3. RESULTS OF THE STUDY ON THE MACHINE MANUFACTURING INDUSTRY

3. MACHINE MANUFACTURING INDUSTRY

3.1 Results of the Study at Ursus Plant

(1) Study period: July 21 to 23, 1997 and September 30 to Octorber 8, 1998

(2) Members of the study team

a. JICA Team

Dr. Yozo Takemura : Leader
Mr. Norio Fukushima : Leader of energy audit & Heat management
Mr. Sadao Nozawa : Process management
Mr. Jiro Konishi : Heat management
Mr. Shiro Honda : Heat management
Mr. Kazuo Usui : Electricity management
Mr. Kiyotaka Nagai : Measuring engineering
Mr. Akihiro Koyamada: Measuring engineering
Ms. Ayako Sato : Coordination

b. KAPE and local consultants

KAPE
Mr. Ryszard Wnuk: JICA Project Manager
Mr. Dariusz Koc : Manager of Energy Audit

Research Center of Warsaw University of Technology
Dr. Krzysztof Wojdyga : Heat management in 1997
Mr. Maciey Chorzelski : Heat management in 1997
Dr. Leszek Krycki : Electricity management in 1997
Dr. Tomasz Wisniewski : Heat management in 1998
Dr. Wiesław Szadkowski: Heat management in 1998
Dr. Jozef Lastowiecki : Electricity management in 1998

(3) Interviewees

Mgr inz. Janusz Metrak : Director of Production, Technical Development
Mgr inz. Stanislaw Niemiec : General manager of the Energy Department
Mgr inz. Benedykt Pasnicki : 2nd manager of the Energy Department
Mgr inz. Jerzy Strzesniewki : Chief of Technology-energy Division
Mgr inz. Banasik Hennyk : General manager of Mechanic Division of the Engine Factory
Mgr inz. Bialek Ena : General manager of energy Division of the Engine Factory
Mgr inz. Kazimiez Matlosz : Director of Production in the Tool Factroy
Mgr inz. Marek Capala : Deputy Director of Production in the Tool Factory
Mgr inz. Boguslaw Sliwoski: General manager in the energy department
Mgr inz. Dziernowski : Department manager in the electric department

Mgr inz. Jakubowski	:	Electrical engineer in the electric department
Mgr inz. J. Wnuk	:	Manager of technology energy division
Mgr inz. Ogonowski	:	Vice manager of the light tractor factory
Mgr inz. Biernacki	:	Chief process engineer, the light tractor factory
Mgr inz. Pets	:	Manager of forging division

3.1.1 Profile of the Factory

(1) Plant name: URSUS, ZAKLADY PREZWMYSLU CIAGNIKOWEGO

(2) Plant address: 02-495 Warzawa, ul. Traktorzystow 10

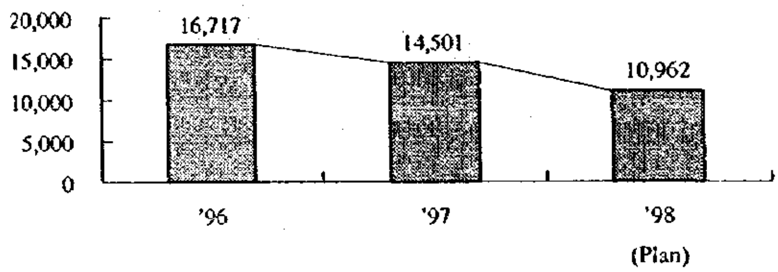
(3) Number of employees: 5,518 (1998), 6,864 (1997)

(4) Major products: Agricultural tractors (28 to 114 kW)

(5) Production capacity

Facility capacity : 50,000 units/y (100,000 units/y for the original plan)
Actual production level: See Figure 3.1.1

Figure 3.1.1 Trend of Production



(6) Overview of process

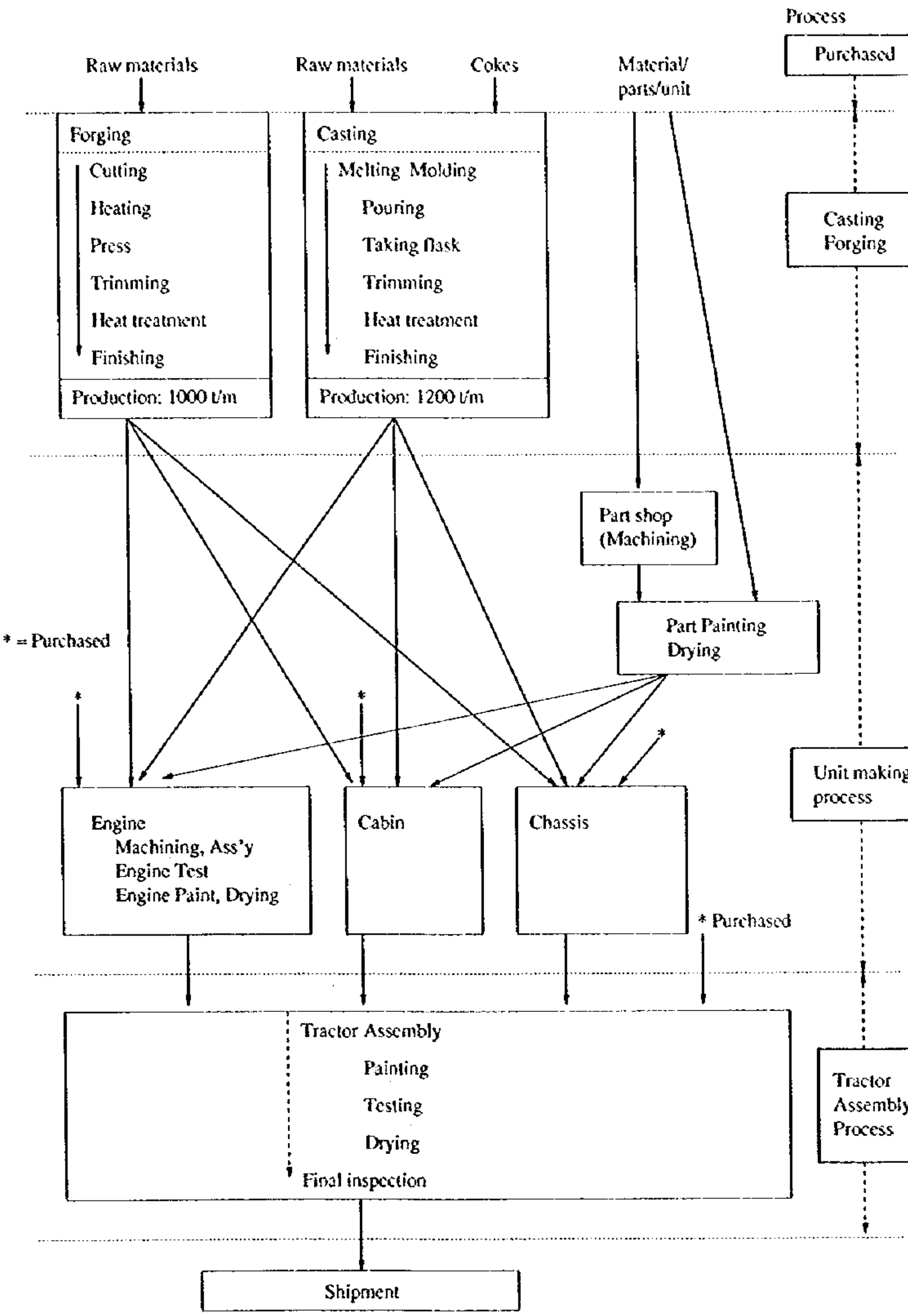
Production plants consist of a casting plant and a forging plant (old factory site), while the new plant site is dedicated to the assembly of engines, chassis, cabins, and tractors, as well as the production of parts, occupying a vast area of 180 ha.

While the plant possesses annual production capacity of 50,000 tractors, actual production is at a low operating rate of around 11,000 units/y, almost entirely produced within a single shift production schedule.

The form of energy used at the plant is private power generation from steam turbines during the seasons when heating demand is high, whereas the power generators are stopped during the non-heating season, and hot water from hot water boilers is supplied as the plant's heat source. Natural gas is used for the heating furnace and heat treatment furnace.

Figure 3.1.2 shows the process flow.

Figure 3.1.2 Process Flow

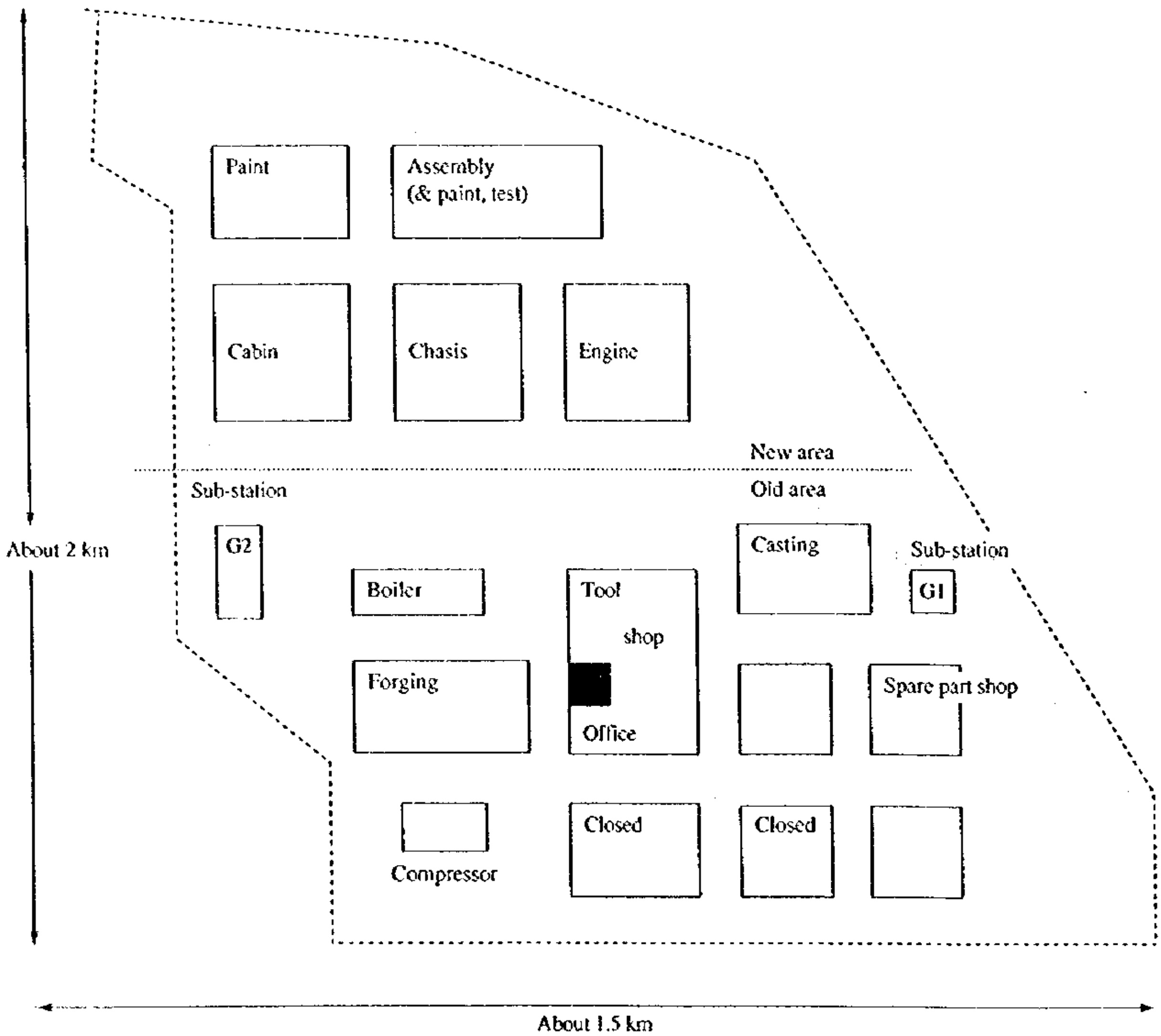


(7) History of the factory

Established in 1893, the plant has a history of about 100 years, and as its buildings and facilities both have excess capacity, its operation rate is at a low level for the capacity. The plant's domestic market share is about 60 %, and its export ratio also accounts for as much as 40 %. It is producing on an OEM (Original Equipment Manufacture) basis for a British tractor manufacturer, "MASSEY-FERGGUNSSON-PERKINS". Today, its production growth is at a standstill as it has to compete with cheap competing products from countries such as China. Currently, a restructuring plan is being devised. According to newspaper, AGCO, a tractor manufacturer in U.S. is considering capital investment in the said plant.

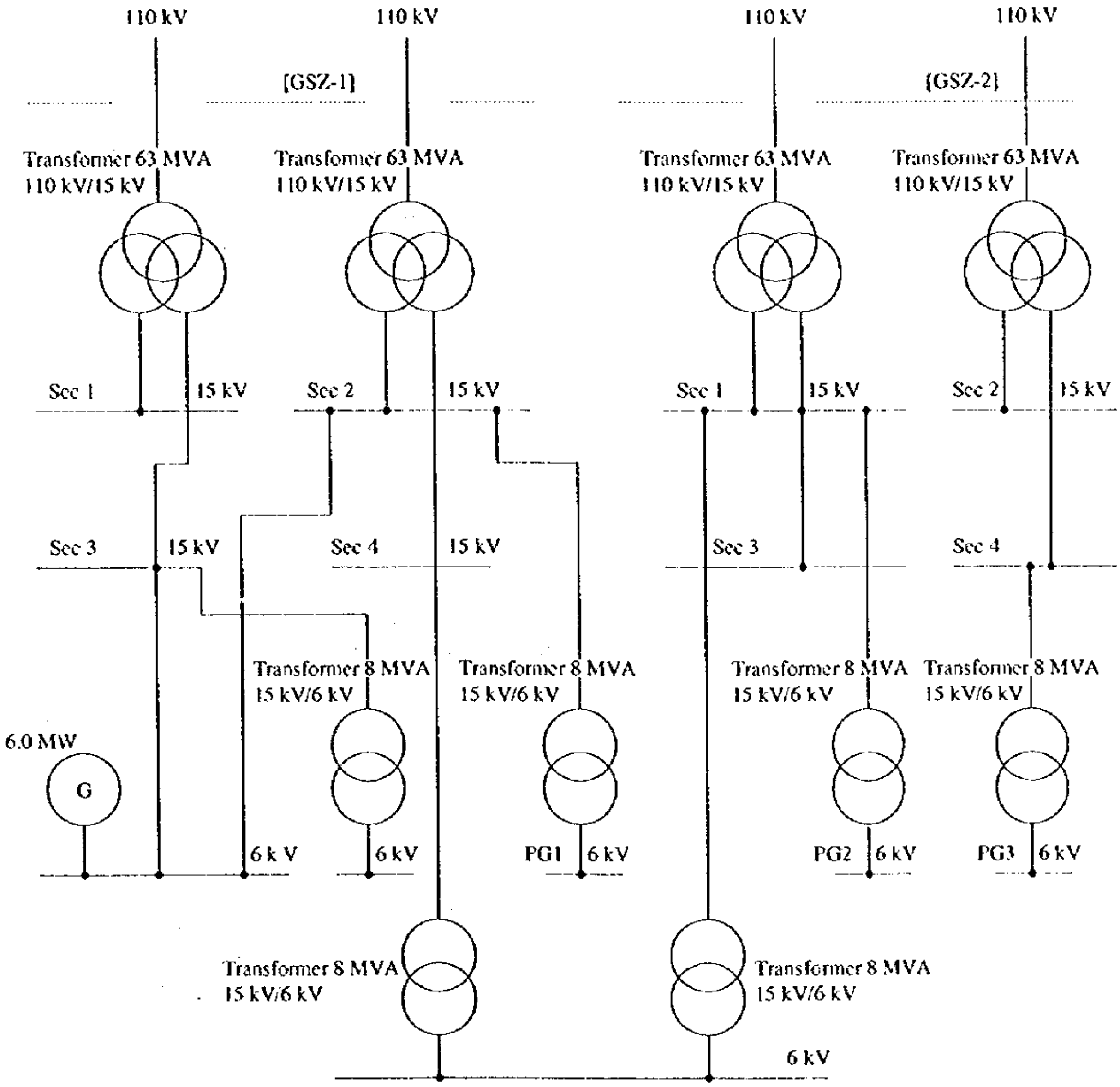
(8) Plant layout

Figure 3.1.3 Plant Layout



(9) One line diagram

Figure 3.1.4 One Line Diagram



6 kV is supplied to the plant load from GS Z-1 and GS Z-2 via PG1 to PG3 through each of Sec 1 to 4.

(10) Outline of major equipment

Many machining and washing equipment are available in the plants for producing parts such as engines, cabins, and chassis. Major types of equipment consuming a large amount of energy are shown below.

Table 3.1.1 Major Types of Equipment

Factory	Equipment	Number	Specification
Utilities	Electric sub-station	2	110 kV*2supply
			Transformer 110 kV/15 kV, 63 MVA*2*2
	Steam boiler	4	32 t/h, 40 kg/cm² (Heating season)
	Water boiler	4	85 – 90 °C, supply: 800 m³/h
	Air compressor	9	Turbo type, 1,910 kW
			16,000 m³/h*8, 15,000 m³/h*1
	Generator	1	7,500 kVA, Steam turbine 6,000 kW, 6 kV, pf = 0.8
Casting	*Production	–	1,200 t/m
	*Operation	–	8 h/d (Cupola: 16 h/d: 6:00 – 22:00)
	Cupola	6	1,200 mm dia (10 t/h)*4, 1,000 mm dia*2
	Induction furnace	–	
	Molding line	4	
Forging	*Production	–	1,000 t/m
	*Operation	–	8 h/d (10 h/m in part)
	Shearing machine	many	125 kW, ------
	Heating furnace (Electric)	3	60, 60, 90 kW
	Heating furnace for shearing	2	
	Heating furnace (N-Gas)	many	
	Press	2 + α	8,000 t, 6,000 t, -----
Parts painting	Main painting line	3	Washing-phosphorate-painting-drying
Tractor assembly	*Production	–	80 tractors/d (8 h/d)
	Main assembly line	2	*Cabinless tractors assembly line
			*Special type tractors assembly line
	Final painting equipment	2	
Engine	Machining	many	
/Chassis	/Washing		
/Cabin	/Drying equipment		

(11) Energy price and heat value

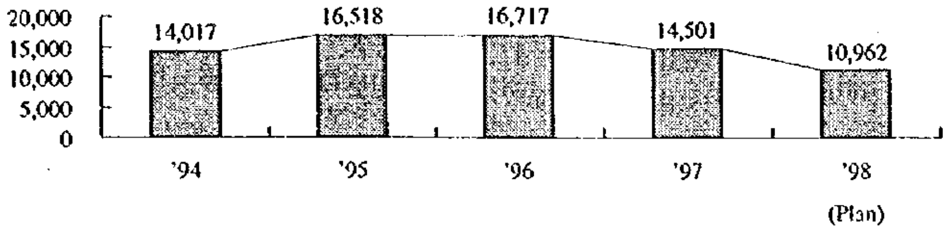
Table 3.1.2 Energy Price and Heat Value

	Energy price (1998)	Heat value
Coal	196.89 PLN/t	22,579 kJ/kg
Natural gas	0.87 PLN/m³	36,636 kJ/m³
Electric power (Purchased)	0.22 PLN/kWh (Purchased)	10,258 kJ/kWh
Electric power (Generated in the shop)	0.101 PLN/kWh (Generated in the shop)	
Electric power (Average)	0.16 PLN/kWh (Average)	

3.1.2 Energy Consumption State

(1) Trend of production

Figure 3.1.5 Trend of Tractor Production (Units/y)



(2) Trend of energy consumption

Table 3.1.3 shows the trend of energy consumption. These data include also the consumption of the affiliated companies on the same premises. The net consumption for the production of tractors only is shown together in the column for 1996 and 1997.

Table 3.1.3 Trend of Energy Consumption

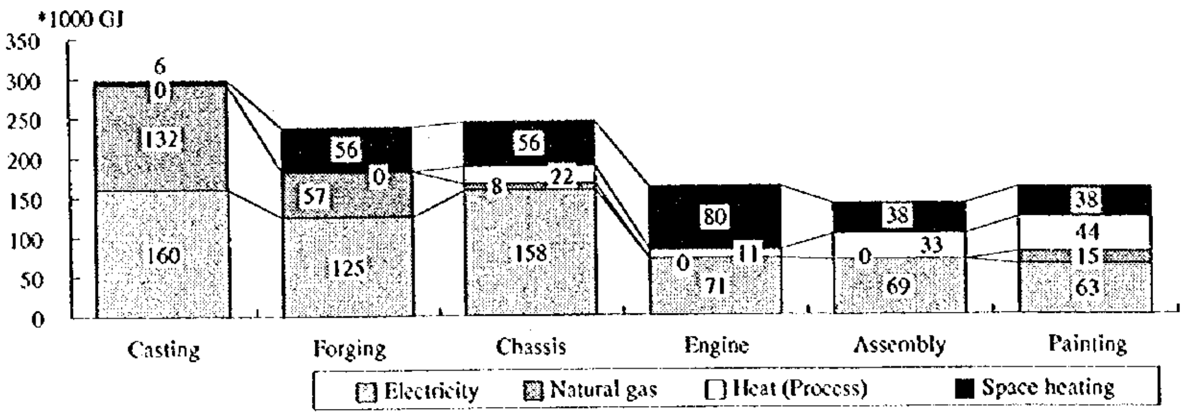
		1993	1994	1995	1996	1997
Coal	(t)	28,508	20,849	27,348	33,358	25,057
*1	(GJ)	643,682	470,747	617,489	753,191	565,762
Natural gas		8,925	7,794	7,755	8,475	8,049
	(GJ)	326,976	285,541	284,112	310,490	294,883
Electricity	(MWh)	112,922	112,457	118,100	118,031	114,087
	(GJ)	1,158,315	1,153,546	1,211,430	1,210,722	1,170,266
Total consumption	(GJ)	2,128,974	1,909,833	2,113,031	2,274,403	2,030,911
Total consumption for tractor production only*2					1,274,000	1,137,611

*1 Coal: These values were calculated based on the submitted heat consumption GJ data. (The purchased tons for 1994 through 1996 were obtained by inverse calculation of the submitted GJ. The value for 1993 was based on the ratio for 1994.)

*2 Energy used for tractor production only excluding that for the related company in the same premises.

Figure 3.1.6 shows energy consumption by process.

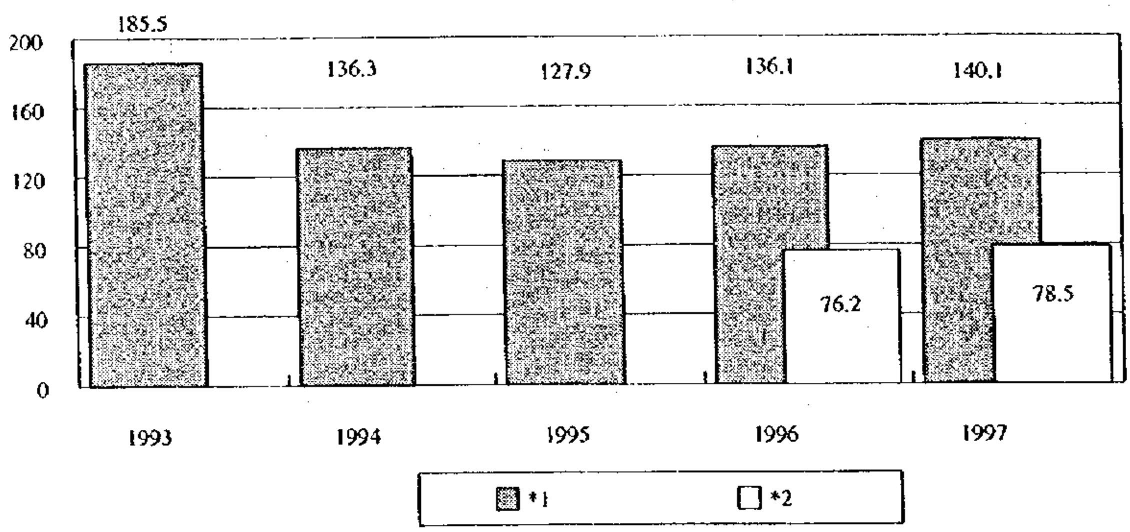
Figure 3.1.6 Energy Consumption by Process in 1997



(3) Trend of energy intensity

As mentioned in Item (2), the energy intensity (*1) from the submitted data includes that for the affiliated companies located on the same premises, and thus it cannot be regarded as the net energy intensity for manufacturing tractors. The data for 1996 and 1997 include also the net energy consumption for manufacturing tarctors. (*2)

Figure 3.1.7 Trend of Energy Intensity (GJ/Tractor)



*2 The surveyed shops include those for "forging", "casting", "engine", "assembly", "painting", and "chassis".

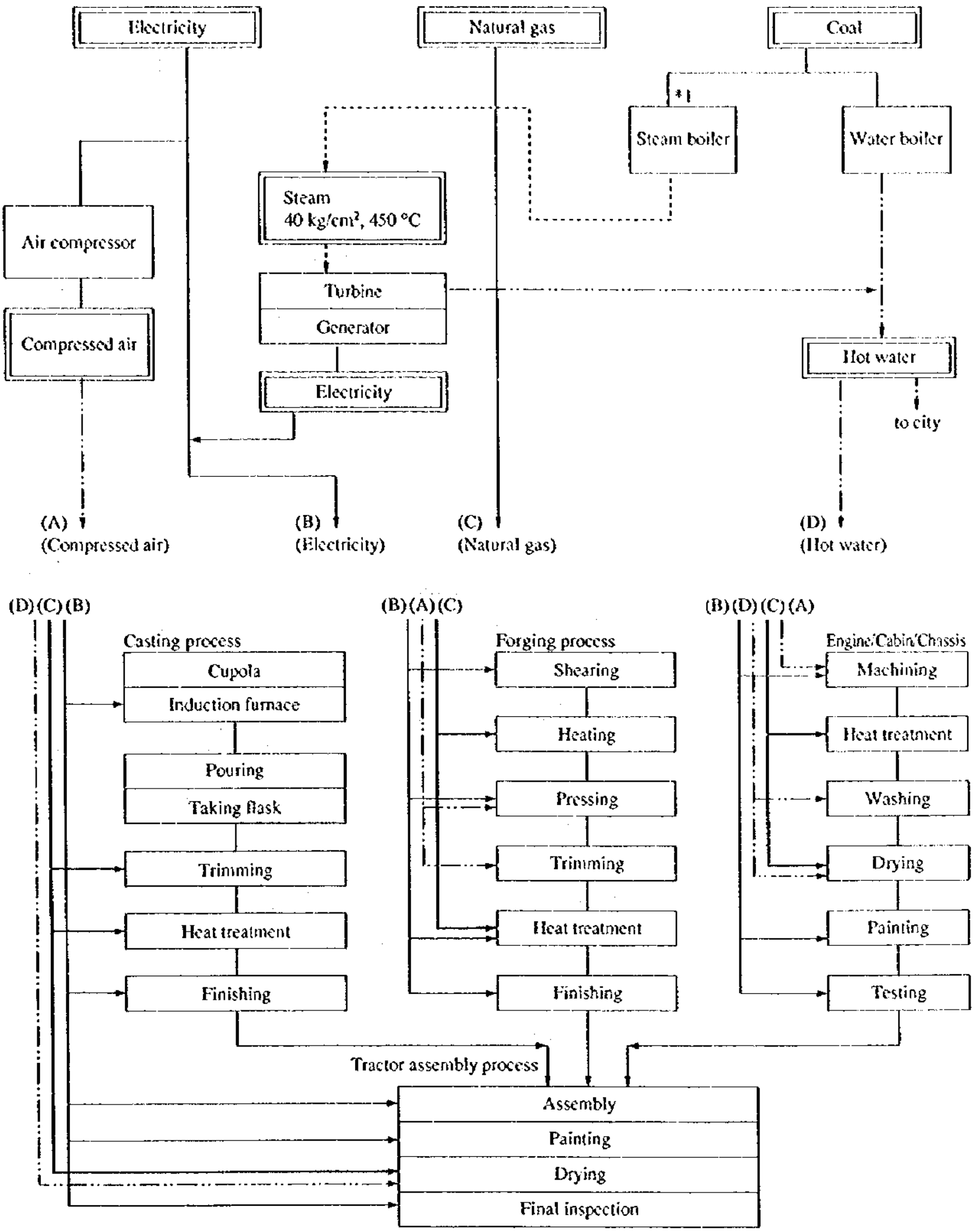
(4) Percentage of energy cost in the total production cost

Factory production cost for 1996	438 million PLN
Energy cost for 1996	24.3 million PLN (5.5 % of production cost)

(No data is available for 1997.)

(5) Energy flow

Figure 3.1.8 Energy Flow



3.1.3 Energy Management State

(1) Setting energy conservation targets

a. Setting targets

Although an energy consumption plan based on their production plan is drafted, no targets in terms of energy conservation for the entire plant have been set.

There are, however, some shops such as the Tool Shop that set up their specific target for energy conservation.

Although an energy department is available, its task is only to ensure a stable supply of necessary energy,a nd the department seems to be in delicate position, thus finding difficulty in determining a target for energy consumption. The "Tool Shop", an affiliated company on the same premises sets up its specific goal to proceed with their energy conservation activities.

b. Problems related to the promotion of energy conservation

These problems include the following:

1) Shortage of technicians and time to spend on analysis of energy use status
2) Lack of funds for introducing high-efficiency equipment
3) Difficulties in obtaining information on proven effective energy conservation case examples
4) Aging of facilities
5) Shortage of data due to lack of measuring equipment
6) Shortage of incentives for improvement effect stemming from energy conservation
7) Low awareness level among employees

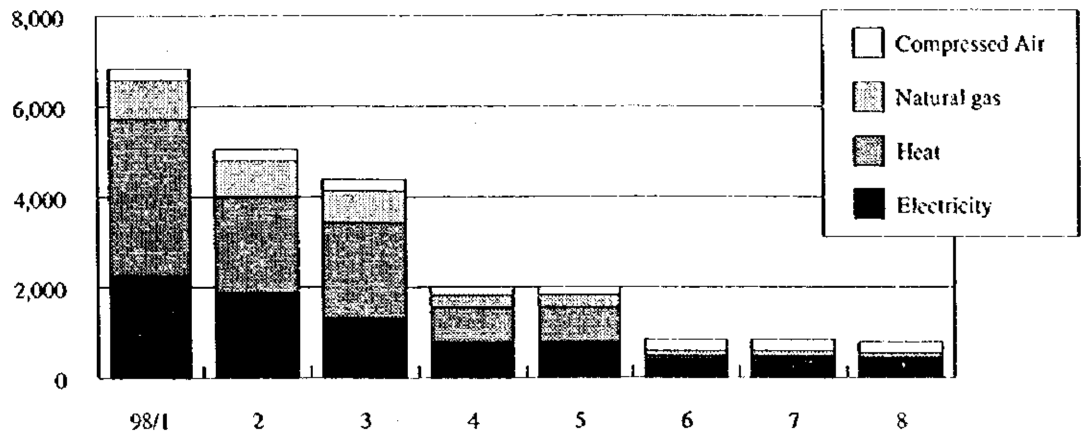
(2) Systematic activities

a. Sections dedicated to energy conservation and the Energy Conservation Committee

An "Energy Department" is available, which is in charge of the procurement of power, private power generation, supply of heat (hot water and steam), air and water supplies, waste water treatment, and environmental protection, and is also positioned to resell energy. There is no organized activity in the form of an "Energy Conservation Committee" going on.

A system is in place where the Energy Department collects slips for the energy costs and bills each department once a month. With regard to energy conservation activities, the Energy Department only checks equipment for any air leakage twice a month, and if some problem is found, the said department asks the responsible department to take a countermeasure. According to the comment of the manufacturing department's staff, they are also aware of high energy cost, but can provide no solutions due to the absolute lack of funds. For this reason, there is not so much mutual communication between these departments. The Tool Shop, is however, currently engaged in HOPP activities (*1), as a part of which they are also implementing energy conservation avtivities, having produced a good effect from since several months ago. (Figure 3.1.9)
*1: HOPP: Human Oriented Program for Productivity

Figure 3.1.9 Energy Consumption at Tool Shop (1998)



b. Stance of top managers towards energy conservation

While they realize the necessity to save energy, progress is not being made in energy conservation investments due to the lack of funds. A countermeasure which does not require much investment, such as changing the work system into the one-shift system, is being implemented.

c. Personnel evaluation system

The wage system is a point system based on work details and experiences.

(3) Data-based management

a. Grasping of the energy consumption

The amount of electricity, coal, natural gas, and water purchased every month is grasped. However, along with in-plant consumption, those amounts include heat sold to the city and energy provided to affiliated firms located on the company premises, and are thus, not equal to the company's own energy consumption level.

b. Grasping of the energy consumption at each major facility

While the amounts related to boiler fuel and electricity that are resold or supplied to affiliated firms on the same premises are grasped by measuring instruments or by calculations, energy consumption levels of individual facilities are not grasped. Quantities for heat, water, and compressed air are calculated from the size of buildings, but accurate measurements for each factory and each facility are not made.

c. Grasping of energy intensity for principal products

While an outline of energy consumption with respect to the production plan is calculated, no grasping of energy intensity as the basis for such calculation is being made.

d. Installation of measuring instruments

While there are measuring instruments for the entire plant, almost no measuring instrument is installed beyond that for each section or building, except for electric power. However, there are some measuring instruments installed for energy resold outside the company (hot water and steam).

Additionally, some departments, such as the Engine Depatment, have started to install measuring instruments individually.

e. Production management and cost management

Judging from their energy unit price setting, their cost management seems to be adequate enough. Their production management also does not seem to suggest any shortcoming, but their operation rate is so low for the capacity of their facilities that their operation does not seem to be moving under production management.

(4) Training of employees

a. Training system

There is no specific training system. While there is supposed to be on-the-iob training (OJT) for newcomers, there is almost no evidence of this either since the number of workers is not increasing.

b. Commendation system

Since the objectives of the party and the labor union were identical in the days of communism, a mechanism to highly evaluate effective proposals and achievements was in place. However, since the union and the management no longer share the same objectives, an awarding system is next to non-existing.

However, the tool shop has its specific commendation system and thus achieves a result, thus attracting the attention of other departments.

(5) Plant engineering

Aging of both production facilities and utilities is noticeably advancing. Most of large scale repairs being carried out by subcontractors are maintenance work to fix problems that hamper production, while damages and aging that do not directly impede production that involve aspects like energy do not seem to be addressed. Maintenance work for areas that cause energy leakage, especially building windows and piping, are inadequate. Under such circumstances, upgrading two out of four coal-fired hot water boilers to natural gas-fired boilers is under planning, and thus modification or upgrading for which such fund as National Fund for Environmental Protection and Water Management is applied is expected to furhter advance.

3.1.4 Improvement Activities by Simplified Energy Audit

(1) Improvement of raw materials and material procurements

At the forging shop, a 90 × 90 steel billet is heated in a large furnace composed of 19 heating chambers as a pretreatment for cutting them to approximately 1 m in length. The result of measuring the exhaust gas in the heating furnace revealed that approximately 50 % of the heat of charged fuel is discharged as exhaust gas heat. Additionally, the distance thereafter to the cutting machine is long, resulting in substantial thermal losses due to heat radiation.

As a countermeasure for this, it was recommended that it would be substantially more advantageous to purchase a steel product already cut to the required dimension in terms of energy, labor and equipment costs. Thereafter cut materials have been delivered. This improvement is estimated to have reduced natural gas of 2 % used for the forging process.

Expected energy saving amount: 1,044 GJ/y (72 MJ/unit)

(2) Energy conservation through batch production

The recommended countermeasure thus proposed is that batch production when the production volume has declined is expected to have the following effect. Currently, the working system has been integrated into one shift, thereby achieving a significant effect.

The effects of batch production include the following:

- Reduction in the space heating energy
- Reduction in the lighting energy
- Reduction in the electricity consumption during equipment stand-by

The energy conservation effect achieved by the engine factory of which the data on the detailed amount of energy use could be obtained will be shown below.

Figure 3.1.10 shows the electricity consumption (January to September) for the engine shop before and after the improvement measure was taken, while Figure 3.1.11 shows the electricity intensity (January to September) of the same shop per unit produced.

Improvement of electricity intensity is 54 kWh/unit (= 300 – 246).
Electricity saving amount: 14,500 × 0.054 MWh/unit = 783 MWh/y

Figure 3.1.10 Electricity Consumption for Engine

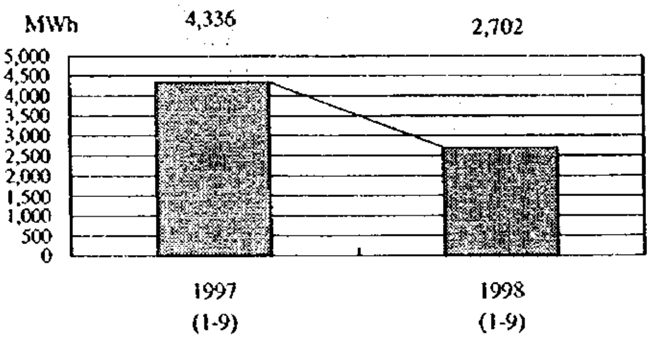
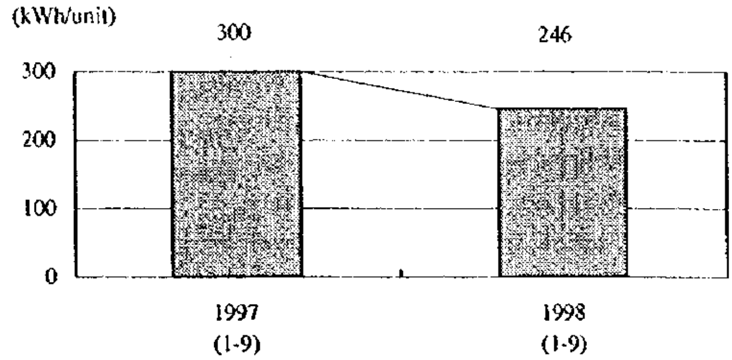


Figure 3.1.11 Electricity Intensity for Engine



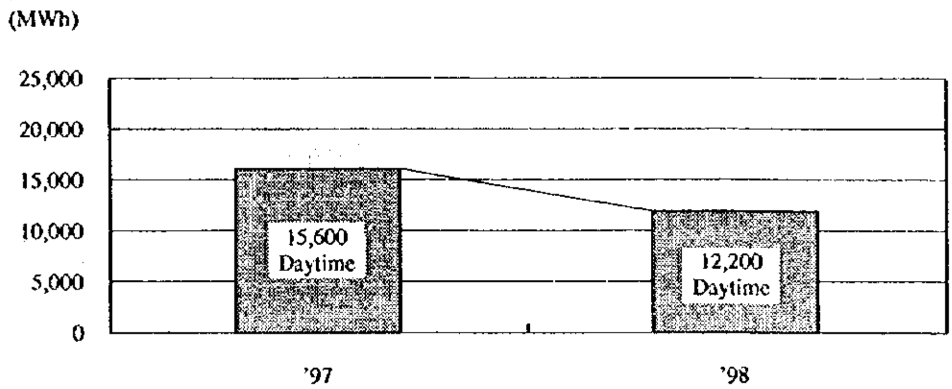
(3) Air supply by a small compressor during low load operation

Large-size 1,910 kW compressors were operating at 50 % of the rated capacity even during the third work shift or on holidays, but now improvement has been made to use an appropriate small type compressor for air supply during low load operation. This improvement can presumably achieve the following energy conservation effect.

Energy conservation effect: $(1.91 - 0.075 \times 2) \times (250\ d \times 8\ h + 115\ d \times 24\ h) = 3,832$ MWh/y (264 kWh/unit)

The electricity consumption in 1997 by compressors as compared with that for 1996 is presumed to produce the effect shown in the figure below.

Figure 3.1.12 Electricity Consumption by Compressor



3.1.5 Problems and Measures Related to Energy Use

(1) Comparison of energy intensity with an excellent factory

Based on energy data from 1997, Table 3.1.4 shows the energy intensity excluding consumption by affiliated firms on the premises, and the energy intensity of each principal manufacturing section.

Also, since we do not have much data on integrated tractor manufacturing factory, and because the classification of in-house and outsourced fabrication (make or buy) differ from company to company, figures for the excellent factory show the energy intensity for tractor as the sum of the intensity of each individual section as a result of the study.

Table 3.1.4 Comparison of Energy Intensity

			Unit	URSUS	Excellent factory	Difference
Energy intensity per production of a tractor			(GJ/unit)	78.5*1	38.4 ~ 46.4	32 ~ 40
By process (a part of the above breakdown)*2	Casting	Melting	(GJ/unit)	5.4	4.0	1.4
		Others	(GJ/unit)	6.7	3.4	3.3
	Total for casting		(GJ/unit)	12.1	7.4	4.7
	Forging		(GJ/unit)	19.4	11.4	8.0
	Engine		(GJ/unit)	11.3	5.9	5.4
	Processes related to body assembly		(GJ/unit)	24.9	11.7	13.2
	Factory air-conditioning		(GJ/unit)	17.4	2.0 ~ 10	7 ~ 15

*1: Excluding those for the related company on the premise, service parts shop and other shops not for comparison.
*2: The ratio for each process was based on that for 1996.

(2) Estimation of Energy Conservation Potential

The energy conservation potential of each process, such as forging, casting, fabrication and assembly, is compiled below.

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

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

Energy intensity was calculated assuming annual production in 1997 to be 14,500 units/y.

A. Process

a. Forging process

1) Measurement and analysis of exhaust gas components of the heating furnace used for material cutting

At the survey in 1997 hot cutting of forging material was conducted; however, at the survey in 1998, as a result of changing the fabrication system, it was outsourced as shown in section 3.1.4 and thus the heating furnace for hot cutting was shut down. The details of the survey on the heating furnace is described below.

In this furnace, 19 heating chambers are placed adjacent in a line in the direction along which the work material passes. The work material (bar steel) is heated by passing it successively through 19 heating chambers from the inlet toward the outlet. Gas is used as fuel for the burners installed in each chamber. A common blower supplies air for combustion to each heating chamber. The exhaust gas is blown out from the gaps in the connecting portions of the adjacent heating chambers, collected in the flue duct, and forced out through the smokestack. To measure the exhaust gas, a test tube was inserted in the gaps of the connecting portions one by one to measure the temperature and oxygen concentration. Continuous measurement was impossible due to the high temperature of the exhaust gas. Therefore, we decided to carry out spot measurement and read the measured value at each measurement point. Table 3.1.5 indicates the measurement results. This table indicates the air ratio and exhaust gas heat loss ratio calculated from the measured values, along with the exhaust gas oxygen concentration and temperature values.

Table 3.1.5 Measurement of Exhaust Gas from Material Heating Furnace

Measuring Positions	2-3	4-5	7-8	12-13	16-17
Current situation (at measurement)					
Exhaust gas oxygen	2.69 %	9.8 %	6.4 %	0.28 %	1.29 %
Exhaust gas temperature	1,089	1,030	1,140	940	1,190
Air ratio	1.13	1.79	1.39	1.01	1.06
Exhaust gas heat loss rate	54.3 %	76.2 %	68.6 %	41.8 %	56.8 %
Calculation of air ratio improvement					
Air ratio	–	1.25	1.25	–	–
Exhaust gas heat loss ratio	–	55.3 %	62.1 %	–	–
Fuel reduction rate	–	46.8 %	17.0 %	–	–

Note: The numbers in the measurement location row are the chamber numbers of the heating chambers as they are placed from the outlet of the furnace.

As shown in Table 3.1.5, the air ratio is high in specific heating chambers. Therefore, the effect to be produced by adjusting the air ratio is also calculated on a trial basis and indicated in this table. The air ratio improvement was calculated on a trial basis based on the standard value in Japan.

The heat loss due to the exhaust gas is very high—approximately 50 %. In other words, about 50 % of the fuel heat value is lost as exhaust gas heat. The exhaust gas measured in the flue leading to the outdoor smokestack merges with air that enters from outside and there is no room for collecting heat as shown in Table 3.1.6.

Table 3.1.6 Exhaust Gas Measurement in the Flue of the Material Heating Furnace

	Duct A	Duct B
Exhaust gas oxygen	19.3 %	19.5 %
Exhaust gas temperature	89 °C	68 °C

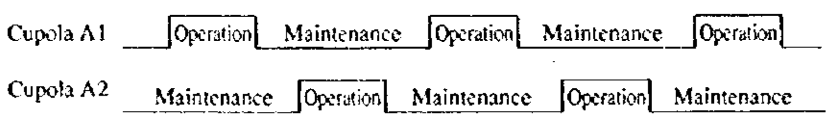
The only way to improve the heat efficiency in this furnace is to change the system. If a single heating chamber is set up instead of 19 chambers, it would be easy to control the combustion air and minimize the entry of air from outside. This method will allow air preheating to recover the exhaust gas heat. Therefore, it is absolutely necessary to install a new furnace for improvement.

b. Casting process

1) Improvement of cupola operation (Step 1)

The current level of casting is about 1200 t monthly, which can be finished in not more than 16 hours per day even with a single 10 t cupola. (Figure 3.1.13)

Figure 3.1.13 Cupola Operation Type on a Weekly Basis



Needless to say, the cupola's operation is intertwined with the capacity of the casting line (line speed), but due consideration should be given to speeding up the line, thus splitting the operation into 2 periods of batch production and complete halt, or to deploying smaller cupolas to accommodate 24 h continuous operations, depending on future production quantity.

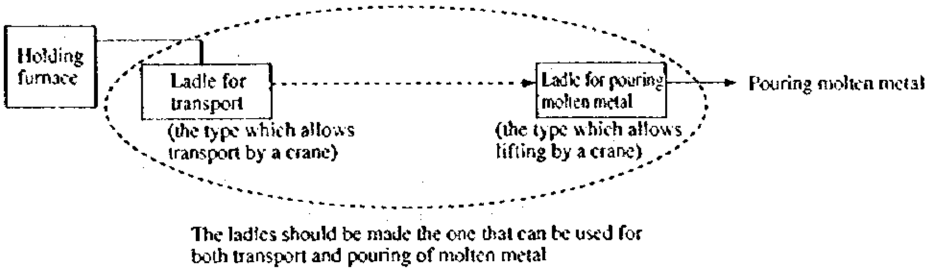
Expected energy saving amount: 2,538 GJ/y (175 MJ/unit)
(Making operation continuous brings about a 0.5 % reduction of coke ratio.)

2) Reducing heat radiation loss by modification of the ladle (Step 2)

In the current molten metal pouring process in casting, the molten metal is transferred to a ladle twice between the holding furnace and the time it is poured into the cylindrical block molding frame. While the transfer ladle is preheated, the one for pouring is not. The final temperature drop is 40 to 60 °C; therefore the ladle should be modified to function for both transfer and pouring so that only 1 transfer is required to pour the molten metal. (Figure 3.1.4 Pouring Molten Metal)

Expected energy saving amount: 304 GJ/y (21 MJ/unit)

Figure 3.1.14 Pouring Molten Metal



3) Improvement of cupola: Blowing pre-heated air by the heat recovery of exhaust gas (Step 2)

Because the heat of the exhaust gas is not recovered, the blowing temperature of the cupola is room temperature, which, coupled with short operating time, results in inefficiency, and a coke rate of almost 14 %. By recovering the heat of the exhaust gas, the blowing temperature can be raised to 250 to 300 °C, and combined with changing the operation to a continuous one, the coke ratio can be improved to about 11 to 12 %. The expected energy conservation effect by raising teh blowing temperature is as follows:

Expected energy saving amount: 5,031 GJ/y (347 MJ/unit) (coke rate reduction: 1.0 %)

c. Fabrication and assembly process

1) Energy conservation through batch production (Step 1)

When the operation rate of a facility is low because production is low for the facility's capacity, the following type of batch production is an effective countermeasure. Especially at factories and areas with high fixed energy consumption unrelated to production quantity, such as heating and illumination, energy intensity worsens substantially just by lowering production, which suggests possibilities of improvements that do not require investments in facilities. Implementation of such improvements will involve reviewing working systems as well as labor management such as shifting workers, but such measures can be expected to be considerably effective at Ursus, and since the introduction of such measures often do give workers the opportunity to improve their awareness, they should be tried at some of the lines as a first step towards the future. The following should be considered upon selecting the lines subjected to such attempts.
Although at present batch production under the one-shift system is conducted, energy conservation can be achieved through further batch production in with due consieration given to the following.

① By investing in people and facilities, the cycle time can be shortened further, and productions that took 1 month or 1 week can be finished in less than half the time.

② The line should be structured so that after the required amount of production is completed, heating and illumination apparatuses can be completely shut down, and the affected area can be closed until the next batch production begins.

③ Shifting of work assignments and training should be carried out so that the workers who were assigned to the closed line can attend other lines while that line is closed.

While it is understandably less easy to operate under a low operation rate and within a tight budget, our recent investigation left us with the impression that utilities are not adequately maintained and managed, and that further aging in these low-operation times should be a concern. Yet, it is precisely at times such as these that the implementation of batch production can make the time to reinforce maintenance efforts using internally available human resources, and thus get ready for the time that production level will recover in the future.

The effect produced at the department which has already implemented such measures is as mentioned in the previous section.

2) Improvement through the centralization of production processes (Step 2)

Since the assembly of engines and fabrication of parts individually do not require so large facilities, it is not that difficult to transfer such production facilities whose operation rate is low. Although it depends on the cost of transfer, to forecast the production level of a few years ahead, to forecast the operation rate of facilities therefrom, and to concentrate the facilities to a production process strictly limited to meet those forecasts will not only improve operation efficiency, but also be effective in substantially reducing energy consumption for heating. (Figures 3.1.15 and 3.1.16)

[Method of Implementation]
Production facilities for fabrication and assembly should be concentrated to a minimum amount of space necessary for operations and maintenance, and the concentrated area should be partitioned in order to raise heating efficiency, and it is important to shut down heating and illumination outside the partitions, or to lower them boldly. For example, there are 2 assembly lines at the assembly factory, but production is taking place at only one of them now due to the low operation rate. For the time being, isolating the line that is stopped from the rest of the area by a simple means such as a vinyl sheet, and temporarily shutting down the illumination and heating there, should have a great energy conservation effect. The month to month change in heating energy consumption in Figure 3.1.15 indicates that heating during the winter takes up an overwhelming proportion, and Figure 3.1.16 shows that its overall proportion is very large as well.

Figure 3.1.15 Trend of Heating Energy Consumption

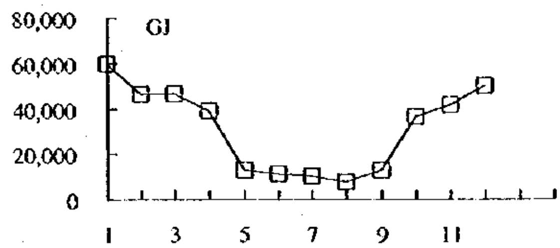
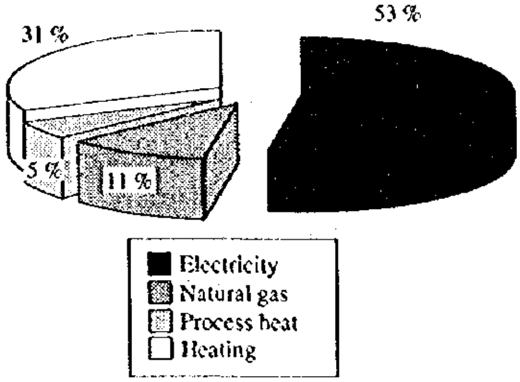


Figure 3.1.16 Heating Energy Ratio by Resource



① Concentration plan (A)

Approximately 20 % of the main factories in the new plant section, such as assembly and engine factories, can be closed. By reducing the heating to 1/3 of the current level in the closed areas, saving in heating energy listed below are possible.

[Effect 2-1]

	Principal Factories	Area that can be closed	Saving Energy
Area	Approx. 250,000 m²	Approx. 50,000 m²	-
Space heating energy	210,000 GJ/y	42,000 GJ/y → 14,000 GJ/y	28,000 GJ/y
Power consumption for space heating	16,000 MWh/y	3,200 MWh/y → 1,067 MWh/y (32,826 GJ/y) (10,945 GJ/y)	2,133 MWh/y (21,881 GJ/y)
Lighting electricity	8,4000 MWh/y	1,680 MWh/y → 0	1,680 MWh/y (17,233 GJ/y)
Already implemented in Engine Dept.			-783 MWh/y

Expected energy reduction effect: 67,114 GJ/y (4,629 MJ/unit)
Heat energy saving : 28,000 GJ/y
Electricity saving : 3,030 MWh/y (= 2,133 + 1,680 − 783)

② Concentration plan (B)

If future production can be forecast quite accurately, and production is estimated to become about twice the current level, it should be possible to boldly concentrate facilities to about half the present space.

If the closed half is completely shut down, the effect will rise even further as listed below.

[Effect 2-2]

	Principal Factories	Area that can be closed	Saving Energy
Area	approx. 250,000 m²	approx. 125,000 m²	
Space heating energy	210,000 GJ/y	105,000 GJ/y → 0	105,000 GJ/y
Power consumption for space heating	16,000 MWh/y	8,000 MWH/y → 0 (82,064 GJ/y)	82,064 GJ/y
Lighting electricity	8,400 MWh/y	4,200 MWh/y → 0	43,084 GJ/y

Expected energy saving effect: 230,148 GJ/y (15,872 MJ/unit)
Energy saving effect by only concentration plan (B) excluding the effect by the plan (A).
Heat energy saving: 77,000 GJ/y
Electricity saving : 8,387 MWh/y

3) Improvement of facilities

① Reducing air leaks (Step 1)

In the engine plant, measures against air leak were implemented after the previous audit. In the forging plant, however, a large volume of air leak was found. In this investigation, the leak volume was measured to estimate the energy conservation effect. As the measuring method, the speed of pressure reduction was measured to calculate the leak volume after the air source valve in the plant was closed during the time zone in which compressed air was not used in the plant. In the forging plant which seemed to use a large volume of compressed air, the air supply valve was closed at PM2:00 after the work was over and reduction in the in-pipe pressure was recorded. Figure 3.1.17 shows the schematic diagram of air piping in the forging plant. Air is supplied from the adjoining compressor room to this plant via two lines of air piping, which are called the hot air line and cool air line. However, these names do not mean the actual air temperatures but are simply names.

Figure 3.1.17 Air Supply for Forging Plant

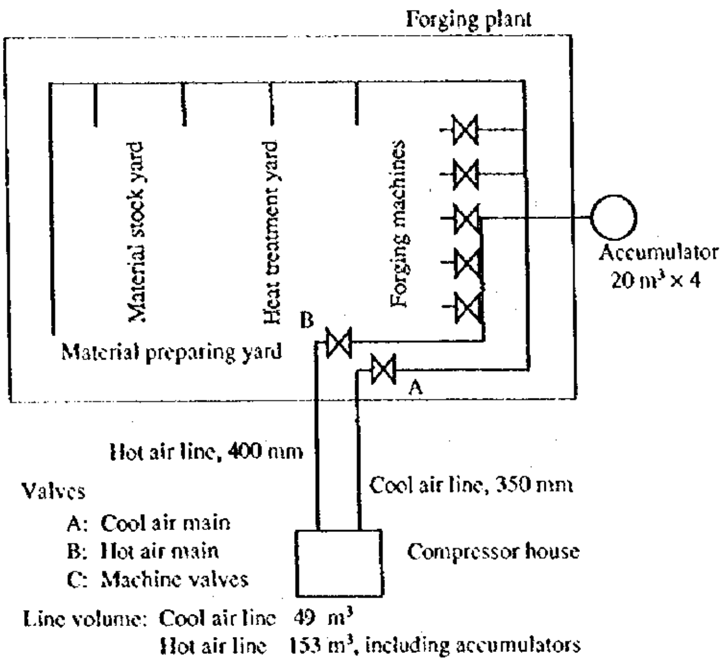
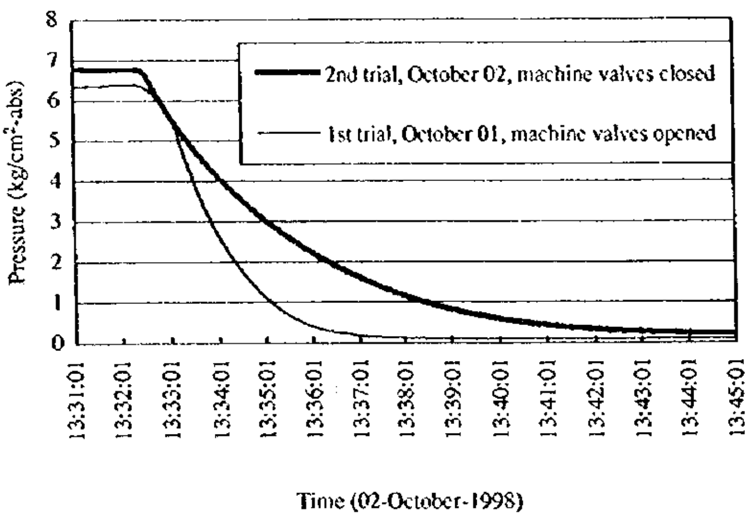


Figure 3.1.18 shows the result of measuring pressure reduction in the cool air line. In this line, measurement was performed twice. In the second measurement, the air valve for each forging machine was closed. This figure overlays the first measurement values over the second measurement result. It can be seen that closing the inlet valve for the forging machine reduces the leak volume.

Figure 3.1.18 Air Pressure, Forging Plant
Cool Air Line



From the record of the pressure effect measured values, sampling of several points was performed. With these points and the piping capacity, the air leak volume was calculated. The result is shown in Table 3.1.7.

Table 3.1.7 Air Leakage Assumption

Cool air line, machine valves closed, October 02

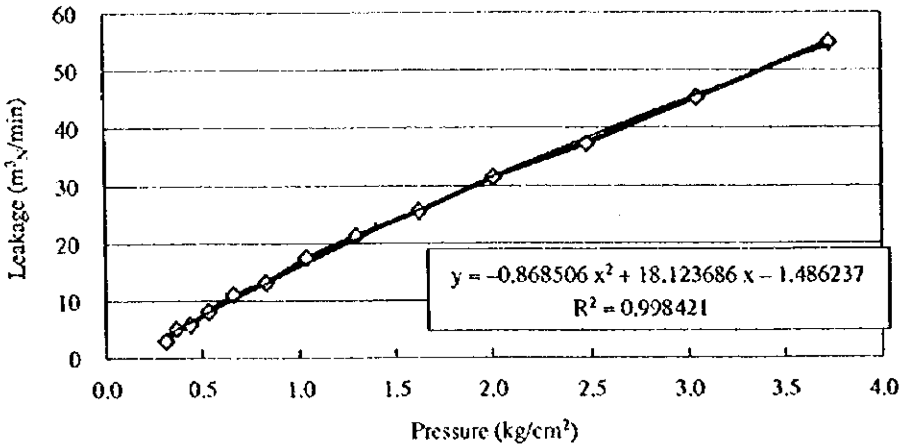
Time	Pressure	Pressure difference	Pressure average	Leakage (m^3_N/h)
13:34:01	4.11			
13:34:41	3.36	0.75	3.74	3,284
13:35:21	2.74	0.62	3.05	2,715
13:36:01	2.23	0.51	2.49	2,233
13:36:41	1.80	0.43	2.02	1,883
13:37:21	1.45	0.35	1.63	1,532
13:38:01	1.16	0.29	1.31	1,270
13:38:41	0.92	0.24	1.04	1,051
13:39:21	0.74	0.18	0.83	788
13:40:01	0.59	0.15	0.67	657
13:40:41	0.48	0.11	0.54	482
13:41:21	0.40	0.08	0.44	350
13:42:01	0.33	0.07	0.37	306
13:42:41	0.29	0.04	0.31	175
On normal pressure, extrapolated			6.20	4,650

On October 01, machine valves were opened; leakage was 12,421 m^3.

Since the leak volume depends on the air pressure, the measured leak volume was represented in a graph by using the pressure as a variable as shown in Figure 3.1.19. By converting this graph into a formula, the leak volume during normal operation was approximated through extrapolation. Table 3.1.7 also shows the leak volume at the normal pressure.

Figure 3.1.19 Air Leakage by Pressure

Cool Air Line, Machine Valave Closed, October 2nd



As shown in Table 3.1.7, leak of 4,650 m^3_N occurs in this line every hour even though the valve for the forging machine is closed. Since the valve for the forging machine is open during operation, leak is calculated to be 12,421 m^3_N/h in this case. During the forging machine's operating, however, no leakage occurs. Therefore, assuming the operation rate of the forging machine to be 30 %, the possible leakage is calculated as follows:

Similarly, leak from the hot air line was measured. Leak was 2,831 m^3_N/h while the valve for the forging machine was closed. This value is no much different from that provided while the valve for the forging machine is not closed.

Presumed value of the air leak volume in the forging plant : 14,485 m^3_N/h × 0.7 = 10,140 m^3_N/h

Annual leak volume conversion for this plant (*1): 20.3×10^6 m^3_N/y

Air leak volume for this plant in terms of electricity: 2,538 MWh/y (26,030 GJ/y)

*1: 8 h × 250 day

The volume of air leak including that in other parts is estimated to account for about 20 % of the total electricity consumption by the compressors.

Estimated compressor electricity consumption: 24,000 MWh/y (= 246,000 GJ/y)

Expected energy saving amount : 4,800 MWh/y (= 49,200 GJ/y) (3,393 MJ/unit)

② Improvement by changing the pressure of compressed air (Step 2)

While the factory setting of air pressure is 7 kg/cm², this setting does not seem to have any particular justification judging from our hearing survey. After studying whether or not pressure can be lowered for every type of facility, a 6 % reduction in electricity consumption can be expected by reducing the pressure setting to 6 kg/cm². However, whether or not there will be any facility that fails to function normally when pressure is reduced to 6 kg/cm² should be investigated, and a booster should be installed where necessary. Similar verification should be conducted in terms of quality aspects as well, and for newly added facilities, the guaranteed pressure supplied by the factory should be incorporated into the facility's specification. After improving air leakage, a 6 % reduction in electricity consumption can be expected if air pressure is reduced to 6 kg/cm².

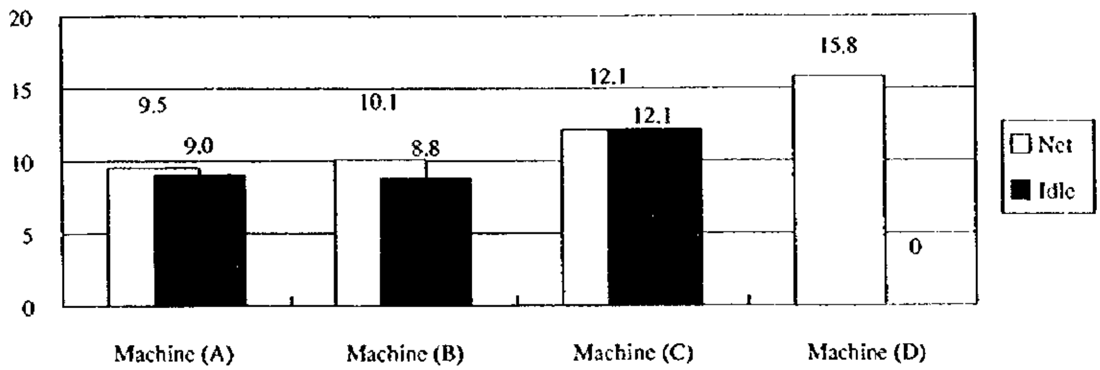
Expected energy saving amount: 1,170 MWh/y (12,000 GJ/y) (827 MJ/unit)

(3) Improvement by stopping facilities for one cycle (Step 2)

Along with the decline in production volume, the machines' waiting time is increasing, Even during such waiting time, a considerable amount of time is consumed and thus in this study some facilities in the engine shop were measures with the power consumption during actual operating time and that during waiting time. The result is shown in Figure 3.1.20. Even during waiting time, facilities A, B, and C, which have no function of stopping after one cycle, consume 80 % or more energy of the load during machining.

Facility A: Milling and centering of the shaft end surface
Facility B: Machining of shaft by lathe
Facility C: Parts cleaner
Facility D: Crank shaft cleaner

Figure 3.1.20 Energy Consumption by Machine (kW)



Thus, this one-cycle stop function combined with the careful stopping of facilities by workers should reduce drive power consumption at the engine and chassis factories by over 1 %.

Expected energy saving amount: 1,116 MWh/y (11,447 GJ/y) (789 MJ/unit)
= (158,000 + 71,000)/10,258 × 0.05

d. Energy conservation applicable to all processes

1) Energy conservation by improving yield

Poor yield means wasting energy without producing any output, and can have a greater impact than directly improving energy intensity. At the forging factory, average yield is said to be 80 to 85 %, but since some of them are as poor as 65 %, it is important to grasp the actual yield of each process and item, and to improve yield by improving production method and materials starting with those with the lowest yields. Also, large burrs exist after pressing at the shaft manufacturing process, and thus, there is ample room for improvements in yield there. Further, for cylindrically shaped forgings, the possibility of employing high yield production methods such as "friction welding" and the use of "upsetters" should be examined. It would be highly desirable to achieve 85 to 90 % yield through such streamlining efforts.

Besides, in fabrication, principal components such as cylinder blocks for engines and cylinder heads are said to have many material related failures. In this connection it is important to set up a cost management mechanism whereby defective items are not discarded but returned to the responsible source where the failure occurred, with the cost of the loss charged to that party so that the party or vendor can contribute to reducing the frequency of failures and improving costs, including energy cost, as well as delivery. Vendors or subcontractors should be made aware that the energy intensity of a failed item is infinite. Although there is no detailed data available to support this estimate, since each of the yields is not fully grasped, it is believed that yields at the forging and fabrication processes can be improved by about 2 %, and the expected effect is as follows.

Forging process : Electricity: 125,000 × 0.05 = 6,250 GJ/y
Heat : 113,000 × 0.05 = 5,650 GJ/y
Machining process : Electricity: 71,000 × 0.02 = 1,420 GJ/y
Heat : 91,000 × 0.02 = 1,820 GJ/y
Energy saving amount: 15,140 GJ/y (1,044 MJ/unit)
Electricity: 6,250 + 1,420 = 7,670 GJ/y (748 MWh/y)
Heat : 5,650 + 1,820 = 7,470 GJ/y

2) Energy conservation through streamlining of management methods (Step 1)

① Enhancing management by installing pressure gauges

While it is claimed that the pressure of the air used at production processes is 7 kg/cm², not many pressure gauges are installed at the facilities used. It is important to check how much loss is caused by air leakage between processes, and if the pressure setting is to be lowered in the future for energy conservation purposes, pressure should be managed by installing a pressure gauge at each process also in order to verify the quality of facilities where torque is determined by pressure, such as air nut runners. Moreover, installation of a pressure gauge will allow grasping the time it takes for pressure to disappear from entire processes and factories when the air supply is stopped, or in other words, how much leakage there is, which can lead to streamlining achievements. It does not take that much investment, allows employees' individual control and thus does not require persuading employees. And yet, it can substantially influence energy consumption.

② Recommendation of temporary maintenance work by employees

Since the operation rate is low due to dull sales, the budget for maintenance is understandably limited. Also, while the management side must be engaged in restructuring efforts for the survival of their enterprise, one cannot help but notice that the number of production site employees is still excessive. As mentioned before, if there is not enough production to match the number of employees, it is desirable to shut down the process after batch production, but if batch production is not possible, another method would be to reduce the number of people involved with production to slow down production speed, and thus, smoothen production to a more even pace. Although efficiency of fixed energy requirements such as illumination and heating will worsen, at the same time, assigning excess personnel to maintenance of facilities and equipment will make it possible to carry out repairs and improvements that cannot be done when production is at a high level and everyone is busy, thus making it possible to produce under optimal conditions when production increases in the future. Additionally, facilities are aging during such low operation times as well, and factors for worsening energy consumption still remain in place. Management and union members should have a thorough discussion, and at least, should carry out the following works by themselves.

- Repairs of gaps and cracks in factory windows and walls which will cause heat emission in the heating season
- Light collecting areas such as windows should be cleaned so that lights can be kept off during the summer.

- Measures against air leakage from piping and other such arrangements (Investigation and repairs)

e. Energy conservation potentials through modernization

Up to this point, energy conserving potentials have been described on the assumption that existing production processes will be used. Supposing that investments are to be made for modernizing the melting process in casting shop and fabrication process, which present a significantly large difference from those of excellent factory, the energy consumption in that case will be estimated as shown below.

1) Modernization of melting furnace

The use of melting furnaces is categorized not simply by cost, but also by the required quality level and operating form, as listed in the Table 3.1.8. The cupolas at the factory which was investigated can exhibit favorable total efficiency when mass production consisting of steady ingredients is continuously performed (= when production is at the originally planned capacity level), but are not performing at their intended efficiency at the current rate of production.

Table 3.1.8 Comparison of Energy Consumption by Melting Furnaces

Type of furnace	Heat source	Energy consumption per ton of iron		Efficiency
Cold air cupola	Coke	150 kg	(4,520 MJ)	27 ~ 32 %
Hot air cupola	Coke	100 kg	(3,010 MJ)	38 ~ 45 %
Arc furnace	Electricity	550 ~ 660 kWh	(5,640 ~ 6,770 MJ)	59 ~ 65 %
Low-frequency furnace	Electricity	500 ~ 630 kWh	(5,120 ~ 6,460 MJ)	62 ~ 70 %
High-frequency furnace	Electricity	600 ~ 650 kWh	(6,150 ~ 6,660 MJ)	60 ~ 65 %

Introduction of the following high frequency induction furnace and the latest cupola were studied as a modernization proposal. While the high frequency furnace will bring about better overall efficiency, cupolas are slightly better in terms of energy consumption when judged by melting requirements alone, and yet, the other effects of the high frequency furnace such as stabilization of the product quality are great. Since the range of ingredients at this factory are thought to be narrow, depending on long run forecasts for future items to be produced and quantities thereof, switching to the latest high efficiency cupola that can recover heat may be effective.

① Study of introducing high frequency furnace

Precondition :	Monthly melting quantity 1,600 t
Furnace to be introduced:	High frequency furnace 3 t × 3 units
Investment sum :	Approximately 7,500,000 PLN for 1 set
Heat source :	Receiving power will increase by about 5,000 kW. (Increase of 5,400 kW, Reduction of electricity with heat holding furnace 400 kW) However, since there is sufficient receiving capacity, this can be accomplished with existing distribution facilities.
Operating Method:	The same daily operating period as the molten metal casting line of 8 hours was chosen. Hourly melting quantity = 9 t was selected, and since this will be divided among 3 units, there is no need for a heat holding furnace.

Energy consumption: Current cupola:

Melting coke	81,000 GJ/y	(1,600 × 0.14 × 12 × 30,144 kJ/t)
Heat holding furnace	8,700 GJ/y	(400 kW × 8 h × 22 d × 12 m)
Total	89,700 GJ/y	

For high frequency furnace:

Melting electricity: 118,000 GJ/y (1,600 t/m × 600 kWh × 12)

Energy saving effect: -28,300 GJ/y (An increase when only focusing on energy consumption)

Other effects :
- Quality will stabilize.
- Drillings can be used (saving of raw material)
- Reduced maintenance costs
- Because of its smaller size, facility space can be saved (illumination, etc.)
- Specialized skills of workers, as in the case with cupolas, become unnecessary.
- Serves as a measure to protect the environment.
- Production can take place with high efficiency even if the operating period is changed.
- Equipment shudowns/stops are easy
- Energy loss, product loss, etc. are small compared to cupola.

② Study of introducing hot blast cupola

Precondition :	Monthly melting quantity 1,600 t
Furnace to introduced:	Hot blast cupola 3 t × 3 units or 10 t × 1 unit (Hot blast water cooled cupola)
Investment sum :	One set: Approximately 9,500,000 PLN (Approximaterly 300 million yen)

Operating method : Same as current one. (Heat holding furnace is also same)
Energy consumption: Current cupola:
Melting coke: 81,000GJ/y (1,600 × 0.14 × 12 × 30,144 kJ/t)
Hot blast cupola:
Melting coke: 57,800GJ/y (1,600 × 0.10 × 12 × 30,144 kJ/t)
Energy conservation effect: 23,200 GJ/y (1,600 MJ/unit)

③ Modernization of machining lines

Because labor costs are extremely high in Japan, automation of facilities and equipment have been advanced in order to stabilize quality even further, while transfer lines adapted for mass production of few items, and FMS (Flexible Manufacturing System) adapted to multi-item small lot production system have become the main stream in parts fabricating lines. Since these systems replaced human operations with machines, only the energy consumption increases. Yet, it can be said that they are highly efficient production systems overall because the functionality of equipment has become so sophisticated that 1 unit can perform many processes, and functions to minimize energy consumption when not in operation have been incorporated into them. An evaluation was made for engine parts fabrication processes assuming that they are automated to the level of similar fabrication factories in excellent factory.

Investment sum : 80,000,000 PLN
(Main line: 15,000,000 PLN × 4, others 20,000,000 PLN)
Energy saving effect: Current engine energy intensity 11 GJ/unit
Annual energy consumption 183,000 GJ/y
Energy intensity for same item after modernization 5.9 GJ/unit
Annual energy consumption 99,000 GJ/y
Energy saving effect 84,000 GJ/y (5,025 MJ/unit)
Other effects :
- Quality improvement (Improvement in yield can be expected)
- Reduction of direct labor
- Reduction of factory building size
- Reduction in lighting and heating can be expected due to unmanned operations and automation

B. Utility (Heat utilization facilities)

a. Boiler

This plant has a private power generating system consisting of a boiler and back pressure extraction turbine. Hot water for manufacturing processes and for selling to the city is supplied in the form of the extracted and exhaust steam of the turbine via a heat exchanger.

Because of the low demand for hot water during the summer (when no heater is used), the private power plant is shut down and the required hot water is supplied from a different hot water boiler. When the heating capacity of the hot water supplied from the private power plant is found to be inadequate during the cold season, the water is heated up using the hot water boiler.

During our survey in 1997, the steam boilers were stopped, while the hot water boilers were operating. During our survey in 1998, one hot water boiler was operating and the steam boilers started operation from the fourth day of our visit. The steam turbine was not operated but was in the warming mode.
Figure 3.1.21 shows the layout of the boiler and the measuring points. Table 3.1.9 and Table 3.1.10 show the specifications of the steam boiler and those of the hot water boilers, respectively.

Figure 3.1.21 Layout and Measured Points for Boiler Exhaust Gas

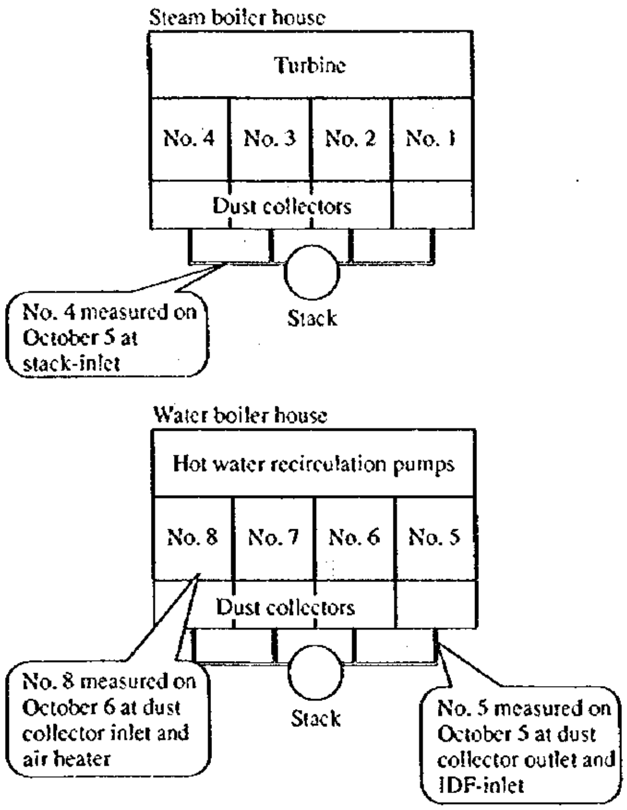


Table 3.1.9 Steam Boiler: Facilities and Operation

Type	Steam boiler, coal stoker fired		
		Designed	Working (October 5/1998)
Model		OR-32	
Capacity	t/h	32	25
Steam temperature	°C	450	400
Feed water temperature	°C	105	105
Steam pressure	MPa	4	3.2
Inatalled in		1976	
No. of installed boilers:	4 units, No. 1 to 4		
Air heater		Not attached	

Steam turbine

Type	Extraction & back pressure turbine with generator		
		Designed	Typical
Power output	MW	6.0	6.4
Power maximum	MW	7.5	
Steam pressure	MPa	3.5	3.6
Steam temperature	°C	435	436
Maximum steam	t/h	80	
Extraction pressure	MPa	0.6	0.7
Back pressure steam	atm	0.01	0
	°C	150	147
No. of installed boilers	unit	1	

Table 3.1.10 Hot Water Boiler: Facilitites and Operation

Type	Water boiler, coal stoker fired, forced circulation			
		Designed	Working	
			October 5/1998	October 6/1998
Model		WR-25	No. 5	No. 8
Capacity	Gcal/h	25	9.0	9.2
	MW	29		
	t/h		360	400
Pressure	maximum/minimum	2.0/1.1		
	working	1.6	0.62	0.5
Water temperature	in/out	70/155	52/71	52/75
Made by/in	RAFAKO/February 1976			
No. of installed boilers:	4 units, No. 5 to 8			
	No. 5 and No. 6 to be replaced with gas boiler next year			

1) Improvement of boiler air ratio

In order to grasp the air ratio of the boiler, the oxygen content of the exhaust gas at the flue and the exhaust gas temperature were measured at the points shown in Figure 3.1.21. The results of these measurements are shown in Figure 3.1.22 and Figure 3.1.23. These figures show also the average, maximum and minimum values.

Figure 3.1.22 Exhaust Gas, Steam Boiler No. 4

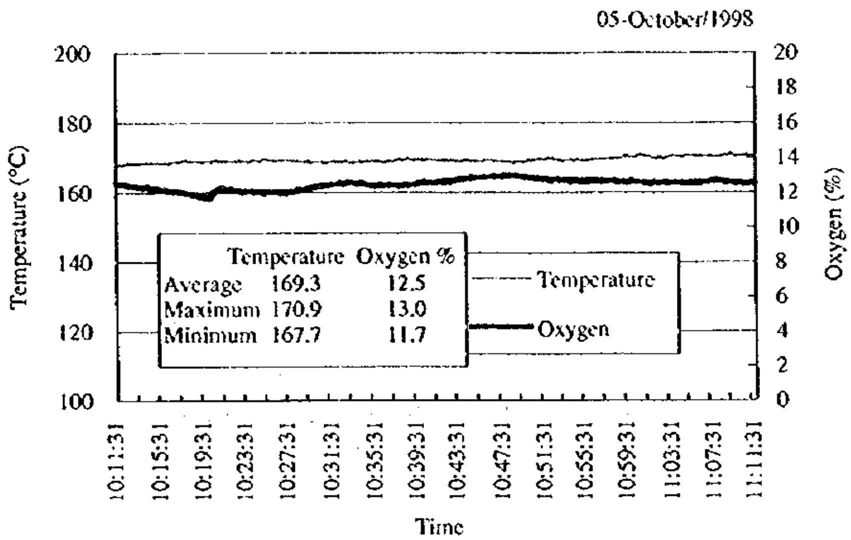
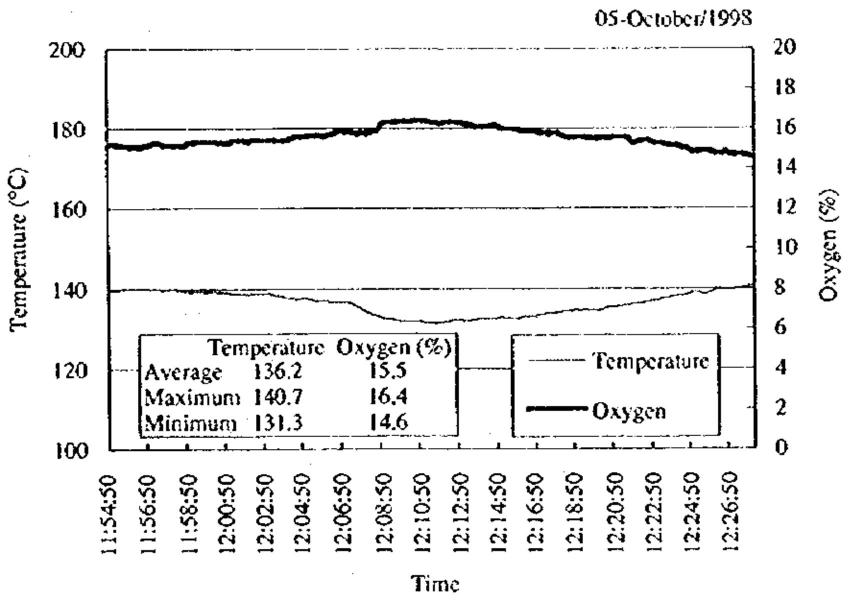


Figure 3.1.23 Exhaust Gas, Water Boiler No. 5



Assuming that the exhaust gas oxygen can be reduced to 11 % by adjusting the combustion air damper, the fuel saving rate for each boiler obtained based on the combustion calculation and heat balance will be as shown in Table 3.1.11.

Table 3.1.11 Combustion Calculation

Items	Theoretical combustion	Steam boiler No. 4		Water boiler No. 5	
		Measured air ratio	Improved air ratio	Measured air ratio	Improved air ratio
Exhaust gas oxygen	0.0 %	12.5 %	11.0 %	15.5 %	11.0 %
Air ratio	1.00	2.44	2.08	3.75	2.08
Air volume (m^3/kg)	6.4	15.7	13.3	24.1	13.3
Exhaust gas (m^3/kg)	6.8	16.0	13.7	24.5	13.7
Exhaust loss (to fuel)		14.5 %	12.5 %	17.0 %	9.7 %
Fuel advantage		Base	2.3 %	Base	8.1 %

Rem AR improved is the minimum in similar factories.

By adjusting the air damper according to the boiler load, fuel consumption is thus reduced. Since air ratio reduction brings about reduction in the combustion air volume and exhaust gas volume as shown in Table 3.1.11, power consumption of the boiler ventilation fans (i.e. the forced draft fan and induced draft fan) is reduced.

Although an air preheater is installed for each of these hot water boilers, it was found in this investigation that the air preheaters were bypassed and unused. If the combustion air volume is reduced, the exhaust gas temperature rises. Therefore, if the air preheaters are used, the fuel consumption volume can further be reduced. If the combustion air is preheated from 20 °C to 50 °C with the exhaust gas at 170 °C, a 3% reduction of the fuel consumption volume is expected in calculation.

Table 3.1.12 shows the fuel components used for calculation of combustion.

Table 3.1.12 Components of Boiler Coal

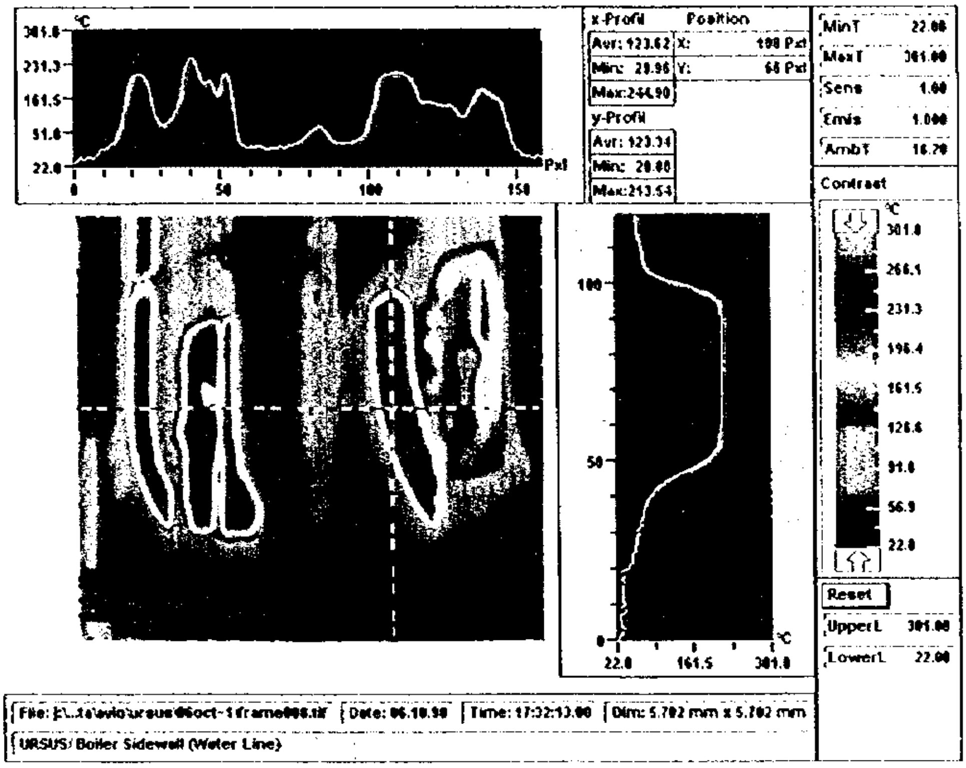
C	H	O	N	S	Water content	Coal ash content
81.5 %	4.9 %	11.4 %	1.3 %	0.7 %	6.0 %	16.2 %

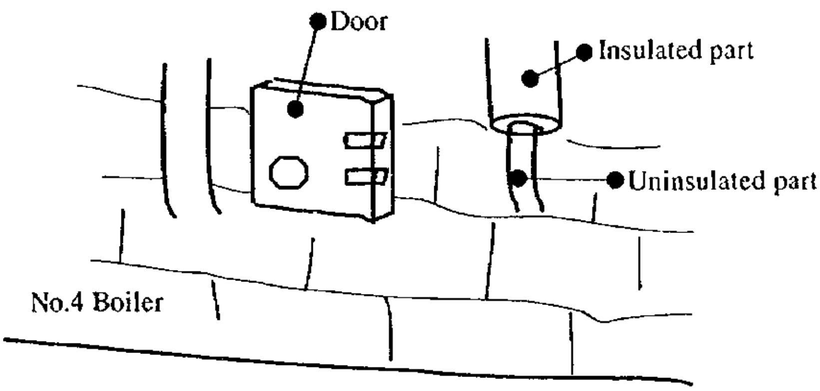
The fuel volume saved as a result of improving the boiler air ratio is as follows:

Steam boiler (No. 4)	: 500,000 GJ/y × 0.023 =	11,500 GJ/y
Hot water boiler (No. 5):	65,000 GJ/y × 0.081 =	5,265 GJ/y
Total		16,765 GJ/y

The coal volume used in 1997 was:
Factory heating season
(January through May and October through December): 500,000 GJ
Factory non-heating season (June through September) : 65,000 GJ

Figure 3.1.24 Thermal Image of the Steam Boiler Side Wall





Heat insulation was partially not applied to the steam piping around the steam boiler. This image shows an example (i.e. a photograph of the steam boiler DOWN pipe).

According to this image, the pipe surface temperature is approximately 210 °C where heat insulation is not applied, and 50 to 60 °C where heat insulation is applied.

2) Factory building heating

[Temperature distribution in the factory building]

Each building in the machine plant and assembly plant has a wide space and a large height. Generally, heated air stays at the top in these buildings during factory heating because of the ascending force. To maintain the temperature at the bottom in the building to the necessary degree for the work environment, a large volume of heat value is required. In these plants, a large number of hot air units are installed along a side or side at the upper portion in the buildings. Theheat consumption and electricity consumption seem to account for a considerable portion of the total heat value used. In this survey, factory heating was not started, and it was therefore impossible to know the indoor temperature distribution while factory heating was being performed. For reference, temperature distribution during our visit (while factory heating was not performed) was measured. Figure 3.1.25 shows the measuring points and Figure 3.1.26 shows the temperature distribution.

Figure 3.1.25 Room Temperature Distribution Measurement

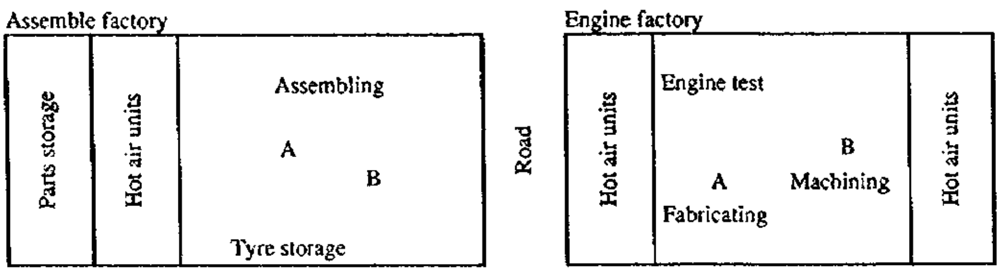
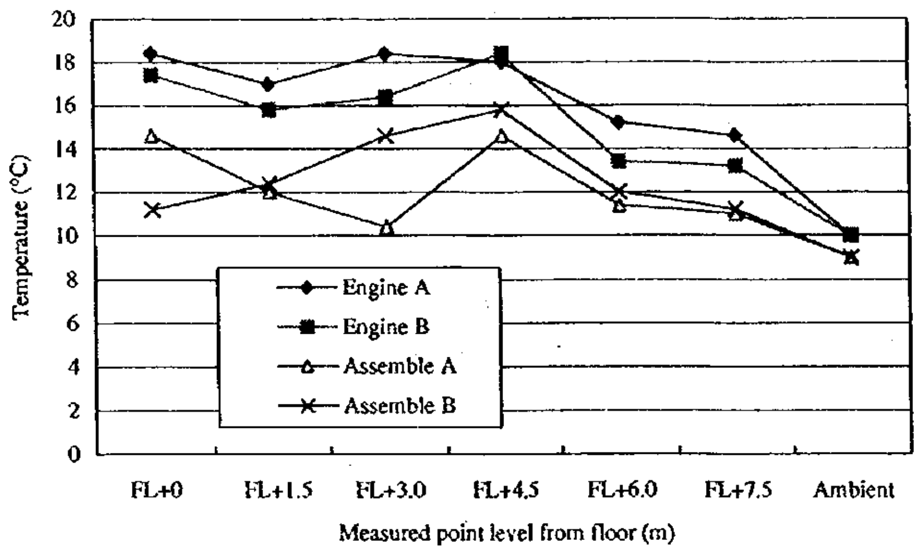


Figure 3.1.26 Room Temperature Distribution without Space Heating



If the temperature at the upper portion in the building is high, the heat emission volume from the roof increases and it is compensated with the factory heating energy. Generally, for such high-ceiling building, heating with hot air, high-velocity jet type are used for hot air nozzles so as to minimize the temperature difference by stirring the air in the building between the upper and lower portions in the building. This method can be considered for these plants.

C. Utility (electricity utilization facilities)

a. Power consumption for the factory

The electricity consumption for each time frame on the study date in 1997 is as follows.

Time frame	06:00 – 14:00	14:00 – 22:00	22:00 – 06:00
Electricity received at factory (MW)	20 – 30	12	6

From the above, the electricity received on operating days and non-operating days can be estimated to be as follows.

Operating days	28 × 8 + 12 × 8 + 6 × 8 = 368 MWh
Non-operating days	6 × 24 = 144 MWh

Annual operating days are assumed to be as follows.

Operating days	52 weeks × 5 – 10 (holidays and others) = 250 d (125 days each for the Summer and Winter)
Number of days off	365 – 250 = 115 d

In addition, the amount of increase in monthly electricity during the winter was estimated, from the monthly electricity use data, to be 1,500MWh. From this, the annual electricity consumption used is calculated.

Operating days	368 × 250 d = 92,000 MWh
Non-operating days	144 × 115 d = 16,560 MWh
Increase in winter	1,500 × 6 m = 9,000 MWh
Total	117,560 MWh/y

Overall, this value is close to actual consumption.

1) Presumption of the electricity volume used in the factory upon detailed audit in 1998

Figures 3.1.27 and 3.1.28 show the daily electricity consumption in January (winter) and September (summer) in 1998. Figures 3.1.29 and 3.1.30 show calculation of the average power consumption by hour in week days and holidays from the values of the daily/hourly received electricity volume in the same seasons. According to Figure 3.1.30, the independent electric power plant is shut down in summer (September), the received electricity is the electricity used in the factory. As shown in this figure, approximately 15 MW is used as the electricity for the first shift. For each of the second and third shifts, approximately 3 MW is used. Electricity used on a holiday is approximately 2 MW. On the other hand, electricity generated by the independent power generating plant is added to the received electricity in winter (January) according to Figure 3.1.29. For the first shift, approximately 40 MW is used. For each of the second and third shifts, approximately 8 MW is used. It is assumed that approximately 6 MW is used on a holiday. Therefore, the difference between summer and winter is 25 MW for the first shift, 5 MW for the second and third shifts, and 4 MW on a holiday. This difference does not immediately mean factory heating but is considered to be (Factory heating + (2-shift operation → 1-shift operation) + Summer holidays consumed in September). In any case, it is assumed that electricity for factory heating is higher than 10 MW. The difference between the electricity used in summer and that used in winter is the "increase in winter".

Annual power consumption is calculated based upon the above data.

Power consumption on a summer operating basis

Operating	160 × 250 days	= 40,000 MWh
Non-operating	40 × 115 days	= 4,600 MWh
Increase in winter	10 MW × 8h × 125 days	= 10,000 MWh (Fist shift)
	3 MW × 16 h × 125 days	= 6,000 MWh (Second and third shifts)
Total		60,600 MWh/y

Overall, this value is close to the actual consumption.

Among these, the electricity consumption for space heating such as blower and fan, etc. is 16,000 MWh/y. accounting for approximately 26 %, which is significantly large. Limiting the heating area leads to a substantial reduction in energy consumption for heating.

Figure 3.1.27 URSUS Daily Power Consumption (January '98)

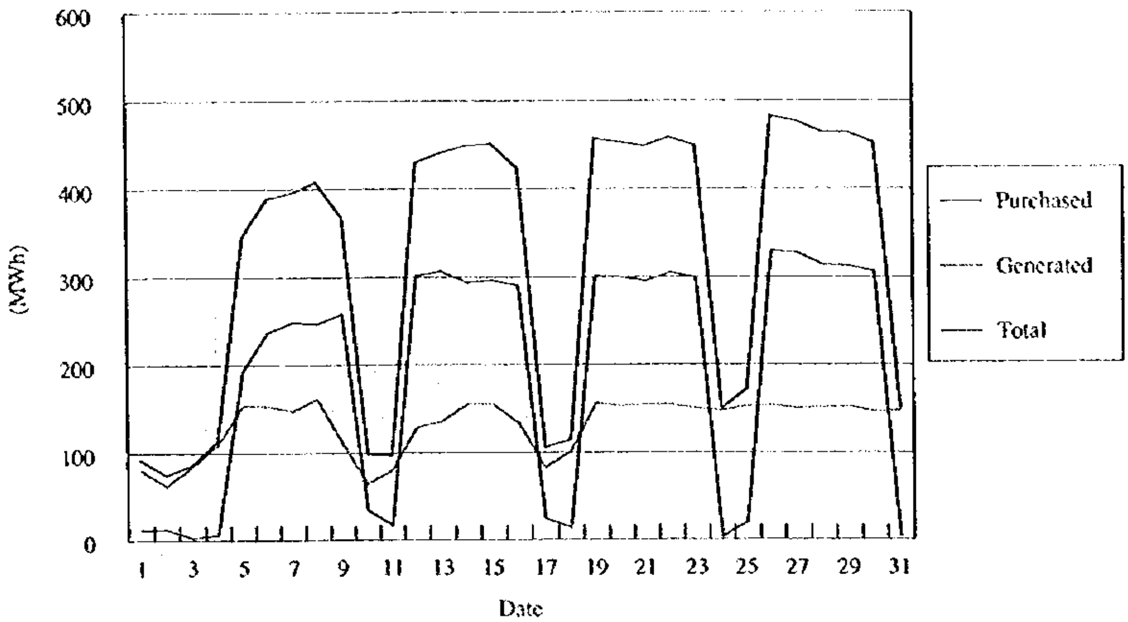


Figure 3.1.28 URSUS Daily Power Consumption (September '98)

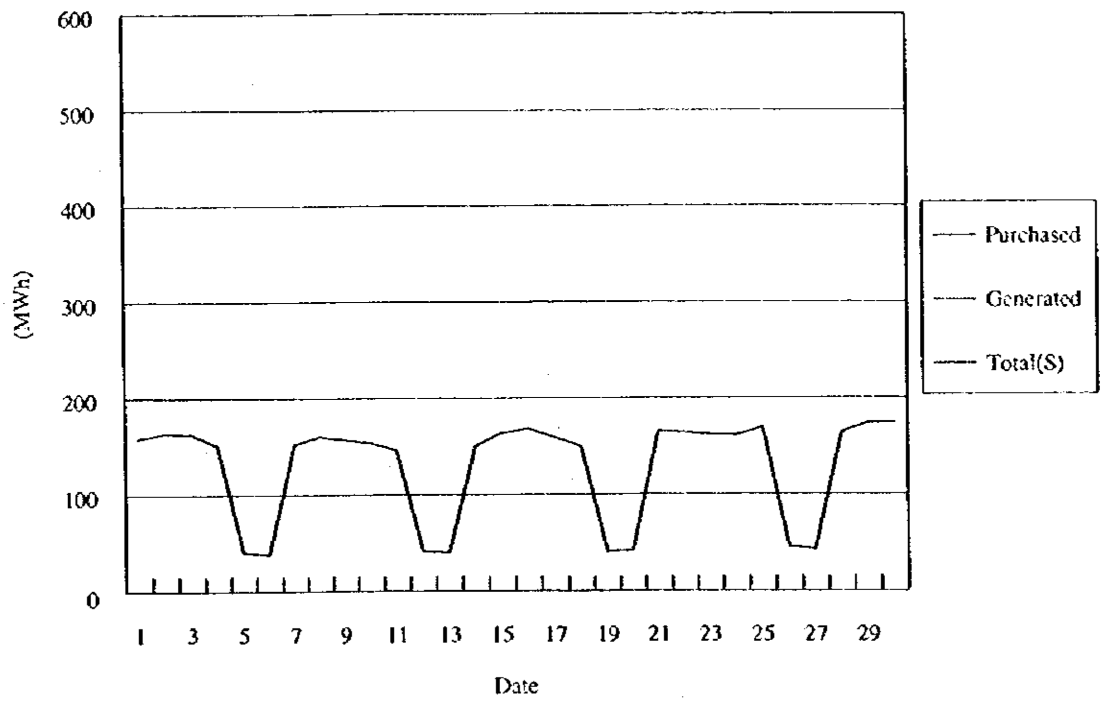


Figure 3.1.29 Purchaced Power Daily Load Curve (Winter, January)

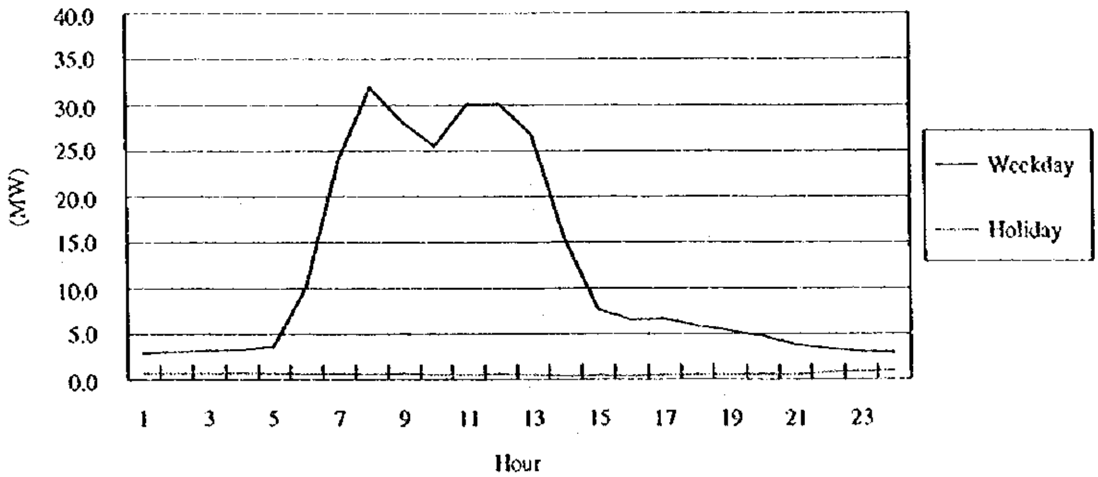
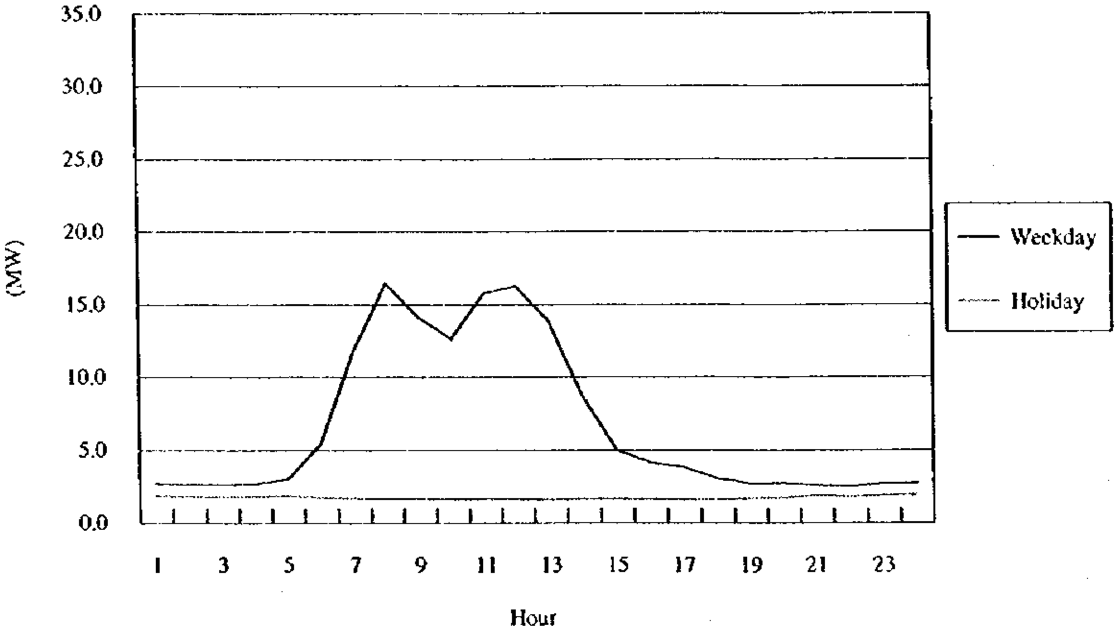


Figure 3.1.30 Purchased Power Daily Load Curve (Summer, September)



b. Electric motor (Step 2)

Electric motor load is believed to almost equal holiday and night time loads and winter loads; therefore, annually, it should be as follows.

3 × 365 d × 24 h × 16,000 MWh = 42,300 MWh

Out of this, air compressor load is estimated to be as follows.

6.4 MW × 250 d × 7 h + 4.8 MW × 250 d × 1 h + 0.15 MW × (250 d × 16 h + 115 d × 24 h) = 13,400 MWh

For the electric motor load excluding that for air compressors, or 30,000 MWh, if the proper amount can be supplied with just half of that by adpting a rotation speed conrol system to operate under the proper load, the energy conservation potential for this would be as follows.

15,000 MWh × 0.2 = 3,000 MWh (2,025 MJ/unit)

(Areas in the factory that are closed are not included)

c. Compressor (Step 1)

In general, 15 % of factory electricity load excluding that for space heating is a proper value of air compressor capacity.

If 15 % of factory load is the correct value for compressor capacity, the energy conservation potential of compressors is as follows.

(6 × 8 h + 3 × 8 h – 0.15 × 20 × 16 h) 250 d = 6,000 MWh/y

The energy conservation potential is expected to be as follows excluding the effect (4,800 MWh in the item A.c.3) resulting from reduction of compressed air leakage and that (1,170 MWh) from pressure change.

6,000 – 4,800 – 1,170 = 30 MWh/y

Since the air volume supplied to the factory has not been available, an air flow meter should be installed on each compressor and the running status of each compressor should be grasped. At the same time, it is necessary to know the air volume and air pressure actually required in the factory and estimate future factory operation. To maintain the centralized air supply system, compressors accommodating the load variation should be installed. In future, distributed layout of compressors should be examined.

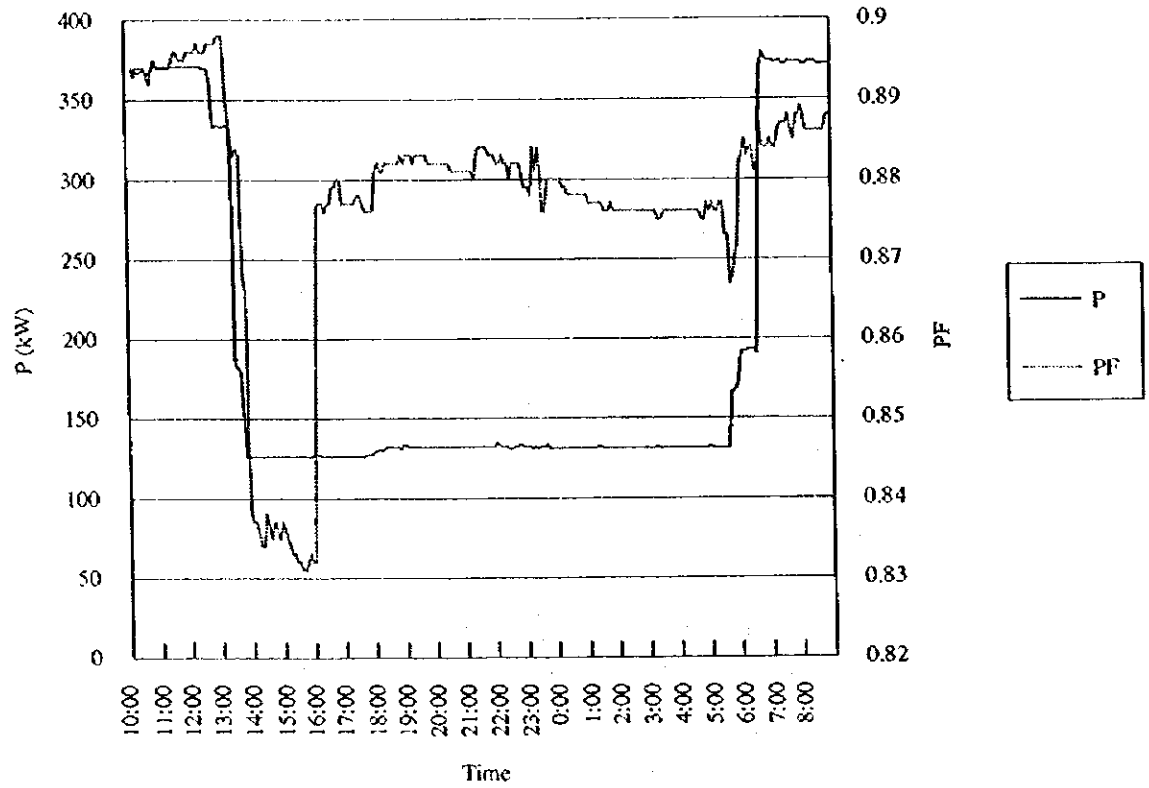
d. Pump system

Electricity consumed by the #278 pump system and #279 pump system was measured. Each pump system consists of pumps for supplying water to the factory (160 kW × 4 sets) and pumps for supplying water to the cooling tower (37 kW × 4 sets). However, the #279 pump system additionally has the pump for supplying water to the factory in the night-time and on holidays (37 kW × 1 set).

1) #278 pump system

Figure 3.1.31 shows the result of measuring electricity consumed by the #278 pump system. The #278 pump system runs pumps for supplying water to the factory (160 kW × 2 sets) and pumps for supplying water to the cooling tower (37 kW × 2 sets) in the first shift, and runs a pump for supplying water to the factory (160 kW × 1 set) in the second and third shifts. According to this result, it can be seen that each pump runs with an approximately constant output excluding shift changeover.

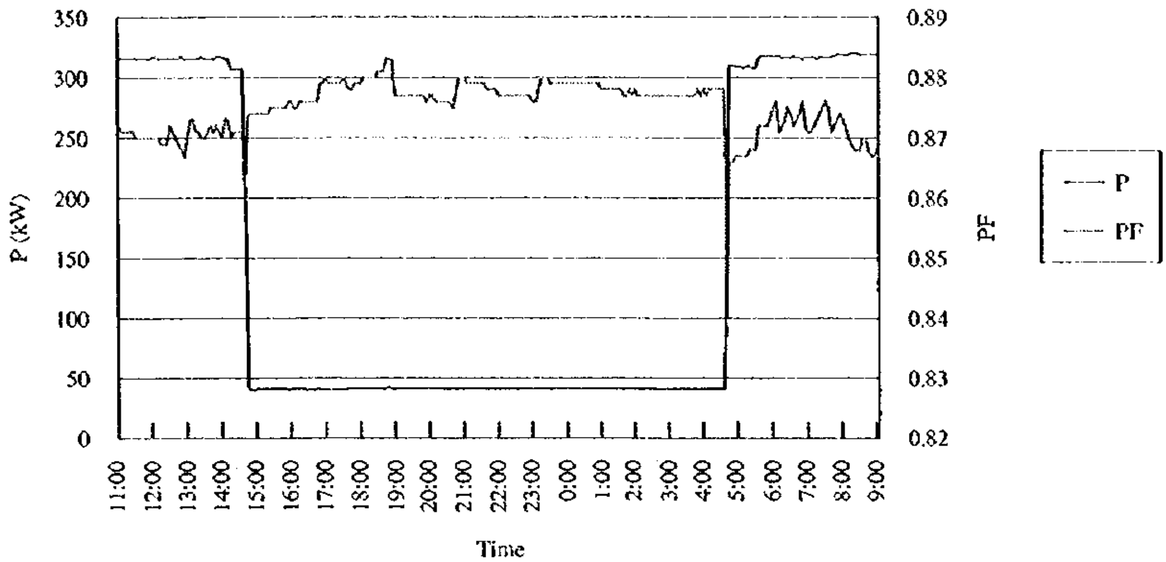
Figure 3.1.31 Power Consumption of #278 Pump System



2) #279 pump system

Figure 3.1.32 shows the result of measuring electricity consumed by the #279 pump system. The #279 pump system runs pumps for supplying water to the factory (160 kW × 2 sets) and a pump for supplying water to the cooling tower (37 kW × 1 set) in the first shift, and runs a pump for supplying water to the factory (37 kW × 1 set) in the second and third shifts. As with the #278 pump system, it can be seen that each pump runs with an approximately constant output excluding shift changeover according to this result. Since the water volume supplied to the factory largely declines in the second and third shifts, the 160 kW pump is shut down and water is supplied to the factory with the 37 kW pump for energy conservation. This is the large difference from the previous investigation.

Figure 3.1.32 Power Consumption of #279 Pump System



3) Energy conservation measures

Presently, water volume control is not implemented in these pump systems except for shift changeover and the cooling water volume and cooling water temperature are not measured. Therefore, the water volume meters and temperature recorders should be installed first. Presently, the temperature of the cooling water returning from the factory was felt to be approximately 15oC when touched by hand and the cooling water volume seems to be larger than necessary. The water volume should be gradually reduced by closing the valve. The factory equipment should be checked for failures and the minimum water volume to be supplied to the factory in each shift should be determined. Then, the water volume to be supplied to the factory and its variation width should be determined on the assumption of the future production volume and its variation, operation time, air temperature difference, etc. The pump systems should be reviewed based on number of pumps control and inverter control. Since closing the valve simply can result in some energy conservation effect, it should be implemented.

e. Transformer

According to the test report sheet, the iron loss of the 63 MVA transformer is so small that there is hardly any recognizable energy conservation potential.

f. Lighting

Since we have received information that approximately 1,000 kW is used for lighting, this figure will be adopted. As energy conservation potentials, the following possibilities arise as measurement results.

1) Forging furnace factory

Current mercury lamp 400 W × 17 lamps × 10 spans = 68 kW
Since there does not seem to be any problem in terms of color rendering properties, 40 % can be reduced by changing to sodium lamps.

Electricity saved 68 kW × 0.4 = 27 kW

Annual electricity saving: 27 × 16 h × 250 d = 108 MWh/y

2) Assembly line

Current fluorescent lamp 40 W × 3 lamps × 8 × 50 m = 48 kW
40 % can be reduced by changing to high frequency fluorescent lamps.
Therefore, the electricity saving amount for this assembly line is:
48 kW × 0.4 = 19.2 kW

Annual electricity saving: 19.2 × 16 h × 250 d = 76 MWh/y

Fluorescent lamps account for approximately 40 % of the all lights in this factory, and thus if this improvement is implemented on a full scale, an approximately 20 % energy conservation can be expected.
Therefore, it can be said that there is energy conservation potential of about 20 % overall.

1 MW × 0.2 × 16 h × 250 = 800 MWh/y

With regard to lighting during our survey in 1998, lights in the locations where no operation was conducted were all turned off and also bulbs were cleaned well, thus leaving us with good impression that management is sufficiently implemented. As the next step, cleaning of the skylight on the ceiling will allow lighting to be further reduced and sunlight to be taken in.

The energy conservation potential, excluding the effect stemming from the thoroughgoing turning off of lights,
on the assumption that the lighting electricity is approximately 700 W and a 20 % energy conservation potential is expected will be as follows:
0.7 MW × 0.2 × 8 h × 250 d = 280 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 3.1.13.

Table 3.1.13 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_x	Dust
Step 0				
Step 1	1,371	3.5	4.1	0.6
Step 2	673	8.5	2.6	1.0
Step 3	3,004	22.2	6.7	4.5
Step 1-3	5,047	34.2	13.4	6.1

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 3.1.14. Furthermore, the payback period required to recover energy conservation investments including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 3.1.14 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	997	2.6	1,000	0	0.00	0.00
Step 2	4,661	3.6	4,665	12,447	2.67	2.67
Step 3	1,919	10.0	1,929	73,429	38.06	38.26
Step 1-3	7,578	16.3	7,594	85,875	11.31	11.33

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

As evident from this Table 3.1.14, 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.

In this factory the effect of the reduced emission fee on the payback period is small. The equipment for the improvement items for the fabrication machines listed in step 3 costs much, thus drastically worsening the investment recovery. Moreover the effect of this item is the reduction in electricity, exerting only a small effect of the reduction in emission fee on the payback period.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 3.1.15.

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 3.1.33. The relationship between energy conservation potential, the period to recover the investment, and the investment cost is shown in Figure 3.1.34.

Table 3.1.15 Summary of Energy Conservation Potential

Natural gas: 0.514 PLN/m^3_N (36.6 GJ/m^3_N) Coke: 400 PLN/t (33.5 GJ/t) Coal: 170 PLN/t (22.5 GJ/t) Electricity: 0.172 PLN/kWh 1 PLN = 30 yen

Item		Energy Conservation Potential: Fuel GJ/y	Fuel 10^3 PLN/y	Fuel %	Electricity MWh/y	Electricity 10^3 PLN/y	Electricity %	Total 10^3 PLN/y	Investment 10^3 PLN	Payback period year
Step 1										
1. Casting process: Improving the cupola operation	CK	2,538	30	0.3				30	0	0
2. Forging process: Improving the purchase materials	G	1,044	15	0.1				15	0	0
3. Improving the boiler air ratio	C	16,765	127	1.9				127	0	0
4. Reducing air leakage	E				4,800	826	4.2	826	0	0
Subtotal		20,347	172	2.4	4,800	826	4.2	997	0	0
Step 2										
5. Casting process: Improving the casting ladle	CK	304	4	0.0				4	4.3	1.2
6. Casting process: Utilizing the waste heat from the cupola	CK	5,031	60	0.6				60	571	9.5
7. Machining shop: Batch production (Implemented in 1998)	E				783	135	0.7	135	100	0.7
8. Machining and assembly: Centralization of production processes and batch production (A)	C,E	28,000	212	3.3	3,030	521	2.7	733	2,857	3.9
9. Machining and assembly: Centralization of production processes and batch production (B)	C,E	77,000	582	8.9	8,387	1,443	7.4	2,024	2,857	1.4
10. Machining and assembly: Changing the air pressure	E				1,170	201	1.0	201	43	0.2
11. Installing small-size compressors	E			0.0	3,832	659	3.4	659	130	0.2
12. Forging shop: Changing the lighting system to sodium lamps	E				108	19	0.1	19	140	7.5
13. Assembly shop: Changing the lighting system to Hf fluorescent lamps	E				76	13	0.1	13	150	11.5
14. Changing the lighting system to Hf fluorescent lamps	E				616	106	0.5	106	1,200	11.3
15. One cycle stopping of equipment	E				1,116	192	1.0	192	109	0.6
16. Controlling the motor revolution	E				3,000	516	2.6	516	1,457	2.8
Subtotal		110,335	857	12.8	22,118	3,804	19.4	4,661	9,618	2.1
Step 3										
17. Forging shop: Introducing hot blast cupolas	CK	23,200	277	2.7				277	2,000	7.2
18. Machining and assembly: Streamlining the machining line	E				8,190	1,409	7.2	1,409	71,429	50.7
19. Improving the product yield	G,E	7,470	105	0.9	748	129	0.7	234	-	-
Subtotal		30,670	382	3.6	8,938	1,537	7.8	1,919	73,429	38.3
Total		161,352	1,411	18.7	35,856	6,167	31.4	7,578	83,047	11.0

As of 1997
Fuel consumption: 565,762 + 294,883 = 860,645 GJ/y
Electricity consumption: 114,087 MWh/y (1,170,304 GJ/y)
Total: 2,030,949 GJ/y

Figure 3.1.33 URSUS Energy Conservation Potential

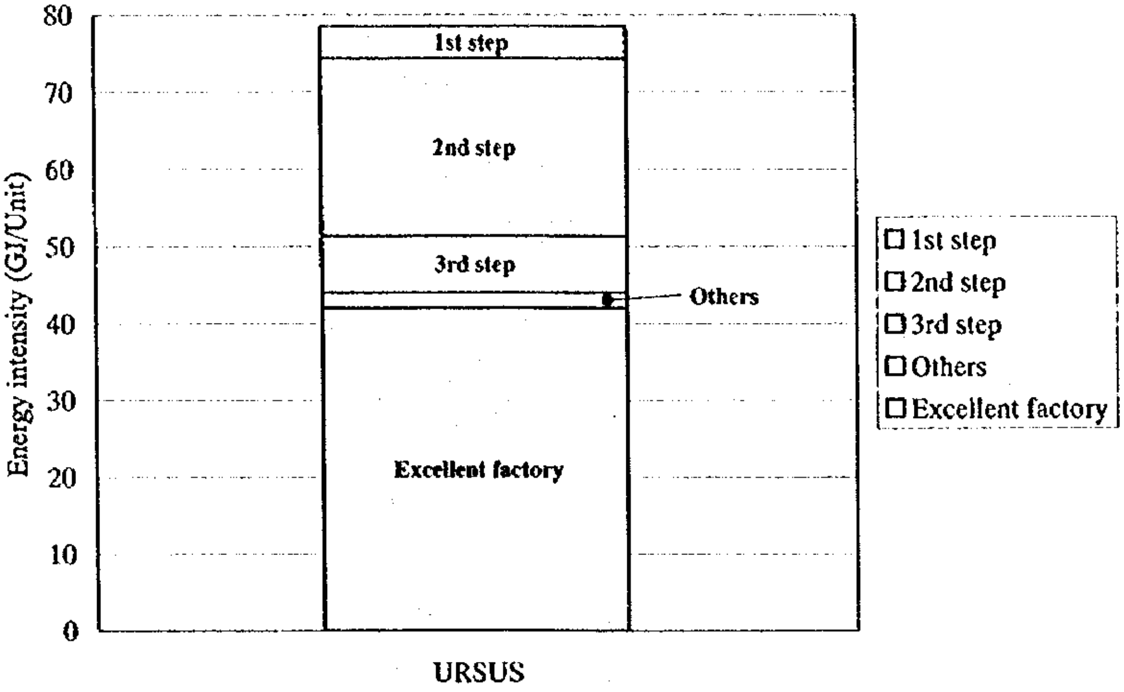
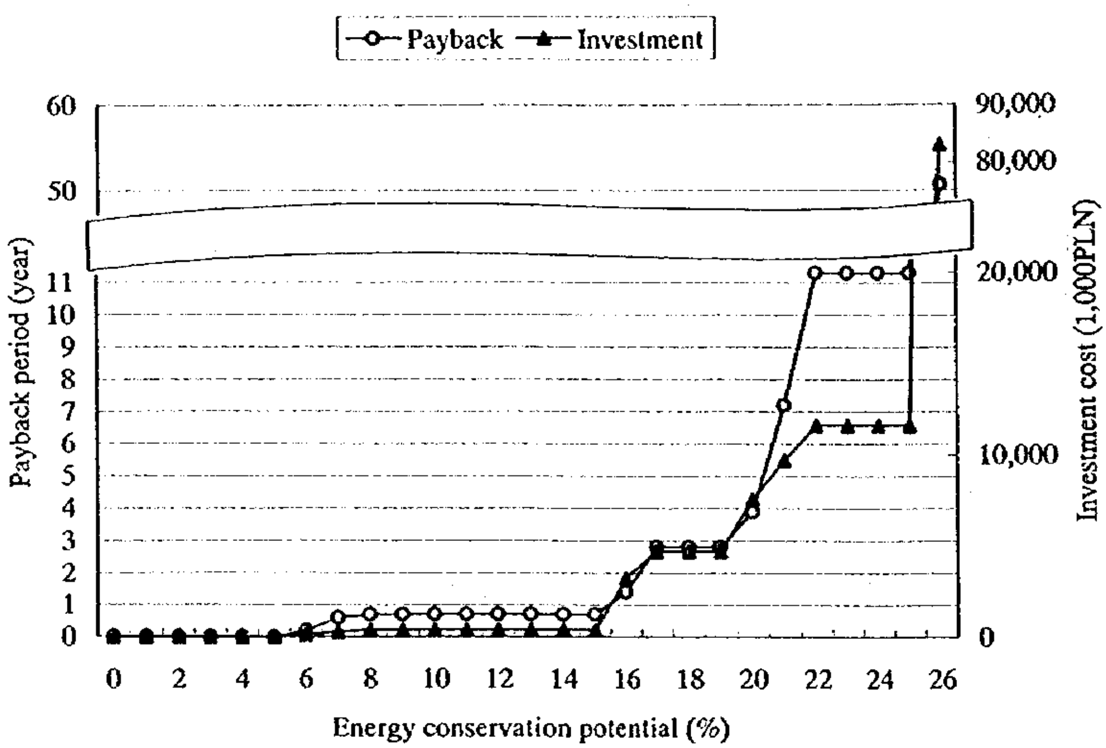


Figure 3.1.34 URSUS Energy Conservation Potential



3.2 Resuslts of the Study at the Star Plant

(1) Study period: August 4 to 6, 1997

(2) Members of the study team

a. JICA Team

Mr. Norio Fukushima : Leader of energy audit & Heat management
Mr. Sadao Nozawa : Process management
Mr. Jiro Konishi : Heat management
Mr. Seiichiro Maruyama: Heat management
Mr. Toshio Sugimoto : Electricity management
Mr. Akihiro Koyamada : Measuring engineerring

b. KAPE and local consultants

KAPE
Mr. Dariusz Koc: Manager of Energy Audit

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

(3) Interviewees

Mgr inz. Tadeusz Trzaskialski	: General Manager, the Energy and Maintenance Department
Mgr inz. Wieslaw Romanczak	: 2nd Manager in the Energy Department
Mgr inz. Zbigniew Wojcik	: General Manager in the Heat Plant
Mgr inz. Wlodzinierz Helman	: Manager of Technology Division
Ms. Marianua Kwiakowska	: Specialist of Technology Division
Mgr inz. Marianua Kaminska	: Technical Expert in Maintenance Department
Mgr inz. Bohdan Jedrasek	: Manager in Cabin Assembly Room
Mgr inz. Wlodzimierz Pawlikowski	: Manager of Toothed wheel Department
Mrg inz. Czeslawa Zbroja	: Manager of Electric Group, Wire Division
Mr. Kubicki	: Deputy Manager, Engine Assembly Department
Mr. Leszek Nowak	: Master in Engine Assembly Department

3.2.1 Profile of the Plant

(1) Plant name: Starachowice Company "STAR" S.A.

(2) Plant address: 27-202 Starachowice, ul. 1 Maja 12

(3) Number of employees: 2,500

(4) Major products: Middle-sized trucks (7.5 t to 12 t)

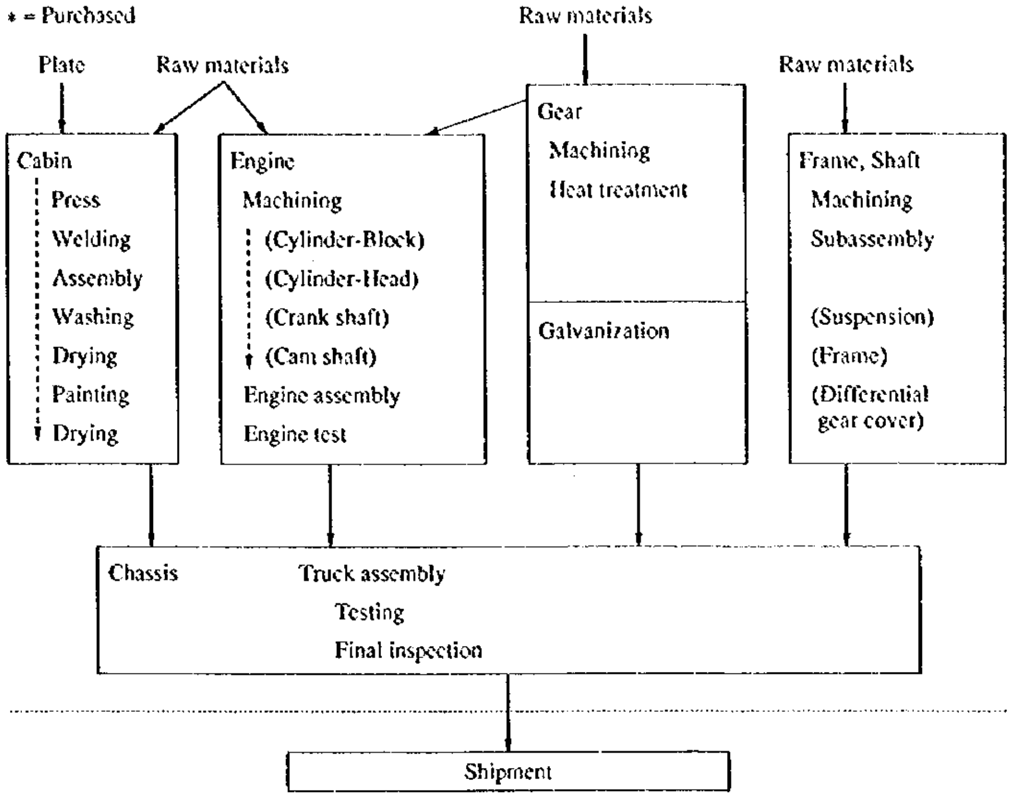
(5) Production capacity: Capacity: 35,000 units/y
Current production: 3,200 units (1996),
3,600 units (expected for 1997)

(6) Outline of production processes

Processes include the cabin (welding, plate painting, drying, cabin assembly), engine (machining of cylinder block, cylinder head, crankshaft, camshaft, flywheel, and connecting rod; engine assembly; performance test), parts machining (gear, shaft, frame machining, hardening, and plating), and car body assembly plants. The raw materials for casting and forging are purchased. There is also a rehabilitation plant, where the employment of workers who cannot carry out normal tasks is guaranteed through light work such as wire harness assembly. With regard to the type of energy use, only the hot water used for processes in summer is supplied by the company from its own facility. This system, however, will be discontinued in 1998. Therefore, all energy supplies including electricity, natural gas, and heat (hot water and steam) will be on a purchase basis in the future.

Figure 3.2.1 shows the process flow.

Figure 3.2.1 Process Flow



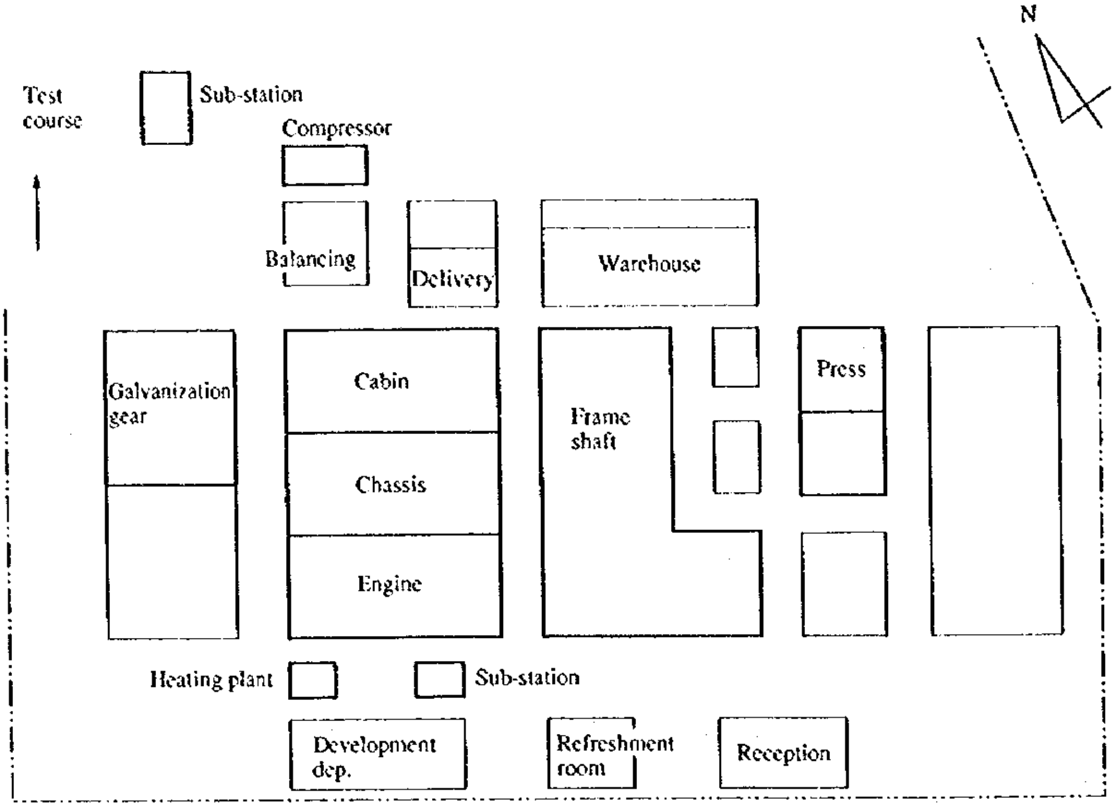
(7) Plant history

STAR began producing trucks in 1947. The first STAR20 was manufactured in 1949. A total of 10,000 trucks were manufactured by 1953 and 50,000 trucks in total by 1957. Although the annual production capacity of the plant is 35,000 trucks, the present output is only about 10 % of this figure. The number of employees, nearly 14,000 at one time, has currently dropped to some 2,500 employees who work only on one shift basis. The plant is implementing a modernization program at the moment. The medium-sized trucks it manufactures holds a large share of the domestic market: 63 to 65 %. The demand for medium-sized trucks, however, is not significant. Thus, the scale of this particular market is small and the company hardly exports medium-sized trucks. When we were conducting this study, the company was discussing tie-up with a German automobile manufacturer. This proposal suggests a possibility of revamping the products to be manufactured at the plant according to the contract made. STAR is now awaiting the conclusion of the tie-up plan.

(8) Plant layout

The plant is situated on a site that has a total area of 200 ha. The plant buildings have a total floor space of 37 ha. The layout of the main plant is shown in Figure 3.2.2.

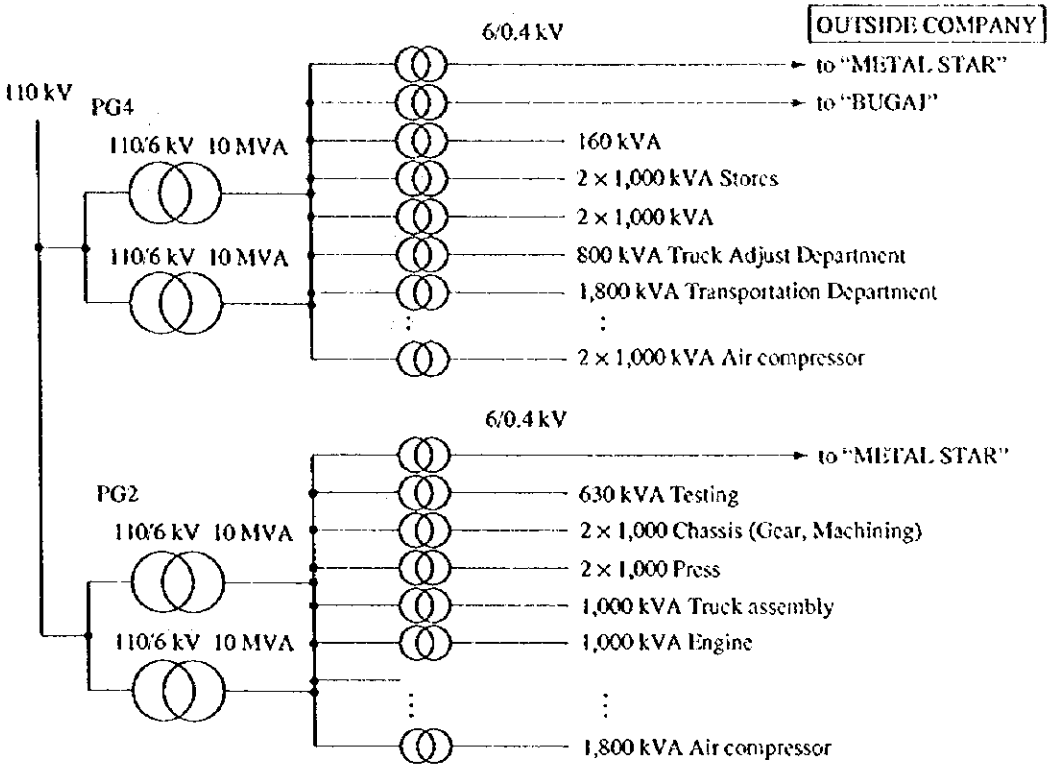
Figure 3.2.2 Plant Layout



(9) One line diagram

Power substations at two locations receive 110 kV, which they transform into 6 kV for the plant's power supply as shown in Figure 3.2.3.

Figure 3.2.3 One Line Diagram



(10) Outline of the main equipment

All raw materials for casting and forging are purchased. The main equipment that consume energy are the equipment for manufacturing, assembly, and painting. All of the equipment are operated during one shift.

Table 3.2.1 Major Equipment

Factory	Equipment	Number	Specification
Utilities	Electricity sub-station	2	110 kV × 2 supply
			Transformer 110/6 kV, 10MVA × 2 × 2
	Water boiler	6	2.5 MW × 6 (Operation: summer only)
	Air compressor	3	Turbo type, 1,800 kW, 300 m³/min
			(Operation: 8 h/d)
Cabin	• Production	–	15 units/d
	• Operaiton	–	8 h/d
	Paint booth	6	
	Drying furnace	6	
	Cabin-assembly line	2	
Frame	Paint booth	2	Suspension, Frame
	Drying furnace	2	Suspension, Frame
	Machining	200	
Gear	Zincification	3	
Galvanization	Chrome-galvanization	1	
	Machining	300	
Engine	Machining	400	Cylinder-block, Crank-shaft etc.
	Engine assembly	1	
	Engine testing	11	Water-dynamometer

(11) Energy price and heat value

The entire heat supply required by the plant will be purchased from the next fiscal year and the purchase of coal for the plant's own heat supply system will no longer be necessary.

Table 3.2.2 Energy Price and Heat Value

	Energy Price (1997)	Heat Value
Coal	186 PLN/t	
Natural gas	0.5 PLN/m³	34,400 kJ/m³
Electricity	0.18 PLN/kWh	10,258 kJ/kWh
Water	2.5 PLN/m³	

3.2.2 Energy Consumption Status

(1) Trend of truck production

Table 3.2.3 Trend of Truck Production

	Unit	1992	1993	1994	1995	1996
Production	units	1,499	1,654	2,229	3,087	3,200

(2) Trend of energy consumption

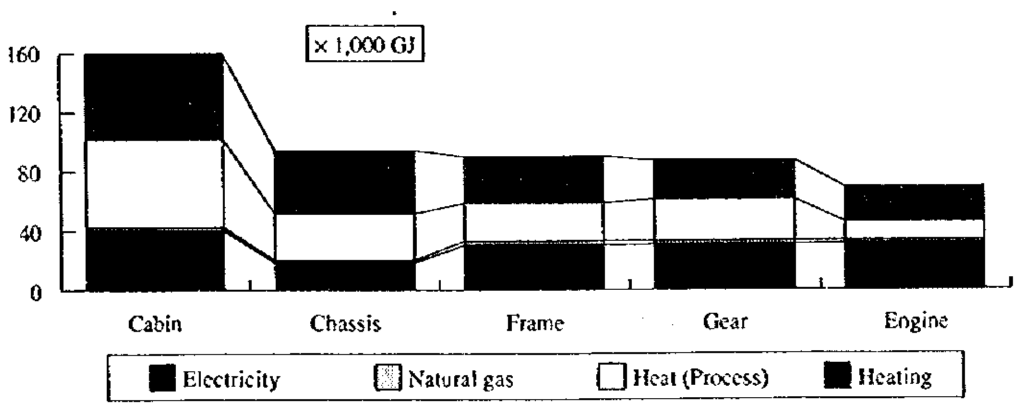
Table 3.2.4 summarizes the energy consumption for each category except that by affiliated companies on the same premises. The "Heat" consumption for drying and heating is extremely high, amounting to 65 % of the total energy consumption.

Table 3.2.4 Trend of Energy Consumption

	Unit	1992	1993	1994	1995	1996
Natural gas	1,000 m^3	306	231	263	226	251
	GJ	10,518	7,942	9,057	7,781	8,634
Electricity	MWh	22,318	21,767	23,203	25,043	23,573
	GJ	228,930	223,278	238,008	256,883	241,804
Heat	GJ	334,000	334,000	360,400	406,011	458,187
Total	GJ	573,449	565,220	607,465	670,675	708,625

Figure 3.2.4 shows the energy consumption for each process (plant). The heating cost amounts to approximately one-third of the total energy consumption by each process.

Figure 3.2.4 Energy Consumption by Process in 1996



(3) Trend of energy intensity

Table 3.2.5 Trend of Energy Intensity

	1992	1993	1994	1995	1996
Enegy intensity (GJ/Truck)	382.6	341.7	272.5	217.3	221.4

(4) Ratio of energy cost to the production cost

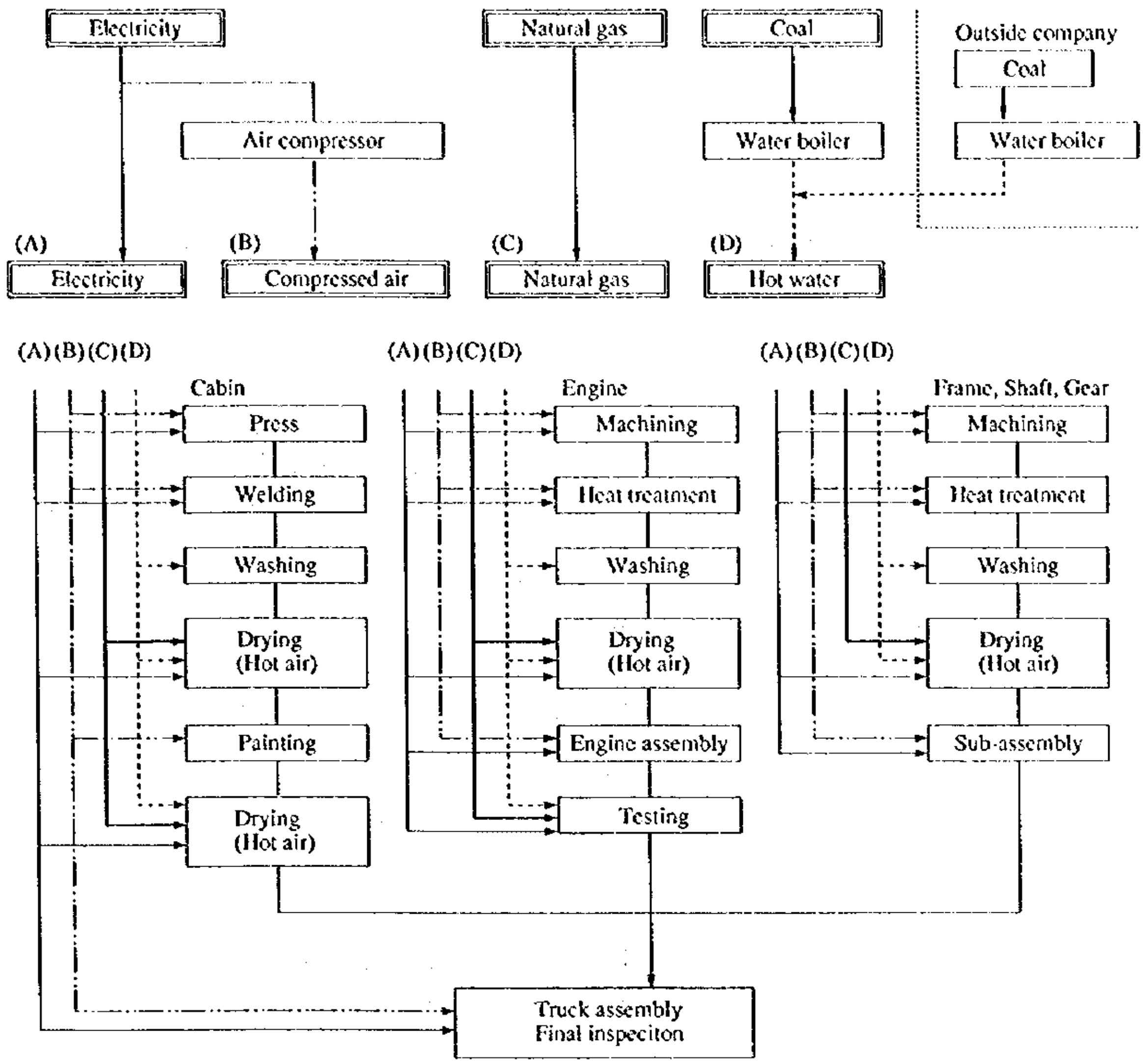
The company has provided only a ratio of the energy cost for production cost instead of individual energy costs.

Ratio of energy cost in production cost: 3.9 % (1995), 5.9 % (1996)

(5) Energy flow

The energy consumption of the plant includes electricity, natural gas, and hot water. The company does not have a private power generating plant for electricity, and has to purchase all required electricity. The plant has six hot-water boilers that were built in 1954. These boilers are operated only in summer to supply hot water to the production processes because hot water cannot be purchased from an outside source for the summer season. However, the use of these boilers will be stopped next year. From 1998, the hot water will be purchased from an outside supplier as it is in winter now. The natural gas is mainly used for production purposes such as heat treatment and drying furnace. Figure 3.2.5 shows the energy flow.

Figure 3.2.5 Energy Flow



3.2.3 Items for the Study of Energy Management Status

(1) Setting the energy conservation target

a. Setting the target value

The plant has not set a target of energy conservation yet. Energy and Maintenance Department carries out energy-related streamlining programs. They have set a goal for the payback period to 2 years.

b. Problems in the promotion of energy conservation

These problems include the following:

1) Lack of funds for improvement
2) Decaying equipment
3) Shortage of data due to a scant supply of measuring instruments
4) The need to improve the awareness of the employees

At present, the awareness of the need for energy conservation is low among the employees.

(2) Systematic activities

The company does have a dedicated Energy and Maintenance Department in charge of energy management, environmental protection, and maintenance with a staff of 140. Although there are no specialized committees for energy management and such, information on energy matters is presented at the weekly general managers' meeting. The 'Production First' policy of the company is so strong, however, that it is difficult to raise employees' awareness for energy conservation.

(3) Data-based management

a. Grasping the energy consumption

The plant keeps track of the monthly consumption of the electricity, natural gas, heat, and water which are purchased. This energy consumption, however, includes the heat sold to the city and the energy supplied to the affiliated companies on the same premises as well as the plant's own consumption. Most of the plant's own energy consumption is calculated on a proportional distribution basis.

b. Grasping the energy consumption for each major equipment

The company has pointed out the shortage of measuring instruments and data as part of its problems. It does not keep track of the energy consumption of each equipment. The company only partly obtains such data from affiliated companies on the same premises for accounting purposes. Such data is used for accounting only. It is not provided to the energy consumption departments. Individual electricity measurement is only made by the affiliated companies and the cabin manufacturing process. At present the company is considering the introduction of individual electricity measuring instruments at present.

c. Grasping the energy intensity of major products

The plant is not aware of the energy intensity for each product.

d. Installing measuring instruments

Although a measuring instrument facility for measuring the energy consumption for the entire plant is provided, almost no individual measuring instruments are installed at department and building levels. Even the electricity can be measured separately in the affiliated companies and some of the buildings.

e. Production management and cost management

The plant carries out cost management in terms of accounting. However, the company needs to improve these activities with a proper awareness of the costs including the energy cost. Production control is also inadequate; for example, the amount of raw materials charged into the machining shop is inconsistent and depends on the production required for each day. Even though the company is operating at low capacity, production management should be carried out with greater care and planning. For quality control, on the other hand, posters on quality control slogans are put up at many places of the plant and maintenance is carried out properly.

(4) Educating the employees

There seem to be no specific education systems.

(5) Plant engineering

Some of the lines in the machining shop have established a daily 10-minute machine cleaning period. The plant observes a basic equipment control classification policy of making the manufacturing site responsible for daily maintenance. The equipment in the engine assembly line in particular is kept very clean. It seems, however, that further effort should be made to introduce a better method of using equipment and floor layout to avoid waste. In the plant building itself, considerable care has been exercised in the heating system, and the introduction of an efficient high-speed shutter is being considered. Light from skylights is utilized effectively in summer and the workers follow a good practice of turning off the lights. However, there are some matters that are not tended to yet such as cleaning of windows and disposal of decaying equipment. These conditions lead to wastage of energy and space in the long run. Such maintenance should be carried out by the employees while the operation capacity remains low. Emergency improvement measures to be made at present are: a) reduction of drying rooms of the painting shop and b) decentralization of small-size compressors. An intensive production center and disposal of unnecessary property are also under consideration, which is what we could obtain through our hearing survey.

3.2.4 Problems and Measures related to the Use of Energy

(1) Comparison of energy consumption intensity with an excellent factory

Table 3.2.6 summarizes the energy intensity according to the energy data of 1996, excluding the energy consumption of affiliated companies on the same premises and energy intensity for each major manufacturing process.

In regard to the excellent factory conditions, it must be noted that very few businesses have all of their production processes inside their plant, and each company has its own way of classifying internal and external fabrication (or make or buy). Therefore, we have presented the excellent energy intensity conditions for each process of several companies and have assumed the total as the energy intensity per truck.

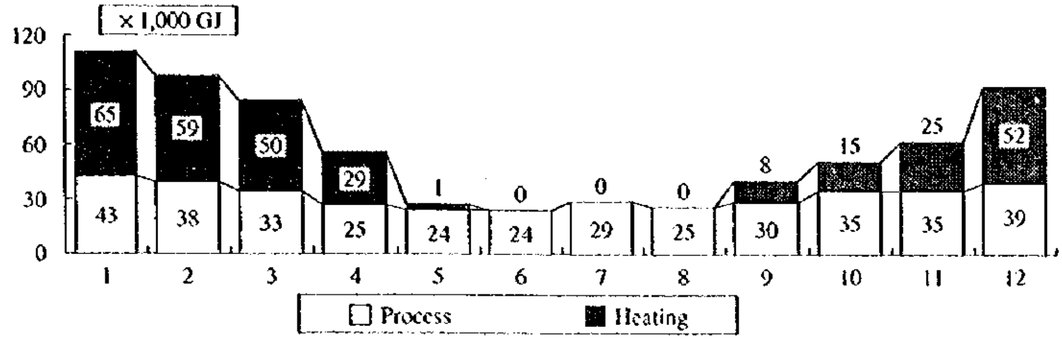
Table 3.2.6 Comparison of Energy Intensity

		Unit	Star	Excellent factory	Difference
For production of one truck		GJ/truck	221.4	30.6 ~ 38.6	183 ~ 191
Net process excluding factory heating			118.8	28.6	90.2
For each process	Body assembly, cabin	GJ/truck	45.6	11.7	33.9
(Part of the above breakdown)	Engine	GJ/truck	13.4	5.9	7.5
	Plate press	GJ/truck	7.2	2.0	5.2
	Shaft, frame, and gear	GJ/truck	28.1	4.5	23.6
	Plating	GJ/truck	7.8	4.5	3.3
	Factory heating	GJ/truck	96.4	2.0 ~ 10	86 ~ 94

(2) Analysis of energy consumption

Figure 3.2.6 illustrates the monthly trend of the overall energy including the energy required for production processes and heating. The energy required for heating is higher than that for production in winter. Therefore, it is necessary for this plant to implement a production process control system which is heating (air-conditioning) energy consumption-conscious.

Figure 3.2.6 Monthly Trend of Energy Consumption



(3) Estimating the energy conservation potential

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

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

The calculation of energy intensity is based on the annual turnout of 3,200 trucks/y.

A. Process

a. Energy conservation by enhancing energy management (Step 1)

1) Management for each process and target setting

As seen in Table 3.2.6, the energy intensity of all processes in general is high even when the heating energy is excluded. First of all, it is regarded as absolutely necessary for all processing departments to be aware of the need for energy conservation. The energy required for each process is only calculated as an accounting process partly using a proportional distribution method. The energy consumption of each plant building at least must be known. We recommend evaluating the energy conservation activities of the side that is using energy by finding out the actual energy consumption of each plant building instead of doing so by proportional distribution. It may not be possible due to the configuration of the building and equipment to manage some of the energy consumed by the production process . However, at least the following energy consumption can be reduced.

- Electricity consumption due to air leakage
- Electricity consumption due to use of unnecessary lighting
- Electricity consumption due to idle operation of equipment not being used
- Energy consumption for producing defective parts
- Energy which can be saved by increasing the production speed
- Heating energy which can be saved by sealing gaps and minimizing the opening of entrance/exit doors of factory buildings.
- Heating energy which can be saved by providing appropriate clothing for workers
- Others

The amount of energy for each of the above items cannot be estimated. If, however, the plant actually succeeds in reducing the energy consumed due to the above, more significant results than from improvement of equipment and production process can be expected. Energy conservation of at least 5 to 10 % may be derived from each process by reinforcing management of the above items. (Energy conservation target: initial year – 5 %; each year after – around 5 %)

Energy saving amount: 35,000 GJ/year (5 % of total energy in 1996) (10.9 GJ/truck)

2) Energy conservation by consolidated production

When the rate of equipment operation is lower than the equipment capacity due to a small output, consolidated production is more effective as indicated below. When only the turnout drops in a plant/area where they consume a large amount of fixed energy (heating and lighting particularly) not related to the production, the energy intensity situation can worsen considerably. Therefore, consolidated production is recommended as an improvement measure instead of further investment in lower capacity equipment. The consolidated production needs to involve further specific details of worker regulation matters such as a review of the working system and work shifts. This can be an opportunity to produce a significant energy conservation effect and also improve the awareness of employees toward energy conservation. Thus, it is recommendable to try this management technique in some production lines as a test for future conservation. Consideration of the following matters may be necessary when selecting the target production lines for testing.

① The cycle time of the target line can be reduced through workers and equipment investment. It is recommended to employ such a line where production requiring one month or one week can be completed in half that time or less.

② The target line must have a configuration by which the heating and lighting of the site can be turned off completely after the required production is finished, and the site can be closed down until the next consolidated production.

③ The work shift or education/training must be arranged in order to keep the workers of the target line occupied with other tasks while the line is closed.

It should be noted, however, that there has been already consolidated production available for the induction furnace and gas-annealing furnace of the shaft shop. (The effect of consolidated production is calculated together with the intensive production process to be explained in the following section.)

b. Energy conservation by modification of equipment (Step 2)

1) Improvement through an intensive production process

Since each piece of equipment used for engine parts machining and assembly processes is not too large, production equipment with a low operation rate can be relocated without much difficulty. Although the matter ultimately depends on the relocating cost, first project the future turnout over several years and then estimate the equipment operating conditions based on the projected turnout. Next, rearrange the current production into minimum required production through an intensive-process production which is in proportion to the above estimations. This method can produce a significant reduction of transportation cost, heating energy consumption as well as improvement of the work efficiency as well.

[Implementation method]
Concentrate the work areas used for manufacturing equipment such as machining and assembly equipment as much as possible by allotting the minimum space required for operation and maintenance. The concentrated (intensive) area must be partitioned to improve the heating efficiency. Heating and lighting outside the partition must be turned off, or the strength of the lighting and heating should be lowered significantly. The areas which can produce a desirable effect are listed below.

- Engine assembly line: The main and sub lines can be notably concentrated. The distance between processes of the main line in particular can be reduced to one-fifth (within 3 m).

- Engine test bench: Half of the benches have been removed already and the lights are turned off. Install partitions, however, to close off the area completely to improve heating.

- Parts and raw material warehouses: There are stock areas for workpieces, finished products, and jigs all over the plant (as in the shaft manufacturing shop). These areas take up considerable space. There are no "operators" in these stock areas, but only "objects." Therefore, if the partitions are put up to separate these stock areas from work areas, heating and lighting consumption can be reduced.

  The main effect will be the saving of heating energy. The target of saving for the plant in the above example is approximately 10 %, and the target reduction of heating in other factories in addition to the shaft manufacturing area is 5 %.

Target energy saving ratio: 15,400 GJ/y (Heating: 5 % of 308,000 GJ) (4.8 GJ/truck)

2) Hot air control of the drying furnace

The excessive consumption of hot water is an all too evident disparity in the energy consumption of this plant.

Figure 3.2.7 Energy Consumption in 1996

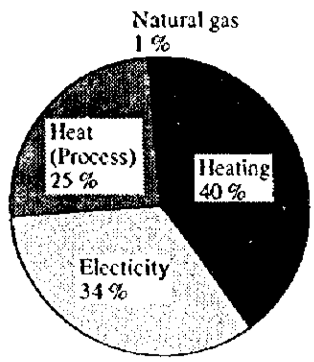
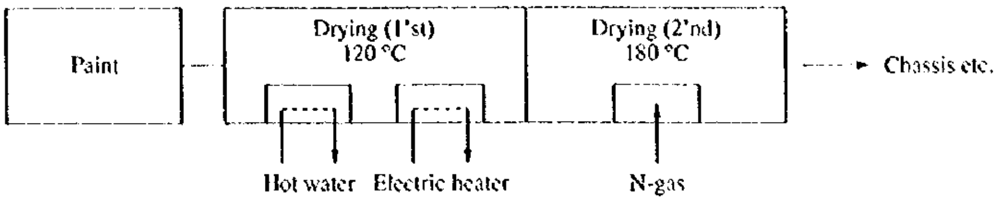


Figure 3.2.7 shows a pie chart of the entire plant's energy consumption divided into relevant categories. The heat energy consumption in the production process is highly evident. Although, if the turnout drops, there may not be a proportionate decrease in the power consumption of the machining equipment, it will decrease to a certain extent. On the other hand, in processes such as the drying furnaces, which are operated continuously, the overall energy consumption will remain the same and the energy intensity will become worse, unless there is some form of management before the next workpiece is loaded. Table 3.2.6 particularly shows the poor state of the energy intensity of body assembly and cabin processes which use the drying furnaces. The plant has already made some emergency improvements in the drying furnaces. The following recommendation is made for further improvements. The structure of a typical drying furnace is shown in Figure 3.2.8.

Figure 3.2.8 Structure of a Drying Furnace



The plant is apparently carrying out temperature control of hot water, which we heard during our interview survey. Actually, however, no control of the electric heater is available and the electricity is not shut off. More hot air than necessary is supplied particularly in summer. The drying temperature must be lowered by improving the paint quality and the temperature in the drying furnace must be set and controlled properly.

For example, to change the amount of heat supply according to the load, it is advisable to use the hot water heating source as the main supply and the electric heater with automatic temperature control for the amount of change required. Also, the minimum drying energy required for each workpiece should be determined while confirming the quality, and the setting temperature should be changed for each workpiece or the drying time should be controlled individually in order to dry the workpiece using minimum energy. In view of the fact that the energy intensity of this plant is some four times higher than that of an excellent factory, the energy used for drying can be reduced to half or less of the present consumption. Here, we have set the target energy reduction to 30% of the entire heating source required for the manufacturing processes and calculated a reduction in energy consumption below.

Target energy saving amount: 52,000 GJ/year (Process heating source: 30% of 174,000GJ) (16.3 GJ/truck)

c. Energy conservation by improving process

1) Improvement by changing the pressure of compressed air

The pressure used in the plant is set to $7kg/cm^2$. As far as we could learn from the surveys we conducted, this value was not set based on any specific reason. If the pressure is decreased by $1kg/cm^2$, the power consumption is expected to decrease by 6 % or so. As a matter of fact, the pressure used in the plant varies between 4.5 and 7 kg/cm^2. Therefore, we recommend lowering the pressure to the $5.5kg/cm^2$ level. It will be necessary, however, to find out if there is any equipment that will not function properly when the pressure is lowered. If such an equipment is found, an amplifier must be installed to cope with the problem. The product quality must also be checked in the same manner, for example, with regard to whether or not sufficient tightening torque is secured for pneumatic bolt tightening. Furthermore, it is important to ensure that the specifications of new equipment comply with the pressure supply guaranteed by the plant. Consideration should be given to prevention of air leakage conditions and decentralization of small-size compressors to reduce the air consumption to the required minimum. If this measure is implemented, a 6 % reduction of power consumption can be expected.

Expected effect of energy reduction: 140 MWh/y (1,440 GJ/y) (0.5 GJ/truck)

2) Energy conservation by improvement of yield

A poor yield means mere consumption of energy without any output. In some cases, the improvement of yield has greater effects than the direct improvement of energy intensity. The output of the engine parts machining process in this plant is especially poor. Two types of raw materials, made in Poland and Hungary, are used for the cylinder blocks, the rejection rate of which is 50 % and 18 %, respectively. Also, cylinder heads that are used after correction have a rejection rate of 30 %. These defects occur mostly due to the raw materials. To resolve this situation, a system which clarifies the responsibilities for defective raw materials and a system which makes the raw material manufacturers bear responsibility must be established. For example, "cause of defects such as blowhole" and "damages such as energy and labor costs for detecting defects" should be defined clearly and the defective materials should be returned to the raw material manufacturers. Thus, the raw material manufacturers will be compelled to produce good-quality raw materials. Since the plant is making an effort to prevent production of defective products by putting a cash incentive on each product made in the plant, it is recommendable to apply this system to the raw materials to be purchased. To achieve this target, the production plan must be reviewed. Raw materials should be restricted to the minimum required quantity each time on an individual order basis instead of a production plan where materials are to be stored over several years. Also, the cylinder-block and cylinder-head lines use a number of equipment which consume approximately

10 % of the electricity required for the engine process. 20 % of this electricity consumption can be reduced by improving the output.

Target energy saving amount: 680 GJ/year (Engine process: 34,000 GJ × 10 % × 20 %) (0.2 GJ/truck)

3) Modernization of machining lines

Automation of equipment in industrialized country has progressed due to the very high labor costs and to reduce the number of workers and yet assure a stable quality. Main stream automation adopted in the parts machining process consists of the transfer line, which is suitable for 'conventional mass production' (small variety of products, large lot production) system, and the Flexible Manufacturing System (FMS), which is suitable for 'multi-item, small lot production' system. The energy consumption will increase if these systems are introduced since the tasks of the workers will be done by machines. The equipment, however, would provide more advanced functions and a single unit would be capable of a number of machining processes. Also, machines help minimize the energy consumption when they are not operated. Thus, as a whole, they are excellent-efficiency production systems. We have presented a case where an operation such as the engine parts machining shop, etc. in this factory is automated in a level equal to a similar machining plant in excellent factory.

Investment amount: 112,500,000 PLN (7,500,000 PLN × 15 systems)

Energy saving effect
The energy intensity for machining processes will attain an excellent factory. Also, the floor space required for equipment will be reduced, and the area of the shaft plant level will be closed down.

		Engine Process	Shaft and Frame	Total
Current situation	Energy intensity	13.4 GJ/truck	28.1 GJ/truck	41.5 GJ/truck
	Total energy	42,880 GJ/y	89,920 GJ/y	132,800 GJ/y
	Heating energy	–	33,000 GJ/y	33,000 + α
	Lighting electricity	–	700 MWh/y	7,180 + α
After modernization	Energy intensity	5.9 GJ/truck	4.5 GJ/truck	10.4 GJ/truck
	Total energy	18,880 GJ/y	14,400 GJ/y	33,280 GJ/y
	Heating energy	–	0	α
	Lighting electricity	–	0	α
Reduction	Energy saving	Δ24,000 GJ/y	Δ115,700 GJ/y	Δ139,700 GJ/y
	Cost reduction			1,860,000 PLN

The purpose of modernization is not limited to the energy saving. It will be long payback year of investment in the view of the energy cost only.

Other effects

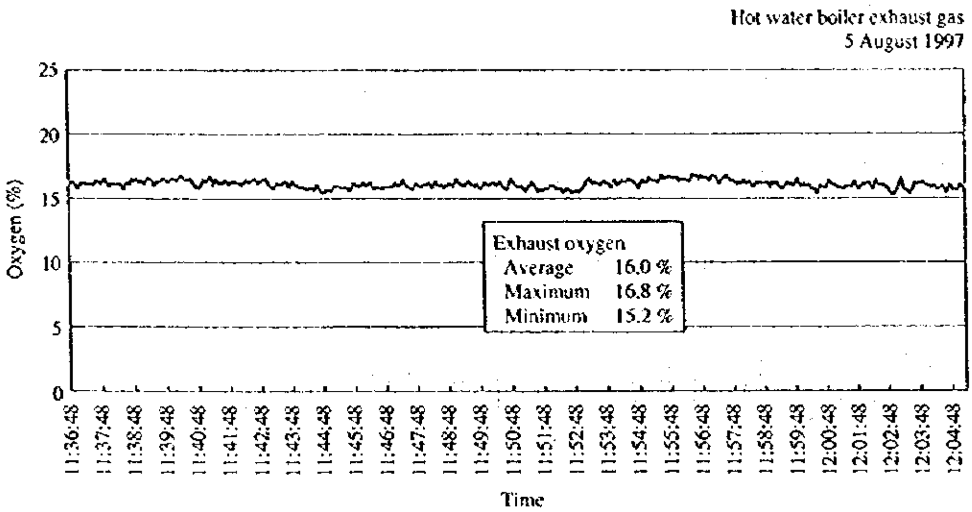
- Quality improvement (Improvement in yield can be expected.)
- Cutback of operators
- Reduction of plant buildings
- Lights can be turned off and the amount of heating energy reduced by unattended operation and automation.

B. Utility (heat utilization facilities)

a. Air ratio improvement of hot water boiler

This plant employs 6 hot water boilers to supply hot water to its manufacturing processes. The exhaust gas oxygen content in one of the boilers (boiler No. 5) was measured. The result is shown in Figure 3.2.9.

Figure 3.2.9 Measurement of Hot Water Boiler Exhaust Gas



The oxygen content is stable, but it is 16 %. This value is equivalent to 4.1 in terms of the air ratio and is extremely high. If the exhaust gas oxygen content can be brought down to 6 % (air ratio 1.75) by air adjustment, it will lead to a fuel saving of approximately 27 %. Table 3.2.7 shows the preconditions and results of this calculation.

Table 3.2.7 Fuel Reduction by Air Ratio Adjustment

Preconditions	
Coal	
Net heat value (kJ/kg)	21,548
Net heat value (kcal/kg)	5,148
Ash content	16.21 %
Water content	6.00 %
Combustion air temperature	26
Exhaust gas temperature	240
Exhaust gas temperature after air preheating	240

Notes: The measuring point is the lower part of the stack.

Calculation Result	Theoretical Combustion	Current Air Ratio	Air Ratio after Improvement
Exhaust gas oxygen	0.0 %	16.0 %	9.1 %
Air ratio	1.00	4.13	1.75
Air flow rate (m^3/kg)	6.4	26.5	11.3
Exhaust gas volume (m^3/kg)	6.8	26.9	11.6
Exhaust gas heat loss rate (to combustion heat)		36.3 %	16.3 %
Fuel reduction rate			24.1 %

Notes: For air ratio improvement, an example of Japanese excellent factory is shown.
The exhaust gas heat loss rate is that after air preheating.

Table 3.2.8 gives the specifications of this hot water boiler.

Table 3.2.8 Specifications of Hot Water Boiler

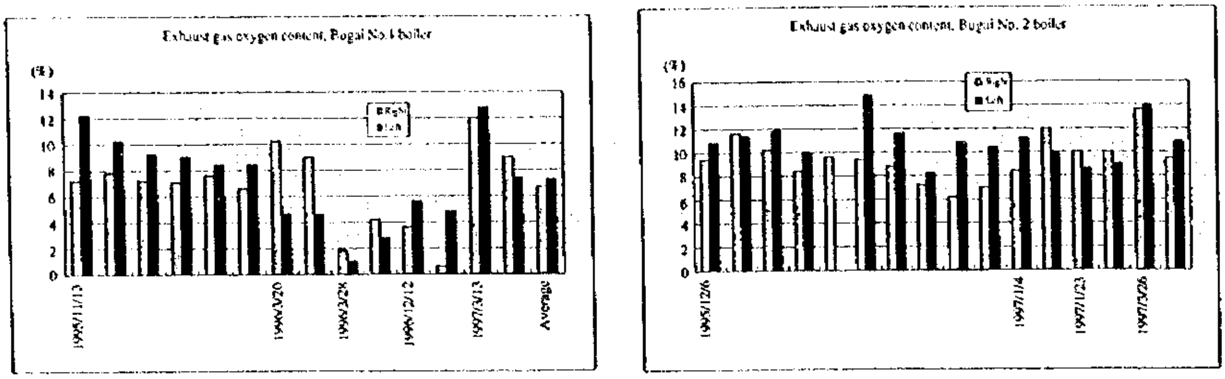
Hot Water Boiler	
Capacity/No. of operating units	6 units; 4 units operating, 2.5 MW × 4, Flow rate: 60 t/h
Year of installation	1954
Fuel	Coal (powdered coal), 2 stokers/boiler
Supplied for	Heating for the plant and processing
Pressure	Pressure reading: 4.8 kg/cm^2
Annual operating months	5 months (May to September) (However, this is only for 1997)
Operating conditions	Under the exhaust gas stack: 220 – 170 °C Flow rate: 45 t/h/unit
Water treatment	Cation exchange resin: Salt regeneration

There is a plan to stop the use of this hot water boiler. Instead, Star intends to upgrade the equipment of its heat supply company Bugaj (owned 100 % by Star) so that the latter can also supply the hot water which Star requires.

Bugai was established 2 years ago. It has two coal stoker-fired 29 MW hot water boilers. The company supplies 80 percent of its output to Star and remaining 20 % to the city. Bugai plans to upgrade the equipment with a new 4 MW gas turbine installation.

For reference, Figure 3.2.10 shows the exhaust gas oxygen content in the Bugaj boilers according to the boiler exhaust gas analysis data.

Figure 3.2.10 Exhaust Gas Oxygen Content of Bugaj Boilers



The simple average exhaust gas oxygen content of Bugai's boilers No. 1 and No. 2 shown above are 7.2 % and 10.9 % respectively. Assuming that the current oxygen content is reduced to 6 % a fuel saving ratio will be 0.9 % and 5.1 %, respectively. Although Bugaj is a separate company, it is owned entirely by Star and the most of the heat produced by Bugaj is supplied to Star. Therefore, the energy conservation of this company is equally important to Star.

b. Measurement of gas burning paint drying furnace (chassis painting plant)

This plant has large-sized, box-type drying furnace installed for chassis drying. The drying furnace using a hot water heat source (drying chamber No. 1) and natural gas heat source (drying chamber No. 2) are installed next to one other. The gas combustion furnace was installed because the drying temperatures for paint were high when the equipment was initially set up. Today, however, the improved quality of the paint has allowed lower drying temperatures, and thus gas combution is not necessarily required. Table 3.2.9 gives the specifications of this equipment.

Table 3.2.9 Gas Burning Paint Drying Furnace (for Chassis Painting Shop)

(Same specifications for one paint pretreatment cleaning and drying furnace and one post-painting drying furnace)

Type	Heat Exchanging with the Circulating Air in the Drying Room by Natural Gas Burning
Air temperature after heat exchanging	180 °C
Dry treatment time	48 min
Fuel gas heat value	34 MJ/m^3_N
Fuel gas flow rate	110 m^3_N/h
Heat load	523 kW
Air flow rate (at the outlet of the heat exchanger 180 °C)	4,000 m^3/h × 4 units

Spot measurement of the exhaust gas oxygen content was carried out at the exhaust gas discharge tube after the heat exchanger process of the gas combustion chamber for these furnaces. Combustion and non-combustion are intermittently repeated for temperature control. The measurement results show that the non-combustion period has an oxygen content level nearly identical to that in the air while the combustion period has an oxygen content of approximately 6 % to 8 %. These values are equivalent to 1.45 in terms of air ratio and are more or less appropriate. The combustion fan runs continuously, however, even during the non-combustion period. Therefore, as a measure for energy conservation besides the air ratio, it is necessary to make sure that the fan outlet damper is fully closed during non-combustion so that air does not leak out. If air leaks out during the non-combustion period, the heat exchanger will cool the air in the drying chamber and this could result in heat loss.

C. Utility (electricity utilization facilities)

1) Improvement of air compressor

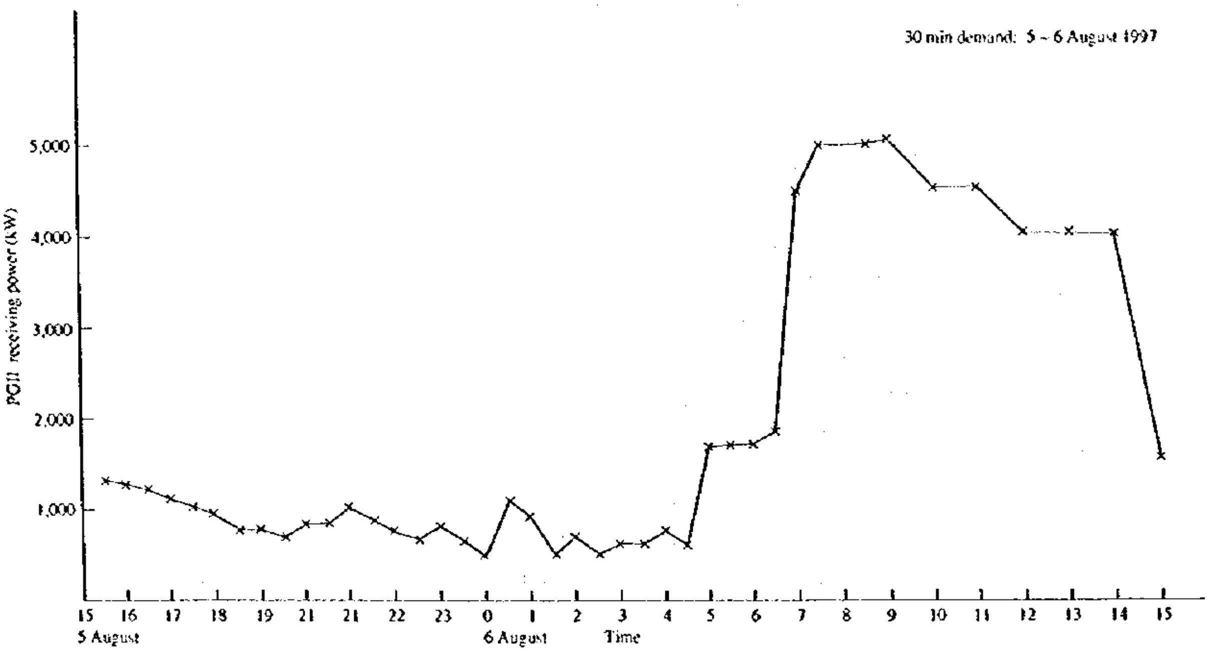
The compressed air is supplied by one 4-stage turbo compressor with a power rating of 1,800 kW. Even when the compressed air consumption changes, the compressor continues to draw the same power because its output is not controlled. The electricity consumption is approximately 1,500 kW and the annual electricity consumption is 2,800 MWh. Although the plant does not use a large amount of compressed air, this compressor accounts for as much as 12 % of the electricity consumption of the entire plant. A system such as suction vane control should be installed for adjusting the compressor output according to the compressed air consumption. Since the air consumption in this plant is actually quite small, the use of small-size compressors which would allow decentralization is recommended. In the excellent company, air consumes 10 % of the total electricity. Thus it can be concluded that if this factory adopts the above-mentioned output control method, enhances management, optimizes the pressure, and takes other such measures, it will be able to reduce the electricity consumption to such a level as that of the excellent factory. The electricity consumption after improvement is implemented will be 2,200 MWh, thus leading to an electricity reduction of 600 MWh.

Present air compressor electricity consumption: 2,800 MWh/y
Compressor electricity consumption after improvement: 2,200 MWh/y
Target energy saving amount : 600 MWh/y (6,154 GJ/y)
(1.9 GJ/truck)

2) Decreasing the peak load and cutting down the number of transformers for power distribution

This company has power received at the substations in two locations from one 110 kV line. The power is then transformed to 6 kV by each 10 MVA transformer, and distributed to the plant, where the power is further transformed to 400 V, which is then supplied to the factory machine. Figure 3.2.11 gives the changes in receiving power for PG 2. As shown in Figure 3.2.11, the load at the start of operation is large. Moreover, the capacity (30.4 MVA) of the distribution transformer is 3.5 to 6 times as large as the load, which is substantially large.

Figure 3.2.11 Changes in Receiving Power



Recommendable Measures

① Consolidating distribution transformers to reduce the number of operating transformers

② Installing a demand monitor to take some countermeasures for controlling the peak demand

Effect

① The reduction in the number of operating transformers will allow reducing the power loss due to transformers, leading to annual reduction of approx. 46 MWh (For details, see Table 3.2.10)

② Peak demand may be controlled, which can then reduce the electricity charge. In addition, the capacity of the transformers can further be decreased.

Peak demand reduction: 500 kW

Table 3.2.10 Electricity Consumption by Reducing Transformer Capacity

Item		PG 2	PG 4	Total
Peak demand (contract)	kW	8,700	5,300	13,100
Cos ϕ of load	%	83	94	87.5
Total capacity of distribution transformer	kVA	30,430	24,400	50,870
Reducing transformer capacity	kVA	21,000	12,000	33,000
(till Cos ϕ of 50 %)				(18 × 1,000 kVA)
Electricity saving*	kWh/y			46,000

Note: Condition of loss of 1,000 kVA transformer; Wi: 2.1 kW, Wc: 11.3 kW

*: = (51 – 33 unit) × {2.1 kW + 11.3 kW × {(13.1/0.875/50.9)² – (13.1/0.875/33)²} × 8,760 h}

3) Energy conservation for ventilator motors

The cabin shop has 4 large-sized 55 kW ventilators, which are each operated at only 75 to 80 % of the rated capacity in terms of electricity consumption. (See Table 3.2.11) These ventilators consume a constant amount of electricity regardless of the availability of work in process, thus occasionally producing unnecessary ventilation.

Since each shop has the painting, plating and assembly processes which each requires ventilation, it may be necessary to take some similar energy conservation measures described below.

Recommendable measures: Ventilation air flow should be controlled in accordance with the quantity of in-process work and the presence/absence of a workpiece so as to attain energy conservation. To this end, the equipment needs to be modified so that it can adjust the air flow; methods generally taken include changing the pulley diameter of the driving belt, or employing an inverter. In recent years, the inverter system is becoming increasingly popular and the use of an inverter can reduce electricity consumption by approximately 40 % for a 20 % reduction in air flow, for example. Thus, this can produce a large saving effect in case of continuous operation.

Electricity saving amount by variable speed control with an inverter unit:
176 kW × 0.4 × 10 h × 365 d/y = 257 MWh/y

Table 3.2.11 Measurement Data of Major Load

Name of Load or Transformer		Rating (kW)	Consumption (kW)	Voltage (V)	Cos ϕ (%)	Remark
PG 2	Receiving tansformer 2	10,000 kVA	500 ~ 5,000	6,060 ~ 6,396	83 ~ 86	Continuous measurement
	P30 TR1 cabin	1,000 kVA	546 ~ 548	369	86	5-min demand
	P30 TR2 cabin	1,000 kVA	320 ~ 327	372	78	5-min demand
	P30 TR3 cabin	1,000 kVA	383	368	78	
	No. 1 ventilator	55	45.5	368	85	
	No. 2 ventilator	55	47	367	86	
	Electric heater		49	212	100	3 circuits in total
	Electric heater		64	209	100	3 circuits in total
	1 ventilator	55	38.5	370	84	
	2 ventilator	55	45	372	87	
	P11 ventilator	45	35	0	98	
	P9 engine department		371 ~ 384	389 ~ 391	86 ~ 99	5-min demand
	P8 engine assembly	2 × 1,000 kVA	384		98	
PG 4	Receiving transformer 3		2,300 ~ 4,100	119.5 kV	94	
	Air compressor	1,800	1,800	6,220	98	

4) Energy conservation for lighting

During our factory survey, turning off of light was positively carried out in this company except for a portion of the cabin. Daylight is taken in from the glass of the roof, and the luminance in the plant ranges from 200 to 300 Lux, showing that they make positive efforts for energy conservation.

However, considering the long lighting hours in the winter season, the use of lighting equipment should be checked and reviewed as a whole, in terms of energy conservation. Taking the cabin shop as an example, fluorescent lights are installed at a considerably high position (about 6 m height) above the walkway, thus not exerting their lighting effect to an adequate level. In this regard there is still much left to be improved. With regard to lighting apparatuses and equipment, it is advisable to check the type of equipment which uses such lighting apparutuses.

Recommendable measures: Replacing these lamps with mercury lamps or high-pressure sodium lights for as many places as possible will lead to a reduction in electricity consumption for the required luminance.
In this plant with a large area, replacing as many outside lights as possible with high-pressure sodium lights can reduce electricity consumption by 15 to 20 %.

(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 air pollutants from this factory achieved as a result of energy conservation is compiled at each stage of energy conservation, and shown in Table 3.2.12.

Table 3.2.12 Emission Improvement by Energy Conservation Measures

Measure	Reduction (ton/year)			
	CO_2	SO_2	NO_2	Dust
Step 0				
Step 1	1,430	0.4	4.4	0.0
Step 2	3,086	0.4	9.4	0.1
Step 3	77	2.3	0.7	0.1
Step 1-3	4,592	3.1	14.6	0.2

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 3.2.13. Furthermore, the payback period required to recover energy conservation investments including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 3.2.13 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	569	1.7	571	486	0.85	0.85
Step 2	1,292	3.4	1,296	780	0.60	0.60
Step 3	2,361	1.0	2,362	112,500	47.63	47.65
Step 1-3	4,223	6.0	4,229	113,766	26.90	26.94

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

As evident from this Table 3.2.13, 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 investment recovery period is also negligible.

In this factory, a reduction in the emission fee has only a small effect in the payback period. The equipment for the modernization of the machining line listed in Step 3 costs much, thus drastically worsening the investment recovery. Moreover the effect of this item is the reduction in electricity consumption and thus it has only a small effect of reduced emission fees on the payback period. Additionally, since steam is purchased from an outside source, many heat-related energy conservation items do not lead to the reduction in the pollutant emission fee.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 3.2.14.

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 3.2.12. The relationship between energy conservation potential, the payback period to recover the investment, and the investment cost is shown in Figure 3.2.13.

Table 3.2.14 Summary of Energy Conservation Potential

Natural gas: 0.514 PLN/m³N (34.4 MJ/m³N) Coal: 170 PLN/t Electricity: 0.172 PLN/kWh 1 PLN = 30 yen

Item	Energy Conservation Potential: Fuel GJ/y	Fuel 10^3 PLN/y	Fuel %	Electricity MWh/y	Electricity 10^3 PLN/y	Electricity %	Total 10^3 PLN/y	Investment 10^3 PLN	Payback period year
Step 1									
1. Enhancing the management for each department	24,000	359	5.1	1,180	203	5.0	562	486	0.9
2. Streamlining transformers				46	8	0.2	8	0	0.0
Subtotal	24,000	359	5.1	1,226	211	5.2	569	486	0.9
Step 2									
3. Centralization of processes and batch production	15,400	230	3.3				230	371	1.6
4. Controlling the drying furnaces	52,000	777	11.1				777	186	0.2
5. Improving the compressors				600	103	2.5	103	143	1.4
6. Reducing the peak demand				500 kW	86	2.1	86	0	0.0
7. Controlling the motors by an inverter				257	44	1.1	44	189	4.3
8. Changing the air pressure				140	24	0.6	24	20	0.8
Subtotal	67,400	1,007	14.4	997	257	4.2	1,265	909	3.2
Step 3									
9. Improving the yield				66	11	0.3	11	-	–
10. Modernizing the machining line	33,000	493	7.1	10,400	1,789	44.1	2,282	112,500	49.3
Subtotal	33,000	493	7.1	10,466	1,800	44.4	2,293	112,500	49.1
Total	124,400	1,859	26.6	12,689	2,269	53.8	4,127	113,895	27.6

As of 1996: Fuel consumption: 466,821 GJ/y
Electricity consumption: 23,573 MWh/y (241,804 GJ/y)
Total: 708,625 GJ/y

Figure 3.2.12 STAR Energy Conservation Potential

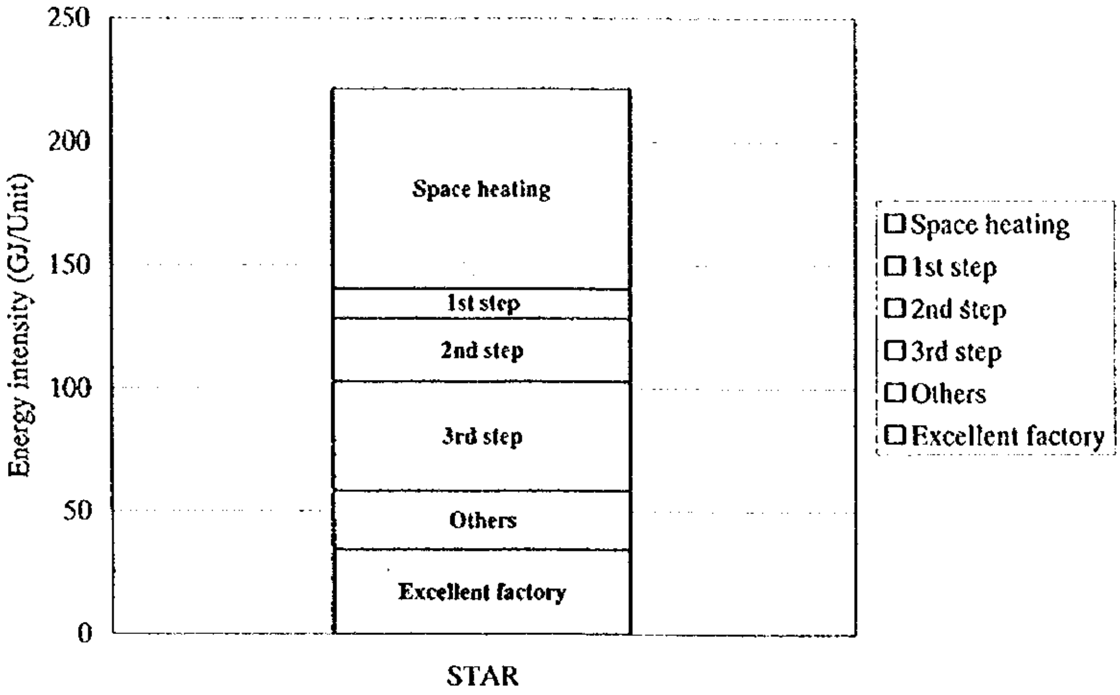


Figure 3.2.13 STAR Energy Conservation Potential