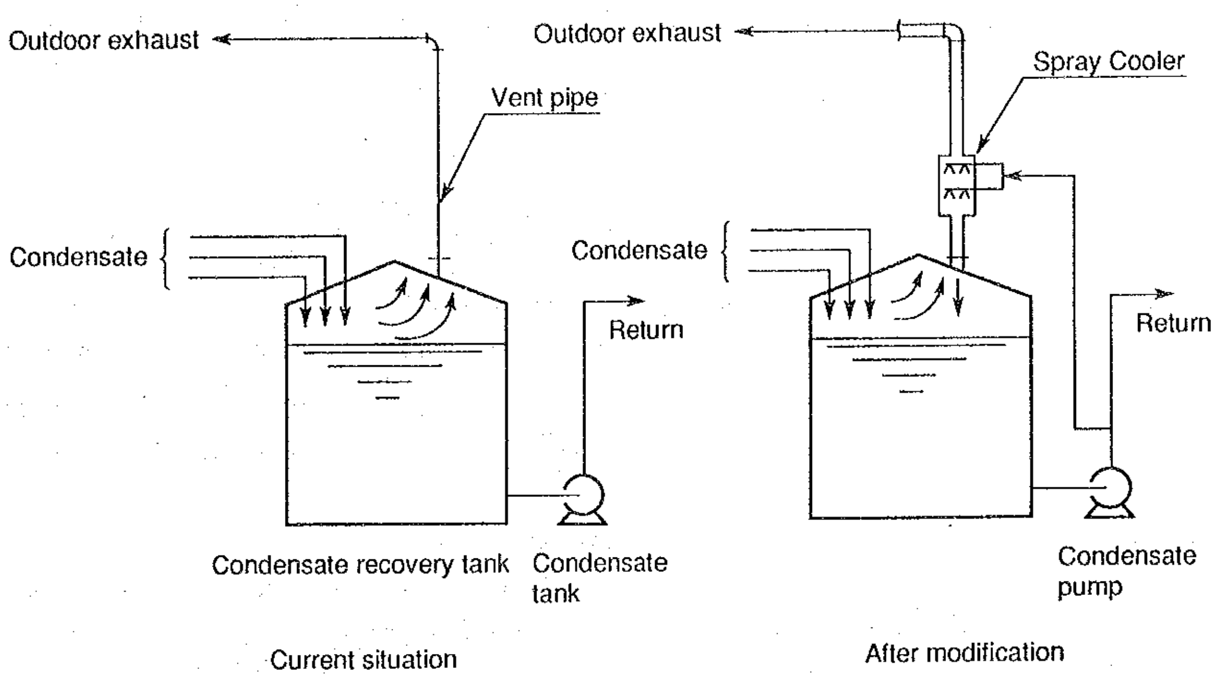
Figure 5.4.22 Recovery of Flash Steam



(8) Power Receiving/Distributing and Electric Equipment

a. Outline of Power Receiving/Distributing Equipment

Figure 5.4.5 is the one line diagram. Power to the factory is received at 6 kV at the central substation. The central substation functions as #1 substation as well, and lowers voltage to 400 V using a 750 kVA transformer, transmitting power mainly to the dyeing and woolen spinning shops. Power is transmitted from the central substation to #2 substation through two 6 kV lines, and voltage is there lowered to 400 V using 750 kVA transformer, 630 kVA transformer and 560 kVA transformer. Here, power is then transmitted mainly to the carding and woolen spinning shops. Here, power is transmitted from the central substation to #3 substation through one 6 kV line, and voltage is there lowered to 400 V using two 400 kVA transformers. Here, power is then transmitted mainly to the weaving and finishing shops. #2 substation is connected with #3 substation using one 6kV line, and thus the central, #2 and #3 substations are looped.

Almost all the major loads in the factory are the load of motors in the blowers, pumps, vacuum pumps, carding machines, spinning machines, weaving machines.

b. Results of Measurement and Consideration

1) #2 Substation, 750 kVA and 560 kVA Transformers

Table 5.4.26 shows the result of the measurement.

Table 5.4.26 Power at #2 Substation

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Date and time of measurement
750 kVA Transformer	188	138	125	95.2	6/30 16:00-17:00
560 kVA Transformer	263	231	209	62.9	6/30 16:00-17:00

There are three transformers in #2 substation, and of the three, the 750 kVA transformer and the 560 kVA transformer are installed side by side. Table 5.4.27 shows the power, apparent power and reactive power of each transformer and total load when the power demand (average 10 min) is maximum in the measuring period.

Table 5.4.27 Maximun Power Demand at #2 Substation

Transformer	Power (kW)	Reactive power (kVar)	Apparent Power (kVA)
750 kVA	131	50	140
560 kVA	246	300	388
Total	377	350	514

The total apparent power is 514 kVA, which is below the capacitance of both transformers, and thus it is possible to stop either of them. Which transformer should be turned off must be determined by continuing the measurement and anticipating the state of load in the future. Here, letting the load be integrated into the 750 kVA transformer with a margin allowed for, the reduction of loss was calculated. Since the test result tables of the transformers were not available, the characteristics of them were considered the same as those of the ordinary ones. As a result, the calculation was made on the condition of average power operation, letting the iron loss of the 750 kVA and 560 kVA transformers, be 3.2 kW and 2.8 kW, respectively and the loss ratio (=copper loss/iron loss: on rated power) be 2.5.

Table 5.4.28 shows the power, apparent power and reactive power of each of the transformers and the total load in average power operation.

Table 5.4.28 Average Power at #2 Substation

Transformer	Power (kW)	Reactive power (kVar)	Apparent power (kVA)
750 kVA	138	44	145
560 kVA	231	285	367
Total	369	329	494

The 750 kVA transformer loss, the 560 kVA transformer loss and the total loss are assumed to be L_1, L_2 and L_3, respectively.

- Transformer loss on the present operation conditions:
  750 kVA transformer $L_1 = 3.2 + 3.2 + \times 2.5 \times (145/750)^2 = 3.50$ kW
  560 kVA transformer $L_2 = 2.8 + 2.8 \times 2.5 \times (367/560)^2 = 5.81$ kW
  Total $L_3 = 3.50 + 5.81 = 9.31$ kW

- Loss when load is integrated into the 750 kVA transformer:
  $L_1 = 3.2 + 3.2 \times 2.5 \times (494/750)^2 = 6.67$ kW

- Reduction of loss : (9.31 - 6.67) = 2.64 kW

- Annual reduction of loss : 2.64 × 8.760 = 23,100 kWh

  If transformers are integrated, therefore, 23,100 kWh is annually saved.

- Annual cost saved : 23,100 kWh/y × 0.7 Lv/kWh = 16,200 Lv/y

2) #3 substation, Two 400 kVA Transformers

Table 5.4.29 shows the measuring result.

Table 5.4.29 Measuring Result of #3 Substation

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Date and time of measurement
#1400 kVA Transformer	(131kVA)	(115kVA)	(81 kVA)		6/30 12:10-14:10
	Power is unmeasurable because of unknown phase sequence.				
#2400 kVA Transformer	154	125	94	97.4	6/30 12:10-14:10

#1 transformer and #2 transformer are installed side by side in #3 substation as well; the integration of transformers should be also considered for #3 substation as done for #2 substation. However, the phase sequence of the bus was unknown, and for #1 transformer, the apparent power only was measured. Therefore, the apparent power after the integration of the load of #1 transformer and that of #2 are considered to be the sum of apparent power of both transformers. The resultant value will be larger than the actual apparent power, which is a calculation result with safety taken into account.

The iron loss and loss ratio of the 400 kVA transformer is assumed to be the same as those of the ordinary ones, and assumed to be 2.5 kW and 2.3 kW, respectively.

In this measurement, the average apparent power of the #1 transformer was 110 kVA, and that of #2 128 kVA. So, the total apparent power is assumed to be 238 kVA as mentioned above.

- Transformer loss on the present operation conditions:
  #1 transformer $L_1 = 2.5 + 2.5 \times 2.3 \times (110/400)^2 = 2.93$ kW
  #2 transformer $L_2 = 2.5 + 2.5 \times 2.3 \times (128/400)^2 = 3.09$ kW
  Total $L_3 = 2.93 + 3.09 = 6.02$ kW

- Loss when load is integrated into a 400 kVA transformer:
  $L1 = 2.5 + 2.5 \times 2.3 \times (238/400)^2 = 4.54$ kW

- Reduction of loss : $(6.02 - 4.54) = 1.48$ kW

- Annual reduction of loss : $1.48 \times 8{,}760 = 13{,}000$ kWh

  If transformers are integrated, therefore, 13,000 kWh is annually saved.

- Annual cost saved : 13,000 kWh/y x 0.7 Lv/kWh = 9,100 Lv/y

However, this calculation is based on the result of the measurement in a limited period, and accordingly, whether to integrate the transformers must be determined by continuing the measurement and anticipating the state of load in the future.

3) Finishing Shop, Power Used by Dryer (Sent Out from #3 Substation)

Table 5.4.30 shows the result of the measurement.

Table 5.4.30 Power from #3 Substation to Dryer

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Date and time of measurement
Send Out to Dryer	36.9	24.6	22.5	52.6	7/1 10:20-11:20
Received at Dryer	35.1	34.2	33.3	57.8	7/1 14:03-14:09

The power factor of the total power used by the dryer is in the level of 50 % and extremely low. This is probably because a special motor named Schtlage Rittel (in this measurement, power factor: 26 %) is installed for the dryer. Simultaneous measurement could not be made this time on the substation side and on the power receiving job site side; however, it is imagined that the cable loss is considerably large due to the low power factor. In the present situation, if you improve the power factor, you are penalized by the electric power company on the strength of the contract, and accordingly, it is hard to implement the improvement of the power factor. Taking the cable loss and the increase in voltage drop into account, nevertheless, we believe that the opportunity should be taken of installing capacitors on the job site side.

4) Finishing Shop, Dryer Circulation Fans #1 - #8 (#2 Fan is out of operation)

Table 5.4.31 shows the result of the measurement

Table 5.4.31 Power of Dryer Circulation Fan

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power (%)	Measuring time
#1	2.5	2.3	2.2	65.1	6/29 12:50-14:10
#3	2.5	2.3	2.1	86.8	6/29 12:50-14:10
#4	2.5	2.4	2.4	68.7	6/29 15:00-16:00
#5	3.0	2.7	2.5	69.9	6/29 12:50-14:10
#6	3.1	2.8	2.5	69.9	6/29 12:50-14:10
#7	2.5	2.4	2.4	65.7	6/29 15:00-16:00
#8	2.5	2.3	2.3	66.5	6/29 15:00-16:00

Four circulation fans are installed on both sides of the dryer, each; #2 fan was out of operation in the period of the measurement. The load of #5 and #6 fans is slightly larger and 2.7 - 2.8 kW on average; that of the other five fans is 2.3 - 2.4 kW on average. The power factor is notable. The power factor of any other fans than #3 fan is in the level of 60 %, indicating a small load. Taking into account the fact that the operation is feasible with #2 fan unused, it may be possible to change the pulley diameter and operate the fans at a lower speed to reduce the output. If number of revolution control is required, then an inverter may be introduced to control the eight fans in a lump. These fans operate in an unfavorable environment at high temperature; some of them have the motor cooling air inlet almost clogged, and others indicate 70 °C of housing temperature. Periodical maintenance is required.

5) Finishing Shop, Ventilation Blower, Hemmel Washer, Finishing Shop, Hemmel Degetiel

Table 5.4.32 shows the result of the measurement.

Table 5.4.32 Power of Dry Finishing Shop

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Date and time of measurement
Ventilation Blower					
Intake Damper Open	16.4	16.1	16.1	78.3	6/30 15:00-16:47
Intake Damper Closed	16.3	16.2	16.1	77.3	6/30 16:00-16:47
Hemmel Washer	15.2	12.6	2.1	76.5	7/1 11:55-12:01
Hemmel Degetiel	—	10.5	9.9	74.0	7/1 12:11-12:17

The motor output is approx. 16 kW before and after the operation of the outdoor air intake damper; virtually no change was observed.

6) Blowers for Air Conditioners, Pump, Doubling Machines, and Vacuum Pumps in Woolen Spinning and Spinning Shops

Table 5.4.33 shows the result of the measurement.

Table 5.4.33 Power of Woollen Spinning Shop

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Date and time of measurement
Blower & 30 kW Pump	74.6	73.1	72.1	94.7	7/1 14:48-14:52
75 kW Blower	58.7	58.2	57.6	95.4	7/1 15:04-15:10
Doubling Machine					
5 of #1-#9	43.2	42.8	42.6	49.9	7/1 14:38-14:44
3 of #10-#15	20.7	20.5	20.2	73.2	7/1 15:56-16:02
Vacuum Pump					
#1 30 kW	27.0	24.7	18.4	85.8	7/1 11:00-16:00
#2 30 kW	29.1	26.4	21.0	85.3	7/1 11:00-16:00

The air conditioning blowers operate at a load factor of 78 %, and this poses no electrical problem. The load factor including that of the pumps is 70 %, and it is supposed because the load factor of the pumps is poor. This calls for consideration. The basics of energy conservation is to determine an air quantity required for a shop, and it should be considered before the determination of the blower capacity.

The load factor of both vacuum pumps exceeds 80%, and this poses no electrical problem. However, consideration should be given, in the future, to whether it is necessary to continuously operate two pumps for the operation in the job site. It should be taken into account to analyze the sucking operation and control the number of units. In some cases, it may be necessary to install a small vacuum pump for each production machine.

7) Water Pump

Table 5.4.34 shows the result of the measurement.

Table 5.4.34 Power of Pump

Measurement items	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Date and time of measurement
Water Pump 22 kW	18.3	14.7	11.3	67.3	6/30 10:45-13:00

Fig. 5.4.23 illustrates the transition of the power of the pump in the passage of time. As seen from the table, the flow rate and the power largely fluctuate within the range of from 35 to 103 m^3/h and from 11.4 to 18.3 kW, respectively. The relation between flow rate and power is almost linear, as shown in Figure 5.4.24. We believe the flow rate is controlled in each shop. In this case, the introduction of number of revolution control will remarkably reduce the power consumption. The expectancy of power consumption reduction was calculated.

Figure 5.4.23 Power Consumption of Water Pump

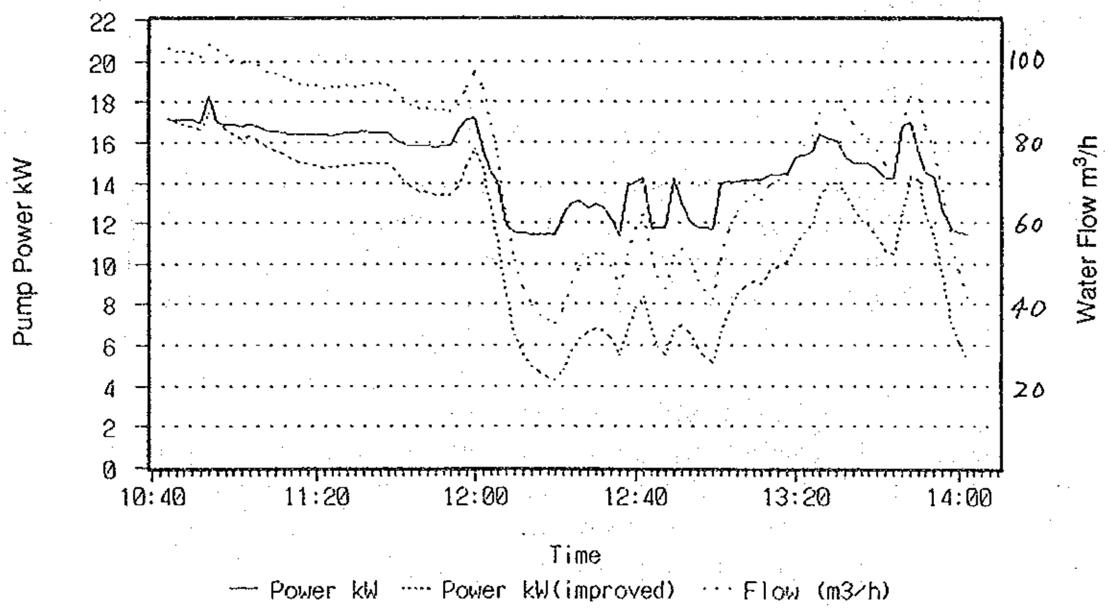
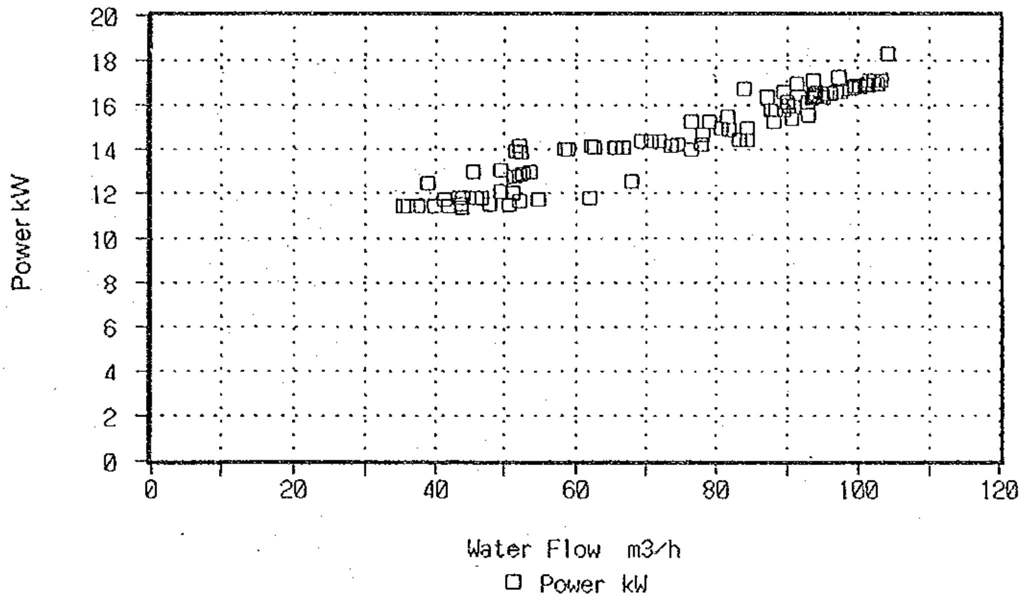


Figure 5.4.24 Q-P Curve of Water Pump



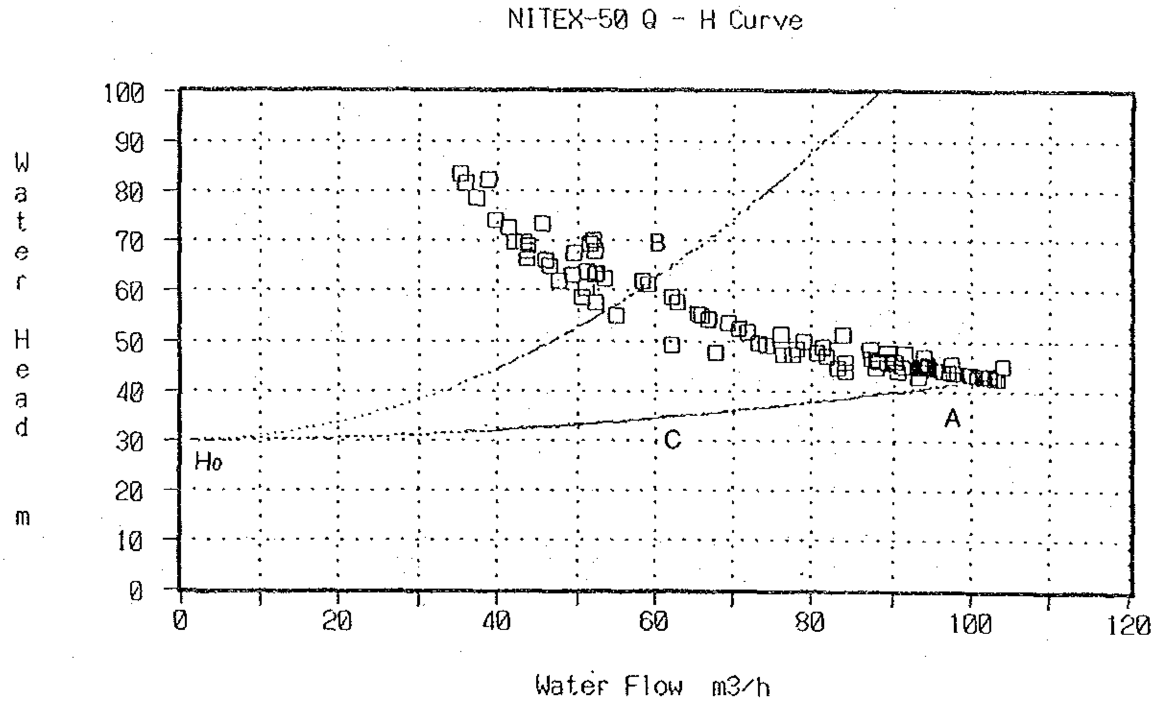
Since the pressure was not measured this time, the actual pump head H_0 is assumed to be 30 m based on examples of ordinary water pumps. Since there is no test result sheet, the pump efficiency, including the motor, is assumed to be 70 %.

Letting the motor input, pump head and flow rate be P (kW), H (m) and Q (m^3/h), respectively, the relation shown below is established:

$$P = \frac{Q \times H}{0.7 \times 6.12 \times 60} \qquad (1)$$

The value of H was found based on measured values of P and Q. Figure 5.4.25 is the Q - H curve drawn based on these values.

Figure 5.4.25 Q-H Curve of Water Pump



The pump head H is the sum of the actual pump head and the pressure loss due to the pipe line resistance; the pressure loss is in proportion with the second power of the flow rate.

That is,

$$H = 30 + a \times Q^2 \qquad (2)$$

Let us consider the number of revolution control with point A (100 m^3/h, 42 m) in the figure taken as reference.

The coefficient a of resistance curve passing point H_0 and A, is obtained using Equation (2), as follows:

$$a = (42 - 30)/100^2 = 0.0012$$

Therefore, the resistance curve is expressed as Equation (3):

$$H = 30 + 0.0012 \times Q^2 \qquad (3)$$

If the number of revolution is controlled and the flow rate is changed, the pump head is also changed along the resistance curve. The result of the calculation of input based on the this, is plotted as "Power (improved)" in Figure 5.4.23. On the contrary, if the valve control is exercised, the pump head is changed according to the flow rate, as the measured value. If the flow rate is changed to that at point B, for example, the resistance curve turns into a curve of second degree connecting H_0 and point B. Then the energy is increased by the quantity equivalent to the difference in pump head between B and C, compared with the case of the number of revolution control.

The increment ΔP is expressed as Equation (4) below:

$$\Delta P = \frac{Q \times (\text{Difference in pump head between B and C})}{0.7 \times 6.12 \times 60} \qquad (4)$$

$\Sigma\Delta P$ is 11.5 kWh in the period of the measurement (approx. 2 hrs). The measurement could not be made in night, and accordingly, it is hard to estimate how frequently such a flow rate change occurs for a year. However, assuming that such a low load state of two hrs occurs by day and that of eight hrs by night everyday, the annual reduction of power by the number of revolution control is calculated.

The calculation result is as follows:

$11.5 \times (10/2) \times 365 = 21{,}000$ kWh

The investment effect is calculated on the basis of prices in Japan. Letting the price of the inverter and the electrical rate be 30 thousand yen/kW and 15 yen/kWh, respectively, the simple investment payback period is 2.1 years as shown below:

The amount of investment = 22 kW × 30 thousand yen/kW = 660,000 yen
The annual reduction of cost = 21,000 kWh × 15 yen/kWh = 315,000 yen

It is necessary to foresee how the situation of pump operation will be changed in future production plans before determining whether to introduce the number of revolution control.

8) Lighting

Daylight is well utilized, and the lighting circuit is well separated. For fluorescent lamps (40 W), however, 140 lamps in total were on in unmanned areas: 50 in the weaving shop, 20 in the finished product depository, 70 in the dry finishing shop. For mercury lamps (400 W), seven lamps were on in the Carding shop where daylight provides sufficient lighting.

If these lamps are kept off for eight hrs everyday, the power shown below is annually saved:

(40 W × 140 + 400 W × 7) × 8 × 365 = 24,530 kWh/y
24,530 kWh/y × 0.7 Lv/y = 17,170 Lv/y

On the contrary, the illuminance is 160 Lx at the side of machines in the spinning shop. This is insufficient, and it is necessary to use local lighting to increase the illuminance at the thread inlet and so on.

(9) Overall Effect

The effects of the improvement plans mentioned above which can be quantitatively estimated, were summed. Table 5.4.35 shows the result of the summing.

Table 5.4.35 Summary

Item	Expected Saving							Investment Payback	
	Steam			Power			Total	Year	
	Mcal/y	1000Lv/y	%	kWh/y	1000Lv/y	%	1000Lv/y	1000Lv	y
Dryer									
Decrease of Drying Load	11750	7.2	0.0						
Wet Finishing									
Heat Recovery of Effluent	675000	411.8	2.4				411.8	500	1.2
Air Conditioning									
Integration of 2 Systems				120000	84.0	3.7	84.0	60	0.7
Steam Substation									
Insulation	850390	518.7	3.0				518.7	4	0.0
Space Heating									
Checking Air Infiltration	4924100	3003.7	17.6				3003.7	0	0.0
Transformer									
Integr'n in #2 Substation				23100	16.2	0.7	16.2	0	0.0
Integr'n in #3 Substation				13000	9.1	0.4	9.1	0	0.0
Water Pump									
Rotation Control				21000	14.7	0.7	14.7	130	8.8
Total	6461240	3941.4	23.0	177100	124.0	5.5	4065.3	694	0.2

5.5 Results of the Study at a Glass Factory

5.5 Results of the Study at a Glass Factory

5.5.1 Overview of the plant

(1) Factory name
Stind Ltd.

(2) Type of industry
Glass

(3) Major product name and production capacity
Glass bottle (0.2 to 1 liter) : 260 million bottles per year
Hand made glassware (decoration wares including vases)

(4) Number of employees
750

(5) Factory address
1. Tsvetan Antov. Str. 1220, Sofia

(6) History
The first factory was started in 1960 to manufacture the glass bottles, and the second factory was founded in 1971 to produce glass bottles and hand made glassware. The company produces two types of glass bottles; green ones and colorless ones. Stind Ltd. is a middle-sized company in Bulgaria, and registered a market share of about 15 percent in 1989 when the production was smooth and active.

Due to sluggish economy after the political renovation, the production has been lowered since 1990. The production for 1992 posts 40 percent of the peak level. Only two out of four glass melting tank furnaces are currently operating. Eighty percent of the products are exported to neighboring countries.

(7) Study period
June 7 to 11, 1993

(8) Members of study group

Mitsuo Iguchi	: Head of the study group, energy management
Teruo Nakagawa	: Assistant Head of the study group, measurement
Akira Koizumi	: Thermal technology
Shoji Nakai	: Glass process
Takashige Taniguchi	: Thermal technology
Tetsuo Ohshima	: Thermal technology
Kazuo Usui	: Electric engineering

(9) Persons interviewed

Mr. Vladimir D. Dimov : President
Mr. Ilia P. Ignatiev : Vice President
Mr. Stoyanov : Electric Engineer
Mr. Tsonev : Process Engineer

(10) Trend of production

Table 5.5.1 Trend of Production

Name of Product		Unit	1987	1988	1989	1990	1991	1992
Bottle Green		M pc	133.9	130.4	129.8	97.6	59.1	48.5
Colorless		M pc	54.8	48.2	55.7	51.9	28.0	22.5
Total		M pc	188.7	178.6	185.5	149.6	87.1	71.0
Glass Ware		1000 pc	2054	2088	2108	1612	1053	890
Bottle								
Green	#1 Fce	1000 t	32.3	30.6	30.9	24.3	7.3	0
	#2 Fce	1000 t	32.9	33.4	34.0	25.1	23.1	25.0
	Subtotal	1000 t	65.2	64.0	64.9	49.4	30.5	25.0
Colorless	#3 Fce	1000 t	16.2	15.3	17.5	15.8	4.0	0.3
	#4 Fce	1000 t	18.8	16.9	19.5	16.3	12.4	12.9
	Subtotal	1000 t	34.0	32.2	37.0	32.2	16.5	13.3
Total		1000 t	99.3	96.2	101.9	81.5	46.9	38.2
Glass Ware		t	419	449	458	300	227	175

(11) Trend of energy consumption

Table 5.5.2 Trend of Energy Consumption

Energy	Unit	1988	1989	1990	1991	1992
Natural Gas	1000m³	30835	34125	35623	26088	22622
Electric Power	MWh	30516	31038	30016	20220	16726
Steam	Gcal		4928		4201	3246
Hot Water	Gcal		2573			2223

(12) Trend of unit energy consumption rate

Table 5.5.3 Trend of Unit Energy Consumption Rate

Energy	Unit	1988	1989	1990	1991	1992
Natural Gas	Mcal/t	2534	2647	3457	4392	4679
Electric Power	kWh/t	316	303	367	429	436

Figure 5.5.1 Heat Energy Unit Consumption Rate

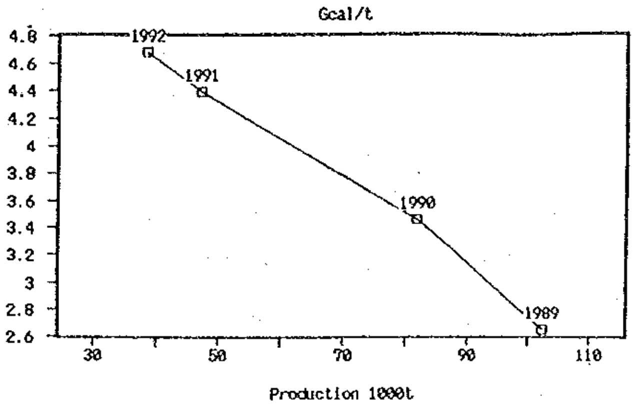
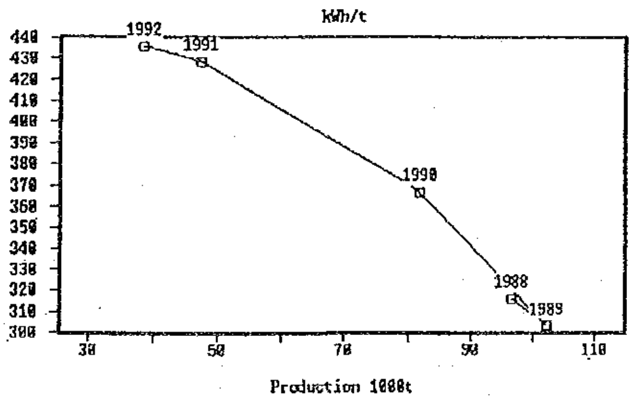


Figure 5.5.2 Electric Power Unit Consumption Rate

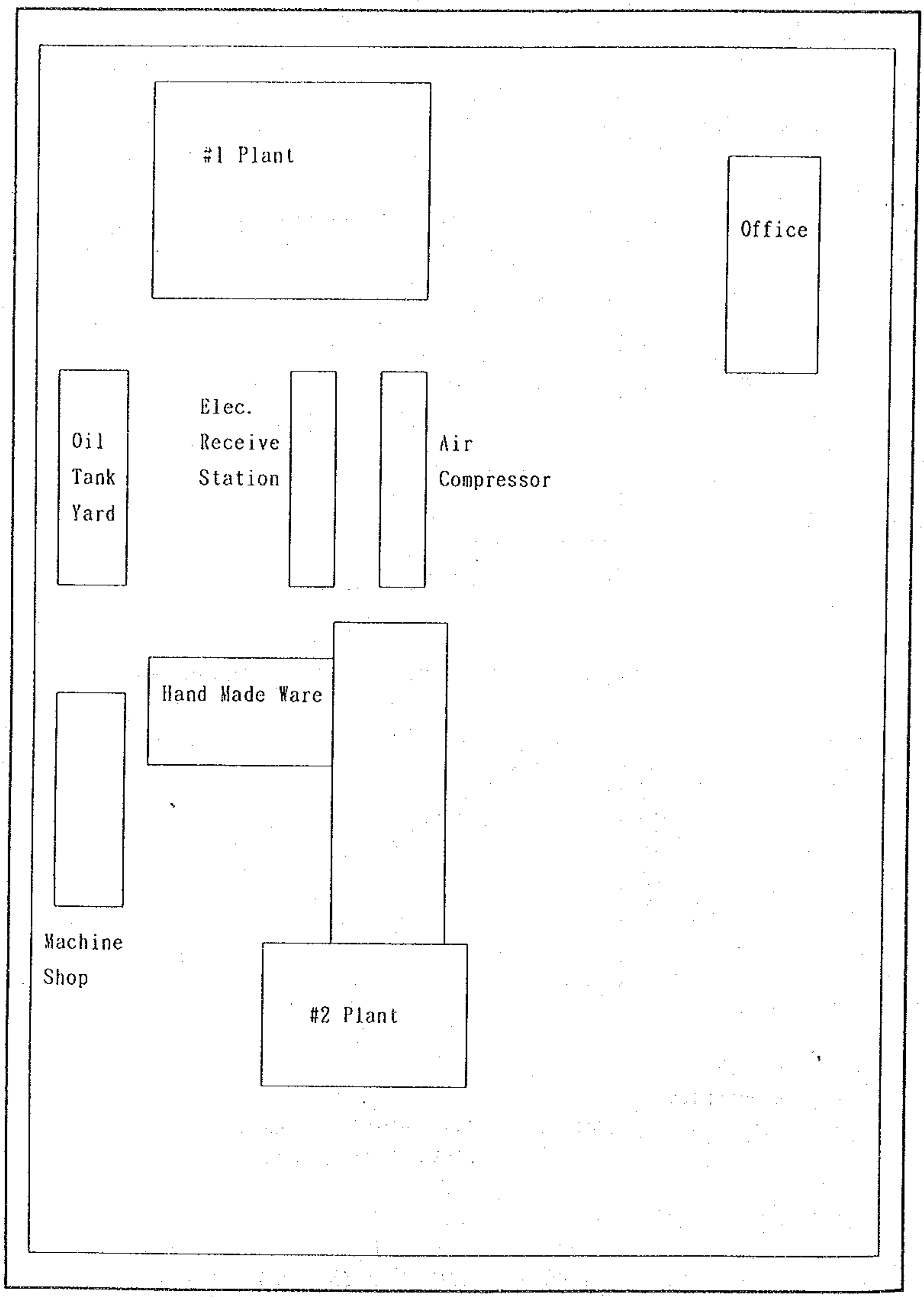


(13) Energy prices

Natural gas	7941 kcal/m³	2360 Lv/1000 m³ Summer			
		1715 Lv/1000 m³ Winter			
Electric power	Time	Peak	Day	Night	
	Lv/kWh	1.395	0.754	0.374	Oct-Mar
	Lv/kWh	1.217	0.655	0.322	Apr-Sep

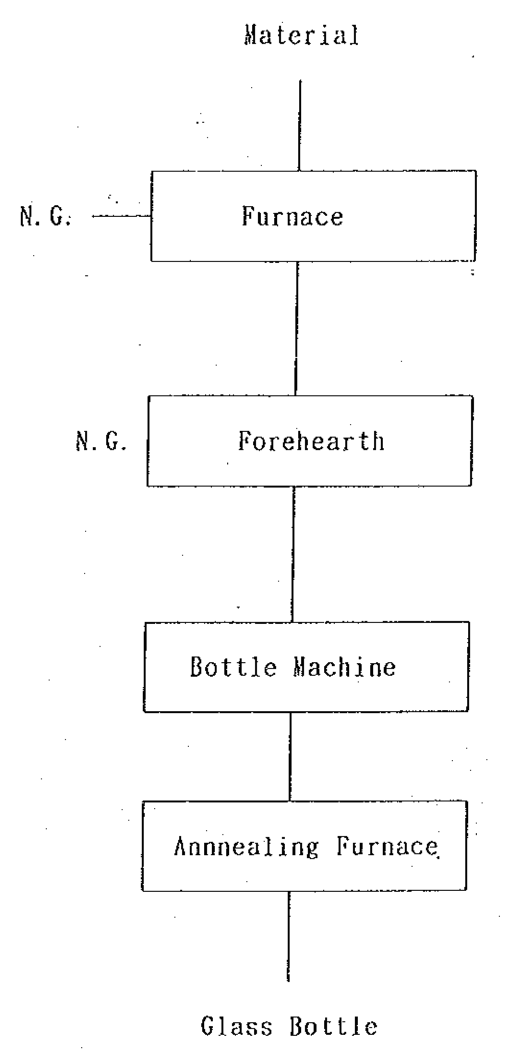
(14) Factory layout

Figure 5.5.3 Factory Layout



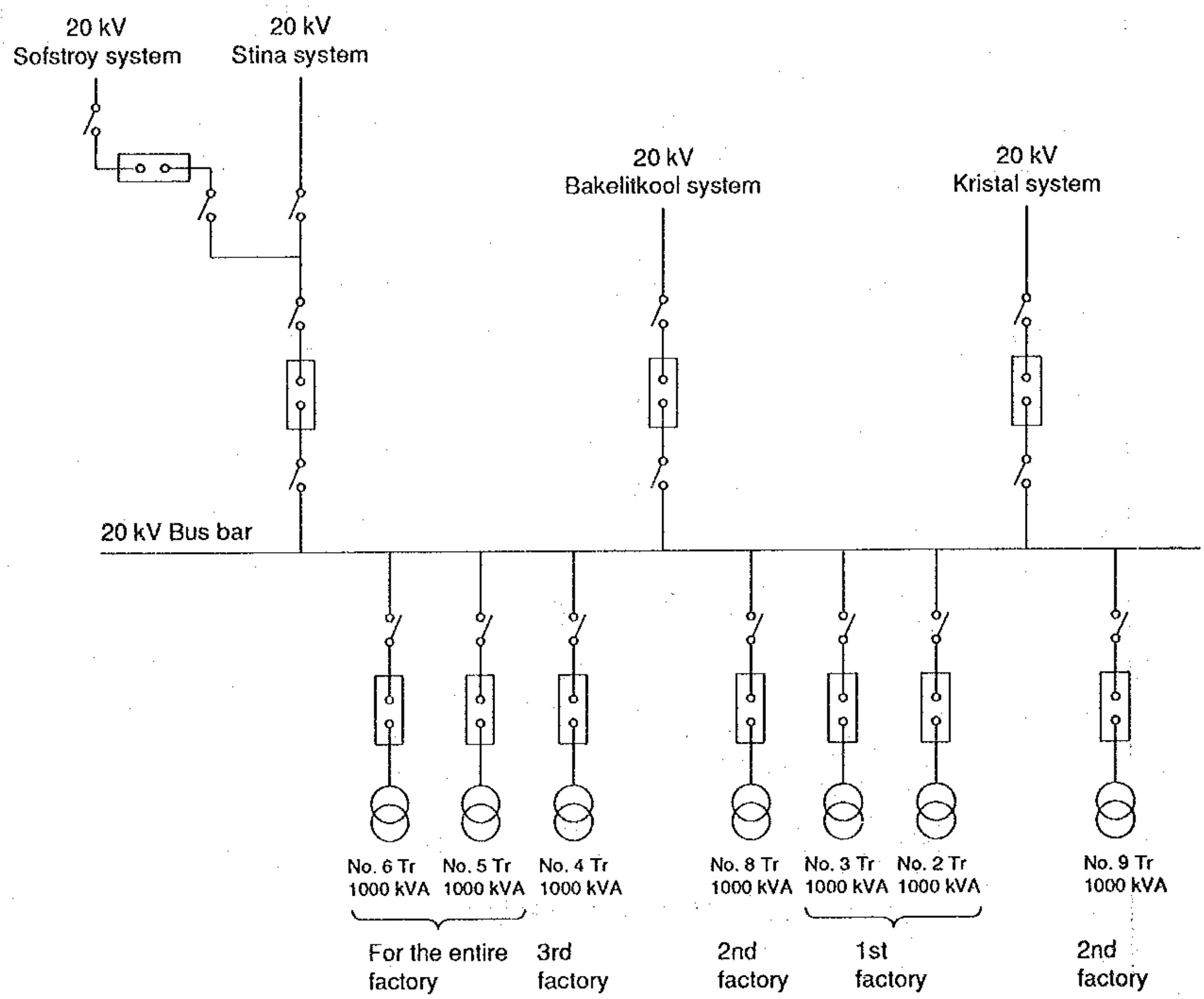
(15) Production process

Figure 5.5.4 Production Processes



(16) Electric power one line diagram

Figure 5.5.5 Electric Power One Line Diagram



(17) Outline of principal equipment

Table 5.5.4 Outline of Principal Equipment

Name	Number	Specification
Tank Furnace No. 4	1	End Port Type Output 70t/d 5.6mW×8.6mL 48.16 m²
Regenerator	1	2.5mW×3.5mL×7.25mH 63.44 m²
Forming Machine	2	Roirant R7
Annealing Lehr	2	Electric Heater

5.5.2 Situation of energy management

In the Stind factory, additional 200 mm Chamotte bricks were heaped on the bottom of the glass melting tank furnace to increase the heat insulation effect. And also energy conservation measures are taken for combustion improvement of natural gas. With the reduction in production volume, however, energy consumption per unit product has been increased to 1.8 times that of the previous level, and the percentage of the energy in the total cost has reached as high as 40 percent. In view of this situation, it is essential to launch a systematic energy saving campaign involving all the factory employees.

Energy consumption efficiency differs according to the performances of the equipment and machinery and operation methods, which depend greatly on the skills and actions of the personnel in charge of operation and maintenance.

Adequate maintenance and servicing must be taken to ensure design performance of the equipment, and minor modification should be made to provide improved performances. It is necessary not only to try to conform to operation standards but also to make improvement efforts to find out better operation methods.

This is related to all the members engaged in the work. To ensure effective promotion of the energy conservation, it is essential to establish an organization to ensure that all the people of the factory make concerted efforts to achieve the target, as well as to take measures for the equipment improvement.

(1) Setting the target for energy conservation

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

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

However, setting the target requires correct information on the current energy consumption in the factory. In this factory, watt-hour meters are installed for the receiving position and respective substations. For the natural gas, however, meters are installed only at the receiving position. The flow meter for each melting furnace was left unrepaired. The total consumption in the factory is reported every day to electric and gas utilities, but it is reported to the management only once in a month, and is not used for daily control. Without correct information on how much energy is consumed in each process, it is impossible to compare it with design conditions to make evaluation or to set up the quantitative target value. Even if energy conservation measures are taken, the effects cannot be confirmed. The top priority should be given to procurement of meters and measuring instruments in order to launch a systematic energy conservation campaign.

(2) Systematic actions

The factory is staffed with the employees in charge of energy, but systematic energy conservation campaign involving all the employees are not yet initiated.

To implement the energy conservation campaign with concerted efforts of all the members, it will be effective to establish a committee comprising representatives of the management division, production division and auxiliary division, so that interaction can be provided between the processes particularly among the production-related divisions. This committee will work out the energy conservation program, determine the budget, approve the technical energy conservation measures, evaluate the results, and introduce various cases. This will ensure uniform understanding to be shared among different divisions, permitting the activity to be made on a priority basis. This will also make it possible to check if a particular action has a total effect including the effect given to the preceding and succeeding processes. It will also permit advice to be given from different angles. To ensure implementation of the items determined at the meeting of this committee, the meeting should be chaired by the chief factory manager or a person having an equivalent authority.

It is also necessary to hold various events in order to keep the employees interested in the energy conservation, or appoint coordinators to make arrangements among different related divisions, in order to ensure smooth implementation of the energy conservation activity.

The employees working in the first line are placed in daily contact with energy consuming equipment, and they get the feel of the problems with their own skin. An effective use of energy cannot be achieved if the equipment are not used effectively and work standards are not observed, no matter how excellent they are. So it is effective to keep the employees in the first line interested in the energy conservation so that they will take an active part in the activity.

(3) Data-based management

In energy conservation activity, as in the quality control, steady improvement can be gained by repeating the PDCA circle where an improvement plan is worked out (PLAN) and implemented (DO), the results are evaluated (CHECK), the work process is modified or fixed (ACTION) in accordance with the evaluated results; then an improvement plan on a higher level is worked out. Thus the control level is gradually increased, repeating the same cycle.

The problems accompanying energy consumption to be studied in working out the improvement plan and suggestions for improvements can be made clear only through an objective analysis of the data (facts) occurring in the factory. The effects of the energy conservation efforts can be confirmed by means of statistical techniques such as unit consumption rate control chart, histogram and correlation analysis on the basis of the actual data. If there is abnormal data, much information can be gained by checking the cause for such fault. So the energy flow meter must be supplied for each major process, and the consumption on a periodic basis must be recorded so that it can be compared with the production situation.

It is important that the result of the evaluation is made public on a periodic basis so that the result of the efforts can be known to all employees. This will bring up rivalry in a good sense in the factory.

It is also important to award official commendation to job sites having achieved a good result or to effective proposals, thereby encouraging their further efforts.

(4) Education and training of employees

It is necessary to give sufficient information in order to promote voluntary activities of the employees. To motivate efforts for energy conservation, the employees should be informed of the trend of energy prices, the weight of the energy cost in the production cost, possible causes for energy losses, preventive measures, and cases of successful energy conservation efforts in other factories.

It is also necessary to promote education and training of the employees by giving instructions through competent staff members, by giving training courses, and by providing them with manuals; thereby increasing their level. In this factory, lectures are said to be given by the factory expert staff members to the operators which are going to sit in for higher qualification test. Energy conservation should be included in the instruction agenda for this lesson.

To improve the engineering level, it is effective to dispatch the engineers to the seminars sponsored by the glass and ceramic research institute, and to encourage information exchange with the employees of rival companies.

(5) Equipment management

If the equipment is not maintained in proper conditions, a great energy loss will occur. This factory adopts the continuous operation system where periodic maintenance is difficult, but the equipment were subjected to effective maintenance and repair. However, the natural gas flow meter was left unrepaired, as discussed above, and the checker brick inside the regenerator was observed to have been damaged; this will reduce the heat efficiency.

The first step for maintenance is to put things in order. It is necessary to clean around the blower to facilitate inspection on patrol.

Drawings are essential for the maintenance of the equipment. Revised drawings must be prepared immediately after any modification work has been made, and they must be put in order so that they can be easily used by any one. In this plant, the drawings were placed in good order.

5.5.3 Problems in energy use and their Solutions

(1) Glass melting furnace

a) Heat balance

1) Calculation basis

① Scope of heat balance calculation

Melting furnace except forehearth

② Reference temperature

The reference temperature shall be 20 °C.

③ Combustion-related measurement results

Figures 5.5.6 and 5.5.7 illustrate the combustion-related measurements.
The fuel gas flow rate was obtained by multiplying the central flow rate measured with the pitot tube, by the Uav/Umax coefficient of 0.84.

Figure 5.5.6 Measuring Data for Combustion (Rightside Combustion)

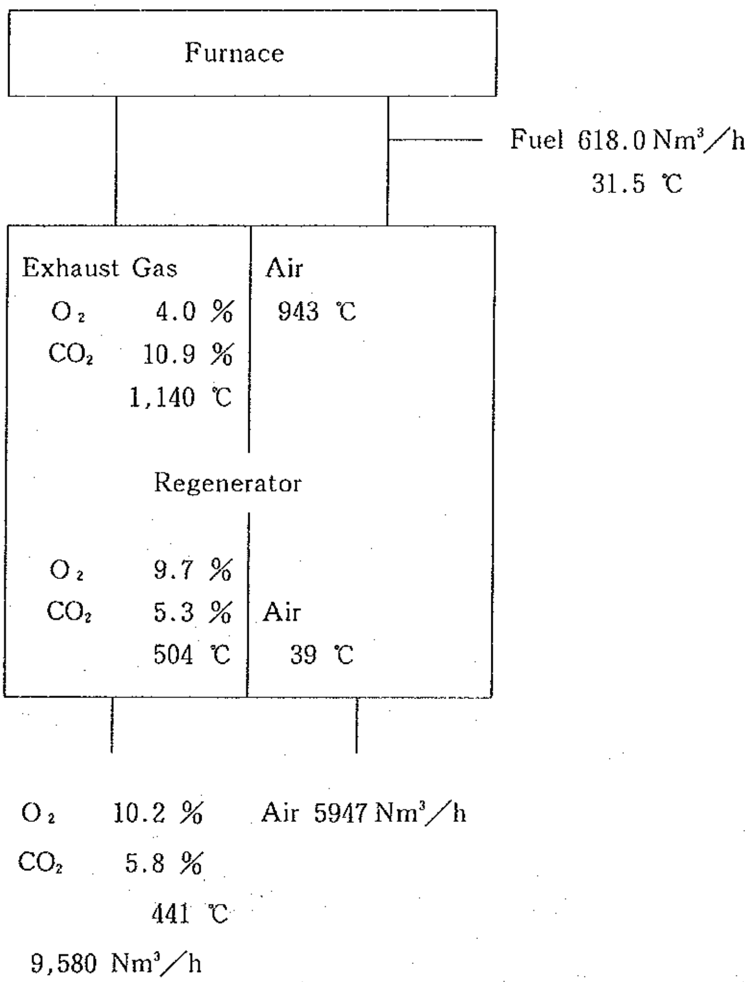
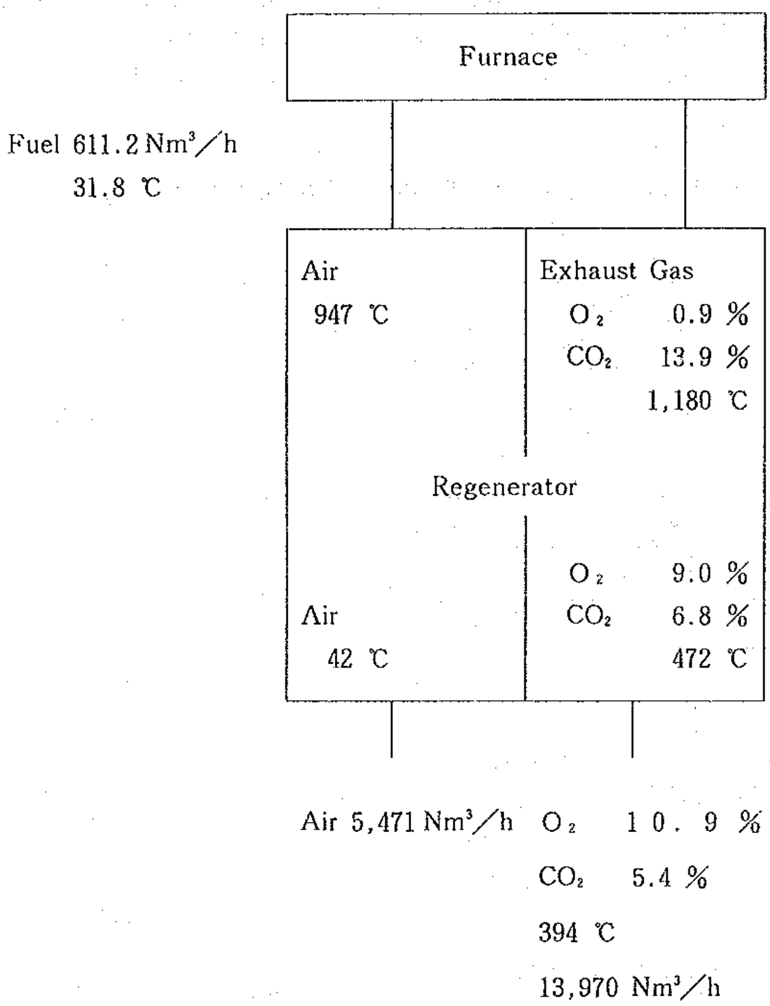


Figure 5.5.7 Measuring Data for Combustion (Leftside Combustion)



2) Fuel gas

① Fuel gas composition and its calorific value

Table 5.5.5 shows the fuel gas composition.

Table 5.5.5 Composition of Fuel Gas

Composition	Nitrogen N_2	Carbon dioxide CO_2	Methane CH_4	Ethane C_2H_6	Butane C_4H_{10}	Total
%	0.94	0.03	98.57	0.39	0.07	100

Net calorific value : 8,512 kcal/Nm³

② Theoretical air flow (A_0)

$$A_0 = 100/21\,(2 \times CH_4 + 7/2 \times C_2H_6 + 13/2 \times C_4H_{10})$$
$$= 9.474 \quad [Nm^3/Nm^3\text{-Fuel}] \quad \cdots\cdots \quad (5.1)$$

③ Theoretical wet exhaust gas flow (G_0)

$$G_0 = (3 \times CH_4 + 5 \times C_2H_6 + 9 \times C_4H_{10} + N_2 + CO_2 + 79/100 \times A_0)$$
$$= 10.477 \quad [Nm^3/Nm^3\text{-Fuel}] \quad \cdots\cdots \quad (5.2)$$

④ Theoretical dry exhaust gas flow (G_0')

$$G_0' = (CH_4 + 2 \times C_2H_6 + 4 \times C_4H_{10} + N_2 + CO_2 + 79/100 \times A_0)$$
$$= 9.474 \quad [Nm^3/Nm^3\text{-Fuel}] \quad \cdots\cdots \quad (5.3)$$

3) Molten glass

① Amount of molten glass

Table 5.5.6 shows the amount of molten glass.

Table 5.5.6 Pulled Glass

Bottling machine (No.)	Entrance glass temperature (°C)	Product weight (g)	Forming speed (number/min.)	Pull rate (kg/h)
3	1,218	500	34.0	1,020
4	1,180	870	29.5	1,540
Total				2,560

② Batch composition

Table 5.5.7 shows the batch composition.

Table 5.5.7 Batch Composition

	Batch composition kg/Batch	Vitrification rate kg/Batch
Silica sand	456	445.8
Feldspar	76	73.4
Dolomite	134	72.6
Soda Ash	160	92.6
Calcium Phosphate	9	3.2
Total	835	697.6

Rate of cullet used	= cullet / total vitrification rate × 100	15.0 %
Batch moisture	= moisture / total batch × 100	3.9 %

③ Material input

The molten volume is assumed as material input.

Table 5.5.8 illustrates the material input.

Table 5.5.8 Input of Material

Material	Input kg/h	Vitrification rate kg/h
Sand	1,422	1,422
Feldspar	237	229
Dolomite	418	226
Soda Ash	499	289
Calcium Phosphate	28	10
Sub Total	2,604	2,176
Cullet	384	384
Moisture	121	
Total	3,110	2,560

④ Gas generated from material

The carbonate of the material is decomposed as follows in the vitrification process to generate carbon dioxide:

Material	Chemical composition		Glass		Volatile matter
Soda ash	Na_2CO_3	→	Na_2O	+	$CO_2\uparrow$
Dolomite	$CaCO_3$	→	CaO	+	$CO_2\uparrow$
	$MgCO_3$	→	MgO	+	$CO_2\uparrow$

Equations (5.4) and (5.5) show the volume in the normal state of 1 kg of the generated carbon dioxide and moisture:

CO_2 22.4/44 = 0.509 .... (5.4)

H_2O 22.4/18 = 1.244 .... (5.5)

The amount of gas generated is calculated as given in Table 5.5.9, according to Table 5.5.8 and Equations (5.4) and (5.5).

Table 5.5.9 Generated Gas from Raw Material

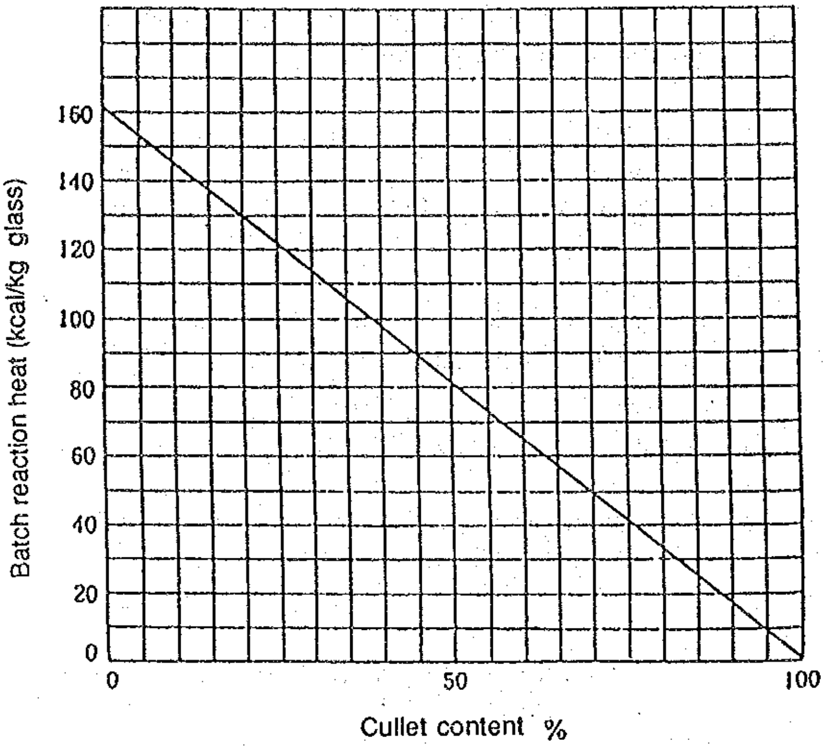
Gas	Raw Material	Generated Gas Flow [Nm^3/h]
CO_2	Feldspa	(237-299) × 0.509 = 4.1
	Dolomite	(418-266) × 0.509 = 97.5
	Soda Ash	(499-289) × 0.509 = 107.0
	Total	208.6
H_2O		121.29 × 1.244 = 150.9

⑤ Reaction heat for vitrification

Figure 5.5.8 illustrates the relationship between the cullet content rate and batch reaction heat. The reaction heat for the glass with 15% cullet content is shown below:

138 kcal/kg - vitrification rate

Figure 5.5.8 Reaction Heat of Batch by Cullet Content



⑥ Specific heat of glass

0.29 kcal/(kg · °C)

4) Calculation of the flow of exhaust gas and air

① Exhaust gas composition

F: Fuel used [Nm^3/h]

CO_2 = (CH_4 + 2 × C_2H_6 + 4 × C_4H_{10} + CO_2) × F + 208.6
= 0.997 × F + 208.6 [Nm^3/h] ······ (5.6)
where 208.6 Nm^3/h represents the amount of CO_2 (carbon dioxide) generated from material: See Table 5.5.9.

H_2O = (2 × CH_4 + 3 × C_2H_6 + 5 × C_4H_{10}) × F + 150.9
= 1.987 × F + 150.9 [Nm^3/h] ······ (5.7)
where 150.9 Nm^3/h represents the amount of H_2O generated from material: See Table 5.5.9.

N_2 = (N_2) × F + 79/100A_0
= 7.494 × F [Nm^3/h] ······ (5.8)

② Air for combustion

(A: Amount of air supplied to regenerator plus air for fuel atomization plus leakage)

$A = mA_0$ .... (5.9)

where m: air ratio

③ Exhaust gas (G)

$G = G_0 + (A - A_0) + 359.5/F$ .... (5.10)

$O_2\ \%/100 = 0.21 \times (A - A_0) / (G - \text{vapor amount}/F)$ .... (5.11)

G (exhaust gas) and A (air) are calculated from Equations (5.10) and (5.11).

④ Calculation of combustion

G, A and exhaust gas composition are obtained from the flow of fuel gas, Equations (5.1), (5.2), (5.6), (5.7), (5.8), (5.10) and (5.11), and O_2 %, as given in Table 5.5.10.

Table 5.5.10 Flow & Composition of Exhaust Gas & Air

		Rightside Firing			Leftside Firing		
Item	Unit	Regenerator Top	Regenerator Bottom	Flue	Regenerator Top	Regenerator Bottom	Flue
Exhaust gas							
O_2	%	4.0	9.7	10.2	0.9	9.0	10.9
A_0	Nm^3/h	5,850	5,850	5,850	5,790	5,790	5,790
G_0	Nm^3/h	6,470	6,470	6,470	6,400	6,400	6,400
G_0'	Nm^3/h	5,250	5,250	5,250	5,190	5,190	5,190
A	Nm^3/h	7,130	10,530	11,000	6,030	9,830	11,610
G	Nm^3/h	8,110	11,510	11,980	7,010	10,810	12,590
CO_2	Nm^3/h	820	820	820	820	820	820
H_2O	Nm^3/h	1,380	1,380	1,380	1,370	1,370	1,370
N_2	Nm^3/h	5,640	8,320	8,700	4,770	7,770	9,180
O_2	Nm^3/h	270	980	1080	50	850	1,220
Total	Nm^3/h	8,110	11,510	11,980	7,010	10,810	12,590
CO_2	%	10.11	7.13	6.84	11.70	7.59	6.51
H_2O	%	17.02	12.00	11.52	19.54	12.67	10.88
N_2	%	69.54	72.35	72.62	68.05	71.88	72.92
O_2	%	3.33	8.52	8.93	0.71	7.86	9.69
m		1.22	1.80	1.88	1.04	1.70	2.01

⑤ Air leakage

Table 5.5.11 gives the results of measuring the air flow at the alternator inlet. It shows air flow of an average of 870 Nm^3 per hour leaking from the burner and regenerator chamber wall, etc.

Table 5.5.11 Flow of Air at Alternator

Firing	Opening m	Press mm-Aq	Area m^2	Velocity m/s	Temp. °C	Flow Nm^3/h	Calc'd Nm^3/h	Leak Nm^3/h
Rightside	0.18	33.5	0.357	5.0	22	5,947	7,130	1,183
Leftside	0.18	35.0	0.357	4.6	22	5,471	6,030	559
Average						5,710	6,580	870

5) Enthalpy of fuel gas, air and exhaust gas

① Enthalpy of fuel gas

Table 5.5.12 shows the results of calculation.

Table 5.5.12 Enthalpy Fuel Gas

Temparature	℃	20	31.5	31.8
Specific heat Cp	kcal/ (℃·Nm^3)			
Component	%			
N_2	0.94	0.305	0.306	0.306
CO_2	0.03	0.392	0.395	0.395
CH_4	98.57	0.375	0.378	0.378
C_2H_6	0.39	0.465	0.469	0.469
i-C_4H_{10}	0.03	1.018	1.054	1.054
n-C_4H_{10}	0.04	1.044	1.077	1.078
Fuel Gas	100.00	0.375	0.378	0.378
Enthalpy	kcal/Nm^3	7.507	11.918	12.034
		0	4.411	4.527

② Enthalpy of air

Table 5.5.13 shows the results of calculation.

Table 5.5.13 Enthalpy of Air

Item	Unit	Rightside Firing Regenerator Top	Rightside Firing Regenerator Bottom	Leftside Firing Regenerator Top	Leftside Firing Regenerator Bottom	Reference
Temperature	℃	943	39	947	42	20
Specific heat Cp	kcal/(℃·Nm^3)	0.336	0.310	0.336	0.310	0.310
Enthalpy	kcal/Nm^3	310.6	5.9	312.0	6.8	0.0

③ Enthalpy of exhaust gas

Table 5.5. 14 shows the results of calculation.

Table 5.5.14 Enthalpy of Exhaust Gas

Item [Unit]	Rightside Firing Regenerator Top	Rightside Firing Regenerator Bottom	Rightside Firing Flue	Leftside Firing Regenerator Top	Leftside Firing Regenerator Bottom	Leftside Firing Flue	Reference
Temperature [℃]	1,140	504	441	1,180	472	394	20
Specific heat Cp [kcal/(℃·Nm^3)]							
CO_2	0.543	0.481	0.472	0.546	0.476	0.465	0.329
H_2O	0.402	0.363	0.359	0.405	0.361	0.357	0.343
N_2	0.339	0.319	0.317	0.340	0.318	0.316	0.311
O_2	0.357	0.334	0.332	0.358	0.333	0.330	0.313
Enthalpy [kcal/Nm^3]							
CO_2	61.9	16.8	13.8	74.6	16.5	11.5	
H_2O	76.8	21.1	17.4	92.1	20.7	14.6	
N_2	264.4	111.8	97.0	268.8	103.4	86.2	
O_2	13.3	13.8	12.5	3.0	11.9	12.0	
Total	416.5	163.6	140.8	438.4	152.6	124.3	0.0

6) Heat release from furnace wall

Heat release from the furnace wall was calculated by substituting the measurements of the outer surface temperature into the Equations (5.12), (5.13) and (5.14).

Radiation heat transfer coefficient (h_r):

$$h_r = \frac{4.88 \times \phi \times \{ (273 + t_o)^4 - (273 + t_a)^4 \}}{108 \times (t_o - t_a)} \quad (5.12)$$

Natural convection heat transfer coefficient: (h_c)

$$h_c = \alpha \times (t_o - t_a)^{1/4} \quad (5.13)$$

$$\text{Heat release per unit area} = (h_r - h_c) \times (t_o - t_a) \quad (5.14)$$

where

t_o	:	Outer surface temperature	[°C]	
t_a	:	Ambient temperature	[40 °C]	
ϕ	:	Emissivity	$\phi = 0.8$	
α	:	Coefficient	Horizontal upward surface	$\alpha = 2.8$
			Horizontal downward surface	$\alpha = 1.5$
			Vertical surface	$\alpha = 2.2$

Table 5.5.15 shows the results of the calculation.

Table 5.5.15 Heat Loss from Wall Surface (kcal/h)

Measuring Point			Heat Release [kcal/(h·m²·℃)]	Surface Temp. [℃]	Surface Area [m²]	Heat Loss [kcal/h]
Bottom	Melter	Under	3,200	231	57.89	185,200
		Side	2,800	200	18.26	51,100
	Throat	Under	1,700	168	0.66	1,100
		Side	1,600	145	0.59	900
	Refiner	Under	900	119	4.28	3,900
		Side	800	101	14.06	11,200
Crown	Melter	Skew	600	91	6.58	3,900
		Others	9,500	356	57.03	541,800
	Refiner	Skew	5,100	272	1.74	8,900
		Others	6,800	300	3.82	26,000
Side - Wall	Melter		5,500	285	38.90	214,000
	Refiner		3,700	231	3.98	14,700
Throat		Sleeper	11,200	402	1.15	12,900
		Cover	15,500	450	0.60	9,300
		Facer	14,400	450	1.80	25,900
Breast - Wall	Melter	Peep Hole	303,900	1,500	0.02	26,100
		Others	4,700	262	23.89	112,300
	Refiner	Peep Hole	148,700	1,200	0.02	24,900
		Others	8,800	359	9.84	86,600
Tuck - Stone	Melter	Side	3,200	213	4.37	14,000
		Under	1,000	125	5.57	5,600
	Refiner	Under	4,400	272	0.44	1,900
Back - Wall		Insulation	21,200	533	7.64	162,000
		Upper	16,200	460	3.40	55,100
Front - Wall		Insulation	8,100	344	12.40	100,400
		Upper	9,100	350	3.40	30,900
Bridge Cover			13,300	453	2.60	34,600
Port		Crown	19,100	495	9.05	172,900
		Skew	4,600	260	1.30	6,000
		Side	3,700	232	13.34	49,400
		Under	1,200	135	7.70	9,200
		Burner Block	7,100	323	1.26	8,900
Regenerator						
	Side	Upper	5,700	288	63.93	364,400
		Middle	3,400	219	55.23	187,800
		Lower	300	66	103.40	31,000
	Crown	Fin	19,500	500	21.22	413,800
		Skew	10,800	380	13.65	147,400
		Others	2,700	194	1.82	4,900
Total					576.83	3,160,900

7) Heat balance table

a) Heat input

① Sensible heat of fuel

See Table 5.5.12.

	[kcal/Nm³]	[Nm³/h]
Combustion on the right	(11.918 − 7.507) × 618.0 =	2,700
Combustion on the left	(12.034 − 7.507) × 611.2 =	2,800
Average		2,750 [kcal/h]

② Combustion heat of fuel

For the net calorific value of fuel, see 2) ①.

	[kcal/Nm³] [Nm³/h]	[kcal/h]
Combustion on the right	8,512 × 618.0 =	5,260,400
Combustion on the left	8,512 × 611.2 =	5,202,500
Average		5,231,450 [kcal/h]

③ Sensible heat of combustion air

See Table 5.5.10, Table 5.5.11, Table 5.5.13.

	[Nm³/h] [kcal/Nm³]	[kcal/h]
Combustion on the right	(7,130 − 1,183) × 310.6 =	1,847,400
Combustion on the left	(6,030 − 559) × 312.0 =	1,706,900
Average		1,777,100 [kcal/h]

④ Sensible heat of leaking in air

See Table 5.5.11.

	[Nm³/h] [kcal/Nm³]	[kcal/h]
Combustion on the right	1,183 × 6.2 =	7,300
Combustion on the left	559 × 6.2 =	3,500
Average		5,400 [kcal/h]

b) Heat output

① Heat taken out by glass

See Table 5.5.6, 3) ⑥.

[kg/h] [kcal/ (kg · °C)] [°C] [kg/h] [kcal/ (kg · °C)] [°C]

1,020 × 0.29 × (1,218 − 20) + 1,540 × 0.29 × (1,180 − 20)

=872,400 [kcal/h]

② Heat of batch reaction

See Table 5.5.6, 3) ⑤.

[kg/h] [kcal/kg]
2,560 × 138 = 353,300 [kcal/h]

③ Batch moisture evaporation heat

See Table 5.5.8.

[kg/h] [kcal/kg]
121.3 × 539 = 65,000 [kcal/h]

④ Heat loss by exhaust gas

See Tables 5.5.10 and 5.5.14.

Heat loss by exhaust gas (regenerator top)

	[Nm³/h] [kcal/Nm³] [kcal/h]
Combustion on the right	8,110 × 416.5 = 3,377,900
Combustion on the left	7,010 × 438.4 = 3,073,100
Average	3,225,500 [kcal/h]

Heat loss by exhaust gas (regenerator bottom)

	[Nm³/h] [kcal/Nm³] [kcal/h]
Combustion on the right	11,510 × 163.6 = 1,881,100
Combustion on the left	11,810 × 152.6 = 1,649,600
Average	1,765,400 [kcal/h]

⑤ Furnace wall loss

See Table 5.5.15.

	[kcal/h]
Melter	1,502,400
Working end	178,100
Throat, bridge cover	84,700
Port	246,400
Regenerator crown	566,100
Total	2,577,700 [kcal/h]

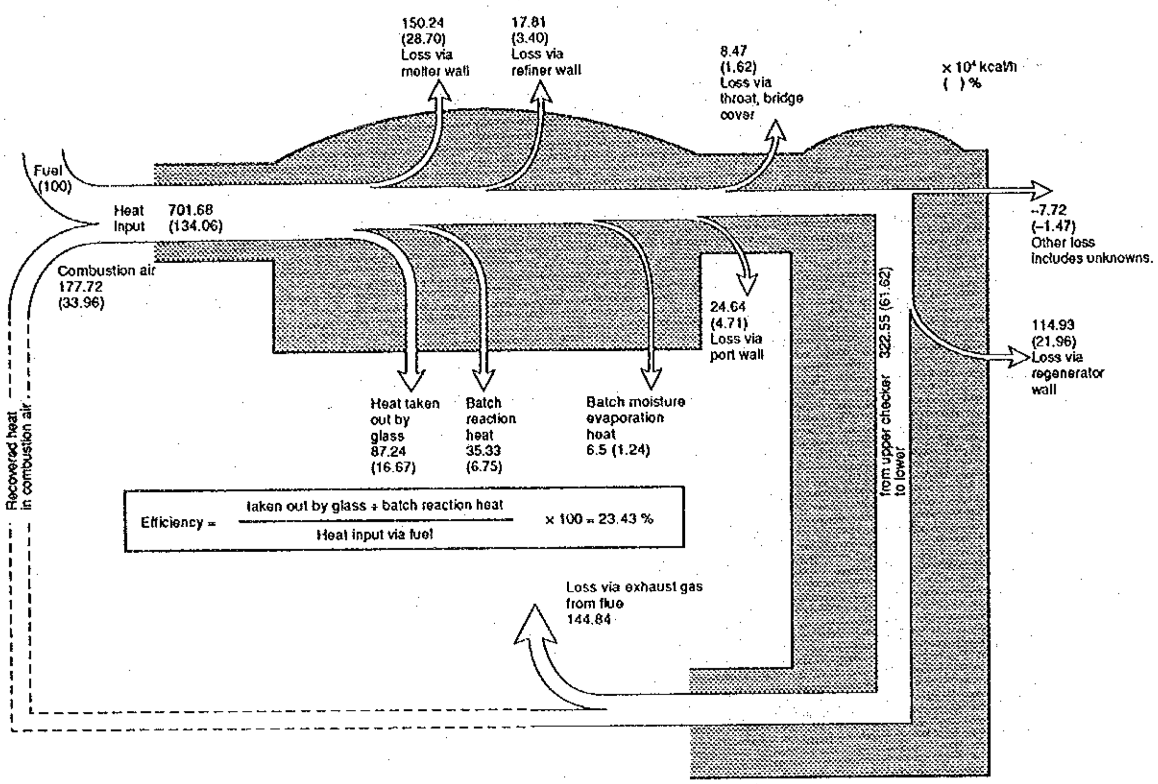
c) Heat balance table and chart

Table 5.5.16 shows the heat balance table, while Figure 5.5.9 shows the heat balance chart.

Table 5.5.16 Heat Balance Table

No	Item	Mcal/h	%/Fuel Heat	%/Total
	Heat Input			
1	Combustion Heat of Fuel	5,231.5	99.95	74.56
2	Sensibe Heat of Fuel	2.8	0.05	0.04
	Sub Total	5,234.3	100.00	74.60
3	Sensible Heat of Combustion Air	1,777.2	33.96	25.33
4	Sensible Heat of Leaking in Air	5.4	0.10	0.08
	Total Heat Input	7,016.8	134.06	100.00
	Heat Output			
11	Heat taken out by Glass	872.4	16.67	12.43
12	Batch Moisture Evaporation Heat	65.0	1.24	0.93
13	Heat of Batch Reaction	353.3	6.75	5.04
14	Heat Loss by Exhaust Gas (Top)	3,225.5	61.62	45.97
	(Regenerator Bottom)	(1,765.4)	(33.73)	(25.16)
15	Heat Loss from Wall			
	Melter	1,502.4	28.70	21.41
	Refiner	178.1	3.40	2.54
	Throat & Bridge Cover	84.7	1.62	1.21
	Port	246.4	4.71	3.51
	Regenerator Crown	566.1	10.82	8.07
	(Regenerator Other Part)	(583.2)	(11.14)	(8.31)
	Sub Total	2,577.7	49.25	36.74
16	Unknown	–77.2	–1.47	–1.10
	Total Heat Output	7,016.8	134.06	100.00

Figure 5.5.9 Heat Balance Chart



8) Evaluation of heat balance chart

① Reference table of heat balance

Table 5.5.17 gives the reference table of heat balance showing the comparison between this plant and similar plant in Japan:

Table 5.5.17 Reference Table of Heat Balance

Item	Unit	Factory			
		STIND	A	B	C
Furnace Type		End Port	End Port	End Port	Side Port
Heat loss from Wall	%	60.4	24.7	18.9	25.7
Exhaust gas loss	%	34.0	29.0	25.0	18.7
O_2 content at Top of regererator	%	2.5	0.8～0.7	5.6～6.4	3.2
Cullet	%	15	54.1	70.4	55
Fuel Consumption	Mcal/t	2,044	1,105	1,042	1,114
Heat efficiency	%	23.4	34.1	35.3	39.5
Load ft²/t		8.4	6.1	5.3	8.7
t/m²		1.3	1.8	2.0	1.2

② Heat loss from furnace wall

The furnace bottom of this plant is provided with heat insulation, but the crown and furnace wall are not heat insulated. The average heat release was 5,500 kcal/($m^2 \cdot h$); this value is as high three times that of the recent Japanese furnace registering 1,200 to 1,500 kcal/($m^2 \cdot h$). This value can be reduced to about 3,200 kcal/($m^2 \cdot h$) if provided with heat insulation recommended in (c).

Cooling air was used also in the breast wall of the melter. It does not raise any problem to hardware even if stopped; it is rarely used in recent furnaces. Stopping the cooling air will contribute to energy conservation.

③ Exhaust gas loss

The checker volume (CV) is 63.44 m^3, and CV/MA ratio (m^3/m^2) is 1.32. It should be at least 2 to 3, which is the value common to recent furnaces. Though the heat transfer area per unit checker volume is 13.4 (m^2/m^3), it can be improved to 19.13 (m^2/m^3) merely by changing conventional setting of checker bricks to the open basket method. This will cause heat transfer area to be increased from 850 m^2 to 1214 m^2.
When the furnace is to be repaired, it is recommended to modify the regenerator according to item (f).

④ Energy unit consumption rate

The average melting unit heat consumption rate at automatic bottle making plants in Japan is about 110 to 120 $\times 10^4$ kcal/t, and is even 100 $\times 10^4$ kcal/t or less at some of the advanced plants. The energy unit consumption of this plant amounting to 204 $\times 10^4$ kcal/t corresponds to the value 15 years ago in Japan, and is considered to be extremely poor. The greatest reason for this poor record is excessive heat release from the furnace wall, in addition to the low load factor. If the heat insulation of item (c) is provided, reduction of heat release of about 90.3 $\times 10^4$ kcal/h will be possible. Energy unit consumption will be improved to about 151 $\times 10^4$ kcal/t. According to the record in Japan, it is possible to save the fuel corresponding to 1.5 times the heat release.

Fuel saved by reduced heat release

$90.3 \times 10^4 \times 0.5 \times$ $= 135.4 \times 10^4$ kcal/h

Expected energy unit consumption

$(523.1 - 135.4) / 2.560$ $= 151.4 \times 10^4$ kcal/t

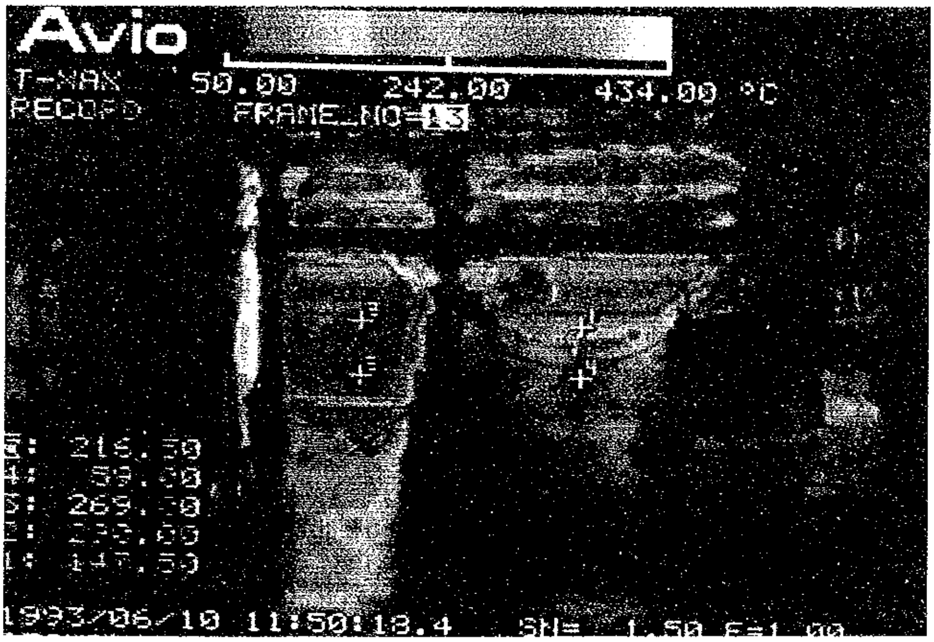
b) Improvement of air ratio and prevention of cooled air suction

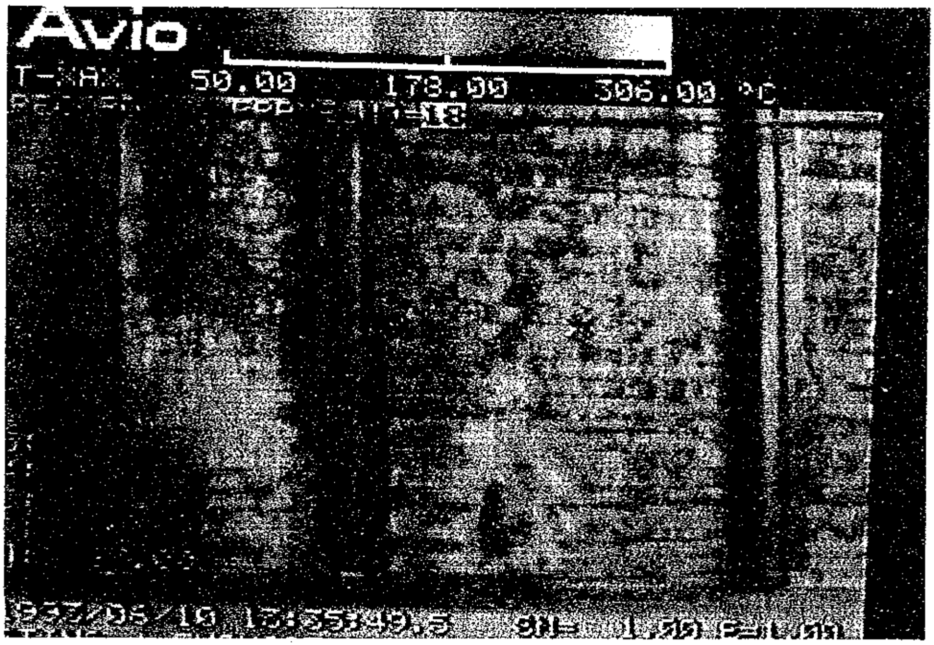
1) Improvement of air ratio

The checker brick of the regenerator on the right of the plant is clogged, as will be clear from the Thermo-Video Picture shown in Figure 5.5.10. The furnace pressure tends to increase during the combustion on the left, resulting in insufficient suction of combustion air. At present, the clogging is not much advanced, and the required amount of air is provided. Forced ventilation will be required if the clogging gets more serious. Furthermore, the furnace pressure is not controlled automatically, the furnace pressure is reduced during the combustion on the right, and the amount of air is excessive, as will be clear from the oxygen concentration on the regenerator top on the left.

Replacement of the checker brick layout requires cost and time, so immediately implementation does not appear to be possible. However, the air ratio can be improved to some extent by automatic control of the furnace pressure. If the oxygen concentration in the exhaust gas can be reduced from 4 to 2 percent, the energy unit consumption rate can be reduced by 5×10^4 kcal/t according to the experience in Japan. Proper maintenance of the furnace pressure will prevent cold air from entering the furnace and will contribute to energy conservation.

Figure 5.5.10 Thermo-Video Picture of Regenerator





2) Closing of the opening

The melter wall is provided with about a 150 mm ϕ opening to measure the temperature inside the furnace, and the heat of about 26,000 kcal/h was observed to be released. This value represents only the heat release by radiation and gas loss by flame release, so the value will be increased by taking into account the loss due to entry of cold air into the furnace at the time of fuel replacement.

To measure the temperature inside the furnace, it is necessary to combine the thermometer with the furnace by the hood provided with water cooled jacket, so that there will be no opening. In order to protect the lens against fume entering the hood, it is necessary to supply a small amount of dry air constantly for purging.

3) Burner improvement

The high pressure gas burner is installed at the position of the oil burner. It is designed in such a structure that 10 percent of the air required for combustion is sucked by the burner. Furthermore, much air is also sucked from the burner tile. Since the high pressure burner is used on the under-port, it seems that air is sucked in order to prevent the flame from becoming long. However, the reduction of the gas pressure will reduce the flame length, hence the amount of sucked air. Energy of about 263×10^3 kcal/t can be saved if 870 Nm^3/h of air being sucked from the burner can be changed into the heated air leading from the regenerator.

It should be pointed out in passing that, the flame brilliance is lower in gas combustion than in oil combustion. So, as described in the guideline, it is recommended to change the design at the time of the next repair and maintenance work so that the port structure will be modified and the brighter flame will be ensured by combining the lean oxygen combustion and secondary combustion.

c) Heat insulation of the furnace and regenerator

This furnace is provided with almost no heat insulation except at the bottom. Basically, it is necessary to improve the brick quality at the time of the next repair and maintenance work and to redesign the furnace into a type featuring energy conservation.

With the current design, many positions of the upper structure can be provided with heat insulation. Much heat release is observed at the melter crown, regenerator crown and port crown. These positions can be provided with heat insulation without any problem, and the work can be done by the current employees with comparatively ease, using the locally available materials; these places have high economical effects. Especially the regenerator crown is provided with bricks having different lengths, designed in fin forms; this has resulted in increased heat release. Immediate action must be taken to prevent it.

The following describes the heat insulation method and expected effects at various positions:

1) Calculation of heat insulation

Table 5.5.18 illustrates the specification of the refractory to be taken into account in the calculation of heat insulation:

Table 5.5.18 Specification of Refractory

Brick	Heat conductivity kcal/ (m · h · °C)	Maximum operating temperature °C	Size mm
Silica brick	1.5	1,600	
Basic brick	2.1	1,500	
Chamotte brick	1.0	1,300	65 × 125 × 250
Rock wool	0.07	600	40 × 1,000 × 1,000

① Melter crown

Current condition
Brick : silica brick, 400 mm thick
Internal temperature : 1,500 °C
External temperature : 356 °C
Heat radiation : 9,500 kcal /(m^2 · h)

Table 5.5.19 shows the heat insulation effect for each insulating material and the results of calculating the temperature at the boundary between new and old bricks.

Table 5.5.19 Insulating Effect of Melter Crown

Insulating Material	Thickness mm	Heat Conductivity kcal/(m · h · ℃)	Brick Boundary Temperature ℃	Surface Temperature ℃	Heat Radiation kcal/(m^2 · h)
Fire Brick	125	1.0	618	210	3,300
Fire Brick	65	1.0	473	220	3,900

② Regenerator crown

Current condition

Brick : basic brick,300 mm thick

Internal temperature : 1,200 °C

External temperature : 500 °C

Heat radiation : 19,500 kcal/ ($m^2 \cdot h$)

Fin section

External temperature : 380 °C

Heat radiation : 10,800 kcal/ ($m^2 \cdot h$)

Table 5.5.20 shows the heat insulation effect for each insulating material and the results of calculating the temperature at the boundary between new and old bricks.

Table 5.5.20 Insulation Effect of Regenerator Crown

Insulating Material	Thickness mm	Heat Conductivity kcal/(m·h·℃)	Brick Boundary Temperature ℃	Surface Temperature ℃	Heat Radiation kcal/(m²·h)
Fire Brick	125	1.0	680	220	3,700
Fire Brick +	65	1.0	1,000	130	1,400
Rock Wool	40	0.07	910		

③ Port crown

Current condition

Brick : basic brick, 300 mm thick

Internal temperature : 1,250 °C

External temperature : 495 °C

Heat radiation : 19,100 kcal/ ($m^2 \cdot h$)

Table 5.5.21 shows the heat insulation effect for each insulating material and the results of calculating the temperature at the boundary between new and old bricks.

Table 5.5.21 Insulation Effect of Port Crown

Insulating Material	Thickness mm	Heat Conductivity kcal/(m·h·℃)	Brick Boundary Temperature ℃	Surface Temperature ℃	Heat Radiation kcal/(m²·h)
Fire Brick	65	1.0	543	245	4,600
Fire Brick	125	1.0	680	220	3,700

④ Melter breast wall

Current condition
Brick : silica brick, 500mm thick
Internal temperature : 1,500 °C
External temperature : 262 °C
Heat radiation : 4,700 kcal (m^2 · h)

Table 5.5.22 shows the heat insulation effect for each insulating material and the results of calculating the temperature at the boundary between new and old bricks.

Table 5.5.22 Insulation Effect of Melter Breast Wall

Insulating Material	Thickness mm	Heat Conductivity kcal/(m·h·℃)	Brick Boundary Temperature ℃	Surface Temperature ℃	Heat Radiation kcal/(m²·h)
Rock Wool	40	0.07	1,000	143	1,500
Fire Brick	125	1.0	550	200	2,800

Table 5.5.22 shows that the rock wool may not be used since the boundary temperature exceeds the maximum operating temperature.

2) Recommended heat insulation method for each position and prediction of economic effect

① Preconditions for calculation

Insulating material cost

Refractory	65 × 125 × 250	15.9 Lv/pce
	65 mm thick	510 Lv/m^2
	125 mm thick	990 Lv/m^2
Rock wool	40 × 1,000 × 1,000	56 Lv/m^2
Natural gas	7,941 kcal/m^3, 2.04 Lv/m^3, 0.257 Lv/1000 kcal	

② Melter Crown

Of the crown surface area of 57.03 m^2, the area of 51.83 m^3 is heat-insulated by the 65 mm thick refractories, except for the expansion areas (200 mm on both sides and 400 at center with a total of 800).

Brick cost	510 × 51.83 = 26,433	[Lv]
Reduced heat release	(9,500 – 3,900) × 51.83 = 290,200	[kcal/h]
Profit	290.2 × 0.257 × 24 = 1,790	[Lv/d]
Cost recovery	26,433 ÷ 1,790 = 14.8	[d]

Construction method

Lay the dry silica mortar on the current crown silica brick to a thickness of 5 to 8 mm; then lay the refractories on them from both sides without using mortar. For the expansion area (straight joint), heat insulation should not be provided on 200 mm on one side from the joint.

③ Regeneration Crown

Heat insulation should be provided, using 130 mm thick (65 mm in two steps) refractories so that the fin section of the ceiling having a surface area of 20.52 m^2 is filled.

Brick cost	20.52 × 1,020 = 20,930	[Lv]
Reduced heat release	(19,500 – 3,600) × 20.52 = 326,300	[kcal/h]
Reduced heat release at fin section	147,400	
Profit	473.7 × 0.257 × 24 = 2,922	[Lv/d]
Cost recovery	20,930 ÷ 2,992 = 7.0	[d]

Construction method

Lay the 65 mm thick refractories all over the crown top in two steps using mortar.

④ Port Crown

The crown having a surface area of 9.05 m² should be provided with heat insulation, using 125 mm thick refractories.

Brick cost	$990 \times 9.05 = 8{,}959.5$	[Lv]
Reduced heat release	$(19{,}100 - 3{,}700) \times 9.05 = 139{,}370$	[kcal/h]
Profit	$139.37 \times 0.257 \times 24 = 859.6$	[Lv/d]
Cost recovery	$8{,}959.5 \div 859.6 = 10.4$	[d]

Construction method

Lay the 65 mm thick refractories all over the crown top in two steps using mortar.

⑤ Total of reduced heat releases by heat insulation

Table 5.5.23 illustrates the total of the insulation effects discussed above. The cost for improved heat insulation can be recovered in a short time.

Table 5.5.23 Summary of Insulation Effect

Position	Decrease of Heat Loss kcal/h	Period of Return days
Melter Crown	290,200	14.8
Regenerator Crown	473,700	7.0
Port Crown	139,370	10.4
Total	903,270	

d) Improvement of liquid glass level control accuracy

The fixed type level meter of this plant is installed at the forehearth entrance. The liquid glass level is controlled in such a way that the batch charger stops when the platinum proof has contacted the liquid glass surface, and is operated when the proof has removed from the surface. No record is available on the variation of the liquid glass level. It can be estimated from the on-off time of the charger that there is a variation of about 1.3 mm. According to the experiment conducted in Japan, the variation of about 1 mm corresponds to the variation of 1 to 1.5 % of the gob weight. This shows that the variation of the weight in this plant will be 10 to 16 g or more.

The product weight tends to incline toward the heavier side. If the variation is reduced to decrease the average value of the weights, a greater number of bottles can be obtained from the glass materials having the same weight. It is recommended to install a level meter which allows continuous measurement of the level, and to adopt the method of controlling the charger operations by means of the stroke or speed, thereby ensuring continuous loading of the materials. If possible, use of PID control method is recommended.

e) Improvement of melting rate

The designed melting capacity is 70 tons per day, and the melting capacity on the day of our inspection was 61.4 tons per day. The melting rate --- designed melting rate of 1.45 t/m^2 and actual value on that date of 1.27 t/m^2 --- was almost half the melting rate of 2.5 to 3.0 t/m^2 of the recent furnaces. Though it may differ according to the market situation, replacement by a large sized forming machine will increase the melting capacity and improve the energy unit consumption rate.

According to the achievement with the equivalent furnaces in Japan, the increase of the melting capacity by 30 percent to 80 tons per day will improve the energy unit consumption rate by 10 percent even though it depends on the size, structure and heat insulation conditions.

f) Improvement of the regenerator

Improvement of the heat recovery efficiency of the regenerator is to increase the amount of recovered heat and to increase the combustion efficiency due to air temperature rise, making a great contribution to energy conservation.

The heat recovery efficiency of the regenerator can be improved according to the following methods:

1) Expansion of the heat exchange area

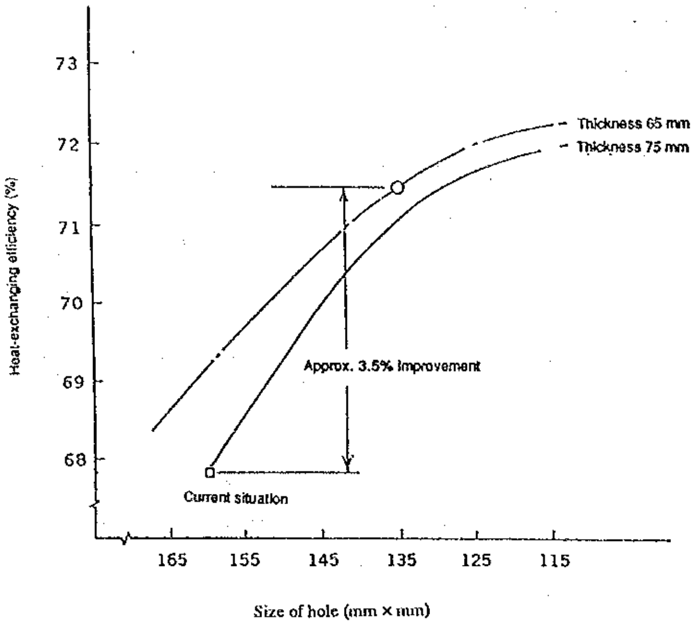
Increase of the checker volume
Making the check brick thinner
Reducing the flue size

2) Improvement of overall heat transfer efficiency

Reducing the flue size (The gas velocity is increased, resulting in improved heat transfer efficiency with bricks).

Figure 5.5.11 illustrates the relationship between the checker flue size, brick thickness and heat recovery efficiency.

Figure 5.5.11 Relation between Checker Size and Efficiency



Increase in the checker volume is not easy, but the heat recovery efficiency can be increased by exchange of the bricks even if the checker volume is unchanged. Cases are reported where change of the flue sizes from 160 mm to 135 mm and brick thickness from 75 to 65 mm improved the energy unit consumption rate by about 3.5 percent in terms of calculated values and by 3 to 4 × 10^4 kcal/t in terms of actual values, as shown in Figure 5.5.11, and reduced brick cost by 10 percent.

It is recommended to change at least the laying of the checker bricks at the time of next furnace repair and maintenance.

g) Increase in the use of cullet

1) Effect of increased use of cullet

To recycle the cullet (waste glass) is to reduce the consumption of the raw material, contributing to resources conservation. Furthermore, the cullet can be melted much more easily than the raw materials, as described in the guideline. So it will make a significant contribution to reduction of melting energy.

Under the guidance of the Ministry of International Trade and Industry, the Japanese glass bottle industry set up a target of increasing the rate of using the cullet to 60 percent, and has been making efforts to achieve the target. According to the record of the cullet use rate in Japan, the rate of 41 percent in 1983 increased to 56 percent in 1992.

The cullet use rate in this plant is 15 percent. If it can be increased to 45 percent, it will be possible to expect the improvement of the energy unit consumption rate amounting to 7.8×10 kcal/t-glass.

Increase in the amount of using the cullet containing a great deal of impurities will deteriorate the bottle quality, and will also damage the furnace. Thus, improvement of the cullet quality is one of the major control items.

For information, Table 5.5.24 illustrates the cullet quality standard in Japan.

Table 5.5.24 Quality Standard of Cullet in Japan

Classification	Foreign Matter	Standard %
Metal	Iron	0.0005
	Aluminium	0.0005
	Others (Copper、Lead、Brass、etc.)	0.002
Stone	Chromite and other mineral Ores	None
	Refractories	None
	Others (Concrete、Soil、Red Brick)	0.005
Ceramics	Ceramics、China	0.002
Non-Soda Lime Glass	Crystallized Glass	0.002
	Others (Crystal Glass 、Optical Glass、Borosilicate Glass、Milk Glass、etc.)	0.3
Plastics	Plastics、Wooden Fragments、etc.	0.01
	Plastic-coated Glass Bottle	0.05

Standard of Japan Glass Bottle Association

2) Cullet quality inspection procedure

About 500 kg of cullet to be inspected is picked up as the sample, and the total weight is measured. Spread the cullet on cardboard or the plywood laid out on the yard so that the thickness will be 10 mm or less. Then pick up all visually observable foreign substances from the sample. Repeat this work until all samples have been inspected. This visual inspection should be carried out under the light of 150 luxes or more.

A great variety of foreign substances picked up from the sample should be classified according to the properties as shown in Figure 5.5.24.

If foreign substances contain more than two kinds of components, they should be decomposed into single components whenever possible. 5 percent of Alumi-label should be classified as aluminum.

The weight of the foreign substance is measured by the scale capable of weighing down to 0.2 g, and the concentration of the foreign substance is obtained.

h) Yield improvement

The production journal (Table 5.5.25) of this plant reveals that the production record has achieved the production target. However, the production yield in relation to the melting capacity and gob drop rate was 71 percent (Table 5.5.26). This value must be increased to 85 percent or more.

The production yield should be represented in relation to melting capacity and gob drop rate, as well as in relation to target. The daily production yield should be shown in graphic forms in order to arouse interests of all employees and to have them cooperate in the production efficiency improvement activities.

Table 5.5.25 Stind Production Data

Plant	Machine	Unit	Today			Cummulative Sum		
			Plan	Actual	A/P %	Plan	Actual	A/P %
#1	#4	1,000 pcs	67.7	61.2	90.4	526.5	517.7	98.3
#2	#3	1,000 pcs	37.8	40.9	108.2	295.7	295.9	100.1
#2	#4	1,000 pcs	33.0	24.7	74.8	280.9	292.7	104.2
#2	Total	1,000 pcs	70.8	65.6	92.7	578.6	588.6	101.7

Table 5.5.26 #2 Plant Production

Machine	Name	Speed		OutputYield	
		pcs/min	1,000 pcs/d	1,000 pcs/d	%
#3	UZO	34.0	49.0	40.9	83.5
#4	SCHWEPS	29.5	42.5	24.7	58.1
Total			91.4	65.6	71.7

(2) Annealing Lehr

Average temperatures at the outlet of the bottling machine No.3 and Lehr inlet were 590 and 505 °C, respectively.

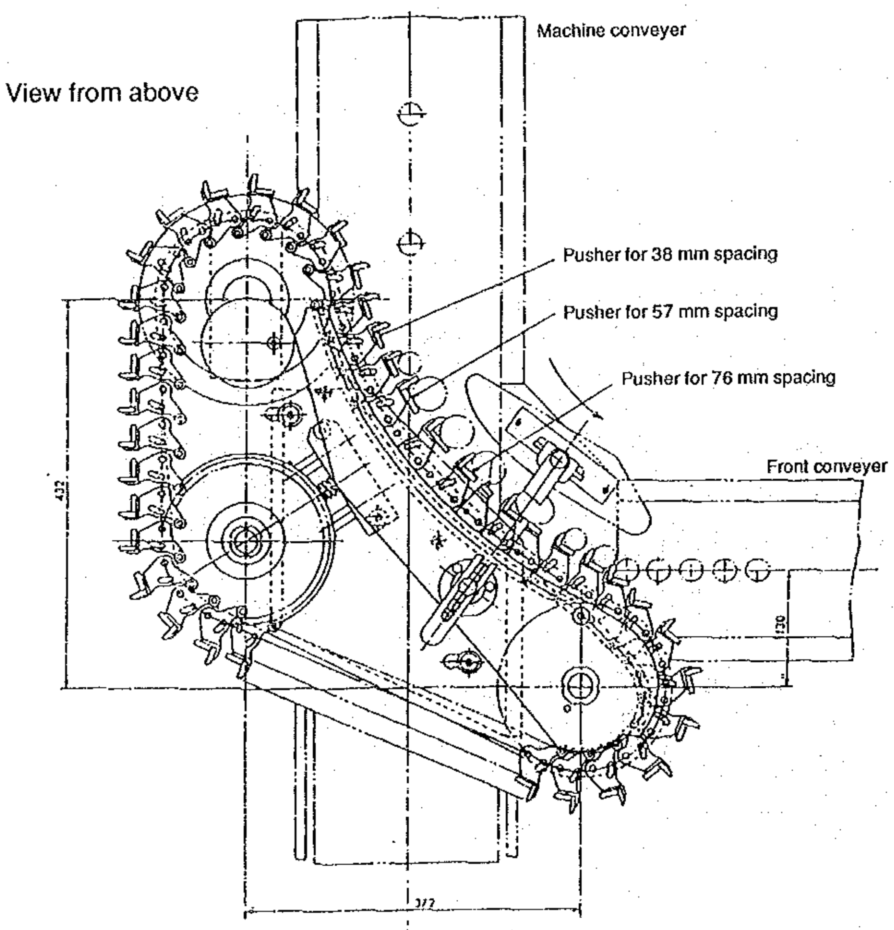
The power of this annealing Lehr heater was 59 kW on average. The energy unit consumption rate is calculated as follows:

$$59 \text{ kWh/h} \times 860 \text{ kcal/kWh} \div 1{,}020 \text{ kg/h} = 49.7 \text{ kcal/kg-glass}$$

This value is not inferior to the Japanese average value of 40 kcal/kg-glass. Power can be furthermore saved by preventing heat release on the conveyer and by increasing the temperature at the Lehr inlet.

The ware transfer was not installed at the Lehr inlet, and bottles were observed to be contacting each other when entering the Lehr. This caused the bottles to be turned over at the stacker and to decrease the quality level. It is recommended to install the ware transfer which allows transfer of the bottles at the specified intervals without contacting with each other. Figure 5.5.12 illustrates an example of the ware transfer.

Figure 5.5.12 A Kind of Ware Transfer



(3) Product chemical composition and calculated physical properties

As shown in Table 5.5.27, the glass composition of this plant exhibits greater amount of Fe_2O_3, R_2O (Na_2O), and smaller amount of RO (CaO,MgO), compared with those of the flint bottles produced at the Japanese representative bottling plants (A, B, C and D), and the melting temperature (Log 2) is 30 °C higher. Meltability is not good in spite of great amount of the Na_2O, because of the small amount of the CaO which contributes to viscosity reduction at a high temperature.
Tables 5.5.27 (at the right end) and 5.5.28 show the proposal of batch composition to improve solubility. According to this proposal, MgO increases slightly. Much MgO is contained in the present batch, and there remains a danger of flaking. Sufficient care should be taken to prevent it.

Reduction material cost can be expected by this proposed batch composition. According to the Japanese experience, reduction of melting temperature by 10 °C improves the energy unit consumption rate by 2.7×10^4 kcal/t-glass. It is possible to improve the energy unit consumption rate by 3.8×10^4 kcal/t-glass by reducing the melting temperature by 14 °C through change of the batch composition.

The batch composition should not be changed all at once; it should be gradually changed ten times separately at intervals of four days or more.

Table 5.5.27 Properties of Products

Item	Unit	STIND	A	B	C	D	Proposal
SiO_2	%	73.20	72.60	72.20	72.30	72.40	72.19
Al_2O_3	%	1.81	1.72	1.96	1.62	2.04	2.06
Fe_2O_3	%	0.104	0.034	0.041	0.040	0.047	0.115
CaO	%	7.02	11.22	11.26	11.11	10.98	7.53
MgO	%	3.71	0.11	0.23	0.23	0.20	4.00
Na_2O	%	14.15	13.10	12.50	13.20	12.50	14.10
K_2O	%		0.67	1.22	1.01	1.26	
Total	%	100.00	99.45	99.41	99.51	99.43	100.00
Log 2	℃	1,493.6	1,451.9	1,458.4	1,444.4	1,464.8	1,479.8
Log 3		1,215.8	1,191.9	1,197.5	1,186.0	1,201.6	1,209.9
Liquidas	℃	966.2	1,031.6	1,044.2	1,023.4	1,038.7	985.1
Softening P.	℃	727.3	733.4	737.1	730.0	732.2	729.0
Coeff. of Expansion	10^{-7}	84.9	87.4	87.1	88.7	86.8	85.6
Cooling Time		107.6	98.3	97.5	99.0	98.1	104.3
Sp.Gravity	g/cm³	2.481	2.499	2.497	2.499	2.495	2.488

Note: A~D Example of Japanese glass bottle manufacturing factories

Table 5.5.28 Recommendable Batch Composition

Material	Unit	Sand	Feldspar	Dolomite	Soda Ash	Ca－phosphte
Present	kg	456	76	134	160	9
Proposal	kg	440	90	145	158	9

(4) Economizer

The economizer was installed to make hot water for room heating in winter by the waste heat of the glass melting furnace. However, when the induced draft fan is operated to pass gas through it, the melting furnace pressure is changed making it difficult to operate the furnace. So it has been left unused so far. At present, there is a concern about the stable supply of steam and hot water provided by the heat supplier, and the plant wants to use this equipment for effective use of energy.

a) Study of equipment capacity

1) Economizer design specifications

Table 5.5.29 illustrates the design specifications.

Table 5.5.29 Specification of Economizer

Item	Unit	Specification			
Heat Transfer Area	m^2	90			
Gas Temperature	℃	Inlet	450	Outlet	250
Gas Flow	m^3/s	5.55			
Water Temperture	℃	Inlet	80	Outlet	140
Water Pressure	MPa	0.7			
Water Flow	kg/s	Normal	4.16	Maximum	5.2
Sectional Area of Water Path	m^2	0.01			
Sectional Area of Gas Path	m^2	1.2			
Power Demand	kw	25			

2) Heat demand

The following shows heat demands for four months (from January to April) in recent winter:

Steam	1,474,697 Mcal
Hot water	1,478,132 Mcal
Total	2,952,829 Mcal
Demand per hour	2,952,829/ (120 × 24) = 1,025 Mcal/h

3) Heat balance according to specification

Heat by gas

Gas flow : 5.55 m^3/s × 3.600 s/h = 19,980 m^3/h
19,980 m^3/h × 273/ (273 + 450) = 7,544 Nm^3/h
Specific heat : 0.33 kcal/ (Nm^3 · °C)
Heat : 7,544 Nm^3/h × 0.33 kcal/ (Nm^3 · °C) × (450 – 250) = 498 Mcal/h

Heat absorbed by water

Water flow : 4.16 kg/s × 3.600s/h = 14,976 kg/h
Heat : 14,976 kg/h × (140 – 80) kcal/kg = 899 Mcal/h

This shows that heat is insufficient on the gas side according to the current design specifications.

4) Gas flow

Tube element gas passage sectional area :
1.614 × (0.914 – 0.006 × 2 – 0.32 × 11) = 0.888 m^2
Tube element gas temperature : 300 °C
Tube element gas velocity : 7.544 Nm^3/h/3.600 × (273+300) /273/0.888 = 5 m/s

This value is a proper tube element gas velocity. Gas flow cannot be increased any more.

5) Heat transfer coefficient outside the tube

Heat conductivity is calculated according to the Schmidt equation (5.15):

$$h_o = 0.45 \times (\lambda/d_o) \times Re^{0.625} \times Pr^{0.33} \quad (5.15)$$

where

h_o : Heat transfer coefficient outside the tube — kcal/ ($m^2 \cdot h \cdot$ °C)
λ : Gas heat conductivity — kcal/ ($m \cdot h \cdot$ °C)
d_o : Tube outer diameter — $d_o = 0.032$ m
Re : Reynolds number

$$Re = v \cdot d_o/\nu \quad \cdots\cdots (5.16)$$

Pr : Prandtl number
v : Gas velocity between tubes — v = 5 m/s
ν : Gas kinematic viscosity coefficient — m^2/s

Table 5.5.30 illustrates the properties of exhaust gas at the gas temperature (300 °C) of the tube group.

C_g : Gas specific heat — kcal/ ($Nm^3 \cdot$ °C)
γ_g : Gas density — kg/m^3

Table 5.5.30 Properties of Exhaust Gas

Composition	%	λ	$\nu \times 10^{-4}$	Pr	C_g	γ_g
CO^2	6.68	0.0336	0.277	0.69	0.450	0.928
H_2O	11.20	0.0336	0.519	1.01	0.352	0.379
N_2	72.77	0.0376	0.479	0.69	0.313	0.588
O_2	9.35	0.0396	0.479	0.71	0.325	0.670
Total	100.00	0.0371	0.470	0.73	0.328	0.595

From equation (5.16)

$$Re = v \cdot d_o/\nu = 5 \times 0.032/\ (0.470 \times 10^{-4}) = 3,404$$

From equation (5.15)

$$h_o = 0.45 \times \lambda/d_o \times Re^{0.625} \times Pr^{0.33}$$
$$= 0.45 \times (0.0371/0.032) \times 3,404^{0.625} \times 0.73^{0.33}$$
$$= 75.7 \quad \text{kcal/ } (m^2 \cdot h \cdot {}^\circ C)$$

6) Overall heat transfer corfficient

Heat recovery can be obtained from equation (5.17).

$$Q = K \cdot A \cdot \Delta T_{lm} \quad \cdots\cdots \quad (5.17)$$

where

Q	:	Heat recovery	kcal/h
K	:	Coefficient of overall heat transfer	kcal/ (m² · h · °C)
A	:	Heat transfer area	$A = 90$ m²
ΔT_{lm}	:	Logarithmic average temperature difference	°C

Coefficient of overall heat transfer K can be obtained from equation (5.18).

$$\frac{1}{K} = \frac{1}{h_i} \times \frac{d_o}{d_i} + \frac{1}{h_f} + \frac{1}{h_o} \quad (5.18)$$

where

h_i	:	Heat transfer coefficient of tube inside	$h_i = 500$ kcal/ (m² · h · °C)
d_i	:	Tube inner diameter	$d_i = 0.025$ m
$1/h_f$	:	Tube outside contamination factor	$1/h_f = 0.005$ (m² · h · °C)/kcal

$$\frac{1}{K} = \frac{1}{500} \times \frac{32}{25} + 0.0051 + \frac{1}{75.3}$$

$K = 48.1$ kcal/ (m² · h · °C)

Logarithmic average temperature difference can be obtained from equation (5.19).

$$\Delta T_{lm} = \frac{(tg_1 - tw_2) - (tg_2 - tw_1)}{\ln \dfrac{(tg_1 - tw_2)}{(tg_2 - tw_1)}} \quad (5.19)$$

where

tg_1	:	Gas inlet temperature	$tg_1 = 450$ °C
tg_2	:	Gas outlet temperature	°C
tw_1	:	Water inlet temperature	$tw_1 = 80$ °C
tw_2	:	Water outlet temperature	°C

The following shows the heat recovery obtained from equation (5.17) and the tg_2 and tw_2 obtained so that gas/water heat balance will agree with each other:

tg_2 : 155 °C
tw_2 : 129°C
Q : 734 Mcal/h

This shows that one economizer can supply 72 % of the heat demand.

Since the amount of exhaust gas at the time of our inspection was 12,100 Nm³/h, about 62 % will be passed through the economizer.

7) Pressure loss on gas side

The pressure loss on gas side is obtained from Briggs equation (5.20):

$$\Delta P_l = n \cdot f \cdot \frac{G_S^2}{2 \cdot g \cdot \gamma_g} \qquad (5.20)$$

where

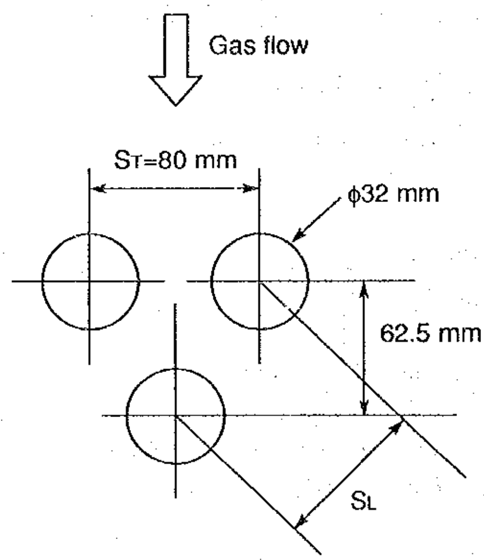
n :	Number of tube rows	$n = 28 \times 4 = 112$
f :	Resistance coefficient	
G_s:	Gas weight flow	kg/ (m² · s)
g :	Gravity acceleration	$g = 9.8$ m/s²

Resistance coefficient f is obtained from equation (5.21).

$$f = 37.86 \times Re^{-0.316} \times (S_T/d_o)^{-0.927} \times (S_T/S_L)^{0.515} \qquad (5.21)$$

where S_T and S_L denote tube pitches (m). Figure 5.5.13 illustrates the heat transfer tube layout. Thus, S_T and S_L are given as follows:

Figure 5.5.13 Heat Transfer Tube of Economizer



$S_T = 0.080$ m

$S_L = (40^2 + 62.5^2)^{1/2} = 74.2$ mm $= 0.0742$ m

Furthermore;

$G_s = v \times \gamma_g = 5$ m/s $\times 0.595$ kg/m³ $= 2.975$ kg/ (m² · s)

Thus, from equation (5.21):

$f = 37.86 \times 3{,}404^{-0.316} \times (80/32)^{0.927} \times (80/74.2)^{0.515} = 1.29$

From equation (5.20):

$$\Delta P_1 = 112 \times 1.29 \frac{2.975^2}{2 \times 9.8 \times 0.595} = 109 kg/m^2$$

The pressure loss due to rectangular curve in the gas passage is obtained from equation (5.22).

$$\Delta P_2 = K_b(v^2/2g) \cdot N \quad \cdots\cdots \quad (5.22)$$

where

K_b :	Constant	$K_b = 1.2$
N :	Number of 90-degree bends	$N = 2 \times 3 + 1 = 7$

Thus,

$\Delta P_2 = 1.2 \times (5^2/(2 \times 9.8)) \times 7 = 8\ kg/m^2$

Furthermore, assuming that the pressure loss in the flue and damper is 43 kg/m^2, the total pressure loss will be:

160 kg/m^2 = 160 mmAq

8) Induced draft fan

Table 5.5.31 illustrates the specifications of the existing induced draft fan.

Table 5.5.31 Specification of Induced Draft Fan

Item	Unit	Specification
Flow(Q)	m^3/h	52,000
	$m^3/min.$	867
Total Head (P_T)	mmAq	320
Efficiencyr (η)	%	80
Motor	kw	75
Rotation Nunber	rpm	1,470

Both the gas which passes through the economizer and that which does not are often induced together. The duct layout of this plant is so designed to indnce only the gas which passes through the economizer.

Assuming that the margin rate of the fan is 1.1 and gas temperature is 200 °C, the gas flow rate can be calculated as follows:

$$Q' = 1.1 \times 7{,}544 \times (273 + 200)/273$$
$$= 14{,}400\ m^3/h = 240\ m^3/min.$$

Thus, it is recommended to choose the fan having the flow of 250 m^3/min. and the total pressure of 230 mmAq.

Assuming that the efficiency is 70 % and the margin rate of the motor is 1.2, the motor output is obtained as shown in the following equation.

$$P = 1.2 \times \frac{250 \times 230}{6{,}120 \times 0.7} = 16(kW)$$

The existing fan has an excessive capacity and power can be saved by reducing the size.

It should be pointed out in passing that, the gas must be discharged upward above the main duct connection inside the stack so that the fan exhaust gas will not flow back in the main duct.

9) Control

When the economizer is installed, and part of the gas is put in the stack, with the remaining gas being led into the economizer, pressure will change if the induced draft fan has been started and the exhaust gas temperature will change with the amount of heat recovery. Change of the stack draft will be caused by those changes, and the disturbance including this change will give an adverse effect.

However, top priority must be given to ensure that the operation of the main equipment will not be adversely affected when waste heat is recovered.

Thus, it is essential to install a damper which works to keep the glass melting furnace pressure constant by the output signal of the automatic controller.

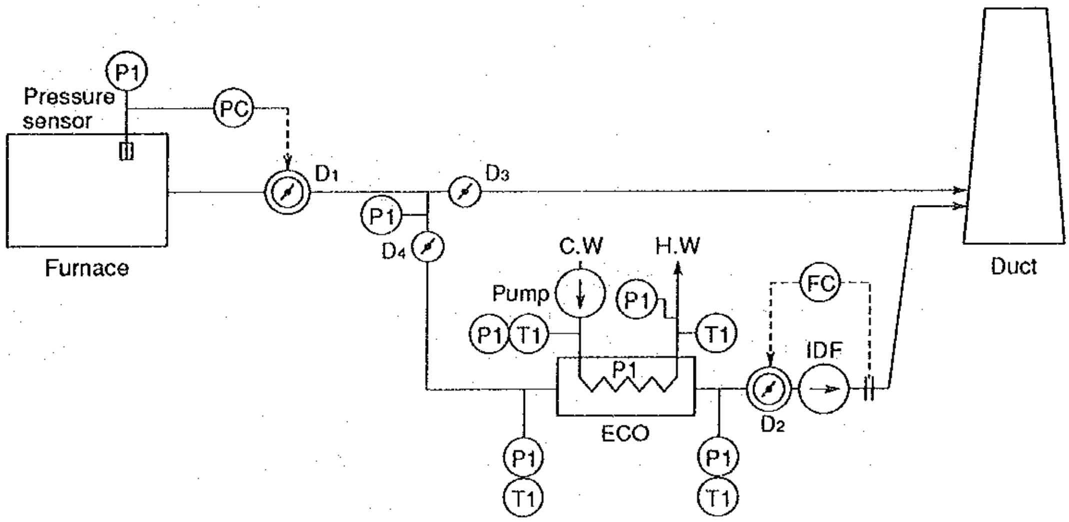
There are two methods available for the fluctuation in heat demand: the warm water temperature changing method and the warm water flow rate changing method. In case of this factory, however, heat demand can not be covered sufficiently by the waste heat.

Therefore, fluctuation in heat demand should be adjusted by heating warm water by steam outside the economizer system. Also, gas amount should be supplied at the specified rate, thereby stabilizing the operating conditions of the economizer.

It is also necessary to install the alarm device for water temperature and pressure to prevent the facilities to be damaged due to the decrease in water amount.

Figure 5.5.14 illustrates the gas flow system

Figure 5.5.14 Flowchart of Economizer



Note

(PC) : Furnace internal pressure controller

(FC) : Gas flow controller

D_1 : Furnace internal pressure control damper

D_2 : Gas flow control damper

D_3, D_4 : Manual damper

After fully opening the manual damper D_3 and D_4, start the induced draft fan, while gradually increase gas flow while observing the furnace pressure.

10) Facilities maintenance

The current facilities have been left for a long time and gathered rust. Pickle the inside and blush the outside by air; then conduct the airtight test. Make sure that gas does not leak from the casing, and provide heat insulation.

The following shows some of the modifications to be made; Insert the rectifier plate in the position where gas takes a U-turn to reduce the pressure loss. Install a compressed air or steam blowing equipment so that the tube can be cleaned during the operation. Install a drainage pipe to prevent it from being frozen when not operating.

(5) Power receiving, distrbution, and electric equipment

a) Overview of electric receiving/distribution facilities

Figure 5.5.5 illustrates the one-line diagram. Electric power can be supplied from four 20 kV systems, but is normally supplied from one line. The plant has seven 1,000 kVA transformers (20 kV/380 V), and power is stepped down to 380 volts by transformers No. 2 and No. 3 of the receiving station for the plant No.1, and by transformers No. 4, No. 5 and No. 6 of the receiving station for the plant No. 3. 20 kV power is transmitted to the plant No. 2, and is stepped down to 380 volts by transformers No. 8 and No. 9 of the substation to be fed to the equipment. Transformers No.1 and No. 7 are not used. The major loads of the plant include motors of the blower, vacuum pump and compressor, as well as the electric heater for annealing after bottle formation.

b) Results of measurement

We measured the following eight positions of the electric system:

① Power received in the plant
② Power for the heater and fan for annealing Lehr of series No.1 in plant No.1
③ Power for the heater for annealing Lehr No. 3 of series No. 2 in plant No. 2
④ Vacuum pump in plant No. 1
⑤ Vacuum pump in plant No. 2
⑥ Forming machine cooling blower No. 3 in plant No. 2
⑦ Compressors (#5 & #6, #5 & #4)

Table 5.5.32 shows the results of measurement.

Table 5.5.32 Measurement Result of Power Consumption

Measurement items	Maximum power (kW)	Average power (kW)	Minimum power (kW)	Average power factor (%)	Time of measurement
Received power	1,750	1,500	1,280	91.1	6/10 12:00 - 6/11 9:00
#1 Plant					
Lehr Heater & Fan	170.1	116.9	29.9	99.6	6/10 12:14 - 15:28
Vacuum Pump	54.3	51.9	47.8	76.2	6/10 14:00 - 14:30
#2 Plant					
#3 Lehr Heater	69.4	59.0	42.6	100.0	6/8 12:13 - 15:02
Vacuum Pump	52.3	52.2	52.1	77.9	6/10 13:20 - 15:50
Machine Blower	35.7	35.4	35.1	86.2	6/10 15:30 - 15:40
Compressor #5	123.1	122.4	121.7	98.0	6/9 15:15 - 16:20
Compressor #6	111.5	110.4	110.1	95.1	6/9 15:15 - 16:20
Sub Total	234.5	232.8	231.8	96.6	6/9 15:15 - 16:20
Compressor #4	132.2	130.9	129.7	97.6	6/10 10:10 - 13:00
Compressor #5	131.3	130.1	129.0	97.8	6/10 10:10 - 13:00
Sub Total	263.1	261.0	258.7	97.7	6/10 10:10 - 13:00

	Flow	Pressure	Motor output
Vacuum Pump	1,750 m^3/h	730 mmHg	55 kW
For Machine Cooling Blower	50,000 m^3/h	440 mmHg	55 kW
Compressor #4, #5, #6	30 m^3/min	8 kg/cm^2	159 kW

Motor: voltage 380 V, Current 365 A, Output 200 kW

c) Study of the measurements

① Power received in the plant

During the measurement period, variation of the received power was from 1.3 MW to 1.8 MW and average power was 1.5 MW. Power factor was adjusted by the synchronous motor of the plant compressor, and received power factor was 91.1 % on average, which is very close to the power factor of 92% under agreement with the utilities.

For the maximum received power of 1.8 MW, the total capacity of seven operating transformers is 7,000 kVA, showing a low availability of the transformers. We could not measure all the transformer loads, but it is necessary to get a correct information on the hourly change of each transformer load to ensure effective operation of the transformers.

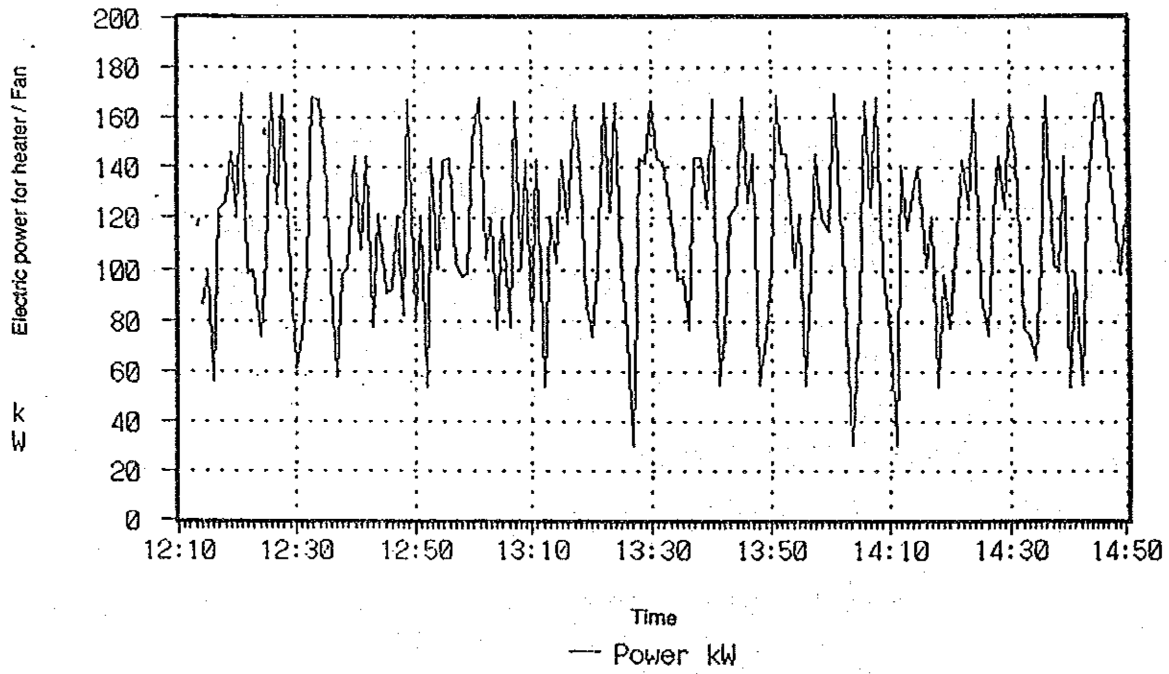
The substation has integrating instruments but no indicating instrument. So it is not possible to get a correct information on ever changing power, power factor, voltage and current at power receiving points. It is recommended to install an indicating instrument and to let the operators check the current operating conditions to see if they conform to the standard. It is also recommended to train them to take appropriate actions when any failure is detected.

② Power for the heater fan for annealing Lehr of series No.1 in plant No.1 (See Figure 5.5.15).

Since the temperature is on/off controlled, power variation is between 170 and 30 kW, but voltage fluctuation and imbalance between phases are not very great.

(voltage fluctuation 7.2 V(1.8 %), imbalance between phases 2.0 V (0.5 %))

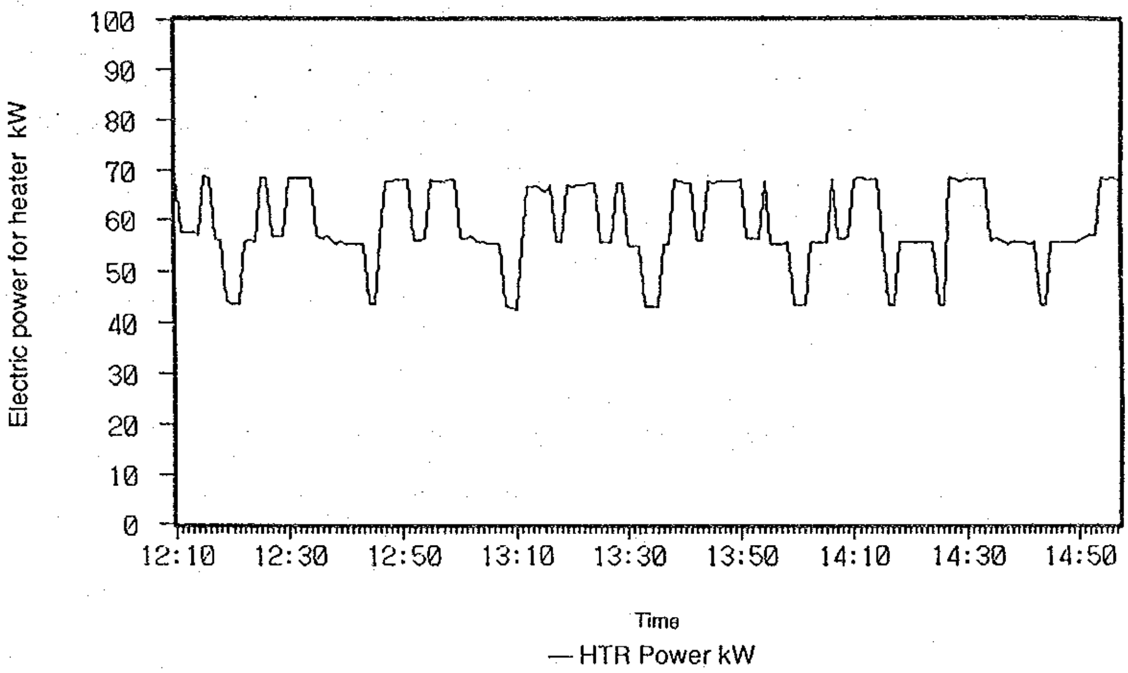
Figure 5.5.15 Power of Heater & Fan of #1 Annealing Lehr



③ Power for the heater for annealing Lehr No. 3 of series No. 2 in plant No. 2 (See Figure 5.5.16.)

We measured the heater power on one side of the series in plant No. 2. Power variation was between 43 and 69 kW, imbalance between phases was 26 volts (6.6 %) and current was 42 amperes (48 %), all of them showing large values. This is because three phases are formed by combination with the single phase heater, but the heater temperature control is done by the on-off control of the single phase heater for each zone.

Figure 5.5.16 Power of Heater of #3 Annealing Lehr



When taking single-phase load from each of the three-phase power source, availability of the power distribution facilities and substation will be reduced if the load on each phase is not uniform; then power loss will increase at heavy load phase. Furthermore, the voltage between phases will lose balance. Even if the imbalance is very slight, it will cause the motor to generate torque in the reverse direction, resulting in reduction in the total torque. Other similar adverse effect will occur, so sufficient care should be taken to avoid it.
However, according to the measurements at other positions, it seems that adverse effect of the imbalance is limited to the small range (for example, the voltage imbalance of the compressor is as small as 2.0 V (0.5 %)).

④ Vacuum pump

The average power is 52 kW in both the plants No.1 and No. 2, showing almost full load operating conditions for the motor rated output of 55 kW.

⑤ Forming machine cooling blower No. 3 in plant No. 2

For the rated blower output of 55 kW, power variation during the measurement period was 35 to 36 kW, the average power was 35 kW, and load operation rate was constant at 64 %. Because of the characteristics of the cooling blower, the cooling capacity is increased in summer, and is reduced in winter. At present the inlet damper is controlled to adjust air flow. It is necessary to select the motor having the optimum output from the cooling capacity required in summer, and to study the feasibility of using the speed control. It can be estimated in passing that the air flow at 64 % output is considered to be about 60 %, if the air flow is 100 % when damper is fully opened during the rated output. When the control is made by reducing the rotation without using the damper control, the motor output is estimated to be about 14 kW, resulting in reduction of 60 %.

⑥ Compressor

Two types of compressors (a total of eight compressors) are installed as shown in Talc 5.5.33.

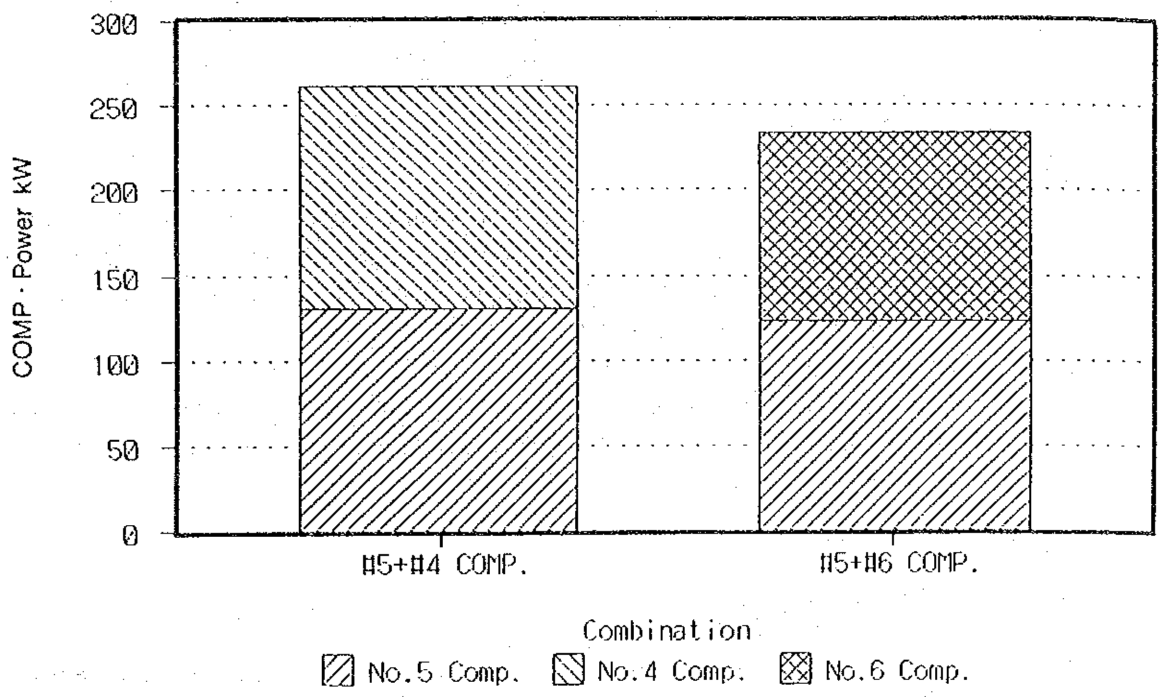
Table 5.5.33 Specifications of Compressors

No.		Motor Rating (KW)	Pressure Flow kg/cm²	m³/min
No. 1 ~No. 6	6	200KW	8	30
No. 7 ~No. 8	2	160KW	9	24

Two 200 kW compressors were operating during our survey. Air pressure sent from the compressors to the plants is 3.5 to 4 kg/cm², but it was reported that no control was used actually.

Measurement was carried out in two cases; when compressors No. 5 and No. 6. were operated and when No. 4 and No. 5 were operated. The average power was 233 kW in the former case and 261 kW in the latter case, as shown in Table 5.5.17. What is to be noted is that the output in the former case was 28 kW lower than that in the latter case, even when the compressors were operated under almost the same conditions. Power can be saved by selecting combinations of highly efficient compressors from six compressors.

Figure 5.5.17 Power of Compressor



For example, assume that there is one highly efficient compressor from six compressors (compressor No.6 in this case). If the highly efficient compressor is operated on the priority basis instead of each two units being operated uniformly, then the annual power conservation can be calculated as follows (where annual operation time is assumed as 8,000 hours):

$8,000 \times (1 - 1/3) \times 28 = 149,000$ kwh/y

Before putting this into practice, continue to measure the efficiency values for each compressor, and select combinations of compressors, with consideration given to hourly change of the efficiency.

The compressed air operating pressure for the forming machine in plant No. 1 was about 2.6 kg/cm^2, and that in plant No. 1 was about 1.2 kg/cm^2. This means that the current air pressure can be reduced. Power conservation can be achieved by adjusting the pressure in accordance with the operating conditions. According to the guideline, if the compressor delivery pressure is reduced from 4 to 3 kg/cm^2, power can be reduced by 10 %. Since the current compressor load is about 250 kW, reduction in the power of 25kW can be expected. Assuming that annual operation time is 8,000 hours, the following power can be saved:

$8,000 \times 25 = 200,000$ kwh/y

Reduction of the air pressure will also serve to reduce the leakage in the compressed air system. It is also worth studying the feasibility of the operation by separating the system into two (the system for plants No. 1 and that for No. 2) and by giving different pressures.

⑦ Others

The gauges must be repaired since the indications of pressure gauges are not uniform according to air tanks, or indications fail to appear. The basis of energy conservation is to collect accurate data. Install the measuring instruments at the required positions, and provides adequate maintenance.

Illumination was generally insufficient, but some of the factories like the machining shop were found to be using the fluorescent lamps, even though they were exposed to plenty of sun light.

(6) Total of the effects

Table 5.5.34 shows the total of the effects gained by taking the improvement measures when quantitative prediction is possible.

Table 5.5.34 Summary

Item	Expected Saving							Investmen payback year	
	Natural Gas			Power			Total		
	m³/y	1000/Lv/y	%	kwh/y	1000Lv/y	%	1000Lv/y	1000Lv	y
Melting Furnace									
Insulation of Crown etc.	1493646	3047.0	6.6				3047.0	56.3	0.02
Air Ratio Improvement	81224	165.7	0.4				165.7	0	0.0
Closing Hole	28682	58.5	0.1				58.5	100.0	1.7
Change of Burner	290125	591.9	1.3				591.9	600.0	1.0
Change of Checker Brick	48734	99.4	0.2				99.4	0	0.0
Increase of Cullet	126709	258.5	0.6				258.5	0	0.0
Change of Batch Composition	61730	125.9	0.3				125.9	0	0.0
Compressor									
Selection of Compressor				149000	104.3	0.9	104.3	0	0.0
Pressure Decrease				200000	140.0	1.2	140.0	0	0.0
Total	2130850	4346.9	9.4	349000	244.3	2.1	4591.2	756.3	0.2

6. Appended Data Materials
(Members, Counterpart, Timetable, S/W and Measuring Instruments)

Appended Data 1

Members of the Study Group

No	Name	Duty	Description of responsibilities
1	Mitsuo Iguchi	Leader, General management	General management, energy management and energy conservation policies
2	Teruo Nakagawa	Deputy leader	Heat management technology and measurement technology, and liaison negotiation
3	Masashi Miyake	Process control	Study of detergent production process and heat management technology
4	Masashi Endo	Process control	Study of vegetable oil production process and heat management technology
5	Akira Koizumi	Process control	Study of paper & pulp production process and heat management technology
6	Shoji Nakai	Process control	Study of glass production process and heat management technology
7	Takashige Taniguchi	Process control	Study of textile production process and heat management technology
8	Yukio Nozaki	Energy management technology	Study of heat management technology
9	Tetsuo Ohshima	Energy management technology	Study of heat management technology
10	Yorihiko Tanaka	Electricity management technology	Study of electric power receiving and distribution and electric facilities at detergent and vegetable oil factories
11	Kazuo Usui	Electricity management technology	Study of electric power receiving and distribution and electric facilities at paper & pulp, glass and textile factories
12	Hironobu Tsukimoto	Energy policy	Study of energy situation and policy
13	Takao Shiomi	Energy management technology	Overall heat management technology (domestic jobs)
14	Masayoshi Morita	Energy management technology	Overall heat management technology (domestic jobs)
15	Jiro Konishi	Energy management technology	Overall heat management technology (domestic jobs)
16	Ayako Sato	Energy management technology	Overall heat management technology (domestic jobs)
17	Motoo Hori	Energy policy and energy conservation popularization	Energy policy, energy conservation popularization (domestic jobs)
18	Yukie Kawaguchi	Energy policy and energy conservation popularization	Energy policy and energy conservation popularization (domestic jobs)

Appended Data 2

List of Counterparts

Members of the Ministry of Industry

No	Name	Assignment
1	Mr. Dobrin Oreshkov	Team Leader and Electric Expert
2	Mr. Valentin Stankov	Heat Expert
3	Mr. Mitko Dimitrov	Heat Expert
4	Mr. Nestor Nestorov	Heat Expert

Appended Data 3

Timetable of the Field Study

1) Primary field study

Members ① Mitsuo Iguchi (Leader)
② Teruo Nakagawa (Deputy leader)
③ Hironobu Tsukimoto (Energy policy)

No	Date	Day of the week	Itinerary
1	June 15, 1992	Monday	Departure from Tokyo
2	June 16	Tuesday	Arrival at Sofia and visit to the Japanese Embassy
3	June 17	Wednesday	Courtesy visit to Ministry of Industry and reporting to the Japanese Embassy
4	June 18	Thursday	Explanation of the inception report
5	June 19	Friday	Explanation of the study method
6	June 20	Saturday	Study (Ecotech Product)
7	June 21	Sunday	Preparation for the study
8	June 22	Monday	Study (Ministry of Industry and the Committee of Energy)
9	June 23	Tuesday	Study (Ministry of Finance, Ministry of Environment and National Statistical Institute)
10	June 24	Wednesday	Study (chemical factory and paper & pulp factory)
11	June 25	Thursday	Study (Textile factory) Movement from Sofia to Veliko Tarnovo
12	June 26	Friday	Study (glass factory and vegetable oil factory) Movement from Polski Trambesh to Sofia
13	June 27	Saturday	Preparation for the study
14	June 28	Sunday	Preparation for the study
15	June 29	Monday	Study (Standardization and Metrology Committee and Bulgarian Chamber of Commerce and Industry)
16	June 30	Tuesday	Study (Scientific and Technical Unions in Bulgaria and Industrial Energetics)
17	July 1	Wednesday	Study (National Electric Company, Electrimpex and Bulgargas)
18	July 2	Thursday	Study (Committee of Energy, Ministry of Industry and Ministry of Construction)
19	July 3	Friday	Study (Ministry of Industry, Petrol and National Statistical Institute)
20	July 4	Saturday	Preparation for the study
21	July 5	Sunday	Preparation for the study
22	July 6	Monday	Study (Ministry of Industry) and preparation of a progress report
23	July 7	Tuesday	Signing of the progress report and reporting to the Japanese Embassy
24	July 8	Wednesday	Courtesy visit to Ministry of Industry and the Japanese Embassy, and departure from Sofia
25	July 9	Thursday	En route home
26	June 10	Friday	Arrival at Tokyo

2) Explanation of interim report in Bulgaria

Members ① Mitsuo Iguchi (Leader)
② Teruo Nakagawa (Deputy leader)
③ Hironobu Tsukimoto (Energy policy)

No	Date	Day of the week	Itinerary
1	October 20, 1992	Tuesday	Departure from Tokyo
2	October 21	Wednesday	Arrival at Sofia
3	October 22	Thursday	Courtesy visit to the Japanese Embassy, reporting to Ministry of Industry, and meeting
4	October 23	Friday	Opening of seminar
5	October 24	Saturday	Data arrangement
6	October 25	Sunday	Data arrangement
7	October 26	Monday	Explanation of the interim report
8	October 27	Tuesday	Meeting with Ministry of Industry, and preparation and signing of minutes
9	October 28	Wednesday	Reporting to Ministry of Industry and the Japanese Embassy. Movement from Sofia to Vienna
10	October 29	Thursday	Reporting to JICA Austria Office, and departure from Vienna
11	October 30	Friday	Arrival at Tokyo

3) Secondary field study

A. First team

Members ① Mitsuo Iguchi (Leader)
② Teruo Nakagawa (Deputy leader)
③ Yukio Nozaki (Heat management technology)

No	Date	Day of the week	Itinerary
1	February 15, 1993	Monday	Departure from Tokyo
2	February 16	Tuesday	Arrival at Sofia and visit to the Japanese Embassy
3	February 17	Wednesday	Explanation to Ministry of Industry
4	February 18	Thursday	Study (Efficient Energy Agency) and Unpacking of received study equipment
5	February 19	Friday	Study (National Statistical Institute) and unpacking of received study equipment
6	February 20	Saturday	Preparation for the study
7	February 21	Sunday	Preparation for the study
8	February 22	Monday	Study (EC Energy Center), and inspection and calibration of study equipment
9	February 23	Tuesday	Study (Committee of Energy), and inspection and calibration of study equipment
10	February 24	Wednesday	Study (Ministry of Construction), and inspection and calibration of study equipment
11	February 25	Thursday	Study (Ministry of Industry), and inspection and calibration of study equipment
12	February 26	Friday	Study (Scientific and Technical Unions in Bulgaria), and inspection and calibration of study equipment
13	February 27	Saturday	Preparation for the study, and joining with the second team

B. Second team

Members
① Mitsuo Iguchi — Leader (Joining from the first team)
② Teruo Nakagawa — Deputy leader (Joining from the first team)
③ Masashi Miyake — Detergent production process
④ Masashi Endoh — Vegetable oil production process
⑤ Yukio Nozaki — Heat management technology (Joining from the first team)
⑥ Yorihiko Tanaka — Electricity management technology

No	Date	Day of the week	Itinerary
1	February 26, 1993	Friday	Departure from Tokyo
2	February 27	Saturday	Arrival at Sofia and joining with the first team
3	February 28	Sunday	Preparation for the study
4	March 1	Monday	Meeting with the detergent factory
5	March 2	Tuesday	Meeting with the vegetable oil production factory and departure of member Tanaka from Tokyo
6	March 3	Wednesday	Meeting with Ministry of Industry and arrival of member Tanaka at Sofia
7	March 4	Thursday	Meeting with Ministry of Industry
8	March 5	Friday	Meeting with Ministry of Industry
9	March 6	Saturday	Preparation for the study
10	March 7	Sunday	Preparation for the study
11	March 8	Monday	Study of the detergent factory
12	March 9	Tuesday	Study of the detergent factory
13	March 10	Wednesday	Study of the detergent factory
14	March 11	Thursday	Study of the detergent factory
15	March 12	Friday	Study of the detergent factory
16	March 13	Saturday	Preparation for the study
17	March 14	Sunday	Preparation for the study. Movement from Sofia to Veliko Tarnovo
18	March 15	Monday	Study of the vegetable oil factory
19	March 16	Tuesday	Study of the vegetable oil factory
20	March 17	Wednesday	Study of the vegetable oil factory
21	March 18	Thursday	Study of the vegetable oil factory
22	March 19	Friday	Study of the vegetable oil factory. Movement from Veliko Tarnovo to Sofia
23	March 20	Saturday	Departure from Sofia of members Miyake, Endo, Nozaki and Tanaka
24	March 21	Sunday	Data arrangement
25	March 22	Monday	Meeting with Ministry of Industry. Arrival at Tokyo of members Miyake, Endo, Nozaki and Tanaka

No	Date	Day of the week	Itinerary
26	March 23	Tuesday	Preparation of a progress report
27	March 24	Wednesday	Preparation and signing of the progress report
28	March 25	Thursday	Reporting to the Japanese Embassy. Movement from Sofia to Vienna
29	March 26	Friday	Reporting to JICA Austria Office
30	March 27	Saturday	Departure from Vienna
31	March 28	Sunday	Arrival at Tokyo

4) Tertiary field study

Members	①	Mitsuo Iguchi	Leader
	②	Teruo Nakagawa	Deputy leader
	③	Akira Koizumi	Paper & pulp production process
	④	Takashige Taniguchi	Textile production process
	⑤	Shoji Nakai	Glass production process
	⑥	Tetsuo Ohshima	Heat management technology
	⑦	Kazuo Usui	Electricity management technology

No	Date	Day of the week	Itinerary
1	May 29, 1993	Saturday	Departure from Tokyo
2	May 30	Sunday	Arrival at Sofia
3	May 31	Monday	Preparation for the study
4	June 1	Tuesday	Meeting with the paper & pulp factory and arrangement for the presentation at the International Conference
5	June 2	Wednesday	Meeting with the glass factory
6	June 3	Thursday	Meeting with the textile factory
7	June 4	Friday	Adjustment of the study equipment
8	June 5	Saturday	Preparation for the study
9	June 6	Sunday	Preparation for the study
10	June 7	Monday	Study of the glass factory
11	June 8	Tuesday	Study of the glass factory
12	June 9	Wednesday	Study of the glass factory
13	June 10	Thursday	Study of the glass factory
14	June 11	Friday	Study of the glass factory
15	June 12	Saturday	Preparation for the study
16	June 13	Sunday	Movement from Sofia to Plovdiv
17	June 14	Monday	Study of the paper & pulp factory
18	June 15	Tuesday	Study of the paper & pulp factory
19	June 16	Wednesday	Study of the paper & pulp factory
20	June 17	Thursday	Study of the paper & pulp factory
21	June 18	Friday	Study of the paper & pulp factory. Movement from Plovdiv to Sofia

No	Date	Day of the week	Itinerary
22	June 19	Saturday	Preparation for the study
23	June 20	Sunday	Preparation for the study
24	June 21	Monday	Movement from Sofia to Varna
25	June 22	Tuesday	Participation in and presentation at the international conference
26	June 23	Wednesday	Participation in and presentation at the international conference
27	June 24	Thursday	Participation in and presentation at the international conference
28	June 25	Friday	Movement from Varna to Sofia
29	June 26	Saturday	Preparation for the study
30	June 27	Sunday	Preparation for the study
31	June 28	Monday	Study of the textile factory
32	June 29	Tuesday	Study of the textile factory
33	June 30	Wednesday	Study of the textile factory
34	July 1	Thursday	Study of the textile factory
35	July 2	Friday	Study of the textile factory
36	July 3	Saturday	Departure from Sofia of members Koizumi, Taniguchi, Nakai, Oshima and Usui
37	July4	Sunday	Arrangement of data materials
38	July 5	Monday	Preparation of a progress report. Arrival at Tokyo of members Koizumi, Taniguchi, Nakai, Oshima and Usui
39	July 6	Tuesday	Preparation of a progress report and adjustment of equipment
40	July 7	Wednesday	Signing of the progress report
41	July 8	Thursday	Reporting to the Japanese Embassy. Movement from Sofia to Vienna
42	July 9	Friday	Reporting to the JICA Austria Office and departure from Vienna
43	July 10	Saturday	Arrival at Tokyo

Appended Data 4

SCOPE OF WORK
FOR
THE STUDY ON THE RATIONAL USE OF ENERGY
IN
THE REPUBLIC OF BULGARIA

AGREED UPON BETWEEN
MINISTRY OF INDUSTRY AND TRADE
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

Sofia, February 28th, 1992

MR.SPAS SPASSOV DEPUTY MINISTER MINISTRY OF INDUSTRY AND TRADE	MR.YUKIO OTSU LEADER OF THE PREPARATORY STUDY TEAM JAPAN INTERNATIONAL COOPERATION AGENCY

I. INTRODUCTION

In response to the request of the Government of the Republic of Bulgaria (hereinafter referred to as "the Government of Bulgaria"), the Government of Japan decided to conduct a study on the rational use of energy in industry in the Republic of Bulgaria (hereinafter referred to as " the Study")in accordance with the relevant laws and regulations in force in Japan.

Accordingly, Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, will undertake the Study in close cooperation with the authorities concerned of the Government of Bulgaria.

The present document sets forth the scope of work with regard to the Study.

II. OBJECTIVE OF THE STUDY

The objective of the Study is to contribute to the promotion and strengthening of rational use of energy in the field of industries in the Republic of Bulgaria(hereinafter referred to as "Bulgaria") by studying the technical and managemental applicability of rational use of energy and formulating the report for the promotion of rational use of energy in the representative industries stated below:

1. Chemical Industry
2. Paper and Pulp Industry
3. Textile Industry
4. Glass Industry
5. Food Industry

III. SCOPE OF THE STUDY

In order to achieve the above objective, the Study shall cover the following items.

1. Study on the energy situation in Bulgaria
   - 1.1 Government policy of the energy
   - 1.2 Present energy situation in Bulgaria
   - 1.3 Situation of energy use in the field of whole industries in Bulgaria

2.Study on the promotion of rational use of energy in the industry

2.1 Related laws and regulations

2.2 Current program for rational use of energy

2.3 To study and evaluate the activities of the authorities concerned

(1)Current activities for promotion of rational use of energy

(2)Achievements of past activities

(3)Future plan/program for promotion of rational use of energy

3.Study on the situation of energy use in the factory of each industry

3.1 Situation of energy use in each factory

(1)Outline of the factory

(2)Situation of energy management

(3)Energy flow chart

(4)Situation of major energy consuming equipment

(5)Problems in each factory and countermeasures without changing the existing production process

(6)Estimated effects of the countermeasures

4.Recommendation for the promotion of the rational use of energy in Bulgaria

4.1 New organization to promote rational use of energy

4.2 Activities of the above organization

4.3 Measures to promote rational use of energy in the field of industries

4.4 Countermeasures without changing the existing production process and to estimate their effects

5.Preparation for the reference of the technical guideline for the promodtion of rational use of energy in industries

IV. SCHEDULE OF THE STUDY

The Study shall be carried out in accordance with the tentative schedule of the Study as shown in the Appendix.

V. REPORTS

JICA shall prepare and submit the following reports in English to the Government of Bulgaria in particular stages of the Study as shown in the Appendix

Twenty (20)copies of the Inception Report
Twenty (20)copies of the Progress Report
Twenty (20)copies of the Interim Report
Thirty (30)copies of the Draft Final Report and its summary
Thirty (30)copies of the Final Report and its summary

VI. UNDERTAKINGS OF THE GOVERNMENT OF BULGARIA

1. To facilitate smooth conduct of the Study, the Government of Bulgaria shall take the necessary measures:

1.1 To secure the safety of the Japanese Study Team (hereinafter referred to as "the Team")

1.2 To permit the members of the Team to enter, leave and stay in Bulgaria for the duration of their assignment therein, and exempt them from foreign registration requirements and consular fees

1.3 To exempt the members of the Team from taxes, duties and other charges on equipment, machinery and other materials brought into, and out of, Bulgaria for the conduct of the Study

1.4 To exempt the members of the Team from income tax and charges of any kind imposed on, or in connection with, any emoluments or allowances paid to them for their services in connection with the implementation of the Study

1.5 To provide necessary facilities to the Team for remittance as well as utilization of the funds introduced into Bulgaria from Japan in connection with the implementation of the Study

1.6 To secure permission for entry into private properties or restricted areas for the conduct of the Study

1.7 To secure permission for the Team to take all data and documents (including photographs) related to the Study out of Bulgaria to Japan

1.8 To provide medical service as needed. Its expenses will be

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chargeable to the members of the Team.

2.The Government of Bulgaria shall bear claims, if any arises against the members of the Team resulting from, occuring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or wilful misconduct on the part of the members of the Team.

3.Ministry of Industry and Trade (hereinafter referred to as "MIT")shall act as the counterpart agency to the Team and also the co-ordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

4.MIT shall provide the Team with the following, at their own expense, in cooperation with other organizations concerned:

4.1 Available data and information related to the Study

4.2 Counterpart personnel

4.3 Suitable office space with necessary equipment in Sofia

4.4 Credentials or identification cards

4.5 Driver of Vehicle(mini-bus)

VII.UNDERTAKINGS OF JICA

For the implementation of the Study, JICA shall take the following measures:

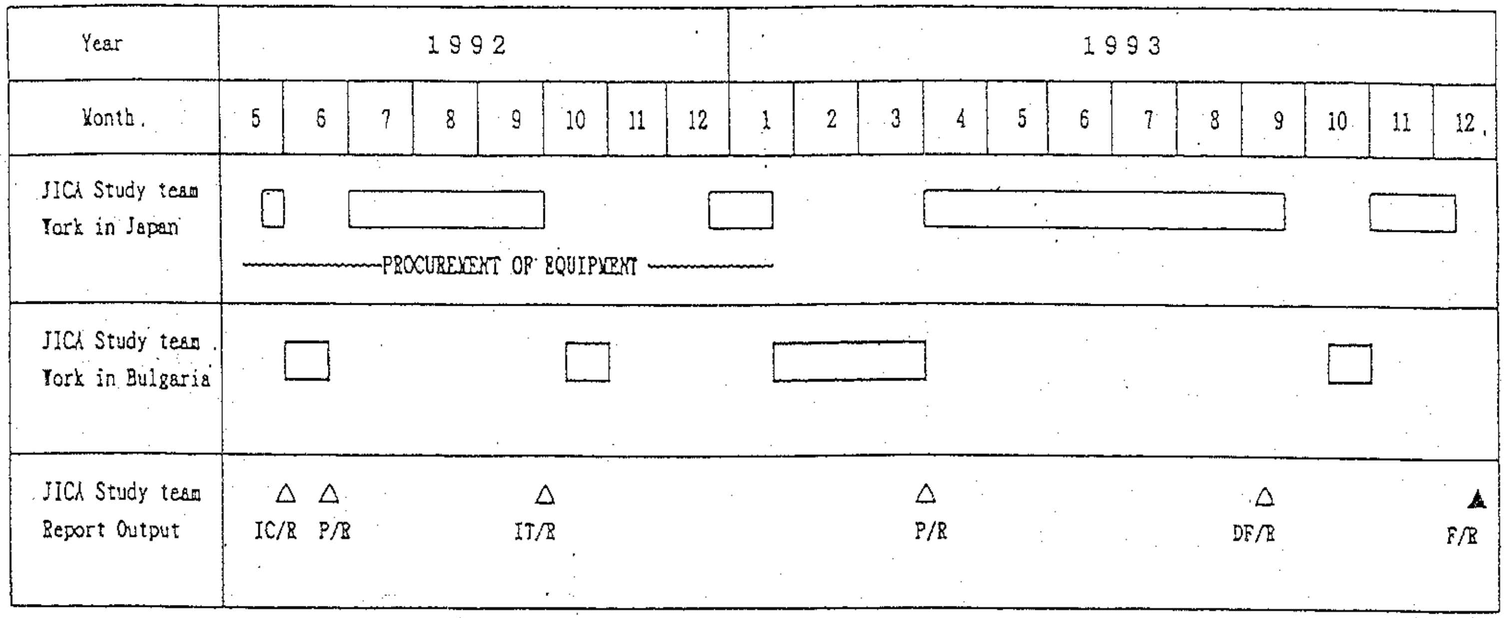
1.To dispatch, at its own expense, study team to the Republic of Bulgaria

2.To pursue technology transfer to the Bulgarian counterpart personnel in the course of the Study

VIII.OTHERS

JICA and, MIT shall consult with each other in respect of any matter that may arise from, or in connnection with, the Study.

TENTATIVE SCHEDULE OF THE STUDY



Abreviations: IC/R: Inception Report
P/R: Progress Report
IT/R: Interim Report
DF/R: Draft Final Report
F/R: Final Report

MINUTES OF MEETING
ON
THE STUDY ON THE RATIONAL USE OF ENERGY
IN
THE REPUBLIC OF BULGARIA
AGREED UPON BETWEEN
MINISTRY OF INDUSTRY AND TRADE
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

1. The Preparatory Study Team organized by the Japan International Cooperation Agency visited the Republic of Bulgaria from February 25 to February 29, 1992 for the purpose of discussing the Scope of Work regarding the Study on The Rational Use of Energy in the Republic of Bulgaria with the Ministry of Industry and Trade of the Government of the Republic of Bulgaria.

2. In connection with the above, a series of meetings were held between the Bulgarian side represented by Mr. Bojidar Fotev, General Director, Ministry of Industry and Trade and the Japanese side headed by Mr. Yukio Otsu, Leader of the JICA Preparatory Study Team. (The attendance list is found in the Appendix)

3. These records should be read in conjunction with the "Scope of Work" agreed upon between the Ministry of Industry and Trade and JICA dated Feb. 28, 1992.

4. SPECIAL ISSUES HIGHLIGHTED

4.1 Regarding Item 3 of Article III.SCOPE OF THE STUDY, selected five(5) factories shall be as follows:
(1)VERILA Ltd. - Sofia (Chemical Industry)
(2)RULON ISKAR Ltd. - Sofia (Paper & Pulp Industry)
(3)NITEX-50 Ltd. - Sofia (Textile Industry)
(4)INTERIOR Ltd. - Elena (Glass Industry)
(5)PRIMA M Ltd. - Polski Trambesh (Food Industry)

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4.2 The Bulgarian side requested the Japanese side to provide the equipment, measuring equipment and equipment carrying vehicle, upon the completion of the said study, and the Japanese side agreed to it.

4.3 The consignee of the above equipment shall be as follows:
Mr.Dobrin Oreshkov
Expert,
Ministry of Industry and Trade
8, Slavyanska Str.
Sofia 1046
BULGARIA

4.4 Both sides agreed on that Bulgarian side assigns counterpart engineers for the Japanese study team while their field survey in Bulgaria for technology transfer, and numbers of Bulgarian counterparts shall be as follows:

(1) 4(four)engineers; 3(three) heat engineers and 1(one) electric engineer, from Ministry of Industry and Trade, who shall be assigned for the the whole field survey at the factories.

(2) 4(four)engineers; 3(three) heat engineers and 1(one) electric engineer, from each factory, who shall be assigned for nearly one week only when the Japanese study team makes field survey at the factory.

Done in Sofia
February 28, 1992

MR.BOJIDAR FOTEV	MR. YUKIO OTSU
GENERAL DIRECTOR,	LEADER,
INDUSTRIAL SCIENCE AND	PREPARATORY STUDY TEAM,
INFORMATICS DEPT.,	JAPAN INTERNATIONAL
MINISTRY OF INDUSTRY AND TRADE	COOPERATION AGENCY

Appendix

LIST OF ATTENDANCES

Bulgarian Side

Ministry of Industry and Trade

Mr. Bojidar Fotev	General Director, Industrial Science and Informatics Dept.
Ms. Margarita Kambosseva	Senior expert, Industrial Science and Informatics Dept.
Mr. Dobrin Oreshkov	Senior expert, Energy strategy
Mr. Tzveti Lazarov	Expert, Internationl economic relationship

Japanese Side

JICA Preparatory Study Team

Mr. Yukio Otsu	Leader
Mr. Takao Kaibara	Member
Mr. Akio Kimura	do.
Mr. Teruo Nakagawa	do.
Mr. Toshinori Isogai	do.

Embassy of Japan

Mr. Kazumasa Sibuta	Attache

Appended Data 5

Equipment List

No	Name	Set (s)
1.	Equipment carrying vehicle with antishock rack and lifter	1
2.	Ultrasonic flow meter for fuel oil or water	2
3.	High temperature anemometer for gas	6
4.	Steam condensate flow meter	1
5.	Pitot type flow meter	1
6.	Differential pressure transmitter for orifice	1
7.	Oxygen meter for exhaust gas	2
8.	Carbon dioxide and monoxide meter for exhaust gas	1
9.	Pretreatment unit for sampling exhaust gas	1
10.	Sampling tube for exhaust gas	10
11.	Thermometer for surface	2
12.	Thermocouple with compensate cable for gas	40
13.	Suction pyrometer	1
14.	Infrared radiation thermometer (low range)	1
15.	Infrared radiation thermometer (high range)	1
16.	Glass thermometer	5
17.	Hygrometer	10
18.	Infrared thermal video system	1
19.	20 channel recorder with data memory and reader	3
20.	Personal computer (desk top type) for analysis	1
21.	Personal computer (book type) for field work	2
22.	Water conductivity meter	1
23.	Water pH meter	1
24.	Water hardness meter	1
25.	Pressure gauge with transmitter for furnace gas	1
26.	Pressure transmitter for steam	1
27.	Steam trap checker	1
28.	Watt-power factor meter	5
29.	Power meter	1
30.	Tachometer	1
31.	Lux meter	1
32.	Circuit tester	1
33.	Voltage detector	5
34.	Heat resisting gloves	5
35.	Cobalt glass for eye protect	5

No	Name	Set (s)
36.	Camera	1
37.	Power insulation gloves	5
38.	Extension power cord with tools	3
39.	Stop watch	2
40.	Wagon desk for field work	4
41.	Training unit for measurment of temperature and power	1
42.	Training unit for measurment of water flow and power	1
43.	Training unit for measurment of gas pressure and power	1
44.	Transducer (for power)	6
45.	Transducer (for current)	2
46.	Transducer (for voltage)	2

JICA