2.1.4.3 Ethylbenzene synthesis

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

Table 2.1.14 Comparison of Energy Intensity in Ethylbenzene Synthesis (I)

	Unit	Blachownia	Excellent factory	Difference
Ethylene	kg/t-EB		736	
Benzene	kg/t-EB		270	
Flux oil make	kg/t-EB		5.7	
Aluminium chloride	kg/t-EB		1.45	
Ethly chloride	kg/t-EB		0.57	
NaOH (90 %)	kg/t-EB		0.36	
Electricity	kWh/t-EB	35.1	25.8	9.3
Steam	MJ/t-EB	3,927	-2,918	6,845
Fuel	MJ/t-EB		2,654	-2,654
Compressed air	m^3/t-EB	30.5	8	22.5
	kWh/t-EB	4.3		
Water	m^3/t-EB	6	0.4	5.6
Production capacity	t/y	103,000	210,000	

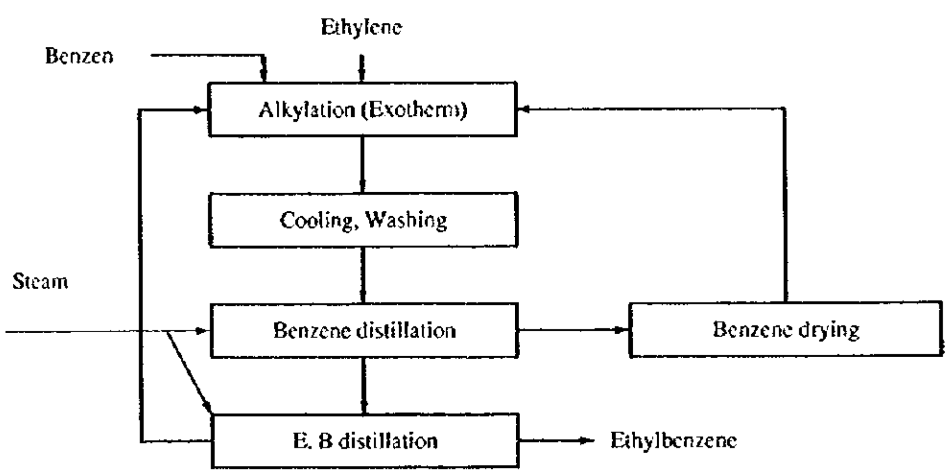
The negative value for steam consumption of the excellent factory in the table indicates that waste heat recovery is implemented there.

(2) Estimating the energy conservation potential

a. Process

1) Flow sheet

Figure 2.1.9 Flow Sheet of Ethylbenzene Synthesis



2) Difference in energy intensity

Table 2.1.15 Comparison of Energy Intensity in Ethylbenzene Synthesis (2)

	Unit	Blachownia	Excellent factory	Difference
Heat	MJ/t	3,927	-264	4,191
Electricity	MJ/t	407	278	129
Total	MJ/t	4,334	14	4,320

① Difference due to external factors

Ethylene, the raw material, is a purchased product, while benzene comes out from the crude benzene distillation process, producing no difference in the product type and quality. There is no significant difference in the process and system either between the two factories.

Since the production capacity of the excellent factory is 2 times larger than that of Blachownia, an approximately 5 % energy intensity is due to scale merit. The annual average temperature is 8 °C in Katowice, and 20 °C at the excellent factory, with a temperature difference of approx. 12 °C. Assuming the operating temperature for the ethylbenzene synthesis process to be 170 °C, the difference due to the temperature difference will be theoretically around 7 % (12/170 = 7 %) since there is no significant difference in raw materials and product composition. Under the current situation where heat radiation from facilities, furnace body and piping is approximately 30 % of the supplied heat energy, the following formula is obtained.

$3{,}927 \times 0.3 \times 0.07 = 83$ MJ/t

Therefore, the difference in energy intensity due to external factors will be as follows:

Although the plant initially planned to introduce an integrated production system for the ethylbenzene synthesis process, the eatablishment of the ethylbenzene synthesis process together with the styrene monomer synthesis process has not been realized yet. On the other hand, in the excellent factory with the both processes available, steam equivalent to 2,918 MJ/t is utilized for the recovered styrene monomer synthesis process through alkylation reaction heat and heat exchange, thus greatly contributing to energy conservation. When approximately 80 % of this recovered energy is used as an external factor based on actual results in Japan, the effect will be as follows:

$2{,}918$ MJ/t $\times 0.8 = 2{,}330$ MJ/t

Energy intensity difference: $83 + 4{,}334 \times 0.05 + 2{,}330 = 2{,}630$ MJ/t

② Difference due to technical factors

1) Production management system

The monthly fluctuation range of energy intensity is relatively small, presenting a definite correlation with production amount. Although the annual plan for energy intensity is drafted based on the actual results of the previous year, it is not sufficiently conveyed to workers on the workplace, and it does not lead to energy conservation. It is necessary to set up a system that will feed back weekly or monthly information to the production department as early as possible to identify problems and take appropriate measures.

2) Reinforcing the heat insulation of the distillator

Heat radiation loss is large because of inadequate heat insulation in the flange part. By reinforcing the heat insulation, at least 10 % energy conservation can be achieved.

$3{,}927 \times 0.1 = 393$ MJ/t (22,201 GJ/y)

3) Leakage of compressed air

The consumption of compressed air is as many as 4 times larger than that of the excellent factory, though its use for processing or for controlling is not yet so clearly categorized. The piping system needs to be checked for any air leaks. The amount of compressed air used for controlling can be reduced to a half of the present value also in terms of equipment configuration. Reducing the current compressed air consumption to around 2 times that at the excellent factory, an energy saving of 20 MJ/t (1,130 GJ/y, 110 MWh/y) will be achieved.

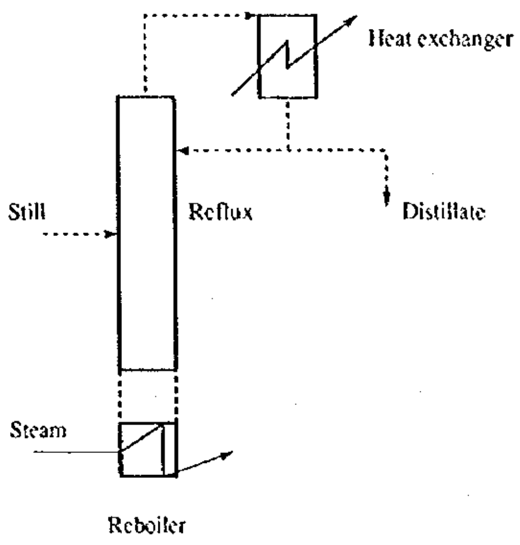
Electricity saving: 20 MJ/y (1,130 GJ/y, 110 MWh/y)

4) Enhancing heat exchangers

In order to increase the heat recovery from the distillate in the distillation column, heat exchangers should be newly installed. This reinforcement will allow the amount of recovered energy to be increased by 20 %.

Increment in the amount of energy recovered: $3{,}927 \times 0.2 = 785$ MJ/t (44,345 GJ/y)

Figure 2.1.10 Heat Exchanger in Benzene Distillaiton



5) Ejector of the distillator

The steam consumption of the steam ejector for generating vacuum in the distillator is 160 MJ/t, which is abnormally high. A substantial reduction in steam consumption will be made possible by optimization of steam pressure, inspection and maintenance of nozzles, use of proper nozzles, etc. At least 30 % steam reduction is estimated to be possible under the assumption based on the equipment capacity and specification.

Energy conservation amount: $160 \times 0.3 = 48$ MJ/t (2,712 GJ/y)

6) Changing and newly installing processes

① Heat recovery from the alkylation reactor

The heat value of alkylation reaction is test-calculated as follows:
Heat value: 25 kcal/mol
Molecular weight: 106
$4.186 \times 25/106 = 0.9$ kJ/g = 900 MJ/t

In order to recover this amount of heat, which is substantially large in terms of heat value, styrene monomer production equipment needs to be also installed and this involves a resultant overall equipment change, thus requiring a large-scale modification. Therefore, due consideration should be given to this matter.

② Installing the styrene monomer process

Utilization of ethylbenzene reaction heat for production of styrene monomer will substantially improve energy efficiency. As mentioned above, styrene monomer production equipment requires a large-scale investment, and hence it should be determined based on managerial strategy in due consideration of the market climate as well.

7) Energy conservation potential

① Reinforcing the heat insulation of the distillator
: Energy intensity improvement: 393 MJ/t
② Leakage of compressed air: Energy intensity improvement: 20 MJ/t
③ Enhancing heat exchangers: Energy intensity improvement: 785 MJ/t
④ Distillator ejector : Energy intensity improvement: 48 MJ/t

2.1.4.4 Polyethylene polymerization

This equipment, which was constructed in 1966, is well maintained and moreover up-to-date. Thus, the electricity and steam intensity, which are equivalent to those of the excellent factory, are at the international standard level as shown in Table 2.1.16.

Table 2.1.16 Comparison of Energy Intensity in Polyethylene Polymerization

	Unit	Blachownia	Excellent factory	Difference
Electricity	kWh/t	1,059	1,050	9
Steam	MJ/t	494	300	194

2.1.4.5 Utilities (Electricity utilization facilities)

a. Improving the power receiving/distributing facilities

Despite the large capacity and size of the existing receiving/distributing facilities, which were installed with future expansion taken into account, electricity consumption is extremely small. Electricity consumption at the peak demand is around 13 MW during the peak demand, and approx. 8.0 MW on the average, accounting for as small a percentage as 20 % of the capacity. (see Table 2.1.17)

Table 2.1.17 Facility Capacity and Power Consumption

	Receiving Equipment	Distributing Transformer	High Pressure Motor	Power Consumption
No. of units	32 MVA	41.2 MVA	17.4 MW	Average 8.0 MW
in operation	2	56	43	Peak demand 13 MW

Receiving transformer not in operation: 64 MVA (4 units)

Recommendable measures: Receiving facility capacity should be reduced. If the demand is expected to increase, however, the minimum capacity of the existing facilities should be maintained.

The current load factor of the power distributing transformer 22.6 % (= (8 MW/ 0.86)/41 MVA) should be improved to approx. 31 % to reduce the capacity of the transformer (reduction in capacity: 11 MVA). This is based upon the assumption that the overall load is 11.5 MW, the high-pressure motor load is 17.4 MW and the operating rate is 20 %.

For implementation of this measure, it is advisable to install inexpensive low-pressure overhead wiring for connecting each transformer station, as required, in order to cover insufficient capacity.

Effect: Implementing the measures will bring about power saving as listed in the table below. Supposing that the annual operating hours (365 days) is 8,760 h, annual power reduction will be 126 MWh.

This is based on the assumption that the total capacity of the distributing transformer is 41 MVA (1 MVA × 41 units), load and power factor are approx. 8 MW (excluding a high-tension motor load 17.4 × 0.2) and 86 % and the load is fixed.

For the transformer loss, iron loss and copper loss are assumed to be Wi: 2.1 kW, and Wc: 11.3 kW, respectively.

Table 2.1.18 Reduction in Electricity Consumption as a Result of Decreasing the Capacity of Distributing Transformer

	Transformer capacity (kVA)	Iron loss Wi (kW)	Copper loss Wc (kW)	Loss total (kW)	Saving power (kW)
Current status	41 × 1,000	86.1	23.9 *	110	
After modification	30 × 1,000	63	32.6 **	95.6	14.4

*: $11.3 \times 41 \times (8/41/0.86)^2 = 23.9$ kW **: $11.3 \times 30 \times (8/30/0.86)^2 = 32.6$ kW

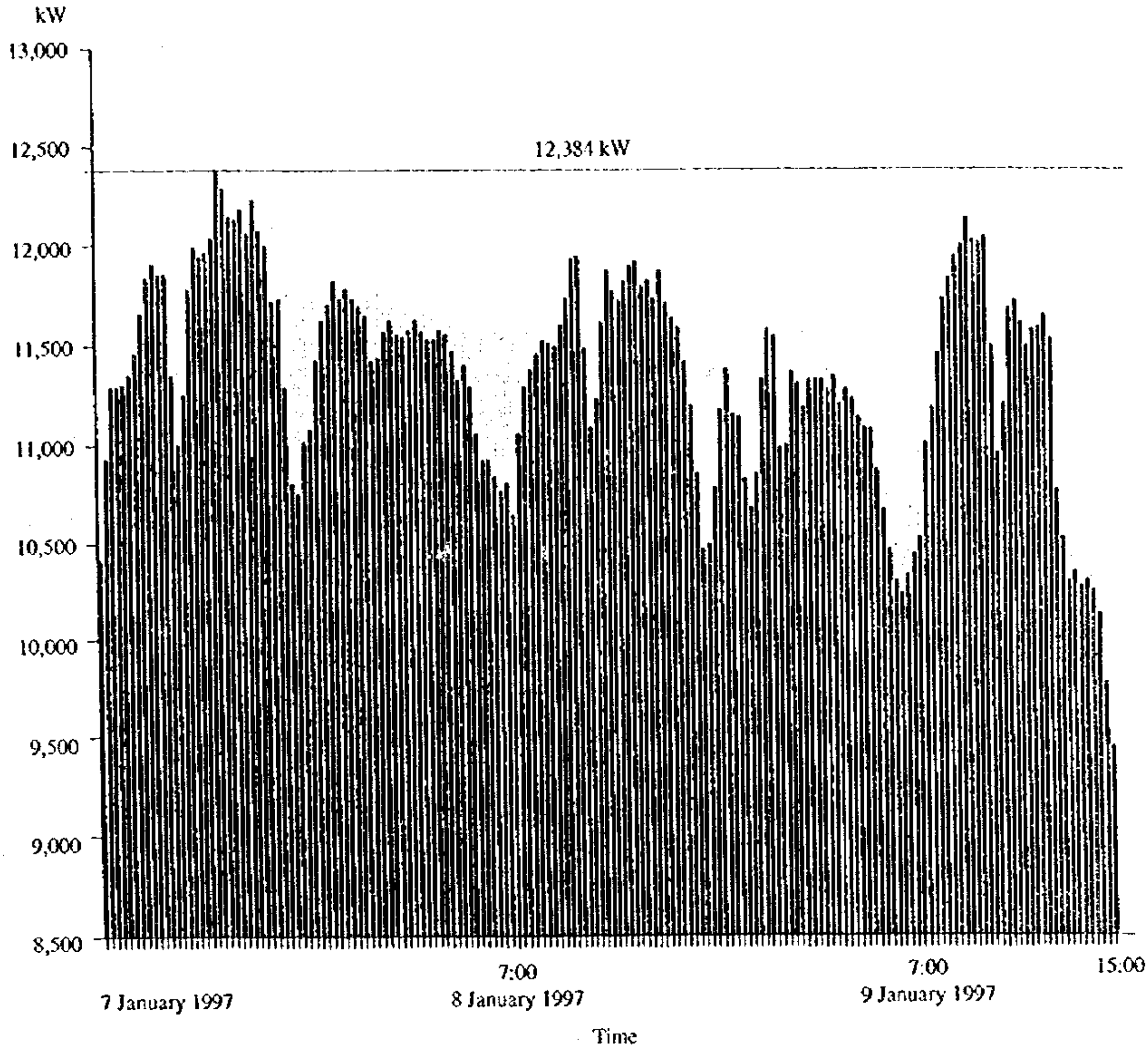
b. Reducing the load at the peak demand

This company's daily load curve chart (see Figure 2.1.11) shows that the peak load occurs almost at a fixed time every day. The cause factor for the occurrence of this peak load should be analyzed and reviewed into details to take measures for reducing the peak load, such as shifting the work starting or ending time.

Measures easily devised include installing monitoring systems to monitor electricity consumption during the peak demand, and giving an alarm when the demand exceeds the contracted amount, while at the same time, stopping the operation of the machine not so immediately needed. Taking these measures is expected to achieve at least the following energy conservation.

Peak demand reduction: $12{,}384 \times 0.04 \fallingdotseq 500$ kW

Figure 2.1.11 Record of Power Consumption



c. Efficient operation of air compressors and cooling water pumps

Only each one of large-capacity air compressors (1,000 kW) and pump (400 kW) is operated: sufficient or surplus equipment is always operated for the load amount, resulting in a considerable amount of loss. It seems that the equipment electricity is let to go wasted without making any other effort for energy conservation than adjusting or distributing the excess amount by means of valves particularly when the peak load declines. Moreover, this will cause a loss due to unavoidable operation of a large-sized machine of excess capacity even during partial operation of the plant.

This is a critically important theme as an electricity conservation measure under the current situation where the electricity consumption for cooling water is 10,775 MWh/y and energy intensity is as high as 0.26 kWh/m^3 (Source: this company's data for 1994).

1) Air compressor

Recommendable measures:

① The required amount of compressed air, fluctuation range, pressure, required amount for partial operation of the plant alone, and so on should be reviewed, as the result of which economical equipment suitable for the supply should be installed.

② Air compressors should properly be loaded/unloaded in accordance with pressure, while at the same time the machine operating rate (on-load time/ Operating time) should be increased as much as possible.

③ For the purpose of implementing the measure in the above item ②, installing a small-capacity compressor than the existing one will make it easier to increase the efficiency.

④ To save compressed air, the pressure of compressed air should be made as low as possible according to the equipment specificaiton and periodical check of air leakage should be performed to prevent it.

Effect: Only the minimum possible amount of compressed air can be generated, thus allowing efficient operation of compressors. Besides, this control can prevent the decrease in air pressure and air leakage, leading to economic operation.

2) Cooling water pumps

Recommendable measures:

① The required amount of the current cooling water should be checked for each process, while the number of necessary equipment to be used concurrently should be counted up to make only the minimum necessary equipment available.

② As the electricity saving plan for this company, it is advisable to reduce the facilities to around 50 % of the current pump capacity to ensure the optimum supply through control. The first equipment to be considered for improvement are PiS pump stations accounting for as much as approx. 50 % of the entire capacity.

③ The energy conservation measures relating to cooling water should be considered in accordance with season, temperature, water amount, water-supply pressure, circulating water system, heat exchanging efficiency, facility operating method and aging degree, etc. According to this company's data (1990-1994), electricity consumption is reduced by only 35.5 % as compared to 46 % reduction of water volume, which cannot be said to be adequate enough in terms of reduction in electricity consumption. Hence overall examination and reviews should be implemented with regard to the facilities and system as a whole in order to attempt their optimization.

Effect: By supplying only the necessary amount of cooling water of a necessary temperature, the required electricity consumption can be minimized, and a 15 to 20 % improvement can be expected by taking a proper measure, such as variable speed control with an inverter unit.

Electricity saving by installation of an inverter unit:

$1{,}775 \times 0.2 = 355$ MWh/t

d. Lighting

This company's plant has large and wide premises. Mercury lamps are used for the outside lighting on the plant premises. The electricity consumption is estimated to be around 15 kW. One of energy conservation measures may be to replace the mercury lamps with high-pressure sodium lamps, which may possibly reduce electricity consumption by approx. 40 %.

15 kWh $\times$ 8,760 $\times$ 12/24 $\times$ 0.4 = 26 MWh/y

(3) Summary of Energy Conservation Potential

a. Improvement of Environment through Energy Conservation

If fuel consumption is reduced through energy conservation, the quantity of pollutants emitted to the atmosphere also decreases. Additionally, if the amount of purchased power is reduced through energy conservation, so is the amount of power generated, that is, the quantity of pollutants emitted to the atmosphere by power plants. This reduction in emission quantity due to energy conservation depends not only on the amount of energy conservation, but also the type of fuel, and equipment, such as boilers, etc. Therefore the correct way to estimate the quantity of pollutants is to use the actual amount emitted by each factory. Here, however, for the sake of the consistency with the comprehensive study on Poland as a whole, calculations are based on information on the unit emission quantity (pollutant tonnage/fuel-heating value TJ), per industrial sector and per fuel type, provided by a document from the Institute of Environmental Protection. The reduction in the emission of air pollutants from this factory achieved as a result of energy conservation is compiled at each stage of energy conservation, and shown in Table 2.1.19.

Table 2.1.19 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_2	Dust
Step 0				
Step 1	4,490	0.7	10.3	0.1
Step 2	10,299	0.9	23.4	0.2
Step 3				
Step 1-3	14,789	1.6	33.6	0.3

Reduction includes emission from fuel and electricity.

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

The result of calculating the amounts of reduction in pollutant emission, for the energy conservation items that were proposed based on our factory survey, and the corresponding reductions in emission fees, is shown in Table 2.1.20. Furthermore, the length of time required to recover investments in energy conservation including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 2.1.20 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ PBP	Economical PBP
Step 0						
Step 1	1,393	4.0	1,397	429	0.31	0.31
Step 2	2,472	8.9	2,481	4,577	1.84	1.85
Step 3						
Step 1-3	3,865	12.8	3,878	5,005	1.29	1.30

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

As evident from this Table 2.1.20, the reduction in emission fee is only a few percents at most compared to reduction in energy cost, and thus, the effect of reduced emission fees on the payback period is also negligible.

This factory purchases steam and therefore, countermeasures for steam reduction, such as additional installation of heat exchangers in the chemical reaction process do not lead to a reduction in the emission fee. Thus, the improvement in the payback period due to a redution in an emission fee is very slight.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 2.1.21.

The energy conservation potential using the Excellent factory as the benchmark for energy consumption intensity, and energy conservation measures in Steps 1, 2, and 3 are shown in Figure 2.1.12. The relationship between energy conservation potential, the payback period, and the investment cost is shown in Figure 2.1.13.

Table 2.1.21 Summary of Energy Conservation Potential

COG: 0.17 PLN/m³N (18.8 MJ/m³N) Steam: 13.6 PLN/GJ Electricity: 0.172 PLN/kWh 1 PLN = 30 yen

Item	Energy Conservation Potential							Investment	Payback period
	Fuel			Electricity			Total		
	GJ/y	10^3 PLN/y	%	MWh/y	10^3 PLN/y	%	10^3 PLN/y	10^3 PLN	year
Step 1									
Tar distillation									
1. Improving the air ratio of the pipe still	1,911	25	0.2				25	0	0.0
2. Reinforcing the heat insulation of the distillation column	25,023	275	3.1				275	143	0.5
3. Preventing the leakage of compressed air				231	40	4.1	40	0	0.0
4. Reducing the steam amount of the ejector of the distillation column	4,368	48	0.5				48	0	0.0
Benzene distillation									
6. Reinforcing the heat insulation of the distillation column	31,997	435	4.0				435	143	0.3
7. Preventing the leakage of compressed air				1,251	215	22.4	215	0	0.0
Ethylbenzene synthesis									
8. Reinforcing the heat insulation of the distillation column	22,201	299	2.7				299	143	0.5
9. Preventing leakage of compressed air				110	19	2.0	19	0	0.0
10. Reducing the steam volume for the ejector of the distillation column	2,712	37	0.3				37	0	0.0
11. Centralization of transformers				126	22	2.3	22	40	1.8
Subtotal	88,212	1,119	10.9	1,718	295	30.7	1,414	469	0.3
Step 2									
Tar distillation									
12. Increasing the No. of heat exchangers	74,978	825	9.3				825	1,429	1.7
13. Reinforcing the heat insulation of the heating furnace	3,102	28	0.4				28	49	1.7
Benzene distillation									
14. Increasing the No. of heat exchangers	64,060	870	7.9				870	1,429	1.6
Ethylbenzene synthesis									
15. Increasing the No. of heat exchangers	44,345	598	5.5				598	1,429	2.4
Overall factory									
16. Lighting: Using sodium lamps				210	36	3.8	35	34	0.9
17. Decreasing the load at peak demand				126	22	2.3	22	40	1.8
18. Reducing the volume of cooling water and controlling the pump revolution				355	61	6.3	61	154	2.5
19. Decreasing the peak volume				500 kW	32	8.9	32	14	0.4
Subtotal	186,485	2,321	23.1	691	151	12.4	2,472	4,577	1.9
Total	274,697	3,440	34.0	2,409	446	43.1	3,886	5,046	1.3

As of 1996: Fuel consumption: 807,953 GJ/y
Electricity consumption: 6,591 MWh/y (57,352 GJ/y)
Total: 865,305 GJ/y

Figure 2.1.12 Brachownia Energy Conservation Potential

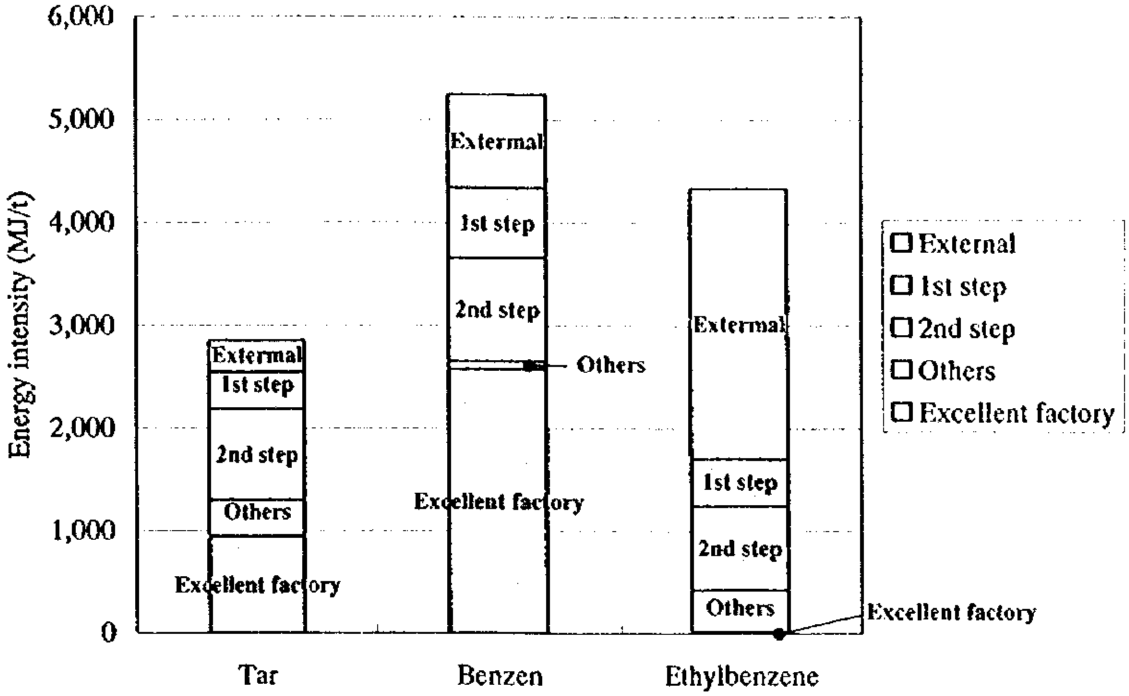
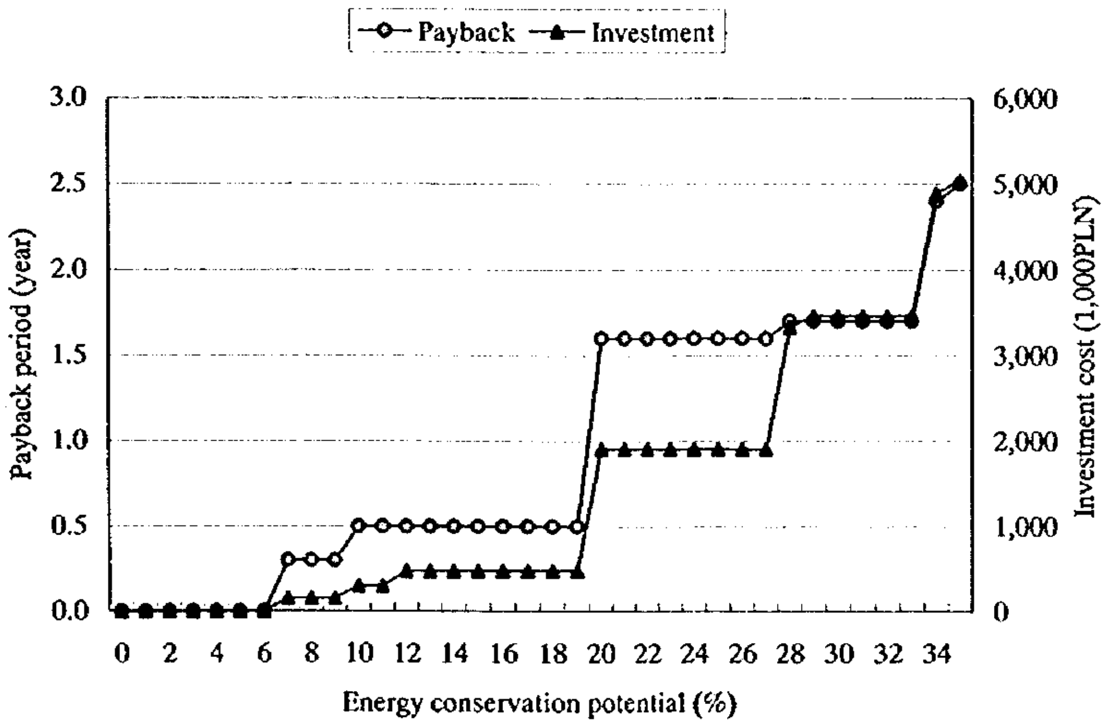


Figure 2.1.13 Brachownia Energy Conservation Potential



2.2 Results of the Study at the Poch Plant

(1) Study period: August 18 to 20, 1997

(2) Members of the study team

a. JICA Team

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

b. Local consultants

POLESCO Investment SA

Mr. Piotr Bortnowski	:	Vice President
Dr. Tadeusz Kruczek	:	Heat management
Dr. Wieslaw Goc	:	Electricity management
Dr. Krzysztof Wilk	:	Heat management

(3) Interviewees

Eng. Andrzei Szpila	:	Vice President of the Management Board Deputy Director of the Factory
M. Sc. Eng. Zygmunt Banas	:	Engineer of Production
Eng. Jan Prygiel	:	Engineer of Technology
Eng. Stanisław Pasternak	:	Head of the Electric-Mechanical Section
Mr. Stouislow Radwanski	:	Electric-Mechanical Section
Mr. Sc. Krystian Lukaszezyk	:	Manager of Research Department
Mr. Stanisluw Peruga	:	Chief of operation of boiler
Mr. Stanislow Zmuda	:	Operator of boiler
Mr. Jozef Derylo	:	Head of Department PO3

2.2.1 Profile of the Plant

(1) Plant name: Polskie Odczynniki Chemiczne

(2) Address: 44-101 Gliwice, ul. Sowinskiego 11

(3) No. of employees: 726

(4) Major products: Chemical reagents
(First-class chemical reagents, Industrial reagents, Industrial chemicals, Medicine raw chemicals and Laboratory testing paper etc.)

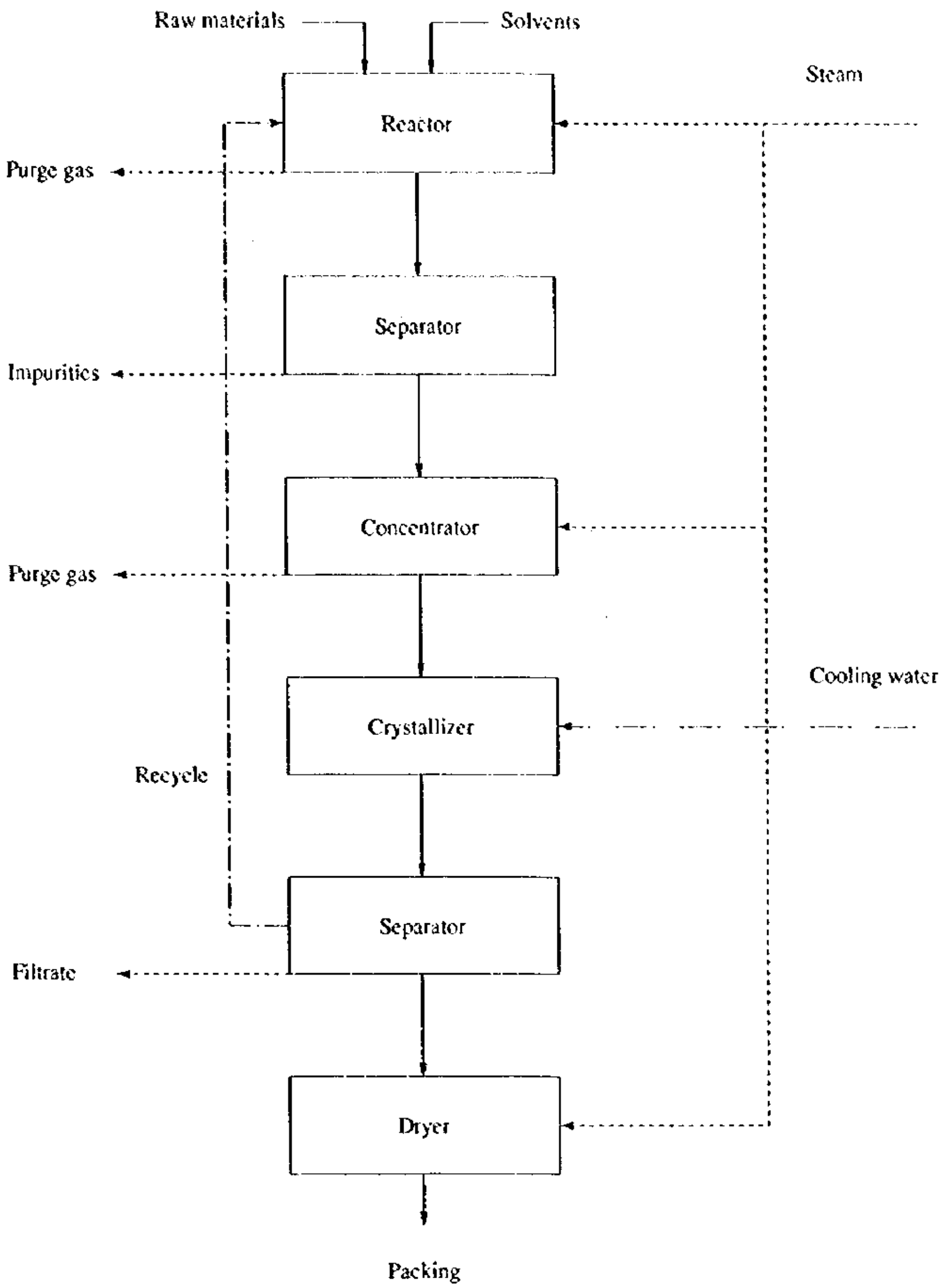
(5) Production capacity: 2,568 t/y (800 items)

(6) Outline of the process

Polskie Odczynniki Chemiczne is equipped with 200 units of reactors, 200 units of concentrators, 200 units of crystallizers, and others including autoclaves, filter presses, dryers, etc. to produce high-purity chemical reagents, industrial chemicals, medicine raw chemicals, health check-up or laboratory testing paper, etc. Figure 2.2.1 shows the typical production process flow.

The products are high-quality reagents produced in the multi-item small lot production system; therefore, to avoid their degradation occurring with the elapse of time, the order production system where no long-term storage is available is employed. The reactors and so on are not always used for specific purposes, but reactors of proper capacity are used in combination upon order after cleaning whenever required.

Figure 2.2.1 Typical Process Flow

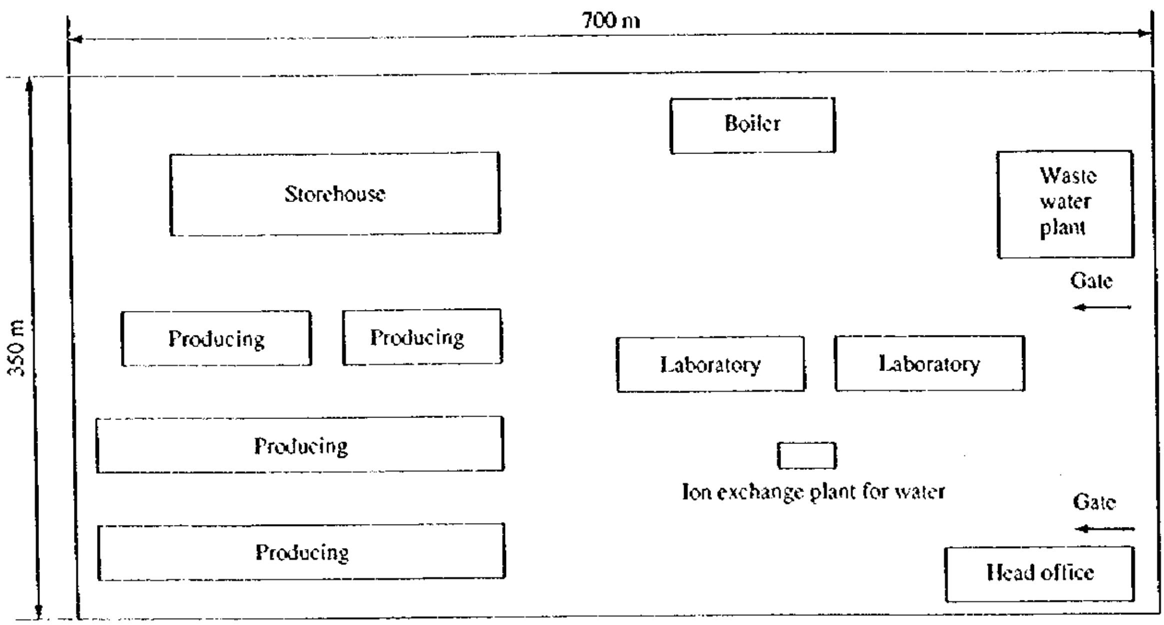


(7) History of the plant

This plant started operation as a chemical reagents plant utilizing the buildings and the waste water treatment facilities used by the former German Cavalry Division which had stationed there, and thereafter in 1992, formed the present Polskie Odczynniki Chemiczne (POCH S. A.). This plant is Poland's only chemical reagent maker, whose chemical reagents and high-purity chemicals account for 70 % of the total sales, imports and sales of chemicals 30 % and the exports 2 %. The plant, which had produced 1500 items up to 1990, are currently producing only 800 items because of the regulations relevant to harmful substances such as heavy metals, while inadequacy in items is supplemented through imports for domestic sales and supply.

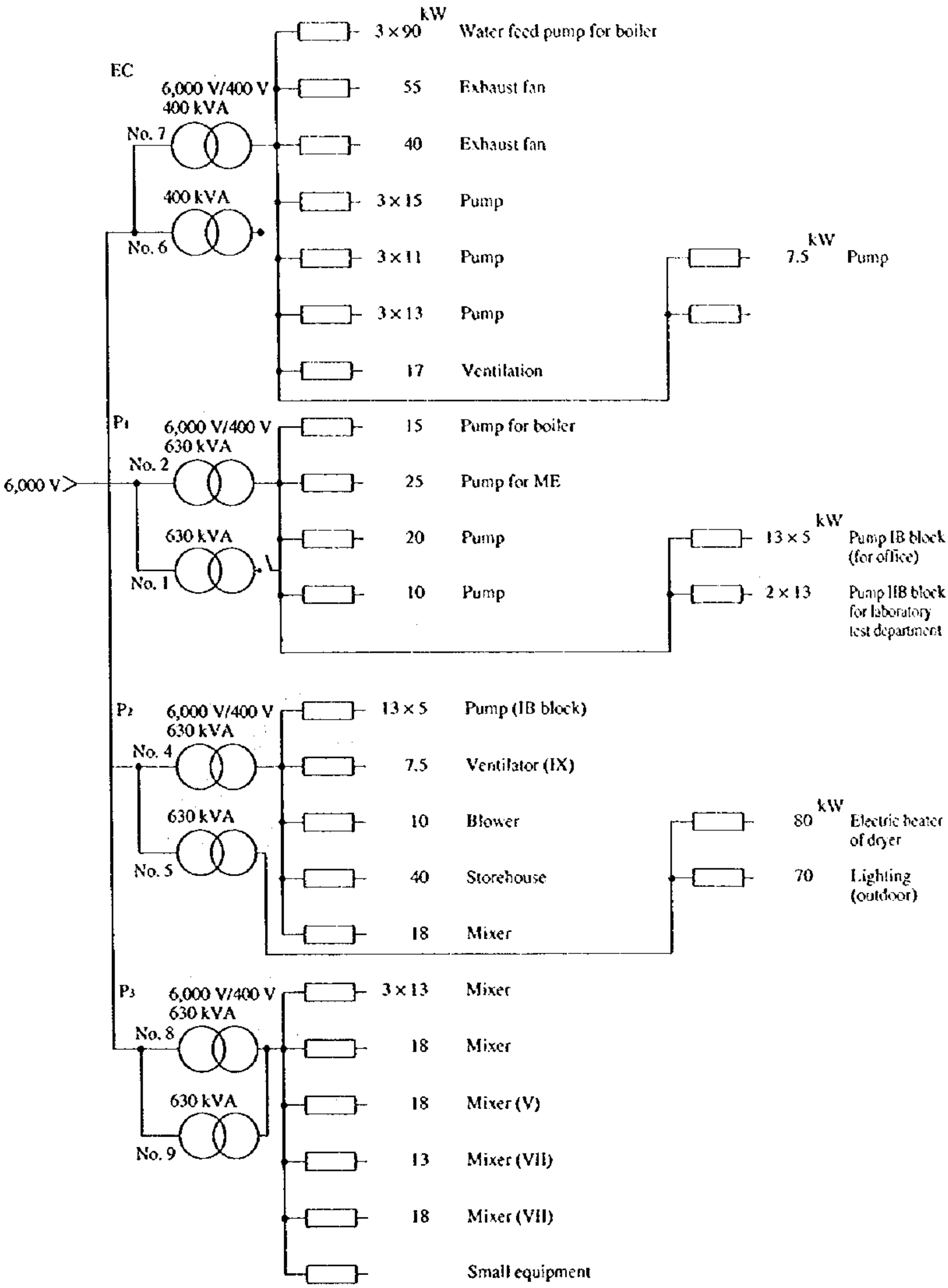
(8) Plant layout

Figure 2.2.2 Plant Layout



(9) One line diagram

Figure 2.2.3 One Line Diagram



(10) Outline of major equipment

Table 2.2.1 Major Equipment

Factory	Equipment	Number	Specification
Process	Reactor	200	0.05 ~ 1.6 m^3
	Concentrator	200	0.05 ~ 1.6 m^3
	Autoclave	60	0.05 ~ 1.6 m^3
	Crystallizer	200	0.05 ~ 1 m^3
	Filter press	NA	
	Dryer	NA	
	Centrifuge	NA	
	Compressor	NA	
	Evaporated crystallizer	NA	
	Acid resisting tank	NA	2.0 ~ 25 m^3
	Fine pulverizer	NA	
Utilities	Boiler	2	16 t/h (40 atm)
	Cooling tower	2	
	Water treatment	1	

(11) Energy price and heat value

Table 2.2.2 Energy Price and Heat Value

	Energy Price	Heat Value
Coal	145.2 PLN/t	28,000 kJ/kg
Natural gas	0.472 PLN/m^3_N (21.74 PLN/MJ)	21,713 kJ/m^3_N
Electricity	0.0995 PLN/kWh	10,258 kJ/kWh
City water	1 PLN/m^3	

2.2.2 Energy Consumption Status

(1) Trend of production

Table 2.2.3 Trend of Production

	Unit	1992	1993	1994	1995
Production	t	2,635	2,636	2,446	2,568

Products mix in 1995:
- First-class reagents : 775 t
- Industrial acid : 507 t
- Medicine raw material: 404 t
- Laboratory test paper : 309 t

(2) Trend of energy consumption

Table 2.2.4 shows the trend of energy consumption.
The large consumption of natural gas for 1992 as shown in the table is due to the temporary switching of the heating energy source from coal to natural gas.

Table 2.2.4 Trend of Energy Consumption

	Unit	1992	1993	1994	1995
Coal (total)	t	8,543	11,579	10,551	11,374
Natural gas	10^3m^3	2,372	126	136	125
Electricity	MWh	4,413	4,854	4,648	4,941
City water	10^3m^3	222	236	174	134

Coal (total: 100 %) = Process (34 %) + Heating (53 %) + [Sale (13 %)]
Steam consumption of process in 1995:

$266,000 \times 0.34 = 90,440$ GJ/y

$90,440/260 = 350$ GJ/d

(3) Trend of energy intensity

Table 2.2.5 Trend of Energy Intensity

	Unit	1992	1993	1994	1995
Coal (Heating)	MJ/t	48,100	65,200	64,000	65,700
Coal (Process)	MJ/t	30,900	41,800	41,100	42,200
Natural gas	MJ/t	19,550	1,034	1,211	1,057
Electricity	kWh/t	1,675	1,842	1,900	1,924
	MJ/t	17,182	18,895	19,490	19,736
Sub total (Process)	MJ/t	67,632	61,729	61,801	62,993
Total	MJ/t	115,732	126,929	125,801	128,693

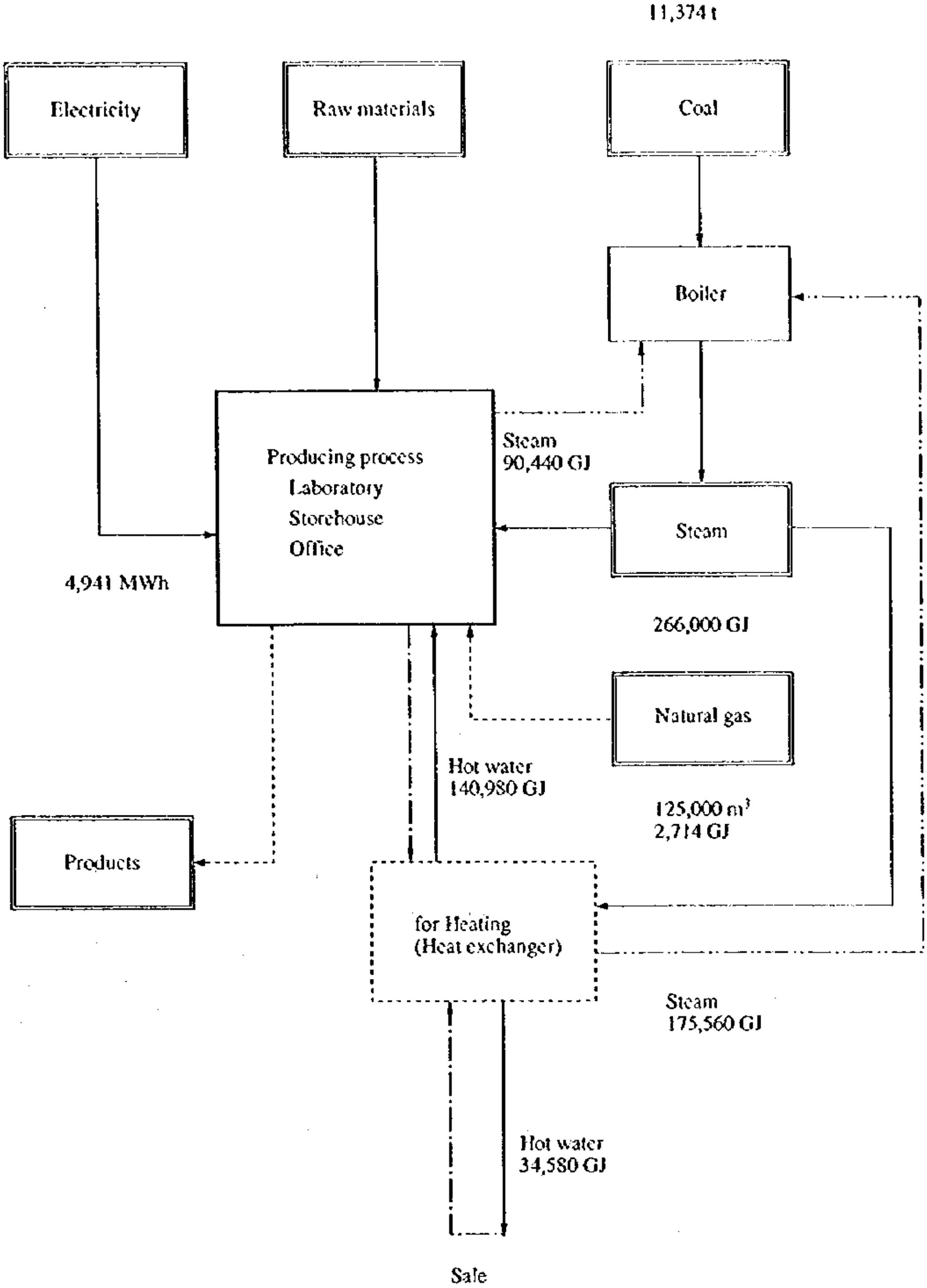
(4) Percentages of the energy costs in the total production cost

Steam (coal):	2.8 %
Electricity :	1.1 %
Total :	3.9 %

(5) Energy flow

34 % of the generated steam is used for the production processes, while 66 % is used for heating (for internal consumption and external sales). All the natural gas and electricity are used for processes. Among other uses, which are not shown in the table, gasoline and diesel oil are used for rental cars for transportation.

Figure 2.2.4 Energy Flow



2.2.3 Current Situation of Energy Management

(1) Setting the target for energy conservation

a. Setting the target value

No target value has been set so far.

b. Problems in the promotion of energy conservation efforts

The percentage of energy cost in production cost is as low as 3.9 % due to expensive raw materials, and the people's awareness for energy conservation is low as well. Moreover, they have a living custom to heat the entire building, thus consuming a large amount of steam.

(2) Systematic activities

a. Setting up a department dedicated to energy conservation

No such department has been available so far.

b. Setting up an energy conservation committee

No such committee has been available so far.

c. Top management's stance

The top management staff seem to have a considerably great sense of crisis under the current economic circumstance of structural renovation, exerting positive efforts to obtain ISO 9000 certification concerning the quality control. In terms of the attainment level, however, they are still at the preparatory stage for quality control, and thus presently do not afford to direct their attention toward energy conservation.

(3) Data-based management

a. Grasping the energy consumption

They manage the boilers well, and have also a correct understanding of the energy consumption in the entire plant.

b. Grasping the energy consumption for each major equipment

They have no correct understanding of the energy consumption for each major equipment since there is no steam measuring instrument available for each production building and facility.

c. Grasping the energy intensity for the major products

They do not keep track of energy intensity. Energy cost is proportionally allocated to each product (800 items).

d. Installing measuring equipment

Although steam measuring instruments are available for the external selling line, there is no other such instrument.

e. Production management and cost management

Quality-oriented management is performed.

(4) Plant engineering

Major types of equipment including reactors are managed well. Exhaust from the facilities in the factory is discharged untreated into the atmosphere because of their inadequate plant maintenance (Number of exhaust stacks: 100). With regard to the exhaust gas, many facilities are not equipped with treatment equipment itself, and thus countermeasures will be required in the future.

2.2.4 Problems and Countermeasures related to Energy Use

(1) Features in energy use

a. Process

The system is of the batch operation type intended for multi-item small lot production. For the facility scale, many containers, each capacity of which is 1 m^3 or smaller, are combined for use according to the product.

For example, in the ammonium diphosphate production process whose scale is relatively larger, reaction occurs in a reactor whose capacity is approximately 1 m^3 and the material is transferred to the cooling tank for crystallization. After separation by a centrifugal separator, the separated substance is transferred to the dryer and the dry product (500 kg) is produced. On the other hand, the amount of ammonium diphosphate produced in 1996 was 7,000 kg, which indicates that the manufacture of this product is implemented 14 times annually. Although this equipment uses piping for connection from the reactor to the centrifugal separator, actually manual intervention is required for transportation in most cases.

As such, efficiency of operating the units configuring the process is lower. However, this may be inevitable because 800 high-purity reagents are being produced.

b. Utilities

A jacket type reactor is used for dissolution and reaction of the material with steam used as the heating source. For separation of the substance generated as a result of reaction, the jacket type container is used for condensation and cooling or cooling alone by means of steam or cooling water. Most products are produced in the form of dry powder and steam is used as the heating source. Because of small-volume operation, the box type dryer is mainly used for drying, while the continuous dryer is used exceptionally.

(2) Estimating the energy conservation potential

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

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

2.2.4.1 Process

a. Reaction process

1) Heat transfer

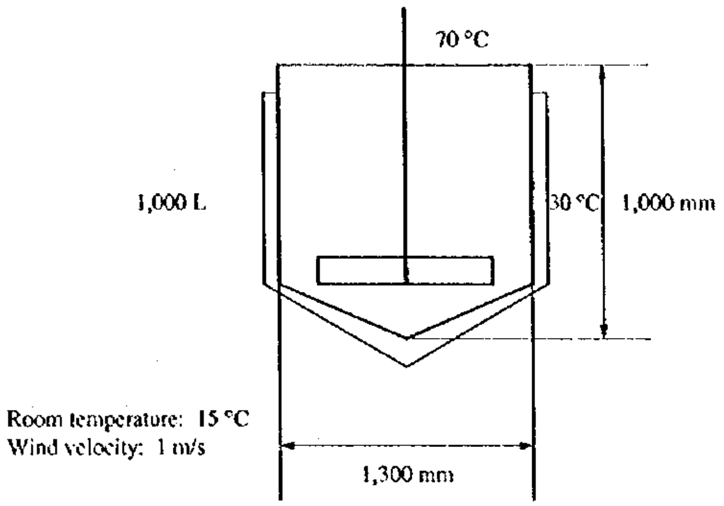
Inorganic reaction is mainly applied with water used as a solvent. The reaction temperature is 100 °C or below (generally between 80 °C and 100 °C). The reaction temperature is about 105 °C at the highest though reaction may also occur at 100 °C or above because the boiling point rises if concentration of inorganic compound solution is high.

Heat required for heating is supplied in the form of steam. Since the containers are to be used for many purposes, the externally-heated jacket type is used instead of the multi-tube type and coil type which are inadequate for washing. The heat transfer efficiency is determined by the shape of the container and the heating surface area. As another factor relating to heat transfer efficiency, the condensation heat transfer efficiency depending on the steam flow is considered.

2) Heat insulation

Although the vessel part of the container is provided with heat insulation, the cap part is not insulated. Relatively large-sized containers should be heat-insulated except for the nozzles. This heat insulation is not regarded to impede the operability.

Calculation is given on typical containers with regard to heat loss due to radiation.



Surface area (m^2)
  Vessel: 4.1 + 1.3 = 5.4 (85 %)
  Cap: 1.3 (15 %)
    Total 6.7
Heat loss (kJ/h)
  Vessel: 3,390
  Cap: 3,000

As shown in the figure, heat nearly equivalent to the radiation heat from the vessel is assumed to be emitted from the cap part.

No. of vessels of 1 m^3 to 1.6 m^3:

Reactor	60
Concentrator	60
Total	120

Assuming that the operating rate is 50 % , the average reaction time is 12 h/d, and the volume is 1m^3, the following formula will be obtained:

Current radiation amount:
  120 × 0.5 × 12 × (3,000 + 3,390) = 4,600,800 (kJ/d)
Radiation amount when the cap is provided with heat insulation:
  120 × 0.5 × 12 × (3,000 × 1/5 + 3,390) = 2,872,800 (kJ/d)
Difference in the radiation heat: 1,728,000 (kJ/d)

Energy conservation amount: 1,728 GJ/d × 260 d/y = 449 GJ/y

Assuming the boiler efficiency to be 80 %, the energy conservation amount on a coal basis will be:

449/0.8 = 561 GJ/y

3) Maintenance of the steam trap

When we visited the factory, many facilities were out of service. Therefore, we could not judge whether the steam trap was operating satisfactorily.

Heating steam pipes for several reactors are centralized and one steam trap recovers condensate. This group trapping will make the temperature of heating each container uneven and as a result, condensate cannot be easily drained. Measures, such as opening the bypass valves, are taken to compensate for the shortage of steam flow rate due to poor condensate discharge, and as a result heat losses involved in these unusual types of operation are likely to occur. If individual trapping in which a steam trap is available for each container is employed, the heating efficiency of each heater can be brought to the maximum because mutual interference between the heaters of reactors can be avoided. By changing from group trapping to individual trapping, 10 % steam saving can be expected. Although the investment payback years may be longer, steam consumption of each reactor can be measured through the steam trap attached to each reactor. By keeping track of the difference of the measured condensate amount and the theoretical required steam consumption, the heat balance for the entire factory can be calculated.

Reactor subjected to calculation:

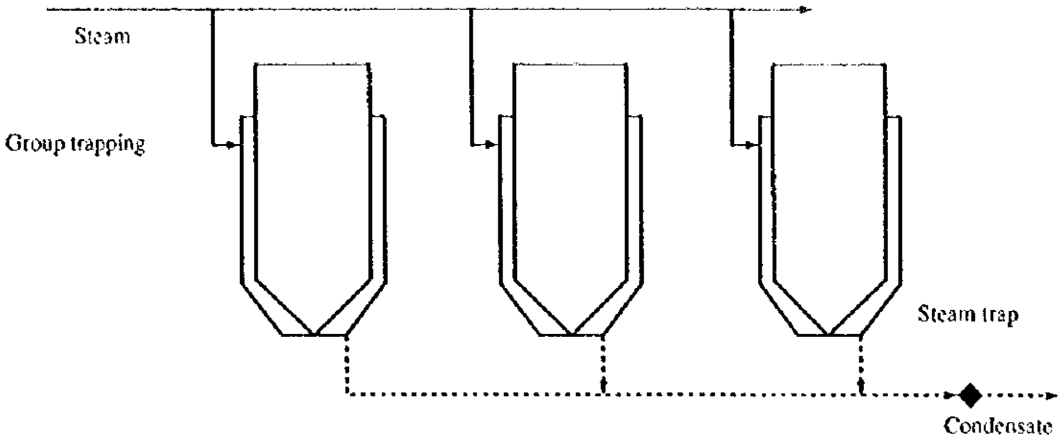
Reactor	200
Concentrator	200
Autoclave	60
Total	460

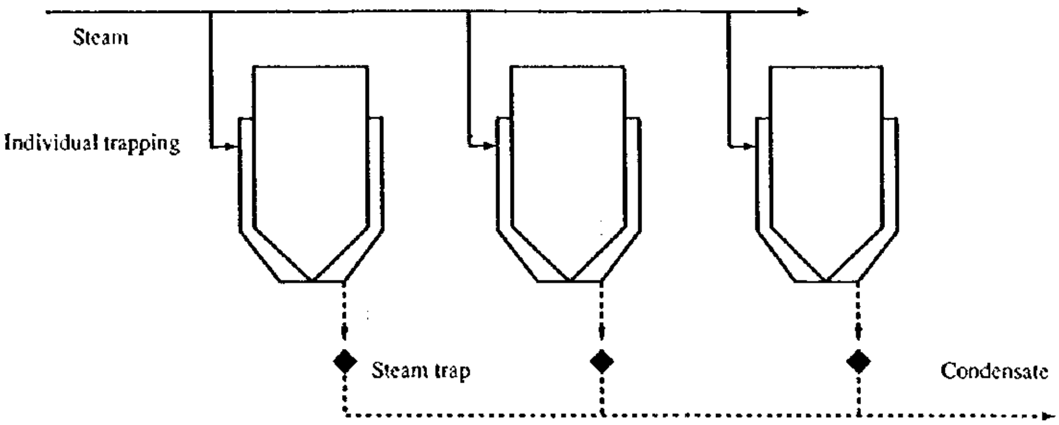
Steam consumption in the process: 90,440 GJ/y

(Second step)
Steam consumption saved by maintenance of the steam trap:
$90,440 \times 0.1 = 9,044$ (GJ/y)

Coal consumption at boiler efficiency 80 %: 9,044/0.8 = 11,305 (GJ/y)

Steam trap maintenance cost:
1,000 (PLN/pc) × 460 pc = 460,000 (PLN)





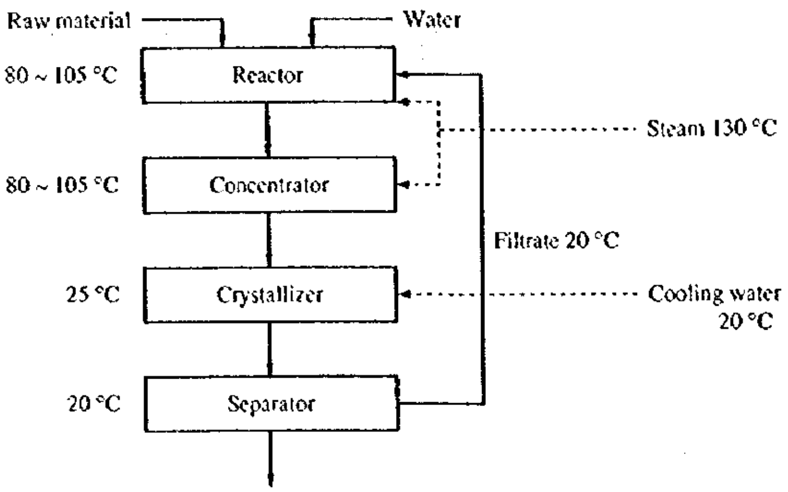
$$\text{Payback period: } \frac{28\times10^{6}\,\text{kJ/t}\times460{,}000\ \text{PLN}}{145.2\ \text{PLN/t}\times11{,}305\times10^{6}\ \text{kJ/y}} = 7.8\ \text{years}$$

b. Concentration process

This process is the same as the reaction process.

c. Crystallization process

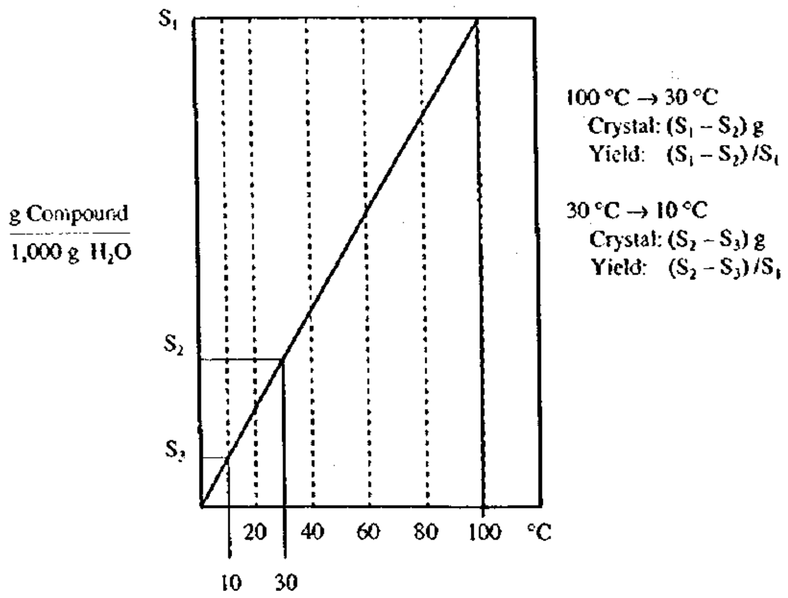
1) Current flow



2) Improvement of crystallization yield

Crystallization yield in winter is higher than that in summer, because crystallization temperature in 30 °C in summer and 10 °C in winter. If crystallization temperature in summer is kept at 10 °C by modification of cooling tower, energy consumption for the circulation of compounds is reduced by the improvement of crystallization yield.

Generally, solubility of inorganic compounds is higher at a high temperature and lower at a low temperature. This pattern is shown below.



In the reaction process of silver nitrate, the yield is improved by 10 % when the crystallization temperature is lowered from 30 °C to 10 °C.

[Example] $AgNO_3$ S_1: 9,860, S_2: 2,550, S_3: 1,530

Yield: 100 °C → 30 °C (9,860 – 2,550)/9,860 × 100 = 74 (%)

100 °C → 10 °C (9,860 – 1,530)/9,860 × 100 = 84 (%)

Difference: 84 – 74 = 10 (%)

To reduce crystallization temperature is an effective means for energy conservation, although temperature characteristics of solubility differ depending on the compound. Improving the yield for each batch is the more effective because of multi-item small-lot production, though the base liquid is circulated, resulting in no loss. The circulated base liquid is reheated to the reaction temperature. Silver nitrate is used for calculation:

[Example] $AgNO_3$: Specific heat Cp = 50 J/°C·mol

= 50/170 J/°C·g = 0.3 J/°C·g

(MW (Molecular Weight) of $AgNO_3$ = 170)

When the separating liquid (filtrate) is circulated and heated for reaction along with the new material, the ratio of the required energy is equivalent to the ratio of the specific heat. If the specific heat for the filtrate is assumed to be simply associated with a conversion treatment (additive property) and each specific heat for water and silver nitrate is used for calculation, the amount to be heated decreases by the increment in the crystallized amount, and as a result the heat value for heating the circulated liquid can be reduced by 6 % for 1,000 g H_2O in the first reaction:

Current status : (100 °C → 30 °C) Filtrate: H_2O 1,000 g, Crystal 2,550 g

$H = (4.186 + 0.3 \times 2.55) = (4.186 + 0.765)$ kJ/°C

After change of cooling temperature:

(100 °C → 10 °C) Filtrate: H_2O 1,000 g, Crystal 1,530 g

$H = (4.186 + 0.3 \times 1.53) = (4.186 + 0.495)$ kJ/°C

Heat saving: (0.765 – 0.459)/(4.186 + 0.765) = 6 (%)

In the next reaction, the material corresponding to the shortage to Si: 9,860 is charged, and energy saving is therefore as follows:

H_2O 1,000 g, Crystal (Raw) 9,860 g

$H = (4.186 + 0.3 \times 9.86) = (4.186 + 2.958)$ kJK^{-1}

Heat saving: (0.765 – 0.459)/(4.186 + 2.958) = 4 (%)

Compared with the current status, the yield per batch is improved by 10 % and the heat value is reduced by 4 %.

Strictly, the specific heat of the solution is not only associated with a conversion treatment (additive property) but also with the reaction heat. Yield is not regarded to be so important unless the filtrate is discarded though uncystallized components remain to decrease the amount to be charged next time and the equipment efficiency drops since the filtrate is circulated. However, for multi-item small-lot production, washing operation is required each time the item is changed. Therefore, improvement of the yield per batch is efficient and it is effective for reduction of the sludge load in waste water.

Fuel saving is calculated as follows:

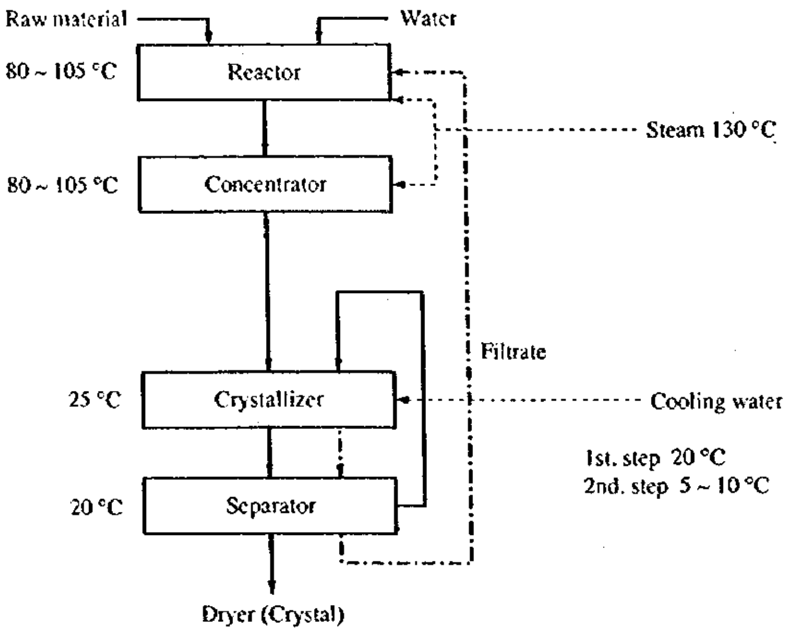
For the 1st class reagent and medicine raw material on the assumption of a 4 % saving (See Table 2.2.3), the following can be obtained.

775 + 404 = 1,179 t/y
1,179 × 6/12 = 590 t/y (Summer)

Energy conservation amount:

590 × 0.04 × 42,200 = 996 GJ/y (Energy intensity in coal): 42,200 MJ/t)

Additionally, this energy calculation is designed to obtain the energy amount required for making the cooling water temperature 10 ° or lower for the period of 6 months in the summer season.



d. Drying process

1) Drying mode

① Spray dryer

For the capacity, the amount of liquid supplied is as small as approximately 120 L/h and the drying temperature is also low. Therefore, installation of a heat exchanger (with a powder adhesion preventive system) is not reasonable and there is almost no allowance for energy conservation.

The process should be to perform cooling in the same way as before and then to cool the base liquid after the crystal is separated. A chilling unit should be installed to reduce cooling water temperature in summer.

② Rotary dryer

Since this dryer of about 400 mm drum diameter is small-sized and also low-temperature drying is implemented. installation of a heat exchanger (with a powder adhesion preventive system) is not reasonable and there is almost no allowance for energy conservation.

③ Box type dryer

This mode is suitable for multi-item small-lot production. For prevention of heat radiation, establishment of the operating procedure that reduces the door open time is effective.

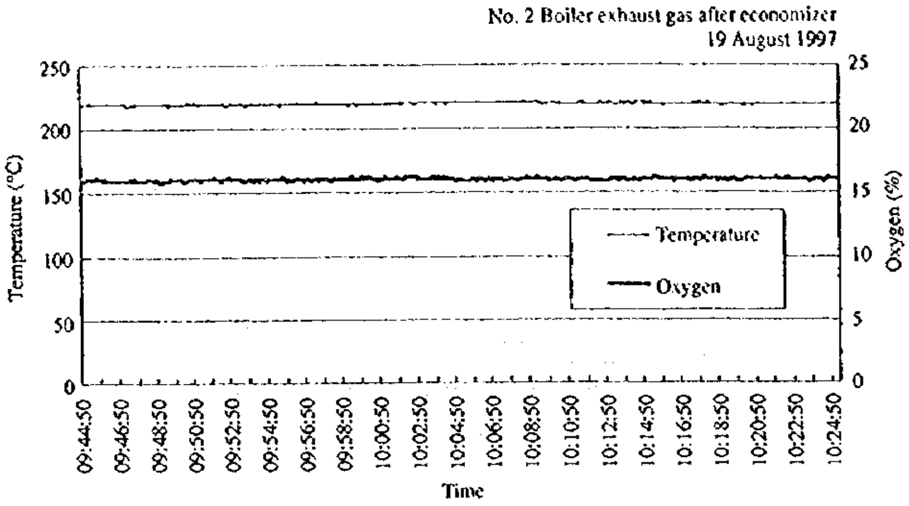
2.2.4.2 Utilities (Heat utilization facilities)

1) Measurement of boiler exhaust gas

This plant is equipped with 2 water tube boilers for heating and for processing. During our survey at this plant, when only one boiler was being operated by coal firing due to non-heating season, the exhaust gas oxygen content and exhaust gas temperature were measured. The measurement was carried out at 2 points, that is, the points after and before the economizer. The boiler load at measurement is 5 t/h, which seems to be this boiler's minimum load operation level.

Figure 2.2.5 shows the results of measurement after the economizer.

Figure 2.2.5 Measurement Results of the Boiler Exhaust Gas (After the economizer)



As shown in Figure 2.2.5, there is hardly any change in the exhasut gas oxygen content or temperatures. Table 2.2.6 shows the mean values and so on within the period of the measurement for the 2 measuring points.

Table 2.2.6 Mean Values in Boiler Exhaust Gas Measurement

	After Economizer 09:44 to 10:24, every 2 seconds			Before Economizer 10:53 to 11:33, every 2 seconds	
	Temperature	Oxygen		Temperature	Oxygen
Average	219.6 °C	16.0 %	Average	420.3 °C	15.0 %
Maximum	221.3 °C	16.2 %	Maximum	427.4 °C	15.6 %
Minimum	218.4 °C	15.8 %	Minimum	413.1 °C	14.4 %

Table 2.2.7 shows the results of combustion calculation conducted using the measurement value after the economizer. As shown in this table, the air ratio obtained from exhaust gas oxygen content 16 % is 4.16, which is significantly high. In our view, however, adjusting the air fuel ratio will allow exhaust gas oxygen to be reduced by 10 % (1.85 for air ratio) or lower even with air intrusion from the outside taken into consideration, which will be mentioned later.

Fuel saving: $11{,}374 \times 0.166 \times 28$ GJ/t = 52,866 GJ/y

Table 2.2.7 Fuel Reduction Effect of Air Ratio Control

Preconditions

Coal	
Net heat value (kJ/kg)	27,995
Net heat value (kcal/kg)	6,688
Ash content	8.00 %
Water content	6.00 %
Combustion air temperature	28
Exhaust gas temperature	216.9

Notes: The measuring point is after the economizer.

Calculation Result

	Theoretical Combustion	Current Air Ratio	Air Ratio after Improvement
Oxygen in exhaust gas	0.0 %	16.0 %	10.0 %
Air ratio	1.00	4.16	1.89
Air amount (m^3/kg)	7.1	29.7	13.5
Exhaust gas amount (m^3/kg)	7.5	30.1	13.9
Exhaust gas loss rate (against fuel heat)		27.5 %	13.1 %
Fuel saving rate			16.6 %

Notes: For air ratio, the minimum values for the other similar factories are listed.

In this connection, the air ratio obtained using the measurement value before the economizer is 3.46, which is 0.7 smaller than the air ratio after the economizer. This means that, if the measurement is correct, in the economizer there was air infiltration equivalent to air ratio 0.7, which corresponds to 4.9 m^3_N/kg of coal in terms of air volume.

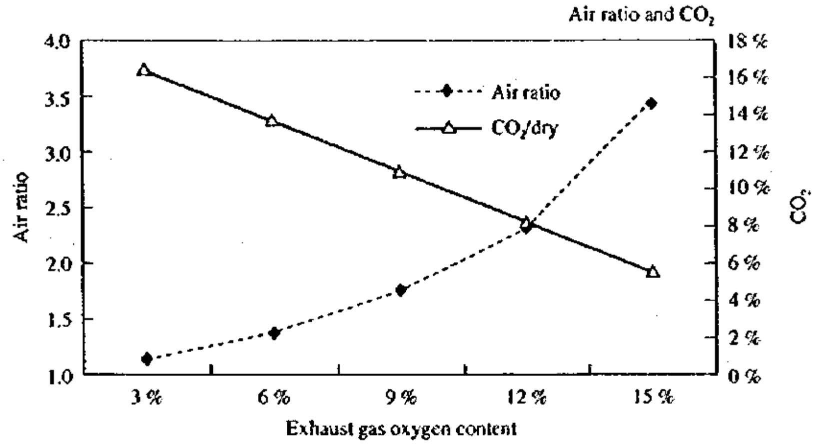
As shown in Table 2.2.7, the heat loss due to exhaust gas is 27.5 %. Therefore, considering other losses, such as heat loss from the furnace body, the boiler heat efficiency is presumed to be 65 %.

The boiler monitoring panel is provided with a CO_2 analyzer, which indicated 6.5 % on the day of our survey.

$(CO_2)_{max}$ is calculated based on fuel composition. Thus it is recommendable as a simplified means to manage the air ratio (= $(CO_2)_{max}/(CO_2)$) using the value indicated on the CO_2 analyzer.

Therefore, for your reference, the relationship between oxygen and CO_2 exhaust gas based on combustion calculation is shown in Figure 2.2.6.

Figure 2.2.6 Exhaust Gas Oxygen Content and CO_2



The fuel composition used for these sets of calculation is as shown in Table 2.2.8. The specification of this boiler is shown in Table 2.2.9.

Table 2.2.8 Composition of Fuel Coal

C	H	O	N	S	Water content	Coal ash content
81.5 %	4.9 %	11.4 %	1.3 %	0.8 %	6.0 %	8.0 %

Table 2.2.9 Boiler Specification (Design value)

No. of units installed	2
Year of installation	1970
Type	Coal stoker-fired water tube boiler
Evaporation volume	16 t/h
Steam pressure and temperature	4 MPa × 450 °C (For operation, 2.9 MPa × 370 °C)
Economizer	Low temperature part: Cast iron tube with fin
	High temperature part: Steel tube
Air preheater	Installed for gas combustion (for one boiler only)
	Not used because coal firing is currently used
Drafting system	Balanced drafting (IDF 55 kW, FDF 40 kW)
Feed water pump (For 2 boilers)	Motor 90 kW: 3 units
	Turbine-driven: 1 unit
Feed water processing	Double-floor type ion exchange processing
	(Used also for processing)
	Deaerated by pressurizing

2) Reducing the electricity for the boiler's auxiliary machine

The power required for the feed water pump under the current boiler operation condition is not more than 11 kW even when the efficiency is assumed to be 50 %. By contrast, 90 kW of the motor for the current feed water is too large; therefore, this requires such considerations as installing a small-sized pump for low-load.

Moreover, although these boilers were initially intended for power generation by steam turbines, no steam turbine was provided. Thus, the pressure of the steam generated by the boiler is higher than necessary (2.9 MPa) for use in processes, which is reduced to 0.4 MPa for use. If operation can be performed under reduced boiler steam pressure, the power required can be decreased by modifying the feed water pump so as to meet the pressure. This matter needs to be further discussed with the boiler designer.

These boilers were initially so desinged as to allow also gas-firing. Thus, one of the boilers is provided with an air preheater. However, this preheater is not used since coal firing system is now employed. In other words, exhaust gas is passed through the preheater, but exhaust air is not passed through it. This causes unnecessary pressure loss corresponding to the amount passing through the air preheater on the exhaust gas side.

If this preheater is removed and this part is connected with the short duct, the pressure loss is reduced, thus resulting in the saving of the electricity for boiler Induction Draft Fan (IDF).

3) Reinforcing the heat insulation of the steam valve

Steam valves in this plant are not provided with heat insulation except for large-size valves. Table 2.2.10 shows the results of calculating the heat radiation based on the No. of installed valves assumed based on the resutlt of our factory survey so as to grasp the standard of the heat radiation from the uninsulated valves. As shown in this table, heat value equivalent to approximately 0.5 t/h of steam volume is presumed to be emitted from the non-insulated steam valves.

Table 2.2.10 Heat Radiation Amount

Nominal Diameter (mm)	Equivalent Length (M)	No. of Units Installed	Radiation Amount (kcal/h)	Radiation Amount (kJ/h)	Equivalent Steam (kg/h)
50	1.11	300	98,279	411,476	164
100	1.27	100	70,813	296,480	118
150	1.50	30	36,265	151,833	60
200	1.68	20	35,453	148,437	59
250	1.76	10	22,991	96,259	38
Total			263,802	1,104,485	440

Preconditions for calculation: Outside temperature 28 °C, valve surface temperature 140 °C,
Steam heat amount 600 kcal/kg = 2512 kJ/kg

Here, energy conservation is estimated with some allowance taken into account on the assumption that the heat radiation loss could be reduced.

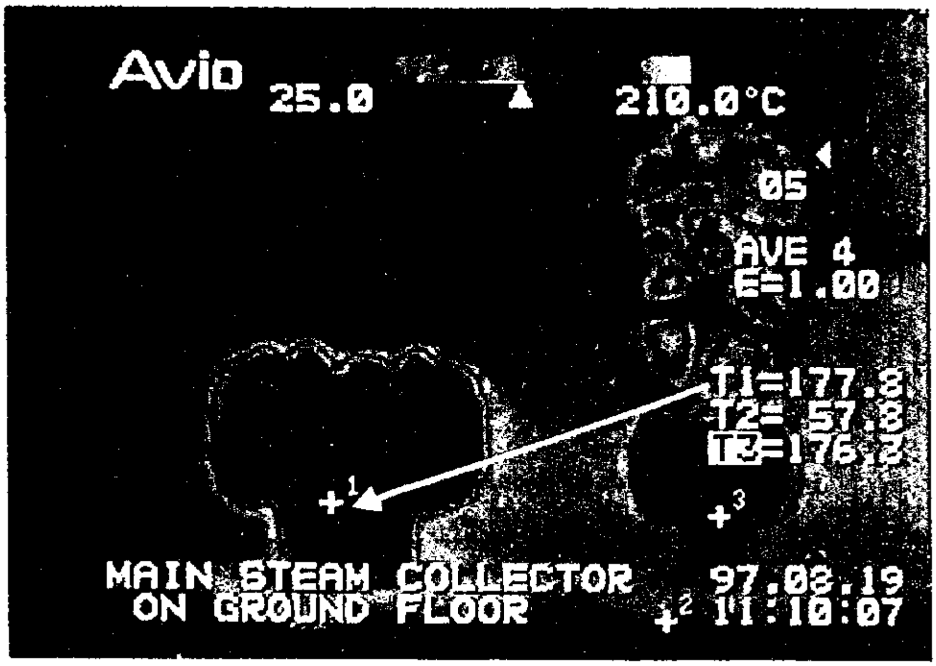
$1{,}104{,}485 \times 8{,}760 \times 0.7 = 6{,}773$ GJ/y

Assuming the boiler efficiency to be 80 %, the coal-based energy consersation amount will be as follows:

$6{,}773 \div 0.8 = 8{,}466$ GJ/y

These uninsulated high-temperature portions can be visually identified using an infrared thermal video system. Figure 2.2.7 shows an example.

Figure 2.2.7 Thermal Image of the Non-insulated Valve (Main steam header in the boiler auxiliary machinery room)



2.2.4.3 Utilities (Electricity utilization facilities)

1) Energy conservation for the electricity supply facility

Two power-receiving transformers in this factory are provided in each of 4 substations (i.e. totally 4,580 kVA provided). Electricity used (including the boiler) is 600 kW to 1,000 kW (in winter). Thus, since each transformer is relatively lightly loaded and the following actions should be examined:

Recommendable measures:

① One of 2 transformers in each of 4 substations should be turned off at the high-voltage side.

② The low-voltage (400 V) power distributing line of each substation should be connected via overhead cable and the unnecessary transformer should be shut down, as required. If possible, the transformers in the P2 (see Figure 2.2.3) substation should be shut down.

Effect: If it is assumed that the power load (except for the boiler whose load is heavy in winter season) is approximately 500 kW, cos ϕ is 96 %, and the power losses of the 630 kVA transformer are 1.9 kW (iron loss Wi) and 8.77 kW (copper loss Wc), the losses before and after improvement are as shown in Table 2.2.11. It is assumed that the load at this factory is roughly constant. As a result, the electricity saving effect is approximately 3.9 kW and saving per year is approximately 34 MWh.

Table 2.2.11 Transformer Capacity Reduction and Changes in Loss

	Transformer capacity (kVA)	Iron loss Wi (kW)	Copper loss Wc (kW)	Loss total (kW)	Saving power (kW)
Current status	5 × 630	5 × 1.9	1.20*	10.7	
After modification	2 × 630	2 × 1.9	2.99**	6.88	3.9

*: $8.77 \times 5 \times (500/630/5/0.96)^2 = 1.20$ kW **: $8.77 \times 2 \times (500/630/2/0.96)^2 = 2.99$ kW

2) Energy conservation for the boiler's motor

① Feed water supply motor (90 kW)

Electricity consumption was measured continuously for approximately 13 hours. As a result, power consumption was 48.4 to 50.5 kW, which indicated no change.

During measurement, we expected the changes in the operation status and feed water (steam) volume in vain. The cause is considered to be one of the following:

- Steam consumption is constant.
- Surplus steam/water is discharged.
- The feed water volume is minimal to boiler.

With regard to pumps for water supply and motor, their capacity is too large for their operation rate as pointed out in previous paragraph B.2). Therefore consideration should be given to the size reduction of these devices.

② Exhaust fan (55 kW)

This fan was operating with about a half of the rated capacity. The volume of combustion air needs to be changed depending on the boiler's load fluctuation and thus the fans should accommodate these fluctuations of the boilers.

Recommendable measures:

- If surplus steam is discharged or exhaust gas valume is less, revolution control with an inverter is considered. For this purpose, the feed water volume, degree of valve opening, pressure variation status, etc. should be investigated.

- Both motors with excess capacity should be replaced with small capacity motors in a timely manner.

Effects: Generally in motor inverter control reduction of the flow rate by 20 % allows electricity consumption to be saved by approximately 45%, although this may differ depending on the control range and flow rate control method.
If the motors are replaced with small capacity motors (e.g. from 90 kW to 75 kW), the motor loss is reduced and the power factor can be improved for saving of electricity but the investment payback period is long because a considerable amount of investment is required.
In contrast, if the flow rate is controlled by an inverter, electricity consumption can be reduced by approximately 40% when the flow rate is reduced by 20%. Thus, although the reduction rate becomes somewhat lower, this method is recommended because of smaller investment and easier introduction. Additionally, control with an inverter is effective for ventilator air flow control in the factory.

Electricity saving by installation of an inverter unit:

$$(50\ \text{kW} + 28\ \text{kW}) \times 0.4 \times 260\ \text{d/y} \times 24\ \text{h/d} = 195\ \text{MWh/y}$$

3) Energy conservation for lighting

Mercury lamps are used for outdoor lighting in this factory, consuming approximately 70 kWh. They are automatically turned on/off depending on illuminance. For general energy conservation measure for this, the mercury lamps are replaced with high-voltage sodium lamps. As a result, power of approximately 40% can be reduced, which means a great electricity saving effect. For example, if all the 70 kW mercury lamps are replaced with high-pressure sodium lamps, an approximately 50 MWh or more power saving can be achieved.

(3) Summary of Energy Conservation Potential

a. Improvement of Environment through Energy Conservation

If fuel consumption is reduced through energy conservation, the quantity of pollutants emitted to the atmosphere also decreases. Additionally, if the amount of purchased power is reduced through energy conservation, so is the amount of power generated, that is, the quantity of pollutants emitted to the atmosphere by power plants. This reduction in emission quantity due to energy conservation depends not only on the amount of energy conservation, but also the type of fuel, and equipment, such as boilers, etc. Therefore the correct way to estimate the quantity of pollutants is to use the actual amount emitted by each factory. Here, however, for the sake of the consistency with the comprehensive study on Poland as a whole, calculations are based on information on the unit emission quantity (pollutant tonnage/fuel-heating value TJ), per industrial sector and per fuel type, provided by a document from the Institute of Environmental Protection. The reduction in the emission of air pollutants from this factory achieved as a result of energy conservation is compiled at each stage of energy conservation, and shown in Table 2.2.12.

Table 2.2.12 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_2	Dust
Step 0				
Step 1	5,086	34.9	16.4	7.6
Step 2	2,054	14.1	6.6	3.1
Step 3				
Step 1-3	7,140	49.0	23.0	10.6

Reduction includes emission from fuel and electricity.

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

The result of calculating the amounts of reduction in pollutant emission, for the energy conservation items that were proposed based on our factory survey, and the corresponding reductions in emission fees, is shown in Table 2.2.13. Furthermore, the payback period required to recover investments in energy conservation including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 2.2.13 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ PBP	Economical PBP
Step 0						
Step 1	383	17.7	401	0	0.00	0.00
Step 2	200	7.1	207	1,009	4.87	5.05
Step 3						
Step 1-3	583	24.8	608	1,009	1.66	1.73

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

As evident from this Table 2.2.13, the reduction in emission fee is only a few percents at most compared to reduction in energy cost, and thus, the effect of reduced emission fees on the payback period is also negligible.

The major recommendation item for energy conservation in this factory is to reduce coal consumption. Since the emission fee for the sulphur content in coal is significant, the effect of reduction in the emission fee is larger than that of other fuels, accounting for several percents as compared to the energy cost reduction effect. The major energy source in this factory is the coal purchased as the fuel for in-house power generating plant, and thus energy conservation measures have a relatively significant effect in the reduction of air pollutant emission fees. In other words, coal has a large amount of pollutant emission per unit heating value of fuel, and accordingly the unit emission fee becomes large, thus exerting a significant effect on the emission fee reduction.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 2.2.13.

The energy conservation potential using the Excellent factory as the benchmark for energy consumption intensity, and energy conservation measures in Steps 1, 2, and 3 are shown in Figure 2.2.8. The relationship between energy conservation potential, the period to recover the investment, and the investment cost is shown in Figure 2.2.9.

Table 2.2.14 Summary of Energy Conservation Potential

Natural gas: 0.514 PLN/m³N (36.5 MJ/m³N) Coal: 170 PLN/t (23.8 GJ/t) Electricity: 0.172 PLN/kWh 1 PLN = 30 yen

Item	Energy Conservation Potential							Investment	Payback period
	Fuel			Electricity			Total		
	GJ/y	10^3 PLN/y	%	MWh/y	10^3 PLN/y	%	10^3 PLN/y	10^3 PLN	year
Step 1									
1. Improving the air ratio of boilers	52,866	378	16.5				378	0	0.0
2. Reducing the capacity of the transformer				34	6	0.7	6	0	0.0
Subtotal	52,866	378	16.5	34	6	0.7	383	0	0.0
Step 2									
3. Reinforcing the cover of the reactor	562	4	0.2				4	17	4.2
4. Increasing No. of steam traps	11,305	81	3.5				81	460	5.7
5. Insulating the steam valves	8,466	60	2.6				60	211	3.5
6. Improving the crystallization yield	996	7	0.3				7	57	8.0
7. Boiler motor control with inverter				195	34	3.9	34	47	1.4
8. Lighting: Changing to sodium lamps			0.0	82	14	1.7	14	217	15.4
Subtotal	21,329	152	6.6	277	48	5.6	200	1,009	5.0
Total	74,195	530	23.1	311	53	6.3	583	1,009	1.7

As of 1995: Fuel consumption: 321,185 GJ/y
Electricity consumption: 4,941 MWh/y (50,685 GJ/y)
Total: 371,870 GJ/y

Figure 2.2.8 POCH Energy Conservation Potential

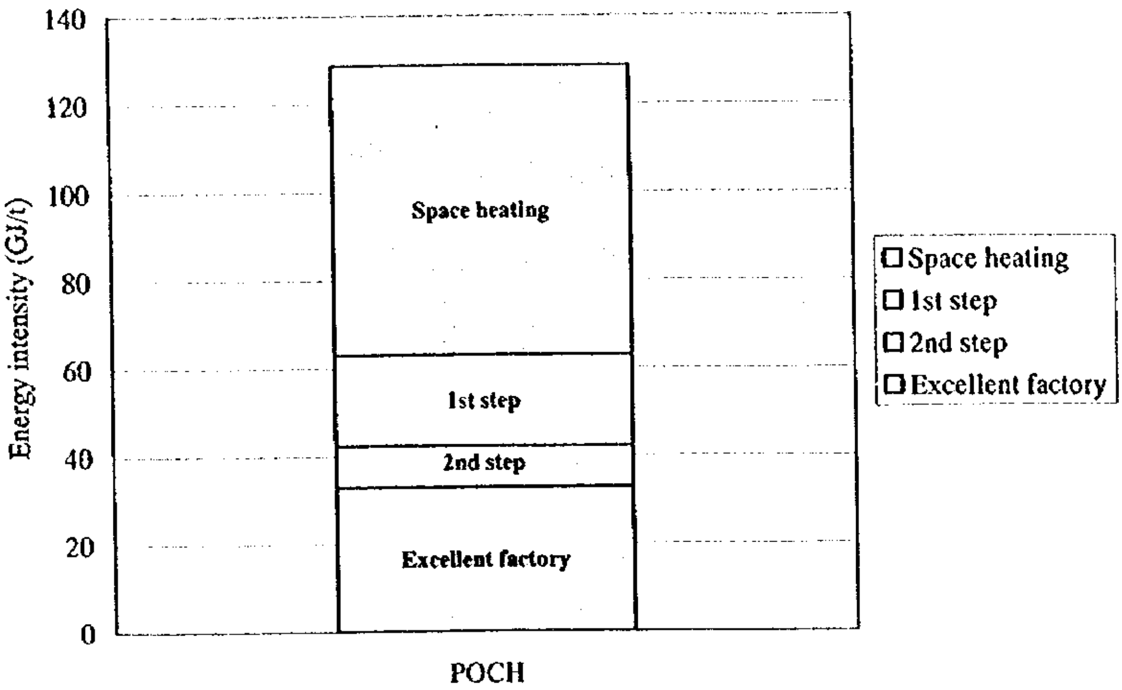
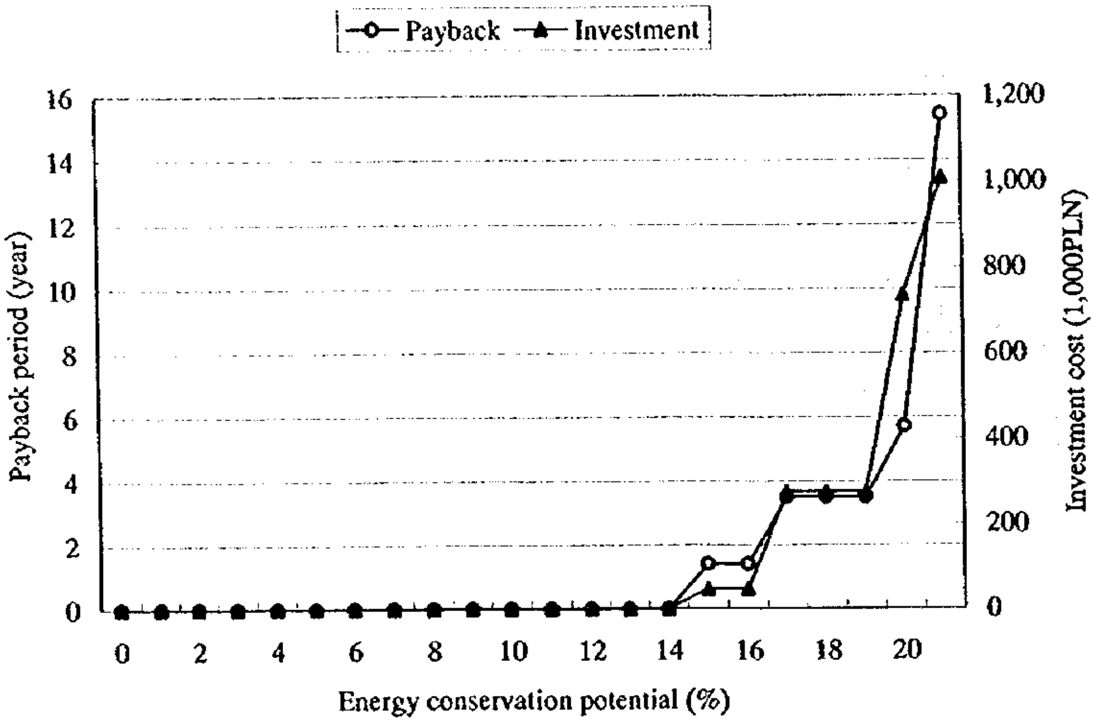


Figure 2.2.9 POCH Energy Conservation Potential



2. CHEMICAL INDUSTRY

2.3 Results of the Study at BORUTA Chemical Plant

(1) Study period: October 8 to 9, and 12 to 16, 1998

(2) Member of the study team

a. JICA TEAM

Mr. Norio Fukushima : Leader of energy audit & Heat management
Mr. Masashi Miyake : Process management
Mr. Jiro Konishi : Heat management
Mr. Seiichiro Maruyama: Heat management
Mr. Kazuo Usui : Electricity management
Mr. Kiyotaka Nagai : Measuring engineering
Mr. Akihiro Koyamada : Measuring engineering

b. Local consultants: Warsaw University of Technology

Mr. Maciej CHORZELSKI (WUT) : Heat management
Mr. Piotr SZEWCZYK (RAPE) : Heat management
Mr. Krzysztof DUSZCZYK (WUT): Electricity management

(3) Interviewees

Mr. Adam ZUREK : Vice President (Board Member)
Mr. Marek OLMA : Chemical production coordinator
Mr. Ieneusz GAJEWSKI: Active dyestuff producing department Chief
Mr. Tersa MAKOWSKA: Electricity Manager
Mr. Adam BIEN : Power Plant President

2.3.1 Profile of the Plant

(1) Plant name: Zaklady Przemyslu Barwnikow "BORUTA" S.A.

(2) Address: ul.Andrzeja Struga 30, 95-100 Zgierz

(3) No. of employees: 756

(4) Major products: Reactive dyestuffs, azo dyestuffs, coloring agents, dye intermediate

(5) Production capacity: 6,500 t/y

(6) Overview of processes

The production divisions of Zaklady Przemyslu Barwnikow "BORUTA" S.A. consist of the divisions of reactive dyestuffs, azo dyestuffs, coloring agents, dye intermediate, etc. and the divisions supplying ice and compressed air—totally, eight divisions. In addition to these, there are five divisions (i.e. engineering/safety, electrical measurement, environment/ maintenance, etc.). There are 12 product types, each of which is further broken down into specific items. Unit operations include batch type organic synthetic reaction, solid-liquid separation through blocking, and box-type or spray-type drying.

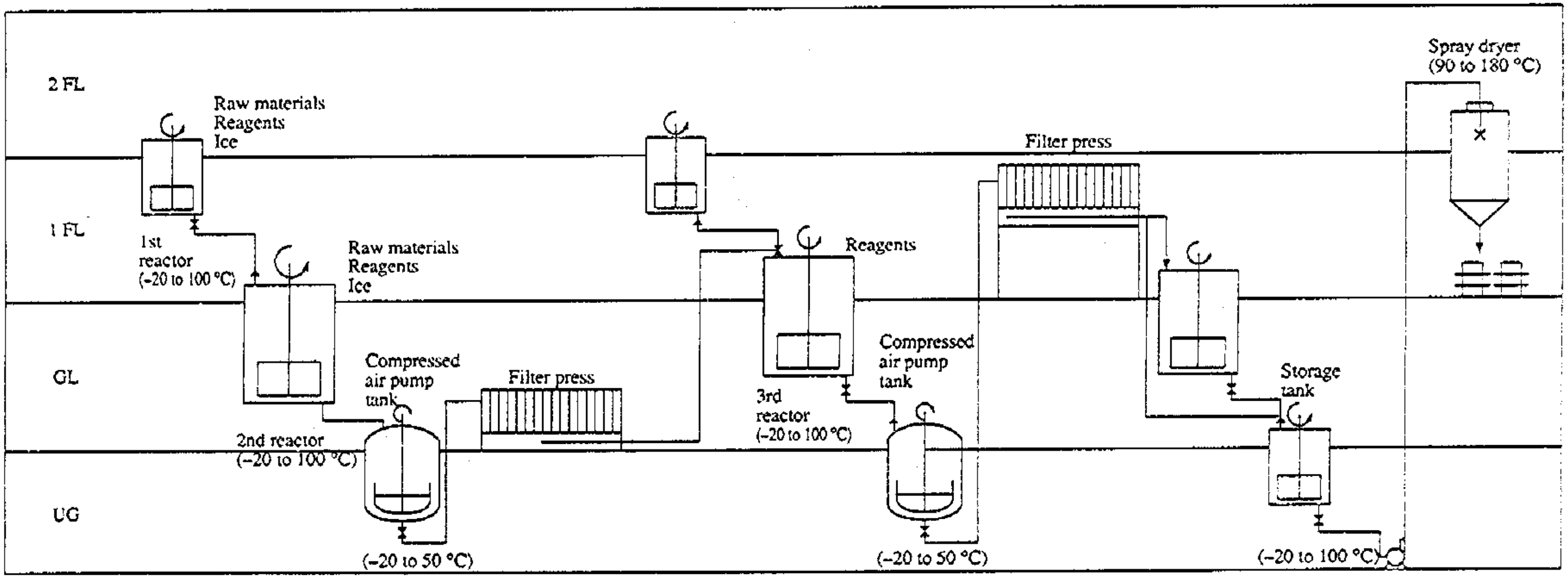
The reactive dyestuffs manufacturing processes are as follows:

Raw material setup → Reaction → Drying → Mixing → Inspection → Packing

Benzene, naphthalene, and anthracene as the main raw materials, their derivatives, and inorganic/organic chemicals are purchased. These are processed to the dye intermediate and then the dye is synthesized. However, some dye intermediates are imported recently because of environmental protection and costs. Ice and compressed air to be used for the dye synthesizing reaction are produced inside the company. Steam and electricity for energy and factory heating are all purchased. Waste water from these processes is fed to the sewage treatment yard in Zgierz city, to be treated.

This survey was limited to the reactive dyestuffs factory, and so the azo dyestuff factory and dye intermediate factory could not be surveyed.
Figure 2.3.1 shows the main production processes in the reactive dyestuff factory.

Figure 2.3.1 Main Process Flow (Reactive Dyestuff Factory)



(7) History of the factory

"BORUTA" S.A. is the largest and oldest organic dyestuff manufacturing factory in Poland. This company was founded as a state-run enterprise in 1894 and has produced dyestuffs mainly for the textile industry. Presently, this company produces many types of textile dyestuffs for dyeing and printing and pigment for leather, paper, and wood. It also produces additives for dyeing or printing woven textile and intermediates for manufacturing dyes.

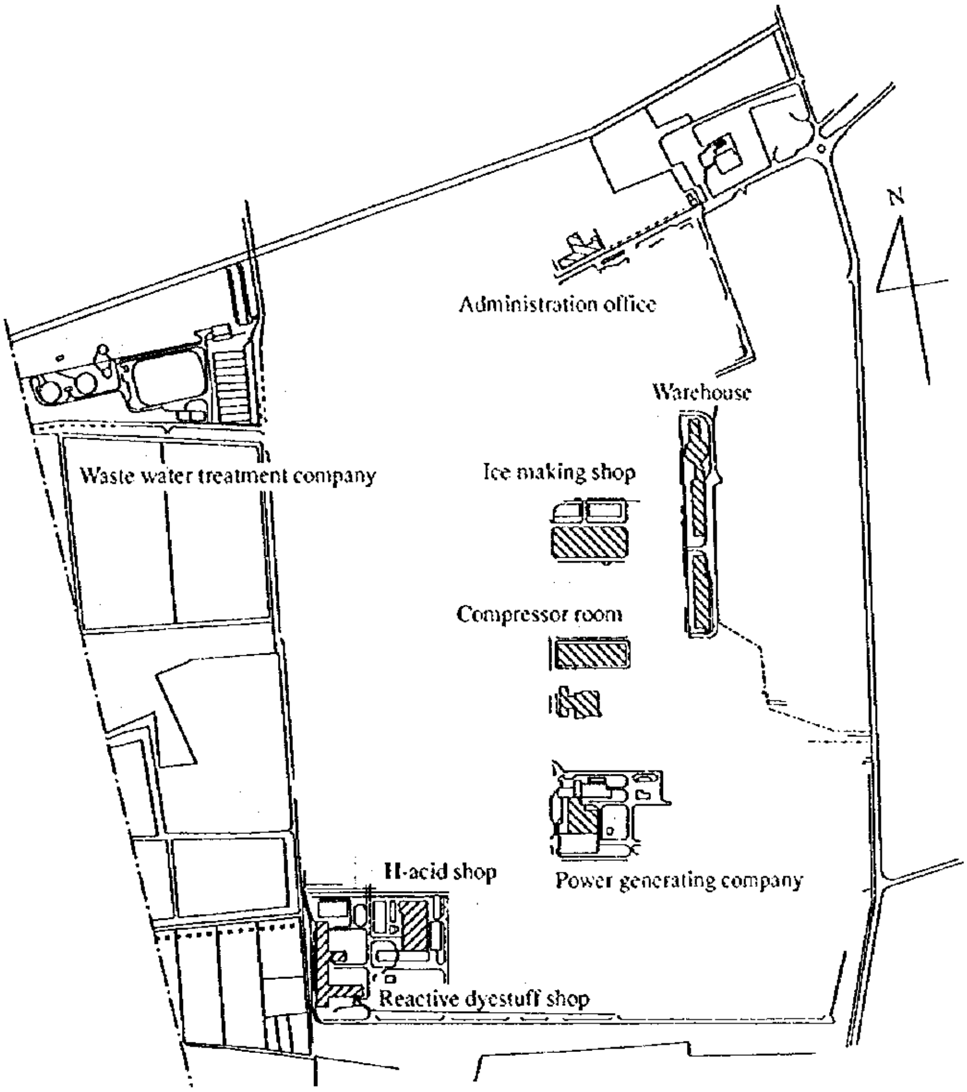
In 1992, this company was changed into a stock company. Since 1996, the systems of the production divisions and sales divisions have been reviewed, and examination of the restructuring plan including the capital distribution method, etc. has been started for conversion into a private company. Achievement of the practical plan is targeted for January, 1999. The power generating division has already been separated and electricity and steam are to be purchased from the power company. For waste water treatment, a waste water treatment yard is run cooperatively with Zgierz city for batch treatment.

For the organization, eight production divisions will be reduced to four divisions by January, 1999. The divisions of engineering/safety, etc. will be separated and the number of employees will be reduced from 750 to 370.

For sales division, due to the present worldwide reform and trade liberalization in the dyestuffs industry, inexpensive dyes imported from India and China are increasing in the Poland's domestic market. Although the production volume in this factory accounts for 80 % of the entire domestic production volume even now, the market share of this company has dropped to 40 %. Presently, the working ratio of this factory is low (i.e. 40 %). Presently, the future demand and sales trend in Poland are not clear at all.

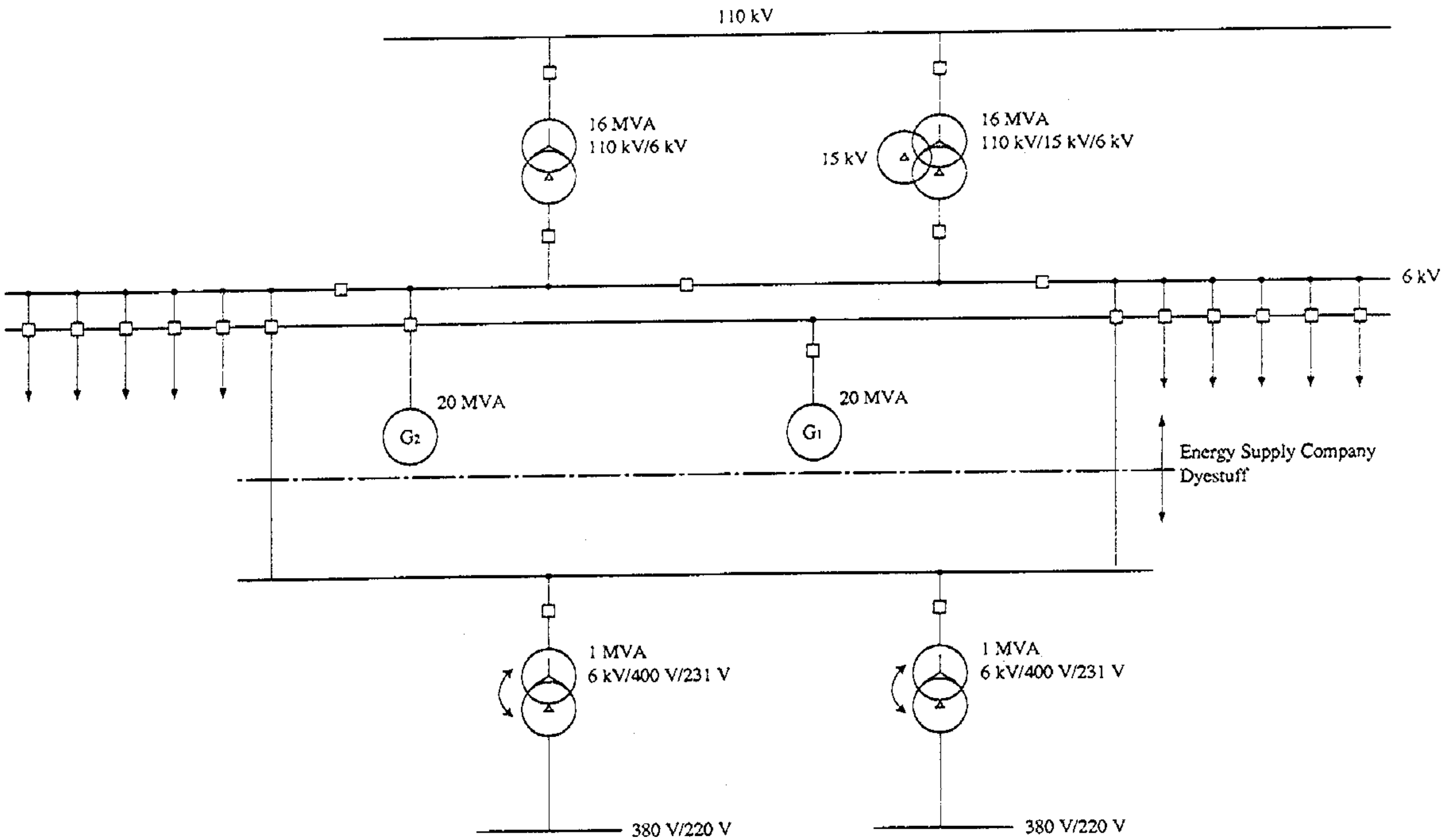
(8) Plant layout

Figure 2.3.2 Plant Layout



(9) One line diagram

Figure 2.3.3 One Line Diagram



(10) Outline of major equipment

Table 2.3.1 shows the major equipment of the reactive dyestuff plant.

Table 2.3.1 Major Equipment

(Reactive dyestuff factory)

Factory	Equipment	Number	Specification
Reactive dyestuff	Reactor	23	5 ~ 11 m^3 (with Agitator)
	Reactor	28	20 ~ 30 m^3 (with Agitator)
	Lift tank (Pump)	16	16 m^3 (Pressure vessel: 0.4 MPa)
	Filter press	18	1.2 m^3 (Pressure: 0.2 MPa)
	Spray dryer	6	80 ~ 100 kg-H_2O/h
Utilities			
Air compressor	Compressor	1	8,000 m^3/h, 4-stage turbo compressor
			0.7 MPa, 1 MW × 1
Ice shop			Capacity 180 t/d
	NH_3 compressor	3	160 kW, 345,000 kcal/h
Substation	Transformer	2	1 MVA, 6 kV/380, 220 V

(11) Energy price and heat value

Table 2.3.2 shows the energy price and heat value.

Table 2.3.2 Energy Price and Heat Value

		Energy price	Heat value
Steam		21.7 PLN/GJ	
Electricity	6 kW	110 PLN/MWh	
	0.4 kV	220 ~ 240 PLN/MWh	
Compressed air		0.07 PLN/m^3*	0.252 kWh/m^3
Water		0.7 PLN/m^3	
		(Sale: 1.2 PLN/m^3)	
Ice		4.6 PLN/t*	20 kWh/t
Waste water treatment		2.5 PLN/m^3	

Note: The values with * were calculated based on electricity intensity.

2.3.2 Energy Consumption Status

(1) Production

a. Reactive dyestuff factory (1997)

Table 2.3.3 shows the production amount in the reactive dyestuff factory. The production amount in the reactive dyestuff factory accounts for 25 % of the overall production in BORUTA.

Table 2.3.3 Production of Reactive Dyestuff Factory in 1997

	1997
Product	Production (t)
Reactive dyestuff	391
Acid dyestuff	152
Direct dyestuff	4
Total	547

b. BORUTA (1997)

The production volume in BORUTA was presumed from the production ratio of each factory based on the production in the reactive dyestuff factory and information obtained. Table 2.3.4 shows the result.

Table 2.3.4 Production of Boruta Factory in 1997

	1997
Product	Production (t)
Reactive dyestuff	547
Azo dyestuff	1,203
Other dyestuff	437
Total	2,187

(2) Energy consumption

a. Reactive dyestuff factory (1997)

Table 2.3.5 shows energy consumption of the reactive dyestuffs factory. For the steam volume for manufacturing processes, the average value of steam intensities in June, September and October during which space heating was not provided in Table 2.3.6 was regarded as the steam intensity for manufacturing processes. The steam consumption for space heating was considered to be the annual steam consumption minus the steam consumption for manufacturing processes. As a result, the steam consumption for manufacturing processes is 76 % and that for space heating is 24 %.

Table 2.3.5 Energy Consumpton of Reactive Dyestuff Factory in 1997

	Unit	1997
Steam for process	(GJ)	54,844
Steam for heating	(GJ)	16,106
Electricity	(MWh)	1,183
Ice	(t)	1,756
Compressed air	(m^3)	3,120,000
Water	(m^3)	142,180

Table 2.3.6 Monthly Production and Steam Consumption of Reactive Dyestuff Factory in 1997

Month	Production (t)	Steam (GJ)	Energy intensity (GJ/t)
1	43.8	8,900	203.2
2	35.6	6,790	190.7
3	55	7,520	136.7
4	42.3	6,160	145.6
5	39.1	5,300	135.5
6	49.9	4,640	93.0
7	38.2	4,840	126.7
8	34	3,850	113.2
9	45.9	3,650	79.5
10	58.7	5,250	89.4
11	56.8	6,790	119.5
12	47.4	7,260	153.2
Total	546.7	70,950	129.8
Total in June to October	226.7	22,230	98.1

Note: Steam for process (GJ/t): 87.6 (67.5 %)
Steam for heating (GJ/t): 129.78 - 87.6 = 42.2 (32.5 %)

b. BORUTA (1997)

Table 2.3.7 shows the estimated energy consumption in BORUTA. The energy consumption in the reactive dyestuffs factory is eatimated at 25 % of the total based on the result of our factory tour and the performance in Japan.

Table 2.3.7 Energy Consumption of Boruta Factory in 1997

	Unit	1997
Steam for process	(GJ)	219,380
Steam for heating	(GJ)	64,420
Electricity	(MWh)	4,733

Note: Process steam: 67.5 %, Space heating steam: 32.5 %

(3) Energy intensity in 1997

Table 2.3.8 shows the energy intensity of the reactive dyestuff factory.

Table 2.3.8 Energy Intensity of Reactive Dyestuff Factory in 1997

	Unit	1997
Steam (Process)	(GJ/t)	87.6
Steam (Heating)	(GJ/t)	42.2
Electricity	(MWh/t)	2.2
Ice	(t/t)	3.2
	(MWh/t)	0.064
Compressed air	(m^3/t)	5,707
	(MWh/t)	1.4
Water	(m^3/t)	260

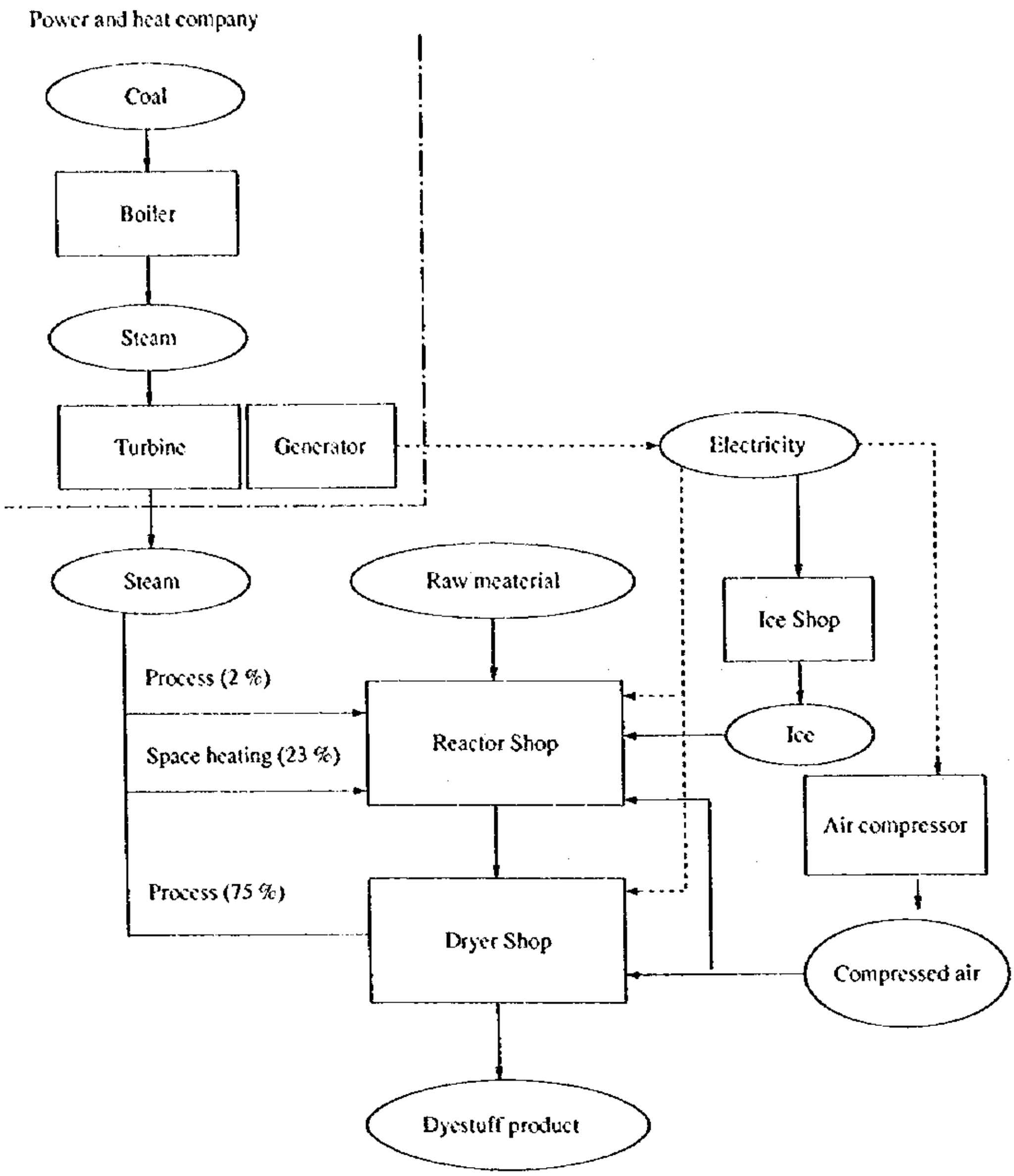
Note: Ice intensity: 20 kWh/t, Compressed air intensity: 0.252 kWh/m^3

(4) Energy flow of reactive dyestuff factory in 1997

Manufacturing processes use 100 % of electricity, 76 % of steam, 100 % of ice, 100 % of compressed air, and 100 % of utility water, while factory space heating uses 24 % of steam.

Figure 2.3.4 shows the energy flow in the reactive dyestuff factory.

Figure 2.3.4 Energy Flow



2.3.3 Energy Management Status

(1) Setting energy conservation targets

a. Setting targets

Targets have not been set yet.

b. Problems related to promotion of energy conservation

The energy consumption data is not arranged for each division.
For 1997, only the information of the reactive dyestuff factory was provided.

(2) Systematic activities

a. Setting up sections dedicated to energy conservation

A division in charge of energy is available but it does not work for energy conservation satisfactorily.

b. Setting up the Energy Conservation Committee

Examination on the organization is in progress in the restructuring scheme targeted for January, 1999 but the Energy Conservation Committee has not been provided.

c. Stance of top managers toward energy conservation

Relatively practical and specific measures have been implemented (e.g. sewage treatment as one of the major issues in business administration of the dyestuffs factory has been switched into the system of treatment at a sewage treatment yard that is cooperatively run by the city).

Also, the top managers are positively engaged in training of the person responsible in each division. For example, they showed their intention to use the OHP film on energy conservation, used in the reporting meeting, immediately in the meeting with the responsible person in each division. As such, their recognition of importance of energy conservation is extremely high and recognition of the persons responsible in the production field is being enhanced. However, practical action taking is hard because restructuring is being planned.

d. Personnel evaluation system

The proposal and evaluation systems relating to energy conservation are not available.

(3) Data-based management

The result of study in the reactive dyestuffs factory is as follows:

a. Grasping the energy volume used

They keep track of the energy volume used in 1997.

b. Grasping the energy volume used by major equipment

They do not keep track of the energy volume used by each process and by each equipment.

c. Grasping the energy intensity of major products

Although they have grasp of the monthly production and energy volume used, they do not know the energy intensity for each product.

d. Installation of measuring equipment

The necessary meters for process control have been installed. However, there are few measuring instruments relating to the energy volume used. The steam flow meters are installed in each division and automatic recording is performed but they are not maintained very well. Electricity, ice, and compressed air are recorded on the supply side. A temperature recorder is provided on the dyestuff synthesizing reaction bath. A control system is provided for the spray dryer.

e. Production management and cost management

It is necessary to enhance the management system. Specifically:

1) Measurement and recording of energy consumption in each production division (electricity, steam, ice, compressed air, and water)

2) Grasping and management of daily/monthly energy intensity

3) Preparation and maintenance of the flow line chart including energy supply to each process, consumption in each process, and discharging from each process

Presently, this company is under examination for acquisition of the ISO 9000 certificate.

(4) Plant engineering

Old equipment that has been used for many years and unnecessary equipment/piping exist in the processes. Systematic plant maintenance is not performed.

Repair is made after a trouble occurs. Present personnel can accommodate a 60 % work ratio, thus still providing an allowance. It is said that there is no problem in production in the present status of a 40 % work ratio because operation can be continued by switching to the standby equipment and then repair can be made if a failure occurs. However, maintenance is essential because the facilities are old. Startup check, week-start check, and month-start check items such as air leak from the lift tank, filter press running status, spray dryer air heater running status, etc. should be lined up and a check list should be prepared. By checking these items, actions to be taken should be planned before occurrence of troubles.

(5) Training

The meeting on the production plan is held on a daily basis. A training meeting for foremen is implemented once every three months. The subjects dealt with in this meeting concern various information in the dye industry but energy is hardly discussed. Since energy is not numerically grasped in detail, it is hard to pick it up as a practical subject.

2.3.4 Problems and Measures Relating to Energy Use

(1) Comparison of the energy intensity between the excellent factory and the reactive dyestuff factory of BORUTA in 1997

As shown in Table 2.3.9, electricity intensity of BORUTA is 24 % higher than that of the excellent factory. Steam intensity of BORUTA is 2.5 times larger even though steam for processes (excluding steam for factory heating) only is checked.

Table 2.3.9 Comparison of Energy Intensity in Reactive Dyestuff Production Process

1997

	Unit	Boruta	Excellent factory	Difference
Electricity	(MWh/t)	3.7	3.0	0.7
	(GJ/t)	(38)	(31)	(7)
Steam (Process)	(GJ/t)	87.6	40	47.6
Steam (Space heating)	(GJ/t)	42.2	0	42.2
Water	(m^3/t)	260	208	52
Production capacity	(t/y)	1,500	1,700	
Energy intensity	(GJ/t)	167.8	71	96.8

Note: Electricity = Power + Ice + Compressed air
Ice intensity: 20 kWh/t, Compressed air intensity: 0.252 kWh/m^3

Table 2.3.10 shows the breakdown percentages of the manufacturing costs.

Table 2.3.10 Comparison of Production Cost Ratio

	Boruta	Japanese factory
Raw material cost	33 %	40 %
Energy cost	25 %	10 %
- Heat for process	(14 %)	(6 %)
- Heat for heating	(4 %)	(0 %)
- Electricity	(6 %)	(3 %)
- Water	(1 %)	(1 %)
Labor cost	12 %	40 %
Fixed cost	30 %	10 %
- Waste water treatment cost	(15 %)	
- Others including tax	(15 %)	

(2) Estimating the energy conservation potential

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

Step 1: Enhansing the menagement
Step 2: Improving the equipment
Step 3: improving the processes

A. Processes

The result of our survey in the reactive dyestuff factory is as follows:

a. Difference due to external factors

For the difference of the production capability in comparison with the excellent factory, the system is an aggregate of batch type equipment. Therefore, this difference is not a factor resulting from a difference of energy intensity. The production capability of the spray dryer in the excellent factory is 250 to 400 kgH_2O/h, while it is 80 to 100 kgH_2O/h in BORUTA. However, the difference of energy intensity due to the difference of the processing capability is not recognized.

In the drying process in BORUTA's reactive dyestuffs factory, 70% of total production volume is treated by means of a spray dryer, while 30 % is processed by a box type dryer. In an excellent factory, on the other hand, a spray dryer is used for all of the production volume. The steam intensity of a box-type is 10 GJ worse than that of a spray dryer, and therefore the difference in the steam intensity is as follows
$10 \text{ GJ/t} \times 0.3 = 3 \text{ GJ/t}$

BRUTA purchases steam and electricity from an electric power generating company, while the excellent factory has its own boiler and electric power generating equipment.

The annual average temperature in Boruta is 8 °C, while that in an excellent factory is 15°, making a difference, which causes a difference in the amount of energy for space heating and the volume of heating steam for processing.

Difference in the amount of energy for space heating (air conditioning): The excellent factory uses almost no energy for space heating and therefore BORUTA's steam intensity for space heating, 42.2 GJ/t is the difference due to external factors.

Amount of heating steam for processes: Assuming the dryer air temperature to be standard operating temperature, the difference in the amount of steam for heating due to temperature difference is $(15\text{-}8)/(150\text{-}8) \times 100 = 5$ %. Hence, the difference in steam intensity is 87.6 GJ/t × 0.05 = 4.4 GJ/t.

The difference in energy consumption due to external factors is as follows:
42.2 + 4.4 + 3 = 49.6 GJ/t
where energy consumption in reactive dyestuff factories is 547 t/y × 49.6 GJ/t = 27,131 GJ/y, and that for BORUTA's entire factory is 2,187 t/y × 49.6 GJ/t = 108,475 GJ/y.

b. Difference due to technical factors

1) Sales promotion of liquid products

When the domestic market is targeted, the product should not necessarily be in the powder form. Selling liquid products allows the drying process to be eliminated. As a result, the percentage (14 %) of steam presently used for processes in the manufacturing costs can be significantly reduced and power of the market competition can be increased. In this case, management for maintaining the composition matching the dyeing process and the quality stability is necessary. Particularly, for the black and dark blue dyes accounting for approximately 50 % of all dyes, they are sold to major users only and their 30 to 40 % is sold as liquid products in Japan, to avoid contamination and skin damages in the dyeing process.
If 10 % of the reactive dyestuff is shipped as liquid products, steam consumption can be reduced by 10 %.

Steam reduction is as follows:
87.6 GJ/t × 0.1 = 8.76 GJ/t

Reactive dyestuffs factory:
547 × 8.76 = 4,792 GJ/t

2) Reduction of the steam consumption by the spray dryer

The steam intensity difference is the difference of steam consumption for the spray dryer. Steam consumption in BORUTA is 2.52 times larger than that in the excellent factory.

In the reactive dyestuff factory, approximately 97 % of steam for processes is consumed by the drying process. Approximately 70 % of the production in the reactive dystuffs factory is reactive dyestuffs, for which spray dryers are used. And so it is a big theme for energy conservation to reduce steam consumption for spray dryers.

Production by spray dryer is as follows:
547 t/y × 0.7/(24 × 365) = 0.044 t/h

Steam intensity is 87.6 GJ/t and steam consumption per hour is as follows:
87.6 GJ/t × 0.044 t/h = 3.85 t/h

According to a manager of the factory, the number of spray dyrers in operation are 2.5 sets in average. Steam consumption per a spray dryer is as follows:
3.85 GJ/h / 2.5 = 1/54 GJ/h/set

① Heat balance of the dryer

To clarify the percentage of heat used by the spray dryer, heat balance calculation was performed. Figure 2.3.5 shows the range to which heat balance calculation was applied and the measured points. Six dryers are installed in the dryer room. Spray of the material liquid is dried by hot air to manufacture powder dyes. The temperature of hot air at the inlet of the dryer and the temperature of exhaust gas at the outlet of the dryer are recorded on the monitor panel. Hot air is produced by heating the air introduced by the blower with the air heater and steam. The air flow rate at the inlet of the blower was measured on a spot basis by using a hot wire anemometer. Based on this measurement data, the air flow rate was calculated and an attempt was made to calculate the heat balance of the dryer. Figure 2.3.6 shows an example of the heat balance calculation result although the heat balance depends on the operation status.

Figure 2.3.5 Spray Dryer Flowsheet

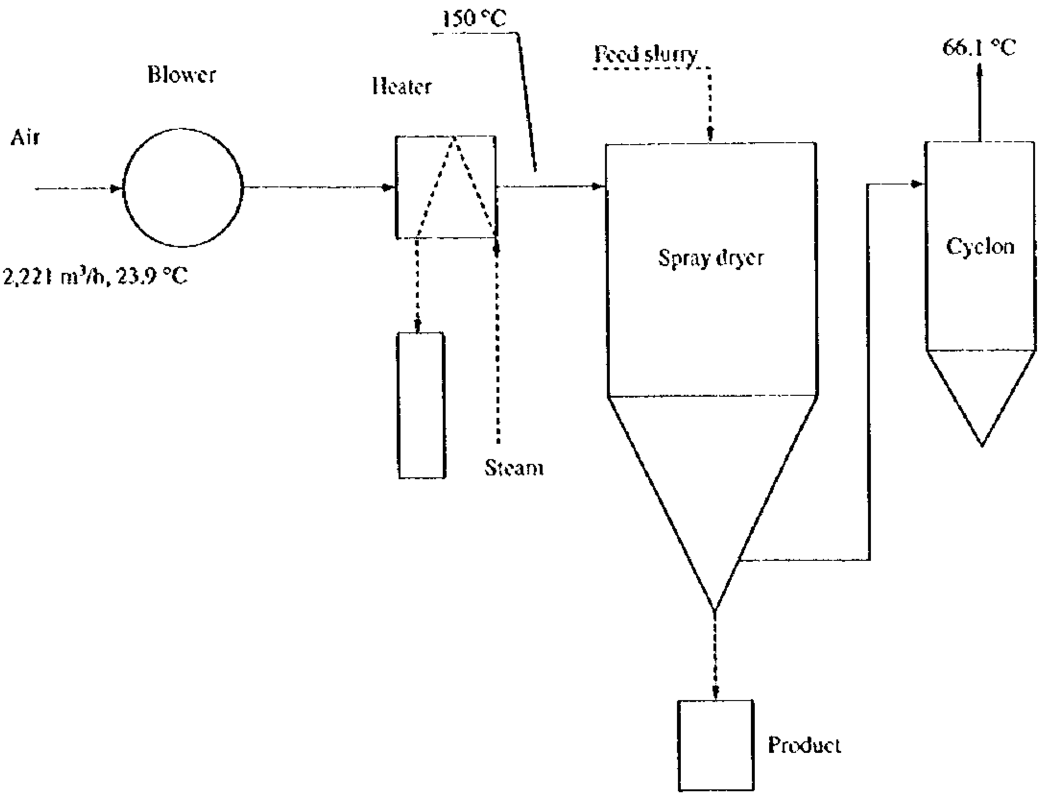
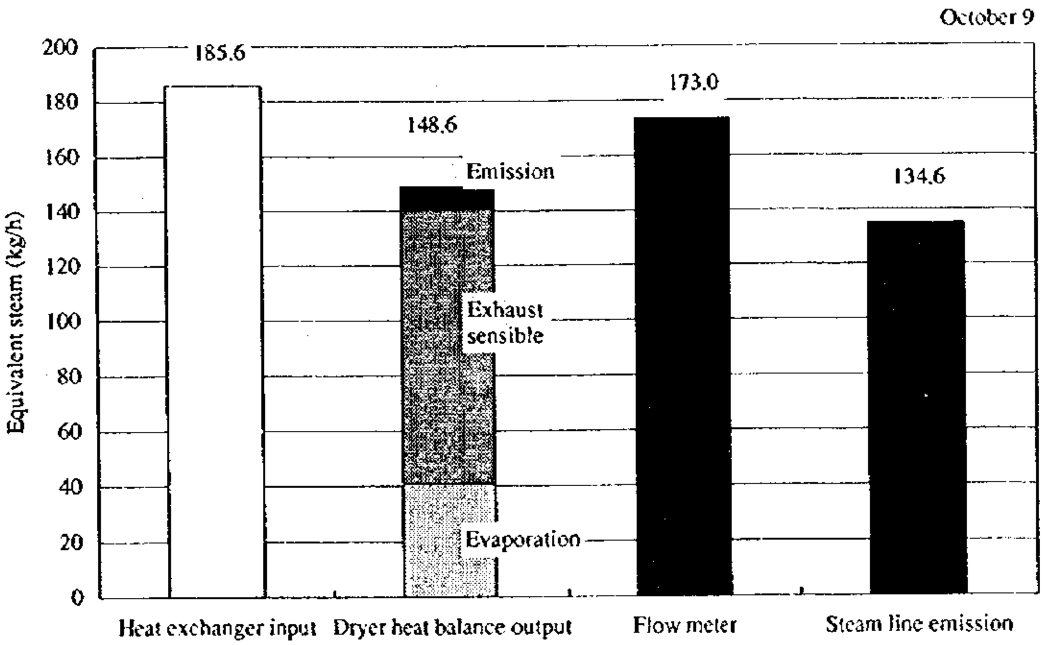


Figure 2.3.6 Steam for Dryer No. 863



This figure shows the heat value converted into the steam volume (kg/h). Also, the calculated value of heat emission from the main steam pipe (outdoors) is indicated for reference. Since a steam flow meter (counter) is installed on the entrance of the dryer room, the steam flow rate obtained from this reading is also shown.

As shown in this figure, the necessary heat value for evaporation of the material liquid is approximately 1/3 to 1/4 of the loaded heat. The other heat value means the heat taken out by the exhaust gas from the dryer. To reduce the loaded heat, it is necessary to reduce the heat loss caused by the exhaust gas. Therefore, the exhaust gas volume should be reduced or the exhaust gas temperature should be dropped. Since these measures will affect the structure inside the dryer, productivity, etc., they cannot be easily determined and examination with professionals is necessary.

The heat balance result obtained from the 8-hour operation performance and measured values at 22:00 on October 8 through 6:00 on October 9, 1998 are as follows:

Spray dryer	No. 863
Duration	8 hr

[Output heat]

(1) Evaporation heat

• Production	125 kg
• Solid content in feed slurry	29 %
• Water content in product	5 %
• Water removed per hour	35.6 kg/h
• Unit evaporation heat	539 kcal/kg
- Gross evaporation heat	19,167 kcal/h
- Steam requirement for evaporation	40.8 kg/h

(2) Exhaust gas sensible heat

• Gross exhaust gas	2,280 m^3_N/h
• Temperature difference	66.1 °C
• Specific heat as air	0.311 kcal/°Cm^3_N
- Exhaust gas sensible heat	46,844 kcal/h
- Steam required	99.6 kg/h

(3) Emission loss 8.2 kg/h (3,877 kcal/h)

(4) Gross steam requirement

- Evaporation + heating up + emission loss 148.6 kg/h (69,888 kcal/h)

(5) Product sensible heat

- Production 125/8 = 15.6 kg/h
- Temperature difference 66.1 °C
- Specific has as naphthalene 0.35 cal/°Cg
  - Product sensible heat 66.1 × (15.6 × 0.95 × 0.35 + 15.6 × 0.05 × 1) = 394 kcal/h

[Input heat]

(1) Heat content of heating air after peheater 185.6 kg/h (87,284 kcal/h)

- Room temperature 23.9 °C
- Air temperature after heater 150 °C
- Air volume at the inlet of blower 2,221 m^3/h
- Specific heat of air 0.312 $kcal/°C{\cdot}m^3$

[Heat balance] (kcal/h)

Input		Output	
Heat content of heating air	87,284	Evaporation heat	19,167 (22.0 %)
		Exhaust gas sensible heat	46,844 (53.7 %)
		Emission loss	3,877 (4.4 %)
		Product sensible heat	394 (0.5 %)
		Others	17,002 (19.5 %)
Total	87,284		87,284 (100 %)

This result is converted into the energy intensity as shown below.
Heat intensity: (87,284 × 8 × 4.2/0.125)/106 = 23.5 (GJ/y)

The heat intensity of 23.5 GJ/y due to the heat balance is almost equivalent to the resulting steam intensity (converted into the latent heat of the excellent factory) of 28.5 GJ/y (= 40 × 1,980/2,780). This measurement was performed while the air heater and dryer were heat-insulated in the regular operation. To grasp steam consumption of the heater, measurement was performed by using the steam flow meter on the entrance of the factory but the measured value (173 kg/h) was smaller than the input heat (185.6 kg/h) listed above. Therefore, maintenance and verification of the steam flow meter should be performed. From this heat balance, it was found that the steam intensity provided when the dryer was regularly operated was equivalent to that of the excellent factory.

② Enhancement of heat insulation for the air heater

The heat insulating materials for three air heaters among six air heaters are removed for repairing steam leak. It is necessary to restore the heat insulating materials immediately after repair is completed. Steam is saved by restoring the heat insulating materials as shown below.

Outer wall surface area of the air heater:	0.5 m × 0.5 m × 4 faces = 1 (m^2)
Outer wall temperature of the air heater:	150 °C
Ambient temperature	: 24 °C
Emissivity	: 0.8
Radiation heat value	: 2421 kcal/h (radiation + natural convection)
Heat recovery rate by heat insulating material:	90 %
Steam saving by improvement of heat insulating material	: 2,412 × 0.9 × 4.1868 = 9.09 MJ/h

According to the field investigation, one spray dryer is always run without heat insulation.

The loss of steam consumption shown in the result of the field survey is as follows:
9.09 MJ/h × 24 h × 365 d/y = 79,628 MJ/y = 79.6 GJ/y
(Steam intensity: 79.6/547 = 0.15 GJ/t)

③ Prevention of steam leak from the air heater

Thirty years have passed since the spray dryers were installed in the reactive dyestuff factory and they are totally deteriorated. Particularly, damages of the air heater are extreme. When operation is started after shutdown for 4 to 5 days, the steam pipe is broken and steam leak arises. Such a status is repeated. If steam leak can be detected from the outside, repair is applied. If the leak is not detected, it is very likely that the steam is mixed into the drying air, causing a drop in drying efficiencyto be mixed. Consequently, drying efficiency drops.

A small volume of steam leak inside the air heater does not allow leak detection during operation.

When the spray dryer reaches the regular operation, operation should be stopped temporarily. The dye deposit status inside the dryer should be checked for earlier detection.

If a drying failure occurs during operation, similar inspection should be performed.

Steam leak from the air heater further results in operation interruption, extension of the drying time, quality degradation, and consequently, increase in the steam intensity. The cause of and action to be taken against damages of the air heater are described below.

○ Cause of damages on the air heater

According to explanation by the person responsible in the reactive dyestuff factory, the steam pipe for air heating receives thermal distortion caused by repeated feed of high-temperature, high-pressure steam. As a result, the bent parts and welded parts are damaged. Three particular air heaters among six air heaters are liable to frequent breakage. Also, the hammer phenomenon caused by abrupt evaporation of drain accumulated in the pipe during shutdown and the shock and wear phenomenon by water drops are also the causes of damages. Although it is necessary to remove the drain upon startup, this work is difficult because of the structure and accumulation of the drain is inevitable. The result of our study revealed that the drain separator and trap were not installed between the electric power plant and factory and a large volume of drain was contained in the supplied air due to the broken pipe. It is necessary to install the drain separator on the inlet of the factory and request the electric power plant to supply steam at a higher degree of dryness.

○ Measures against damages of the air heater

The spray dryer was made in Denmark and the air heater was made of copper pipe but they are not manufactured presently. There is no manufacture drawing and the heating surface area is unknown. If the equivalent product is to be imported, it costs at least 18,000 PLN. Due to limitation on the foreign currency, an air heater made of steel pipe is manufactured by a domestic manufacturer at a price of approximately 1/3. It is being used by repeating repair in the company. The division has personnel qualified as welders, who repair the air heater and the dryer body. For the steel pipe for steam, bent pipes with an outer diameter of 8 to 10 A are laid out flat and welded to the collection pipe and there are no fins. Although the structure is designed elaborately, accumulation of drain cannot be avoided.

In the excellent factory, an air heater made of steel pipe with fins, that was custom-made by a finned tube manufacturer, is installed and run for a long time without troubles in the intermittent operation, because of experience of troubles similar to those in BORUTA.

The features are that no drain is accumulated in the air heater and its line and welding is accurate. For the air heater body, a finned pipe made of steel is laid out vertically. The collecting pipe for feeding steam and the collecting pipe for discharging drain are welded to the top and bottom, respectively. The collecting pipes are assembled with a water slope. The steam trap and drain discharging pipe are installed for each air heater. Its purpose is to prevent reverse flow of drain caused by pressure fluctuation or siphon effect between the mutual drain discharging lines for the air heaters.

Assuming that the breakage of the air heater occurs 10 times per month and thus the drying time increase by 5 h/time, which is based on the explanation by the factory's responsible personnel, the steam loss is as follows:
Steam consumption by increasing the drying time is as follows:
1.54×5 h/time $\times$ 10 times/month $\times$ 12 months = 924 GJ/y
where, steam consumption per set is 1.54 GJ/h/set.
The amount of steam leakage on the assumption that steam leaks through the hole of 2 mm is as follows:
Steam pressure: 130,000 kg/m^{2}abs, steam specific volume: 0.1540 m3/kg, steam enthalpy: 665.1 kcal/kg.
$G = 1.99\,F\,(P/v)^{0.5} \times 3{,}600 = 1.99 \times 0.002^2/4 \times 3.1416 \times (130{,}000/0.154)^{0.5} \times 3{,}600 = 20.7$ kg/h
20.7 kg/h $\times$ 665.1 kcal/kg $\times$ 4.1868 5 h $\times$ 10 times/months $\times$ 12 months/1,000 = 34,585 MJ/y = 35 GJ/y
Steam consumption saving by preventing the steam pipe damage with the modificaition of air heater is as follows:
Steam saving amount: 924 + 35 = 959 GJ/y
Improvement of steam intensity: 959/547 = 1.753 GJ/t = 1,753 MJ/t

④ Utilization of steam condensate

Steam used by the air heater is guided to the outdoor condensation tank. The temperature of the condensate stored in this tank is approximately 80 °C, and thus the cendensate is presently used for cleaning equipment, etc. If air for the dryer is preheated by using the condensate, the steam cunsumption by the dryer can be reduced. As a result, steam for the air heater can be reduced by 19 %. Figure 2.3.7 shows the concept of air preheating through utilization of the condensate. Table 2.3.11 shows heat balance comparison made as a result of installing the air preheater.

Figure 2.3.7 Air Preheater with Condensate Heat

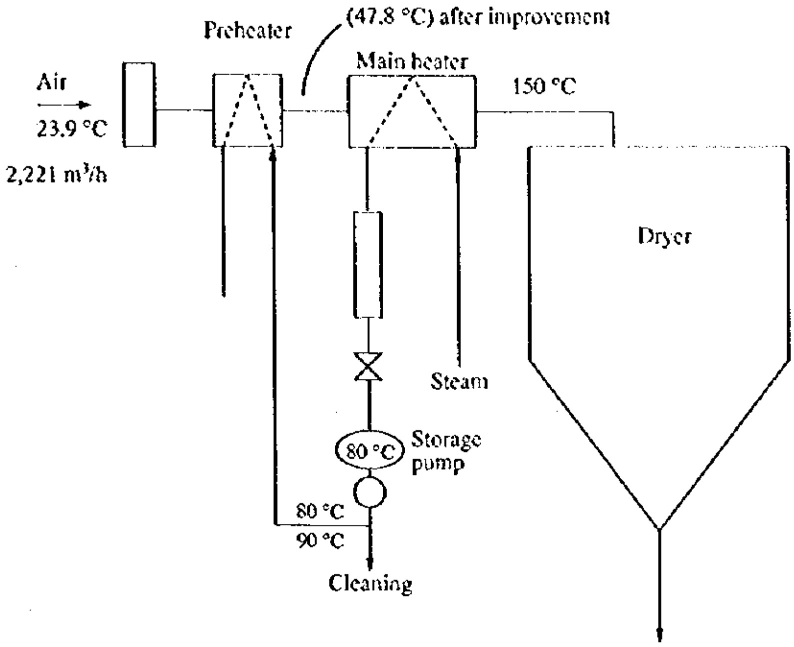


Table 2.3.11 Heat Balance in Air Preheater

Heat balance in air prehecter	Existing	After improvement
Air temperature after heater	150 on panel	150 on panel
Temperature difference	126.1 °C	102.2 °C
Specific heat in the range	0.312 kcal/(°C × m³)	0.312 kcal/(°C × m³)
Air unit heat	39.30 kcal/m³	31.86 kcal/m³
Air gross heat content	87,284 kcal/h	70,741 kcal/h
Steam requirement for air heating	185.6 kg/h	150.4 kg/h

In this case, the existing condensation tank should be heat-insulated. Heat-insulation allows the temperature of the hot water for the air preheater to be kept high, the necessary heat value to be maintained, and no trouble to occur in existing utilization of condensate. The number of dryers being run is 2.5, the steam volume saved as a result of using the steam condensate is as follows. It is assumed that air for preheated is heated to approximately 50 °C.

$(87{,}284 - 70{,}741) \times 4.1868/1{,}000{,}000 \times 24 \times 365 \times 2.5 = 1{,}517$ GJ/y

3) Yield improvement through automation of material supply

The reaction processes and yield of the reactive dyestuff (Reactive Yellow 3) are as follows:

(Reaction)	Diazotization →	Coupling →	Cyanuric conversion →	Amination →	Filtration →	Total yield
(Yield of the excellent factory)	95 %	90 %	98 %	95 %	90 %	70 %

Although information about the yield was not available, the material was loaded by intuition of the operator. The reaction temperature is not always maintained at the same level. In the coupling reaction process, effects of the reaction temperature, acid concentration, chemical supply, speed, etc. to the yield are large. If the yield of the coupling reaction process is 90 % or lower, the yield can be improved. In the excellent factory, a system is adopted that supplies the chemicals quantitatively with a table feeder in the reaction process requiring strict reaction temperature control. Therefore, it contributes to reduction of the labor cost, thus improving the yield by approximately 10 %.

The electricity volume saved by improving the yield by 10 % is as follows:
3.7 MWh/t × 0.1 × 547 t/y = 202 MWh/y

4) Yield improvement and energy conservation by eliminating the filtration process

As the present trend, an attempt is made for yield improvement and energy conservation by eliminating the filtration process and drying with the spray dryer directly. For this purpose, adequate reaction condition setup and process management are necessary.

There are two filtration processes. If the purity of the material to be used is low and mixing of impurities is considered, the first process cannot be eliminated. However, the filtration process before the spray dryer can be eliminated. If this process is eliminated, electricity for compressed air used in the filtration process which accounts for 40 % of the total electricity consumption can be reduced to 30 %.

The electricity volume to be saved is as follows:
3.7 MWh/t × 0.1 × 547 t/y = 202 MWh/t

5) Reduction of the waste water volume with the filter press waste water receiving tray

The waster water intensity in the dyestuff factory at BORUTA is 260 m^3/t, which is 1.25 times larger than 208 m^3/t in the excellent factory. Since the waste water processing cost accounts for 15 % of the total manufacturing cost, reduction in the waste water volume will lead to a reduction in the manufacturing cost. The waste water volume as a result cleaning containers and floors is substantial. If water coming from the filter press is not let to flow down on the floor but received by a receiving tray and fed to the waste water gutter, water for cleaning the floor at the bottom of the filter press can be reduced.

6) Supply of ice and compressed air

Since ice and compressed air are transported from a long distance to BORUTA, the energy loss is large. The product yield can be improved by at least 2 % if the following are implemented:

To concentrate lines using ice, which is to be stored in a checkers form, To neewly install the screw feeder and belt conveyer in the reactive bath line,
To automatically prepare ice as required by using these devices,
To put the screw feeder in the on-off automatic control mode, and
To implement quantitative preparation and temperature control.

The electricity volume to be saved as a result of improving the yield by 2 % is as follows:
3.7 MWh/t × 0.02 × 547 = 40 MWh/y

7) Renewal of the spray dryer

The welded part of the inner stainless steel lining sheet of the spray dryer body is likely to be corroded. Liquid enters between the container and inner lining and corrosion proceeded. Repair is gradually becoming hard.

Presently, the work ratio is low and two or three dryers among six dryers run. Therefore, time for repair is available and no problem occurs in the operation. Presently, repairs for problems are made inside the company. If the damage is large, repair is subcontracted to a professional company. Since the most energy is consumed for the drying operation in the dyestuff manufacturing processes, it is necessary to determine the equipment capability based on the future demand and newly install proper stray dryers based on an adequate design.

B. Utility (heat)

a. Pressure loss and heat emission of the steam pipe

The 1.2 MPa steam pipe between the co-generation plant and dyestuffs factory is 300 mm in pipe diameter. The 0.6 MPa steam pipe for factory heating is 150 mm in pipe diameter and they are 1,200 m in length. The pressure loss of the 1.2 MPa steam piping corresponding to this distance is approximately 0.01 kg/cm² and very small as shown in Table 2.3.12 even though the steam flow rate is 3 t/h. However, the heat emission volume from the steam pipe corresponding to this distance is 134 kg/h and very large (when converted into a steam volume) as shown in Table 2.3.13 (although the steam pipe is heat-insulated). This volume corresponds to the steam volume used by a dryer. The heat emission volume of the 0.6 MPa steam piping is 86.7 kg/h, which means a large heat loss like that of the 1.2 MPa line. This factory is planning to integrate two high-/low-pressure steam pipes into a high-pressure line in the near future. When this plan is achieved, heat emission loss of at least one steam pipe can be reduced and large energy conservation can be accomplished. Therefore, earlier achievement is expected.

Table 2.3.12 Steam Line Pressure Loss Study

L = 1,200 m

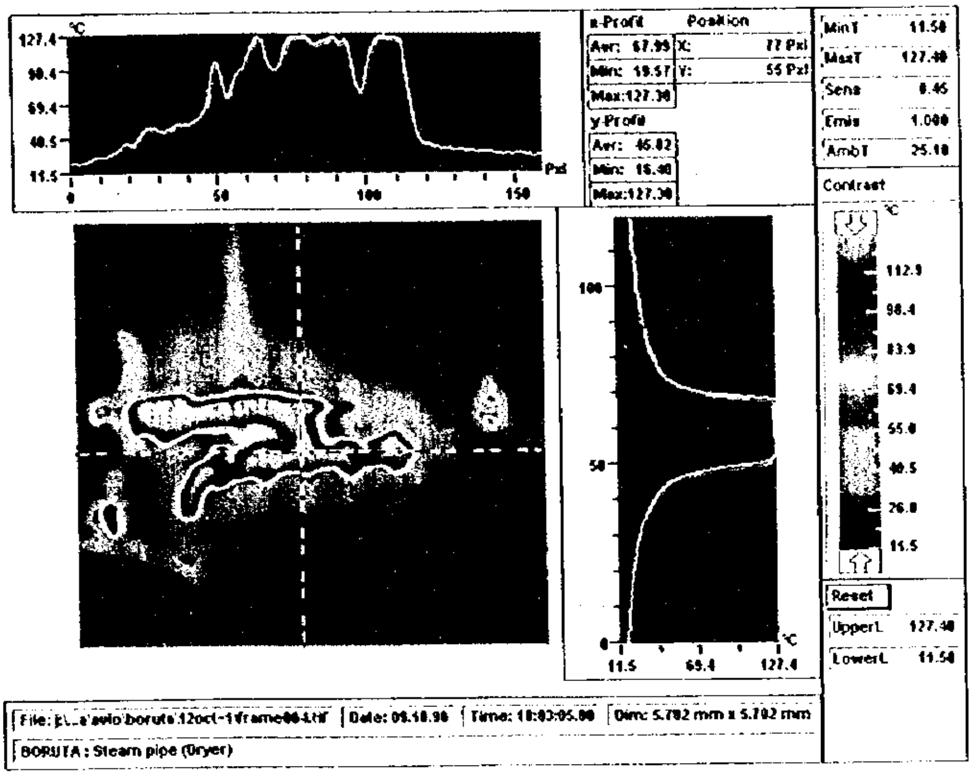
Diameter (mm)	Flow (t/h)	Velocity (m/s)	Pressure drop (kg/cm²)
300	3	1.9	0.010
150	3	7.6	0.294

Table 2.3.13 Steam Main Line Heat Emission Loss

	300A	150A
Ambient temperature	10 °C	10 °C
Temperature, inside	190.8 Pressure saturated	190.8 Pressure saturated
Pipe size, nominal	318.5 mm	165.2 mm
Pipe thickness	10 mm	10 mm
Insulation 1st layer	G.W.blanket-2a	G.W.blanket-2a
Insulation thickness	150 mm	150 mm
Pipe length	2,000 m	2,000 m
Pipe surface temperature	13.6 °C	13.05 °C
Heat emission	31.66 kcal/m/h	20.40 kcal/m/h
Gross heat emission	63,319 kcal/h	40,797 kcal/h
Converted to steam	134.6 kg/h	86.7 kg/h

If use of the 0.6 MPa piping is canceled and the 1.2 MPa piping only is used, the steam volume saved is as follows:
If it is assumed that the 0.6 MPa is being used for 6 months (from October to April):
40,797 × 180 × 24 × 4.1868/1,000,000 = 738 GJ/y (1.3 GJ/t)

Figure 2.3.8 Thermal Image of the Uninsulated Steam Pipe

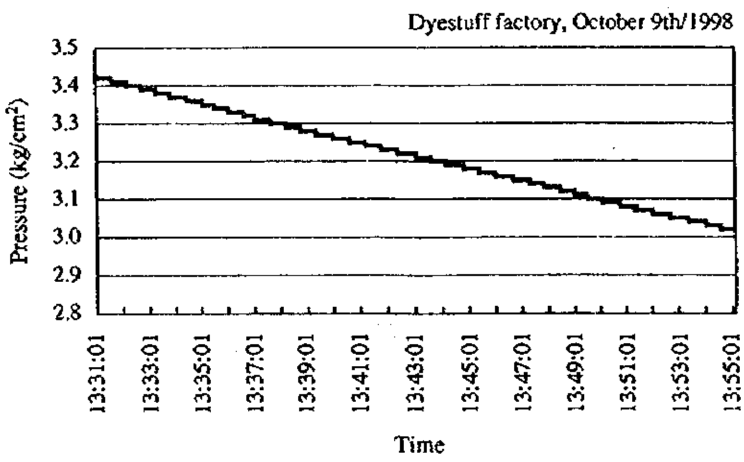


In this factory, the outdoor steam pipe is sufficiently heat-insulated and maintenance and repair of heat insulation are being performed. However, heat insulation is not provided to indoor steam pipe valves. The image in Figure 2.3.8 is a photograph of the high-pressure steam pipe entering the building where the dryer is provided. As shown in the figure, no heat insulation is provided to the valve, branch, and orifice. The surface temperature of the uninsulated parts was 127 °C, while on the other hand the insulated parts were at 40 to 50 °C. This fully verifies the effect of heat insulation. It is thus necessary to ensure heat insulation where required depending the location and/or purpose. Whether heat insulation is provided or not gives a large effect to energy conservation.

b. Survey of compressed air leak

In the factory building of the reaction/dehydration process for manufacturing dyestuff, compressed air is used to feed the material liquid to the dehydrator (filter press). Since pneumatic piping is routed around in the building, air leak was investigated. Upon this investigation, a time zone during which the related process did not use compressed air was selected, the air source valve (at the inlet of the building) was closed, in order to measure and record the pressure along time of the in-pipe air pressure at the downstream was measured and recorded. Based on this result, the air leak volume was calculated from the capacity of the pneumatic piping. Figure 2.3.9 shows the record of the measurement result.

Figure 2.3.9 Air Leakage Test

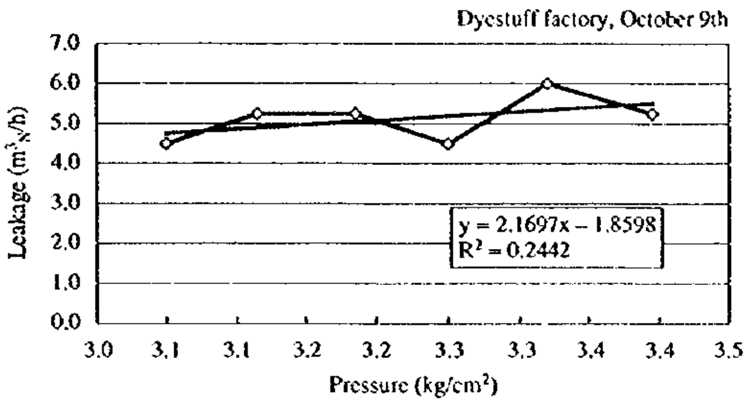


Since this data was recorded every 2 seconds, sampling of 7 points was performed from this data every 4 minutes and leak from six sections between each two points among the 7 points was calculated. The leak volume depends on the pressure, and therefore linear approximation was applied to the calculated leak volume by using the pressure as a variable and the leak volume at the normal operation pressure was approximated through extrapolation. Table 2.3.14 shows the calculation sheet and Figure 2.3.10 shows the pressure and calculated leak volume. This figure shows the linear approximate expression depending on the pressure.

Table 2.3.14 Air Leakage Study

Time	Pressure (kg/cm²)	Time difference (min)	Pressure difference (kg/cm²)	Pressure average (kg/cm²)	Pipeline volume (m³)	Volume × Pressure difference (A) (m^3_N)	Leakage at the pressure (A)/Time difference (m^3_N/min)	(m^3_N/h)
13:31:01	3.43							
13:35:01	3.36	4.000	0.07	3.395	5	0.350	0.088	5.3
13:39:01	3.28	4.000	0.08	3.320	5	0.400	0.100	6.0
13:43:01	3.22	4.000	0.06	3.250	5	0.300	0.075	4.5
13:47:01	3.15	4.000	0.07	3.185	5	0.350	0.088	5.3
13:51:01	3.08	4.000	0.07	3.115	5	0.350	0.087	5.2
13:55:01	3.02	4.000	0.06	3.050	5	0.300	0.075	4.5
Leakage at working pressure, extrapolated				3.50				5.7

Figure 2.3.10 Air Leakage by Pressure



As shown in Table 2.3.14, the leak volume in this case was calculated to be 5.7 m3/h, which is not so a large volume. Such measurement can be easily performed and air leak can be easily audited in the factory, an therefore measurement should be positively adopted and implemented.

Air leak from the piping was seldom observed but a large volume of air leak from the lift tank pump shaft seal was found. Air leak simply wastes energy,and hence prevention of air leak directly leads to energy conservation and cost reduction. Therefore, it is important to prevent air leak with full attention.

c. Heating in the factory building

Almost all of both side of the building of the dyestuff manufacturing factory is covered with glass windows, through which a large volume of heat loss occurs in the heating season. Outer air at a low temperature enters through the broken glass window and the gap on the door at the entrance, and consequently, the heating load increases. Table 2.3.15 shows calculation of the thermal load for factory heating based on information on the number of windows, etc. obtained from the factory and the presumed surface area of the door gap, etc. This table also shows the calculation expression and prerequisite. Figure 2.3.11 shows the numerical values required for calculation.

Table 2.3.15 Heat Emission from Openings and Windows

Calculation results	
Heat emission through the window shield	898 kg/h
Heat loss due to the invasion of outside air from openings	642 kg/h
Total	1,540

Requirements:		
Indoor temperature	T1	14.00 Laber protecting
Outdoor temperature	T2	2.16 Average of heating season
Width of the opening	W	0.7 m
Height of the opening	Ha	1.28 m
Heat transfer coefficient		
Glass (single)		5.5 kcal/m²/h/°C
Plastic honeycomb		3.1 kcal/m²/°C
Total number of windows		7,813
Rate of broken windows		3 %
Opening rate of broken windows		50 %
Number of doors		20 0.9 mW × 2 mH
Opening rate of a door		20 %
Rate of the area of other openings to that of doors		20 %
In terms of the number of windows		8.04
Total amount of air invasion (calculated value)		86,544 m³/h

Formula for calculating the amount of air invasion:

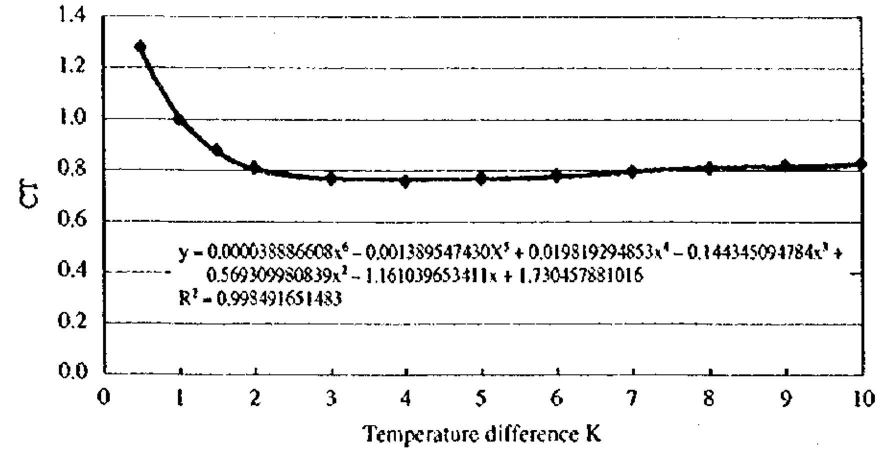
$= CT \times 2/3 \times W \times h \times (2 \times g \times h \times d\_diff/d\_avg)^{(1/2)}$

where

CT:	Coefficient of temperature, which is shown below
h = Ha/2	
g:	Acceleration of gravity
d_diff:	Difference in air density
d_avg:	Average density

(Indicated in terms of steam amount for heating)

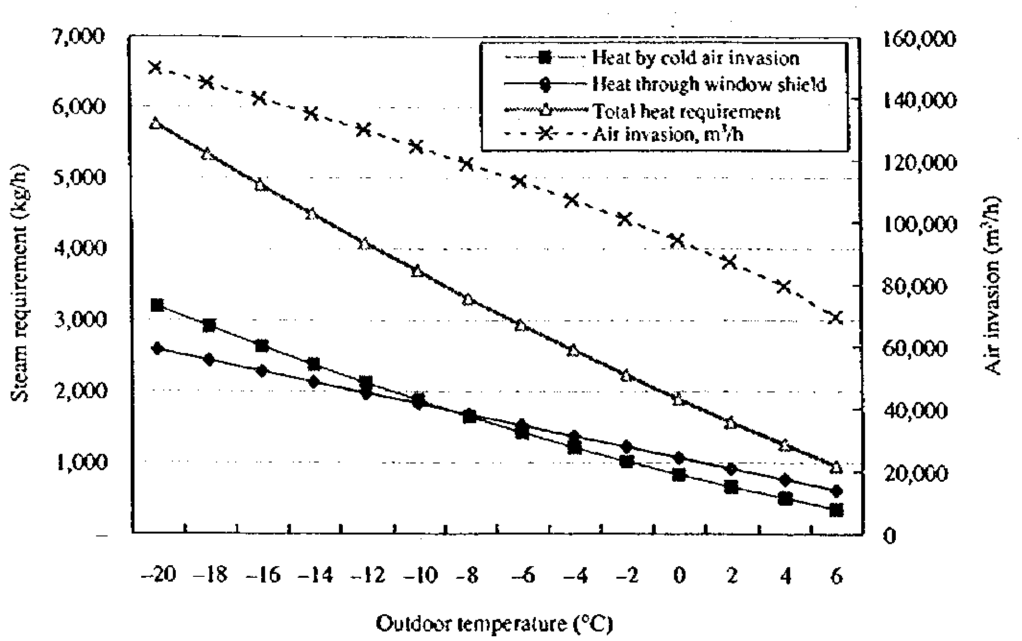
Figure 2.3.11 Coefficient of Temperature



This calculation uses the average atmospheric temperature in the heating season (from October to April) in Warsaw for the outdoor temperature. According to this calculation, the heat emission volume through glass windows is approximately three times larger than the air volume entering through openings. Of course, heat generation inside the building and heat loss through the roof and walls are considered, and thus the calculated steam volume is not immediately the necessary volume of seam for heating but the percentage against the thermal load can be known.

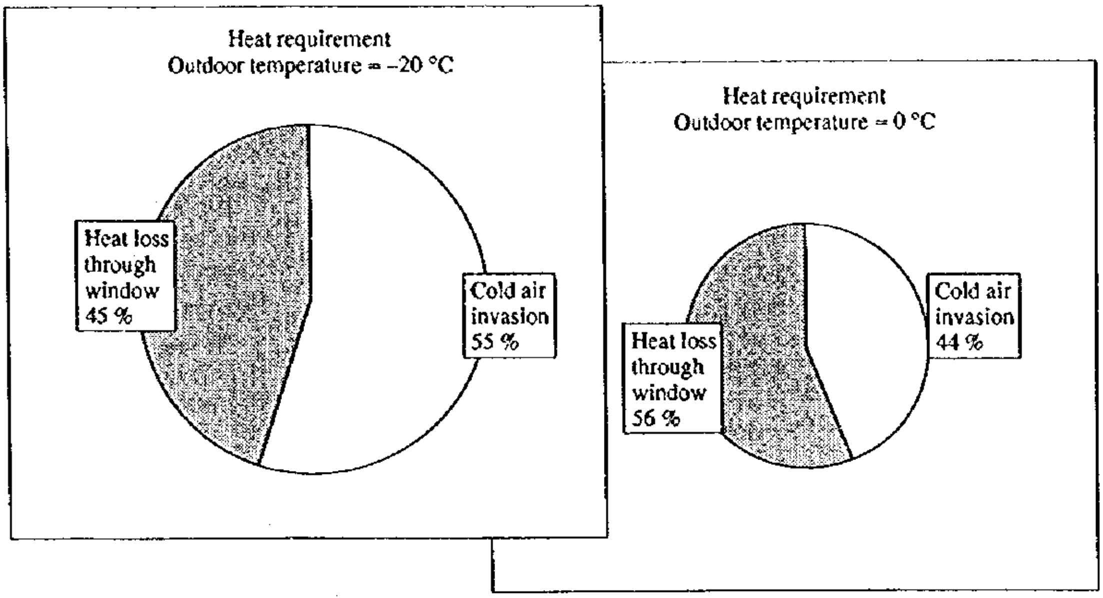
Figure 2.3.12 shows the changes of the load for heating calculated when the outdoor temperature is changed with the indoor temperature as a fixed prerequisite.

Figure 2.3.12 Heating Steam by Temperature



The ratios of the entering air and heat emission through windows slighltly change depending on the outer air temperature. Figure 2.3.13 shows an example.

Figure 2.3.13 Heat Loss through Window and Heat Requirement by Cold Air Invasion



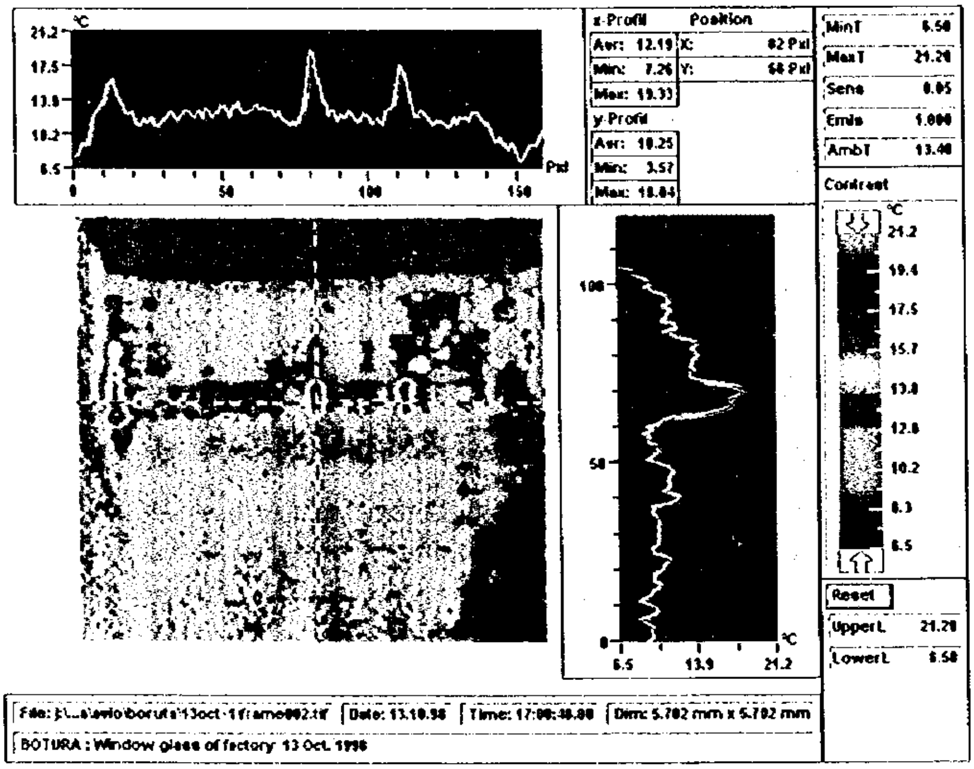
As shown in Figure 2.3.13, if the outer air temperature is low (i.e. the temperature difference with the indoor temperature is large), the heating load factor caused by the entering air increases. Therefore, it is necessary to repair the broken window and fully close the doors.

In this factory, plastic honeycomb sheets are used for some window glasses and its use ratio is approximately 5 % of the total window surface area. The heat conductivity of the plastic honeycomb is about a half of that of single-layer glass and approximately equivalent to that of double-layer glass. Therefore, installation of the plastic honeycomb results in the same heat insulation effect as that provided when double-layer glass is adopted.

The entering air volume is approximately 86,000 m^3/h according to this calculation. The number of ventilation times for the entire capacity of the building is estimated as approximately twice/h. Since this factory contains chemical processes, some ventilation should be performed certain times. Generally, localized ventilation at the location where hazardous gas is generated is effective and practical. An air distribution route should be formed that allows air entering from the first floor to go through the space on each floor, reaching the highest floor.

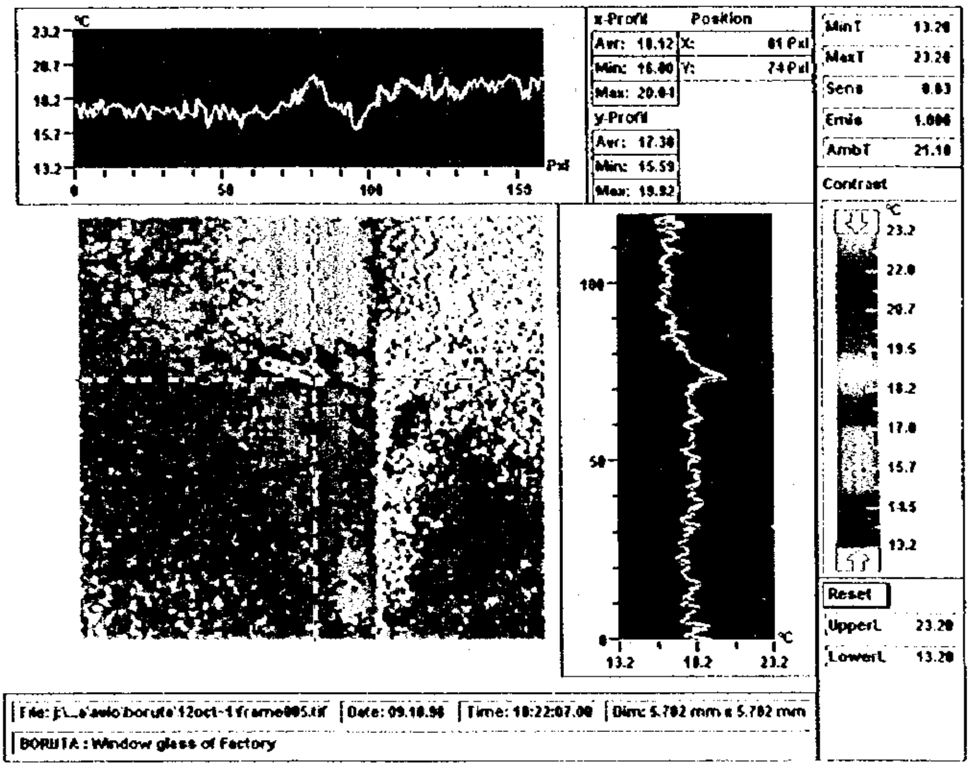
Sides of this building are entirely composed of glass windows. Some window glasses are broken. The thermal video image in Figure 2.3.14 shows the photograph of the broken window glass. Compared with the monochrome photograph at the bottom in Figure 2.3.14, it can be known that the temperature at the broken window is high. According to this figure, the broken window is at 20 °C, while the non-broken window is at approximately 10 °C.

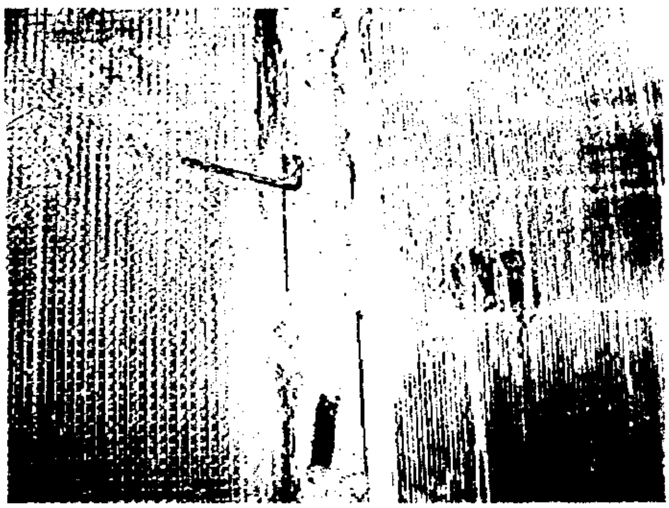
Figure 2.3.14 Thermal Image of the Reactive Dye Factory Window Glass



Plastic double honeycomb sheets are used for some windows of the building in the reactive dyestuffs factory. The thermal video image of Figure 2.3.15 shows one of these windows and ordinary single glass window photographed from the inside of the building. The photograph at left shows glass. It can be known that the surface temperature is lower than that of the plastic window shown at right. It means that thermal conductivity of the plastic window is lower.

Figure 2.3.15 Thermal Image of the Single Window Glass and Double Honeycomb Plastic Window





C. Utility (electrical facilities)

a. Electricity contract of BORUTA

Electricity is supplied by an energy supply company separated from BORUTA. The contract is based on the unit price of kWh. Therefore, the charge by time zone and demand change do not exist. This contract is advantageous to BORUTA but does not give the incentive for energy conservation.

The energy supply company generates electric power with its independent electric power plant (20 MVA + 25 MVA steam turbine) and purchases electricity from an electric power company to supply electricity to BORUTA. In June through August when steam is not used for factory heating, the steam turbine electric power generator is shut down but electricity is simply purchased. The maximum electric power in winter when a large volume of steam is used for heating is 14 MW. The load of the BORUTA factories is 3.5 to 4.5 MW (approximately 4.0 MW on an average). In winter, the amount of generated electricity is excessive and therefore the excess of electricity is sold. The price is 85 % of the electricity charge (charge by time zone).

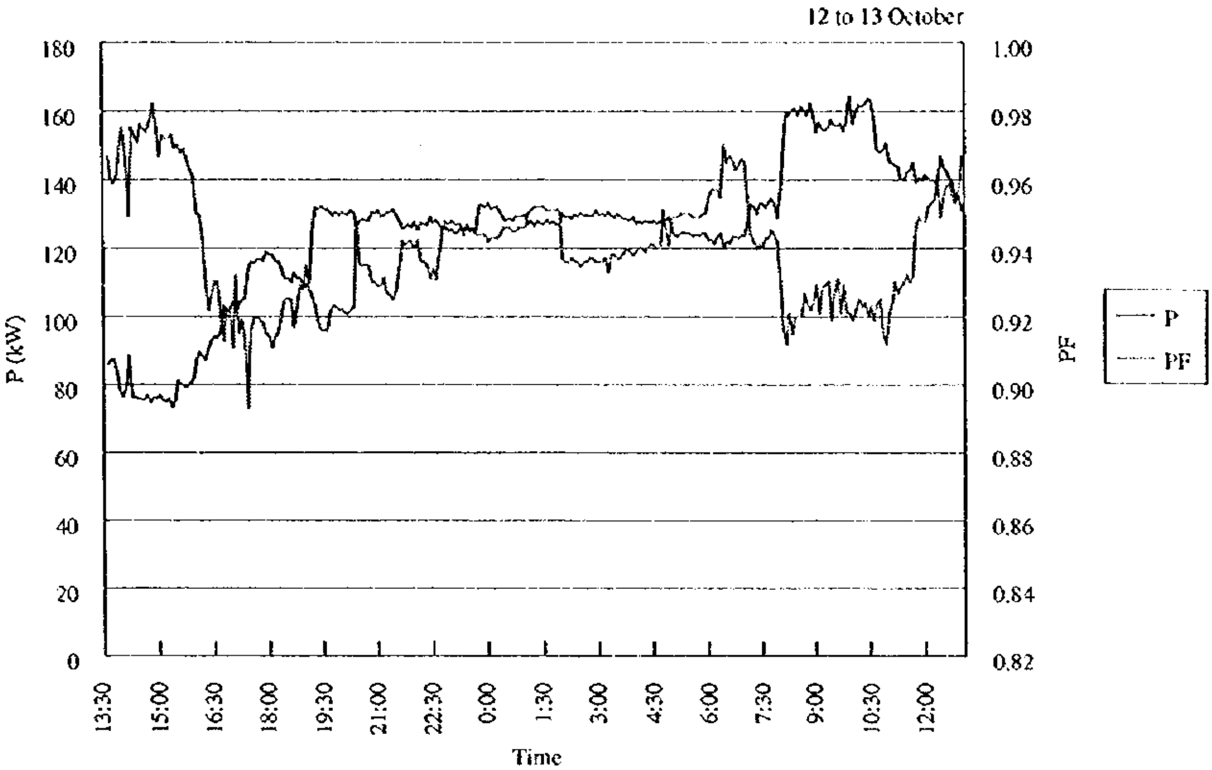
From the standpoint of the BORUTA group (i.e. the energy supply company is a subsidiary of BORUTA), merits through electricity operation by time zone or load leveling can be considered. For electricity purchasing, the ordinary A23 contract (various categorized contract modes provided) is made and the demand change and charge by time zone exist.

b. Electricity load of the reactive dyestuff factory

According to the person in charge of electricity in the factory, monthly electricity consumption is 180 (max.) to 120 (min.) MWh excluding the freezer and compressor.

Figure 2.3.16 shows the result of measuring electricity consumption in the dyestuff factory. Electricity consumption changes between 80 kW and 160 kW. Electricity consumption on the measurement day is at a lower level when it is viewed from monthly electricity consumption. Although one-day measurement is insufficient, the peak and bottom of the load are in the daytime zone. Therefore, the load may be leveled by selecting the optimum combination of loads. The power factor is mostly above 90 % and excellent.

Figure 2.3.16 Power Consumption of Reactive Dyestuff Shop



c. Compressor

Upon factory investigation, the compressor was running at a pressure of 0.44 MPa, an air feed volume of 3,300 $m^3{}_N$/h, and an output of 750 kW, among which 407 $m^3{}_N$/h was supplied to the electric power plant.

Figure 2.3.17 shows the result of measuring electricity consumption by the compressor. The air feed volume was read from the integrating flow meter in the compressor control room. The electricity variation range is 700 to 900 kW, while corresponding variation of the air feed voltage ranges from 1,900 to 5,700 $m^3{}_N$/h. According to this result, changes of electricity are smaller than variation of the air feed volume.

In other words, electricity consumption is large when the load is light. Therefore, renewal should be examined at a proper point.

Assuming replacement with a new compressor, the following specifications are considered.

Two-stage compression screw type	Slide valve control	Output: approximately 600 kW
Discharge pressure: 0.5 MPaG	Suction pressure: 0.1013 MPaG	Discharge air flow rate: 6,000 $m^3{}_N$/h

The average power consumption is assumed to be 360 kW.

The consequent energy conservation effect is presumed as described below.

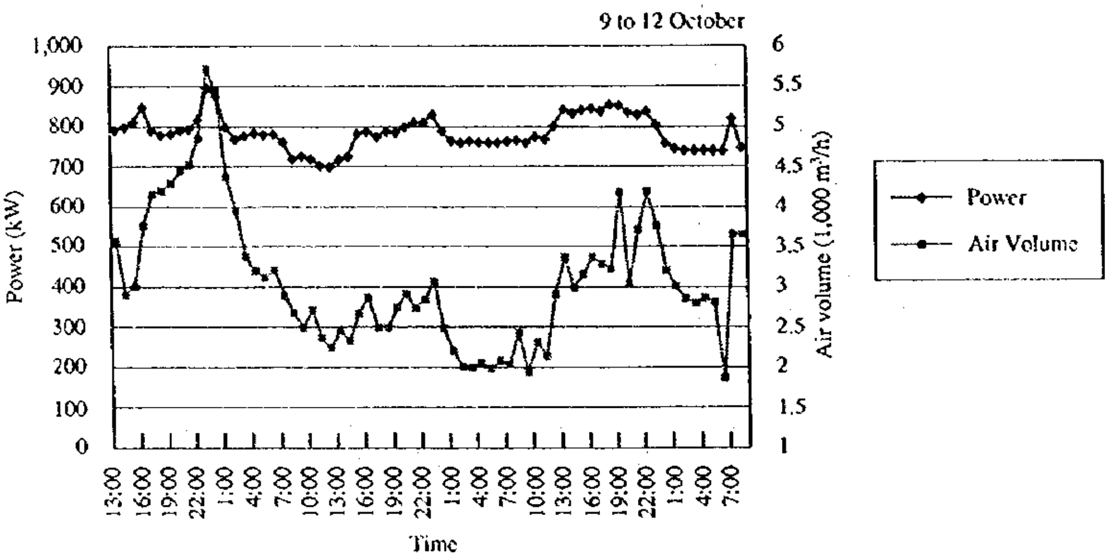
The amount of electricity saved : (800 – 360) kW × 8,000 h = 3,520,000 kWh/y
Amount saved in monetary terms: 0.13 PLN × 3,520,000 kWh = 457,600 PLN/y
Equipment investment : 1,000 PLN/kW × 600 kW = 600,000 PLN

Assuming the compresed air consumption in the reactive dyestuff factory to be 25 %, an electricity saving can be obtained as follows:

3,520,000 × 0.25 = 880,000 kWh/y

The payback period is 1.3 years.
However, the factory is in restructuring. It is planned to shut down this compressor and place a compressor in each factory in distributed mode. It is important to suppress the current air leak and determine the future air supply mode and compressor capacity (the air volume used in the factory).

Figure 2.3.17 Power Consumption & Air Volume of Compressor



d. NH_3 compressor

Figures 2.3.18 and 2.3.19 show the result of measuring electricity consumption by the #2 and #6 compressors. For each compressor, electricity consumption at the initial stage is approximately 150 kW and then consumption slightly drops as time goes by. Electricity consumption by the compressor itself is not so different from the compressor in Japan in terms of specifications and performance. However, the actual ice making capability is not known. For future, it may be considered to replace with the NH_3 absorption type freezer in terms of the electricity charge and steam charge. Since the power factor is low (0.85) in terms of electricity, it should be improved in future.

Figure 2.3.18 Power Consumption of Refrigerator #2

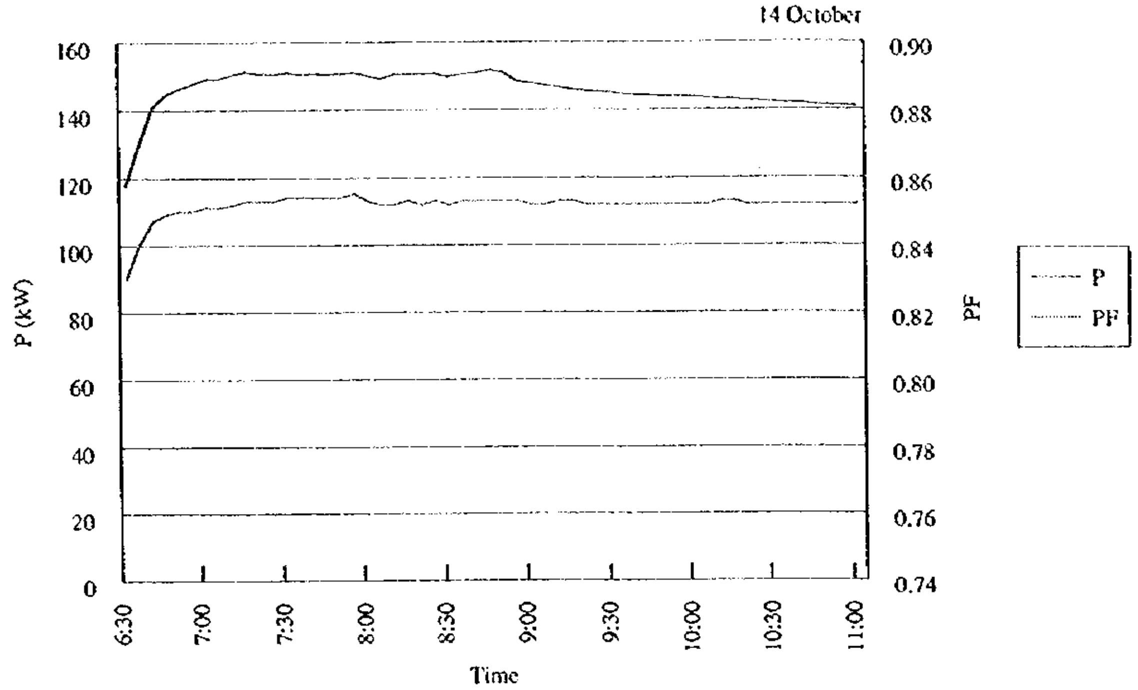
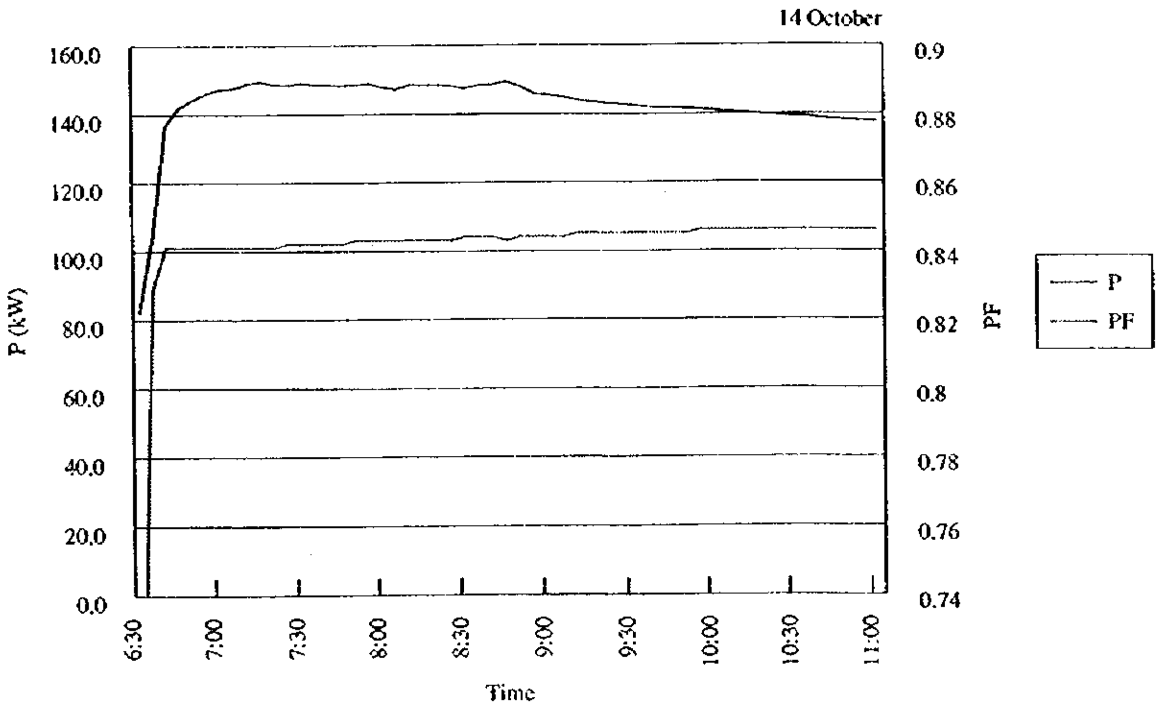


Figure 2.3.19 Power Consumption of Refrigerator #6



e. Factory lighting

Windows in the factory are very wide and suitable for utilizing natural light. Lighting is adopted and satisfactory lighting is provided by natural light in daytime. If higher illuminance is required, localized lighting with fluorescent lamps should be provided. (Actually, this is implemented in the areas around meters)

Unnecessary lighting is as follows:

1) New dryer room

Fluorescent lamps: 10 positions (40 W × 2 lamps)

2) Dryer room

1F: Mercury lamp : 13 lamps
2F: Mercury lamp : 6 lamps (Some sodium lamps are currently used, which is a good practice)
3F: Fluorescent lamp: 6 positions
Mercury lamp : 4 lamps (window side only)

3) Reactor room (main part of the factory)

4F : Mercury lamp : 18 lamps
Fluorescent lamp : 6 positions
Total: Mercury lamp : 41 lamps
Fluorescent lamp : 22 positions
Power consumption: Approximately 10 kW
Annual electricity saved = 10 kW × 8 h × 365 d = 29,200 kWh/y

Since lighting accounts for approximately 10 % of electricity consumption (during daytime) by the factory, the improvement effect will be substantial.
Electricity intensity improvement: 29,200 kWh/y ÷ 547 t/y = 53 kWh/t

(3) Summary of Energy Conservation Potential

a. Improvement of Environment through Energy Conservation

If fuel consumption is reduced through energy conservation, the quantity of pollutants emitted to the atmosphere also decreases. Additionally, if the amount of purchased power is reduced through energy conservation, so is the amount of power generated, that is, the quantity of pollutants emitted to the atmosphere by power plants. This reduction in emission quantity due to energy conservation depends not only on the amount of energy conservation, but also the type of fuel, and equipment, such as boilers, etc. Therefore the correct way to estimate the quantity of pollutants is to use the actual amount emitted by each factory. Here, however, for the sake of the consistency with the comprehensive study on Poland as a whole, calculations are based on information on the unit emission quantity (pollutant tonnage/fuel-heating value TJ), per industrial sector and per fuel type, provided by a document from the Institute of Environmental Protection. The reduction in the emission of air pollutants from this factory achieved as a result of energy conservation, is compiled at each stage of energy conservation, and shown in Table 2.3.16.

Table 2.3.16 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_2	Dust
Step 0				
Step 1	2	0.1	0.0	0.0
Step 2	8	0.3	0.1	0.0
Step 3				
Step 1-3	10	0.3	0.1	0.0

Reduction includes emission from fuel and electricity.

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

The result of calculating the amounts of reduction in pollutant emission, for the energy conservation items that were proposed based on our factory survey, and the corresponding reductions in emission fees, is shown in Table 2.3.17. Furthermore, the length of time required to recover energy conservation investments including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 2.3.17 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ PBP	Economical PBP
Step 0						
Step 1	42	0.0	42	30	0.72	0.72
Step 2	410	0.1	410	690	1.68	1.68
Step 3						
Step 1-3	452	0.1	452	720	1.59	1.59

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

As evident from this Table 2.3.17, the reduction in emission fee is only a few percents at most compared to reduction in energy cost, and thus, the effect of reduced emission fees on the payback period is also negligible.

Since this factory purchases steam for heating source, energy conservation through the reduction of steam does not lead to a reduction in the emission fee. Although energy conservation for electricity results in a reduction of electricity, the load on the emission fee in the purchase of electricity is relatively set to a small rate, and thus the effect of energy conservation on the emission fee is less significant. The apparent effect stemming from their energy conservation is observed in the installation of high-efficiency exhaust gas dust collector in power plants for business purposes.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 2.3.18.

The energy conservation potential using the Excellent factory as the benchmark for energy consumption intensity, and energy conservation measures in Steps 1, 2, and 3 are shown in Figure 2.3.20. The relationship between energy conservation potential, the payback period, and the investment cost is shown in Figure 2.3.21.

Table 2.3.18 Summary of Energy Conservation Potential

Steam: 25.0 PLN/GJ Electricity: 0.172 PLN/kWh 1 PLN = 30 yen

Item	Energy Conservation Potential							Investment	Payback period
	Fuel			Electricity			Total		
	GJ/y	10^3 PLN/y	%	MWh/y	10^3 PLN/y	%	10^3 PLN/y	10^3 PLN	year
Step 1									
1. Reinforcing the heat insulation of the dryer air heater	80	2	0.1		0		2	0	0.0
2. Omitting the filtering process		0	0.0	202	35	10.0	35	30	0.9
3. Turning off lighting during daytime			0.0	29	5	1.4	5	0	0.0
Subtotal	80	2	0.1	231	40	11.4	42	30	0.7
Step 2									
4. Expanding the sales of liquid type products	4,792	120	6.8		0	0	120	150	1.3
5. Preventing steam leakage of dryer air heater	959	24	1.4		0	0.0	24	40	1.7
6. Using the dryer condensate	1,517	38	2.1		0	0.0	38	50	1.3
7. Automating the material feeding		0	0.0	202	35	10.0	35	150	4.3
8. Improving the ice feeding method		0	0.0	40	7	2.0	7	50	7.3
9. Centralizing the steam piping	738	18	1.0	0	0	0	18	10	0.5
10. Arranging the air compressors in a dispense way			0.0	880	151	43.5	151	250	1.7
Subtotal	8,006	200	11.3	1,122	193	55.4	393	700	1.8
Total	8,086	202	11.4	1,353	233	66.8	435	730	1.7

As of 1997: Reactive dyestuff factory
Production volume: 547 t/y
Steam consumption: 70,950 GJ/y
Electricity consumption: 2,024 MWh/y

Figure 2.3.20 Boruta Energy Conservation Potential

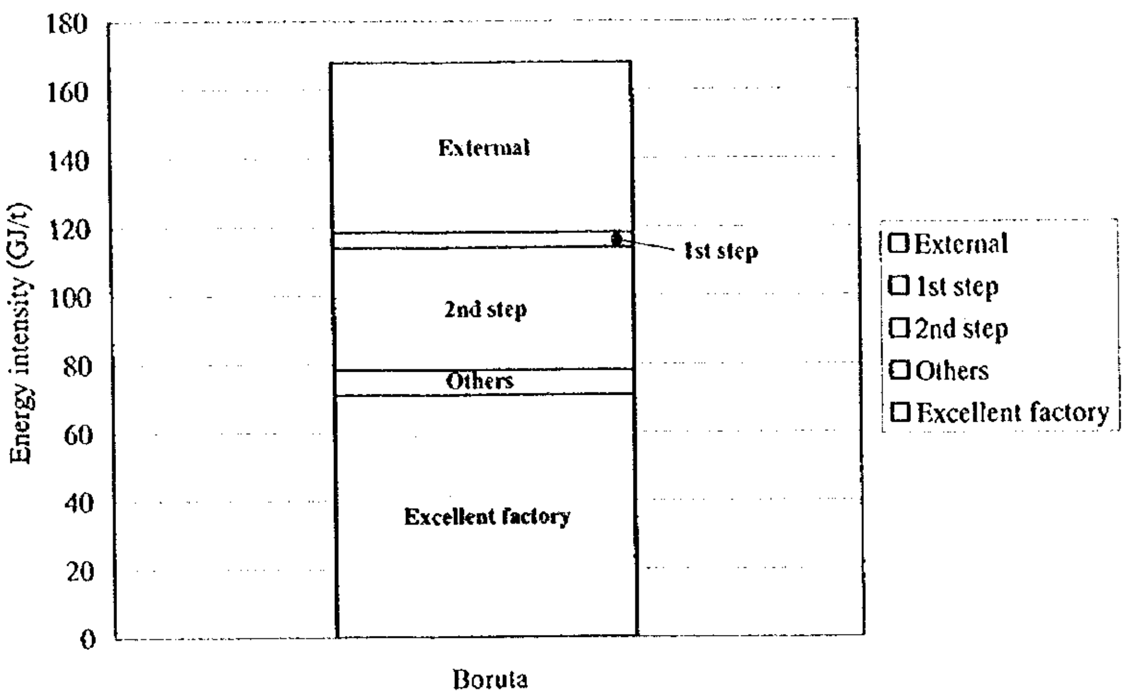


Figure 2.3.21 Boruta Energy Conservation Potential