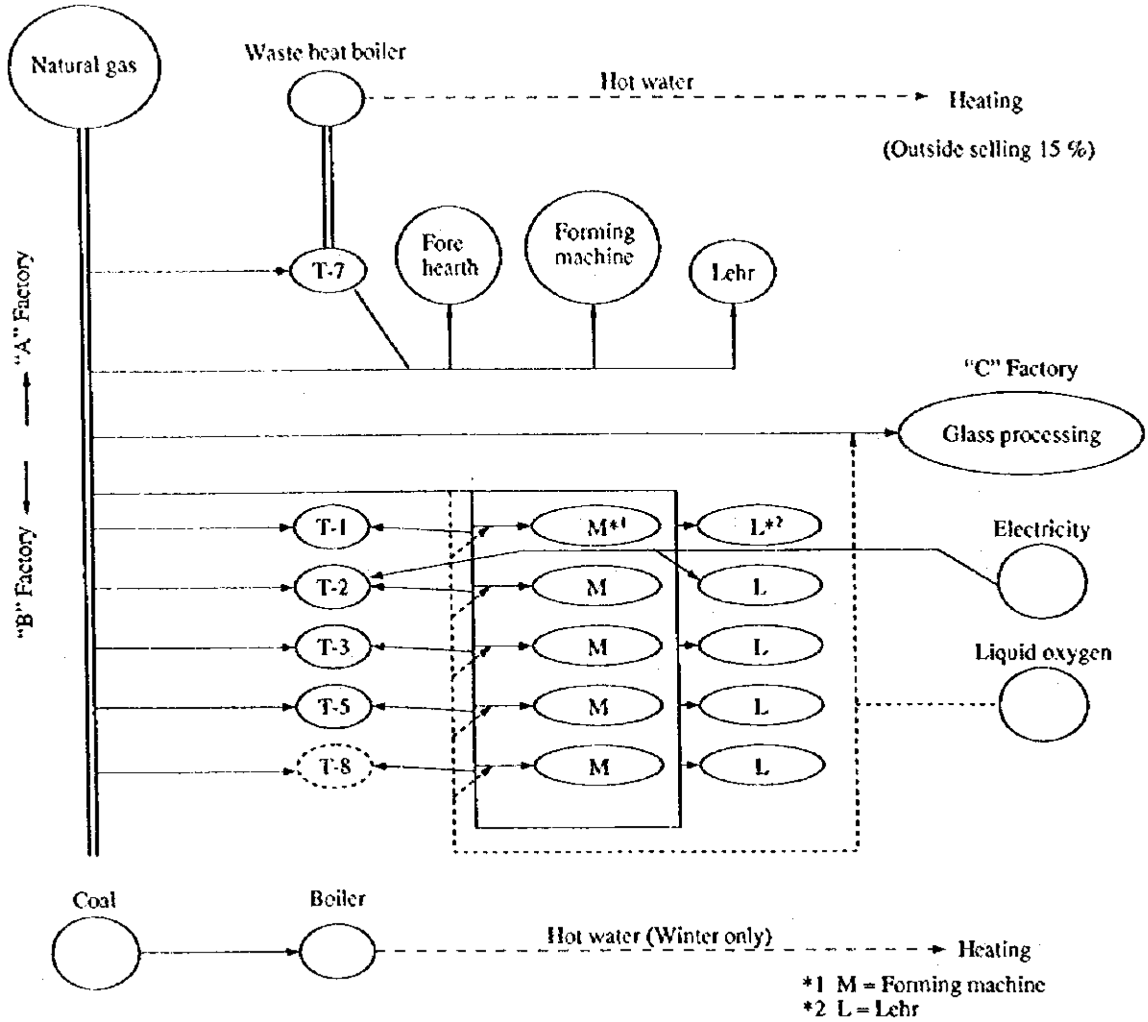
1997

	Product (t)	MG (t)	Cullet (%)	MGS (t)	Natural Gas (10^3 m^3)	Electricity (MWh)	Coal (t)	Energy Intensity (GJ/t-MG)	(GJ/t-product)
T-1	560	1,476	46.5	1,332	1,610	1,581	–	50	132
T-2	887	2,781	51.9	2,446	3,588	2,372	–	55	173
T-3	373	1,132	53.4	988	2,232	1,505	–	84	256
T-5	1,251	1,567	43.0	1,438	3,102	1,323	–	80	100
T-7	18,551	36,046	40.1	33,553	9,618	9,723	–	12	24
Common	–	–	–	–	813	2,876	1,774	–	–
								Average	Average
Total	21,622	43,002	–	39,757	20,963	19,380	1,774	22	44

(5) Ratio of the energy cost to the production cost: 23 %

(6) Energy flow

Figure 4.1.4 Energy Flow



4.1.3 Energy Management State

(1) Setting the energy conservation target

a. Setting target values

No specific target value has been set yet.

A target should be set to implement control according to the target management chart and clarify the work responsibility assignment.

b. Problems related to the promotion of energy conservation efforts

The facilities are not so modern as those in Western European countries; however they stand favorably with them.

Rather a current problem is that demand is not so great enough to allow for a full-scale operation of the equipment, thus making the load very low.

Problems related to software such as quality control, production management, and so on are more serious than those related to hardware including equipment.
Hence, all the members of the company should acquire a TQC concept of total involvement or all-member-participative activities in aspects ranging from management technologies for quality control, etc. to marketing, and they should also renew their awareness towards energy conservation.

c. Systematic activities

No systematic committee activities have been carried out.

An energy conservation committee should be established to strengthen the system for proposing improvements, and set up a quality control department.

d. Data-based management

Only a minimum number of measuring equipment, which are of old type, are available, but the measured values do not seem to be effectively utilized.

No adequate management of yield nor loss analysis is performed.

It is necessary for them to perform data management at an ISO 9000-certified level.

It is equally advisable to obtain reliable data, proceed with standardization, and implement control based on the control chart.

e. Plant engineering

They have a plan to perform periodical repairs of furnace tanks every 8 years for newly installed ones and thereafter every 5 years. However, the furnaces with low loads and temperatures need to be maintained longer. They should exert much more effort for prolonging their service life by improving a weak point of the furnace at every periodical repair.

With regard to the maintenance and cleaning state of mechanical equipment, there is nothing poor in particular. The cullet (raw material) storage place was dirty, and foreign matter was found to be mixed in. Some new and typical plants in excellent factory are thoroughly cleaned up at every corner through their TPM (Total Productive Maintenance) efforts, thereby producing great effects such as a remarkable reduction in the frequency of equipment and machine failures. Therefore, it is advisable to use these successful cases for reference.

f. Energy conservation activities in 1997

1) Results of Energy Conservation Activities from 1996 to 1997

The difference in the amount of molten glass, production volume and energy intensity between 1996 and 1997 are as follows.

Plant	Production (1997) [t]	Molten glass	Product	Energy [GJ/t-MG]	Intensity [GJ/t-products]
No. 1, 2, 3, 5	3,071.3	+4.4 %	+14.2 %	-9.2 %	-15.6 %
No. 7	18,550.9	-3.8 %	-8.7 %	+6.7 %	+12.7 %

Energy intensity at plants No. 1, 2, 3, and 5 improved significantly due to improved yield. On the other hand, the energy intensity at plant No. 7 worsened by 10 %, because its glass melting furnace went into its 7th year of operation, and it operated at a low yield. See Section 4.1.4 for details.

2) State of Progress Pointed Out at Simplified Factory Audit

While the following 3 items are implemented, most of the other measures have not been implemented.

① Combustion air ratio for glass melting furnace
② Sealing of glass melting furnace opening
③ Prevention of air leakage at compressed air piping joints

State of combustion at T-7 glass melting furnace : The result for the exhaust gas oxygen concentration at the T-7 furnace was 4%. This was a 3% improvement compared to the measurement result for the T-7 furnace last year. Consequently, heat loss carried away by the exhaust gas was reduced by 2%, and the fuel consumption was reduced 3%.

4.1.4 Problems and Measures related to the Use of Energy

(1) Comparison of the energy intensity with the excellent factory

For the excellent factory, the average value among the factories producing similar products in Japan is used.

Table 4.1.7 Comparison of Energy Intensity in 1996 and 1997

1996

		Fuel intensity (GJ/t-MG)	(GJ/t)	Electricity intensity (GJ/t-product)	Common energy intensity (GJ/t-produt)	Total intensity (GJ/t-product)
Wolomin	T-1	40.5	137.9	34.6	7.9	180.4
	T-2	46.0	151.9	28.4	7.7	188.0
	T-3	69.4	237.9	44.0	8.0	289.9
	T-5	105.5	120.5	12.5	2.6	135.6
Excellent factory		28.7*1	71.9	29.8	29.9	131.6
Wolomin	T-7	9.0	16.5	4.8	4.3	25.6
Excellent factory		5.0	6.2	2.8	2.2	11.2

Note: Heat value of heavy oil is 41.4 MJ/L

Common energy is divided by amount of molten glass.

*1: Similar boro silicate glass which is high quality and MG 4.5 t/d

1997

		Fuel intensity (GJ/t-MG)	(GJ/t)	Electricity intensity (GJ/t-product)	Common energy intensity*3 (GJ/t-produt)	Total intensity (GJ/t-product)
Wolomin	T-1	39.2	103.2	29.0	18.6	150.9
	T-2	46.3	145.2	27.4	22.3	194.9
	T-3	70.8	214.8	41.4	21.6	277.8
	T-5	71.1	89.0	10.8	8.9	108.7
	Average	54.4	123.1	22.7	16.1	161.9
Excellent factory*1		28.7	71.9	29.8	29.9	131.6
Wolomin	T-7	9.6	18.6	5.4	2.7	26.7
Excellent factory*2		5.0	6.2	2.8	2.2	11.2

Note: *1: Excellent factory of special glass which is MG4.5 t/d and high quality.

*2: Excellent factory of bottle glass which is the average value of Japanese bottle glass furnaces and heat value of heavy oil is 41,400 kJ/t.

*3: Common energy is divided by the factory "A" (bottle glass furnace) and factory "B" (total of special glass furnaces) into half and half, and then allocated by production ratio in the "B" factory.

It is difficult to compare the energy intensity of each furnace at factory B, which manufactures customized glass, because it varies substantially depending on conditions.

T-1: With a composition similar to bottle glass, in terms of melting property, glass for thermos vacuum bottles is superior in energy intensity even compared to that of the "Excellent factory" in the above table.

T-2: With a Termisil composition, its melting property is nearly identical to the one for the "Excellent factory," but its melting quantity is approximately twice as large, and therefore, even though it has an advantage in terms of reducing energy intensity, its energy intensity is 50 to 60 % worse than that of the "Excellent factory."

T-3: Not only its Termisil composition, but its melting quantity is also identical to that of the "Excellent factory." Even though the one for the "Excellent factory" is subject to far greater quality requirements, the energy intensity for Wolomin is 2 to 2.5 times worse.

T-5: While its Termisil composition and melting quantity is identical to those of T-3, even with a somewhat inferior melting intensity (fuel intensity) as a result of not recovering heat with a "Unit melter," its energy intensity at the product stage is valued at less than half, as its yield is more than twice as good, which is a high mark even compared to the "Excellent factory."

Even after taking into consideration factors such as quality difference, when evaluating the average for furnaces at factory B, and that of the "Excellent factory," the current energy intensity of Wolomin can be said to be 2 to 2.5 times worse.

T-7: As for bottle furnaces, they are approximately 2 times higher than bottle furnaces in Japan in melting intensity (fuel intensity), and 2.4 times worse in energy intensity at the product stage.

(2) Estimation of the energy conservation potential

Energy conservation is divided into the following three steps to sort out its potential.

Step 1: Enhancing the management
Step 2: Improving the equipment
Step 3: Improving the processes

a. Process

a1. Difference due to external factors

For materials granular size distribution of silica and as the major material is better than that in excellent factory. There is no negative element in the melting property.

For products there are three product types: heat-resistant glass, thermos bottles, and general bottles. The composition of the thermos bottles can be considered to be not so different from that of general bottles. Since each quality is worse than that from the excellent factory, this factory has advantages in terms of energy conservation. However, it is necessary to pay attention to and cope with the changes in market demands.

a2. Difference due to technical factors

Improving the production process management

1) Improving the management of production processes

① Renewal and enhancement of measuring equipment

Now is the time to renew most of the measuring equipment as the indicator of process management. It is essential to replace them with modern measuring equipment upon periodic repair of each furnace and to enhance management by increasing the measuring points.

② Improving the process management

The production amount and yield of each process should be grasped and analyzed according to the scientific approach based on the reliable measured values. With a cycle of standardization, implementation, check, and improvement, the yield described below can be improved and the energy intensity can be reduced.

The energy intensity reduction rate is included in operation improvement described below and yield improvement explained later.

b. Melting furnace

b1. Difference due to the melting load

Before discussing the difference due to technical factors, it is necessary to recognize the difference due to the melting load which is the major factor worsening the energy intensity. Figures 4.1.5 and 4.1.6 show the design values of the Wolomin factory vs. those of the excellent factory, the actual operation value in 1996, and the case where the melting load is increased up to the level of the excellent factory.

Also, the relationship between energy intensity and the melting load when it is increased is plotted.

Figure 4.1.5 Melting Load vs. Molten Glass

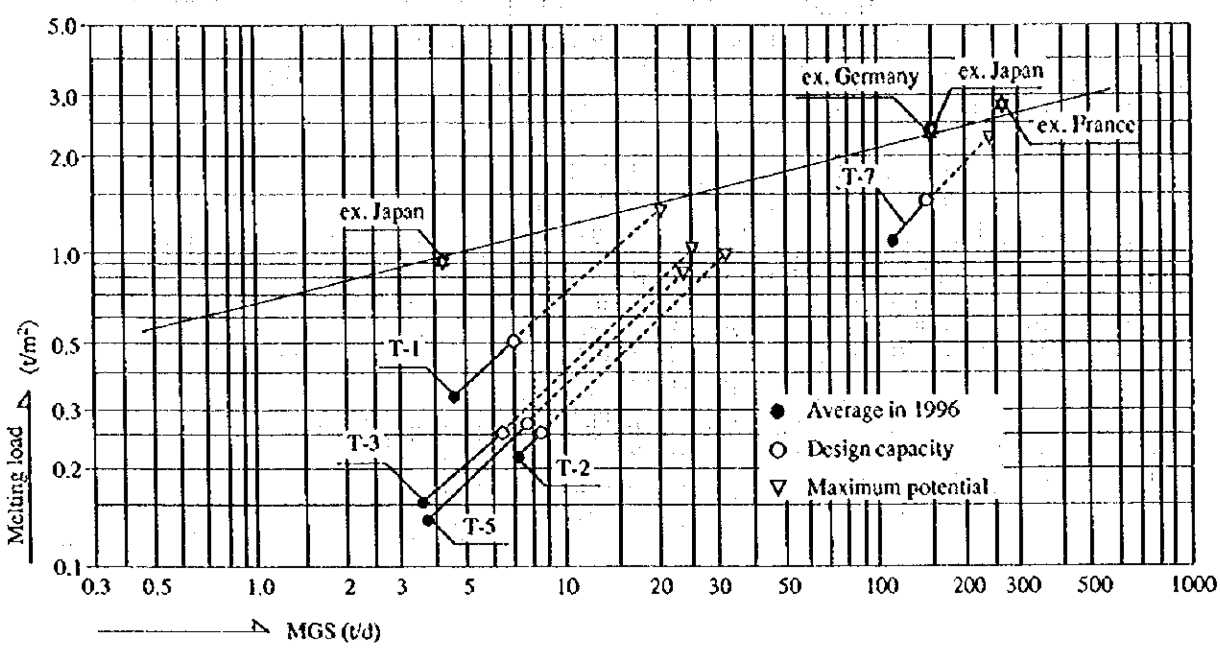
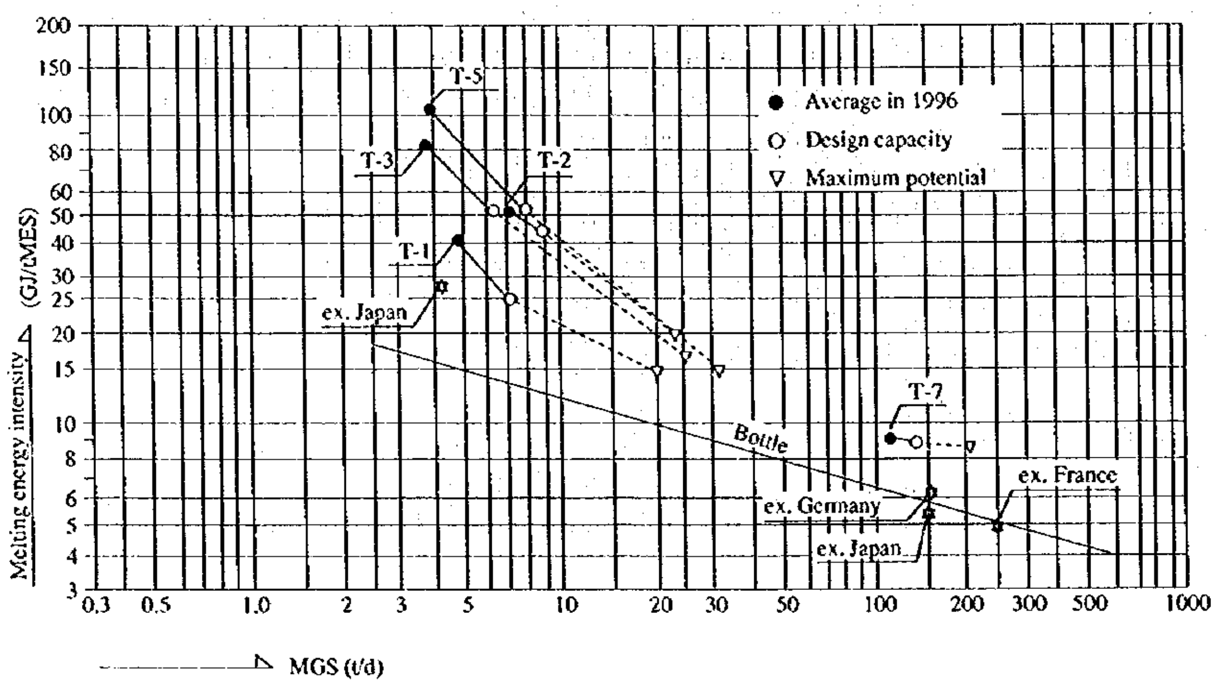


Figure 4.1.6 Melting Energy Intensity vs. Molten Glass



As shown in Figure 4.1.5, the designed melting load of the melting furnace in Wolomin is as small as 1/2 to 1/4 of that in the excellent factory, which is very small. The actual value is much smaller than the designed value. Therefore, as shown in Figure 4.1.6, the difference of the energy intensity is highly due to the difference of the melting load.

b 2. Comparison by Heat Balance

Heat balance was calculated based on the measurements for T-5 and T-7 furnaces obtained in the sturdy in February 1998, and compared to that of the "Excellent factory."
Results of the heat balance calculation for T-7 and T-5 are shown in Table 4.1.8.

Table 4.1.8 Summary Heat Balance T-7, T-5

		T-7		Confer	T-5		Confer
	Items	(MJ/h)	(%)	Excellent bottle furnace	(MJ/h)	(%)	Excellent unit melter
Heat input	Combustion heat of fuel	40,531	100.0	100.0	11,596	100.0	100.0
	Sensible heat of fuel	0	0	0	0	0	0
	Heat value of electric heater (F.H.)	43	0.1	0	0	0	0
	Sensible heat of combustion air	(21,523)	(53.1)	(56.6)	(2,126)	(18.3)	(19.2)
	Sensible heat of batch and cullet	0	0	0	0	0	0
	Total	(62,054)	(153.2)	(156.6)	(13,722)	(118.3)	(119.2)
Heat output	Heat loss of exhaust gas (Top of regenerator)	(30,018)	(74.1)	--	(8,208)	(70.8)	–
	Heat loss of exhaust gas (Flue)	(14,880)	(36.7)	–	5,321	45.9	40.0
	Heat loss of exhaust gas (Under chimney)	13,122	32.4	13.9	–	–	--
	Latent heat of water in batch	197	0.5	2.5	0	0	0
	Reaction heat of batch	2,043	5.0	12.6	61	0.5	2.5
	Heat carried out by glass	6,392	15.8	31.4	350	3.0	27.1
	Available heat	(11,526)	(28.4)	–	(447)	(3.9)	–
	Heat loss from furnace wall	14,608	36.1	39.3 ←	3,963	34.2	5.6 ←
	Heat loss by water cooling	0	0	–	0	0	
	Heat loss by air cooling	2,892	7.1	–	1,093	9.4	8.7
	Heat loss from opening parts	336	0.8	–	0	0	
	Recovery heat by waste heat boiler	1,758	4.3	0	761	6.6	–
	Others	–817	–2.0	–	47	0.4	16.1
	Total	40,531	100.0	100.0	11,596	100.0	100.0

Recovery heat of regenerator (ratio)

$$\frac{\text{Quantity of heat in the combustion air leaving top of the regenerator}}{\text{Quantity of heat in exhaust gas entering top of the regenerator}} = 71.7\ \% \qquad 25.9\ \%$$

Recovery heat of waste heat boiler (ratio)

$$\frac{\text{Quantity of recovery heat by waste heat boiler}}{\text{Quantity of heat in exhaust gas at flue}} = 11.8\ \% \qquad -$$

$$\text{Efficiency (1)} = \frac{\text{Taken out by glass + Batch reaction heat}}{\text{Heat input via fuel}} = 20.8\ \% \qquad 3.5\ \%$$

$$\text{Efficiency (2)} = \frac{\text{Available heat}}{\text{Heat input via fuel}} = 28.4\ \% \qquad 3.9\ \%$$

T-7: Its melting efficiency is about half compared to that of the Excellent factory. This is because its melting quantity is small with respect to its furnace size. Additionally, the negligible difference in radiation heat loss from furnace walls is due to the fact that, while there is a difference in the degree of adiabatic heat insulation to the furnace walls, a small load, low temperature operation is being carried out, and the two are canceling each other out. Furthermore, there is almost no difference in quantity of recovered heat ratio at the regenerator, because even though there is a difference in the size of heating area of checker bricks, the regenerator is relatively sizeable (m^3/Fuel) as a result of the small load operation. As a result, the heat recovery ratio of the exhaust gas is increased by the extent to which the rate of melting heat for the raw material is low.

T-5: Although there is little difference with T-5 in dimension and structure of furnace, the excellent unit melter is a furnace for the manufacture of glass wool, which is 4 times easier to melt than termisil. Yet, its melting efficiency differential is about one eighth. This means that, even when considering the difference in product type, T-5, as was the case for T-7, only has about half the melting efficiency. Additionally, the high radiation heat loss ratio from the furnace walls is attributable to the small load, high temperature melting, and high temperature forming, required by termisil. Because waste heat recovery and air preheating using a recuperator, as in the case of this unit melter, are inefficient for T-5, and high temperature air is hard to obtain, and thus a high temperature flame become hard to obtain, and efficiency worsens.

b3. Difference due to technical factors

1) Operation improvement

① Reduction of the excess air (Step 1)

Energy saving (average): Factory A: 14,925 GJ/y (805 MJ/t)
Factory B: 15,905 GJ/y (5,179 MJ/t)

Concentration of oxygen in the combustion exhaust gas from each melting furnace was measured in a short time. The excess air of each furnace from oxygen content is calculated as follows:

	1997	1998
T-1:	30 %	30 %
T-2:	25 %	25 %
T-3:	80 %	50 %
T-5:	–	13 %
T-7:	48 %	27 %

By contrast, the excess air in the excellent factory is 10 to 15 %. By the way, the excess air can be reduced to 15 % by enhancing combustion control even though any particular facility modification is not performed.

<Melting furnace exhaust gas component measurement and analysis>

Figure 4.1.7 shows an example of oxygen content in the exhaust gas and exhaust gas temperature measured at the inlet of the regenerator for the melting furnace (T-7 furnace) in the bottle plant.

Figure 4.1.7 Exhaust Gas Measurement at Melting Furnace in Bottle Plant

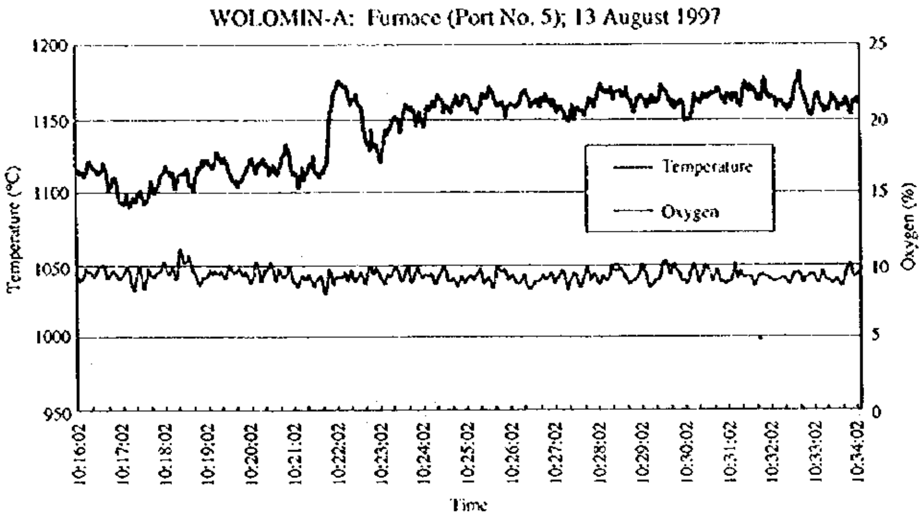


Table 4.1.9 shows the oxygen content in the exhaust gas together with the results of other melting furnaces.

Table 4.1.9 Measurement of the Exhaust Gas from the Glass Melting Furnace (Exhaust gas at the inlet of the regenerator)

Furnace No.	O_2 average value	O_2 maximum value	O_2 minimum value	Average gas temperature
T-7 Port 5	7.3 %	11.2 %	8.0 %	1,145 °C
T-7 Port 3	5.1 %	9.7 %	4.4 %	No measurement available
T-7 Port 2	6.6 %	7.3 %	6.3 %	No measurement available
T-7 Port 1	8.2 %	8.7 %	8.0 %	No measurement available
T-2 Port 1	3.6 %	4.3 %	3.2 %	No measurement available
T-2 Port 3	5.0 %	6.2 %	4.2 %	No measurement available

Since in excellent factory, oxygen content in the exhaust gas is 3 % (1.15 as the air ratio), the measured values listed above are higher than those in excellent factory, thus allowing for further fuel saving by adjusting the air ratio.

Table 4.1.10 shows the result of calculating the air ratio adjustment effect for the T-7 furnace. This calculation is based on the assumption that the exhaust gas temperature at the furnace exit is not different between before and after air ratio adjustment, and uses the temperature estimated from the heat balance of the regenerator as the preheated air temperature.

Table 4.1.10 Air Ratio Adjustment Effect for the Glass Melting Furnace

Preconditions

Fuel gas	
Net heat value (kJ/kg)	35,282
Net heat value (kcal/kg)	8,427
Combustion air temperature	1,050
Exhaust gas temperature	1,145
Combustion air temperature after air preheater	405
Furnace infiltrating air ratio	20 %

Notes: The measuring point is at the inlet of the air preheater.
The exhaust gas temperature after air heater is estimated based on the heat balance of air heater.
The exhaust gas temperature is that at the inlet of the air preheater.

Calculation Result

	Theoretical Combustion	Current AR Condition	After AR Improvement
Oxygen in exhaust gas	0.0 %	7.3 %	3.0 %
Air ratio	1.00	1.48	1.15
Air amount (m^3/kg)	9.6	14.2	11.0
Exhaust gas amount (m^3/kg)	10.6	15.2	12.0
Exhaust gas loss rate (against fuel heat)		22.5 %	18.1 %
Fuel saving rate			5.3 %

Notes: The exhaust gas loss rate is that at the outlet of the air preheater.

As shown in Table 4.1.10, the fuel can be saved by 5.3 % by adjusting the air ratio. If the same calculation is applied to the average value (4.3 %) of the O_2 measured value in the exhaust gas at factory B, the fuel saving rate is 1.2 %. Table 4.1.11 shows the composition of the fuel gas estimated based on these calculations.

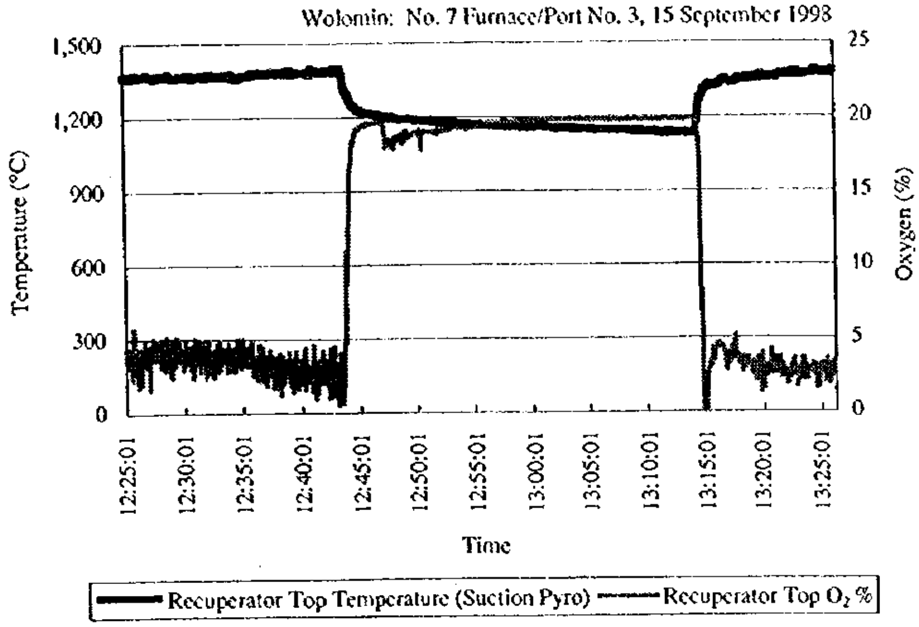
Table 4.1.11 Composition of Fuel Gas

Gas Content	CO_2	H_2	CH_4	C_2H_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	O_2	H_2O
Wet volume	0.2 %	–	96.9 %	–	0.9 %	–	–	1.8 %	–	–

Note: For the energy saving rate, energy consumption of each furnace is calculated as shown below. The average value was obtained by proportinally allocating the intensity per molten glass volume.

An example in which exhaust gas temperature and oxygen contained in the exhaust gas were measured, for a bottle manufacturing furnace (T-7), in September 1998 is shown in Figure 4.1.8.

Figure 4.1.8 Glass Furnace Exhaust Gas



In addition to the furnace port shown in this figure, other exhaust ports are measured with regard to each 1 cycle. This measuement data is used to obtain the average, maximum and minimum value of the exhaust gas temperature and the oxygen content in the exchaust gas. The result is shown in Table 4.1.12.

Table 4.1.12 Exhaust Gas Measurement of T7 Furnace by Ports

	T7 furnace					
	Port-1	Port-2	Port-3	Port-4	Port-5	Overall
Exhaust gas temperature						
Average	1,233.4	1,183.3	1,366.9	1,394	1,223.0	1,280.1
Maximum	1,240.9	1,197.1	1,385.5	1,399	1,232.8	1,398.5
Minimum	1,229.8	1,146.8	1,324.5	1,375	1,201.6	1,146.8
Preheated air temperature						
Average	1,080.5	1,048.4	1,169.9	1,268	1,051.7	1,048.4
Maximum	1,114.4	1,056.6	1,214.9	1,279	1,097.8	1,056.6
Minimum	1,053.7	1,043.0	1,142.4	1,259	1,027.0	1,027.0
Exhaust gas oxygen						
Average	5.7 %	6.4 %	3.3 %	-	8.3 %	6.0 %
Maximum	6.2 %	7.0 %	5.7 %	-	9.8 %	9.8 %
Minimum	5.1 %	2.2 %	1.0 %	-	6.4 %	1.0 %

30 °C is added to measured gas temperature for compensating brick radiation.

80 °C ia subtracted from measured air temperature for compensating brick radiation.

Based on this measurements, combustion when the air ratio was reduced by adjusting the volume of combustion air was calculated. The result is shown in Table 4.1.13. Reducing the oxygen content in the exhaust gas to 3 % (Equivalent to air ratio 1.15) can achieve a 2.6 % fuel saving.

Table 4.1.13 Air Ratio Improvement for T7 Furnace

Premises	
Fuel gas	
Heat value Net (kJ/m³)	35,282
Heat value Net (kcal/m³)	8,427
Combustion air temperature	1,048
Exhaust temperature (before regenerator)	1,280
Exhaust temperature (aft regenerator; assumed)	441

Rem: Measured at before regerator
After regenerator assumed by heat balance

Results	Theoretical	AR actual	AR improved
Exhaust gas oxygen	0.0 %	6.0 %	3.0 %
Air ratio	1.00	1.36	1.15
Air volume (m^3/m^3)	9.5	12.9	10.9
Exhaust gas (m^3/m^3)	10.5	13.9	11.9
Exhaust loss (to fuel)		76.5 %	66.2 %
Fuel advantage			2.6 %

Rem: AR improved is that for Japanese similar factory.
Exhaust gas loss is that before regenerator.

Measurement was conducted for T-5 furnace in September 1998.

Unlike other furnaces, the heat-proof tableware manufacturing furnace (T5 furnace) has a radiation type recuperator at the rear of the furnace. This is so devised as to let air flow in the outer cylinder of the metal double cylinder and exhaust gas in the inner cylinder. Since the exhaust gas after air preherating has still a high temperature, cooking air is injected. Figure 4.1.9 shows the conceptual drawing and the measuring poinmts of the recuperator.

Figure 4.1.9 Recuperator for T5 Furnace

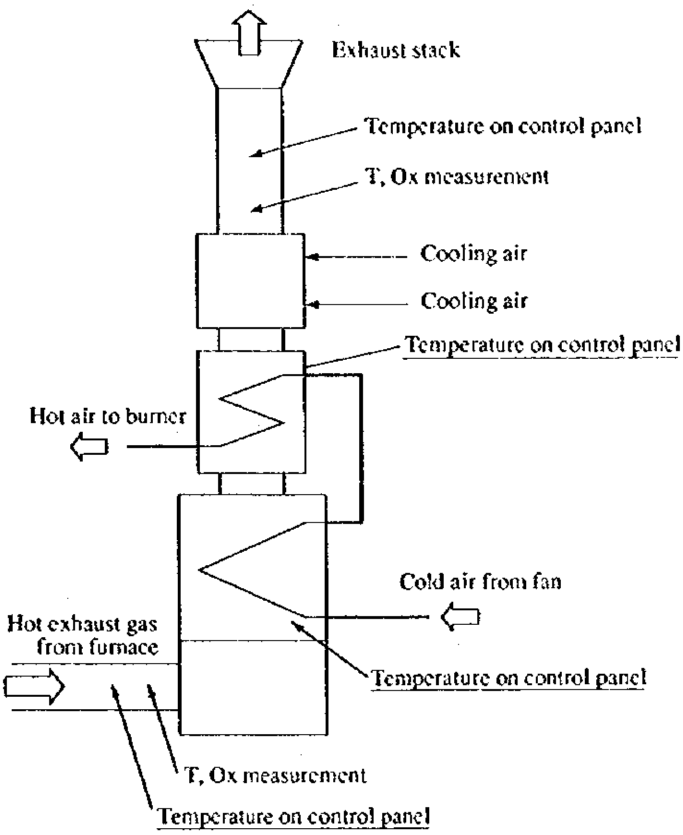


Figure 4.1.10 shows the results of the of oxygen content in the exhaust gas and temperature measured at the measuring points shown in Figure 4.1.9.

Figure 4.1.10 Glass Furnace Exhaust Gas

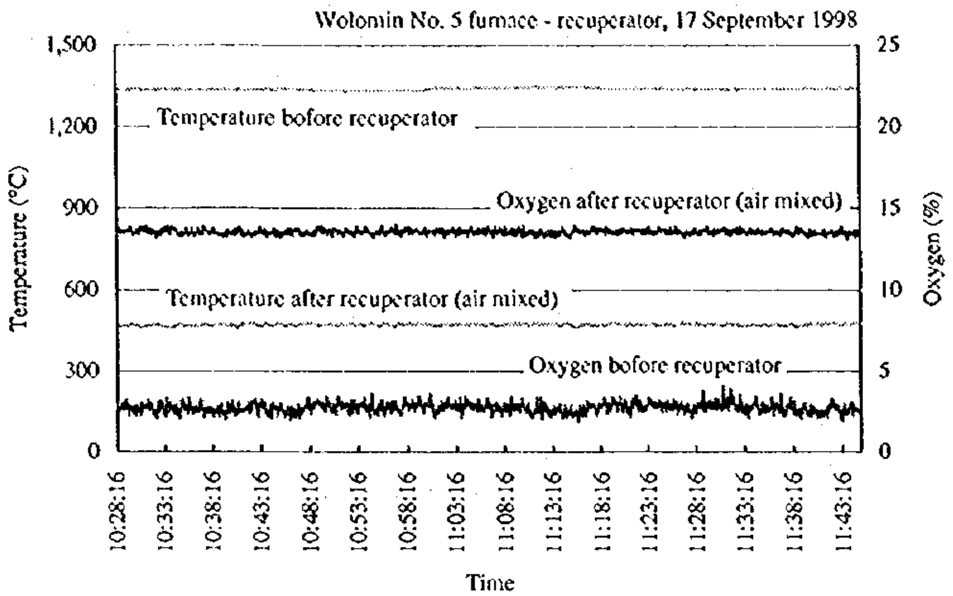


Table 4.1.14 shows the results of combustion calculation based on the measurements shown in Figure 4.1.10.

Table 4.1.14 Combustion Calculation for T5 Furnace

Premises	
Fuel gas	
Heat value Net (kJ/m³)	35,282
Heat value Net (kcal/m³)	8,427
Combustion air temperature	450
Exhaust temperature (before regenerator)	1,340
Exhaust temperature (aft regenerator, assumed)	1,038
Exhaust loss, after regenerator	51.3 %

Rem: Measured before recuperator
The values after regenerator are assumed based on heat balance.

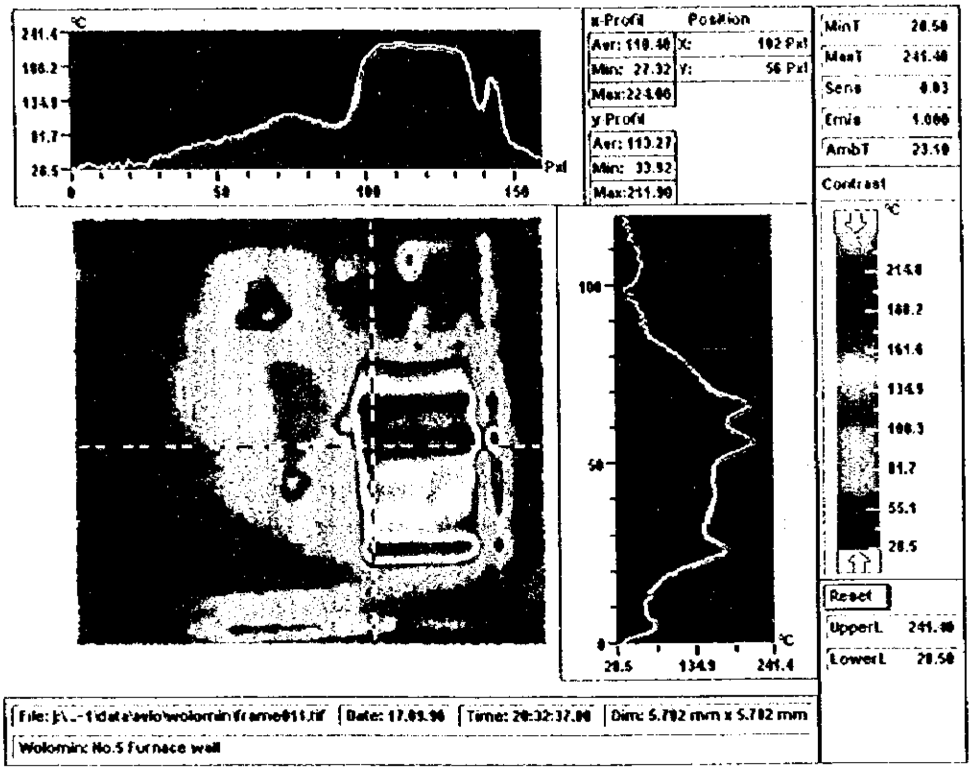
Results	Theoretical	AR actual
Exhaust gas oxygen	0.0 %	2.7 %
Air ratio	1.00	1.13
Air volume (m³/m³)	9.5	10.8
Exhaust gas (m³/m³)	10.5	11.8
Exhaust loss (to fuel)		68.9 %

Rem: Exhaust gas loss is that before regenerator.

The oxygen content of the exhaust gas from this furnace was an average of 2.7 %. With this oxygen concentration, the air ratio becomes 1.13, indicating the combustion state is very good.

The measurement of exhaust gas temperature after the recuperator turned out to be 471 °C (420 °C on the control room instrumentation). However, this measurement point was after the air for cooling was mixed in. The exhaust gas temperature before cooling air got mixed in is estimated to be 1,035 °C, judging from the heat balance of the recuperator. Additionally, the exhaust gas heat loss becomes 51 % at this temperature. On the other hand, the exhaust gas temperature after subjected to the regenerator, for the T-7 furnace, is estimated to be 508 °C, and the exhaust gas heat loss at this time is 27.7 %. Thus, because the T-5 furnace uses a radiation type recuperator, the heat recovery rate of its exhaust gas is low, and in this respect, it has an inferior rate of exhaust gas use compared to furnaces that have regenerative air preheater.

Figure 4.1.11 Thermal Image of the T-5 Furnace Flue Gas Duct



This thermal image was taken at the area where the flue of the T-5 furnace connects with the recuperator bottom. The high temperature zone is indicated to be 220 °C in the picture. In contrast, the recuperator bottom is about 120 °C. The amount of radiation heat becomes greater around the high temperature zone of the flue part, and the exhaust gas entering the recuperator becomes lower. As a result, the temperature of the air preheated by the recuperator is also considered to becomes lower. A possible explanation for this would be the bricks at this flue part might be thin.

Note:
For the energy saving rate, energy consumption of each furnace is calculated as shown below. The average value was obtained by proportinally allocating the intensity per molten glass volume.

The same formula is applied to the heat holding effect and regenerator checker brickwork modification effect.

Formula for calculating heavy oil consumption in the glass melting furnace:

$$y = \frac{0.065\,MGS + \left(0.63 + 0.37\dfrac{MGS}{MGSmax}\right)\cdot Q_L}{\eta}$$

MGS: Standard molten glass in terms of cullet ratio 25 %

$$MGS = \frac{434 - C\,\%}{400 + C\,\%} \times 1.04 \times MG\ (t/d)$$

y : Heavy oil consumption (kL/d)

Q_L : Heat loss from the melter wall

Q_L: = $0.05 \cdot \lambda \cdot MA'$

MA': Surface area of melter wall (m^2)

λ: Insulation coefficient

- no insulation: 1.0
- simple insulation: 0.9 ~ 0.95
- heavy insulation: 0.76 ~ 0.8

η : Furnace efficiency

$$\eta = 85 - 633 \cdot \frac{y}{CV} - 0.25 \cdot EA$$

CV: Heat surface area of checker
= {Total checker volume in one side of the regenerator (m^3)}
× {unit surface area of checker (m^2/m^3)}

in case of Recuperator:

$-633 \cdot Y = 0.022\,Ta - 37.4$

Ta: Preheated air temperature (°C)

EA: Excess air (%)

② Closing the openings (Step 1)

If openings such as the inspection hole on the furnace wall are not closed and the brick joints are not sealed, the radiant heat loss may occur, the exhaust gas may come out, and cold air may enter the furnace through the burner tile, etc., resulting in heat loss. Although this item is not so important for worsening of energy intensity, it is the standard item to indicate the level of employees' energy conservation awareness.

Energy saving (average): Factory A: 2,943 GJ/y (159 MJ/t)
Factory B: 3,259 GJ/y (1,061 MJ/t)

2) Facility improvement

① Reinforcing the heat insulation (Step 2)

Although heat insulation for the furnace wall is different depending on each furnace, simple heat insulation has been implemented. The energy conservation effect of simple heat insulation is 10 % and that of heavy heat insulation is 20 %. Therefore, the effect of heavy heat insulation in the level of the excellent factory is shown. If heavy heat insulation is performed, the temperature of the furnace inner wall will rise. Therefore, the investment must include upgrading of the furnace refractories.

T-1: 0.95 → 0.80
T-2: 0.90 → 0.80
T-3: 0.92 → 0.80
T-5: 0.80 → 0.80
T-7: 0.90 → 0.80

Energy saving (average): Factory A: 24,053 GJ/y (1,297 MJ/t)
Factory B: 31,693 GJ/y (10,320 MJ/t)

<Measurement of furnace surface temperature and calculation of heat radiation>

On the T-7 furnace, ceramic fiber board is partly applied to the regenerator wall surface and the surface temperature is low. However, at the portion where the ceramic fiber board is not applied, the measured surface temperature was approximately 100 °C. On the T-2 furnace, the regenerator surface temperature was as high as 200 to 240 °C.

Table 4.1.15 shows the heat radiation calculated from the surface temperature and surface area (side surface only) visually checked.

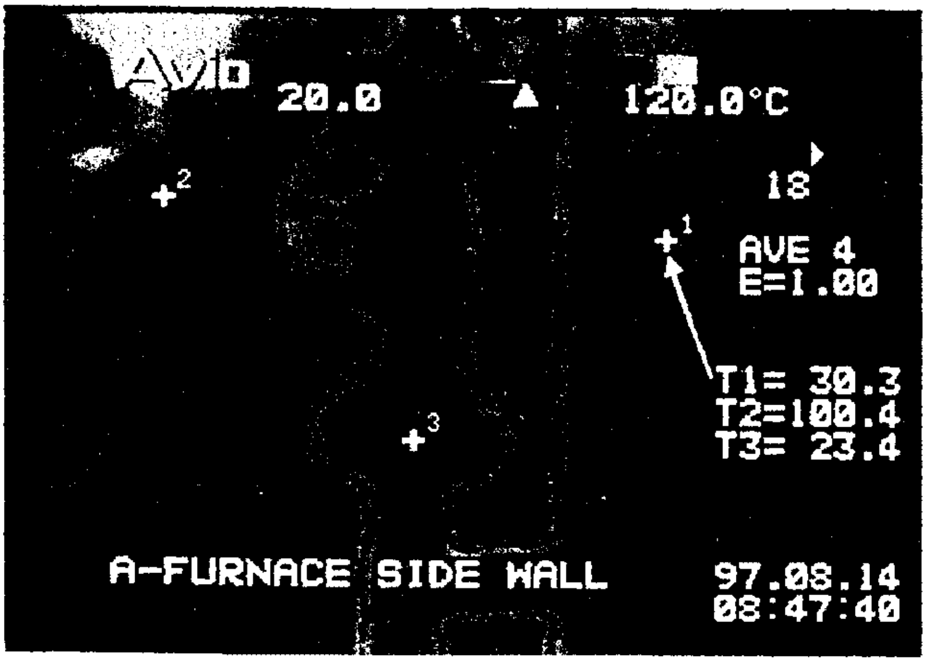
Table 4.1.15 Heat Radiation from the Regenerator Side Surface of the Melting Furnace

Case	Portion	Area	Surface Temperature	Room Temperature	Heat Radiation	Heat Radiation
		(m^2)	(°C)	(°C)	(kJ/h)	(kcal/h)
1	T-7 Regenerator brick wall	360	100.0	30.0	1,105,803	264,167
2	T-2 Regenerator brick wall	86.4	240.0	30.0	1,280,961	306,011
3	T-7 Regenerator fiber wall	360	60.0	30.0	378,262	90,364

Case 3 shows the heat radiation calculated for comparison based on the surface temperature (60 °C) of the portion to which ceramic fiber board is applied on the T-7 furnace. Since the surface temperature is low, heat radiation is approximately 1/3 compared with the case in which the lining is not provided.

The surface temperature difference between the wall surface with ceramic fiber board and that without ceramic fiber board can be viewed with a thermal image display unit. Figure 4.1.12 shows an example.

Figure 4.1.12 Thermal Image of T-7 Furnace Regenerator Wall Surface



② Increasing heat recovery by modification of regenerator checker brickwork (Step 2)

An increase in heat recovery from the regenerator will raise the preheating temperature for the combustion air and improve the fuel intensity. The heat exchange efficiency in the regenerator is closely related with the checker brickwork design. The heat exchange efficiency increases in proportion to the heating surface area of the checker brick per unit volume. The checker brick should be as thin as possible and the flue for exhaust gas and air should be as narrow as possible, which is limited by possible occurrence of brick collapsing due to erosion and blocking with dust.

On the other hand, making the regenerator larger and building up the checker bricks high will, of course, increase heat recovery. In this case, however, a large amount of investment is needed for modification. Although building up checker bricks as high as possible in the existing regenerator can be considered, there is no allowance for more bricks in the Wolomin's melting furnace. Therefore, the following may be recommended for improvement of the material and shape:

T-1: High-alumina checker brick → Magnesia brick (40 mm thick) with box type: 11.3 m^2/m^3 → 16.7 m^2/m^3

T-2: High-alumina checker brick → SEPR cruciform 11.3 m^2/m^3 → 17.3 m^2/m^3

T-3: Current status because the cruciform is already used: 17.3 m^2/m^3

T-5: Since a recuperator is used, modification into a regenerator requires a large amount of investment and is not practical. The use of an oxygen burner described later will be more advantageous.

Hence, the possibility of improving the current recuperator should be considered.

The current survey revealed that there is a good chance that a sizeable amount of air for preheating leaked to the exhaust gas side inside the recuperator. The temperature of the preheating air can be raised substantially if the leakage can be prevented by repairing the recuperator. Air preheating temperature 450 °C → 550 °C

T-7: High-alumina checker brick → Magnesia brick (40 mm thick) with box type: 11.3 m^2/m^3 → 16.7 m^2/m^3

As a result of simulation that further raises the combustion air temperature without changing the exhaust gas temperature at the outlet of the furnace, it is found, as shown in Table 4.1.16, that the exhaust gas temperature at the outlet of the regenerator drops and the heat utilization rate of the furnace including the regenerator is improved. This means enhancing heat recovery by the regenerator. For this purpose, the heating surface area of the regenerator should be increased. Also, if this improvement is implemented, the exhaust gas temperature will go down, and the input heat to the waste heat boiler decreases, and steam generation is reduced.

Table 4.1.16 Trial Calculation of Rise of Air Preheating Temperature (T-7 Furnace)

Case	Air Temperature	Exhaust Gas Temperature	Exhaust Gas Loss Rate	Heat Utilization Rate
Current status	1,050 °C	405 °C	22.4 %	77.6 %
Increase in temperature	1,100 °C	362 °C	19.7 %	80.3 %

Exhaust gas loss rate: Ratio of the heat held by the exhaust gas at the outlet of the regenerator to the fuel latent heat

Heat utilization rate : Fuel latent heat minus the heat held by the exhaust gas

Energy saving (average): Factory A: 9,563 GJ/y (515 MJ/t)
Factory B: 10,085 GJ/y (3,284 MJ/t)

③ Reducing the furnace size (Step 3)

When the air ratio was improved, openings sealed off, heat insulation reinforced, and regenerators modified, as energy conservation measures for melting furnaces, energy conservation per unit of molten glass amount (MGS) was 14.7 % at factory A, and 16.3 % at factory B. To achieve the energy intensity of the Excellent factory, the amount of molten glass would have to be increased to a level that achieves peak capacity for the factories. That means production at factory A will have to be increased 2.5 times, and average production will have to go up 4.4 times at factory B.

If energy conservation is to be achieved with production levels frozen at 1997 levels, the furnaces will have to be reduced in size.
The T-7 furnace at factory A will have to be reduced in size, and modified into an end-port type furnace. The furnace before and after such modification will compare as follows.

Item	Current state (before modification)	Reduced furnace (after modification)	Difference
Furnace type	Side-port type	End-port type	
Maximum molten glass amount (t-MGS/d)	236	127	109
Melting area (m^2)	100	58	42
Molten glass amount in 1997 (t-MGS/d)	95.9	95.9	0
Fuel consumption (kl-oil/d)	22.8	17.6	5.2
Annual fuel consumption (GJ/y)	326,618	248,907	77,711

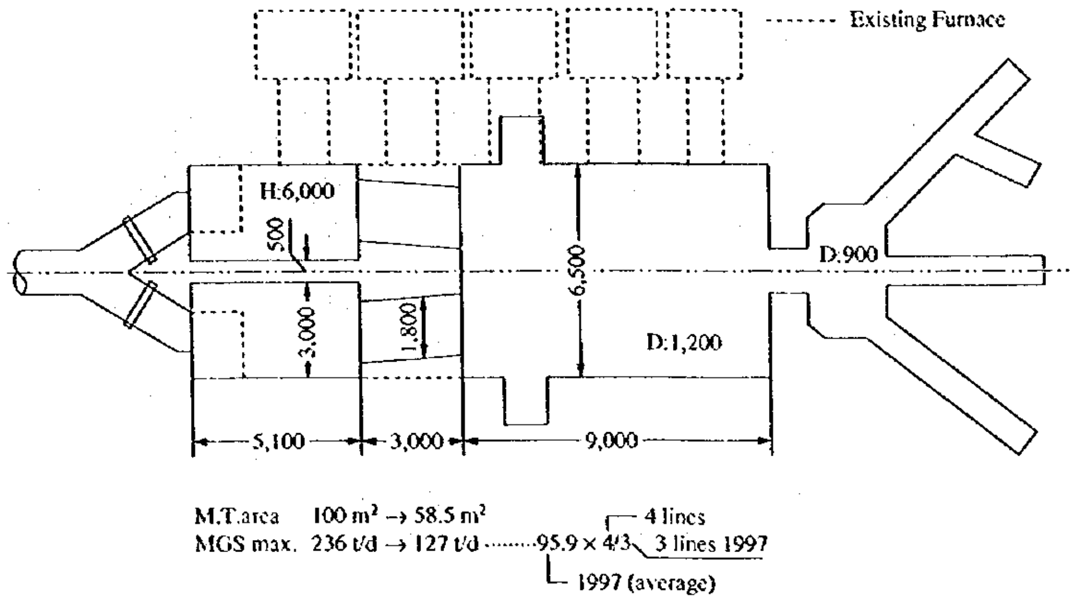
If the melting capacity of the current melting furnace is reduced and modified, fuel consumption will be reduced by 77,711 GJ/y. Since the saving in fuel will amount to 51,484 GJ/y, if reinforced combustion management, reinforced heat insulation, and modifications to regenerators, etc., were implemented to the current melting furnace, the amount of fuel saved by reducing and modifying furnace capacity will be 26,277 GJ/y.

The reduction of furnace capacity will reduce the amount of cooling air for the furnace. If the melting area was 58 % of the current size, the furnace's wall surface area will be reduced by 23 %, and therefore the amount of power currently used by the cooling fan, or 69 kW, will go down by 15.9 kW.

Annual saving in fuel will be
$15.9 \times 24 \times 365/1,000 = 139$ MWh/y.

Amount of fuel saved by reducing furnace capacity
of T-7 furnace at factory A : 26,227 GJ/y (1,414 MJ/t)
Amount of electric power saved: 139 MWh/y (7.5 kWh/t)

Figure 4.1.13 New Dimension of T-7 Furnace



④ Conversion into full-electric melting tank furnaces (Step 3)

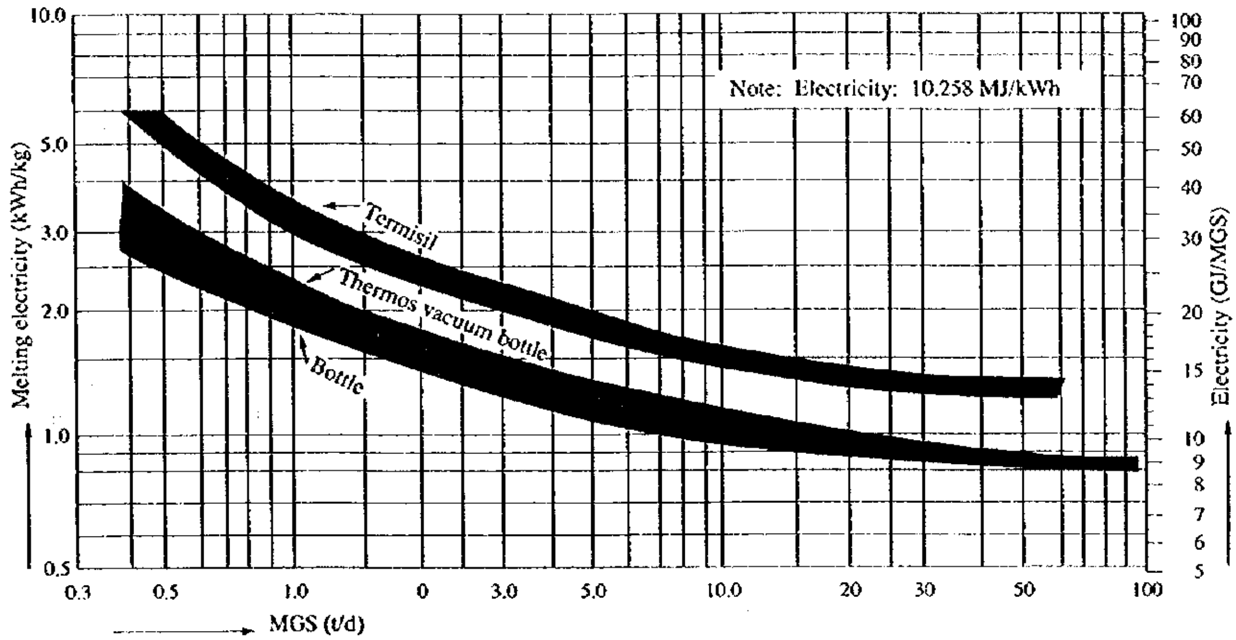
Although the 4 furnaces at factory B all fall into the small scale category, increasing melting quantity to peak production level will not be realistic, since that will increase current production by 4 times.

On the other hand, in order to further reduce furnaces for achieving energy conservation and increasing the melting load, it would not seem promising to modify, reduce the existing type of furnaces, or newly install a furnace. Rather it would be more advisable to convert furnaces into electric melting tank furnaces since they perform better as the furnace size gets smaller.

Additionally, the notion of consolidating the T-2 and T-3 furnaces, that treat the same glass composition and are installed in parallel, was also examined, but then discarded, because linking the bodies of 1,500 °C molten glass by a canal stretching several meters over 10 m would be far more challenging than first anticipated, not to mention the problem in terms of cost efficiency.

Since running electric power directly through molten glass achieves high efficiency in melting glass, its advantage in gas combustion becomes greater especially when the furnace gets smaller. Because there are advantages in terms of economy, quality, and even in terms of environmental pollution, such conversions for small scale furnaces of 20 t/d or less often take place even in Japan, where electric power rate is expensive.
Since the concept of melting differs between electric melting tank furnaces and gas or heavy oil combustion furnaces, it is important to pay careful attention not only to furnace structure, but also to the raw material.
The relationship between molten glass amount and energy intensity is shown in Figure 4.1.14.

Figure 4.1.14 Melting Energy Intensity of Electric Melting Tank Furnace



While electric melting tank furnaces come in several variations, depending on how the electrodes are inserted (side, bottom, and upper, etc.), each type has its advantages and disadvantages, with the side electrode rod furnace, shown in Figure 4.1.15, being the type that is most often used. Additionally, each type of electric melting tank furnace is shown in Figure 4.1.16.

Figure 4.1.15 Side Electrode Rod Type (Staneck)

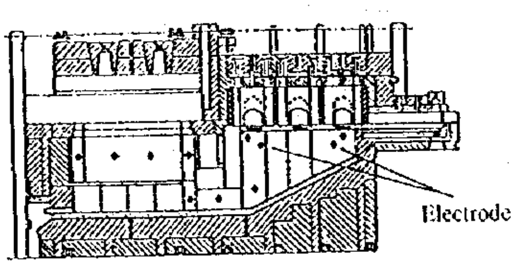
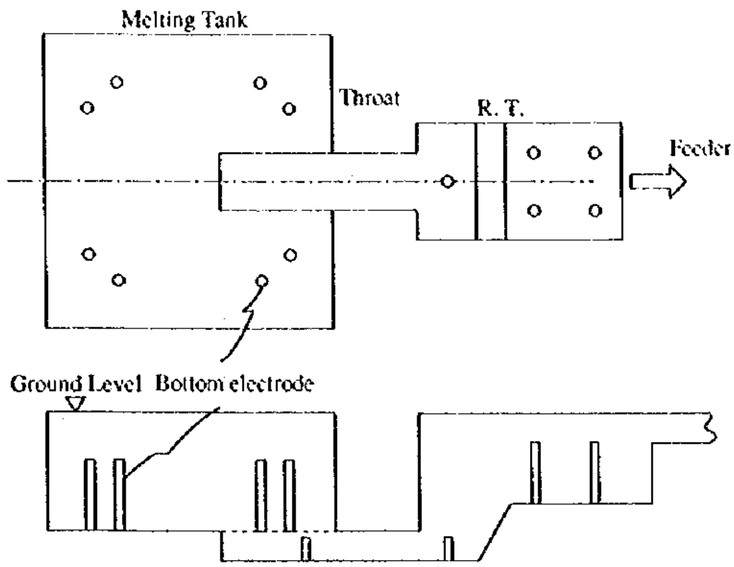
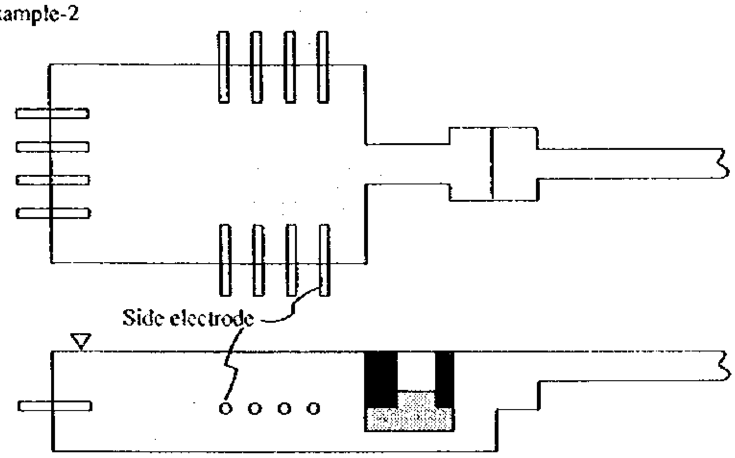


Figure 4.1.16 Types of Electric Melting Tank Furnaces

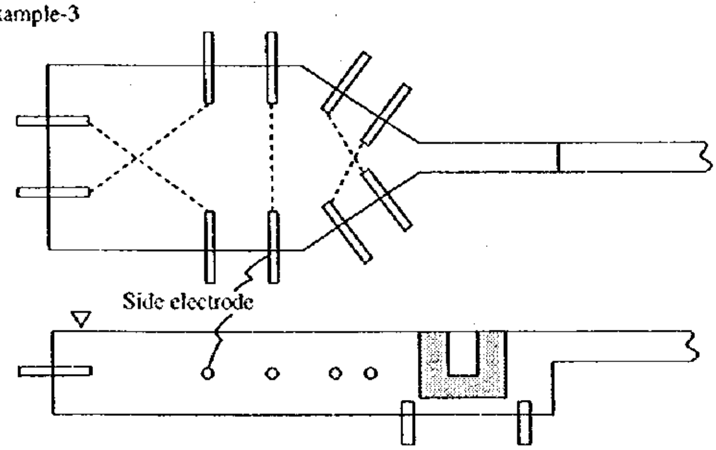
Example-1



Example-2



Example-3



The specification for modifying furnaces T-1, 2, 3, and 5, at factory B, into electric melting tank furnaces is as follows.

Item	T-1 furnace	T-2 furnace	T-3 furnace	T-5 furnace	Total for factory B
1. Current state					
1.1 Maximum amount of molten glass (t-MGS/d)	20	24	20	18	82
1.2 Melting area (m^2)	14.1	32.7	25.0	28.9	100.7
1.3 Amount of molten glass in 1997 (t-MGS/d)	4.0	6.7	3.5	4.3	18.5
1.4 Fuel consumption (kl-oil/d)	3.6	8.1	6.2	7.7	25.6
1.5 Annual fuel consumption (GJ/y)	51,804	119,762	75,175	104,505	351,245
2. Electric melting tank furnace (after modification)					
2.1 Melting area (m^2)	2.3	6.8	4.2	4.9	18.2
2.2 Amount of glass in 1997(t-MGS/d)	4.0	6.7	3.5	4.3	18.5
2.3 Electricity intensity (kWh/kg)	1.5	1.8	2.2	2.1	1.9
2.4 Electricity consumption (MWh/y)	3,069	6,605	3,602	4,629	17,905
2.5 Annual electricity consumption (GJ/y)	31,482	67,754	36,949	47,484	183,669

If all 4 furnaces at factory B are modified into electric melting tank furnaces, energy consumption will drop from 351,246 GJ/y to 183,669 GJ/y, realizing an approximately 50 % saving. After subjecting existing melting furnaces to measures such as strengthening combustion management, reinforcing heat insulation, modifying regenerators, etc., fuel consumption will be 290,304 GJ/y, and by reducing furnace capacity and modifying the electric melting tank furnaces, this figure becomes 0 while 17,905 MWh/y of electric power is used.

Reducing furnace capacity reduces the amount of air for cooling the furnace. When melting area is reduced by 18 % (= 18.2 m^2/100.7 m^2 × 100), the furnace's surface area is reduced by 58 %, and thus, the amount of electric power currently used by the cooling fan, or 112 kW, drops by 65 kW.

The amount of fuel saved annually is 65 × 24 × 365/1,000 = 569 MWh/y.

The amount of fuel saved by reducing furnace capacity and modifying T-1, 2, 3, and 5 furnaces at factory B into electric melting tank furnaces are as follows : 290,304 GJ/y

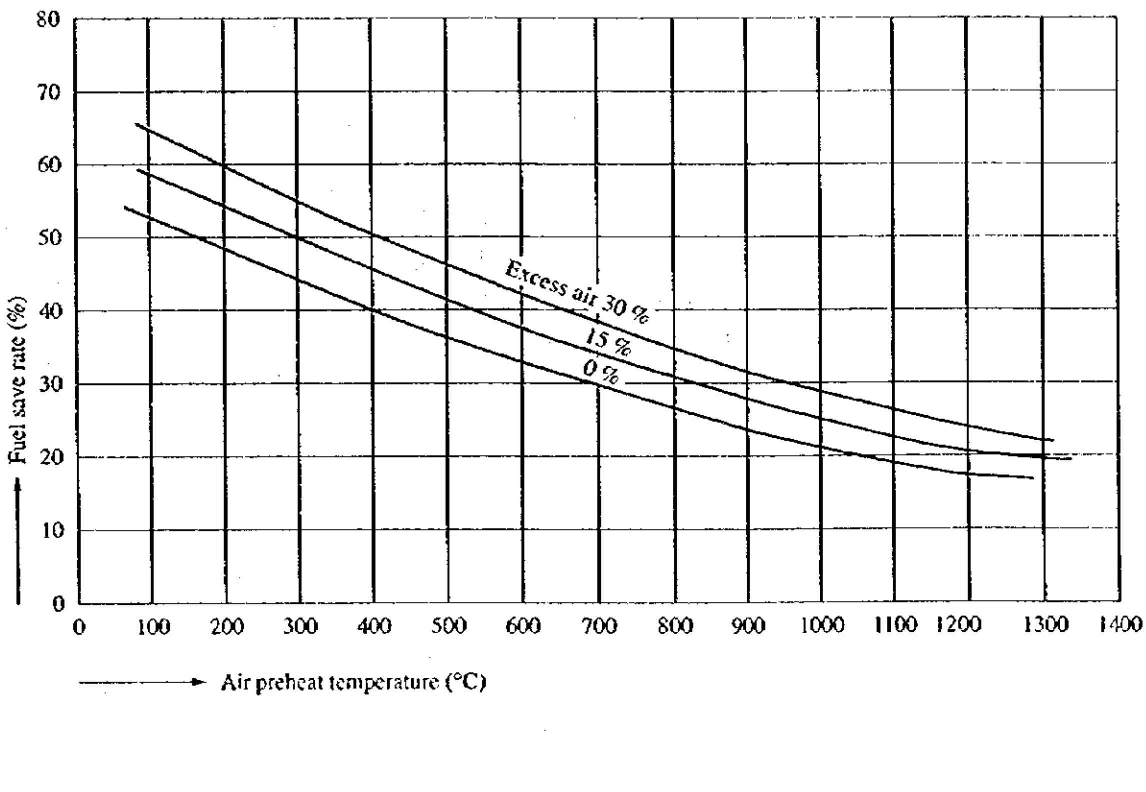
Increase in electric power use due to introducing electric melting tank furnace : 17,905 MWh/y (5,830 kWh/t)

Amount of electric power saved by cooling fan: 569 MWh/y (185 kWh/t)

⑤ Conversion into oxygen combustion (Step 3)

Along with electric melting tank furnaces, a system for melting glass that is becoming widespread in recent years is the oxygen burning process. While there are methods that use oxygen for boosting, oxygen combustion currently being introduced to small size furnaces is a combustion method using 100 % oxygen, eliminating the need for regenerators and for switching the direction of blow, giving them the advantage of stable, continuous combustion at high temperature. The appearance of compact oxygen generators that can be installed onsite is an especially important factor in their increased use. With regard to electric melting, it is advatageous for the T-1, 2, 3, and 5 furnaces at Wolomin to adopt it from an energy conservation standpoint. Figure 4.1.17 reveals that when a furnace with an air preheating temperature of 400 °C, and excess air ratio of 30 %, is converted into an oxygen combustion furnace, an approximately 50 % energy conservation can be anticipated.

Figure 4.1.17 Fuel Save Rate by Oxygen Combustion



3) Improving the operation rate (Step 3)

In the continuous glass manufacturing plant, the operation rate should be close to 100 % unless periodical repair or color change is required. However, as shown in Table 4.1.17, it is approximately 85 % in Wolomin every year, which cannot be understood. If the annual plan and monthly plan are made correctly, naturally the operation rate should be adjustable with the daily molten glass volume. If the plant is often shut down by accidents or machine repair, the problem lies in daily maintenance, which can be prevented by implementing the TPM activities.

Thus, a reduction in the operation rate invites an increase in energy consumption, which is disadvantageous from a cost efficiency perspective, and therefore, efforts should be made to keep the operation rate as high as possible. The average monthly energy intensity for stable operation months, derived from the monthly data of each furnace in 1996, and the monthly average energy intensity for all months, based on the annual data, are compared, and the difference is shown in Table 4.1.17. The difference in energy intensity is 6.5 % on average, and appears to have room for more energy conservation. However, under current circumstances in which demand is sluggish, and production has to be adjusted, the only avenues for energy conservation would be to reduce melting quantity and implement low temperature operations; yet, if operations are already taking place at temperatures lowered to their bottom limits, there can hardly be ways of energy conservation left. Therefore, possibilities for energy conservation were calculated under the assumption that furnaces are reduced, melting loads are returned to normal levels, and operation rates are raised to average levels. The energy intensity reduction rate for T-7 at factory A becomes 4.1 %, but factory B shows an increase in energy, according to calculations. It is important to make considerations to allow melting furnaces to always operate at full capacity, and to plan production according to sales activities and accurate forecasts of demand.

Table 4.1.18 shows the operation rate for each furnace, and the monthly fuel intensity for full operation months and for months that included days when production was stopped, in 1997. Judging from this table, the difference in fuel intensity is smaller than anticipated. Moreover, since causes of reductions in operation rates include problems related to demand, and manpower problems related to manual blowing operations, that cannot always be avoided, the operation rate will not be considered when calculating energy conservation potential.

Table 4.1.17 Trend of Operating Hours and Difference of Energy Intensity by Operation Rate

Plant	Operation hours 1992	1993	1994	1995	1996	Energy intensity in 1996 GJ/t-MGS	Stable operation month only	Difference (%)
T-1	5,568	5,544	5,544	5,544	7,800	41.3	37.6	9.0
T-2	8,784	8,760	8,760	7,896	8,160	51.9	50.9	1.9
T-3	5,688	5,568	5,160	5,904	6,750	80.6	77.2	6.2
T-5	8,784	8,760	8,760	8,760	7,360	111.1	106.0	4.6
T-7	8,784	8,760	6,600	8,760	7,660	9.3	8.5	8.9
					average	average	average	
Operation rate (average %)	85.9	85.4	79.5	84.2	85.9	17.6	16.5	6.5

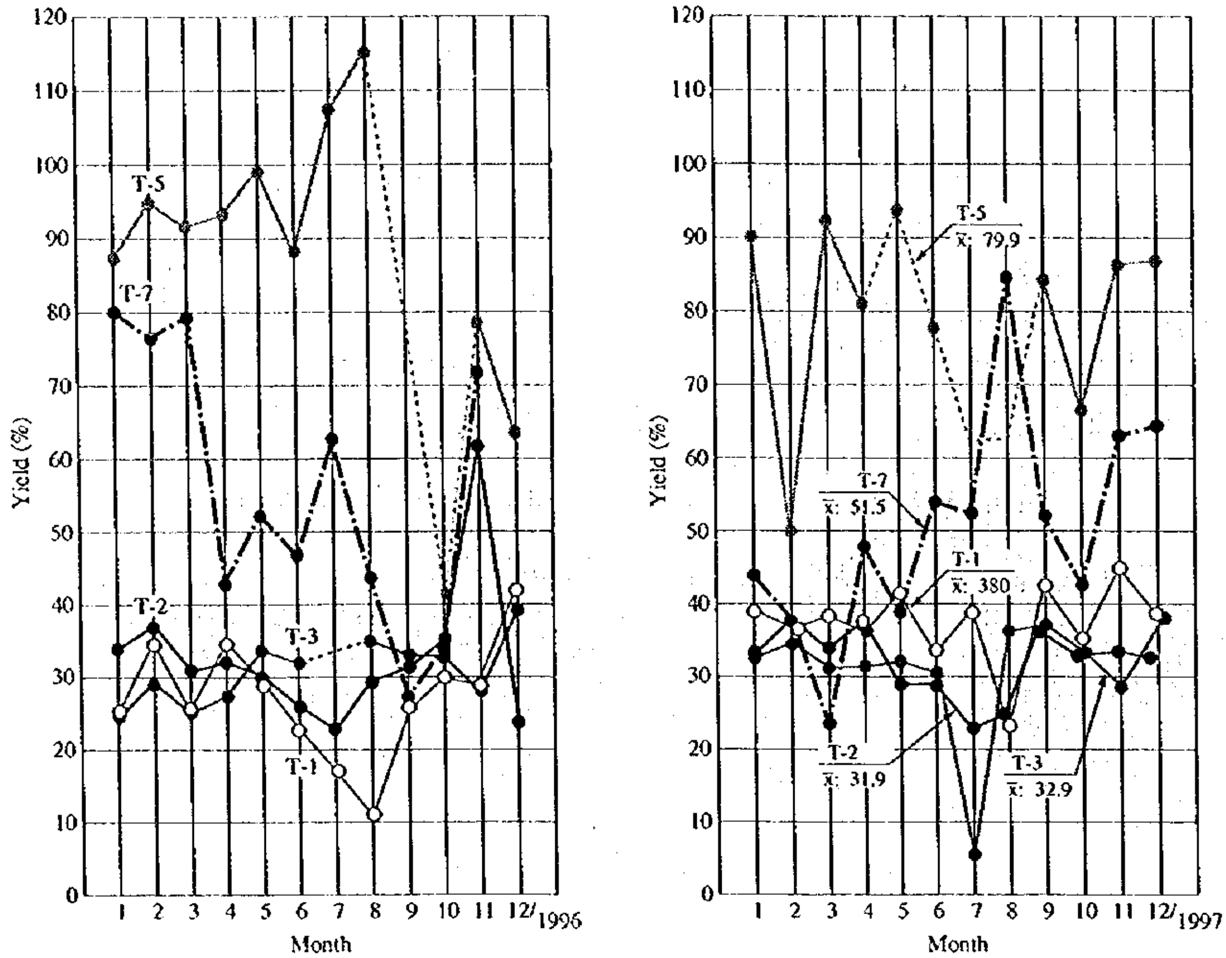
Table 4.1.18 Difference of Energy Intensity by Operation Rate in 1997

Plant	Operation stop (d/y)	Operation rate (%)	Natural gas/MGS (× 10³ m³/t)/y	→ Stable month (× 10³ m³/t)/y	Energy intensity (GJ/t-MGS)	→ (Stable)
T-1	29	92.1	1,443/ 1,335	664/ 613	38.8	38.9
T-2	0	100.0	3,336/ 2,446	3,336/ 2,446	49.0	49.0
T-3	78	78.6	2,094/ 989	1,768/ 892	76.0	71.2
T-5	31	91.5	2,911/ 1,438	2,471/ 1,130	72.7	78.5
Sub-total	138	90.5	9,784/ 6,208	8,239/ 5,081	56.6	58.2
T-7	15	95.9	9,098/33,553	6,933/26,482	9.73	9.40
Total	153	91.6	18,882/39,761	15,172/31,563	17.0	17.3

4) Yield improvement (Step 3)

So far, the energy intensity per molten glass volume has been discussed. Since energy conservation should finally be evaluated in terms of the energy intensity per product, the effect of the product yield to the energy intensity will be great. As shown in Table 4.1.7, the energy intensity per product has a big difference even though the energy intensity per molten glass volume is at the level of the excellent factory. Figure 4.1.18 plots the yield from the monthly data in 1996 for each furnace. The graph reveals that there is a large disparity in spite of the monthly average yield and that management is insufficient.

Figure 4.1.18 Monthly Data of Product Yield at Each Furnace in 1996 and 1997



Note: T-1: 15-operation stop day in August
T-3: 24-operation stop day in July

Therefore, the average value can be expected to be increased to the higher yield level by promoting TQC and other similar activities and adequately implementing process control and quality control as shown in the following table.

	Yield (%)			
	1996	1997		Target
T-1	29.3	38.0	→	45.0
T-2	30.3	31.9	→	40.0
T-3	29.1	32.9	→	40.0
T-5	87.6	79.9	→	90.0
T-7	54.3	51.5	→	80.0
Average	52.3	50.3	→	74.6

Therefore, the intensity improvement rate is $(1 - 0.523/0.746) \times 100 = 32.7$ %. If it is assumed that the production increase caused by yield improvement is adjusted by reducing the molten glass volume, the effect of energy conservation will be small for the current furnaces like the operation rate improvement described above. Besides, since a few years will be needed to achieve this, it should be applied in Step 3.

The effects of yield improvement for the T-7 furnace at factory A are as follows.

Item	Current state	After furnace capacity reduction and yield improvement	Difference
Yield (%)	51.5	80.0	28.5
Production amount (t/y)	18,551	18,551	0
Cullet ratio (%)	40.1	20.8	-19.3
Amount of molten glass (t-MGS/d)	95.9	67.7	-28.2
Fuel consumption (kl-oil/d)	22.8	13.9	-8.9
Annual fuel consumption (GJ/y)	326,618	194,858	-131,760

If yield is improved after furnace capacity is reduced, fuel consumption will become 131,760 GJ/y less than the current state. Since fuel consumption after furnace capacity reduction takes place is 248,907 GJ/y, the amount of fuel saved due to improved yield is 248,907 - 194,858 = 54,049 GJ/y.

The effects of yield improvement for the furnaces T-1,2,3, and 5 at factory B are as follows.

Item	T-1 furnace	T-2 furnace	T-3 furnace	T-5 furnace	Total for factory B
1. Current state					
1.1 Yield (%)	38.0	31.9	32.9	79.9	
1.2 Production amount (t/y)	560	887	373	1,251	3,071
1.3 Cullet ratio (%)	46.0	51.9	53.3	43.0	48.8
1.4 Amount of molten glass(t-MGS/d)	4.0	6.7	3.5	4.3	18.5
1.5 Fuel consumption (kl-oil/d)	3.6	8.1	6.2	7.7	25.6
1.6 Annual fuel consumption (GJ/y)	51,804	119,762	75,175	104,505	351,246
2. Yield improvement by electric melting tank furnace					
2.1 Yield (%)	45.0	40.0	40.0	90.0	
2.2 Production amount (t/y)	560	887	373	1,251	3,071
2.3 Cullet ratio (%)	40.5	40.1	40.5	40.1	40.3
2.4 Amount of molten glass (t-MGS/d)	3.4	5.7	3.0	3.9	16.0
2.5 Electricity intensity (kWh/kg)	1.6	1.9	2.3	2.1	1.9
2.4 Electricity consumption (MWh/y)	2,843	5,887	3,396	4,345	16,471
2.5 Heat value equivalent to annual power consumption (GJ/y)	29,163	60,389	34,836	44,571	168,959

If yield is improved at the 4 furnaces at factory B after they are modified into electric melting tank furnaces, energy use drops from 351,246 GJ/y to 168,959 GJ/y. Since electric power consumption is reduced to 183,669 GJ/y because of the modification to electric melting tank furnaces, the amount of energy saved due to improved yield is 14,710 GJ/y. The amount of electric power saved is 1,428 MWh/y.

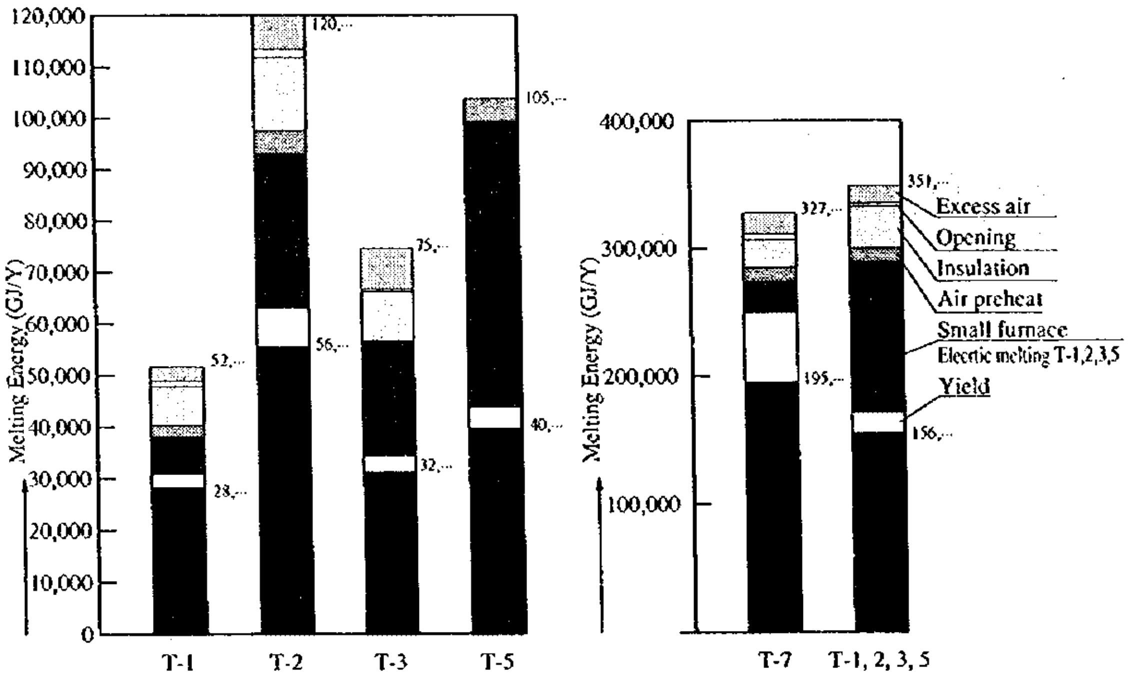
Fuel saving due to improvement of yield at factory A: 54,049 GJ/y (2,914 MJ/t)
Electiricity saving due to improvement
of yield at factory A : 1,434 MWh/y (467 kWh/t)

Note:
Since the amount of the raw material cullets can be reduced as a result of yield improvement, cullets recycled from the town contribute not only to environmental protection but also to energy conservation. Presently, T-7 uses approximately 1,000 tons of cullets recovered from the town a year. For melting furnaces for bottle in excellent factory, 35 to 40 % of product tons is the cullets recycled from the town. (However, care must be taken so that impurities will not be mixed.)
Use of 1 ton of cullets corresponds to energy conservation of approximately 1.65 GJ.

As described above, the energy conservation potential including the melting energy has been estimated. In this audit, fuel energy conservation in the fore-hearth, molding, and annealing processes could not be performed.

Figure 4.1.19 shows trend of energy conservation measures.

Figure 4.1.19 Trend of Melting Energy of Each Furnace by Energy Conservation Step



c. Utilities (heat utilization facilities)

1) Boiler

A waste heat hot water boiler is installed for T-7 in factory A to recover the exhaust heat of 9.2 GJ/h. This corresponds to 5 % of the input heat of the T-7 furnace. On the other hand, four coal-firing hot water boilers are installed in factory B and their capacity is 4 GJ/h-boiler. According to the actual result in 1996, they are operated for heating in winter and energy of 12 GJ/h is consumed if they run for 200 days a year.

As with T-7, if a waste heat hot water boiler is installed, and the heat value of exhaust gas from T-1,2,3 and 5 is recovered, a maximum of 11 GJ/h can be recovered, but as explained earlier, the amount of energy recovered will drop as various energy conservation measures make progress. Moreover, the adoption of oxygen combustion furnaces and the conversion of all melting furnaces into electric melting tank furnaces will render the installation of waste heat hot water boilers meaningless, because almost all exhaust gas will be eliminated. Therefore, the installation of waste heat hot water boilers should be considered only as part of an overall plan.

According to the investigation of September 1998, the coal consumption intensity of the boilers for heating was improved by 30 %. What is especially noteworthy is that the coal consumption intensity of the boilers was improved by over 30 %. This is due to improved boiler efficiency which resulted form thoroughly cleaning the inside of the boilers.

It is hoped that maintenance and operation management will be performed adequately so this level will be maintained into the future.

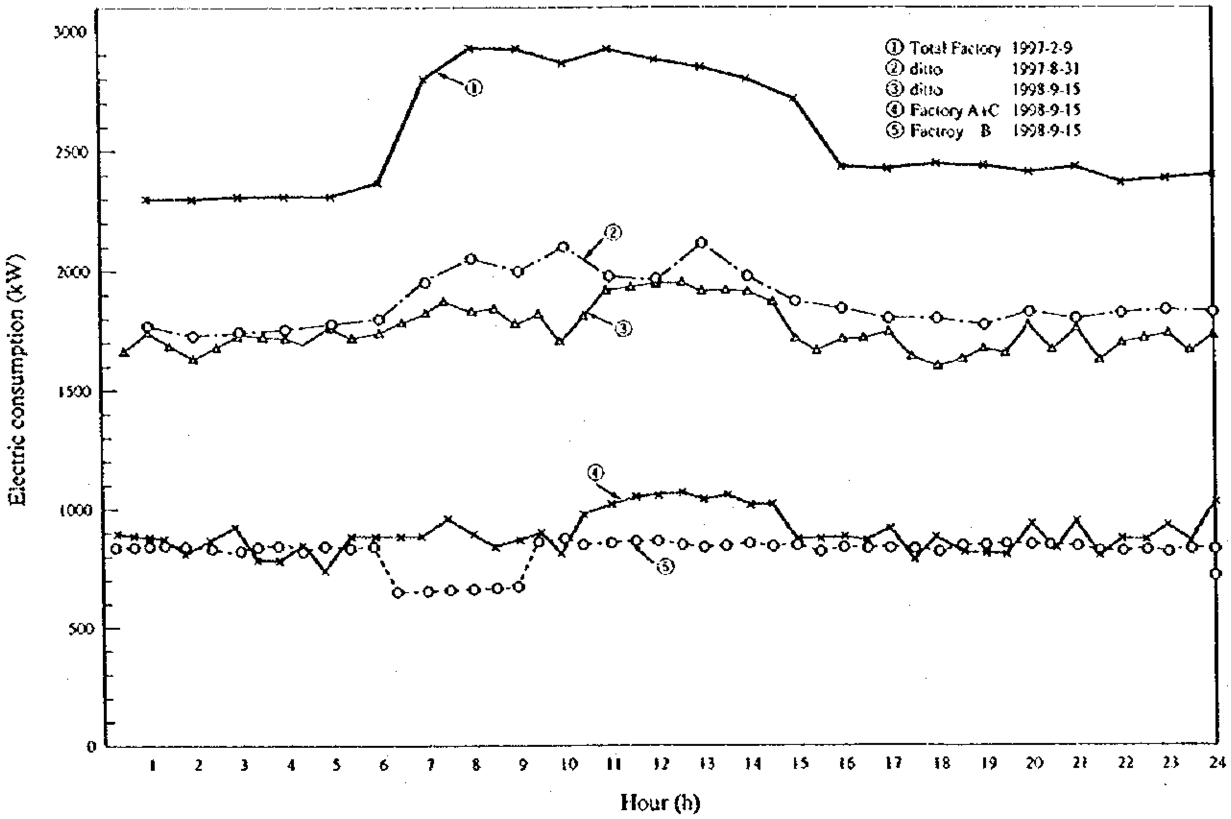
d. Utilities (electricity utilization facilities)

1) State of Electric Power Load at Factory

Judging from the state of electric power use in Figure 4.1.20, consumption is greater during the winter than in the summer, and factory A spends more power than factory B. Additionally, a peak load of 100 to 150 kW occurs on specific days of the week, and just before and after starting time, which is probably the principal factor that is increasing the contract demand for electricity. This condition can also be observed from the difference between the maximum value and demand (50 kW) when demand at factory A was measured. As causes for this difference, the simultaneous starting of all electric heaters, and reduction in air compressor efficiency, etc., are possible. If these factors are investigated, and countermeasures implemented, contract demand can be reduced by about 50 kW. If this improvement is made, demand price can probably be reduced by approximately 1.4 % of the total annual electricity bill (26,700 PLN).

Reduction in electric power cost: 26,700 PLN/y (≈ 50 kW × 44.5 PLN/kW × 12 M)

Figure 4.1.20 Daily Load Curve of Factory



2) Electricity conservation for the air compressor

Electricity used by the air compressors in this factory is 465 kW (3 units) at factory A and 124 kW at factory B, totally 589 kW (643 kW for 1990), thus accounting for approximately 34 % of total electricity consumption. Four 200 kW reciprocating air compressors are running at this time. This load condition is presumed to occur within the time zone 11:30 ~ 14:30 on the daily load curve in Figure 4.1.20. The load conditon in the time zone is lower by about 100 kW.

The air pressure of the air compressor is 0.6 MPa, while its air feed pressure is 0.4 + 0.02 MPa. The pressure needed by the factory is low, being 0.33 MPa for forming machines and 0.28 MPa for blowing. For this reason, the air feed pressure is adjusted manually, viewing a dial gauge. A pressure of about 0.6 MPa is occasionally required for receiving raw materials, and for transferring fine material between factories A and B.

Thus, the following forms of electric power use can be considered wasteful. In other words, ① the pressure of the air used in mass quantity is too high with respect to that of the air generated, and ② because the pressure of the air supply is adjusted manually, and the accuracy of the pressure gauge is not good, electric power consumption is probably accumulating wastefully. Besides these wastes, air is probably leaking from machinery and equipment, as well as from each location of use.

As countermeasures for such energy loss

① The pressure of generated air at the compressor should be lowered from 0.6 MPa to 0.4 MPa. This will lead to an approximately 15 % reduction in electricity consumption, which means a saving of about 663,789 kWh annually, or about 3.4 % of total electricity consumption.

Amount of electric power saved:
((= 589 kW × 4 h + 489 kW × 20 h) × 0.15 × 365 d)

{ Factory A: (465 × 4 + 368 × 20) × 0.15 × 365 ÷ 1,000 = 505 MWh/y
{ Factory B: (124 × 4 + 103 × 20) × 0.15 × 365 ÷ 1,000 = 140 MWh/y

As another effect, the number of times air compressor valves have to be changed, due to damage related accidents, which is currently occurring every month, will go down, reducing the amount of maintenance work.

② The pressure setting of the pressure detector should be lowered as much as possible by improving its detection accuracy, and ways to automate its adjustment should be devised. Additionally, small scale air compressors should be installed where needed,and the number of facilities operating can be minimized, thus, improving the efficiency of facilities in constant use.
As a result of this, assuming normal operation is taking place, a reduction of about 860 MWh in electricity consumption (about 4.6 % of total power consumption) can be anticipated.

In addition, labor required for adjusting air pressure can be saved.

{ Factory A: (465 × 4 + 368 × 20) × 0.2 × 365 ÷ 1,000 = 673 MWh/y
{ Factory B: (124 × 4 + 103 × 20) × 0.2 × 365 ÷ 1,000 = 187 MWh/y

③ In order to prevent air leakage from air compressors and areas where the air is used, checks should be conducted frequently, and air leakage should be stopped in its earliest stage. The pressure reduction for generated air mentioned earlier can also be expected to reduce leakage.

Amount of electric power saved:
663,789 kWh/y + 885,928 kWh/y = 1.550 MWh/y

3) Light motor load and measures to improve power factor

According to results of measuring power use and power factor of principal facilities in Table 4.1.19, there are some light load, low power factor facilities. Additionally, although not light in load, there are also facilities whose damper valves, and other such devices are reduced, or bypassed, and thus, wasting energy.

Table 4.1.19 Measurements Data of Major Load in 1998

Name of load		Rating (kW)	Consumption (kW)	Voltage (V)	p.f. (%)	Remark
Receiving power total			1,855			by factory computer
	Factory A, C		1,014			A: 978 kW, C: 36
	Factory B		841			
TA-1	Air compressor #2	200	150	388	76	Continuous
	Air compressor #3	200	147			
	Air compressor #5	200	165	386	74	
	Exhaust fan of furnace	2 × 55	55	381	87	
	Booster for furnace	80	16			
	Annealing furnace	2 ×	31	391	60	#
	Regeneration boiler	70				
TA-2	Ventilation fan for furnace	3 × 30	69	392	74	
	Cooling fan for forming machine	2 × 132	85	392	73	
	Raw material department	70	24			
Factory C	Annealing furnace	3 × 90	90			
1,000 kVA	Electric heater	50	50			
Factory B	Annealing furnace #2		63			#
1,600 kVA	Annealing furnace #3	120+	153			#
RNN	Raw material department		122	393	89	#
	Recuperator		39	393	80	
	Vacuum pump for thermos bottole	4 × 30	30	393	52	
	Ventilator fan #2, #3	4 × 22 ~ 30	112	388	84	
	Ventilator for laboratory		20	394	87	
	Annealing furnace for thermos bottle		30	393	52	
	Plastic extruder	7 × 15	53	393	88	
RNN 1	Water pump		18	393	71	#
630 kVA	Vacuum pump of form	30	11	386	51	
	Air compressor	4 × 200	124			#
	Plastic department	7 × 15	29	375		#
RNN 2	Water pump for cooler	3 × 15	27	393	83	#
630 kVA	Water pump for cooler	3 × 11	19	389	39	

Notes: #: Watching value of computer cont: Continuous measurement

The following two facilities should have their efficiency improved.

① Loads with low power factors: Fans and pumps with low power factors are running under light loads with respect to their capacities, with their flow rates probably being adjusted by means of reducing or dispersing dampers and valves.

Such situations should be compensated by either reducing facility capacity, or controlling the flow rate using an inverter. The latter is a control method that changes the number of motor revolutions by installing an inverter to the motor to obtain the specified flow rate, and is utilized often lately. If the flow rate is reduced by 20% when an inverter is adopted, the amount of electric power use can be expected to go down by 40% of rated value.

For example, if it is applied to the vacuum pump motors (30 kW) of thermos bottle line and the exhaust fan motor (55 kW) at factory A, and the flow rate is reduced by 20 %, the amount of power saved will be approximately 34 kW, and annual reduction is estimated to be about 245,280 kWh (1.3 % of total).
Additionally, inverter control can be applied, and the energy conservation effect will still be great, even if a pump's piping resistance is low, and fluctuation in pressure due to flow rate fluctuations is negligible. Additionally, the use of high efficiency motors whose losses are reduced is another way to go, but they still cost too much, and pose cost efficiency problems, and thus, omitted here.

$$\begin{cases} \text{Factory A: } 55 \text{ kW} \times 0.4 \times 24 \times 365 \div 1{,}000 = 193 \text{ MWh/y} \\ \text{Factory B: } 30 \text{ kW} \times 0.4 \times 24 \times 365 \div 1{,}000 = 105 \text{ MWh/y} \end{cases}$$

Amount of power saved: 245 MWh/y

4) Illumination

The amount of power used by indoor facilities at the factory is estimated at about 200 kW (building area is about 31,200 m^2), and that by outdoors illumination is about 30 kW (mercury lamps 100 × 300 W). During the day, daylight was largely used, and the lights were turned off. The illuminance where lighting is available was 200 to 300 lux, which is an appropriate level. Yet, the following measures are probably necessary from an energy conservation standpoint.
Lamps and related equipment should be cleaned about once or twice a year. Additionally, unnecessary lighting should be removed, and the mounting height of remaining lighting devices should be lowered as much possible. Furthermore, efforts should be made to turn them off during breaks.

The measures related to indoor illumination described above, cleaning lighting devices, turning off unnecessary lighting, and switching lamps installed at high locations (6 m or higher) to mercury lamps, etc., are estimated to result in about 20 % annually, or about 122,640 kWh of electric power can be expected to be saved. Additionally, by switching the outdoor mercury lamps to low pressure sodium lamps, electric power can be reduced by about 40 %, and since this can be applied to 30 % of the total, an annual reduction of 11,826 kWh can be achieved.

$30 \times 0.4 \times 0.9 \times 10h \times 365\ d \times 0.3 = 11{,}826\ kWh$

Thus, a total reduction of about 0.9 % of total power consumption can be expected.

Incidentally, the above estimates assume that indoor lights are turned by a factor 0.7, 12 hours a day, while the figures for outdoor lights are 0.9, and 10 hours, respectively.

Amount of power saved:	(Indoor)	122,640 kWh/y
	(Outdoors)	11,826 kWh/y

(3) Summary of Energy Conservation Potential

a. Improvement of Environment through Energy Conservation

If fuel consumption is reduced through energy conservation, the quantity of pollutants emitted to the atmosphere also decreases. Additionally, if the amount of purchased power is reduced through energy conservation, so is the amount of power generated, that is, the quantity of pollutants emitted to the atmosphere by power plants. This reduction in emission quantity due to energy conservation depends not only on the amount of energy conservation, but also the type of fuel, and equipment, such as boilers, etc. Therefore the correct way to estimate the quantity of pollutants is to use the actual amount emitted by each factory. Here, however, for the sake of the consistency with the comprehensive study on Poland as a whole, calculations are based on information on the unit emission quantity (pollutant tonnage/fuel-heating value TJ), per industrial sector and per fuel type, provided by a document from the Institute of Environmental Protection. The reduction in the emissiom of air pollutants from this factory achieved as a result of energy conservation is compiled at each stage of energy conservation, and shown in Table 4.1.20.

Table 4.1.20 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_x	Dust
Step 0				
Step 1	2,048	0.5	12.3	0.1
Step 2	4,508	6.7	24.6	1.4
Step 3	20,267	−2.0	121.2	0.2
Step 1-3	26,822	5.1	158.1	1.74

Reduction includes emission from fuel and electricity.

Also, in Poland, there is a system available that charges an emission fee (fee) to the polluter, and thus, the emission fee can be reduced through energy conservation. The unit price of the fee is specified per pollutant type. Additionally, for emissions that exceed a certain amount, a penalty fee (charge) is charged. The unit price of the charge is 100 times that of the fee. The prices listed below are the regular emission fees.

The result of calculating the amounts of reduction in pollutant emission, for the energy conservation items that were proposed based on our factory survey, and the corresponding reductions in emission fees, is shown in Table 4.1.21. Furthermore, the payback period required to recover investments in energy conservation including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 4.1.21 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ PBP	Economical PBP
Step 0						
Step 1	816	4.2	820	500	0.61	0.61
Step 2	1,143	10.3	1,154	6,175	5.35	5.40
Step 3	2,595	38.8	2,634	11,252	4.27	4.34
Step 1-3	4,555	53.3	4,608	17,927	3.89	3.94

Units: Thousand PLN or thousand PLN/y for expense, Year for PBP

As evident from this Table 4.1.21, the reduction in emission fee is only a few percents at most compared to reduction in energy cost, and thus, the effect of reduced emission fees on the investment recovery period is also negligible.

The conversion from the melting furnace to an electring melting furnace included in Step 3 has a significant energy conservation effect and accordingly a large pollutant emission reduction effect. Here, however, the conversion is from gas fuel to electric energy (in other words, not conversion from coal fuel), and therefore the effect of reduced pollutant emission fee is at most 1 % of the effect of reduced heating source cost.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 4.1.23.

The energy conservation potential using the Excellent factory as the benchmark for energy consumption intensity, and energy conservation measures in Steps 1, 2, and 3 are shown in Figure 4.1.21. The relationship between energy conservation potential, the period to recover the investment, and the investment cost is shown in Figure 4.1.23.

Table 4.1.22 Summary of Energy Conservation Potential

Wolomin A — Coal: 170 PLN/t Electricity: 0.172 PLN/kWh Natural gas: 0.514 PLN/m³N (35.9 GJ/m³N) 1 PLN = 30 yen

Item		Energy Conservation Potential: Fuel GJ/y	Fuel 10^3 PLN/y	Fuel %	Electricity MWh/y	Electricity 10^3 PLN/y	Electricity %	Total 10^3 PLN/y	Investment 10^3 PLN	Payback period year
Step 1										
1. Reducing the volume of excess air	A	14,925	214	1.9				214	250	1.2
2. Blocking the openings	A	2,943	42	0.4				42		0.0
3. Controlling the air compressor pressure	A				1,178	203	6.1	203	0	0.0
4. Reducing the peak load	A				50 kW	27		27	0	0.0
Subtotal		17,868	256	2.3	1,178	203	6.1	486	250	0.5
Step 2										
5. Reinforcing the heat insulation	A	24,053	344	3.0				344	1,070	3.1
6. Increasing the amount of recovered heat by restructuring the brickwork of the regenerator chamber	A	9,563	137	1.2				137	1,746	12.8
7. Controlling motor revolution by inverter	A				193	33	1.0	33	128	3.9
8. Lighting: Changing to sodium lamps	A				75	13	0.4	13	30	2.3
Subtotal		33,616	481	4.2	268	46	1.4	527	2,974	5.6
Step 3										
9. Reducing the size of the melting furnace (*1)	A	26,227	376	3.3	139	24	0.7	400	750	1.9
10. Improving the yield of Factory A	A	54,049	774	6.8			0.0	774	2,286	3.0
Subtotal		80,276	1,149	10.1	139	24	0.7	1,173	3,036	2.6
Total for Factory A		131,760	1,886	16.6	1,585	273	8.2	2,186	6,260	2.9
Total for Factory B		351,246	5,031	44.1	Δ15,476	Δ2,662	Δ78.9	2,369	11,608	4.9
Total		483,006	6,917	60.7	Δ13,891	Δ2,389	Δ70.7	4,555	17,868	3.9

A: Factory "A"/T-7, B: Factory "B"/T-1,2,3,5

*1: Furnace modification cost is the difference (750,000 PLN) between the periodical repair cost (11,820,000 PLN) and reduction modification cost (12,570,000 PLN).

As of 1997: Overall factory: (A + B)

Fuel consumption: 792,661 GJ/y

Electricity consumption: 19,380 MWh/y (198,800 GJ/y)

Total: 991,461 GJ/y

Table 4.1.23 Summary of Energy Conservation Potential

Wolomin B — Coal: 170 PLN/t Electricity: 0.172 PLN/kWh Natural gas: 0.514 PLN/m³N 1 PLN = 30 yen

Item		Energy Conservation Potential							Investment	Payback period
		Fuel			Electricity			Total		
		GJ/y	10³ PLN/y	%	MWh/y	10³ PLN/y	%	10³ PLN/y	10³ PLN	year
Step 1										
1. Reducing the excess air	B	15,905	228	2.0				228	250	2.4
2. Blocking the opening	B	3,259	47	0.4				47	0	0.0
3. Controlling the compressor pressure	B				327	56	1.7	56	0	0.0
Subtotal		19,164	274	2.4	327	56	1.7	330	250	0.8
Step 2										
4. Reinforcing the heat insulation	B	31,693	454	4.0				454	1,348	3.0
5. Increasing the amount of recovered heat by modifying the brickwork of the regenerator chamber	B	10,085	144	1.3				144	1,784	12.4
6. Controlling the motors by inverter	B				105	18	0.5	18	69	3.8
7. Changing the lighting system to sodium lamps	A				60	10	0.3	10	20	2.0
Subtotal		41,778	598	5.2	165	28	0.8	626	3,221	5.1
Step 3										
8. Conversion to a fully electric melting furnace (*1)	B	290,304	4,158	36.4	Δ17,905	Δ3,080	Δ91.2	1,078	5,930	5.5
9. Reducing the output of the cooling fan	B		0	0.0	569	98	2.9	98	0	0.0
10. Improving the yield for Factory B	B		0	0.0	1,428	246		246	2,286	9.3
Subtotal		290,304	4,158	36.4	Δ15,908	Δ2,736	Δ91.1	1,422	8,216	5.8
Total		351,246	5,031	44.1	Δ15,416	Δ2,652	Δ78.6	2,379	11,687	4.9

A: Factory "A"/T-7, B: Factory "B"/T-1,2,3,5

*1: The modification cost for conversion to a fully electric melting furnace is the difference (5,930,000 PLN) between the periodical repair cost (15,260,000 PLN) and the construction cost (21,190,000 PLN) of the electric melting furnace.

Figure 4.1.21 Wolomin Factory-A Energy Conservation Potential

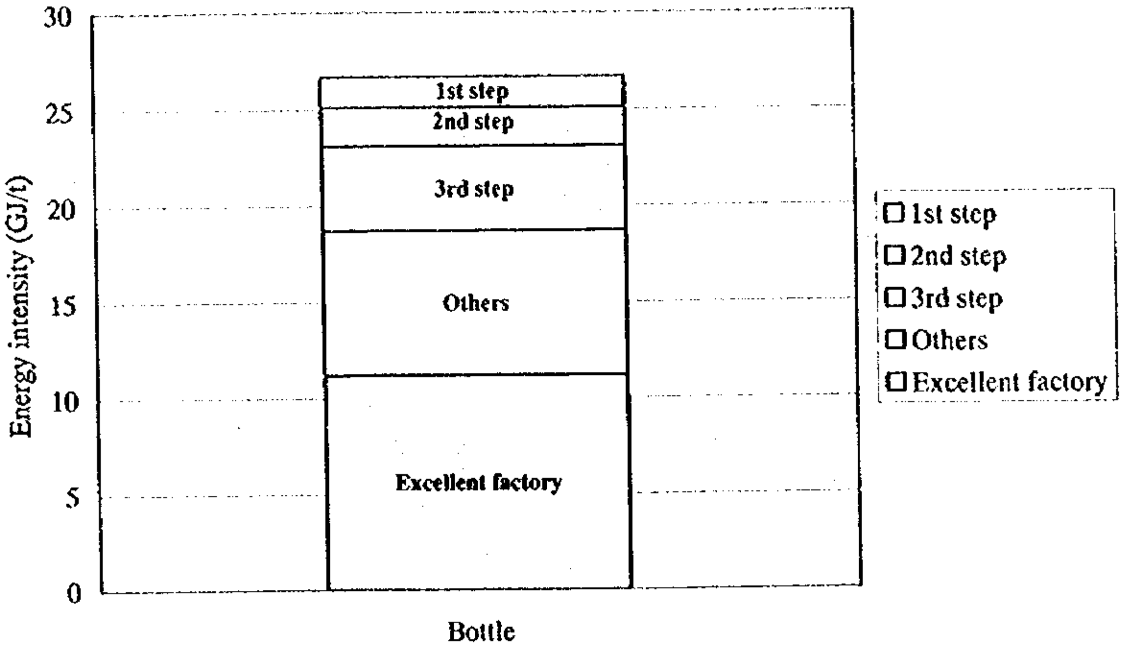


Figure 4.1.22 Wolomin Factory-A Energy Conservation Potential

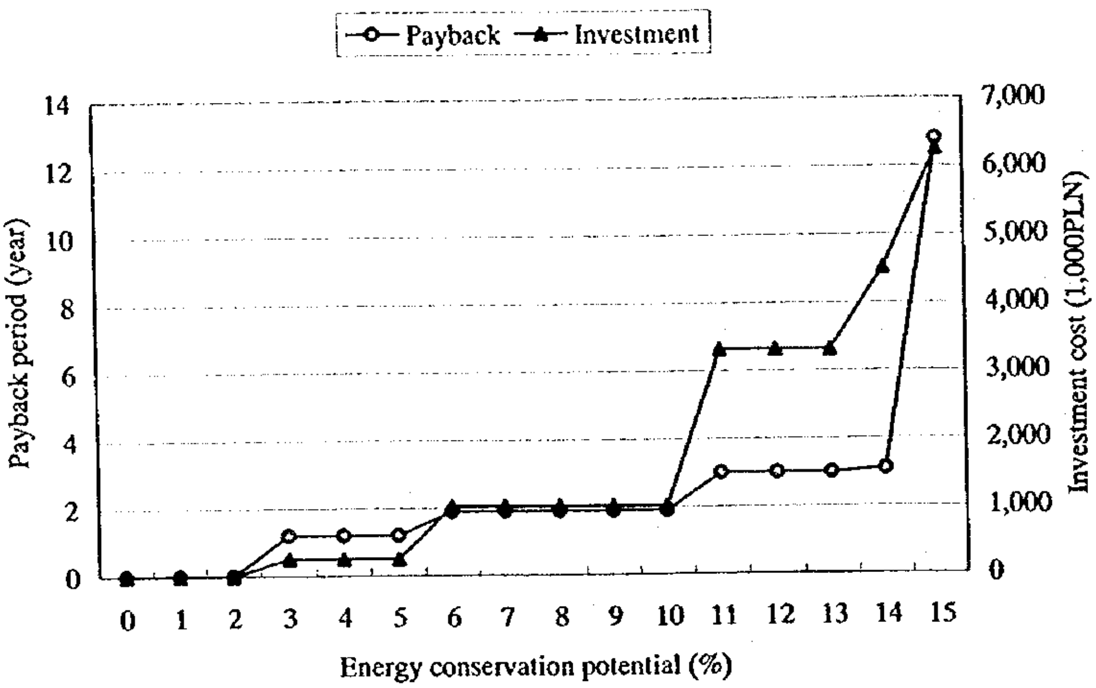


Figure 4.1.23 Wolomin Factory-B Energy Conservation Potential

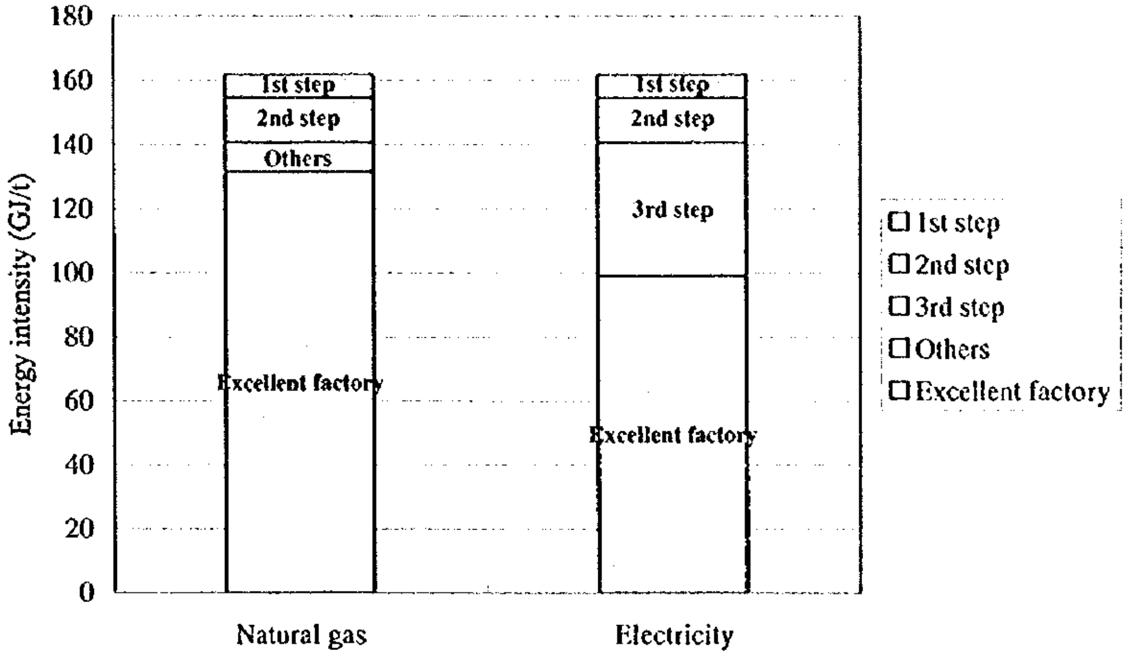
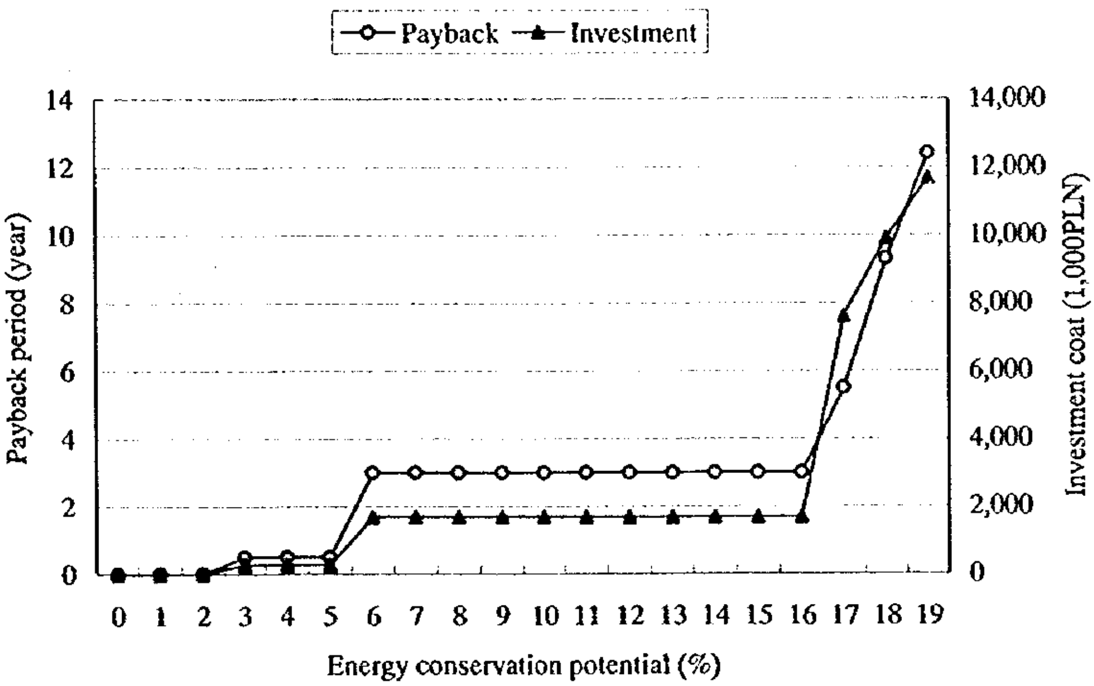


Figure 4.1.24 Wolomin Factory-B Energy Conservation Potential



4.2 Results of the Study at the Silikaty Plant

(1) Study period: August 22, 25 and 26, 1997

(2) Members of the study team

a. JICA Team

Mr. Norio Fukushima : Leader of energy audit & Heat management
Mr. Masami Kato : Process management
Mr. Jiro Konishi : Heat management
Mr. Masashi Miyake : Heat management
Mr. Toshio Sugimoto : Electricity management
Mr. Akihiro Koyamada: Measuring engineerring

b. Local consultants

Research Center of Warsaw University of Technology
Mr. Maciey Chorzelski: Heat management
Mr. Wrobel Waldemar : Electricity management

Regional Energy Conservation Agency (RAPE)
Mr. Stefan Tatarec : President
Mr. Wieslaw Lesisz: Vice President

Radom Prefecture
Mr. Zbigniew Golabec: Governor

(3) Interviewees

Ms. Jadwiga Orzechowska: President
Mgr inz. Witold Matusic : Technical Director
Mgr inz. Jerzy Jakubowski: Production Manager
Mr. Dariusz Gorlci : Chief of Power Engineering Department

4.2.1 Profile of the Plant

(1) Plant name: Zaklady Wapienno-Piaskowe "SILIKATY"

(2) Plant address: ul. Witosa 62, 26-600 Radom

(3) No. of employees: 76

(4) Major products: Silica-lime block (White, Yellow, Red, Green, Black)

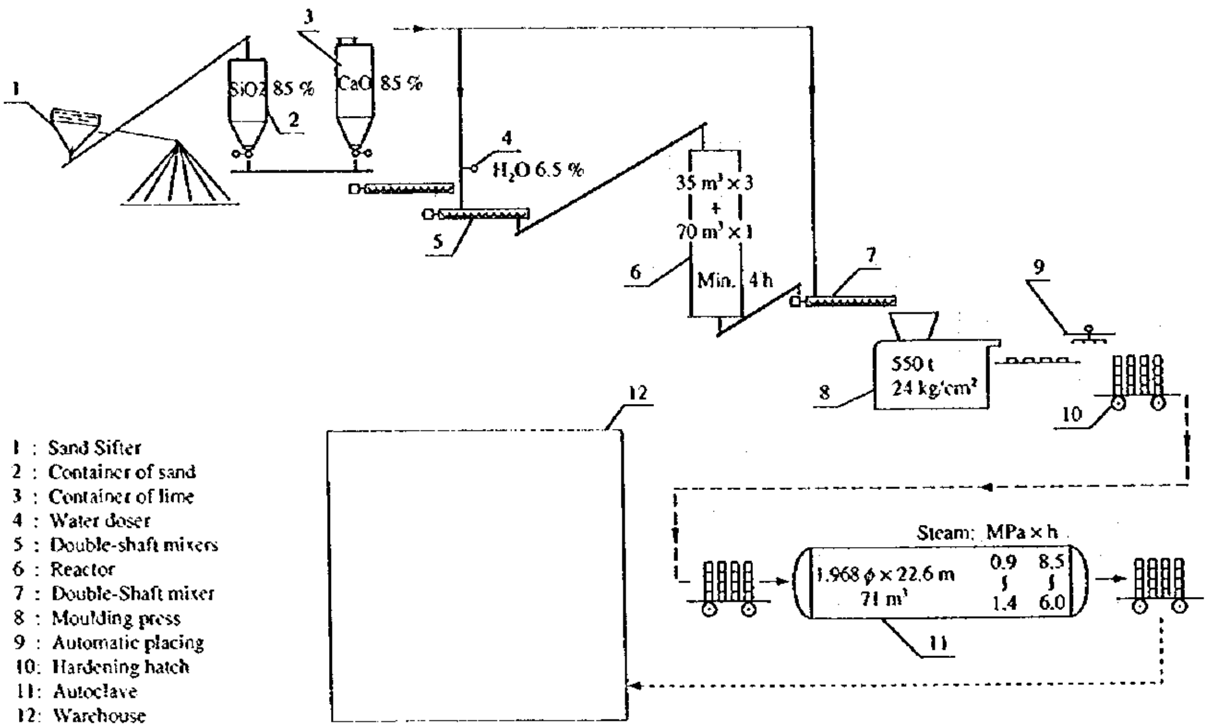
(5) Production capacity: 75,000 t/y

(6) Overview of process:

Specified quantities of raw materials, i. e., silica, lime and water are weighed, mixed and thereafter formed into blocks, which are then cured through autoclave processing to come out as products. There are a variety of product types ranging from silica blocks of standard red brick size to checkered large-size blocks, including colored ones. These products are used as wall materials for housing. Figure 4.2.1 shows the process flow.

Steam for the autoclave is generated by the in-plant boilers, while electricity is purchased.

Figure 4.2.1 Process Flow

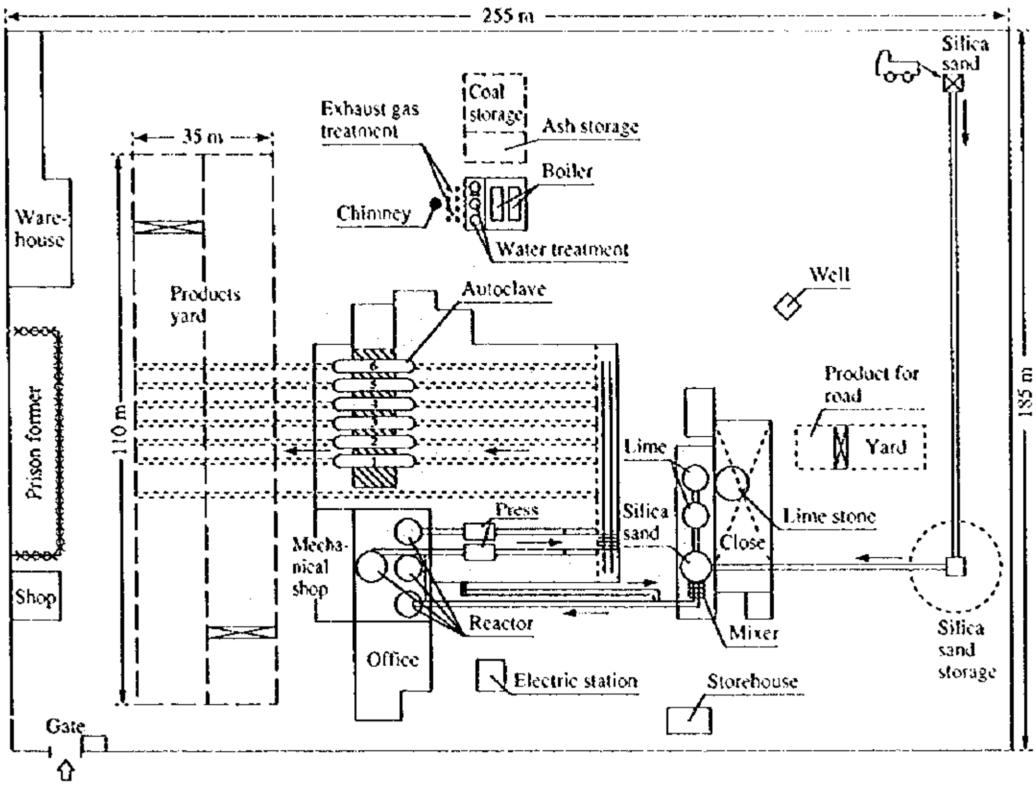


(7) History of the plant

In 1962, this company was established as a government-run company with four factories: three silica lime block factories and one red brick factory.
In 1991, one of the four factories was developed to Silikaty. Thereafter, in 1993, it was transferred to a private company.

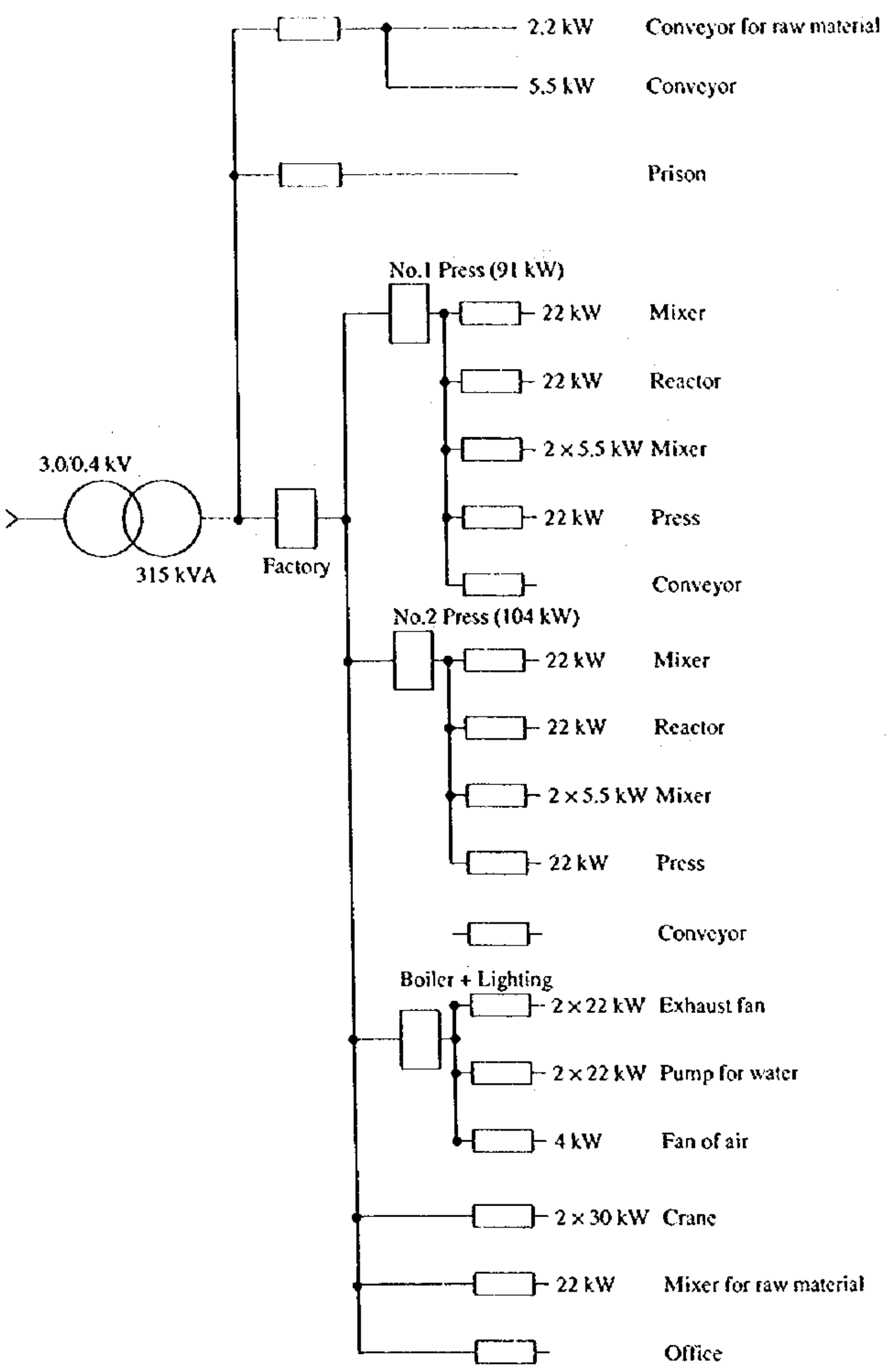
(8) Plant layout

Figure 4.2.2 Plant Layout



(9) One line diagram

Figure 4.2.3 One Line Diagram



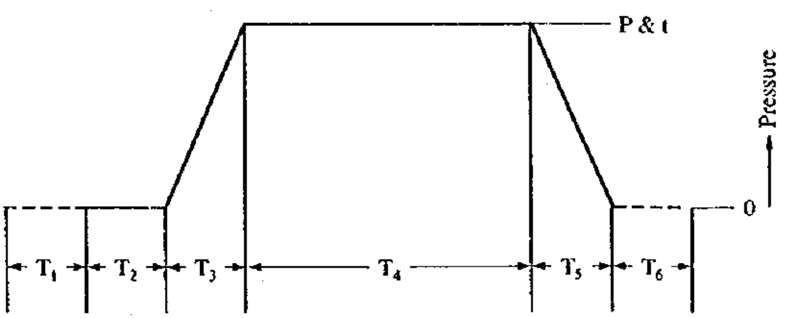
(10) Outline of major equipment

Energy-intensive equipment include steam boilers and autoclaves.

Table 4.2.1 Major Equipment

Factory	Equipment	Quantity	Specifications
Raw material	Double shaft mixer	1	30 kW
	Reactor	4	70 m³ × 1, 35 m³ × 3
	Double shaft mixer	1	30 kW
	Belt conveyor	1	
Molding	Molding press	2	
Curing	Autoclave	6	2 m diameter × 22.6 m length. 71 m³ 40 t/charge, 1.6 MPa, 210 °C
Utilities	Steam boiler	2	Smoke tube type with 2 stokers Coal combustion 3.8 t/h, 1.8 MPa, 209 °C

Operation Time Cycle and Pressure and Temperature



Time (min): carry in T_1(30), air purge T_2(30),
pressure up T_3(60), keeping T_4(390),
pressure down T_5(30), carry out T_6(30),
Pressure (MPa) P: 1.3
Temp (°C) t: 200

(11) Energy price and heat value

Table 4.2.2 Energy Price and Heat Value

	Energy price	Heat value
Coal	0.185 PLN/kg	26.5 MJ/kg
Diesel oil	1.22 PLN/L	
Electricity	0.141 PLN/kWh	10.251 MJ/kWH

4.2.2 Energy Consumption Status

(1) Trend of production

Table 4.2.3 Trend of Production

	Unit	1992	1993	1994	1995	1996
Production	t	54,194	49,025	68,825	59,203	49,306

(2) Trend of energy consumption

Table 4.2.4 Trend of Energy Consumption

	Unit	1992	1993	1994	1995	1996
Coal	t	4,952	4,714	4,036	3,031	2,857
	GJ	131,228	124,921	106,954	80,321	75,711
Electricity	MWh	655	670	824	783	663
	GJ	6,714	6,868	8,447	8,027	6,796
Diesel oil (for car)	kL	9.6	8.8	9.8	9.8	6.7
Water	t	35,728	32,466	43,466	37,429	36,322
Total	GJ	137,942	131,789	115,401	88,348	82,507

Note: Heat value is calculated from coal and electricity

(3) Trend of energy intensity

Table 4.2.5 Trend of Energy Intensity

	Unit	1992	1993	1994	1995	1996
Energy intensity	MJ/t	2,545	2,688	1,677	1,492	1,673

(4) Analysis of energy intensity

Monthly production, energy consumption, and water consumption for other uses were estimated. The water consumption for others than boiler was calculated from the steam consumption (boiler feedwater) for the autoclave measured in this study and the total factory water consumption, each separately for the summer season where the boiler-generated steam is not used for heating and for the winter season. The results of the calculation are shown in Table 4.2.6 and Table 4.2.7.

Table 4.2.6 Monthly Production and Energy Consumption in 1996

Unit	Production t	Operation h	Coal t	Electricity kWh	Water t
January	2,266	368	290	68,388	3,576
February	1,738	352	271	64,074	3,448
March	2,138	368	140	41,987	3,330
April	4,037	352	260	74,877	2,679
May	4,274	448	270	56,572	3,345
June	4,426	480	231	42,617	2,994
July	6,698	576	229	66,497	2,466
August	5,318	552	233	45,374	3,030
September	4,553	552	227	24,646	2,434
October	4,044	384	210	44,422	2,802
November	5,626	336	246	64,061	3,113
December	4,195	336	250	69,129	3,105
Total	49,313	5,104	2,857	662,644	36,322

Table 4.2.7 Basic Data and Energy Intensity by Season in 1996

	Unit	Summer (June, July, August)	Winter (December, January, February)	Annual
Production	t	16,442	8,199	49,306
Operation hour	h	1,608	1,056	5,104
Consumption				
Coal	t	693	811	2,857
Electricity	kWh	154,488	201,591	662,644
Water	t	8,490	10,129	36,322
for bolier	t,	4,663	6,302	21,014
for others	t	3,827	3,827	15,308
Steam/Coal	t/t	6.73	7.78	7.36
Boiler efficiency	%	66.8	77.2	73.1
Water for autoclave	%	55	23	38
Water for heat	%	0	39	20
Water for others	%	45	38	42
Production/Operation hour	t	10.225	7.764	9.960
Coal/Produciton	GJ/t	1.17	2.62	1.54
Electricity/Production	GJ/t	0.10	0.25	0.14
Energy intensity	GJ/t	1.27	2.87	1.68

Summer season: All of steam for the autoclave

Measuring data at 25 August 1997: 2.9 t/h

Summer (June, July, August in 1996)

Water consumption : 8,490 t

Water consumption for boiler : 2.9 × 1,608 h = 4,663 t

Water consumption for others : 8,490 − 4,663 = 3,827 t = 1,276 t/m

$$\text{Ex. Boiler efficiency in summer} = \frac{6.73 \times \{(663 - 0.02 \times 48.16) - 15\}}{26.5/0.985 \times 0.239 \times 1,000} = 66.8\ \%$$

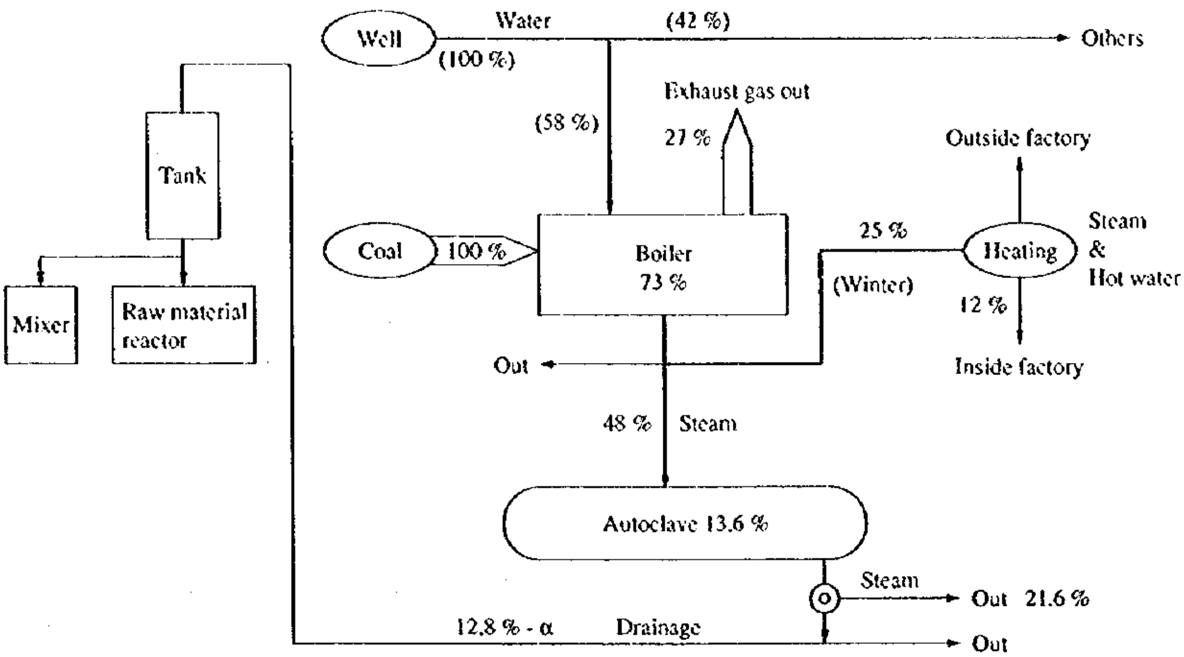
(5) Ratio of the energy cost to the production cost

Fuel : 11.9 %

Electricity: 22 %

(6) Energy flow

Figure 4.2.4 Energy Flow Chart



4.2.3 Energy Management Status

(1) Setting the energy conservation target

a. Setting target values

No specific target value has been set yet.

b. Problems in the promotion of energy conservation

No scientific and rational process management is available because they have no measuring equipment and keeps no record of data.

The seasonal fluctuation of demand is too large to ensure a stable production and efficient operation of equipment.

They have an intention to introduce new equipment, but they cannot afford it because of a lack of funds.

Since this company is not such a large-scale one, it cannot afford human resources; hence drawbacks in terms of technology.

(2) Systematic activities

a. Setting up a department dedicated to energy conservation

A manager in charge of energy is available.

b. Setting up an energy committee

Nothing in particular.

c. Management's stance towards energy conservation

Along with the privatization, they are now exerting positive efforts for business activities, company's publicity, enlargement of product items and so on.

They recognize quality control and energy conservation as matters of importance.

(3) Data-based management

Since there are hardly any measuring equipment and recorders installed, it may be difficult for them to perform a scientific management based on a correct understanding of data.

(4) Plant engineering

Equipment maintenance is carried out intensively during the non-demand winter season. This may be good for major repairs, while, on the other hand, routine or daily maintenance seems to be neglected.

Besides, at many places of the plant, there are steam leakages, spilling-out of raw materials, i. e., lime, and poor cleanings observed.

4.2.4 Problems and Countermeasures related to the Use of Energy

(1) Comparison of the energy intensity with the excellent factory

Comparison is made with an excellent factory that manufactures the roofing materials made of the similar calcium silicate hydrate. The excellent factory has an electric dryer for drying the roofing materials; therefore, its electricity intensity is nearly equal to that of Silikaty.

Silikaty is nearly equal in electricity intensity but superior in fuel intensity to the excellent factory except for the electric furnace for drying.

Table 4.2.8 Comparison of Energy Intensity

	Unit	Silikaty	Excellent factory	Difference
Fuel intensity	GJ/t	1.54 (1.17)	0.58	0.96 (0.59)
Electricity intensity	GJ/t	0.14 (0.10)	0.14*	0 (-0.04)
Total energy intensity	GJ/t	1.68 (1.27)	0.72	0.96 (0.55)

Note: ( ) = except heating of building

*: Excluding the electricity consumed by the electric dryer

(2) Estimation of the energy conservation potentials

Energy conservation is divided into the following three steps to sort out its potential.

Step 1: Enhancing the management
Step 2: Improving the equipment
Step 3: Improving the processes

a. Process

a1. Difference due to external factors

Table 4.2.9 Comparison of Raw Material and Product

		Silikaty	Excellent factory	Remarks
Raw material	Silica sand	: 85 %	Cement : 40 %	
	Quick lime (CaO)	: 8.5 %	Silica sand : 30 %	
	Waste	: 1 %	Waste*1 : 20 %	*1 Aggregate
	Water	: 6.5 %	Water : 10 %	
Product	Thickness	: 65 ~ 220 mm	4.5 ~ 7 mm	
	Weight	: 3.5 ~ 35 kg	3.1 ~ 5.1 kg	
	Density	: 1,800 ~ (1,200*2) kg/m³	1,900 kg/m³	*2 Open hole
	Stregth	: 8.0 ~ 26 MPa (Compress)	24 MPa (Bend)	

Although the quality of the material used and product is slightly different, its effect on energy consumption is not so significant.

Table 4.2.10 Comparison of Production Process

		Silikaty	Excellent factory	Remarks
Crushing		None	For waste material	
Surface heating		None	For painting*	* Two sets each
Drying				
Autoclave	Size	: 2.0ϕ × 22 m	2.1ϕ × 40 m	
	Material	: 35 t	51.2 t	
	Insulate	: 100 mm	75 mm	
	Press × time	: 0.9 MPa × 9 h	0.85 MPa × 9 ~ 12 h	

Since the painting and crushing processes are not provided in manufacturing processes, electricity required for heating, drying, feed conveyers, etc. is small and the electricity intensity is low. Although the length of the autoclave is approximately 1/2, demerits caused by the scale difference can hardly be considered. The operating conditions (e.g. pressure, temperature, and time) are not significantly different.

a2. Difference due to technical factors

1) Improving the production process management and minimizing the fuel for heat holding

① Improving the production process management (Step 1)

- Installation of measuring equipment: A steam flow rate recorder and temperature recorder (or pressure recorder) for the autoclave are required.

- Implementation of scientific process management: This is achieved in the order of measurement, grasping of the actual status, standardization, improvement, and energy conservation. However, scientific process management based on measurement data is necessary for evaluating the energy intensity improvement quantatively.

② Operation improvement

②-1 Grasping the current status of the autoclave operation

Figures 4.2.5 and 4.2.6 show the autoclave temperature measured this time and the surveyed data.

Figure 4.2.5 Heat Pattern of No. 2 Autoclave

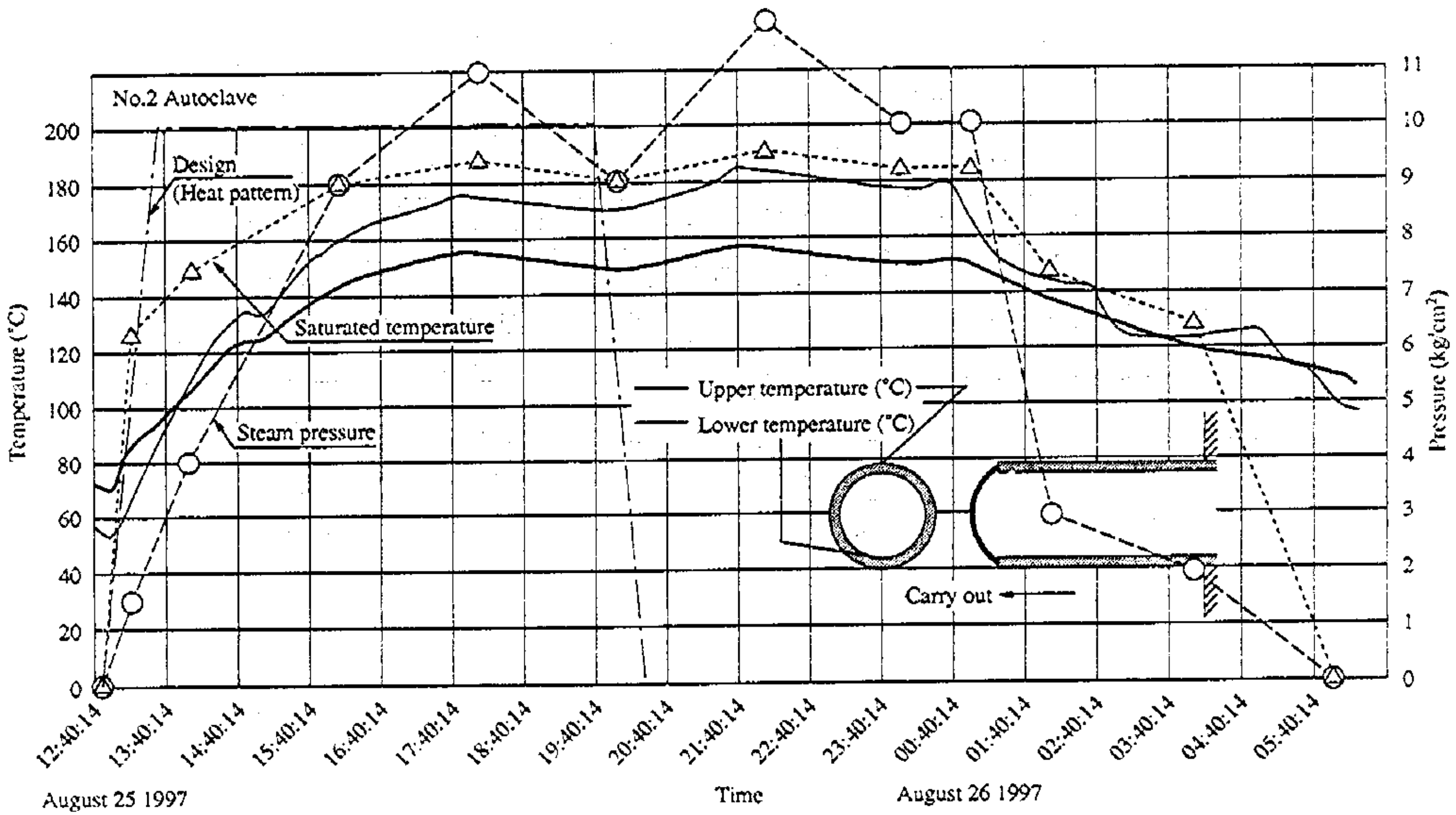
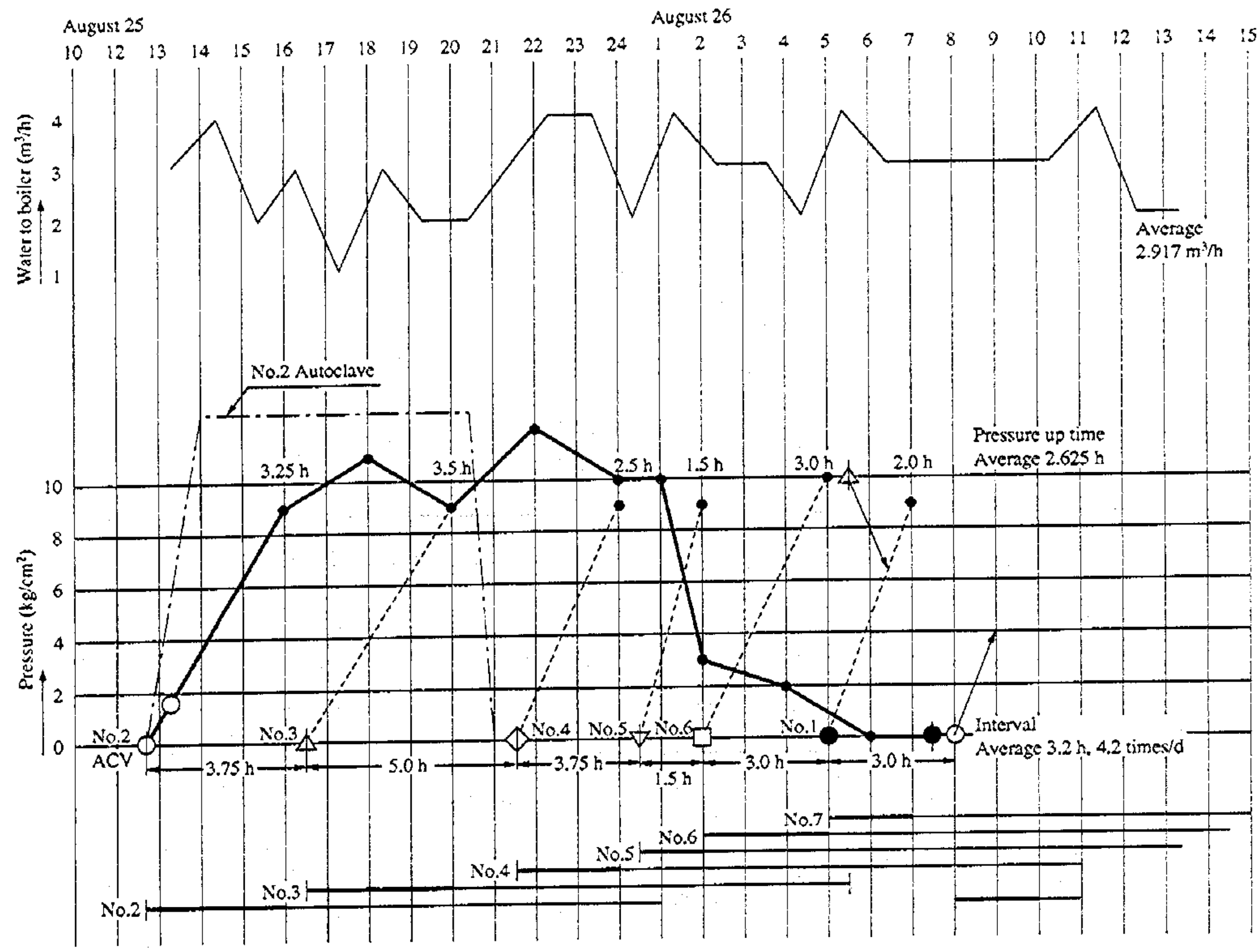


Figure 4.2.6 Operation Progress of Autoclave



The pressure-up (heat-up) time and the amount of steam actually consumed during the pressure-up period are obtained from Figure 4.2.6. Although data accuracy is low because of a wide distribution in data, the steam amount covering heat radiation from the autoclave is assumed to be 0.10 t/h to 0.45 t/h, which is plotted in Figure 4.2.7.

Figure 4.2.7 Steam Consumption vs. Pressure-up Time in Several Cases of Heat Loss from Surface

[Case 1]

	Heat out (t/h)		Up (t/h)	
No.2 autoclave	0.10	+	3.00	= 3.1 t/h*1
No.3 autoclave	0.20	+	2.00	= 2.2 t/h*2
No.4 autoclave	0.30	+	3.40	= 3.7 t/h*3
No.5 autoclave	0.33	+	2.77	= 3.1 t/h*4
No.6 autoclave	0.40	+	2.40	= 2.8 t/h*5
No.1 autoclave	0.43	+	2.97	= 3.4 t/h*6

[Case 2]

Heat out (t/h)		Up (t/h)
0.16	+	2.94
0.32	+	1.88
0.48	+	3.22
0.53	+	2.57
0.64	+	2.16
0.68	+	2.72

[Case 3]

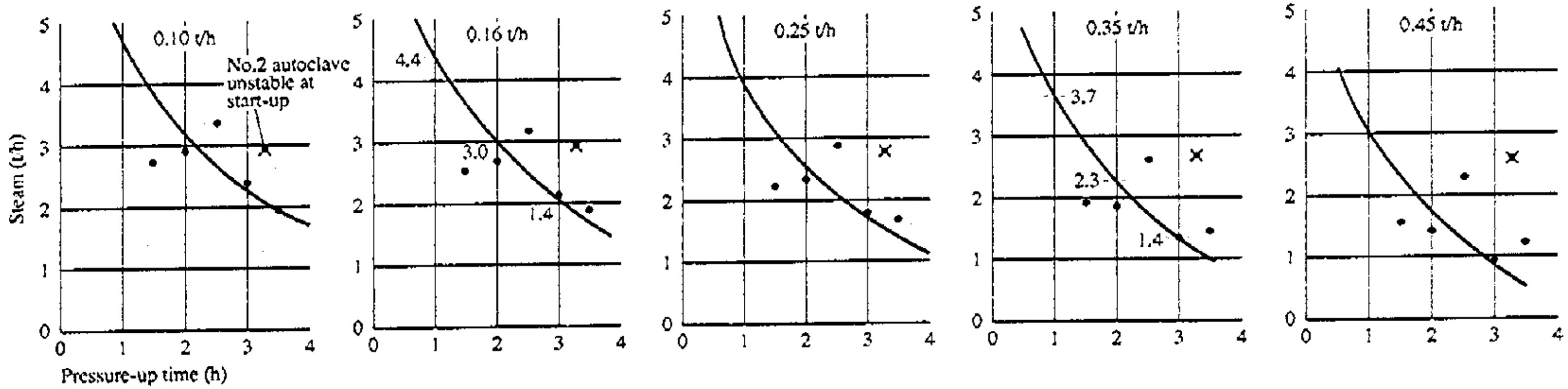
Heat out (t/h)		Up (t/h)
0.25	+	2.85
0.50	+	1.70
0.75	+	2.95
0.83	+	2.27
1.00	+	1.80
1.06	+	2.34

[Case 4]

Heat out (t/h)		Up (t/h)
0.35	+	2.75
0.70	+	1.50
1.05	+	2.65
1.17	+	1.93
1.40	+	1.40
1.50	+	1.90

[Case 5]

Heat out (t/h)		Up (t/h)
0.45	+	2.65
0.90	+	1.30
1.35	+	2.35
1.50	+	1.60
1.80	+	1.00
1.91	+	1.49



Calculation in Figure 4.2.6

No.2 autoclave start-up	No.3 autoclave start-up	No.4 autoclave start-up	No.5 autoclave start-up	No.6 autoclave start-up	No.1 autoclave start-up
3 t × 1 h	3 t × 0.7 h	3 t × 0.7 h	2 t × 0.7 h	4 t × 0.2 h	2 t × 0.2 h
4 t × 1 h	1 t × 1 h	4 t × 1.8 h	4 t × 0.8 h	3 t × 2 h	4 t × 1 h
2 t × 0.8 h	3 t × 1 h			2 t × 0.8 h	3 t × 0.8 h
	2 t × 0.8 h				
8.6 t/2.8 h	7.7 t/3.5 h	9.3 t/2.5 h	4.6 t/1.5 h	8.4 t/3.0 h	6.8 t/2.0 h
3.1 t/h*1 3.25 h	2.2 t/h*2 3.5 h	3.7 t/h*3 2.5 h	3.1 t/h*4 1.5 h	2.8 t/h*5 3.0 h	3.4 t/h*6 2.0 h
Run: 1 ACV	Run: 2 ACV	Run: 3 ACV	Run: 3.3 ACV	Run: 4 ACV	Run: 4.25 ACV

According to Figure 4.2.7, there is not a significant difference among these cases; however heat radiation loss of 0.16 t/h in Case 2 is applicable to steam consumption calculation.

Figures 4.2.8 and 4.2.9 show the autoclave temperature-drop curve after steam is stopped in the state shown in Figure 4.2.5 and the relationship between the autoclave pressure and holding time (interview survey data).

Figure 4.2.8 Temperature-drop Curve after Steam is Stopped

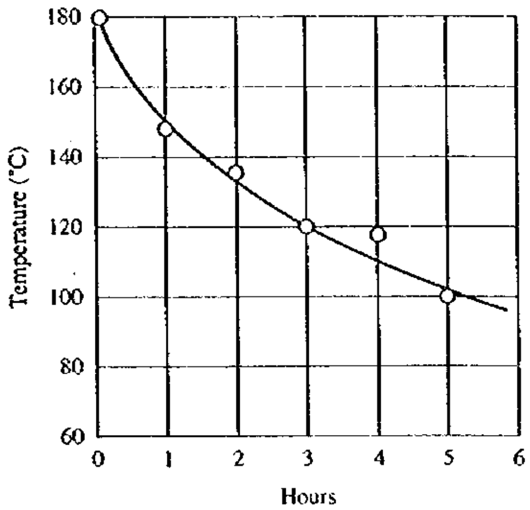
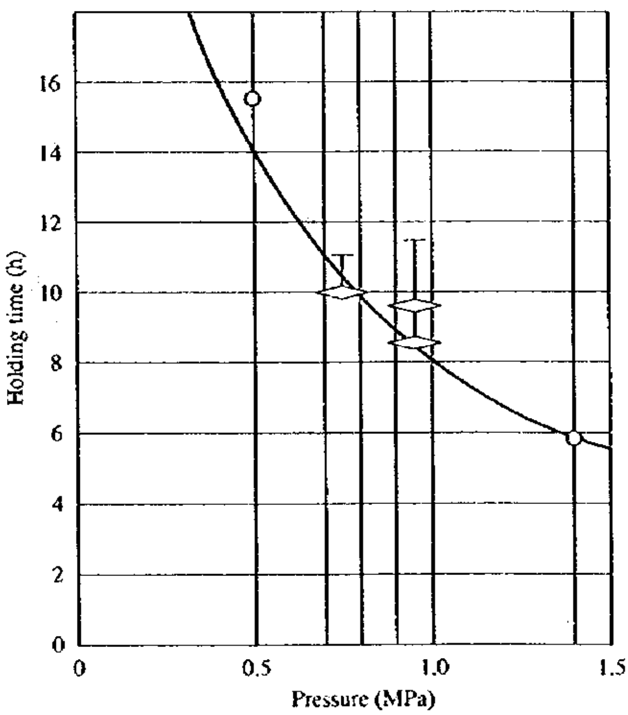


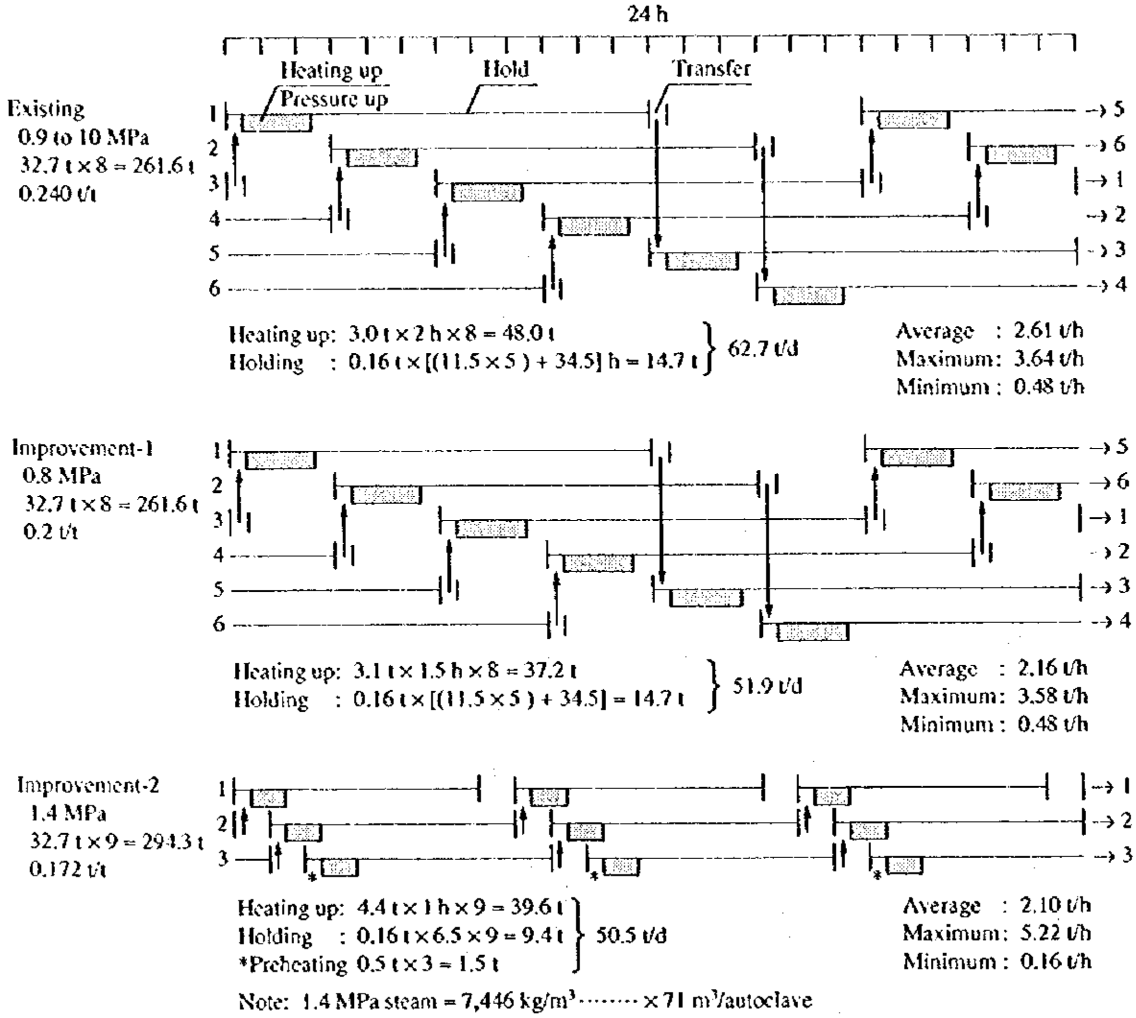
Figure 4.2.9 Autoclave Holding Time vs. Pressure



②-2 Autoclave operation pattern improvement

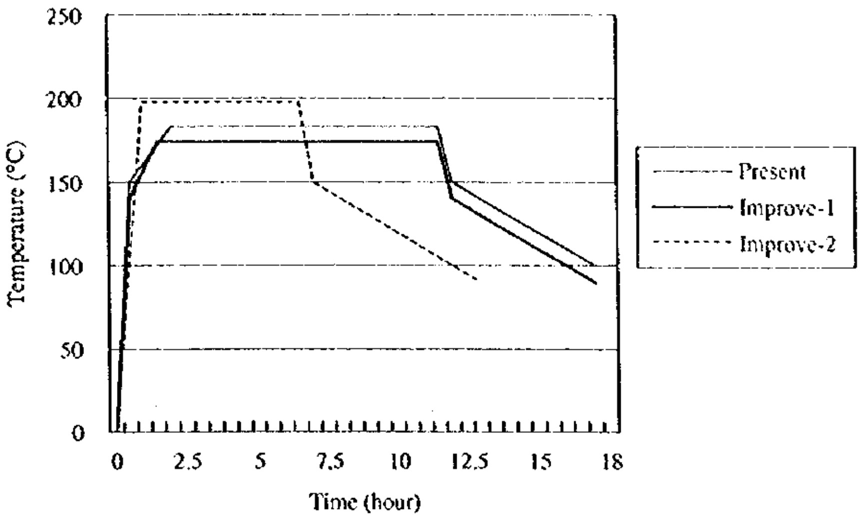
Figure 4.2.10 shows the current autoclave operation pattern and the improved pattern. Figure 4.2.11 illustrates the heat pattern for each operation pattern.

Figure 4.2.10 Autoclave Operation Pattern and Improvement Plan (Case of "hold" = 0.16 t/h each)



Remark: Hold = heat loss from the surface = heat out

Figure 4.2.11 Autoclave Heat Pattern



The existing operation condition and steam intensity and those after improvement are given below.

	Present	Improvement-1	Improvement-2
Production (t/d)	261.6	261.6	294.3
Holding steam pressure (MPa)	1.0	0.8	1.4
Holding temperature (°C)	183.2	174.5	197.4
Holding time (h)	9.5	10.0	5.5
Heating up time (h)	2.0	1.5	1.0
Steam for curing (t/h)	0.16	0.16	0.16
Maximum steam consumption (t/h)	3.64	3.58	5.22
Steam intensity (t/t-product)	0.24	0.20	0.172

The steam volume required for curing the block in the present operation pattern is assumed as 0.16 t/h, which is the same steam volume as the heat loss in Case 2 in Figure 4.2.7.

The improvement proposal-1 is an operation pattern in which the longest cycle time is employed under the current production amount and steam consumption. To reduce heating up time and to increase holding time by lowering holding steam pressure lead to energy conservation in terms of the effective use of latent heat of saturated steam. The holding time at holding steam pressure of 0.8 MPa is 10 hours from Figure 4.2.9 and heating up time is 1.5 hours. The steam volume required for curing the block will be $0.16 \times 662.9 \times 11.5/(660.8 \times 11.5) = 0.1605 = 0.16$ t/h

The energy intensity improvement in the improvement proposal-1 is as follows:

$(0.24 \times 662.9 - 0.2 \times 660.8) \times 4.1868 = 113$ MJ/t

Assuming the boiler efficiency to be 73 %, this value is equivalent to 155 MJ/t in terms of coal.
Energy saving amount: 155 MJ/t (7,642 GJ/y)

- Improvement plan 2 (Step 2)
  The production amount is 293 t/d and the number of charges is 9 charges/d.

  This is based on the assumption that the autoclave operation rate is increased, loading and unloading to and from the autoclave are performed at the same time, and the residual heat is used efficiently. As shown in Figure 4.2.12, this plan improves energy intensity of 187 MJ/t (= 665 – 478) better than the existing operation. For this improvement, however, it is necessary to use three autoclaves, increase the production amount by 12.5 %, and finish renewing to the boiler corresponding to large load variation. Due consideration needs to be given to carriage connection, traction device, autoclave inner inspection method, etc.

Figure 4.2.12 shows the autoclave's heat balance compared among the current status, improvement plan 2, and excellent factory. This figure shows the heat input obtained based on the steam amount calculated according to the operation pattern in Figure 4.2.10 and the drain loss and other loss (steam loss) for the sensible heat output and steam heat input shown in Tables 4.2.11 through 4.2.13. The figure indicating the current status shows the difference from the measured value as the low-load operation loss. The loss that cannot follow up the load variation is also included in the steam loss.

Table 4.2.11 Steam Heat Value by Gauge Pressure

Pressure (MPa [gauge])	Saturated temperature (°C)	Enthalpy (kcal/kg)	Heat of evaporation (kcal/kg)	Ratio (%)	Holding heat* (kcal/kg)
0.5	158.1	657.9	498.6	75.8	632.9
0.9	179.0	662.9	481.6	72.7	638.3
1.4	197.4	666.2	465.5	69.9	641.9

* Dryness of steam: 98 %
Enthalpy of supply water: 15 kcal/kg

Table 4.2.12 Heat Value for Heating One Autoclave

Pressure (MPa [gauge])	Cart (Mcal)	Autoclave body (Mcal)	Insulation (Mcal)	Sub total (Mcal)	Material (Mcal)	Total (MJ)
0.5	105	240	36	381	870	5,234
0.9	122	171	26	319	1,007	5,548
1.4	137	60	9	206	1,127	5,577

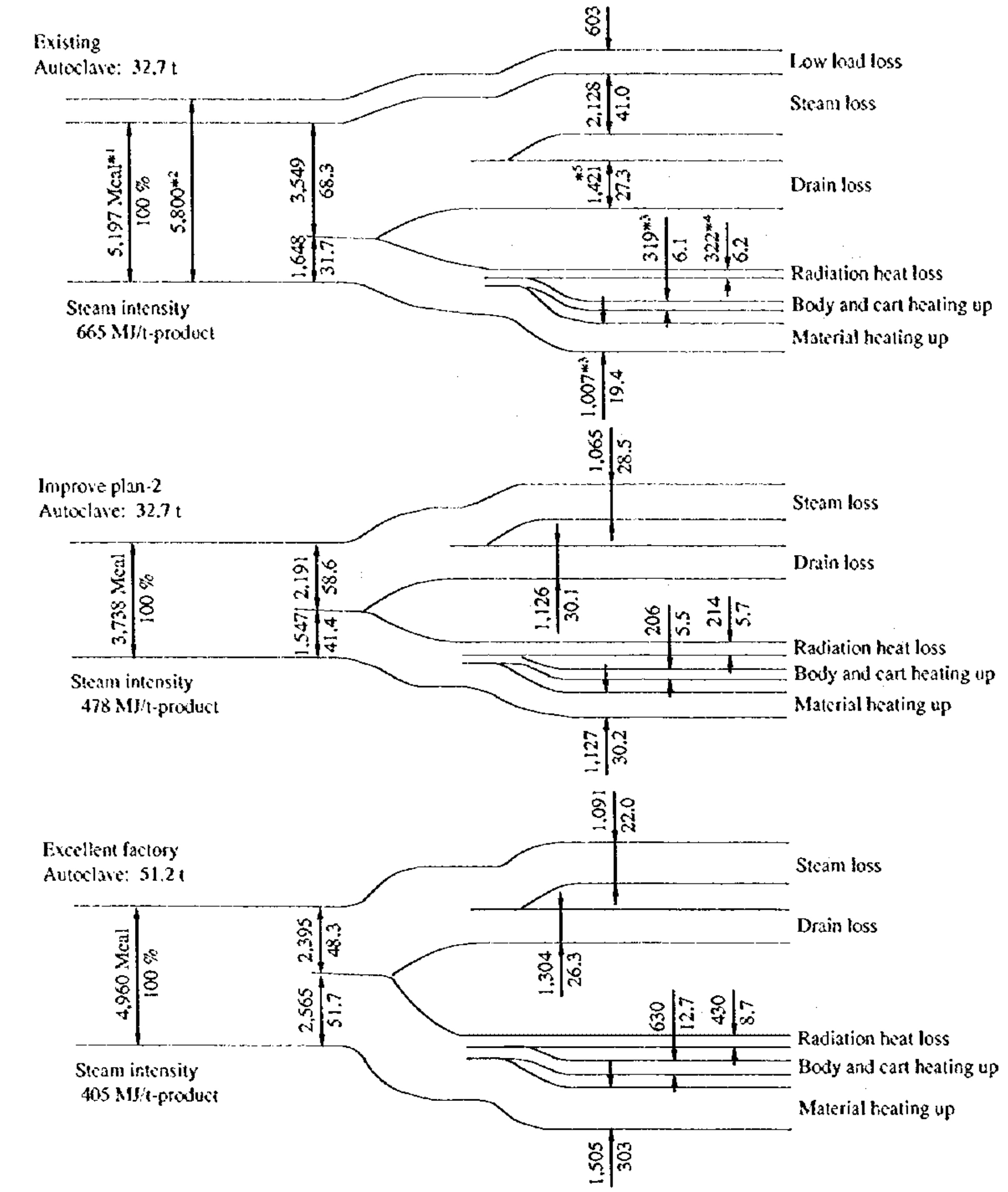
Note: Cart: 400 kg × 18 pcs/one autoclave
Autoclave body: 18.3 t Existing: ΔT = 85 °C
Improvement-2: ΔT = 30 °C (Case of 1.4 MPa)
Insulation: Thickness 100 mm, glasswool
Material: 32.7 t/autoclave

Table 4.2.13 Steam Catchable Heat Intensity per Product

Pressure (MPa [gauge])	Heating up of autoclave (MJ/t)	Radiation heat loss of autoclave (MJ/t)	Total (MJ/t)
0.5	160.1	55.2 (23.3)	215.3 (183.4)
0.9	169.7	41.2 (17.0)	210.9 (186.7)
1.4	170.6	27.3 (11.1)	197.9 (181.7)

Note: ( ): Case of insulation on the gate door of autoclave
Operation hours of autoclave one cycle
0.5 MPa: 19 h — Hold 15.5 h
0.9 MPa: 12 h — Hold 9.5 h
1.4 MPa: 7.0 h — Hold 5.5 h

Figure 4.2.12 Heat Balance of Autoclave (one cycle)



Note *1: 0.9 Mpa steam = 662.9 kcal/kg

Autoclave one cycle steam = 3.0 t × 2 h + 0.16 t × 11.5 h = 7.84 t (cf. Figure 4.2.10)

*2: 2.917 t × 24 ÷ 8 = 8.75 t (measured value)

*3: cf. Table 4.2.12

*4: 26.8 Mcal/h × 12 h

*5: $5{,}197 \times \frac{662.9 - 4{,}816}{662.9}$

The current method of laying the blocks on the carriage to be charged in the autoclave should be improved for reducing the void ratio for the autoclave cross section. Laying more blocks will reduce the heat loss, leading to the improvement of steam intensity.

2) Reducing the fuel intensity of the designed energy intensity

① Heat recovery (Step 1)

Although water drained from the autoclave is recovered as the water for the material, it is not effectively used for the heat value. Therefore, the heat value of the drained water and emitted steam will be used to preheat water supplied from the boiler via a heat exchanger, and then the water will be recycled as the water for the material. The temperature of feed water of the boiler can be increased to 80 °C. According to the annual data in Table 4.2.7:

$$21{,}014\ t \times (80 - 15) \times 1 \div 49{,}306 \times 4.1868 = 116\ MJ/t$$

Reduced energy intensity: 116 MJ/t

Supposing the boiler efficiency to be 73 %, the coal saving amount will be 116/0.73 = 159 MJ/t (7,840 GJ/y)

3) Facility improvement

① Renewing the mixing facility (Step 1)

As a result of replacement with modern weighing machine and mixing machine, installation of a moisture meter, and scientific process management, the production and quality will be stabilized, thereby achieving energy conservation. It also leads to yield improvement.

The energy reduction rate will be 10 %:

$$1{,}693\ MJ/y \times 0.1 = 169\ MJ/y\ (8{,}332\ GJ/y)$$

② Stockyard expansion (Step 2)

By making the stockyard for at least one-month stack and drafting a plan for streamlined production, energy conservation is indirectly achieved.

4) Yield improvement

For the present yield, it is said that the rejection rate after autoclave processing is approximately 1 %. Apparently, however, there are many products with cracks. The products with minor defects are said to be sold as the second-class ones. If free competition increases in future, the yield will be reduced, worsening the energy intensity. To prevent it, improvement of production management is indispensable along with facility improvement described above.

5) Reducing the seasonal fluctuation

Reduction in the demands and production amount in the winter season is a factor worsening the facility operation rate and energy intensity.

Presently, since the steam consumption for heating is not separated from process use, the energy intensity is further worsened in the winter season. (See Table 4.2.7.)

To minimize the reduction of the production amount in the winter season, some measures such as development of new products which does not allow the demands to drop should be considered.

b. Utilities (heat utilization facilities)

1) Air ratio improvement of boiler

Figure 4.2.13 shows examples of exhaust gas oxygen content and exhaust gas temperature measured at the exhaust manifold part of the flue outlet of No. 1 boiler in operation.

Figure 4.2.13 Measurement of No.1 Boiler Exhaust Gas

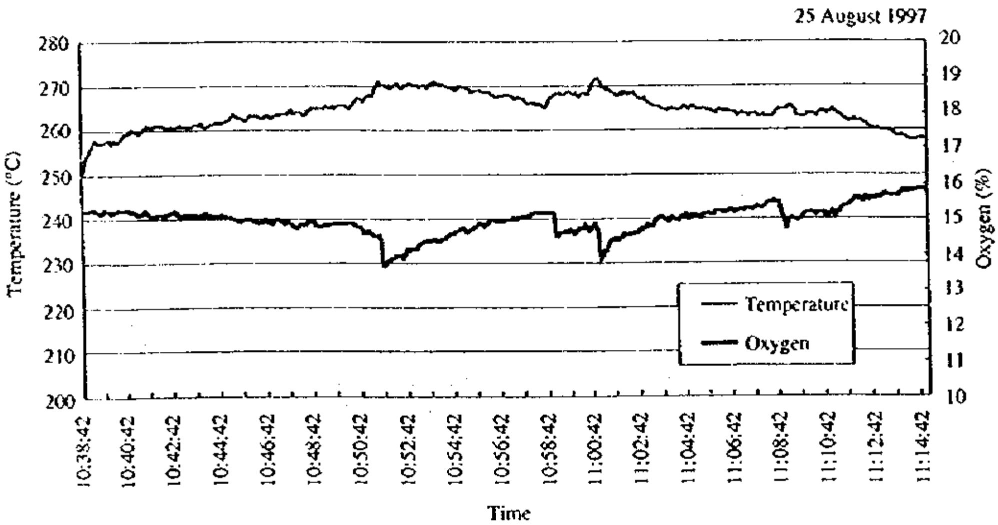


Table 4.2.14 shows the design specifications of this boiler.

Table 4.2.14 Boiler Design Specifications

No. of units	2
Year of installation	1988 and 1990
Type	Flue and smoke tube (2 flues per boiler)
Manufacturer	SEFAKO (Polad)
Pressure/temperature	18 kg/cm², 209 °C (Saturated)
Evaporation	3.8 t/h
Fuel	Coal (26,000 kJ/kg)
Combustion unit	2 coal stokers (Furnace floor 0.6 W × 0.4 L)
Blower	1 blower per stoker 1 IDF/boiler
Feedwater treatment unit	Softener. Water is fed after being preheated to 95 °C in the feedwater tank.
Dust collector	Cyclone dust collector

As shown in Figure 4.2.13, the exhaust gas oxygen content and exhaust gas temperature change in the form of step, which is presumably because the combustion damper is manually adjusted.

Table 4.2.15 shows the average, maximum and minimum of the measured values during the measurement time. This table lists also the air ratio calculated from the exhaust gas oxygen.

Table 4.2.15 Average, Maximum and Minimum of Exhaust Gas Oxygen/Exhaust Gas Temperature

	Oxygen in Exhaust Gas	Air Ratio	Exhaust Gas Temperature
Average	15.0 %	3.4	265
Maximum	15.9 %	4.0	272
Minimum	13.7 %	2.8	250

Reducing the air ratio decreases the volume of exhaust gas. Here, supposing that the exhaust gas temperature remains unchanged, exhaust gas heat loss will decrease, resulting in the reduction of fuel consumption required. Table 4.2.16 shows the result of calculating the fuel saving attained through adjustment of air ratio. The fuel saving to be achieved when the oxygen concentration is reduced from the existing oxygen content (average) to the minimum in the measurement is obtained in this figure.

Table 4.2.16 Fuel Reduction Effect by Air Adjustment

Preconditions

Coal	
Net heat value (kJ/kg)	24,995
Net heat value (kcal/kg)	5,971
Ash content	6.2 %
Water content	6.0 %
Combustion air temperature	30 °C
Exhaust gas temperature	265 °C

Calculation Result

	Theoretical combustion	Current air ratio condition	After air ratio improvement
Oxygen in exhaust gas	0.0 %	15.0 %	13.7 %
Air ratio	1	3.4	2.8
Air amount (m^3/kg)	7.1	24.4	20.1
Exhaust gas amount (m^3/kg)	7.5	24.8	20.5
Exhaust gas heat loss rate (against fuel heat)		31.7 %	26.4 %
Fuel saving rate			7.3 %

Notes: Air ratio after improvement is the minimum of the measured O_2 values.

If, as shown in Table 4.2.16, exhaust gas oxygen content can be reduced through adjustment to 13.7 %, which is the minimum measured value, fuel consumption can be reduced by 7.3 % compared to that before adjustment. At this time, exhaust gas heat loss will be decreased from 31.7 % to 26.4 %. This means an approximately 5 % improvement of boiler efficiency in this calculation. As shown in Figure 4.2.13, however, the reduction on exhaust gas oxygen content in this boiler tends to increase the exhaust gas temperature; hence the efficiency improvement produced by controlling the exhaust gas oxygen can presumably be smaller than the calculated value.

The composition of the fuel used for these calculations is as shown in Table 4.2.17.

Table 4.2.17 Composition of Fuel Coal

C	H	O	N	S	Water content	Ash content
81.5 %	4.9 %	11.4 %	1.3 %	0.8 %	6.0 %	6.2 %

Fuel saving: 1.54 GJ/t × 0.073 = 0.112 GJ/t (5,542 GJ/y)

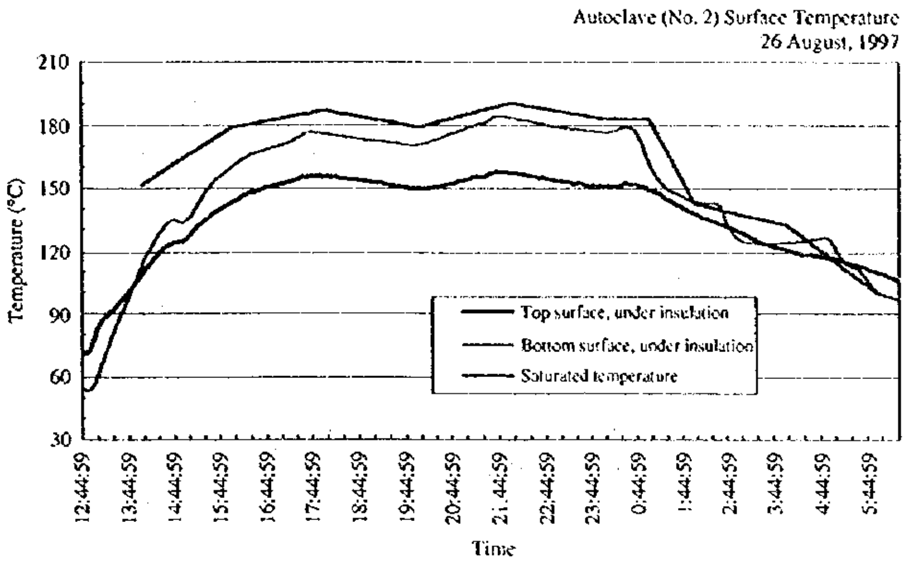
2) Measurement of the autoclave surface temperature and calcualtion of heat radiation

Figure 4.2.14 shows the results of measuring the surface temperatures of the autoclave shell. The measuring points are the outer surfaces of the autoclave shell upper and lower parts, for both of which measurement was made by inserting a thermocouple under the insulation layer. Thus, although the degree of the contact between the thermocouple and the outer surface of the autoclave is not identified, the effect on the result of temperature measurement is considered to be small because it is the inner side of the insulation layer.

Figure 4.2.14 shows also the saturated temperature obtained from the autoclave operation record. The bottom surface temperature of the autoclave indicates a value close to this saturated temperature.

This measurement shows that the top surface temperature is around 20 °C lower than the bottom surface temperature. The reason is presumably that some amount of air remaining in the upper part inside the autoclave body may reduce the steam pressure in this part. This requires further consideration.

Figure 4.2.14 Autoclave Surface Temperature



3) Reinforcing the heat insulatuion of the steam system

No valve heat insulation is provided to the steam headers in the boiler room and the autoclave room. Providing some thickness insulation material to steam pipes will reduce heat emission from the surface to 10 % as compared with the case without any insulation. Specifically for the valves, the radiation heat loss is large because of the large surface area. Therefore, heat insulation is vitally important.

To quantify the effect of heat insulation, heat radiation was calculated based on the assumed No. of steam valves in this factory.

Table 4.2.18 and Table 4.2.19 show the preconditions and calculation results, respectively.

Table 4.2.18 Assumed No. of Valves Installed

Nominal size (mm)	Actual diameter (mm)	Number installed	Equivalent length (m/piece)	Length (m)
50	60.5	20.0	1.28	25.6
80	89.1	40.0	1.56	62.4
100	114.3	30.0	1.58	47.4
125	139.8	6.0	1.74	10.44

Table 4.2.19 Calculation of Heat Radiation from the Valve

Pipe size	Length (m)	Surface (°C)	Room (°C)	Emission (kJ/m/h)	Emission (kJ/h)	Emission (kcal/m/h)
50 mm diameter	25.6	150.0	30.0	1,346	34,479	321
65 mm diameter	62.4	150.0	30.0	1,983	123,771	473
100 mm diameter	47.4	170.0	30.0	3,161	149,857	755
125 mm diameter	10.44	170.0	30.0	3,866	40,370	923
Total					348,478	

Supposing that heat radiation is reduced by 90 % through heat insulation of the valve, the saving amount will be 313,630 kJ/h according to this table.
Fuel saving will be 3,225 GJ/y assuming that the operation hours are 7,500 h/y and the boiler efficiency is 73 %.

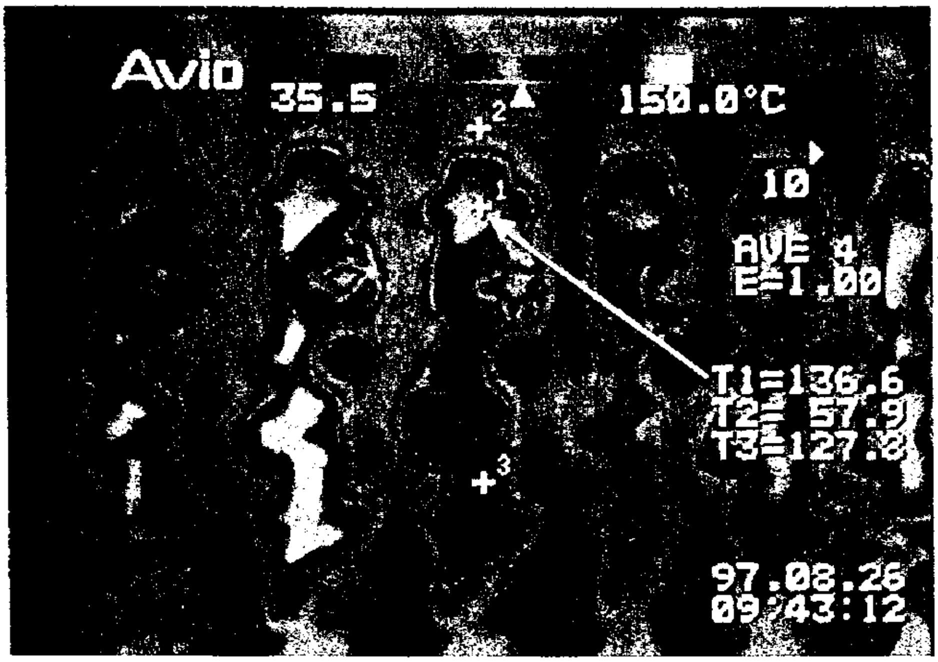
4) Cogeneration

There are some examples of building material factories that have introduced cogeneration and greatly improved the total efficiency of electricity and steam. On the other hand, Silikaty consumes less electricity and the fluctuation is large; therefore, introduction of cogeneration cannot be considered. Introduction of cogeneration should be considered when production has increased and seasonal variation has been reduced.

5) Thermal imaging system of the uninsulated valve

In the picture of an uninsulated high-temperature zone taken using an infrared thermal imaging system, the high-temperature zone can be represented as color of the image.

Figure 4.2.15 Thermal Image of Steam Header

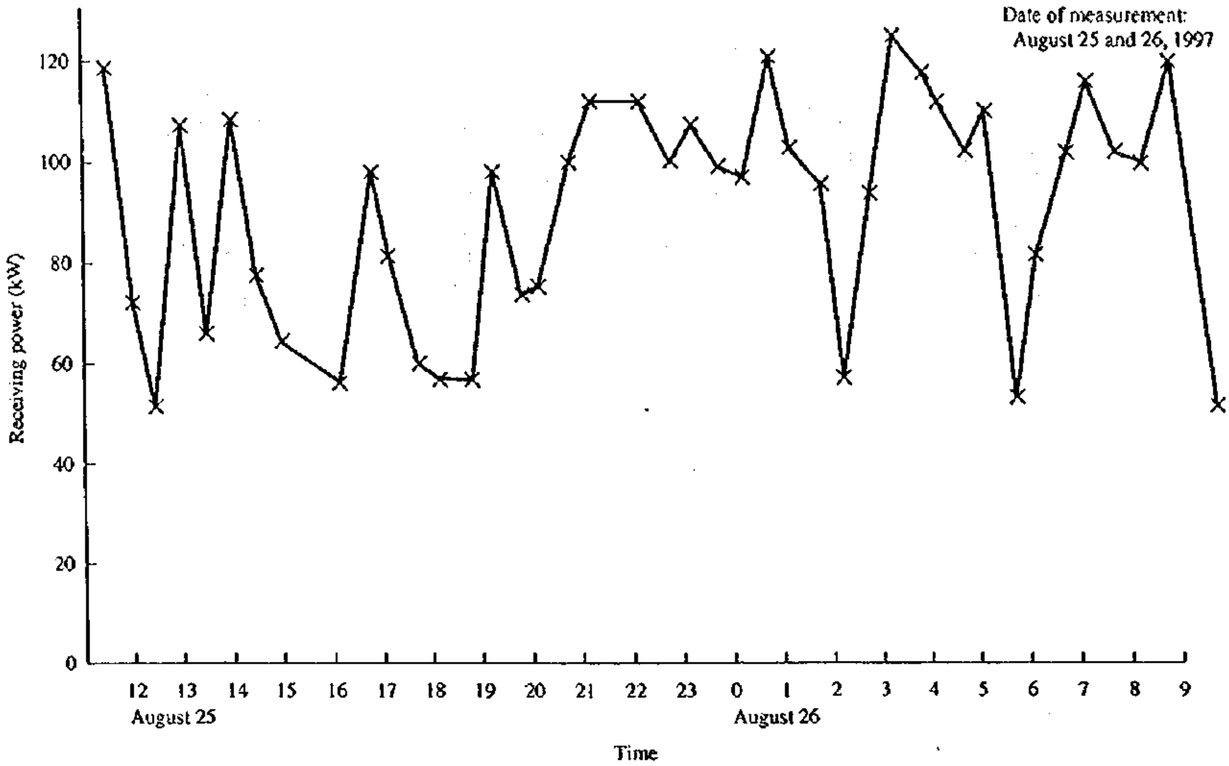


c. Utilities (electricity utilization facilities)

1) Maintenance for the facilities and equipment in the factory should be improved to increase the production efficiency. Figure 4.2.16 shows the result of continuous measurement of electricity consumption of the factory. The reduction in electricity consumption shown in the figure suggests production shutdown. The probable reason will be equipment failure. Upon a process failure, electricity for the related facilities is wasted.

In the factory, we heard the sound of the material feed conveyer and saw the empty conveyers running. Equipment management should be enhanced so as to stop, as much as possible, equipment that may be stopped in terms of energy conservation.

Figure 4.1.16 Receiving Power Demand (30 min.)



Recommendable measures:

- Maintenance for facilities should be improved and the production stop time should be reduced.
- If production overflows in a particular process, that process should be stopped for a certain period and the number of start/stop times should be minimized.

Effects:

- The production amount increases to a certain amount in reverse proportion to the machine stops or reduction in the failure rate.
- Useless operation of the machines is reduced, leading to electricity savings.

2) Reduction in the peak load

Electricity consumption on our survey day was 100 kW or lower on an average but the variation was large from 50 to 120 kW. Since the average electricity consumption in 1996 was 130 kW, the peak demand (280 kW) is slightly larger.

Recommendable measures:

- Many large equipment should not be started at the same time. Instead, they should be started sequentially at a certain interval.
- Operation of the equipment not immediately required should be avoided during the peak time.

Effects:

The peak demand charge is reduced. Since approximately 80 kW may be reduced, around 7,488 PLN (80 kW × 7.8 PLN/kW × 12 months) can be reduced a year.

3) Keeping the voltage supplied to the motor at the optimum value

As shown in Table 4.2.20, the measurement result indicates that generally electricity consumption is small and the power factor is low. In such a case, for example, the supply voltage should normally be reduced slightly because the efficiency of conversion into dynamic power is low. As a result, the motor efficiency is improved, although slightly.

However, the maximum and minimum voltages separately investigated were 427 V and 378 V and the variation width in voltage is large; therefore before the above-metioned measure is taken, the electricity supply side should minimize the variation. The voltage in this company (excluding the variation) is considered to be appropriate.

Table 4.2.20 Measurement Data of Major Load

Name of load	Rating (kW)	Consumption (kW)	Voltage (V)	Power factor (%)	Remark
Conveyor for raw material	22	6	415	39	Idling
	5.5	3.9	410	65	
No. 1 Press line	91	25	409	94	
Mixer of raw material	22	22.5	401	65	
No. 2 Press line	104	22	405	90	Total
Mixer (internal)	11	9	415	86	
Press machine	22	12	413	40	
Reactor	5.5	3.6	410	35	
Mixer (front side)	22	6.4	419	44	
Boiler		42	401	73	Total
Exhaust fan	22	17.5	407	80	
Pump	22	13.6	404	78	
Crane	30	10	405	32	
Lighting	44*				Outdoor
Prison (Selling)		7	401		Outside of factory

4) Energy conservation for lighting

Illuminance in the factory is 200 to 300 Lux, which means no problem. For outdoor lamps, approximately 30 mercury lamps are used and they are automatically turned on/off for about 8 hours a day.

Recommendable measures:
Outdoor mercury lamps should be replaced with high-pressure sodium lamps. Instead of the current mercury lamps of 125 W, 20 high-pressure sodium lamps of 110 W should be used.

Effect:
Electricity use efficiency can be improved, thus achieving electricity conservation by approximately 40 %.

Electricity saving:
(125 W × 30 – 110 W × 20) × 8 × 365/1,000,000 = 4 MWh/y

(3) Summary of Energy Conservation Potential

a. Improvement of Environment through Energy Conservation

If fuel consumption is reduced through energy conservation, the quantity of pollutants emitted to the atmosphere also decreases. Additionally, if the amount of purchased power is reduced through energy conservation, so is the amount of power generated, that is, the quantity of pollutants emitted to the atmosphere by power plants. This reduction in emission quantity due to energy conservation depends not only on the amount of energy conservation, but also the type of fuel, and equipment, such as boilers, etc. Therefore the correct way to estimate the quantity of pollutants is to use the actual amount emitted by each factory. Here, however, for the sake of the consistency with the comprehensive study on Poland as a whole, calculations are based on information on the unit emission quantity (pollutant tonnage/fuel-heating value TJ), per industrial sector and per fuel type, provided by a document from the Institute of Environmental Protection. The reduction in the emission of air pollutants from this factory achieved as a result of energy conservation is compiled at each stage of energy conservation, and shown in Table 4.2.21.

Table 4.2.21 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_x	Dust
Step 0	785	5.5	1.7	1.2
Step 1	1,168	8.2	2.5	1.8
Step 2	1,042	7.3	2.2	1.6
Step 3				
Step 1-3	2,211	15.5	4.7	3.4

Reduction includes emission from fuel and electricity.

Also, in Poland, there is a system available that charges an emission fee (fee) to the polluter, and thus, the emission fee can be reduced through energy conservation. The unit price of the fee is specified per pollutant type. Additionally, for emissions that exceed a certain amount, a penalty fee (charge) is charged. The unit price of the charge is 100 times that of the fee. The prices listed below are the regular emission fees.

The result of calculating the amounts of reduction in pollutant emission, for the energy conservation items that were proposed based on our factory survey, and the corresponding reductions in emission fees, is shown in Table 4.2.22. Furthermore, the payback period required to recover energy conservation investments including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 4.2.22 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ PBP	Economical PBP
Step 0	53	2.5	56	150	2.70	2.83
Step 1	94	3.7	97	43	0.44	0.46
Step 2	78	3.3	81	173	2.13	2.22
Step 3						
Step 1-3	171	7.1	178	216	1.21	1.26

Units: Thousand PLN or thousand PLN/y for expense, Year for PBP

As evident from this Table 4.2.22, the reduction in emission fee is only a few percents at most compared to reduction in energy cost, and thus, the effect of reduced emission fees on the investment recovery period is also negligible.

The major theme for energy conservation in this factory is the reduction of coal consumption. In case of coal, the emission fee for the sulfur content makes up a large proportion, and consequently the effect of reduced emission fee is larger than for other fuels, accouting for several percents compared to the effect of reduced energy cost.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 4.2.23.

The energy conservation potential using the Excellent factory as the benchmark for energy consumption intensity, and energy conservation measures in Steps 1, 2, and 3 are shown in Figure 4.2.17. The relationship between energy conservation potential, the payback period, and the investment cost is shown in Figure 4.2.18.

Table 4.2.23 Summary of Energy Conservation Potential

Coal: 170 PLN/t (26.5 GJ/t) Electricity: 0.172 PLN/kWh 1 PLN = 30 yen

Item	Energy Conservation Potential							Investment	Payback period
	Fuel			Electricity			Total		
	GJ/y	10^3 PLN/y	%	MWh/y	10^3 PLN/y	%	10^3 PLN/y	10^3 PLN	year
Step 0 (Under planning)									
1. Upgrading the weighing equipment and mixing equipment	8,332	53	11.0				53	150	2.8
Subtotal	8,332	53	11.0				53	150	2.8
Step 1									
2. Improving the autoclave operation pattern	7,642	49	10.1				49	43	0.9
3. Improving the air ratio of boilers	5,542	36	7.3				36	0	0.0
4. Decreasing the peak load				80 kW	7		7	0	0.0
Subtotal	13,184	85	17.4	0	7		92	43	0.5
Step 2									
5. Recovering heat	7,840	50	10.4				50	64	1.3
6. Reinforcing the heat insulation of the steam valves	3,225	21	4.3				21	100	4.8
7. Lighting: Changing to sodium lamps				4	1	0.6	1	9	13.1
Subtotal	11,065	71	14.6	4	1	0.6	72	173	2.4
Total	32,581	209	43.0	4	8	0.6	217	366	1.7

Production : 49,306 t/y (in 1996)
As of 1996: Fuel consumption: 75,711 GJ/y
Electricity consumption: 663 MWh/y (6,796 GJ/y)
Total: 82,507 GJ/y

Figure 4.2.17 SILIKATY Energy Conservation Potential

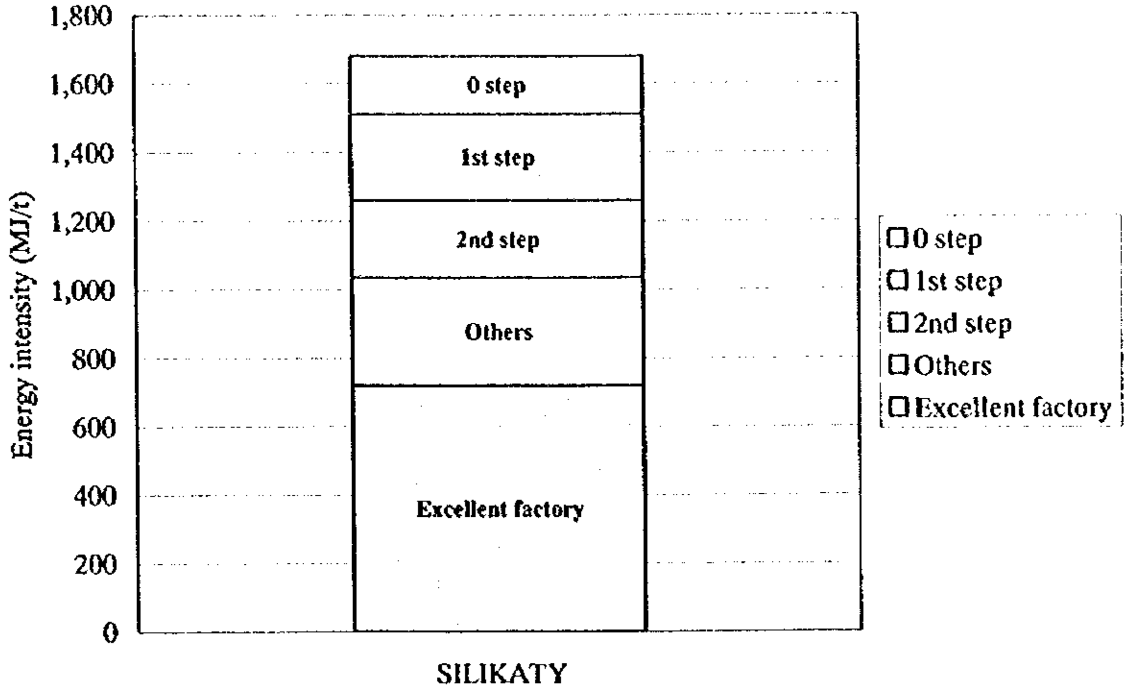
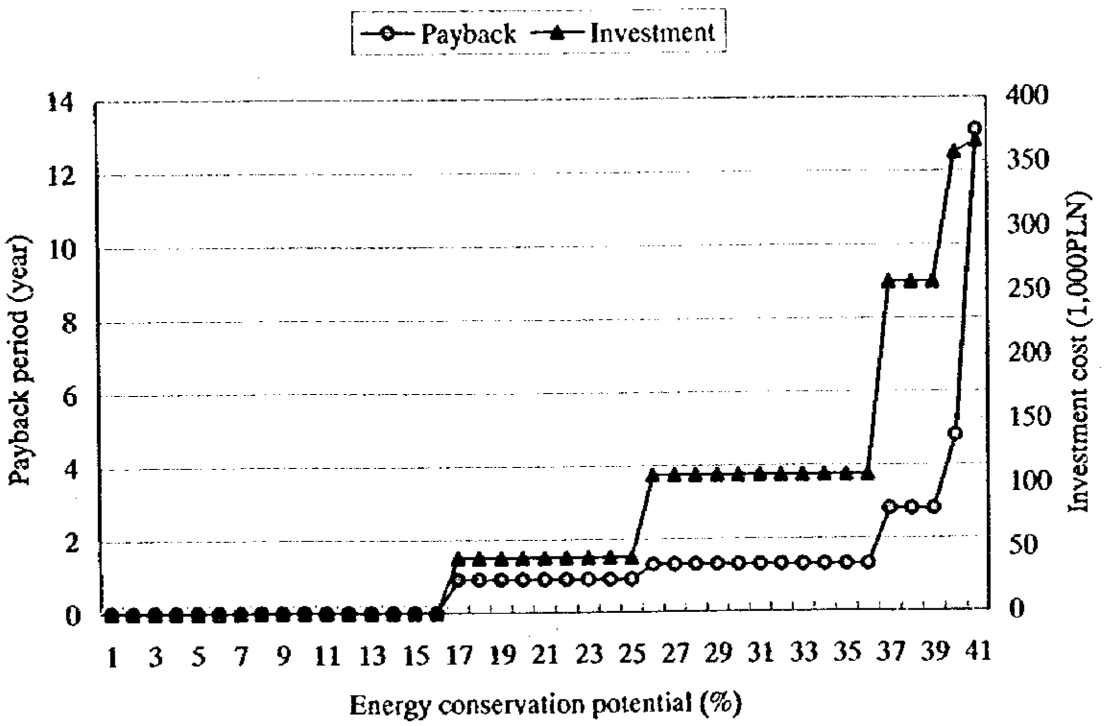


Figure 4.2.18 SILIKATY Energy Conservation Potential



5. RESULTS OF THE STUDY ON THE FOOD PROCESSING INDUSTRY

5. FOOD PROCESSING INDUSTRY

5.1 Results of the Study at the Olvit Plant

(1) Study period: September 11, 12 and 15, 1997

(2) Members of the study team

a. JICA Team

Mr. Norio Fukushima : Leader of energy audit & heat management
Mr. Shiro Honda : Process management
Mr. Jiro Konishi : Heat management
Mr. Toshio Sugimoto : Electricity management
Mr. Akihiro Koyamada: Measuring engineering

b. KAPE and local consultants

KAPE
Dr. Roman Babut: Director of International Cooperation Division

Baltic Energy Conservation Agency
Dr. Edmund Wach : Heat management
Dr. Andrzej Szajner: Heat management
Dr. Pawel Bucko : Electricity management

(3) Interviewees

Mr. Tadeusz Brozek : Chief Engineer, Head of Energy Department
Mr. Romuald Hetmenski: Energy Department
Mr. Krzysztof Palacha : Energy Department
Mr. Piotr Grot : Head of Refinery Department
Ms. Elzbieta Grot : Head of Hydrogenation Department
Mr. Wiesława Tomczyk : Head of Margarine Department
Mr. Borkowski : Electrical Engineer

5.1.1 Profile of the Plant

(1) Plant name: OLVIT, Gdansk

(2) Address: Gdansk, ul, Wislnal 80-555 Gdansk, Poland

(3) No. of employees: 427

(4) Major products: Refined oil and margarine

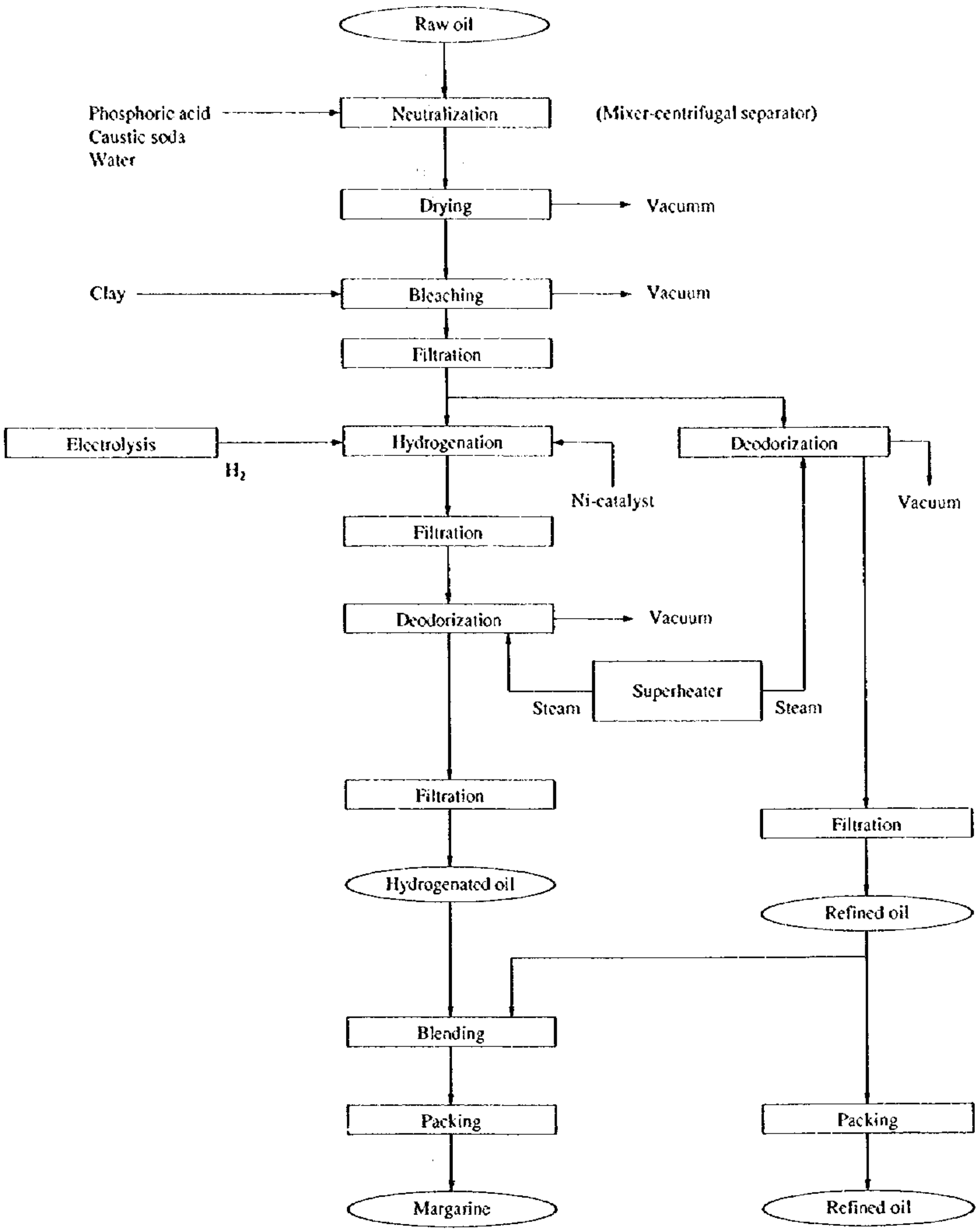
(5) Production capacity: 370 t/d × 280 d = 103,600 t/y

(6) Overview of process

This factory has two lines of neutralization and bleaching units and three deodorizing towers to produce refined oil. Also, it has an electrolytic hydrogenation plant to produce hardened oil for margarine as the major product. A new packing line is provided and the refined oil products packed in PET bottles are under manufacture. Figure 5.1.1 shows the process flow.

The raw vegetable oil includes mainly the rape oil, soybean oil, and sunflower oil, which are all domestically produced. Steam is purchased from the adjoining central heat plant (CHP). Heating steam for the deodorizing facility is generated by its own small boiler.

Figure 5.1.1 Process Flow

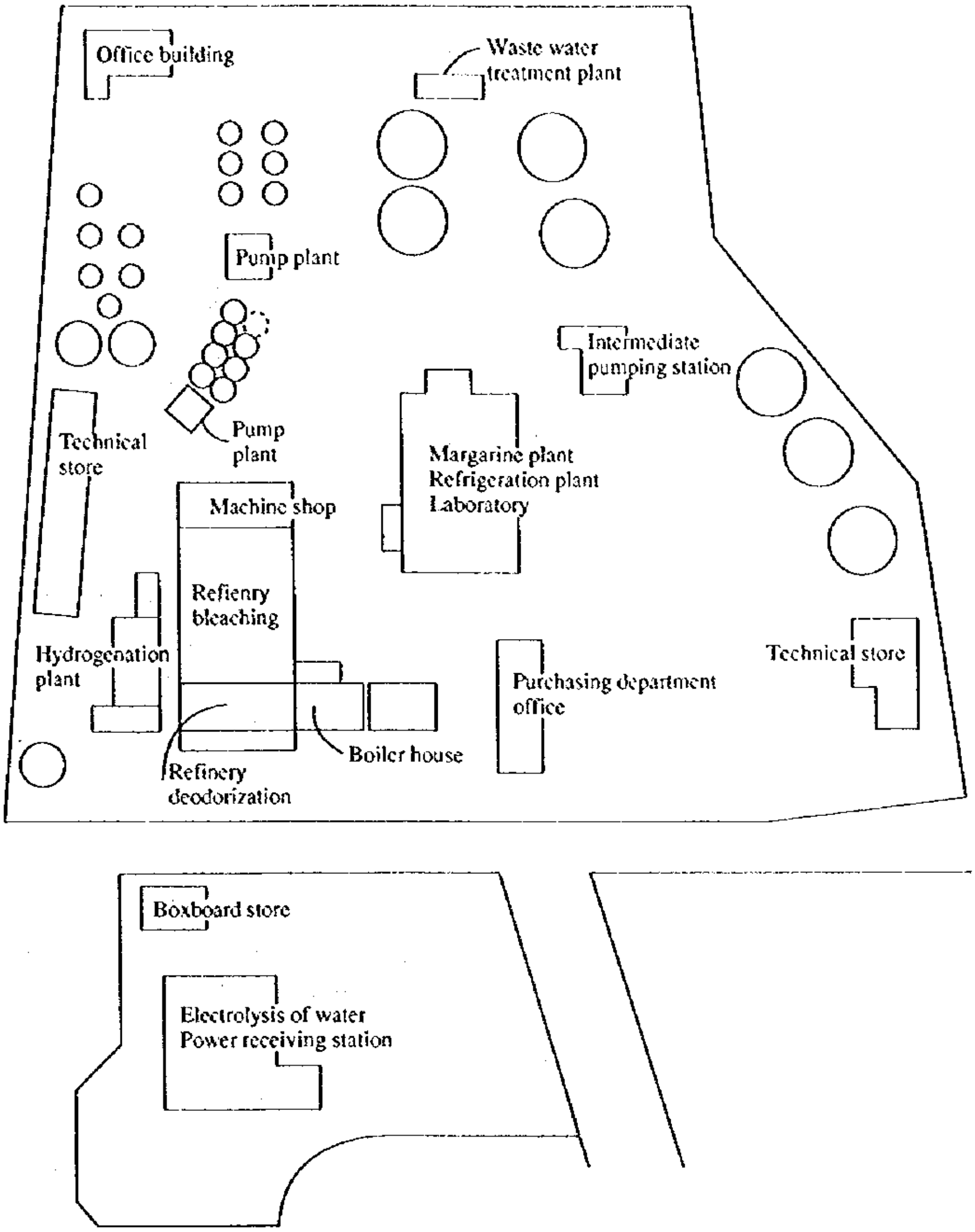


(7) History of the plant

The facilities of this factory, which was constructed 50 years ago, have become old. The plant entered the Verdermolt group in Belgium in 1996 and has attempted to renew the major facilities. One of three deodorizing towers was renewed to the De Smet type in 1996 and a half of the margarine plant facilities have been replaced with new ones. The molding machine for the polyethylene terephthalate (PET) bottles has been installed to pack salad oil for partial improvement. For the refined oil processes, they have a plan to retrofit the old filtering facility through the introduction of an automatic filter. Measuring equipment will be enhanced in the future and restructuring is being planned.

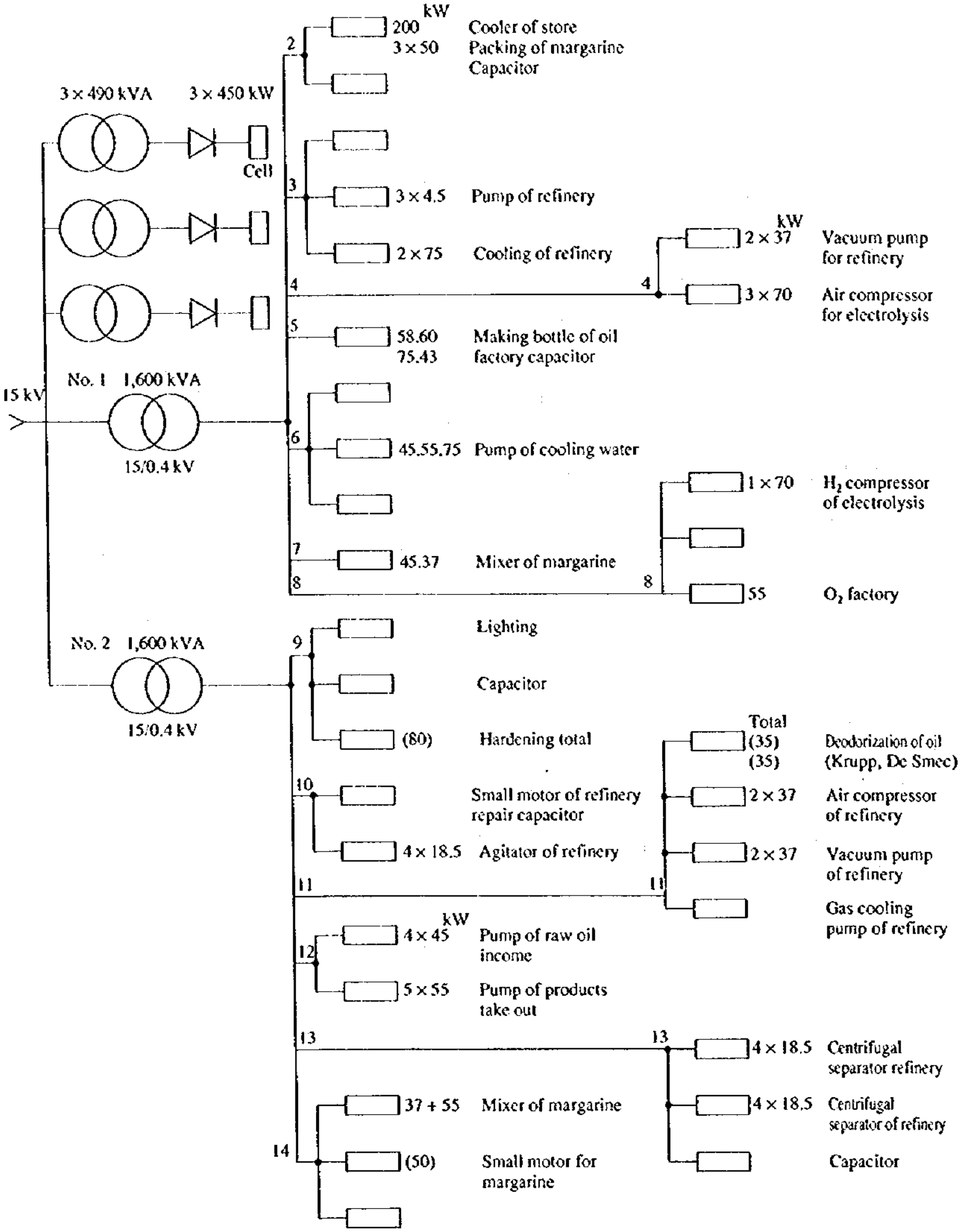
(8) Plant layout

Figure 5.1.2 Plant Layout



(9) One line diagram

Figure 5.1.3 One Line Diagram



(10) Outline of major equipment

Table 5.1.1 Major Equipment

Factory	Number	Specification	
Refined oil & margarine			
Neutralizer	2	6 m^3/h, 100 Torr	
Bleaching tank	2	ALFA-LAVAL type	
Centrifugal	8	18.5 kW	
Deodorizer	4	No. 1: 150 t/d (stand-by)	Krupp type 240 °C 4-6 Torr
		No. 2: 120 t/d	Ditto
		No. 3: 250 t/d	Ditto
		No. 4: 250 t/d	De Smet type 240 °C 4-6 Torr
Hydrogenator	5	9.5 t × 4 9.0 t × 1	
Filter	5	Filter press	
Margarine tank	8	3 t/batch old type, Old line	
Packing machine	2	Old line	
Margarine tank	1	New line	
Packing machine	3	New line	
Oil packing machine	1	For PET bottle	
New margarine line	2	Denmark production line, Poland production line, New type	
Utility			
Electrolyzer	1	450 kW × 3, Hydrogen generator	
Boiler	3	Small sized once-through boiler, (0.5 + 0.8 + 1.8) t/h, 7.5 bar × 291 °C	
Freezer	5	Ammonia compressors: Reciprocating type; 3 units, and screw type; 2 units	
Air compressor	1	75 kW	

(11) Energy price and heat value

Table 5.1.2 Energy Price and Heat Value

	Energy price	Heat value
Steam	0.097 PLN/kg	2.85 GJ/t (1.4 Mpa, 200 °C)
Electricity	0.122 PLN/kWh	10.256 GJ/MWh
Fuel oil	0.92 PLN/kg	42 GJ/t