No. 25

Japan International Cooperation Agency (JICA)
The Republic of Poland
Ministry of Economy
Polish National Energy Conservation Agency (KAPE)

THE MASTER PLAN FOR ENERGY CONSERVATION IN THE REPUBLIC OF POLAND

FINAL REPORT

III. Results of Factory Energy Audit

June 1999

The Energy Conservation Center, Japan (ECCJ)
The Institute of Energy Economics, Japan (IEEJ)

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[Definition of Terms]

1. Excellent factory:

"Excellent factory" refers to a factory in Japan or other industrialized country of a similar size and in the same industrial sector as each subject factory of this study, and having an energy intensity better than average.

2. Energy price:

For the prices of coal, coke, natural gas and electricity in the table "Summary of Energy Conservation Potential" for each factory, the estimated average prices in the period 1998 to 2005 have been utilized, which are as shown below:

Coal : 0.170 PLN/kg
Coke : 0.400 PLN/kg
Natural gas: 0.514 PLN/m^3N
Electricity : 0.172 PLN/kWh

3. Breakdown of Energy Conservation Potential for Each Factory in Graphs:

(1) Step Zero:
Energy conservation measures in this step have already been implemented or are currently under planning, and are not included in the data on the previous year.

(2) Step 1: The effort is primarily aimed at the enhancement of operation, maintenance and management; energy conservation measures at this phase include installation of measuring instruments and other such minor measures, which require only a small amount of investment.

(3) Step 2: Energy conservation measures through improvements to equipment or such means, which do not require a large amount of investment

(4) Step 3: Energy conservation measures through process improvement, etc., which require a large amount of investment

(5) Others: Items which could not be quantified during the factory surveys, which are presumed to be principally affected by availability (shutdown time, downtime due to faults, maintenance time) and such factors.

(6) External: External factors such as differences in energy intensity attributable to radiation heat loss due to differences in temperatures or in manufacturing processes

(7) Space heating: Energy required for space heating in plant buildings; this level of heating may not be needed in factories in Japan or other industrial countries that are located in warm climates.

4. Investment Amount and Payback Period

The investment amount is the equipment cost or construction cost in Japan converted on a basis of 1PLN = 30 yen.

The investment payback period is based on a simple payback method, i.e., [investment amount/ annual benefit]

III. RESULTS OF FACTORY ENERGY AUDIT

1. RESULTS OF THE STUDY ON THE STEEL-MAKING INDUSTRY

1. STEEL-MAKING INDUSTRY

1.1 Results of the Study at Huta Labedy Plant

(1) Study period: July 25, 28 and 29 1997

(2) Members of the study team

a. JICA Team

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

b. Local consultants

POLESCO Investment SA
Mr. Piotr Bortnowski: Vice President
Dr. Tadeusz Kruczek: Heat management
Dr. Marcin Szega : Heat management
Dr. Joachim Bargiel : Electricity management

(3) Interviewees

M. Sc. Eng. Wilhelm Stanislaw Kirsz: Director of the Steel Plant
M. Sc. Eng. Jeizy Sitek : Director of Production in the Plant
M. Sc. Eng. Jacek Malanowics : Chief of Energy-machine Department
M. Sc. Eng. Jerzy Gajecki : Head of Universal Rolling Mill
M. Sc. Eng. Jozef Hoder : Head of the Furnace Department
M. Sc. Eng. Marek Ceglarz : Head Responsible for Operation of Medium Rolling Mill
M. Sc. Eng. Marek Trefler : Head of Cramps and Yoke Department
Eng. Andrzej Borowik : Head of Energy Departmenet
Eng. Eugeniusz Lochtara : Head of Electrical Stations and Networks of Electrical Supply
Mr. Grzegorz Dudek : Responsible for Reports of Energy Carriers Consumption
Ms. Halina Fijalkowska Kornas : Economist

1.1.1 Profile of the Plant

(1) Plant name: Huta Labedy

(2) Plant address: 45 Zawadzkiego Street, 44-109 Gliwice

(3) No. of employees: 1,500

(4) Major products: Steel support (Mining beam and cramp), and steel plate

(5) Production capacity: Steel support: 300,000 t/y, Steel plate: 60,000 t/y

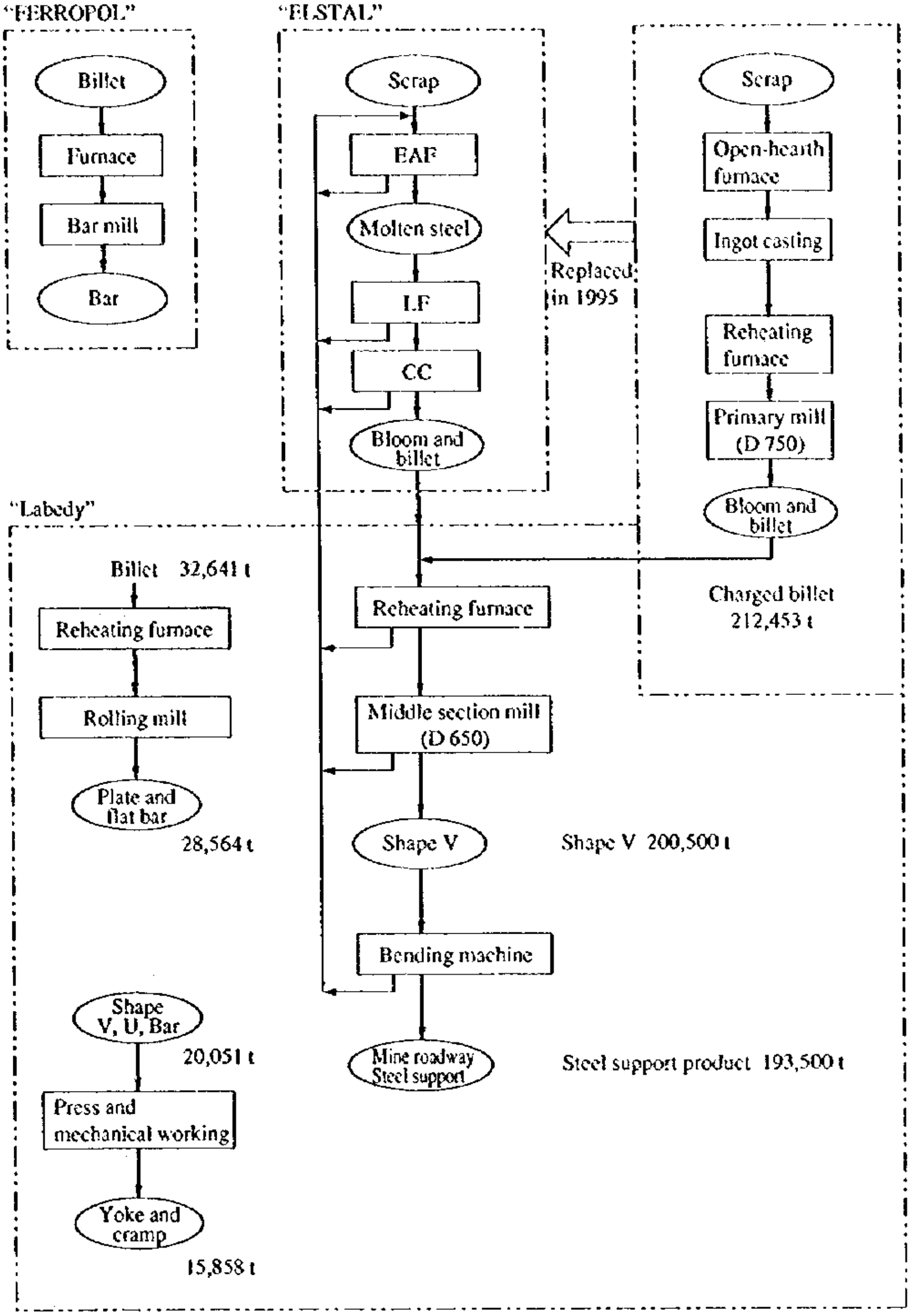
(6) Overview of process

Huta Labedy is a so-called simple rolling factory that receives semi-finished products or billets from its affiliate ELSTAL Company (electric furnace mill), and produces steel support (mining beam and cramp) at the middle section mill, and steel plate at the steel plate mill. This factory also produces yoke and cramp as auxiliary parts for mining beam and cramp. Figure 1.1.1 shows the process flow. The electric arc furnace (EAF) and bar mill constituting a part of the production processes in the LABEDY plant are owned by other companies and thus were excluded from the targeted factories for this study. Additionally, since LABEDY supplies a part of energy (utility) to other companies, energy consumption and energy potential for it were calculated in this study excluding the amount of energy supplied to these companies.

(7) History of the plant

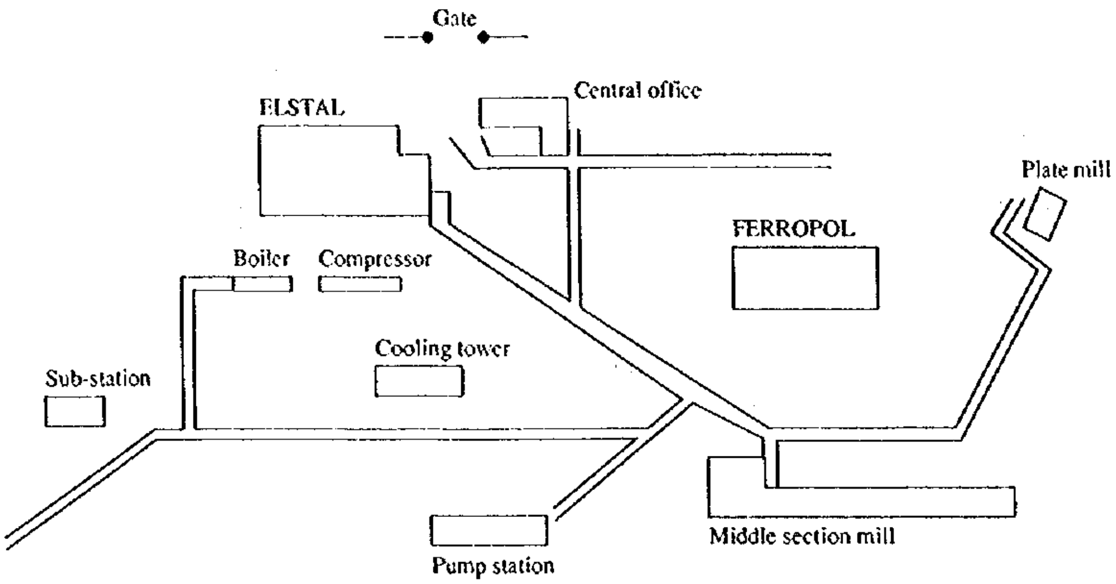
Established in 1948, this company is now producing steel support (mining beam) and steel plate as a state-run simple rolling factory. Restructuring is currently in progress since the country's economic system was shifted to market economy. In 1995, the open-hearth furnace was converted to the electric furnace, which started operation as ELSTAL Company, while the bar steel mill was separated as FERROPOL Company, each of which was thus independently started as a separate company. At present, modernization of the middle section mill is under consideration.

Figure 1.1.1 Process Flow

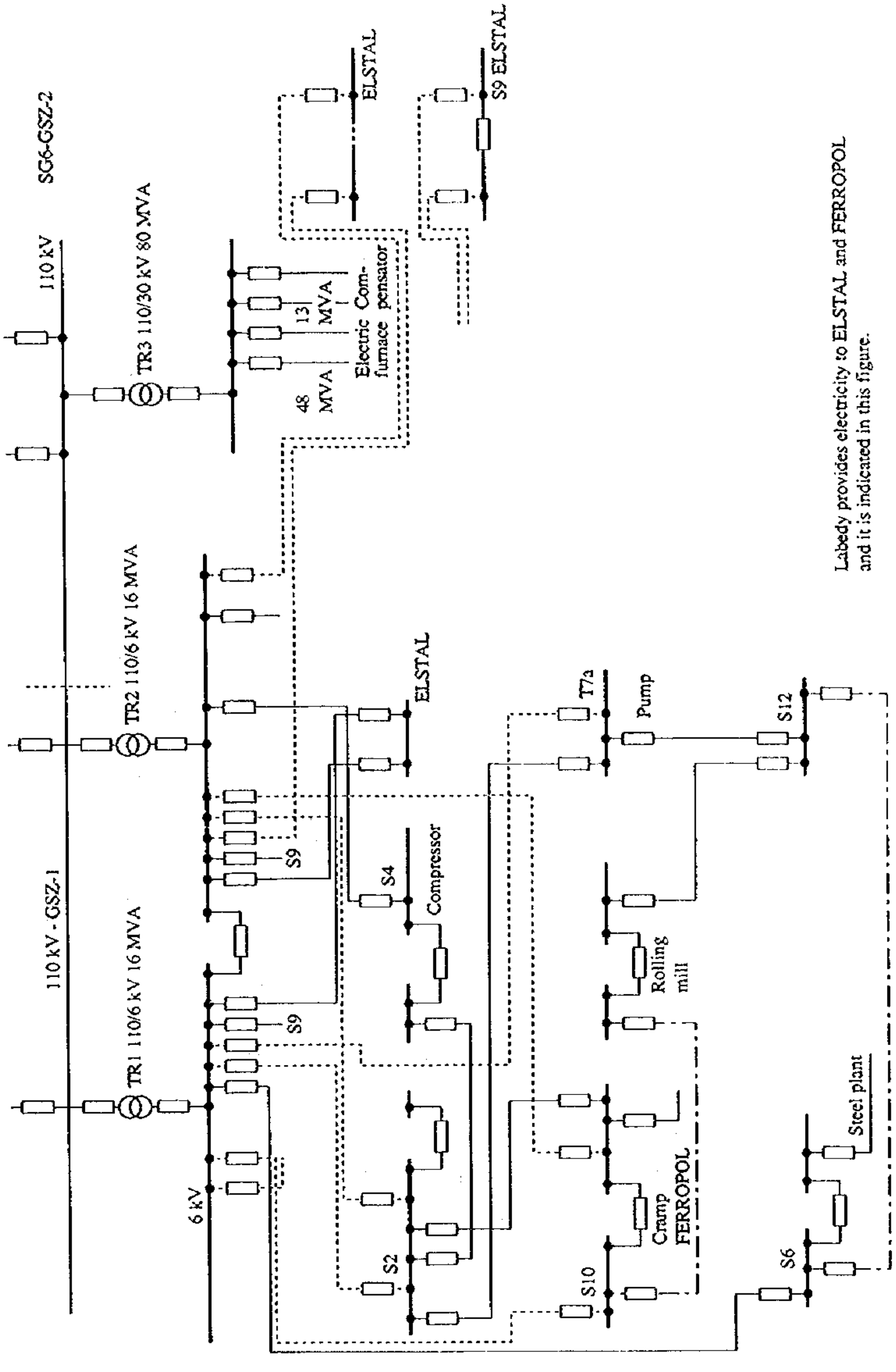


(8) Plant layout

Figure 1.1.2 Plant Layout



(9) One line diagram



Labedy provides electricity to ELSTAL and FERROPOL and it is indicated in this figure.

Figure 1.1.3 One Line Diagram

(10) Outline of major equipment

Table 1.1.1 Major Equipment

Factory	Equipment	Number	Specification
V shape mill	Reheating furnace	1	Type: Pusher type Capacity: 60t/h (design), 40t/h (actual) Fabricator: Modernized by BIPROHUT Furnace dimension: 7m-width × 21 m-effective length Charged material: Bloom 160 × 140 × (5,500 – 6,200) mm Fuel: Natural gas Burner capacity: About 25 MW
	Middle section mill	1	60 t/h, 4 MW × 742 rpm (rougher) 2 MW × 990 rpm (finisher)
Mining beam shop	Bending machine	–	300,000 t/y
Yoke and cramp shop	Mechanical working machine	1	
	Press and shears	–	
Plate mill	Reheating furnace	1	Type: Pusher type Capacity: 8t/h, average 5t/h Furnace dimension: 2.7m-width × 14.4 m-effective length Charged material: Bloom (80 – 240) T × (80-500) W × (1,350 – 2,450) L mm Fuel: Natural gas Burner capacity: About 4.4 MW
	Universal mill		8 t/h, 750 kW
Energy plant	Power receiving station	1	110 kV × 4 Lines Main transformer 16 MVA × 2 80 MVA (to ELSTAL)
	Hot water boiler	3	4 MW each
	Oxygen plant	–	1,200 m^3_N/h
	Air compressor	3	2,500 m^3_N/h × 350 kW Centrifugal oil free
cf. ELSTAL plant	Electric arc furnace	1	70 t/ch-EBT, 48 MVA } Newly installed
	Ladle furnace	1	70 t/ch, 13 MVA } (ELSTAL Co.)
cf. Open-hearth furnace	Open-hearth furnace	7	100 t/ch × 5 } Stopped 200 t/ch × 2 } (Labedy)

(11) Energy price

Table 1.1.2 Energy Price and Heat Value

	Energy Price		Heat Value
Electricity	110 PLN/MWh	(Jun. 1997)	10.258 GJ/MWh
Natural gas	0.51 PLN/m³N	(Jun. 1997)	35.930 GJ/10^3 m^3_N
Hot water (for selling)	36.68 PLN/GJ	(Jun. 1997)	–

Table 1.1.3 Components of Reheating Furnace Fuel Gas

Gas content	CO_2	H_2	CH_4	C_2H_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	O_2	H_2O
Wet volume	–	–	97.0 %	–	–	–	1.0 %	2.0 %	–	–

1.1.2 Energy Consumption State

(1) Trend of production

Table 1.1.4 Trend of Production

	Unit	1992	1993	1994	1995	1996
Mining beam and cramps	t	248,936	204,920	285,202	246,244	209,358
Plate	t	24,028	28,605	32,463	36,467	28,564
cf. OHF ingot production	t	308,363	271,617	314,328	232,191	0

(Note) In 1995, OHF is replaced to EAF (of ELSTAL company).

(2) Trend of energy consumption

Table 1.1.5 Trend of Energy Consumption

	Unit	1992	1993	1994	1995	1996
Fuel oil	kL	24,359.7	17,047.0	22,749.0	14,171.5	44.6
Diesel oil	kL	595.4	573.0	611.2	580.4	563.3
Natural gas	10^3 m^3_N	–	15,792.3	74,464.0	66,371.3	18,175.8
Gasoline	kL	24.8	20.2	22.2	24.5	25.8
Others		116,254.2	75,957.8	–	–	–
Coal	t	–	100	25	9.8	–
Benzol	t	5,775	10,586	3,694	3,317	
Electricity	MWh	57,808.8	51,444.9	59,818.8	53,050.3	36,939.9

(3) Trend of energy consumption and energy intensity

Table 1.1.6 Trend of Energy Consumption and Energy Intensity (A)

	Unit	1992	1993	1994	1995	1996
Fuel oil	GJ	957,336	669,947	894,036	556,940	1,753
Diesel oil	GJ	25,424	24,467	26,098	24,783	24,053
Natural gas	GJ	–	567,417	2,675,492	2,384,721	653,056
Gasoline	GJ	1,074	875	961	1,061	1,117
Others	GJ	2,559,685	1,672,439	–	–	–
Coal	GJ	–	2,100	525	206	–
Benzol	GJ	234,534	429,919	150,021	134,710	–
Electricity	GJ	593,003	527,722	613,621	544,190	378,929
Total energy (A)	GJ	4,371,056	3,894,886	4,360,754	3,646,611	1,058,908
Energy	MJ/t	14,175	14,340	13,873	15,705	–
intensity	(Mcal/t)	(3,386)	(3,425)	(3,314)	(3,751)	---

(Heat value) Fuel oil : 39.300 GJ/kL
Diesel oil: 42.700 GJ/kL
Gasoline : 43.300 GJ/kL
Others : 22.018 GJ/kL
Coal : 21.000 GJ/t
Benzol : 40.612 GJ/t

In December of 1995, the open-hearth furnace (OHF) and blooming mill owned by LABEDY were shut down, and replaced with an electric arc furnace (EAF). This newly established EAF was separated as auxiliary facilities to ELSTAL, and data related to EAF is therefore unavailable, thus making it difficult to evaluate the effect stemming from energy conservation. Hence energy consumption for OHF and EAF were excluded from the calculation and comparisons were made with regard to energy consumption involved in the processes from the reheating furnaces to the product. First the energy consumption for OHF was obtained, and then the heat consumption for OHF was subtracted from the total energy consumption for LABEDY, to correct the energy consumption during the period from 1992 to 1995, and thereby estimate the trend of energy intensity. The result is shown in Table 1.1.7.

Table 1.1.7 Trend of Energy Consumption and Energy Intensity (B)

	Unit	1992	1993	1994	1995	1996
Total energy (A)	GJ	4,371,056	3,894,886	4,360,754	3,646,611	1,058,908
OHF energy (B)	GJ	2,599,188	2,380,969	2,486,956	1,882,520	0
(A) – (B)	GJ	1,771,868	1,513,917	1,873,798	1,764,091	1,058,908
Production	t	272,964	233,525	317,665	282,711	237,922
Energy intensity	MJ/t	6,491	6,483	5,899	6,240	4,451
	Mcal/t	(1,550)	(1,548)	(1,409)	(1,490)	(1,286)

(Note)
- Total energy (A): For Labedy total energy consumption, see Table 1.1.6
- OHF energy (B): For Labedy OHF energy consumption, see Table 1.1.8
- Energy intensity: per steel product ton

Table 1.1.8 Trend of OHF Energy Intensity

	Unit	1992	1993	1994	1995	1996
Electricity	GJ	74,545	66,821	71,611	62,174	–
Oil	GJ	957,348	669,947	894,036	556,252	–
Benzol	GJ	234,534	429,919	150,021	134,710	–
Gas	GJ	1,333,701	1,249,584	1,402,635	1,123,244	–
Compressed air	GJ	108,502	79,563	95,248	66,658	–
Cooling water	GJ	8,242	7,279	9,451	7,305	–
Steam (consumption-production)	GJ	Δ117,684	Δ122,144	Δ136,046	Δ67,823	–
OHF energy consumption total (B)	GJ	2,599,188	2,380,969	2,486,956	1,882,520	–
OHF energy intensity	MJ/t	8,429	8,766	7,912	8,108	–
	(Mcal/t)	(2,013)	(2,094)	(1,890)	(1,936)	

Enegy intensity: per OHF ingot ton

(Heat value) Compressed air: 1.0467 GJ/$10^3{}_N$ m^3

Cooling water : 2.5958 GJ/10^3 m^3

(4) Percentage of the energy cost in the product cost

Although the cost list was not available, it was found that the percentage of energy cost in the total cost is within the range of 20 % to 23 %.

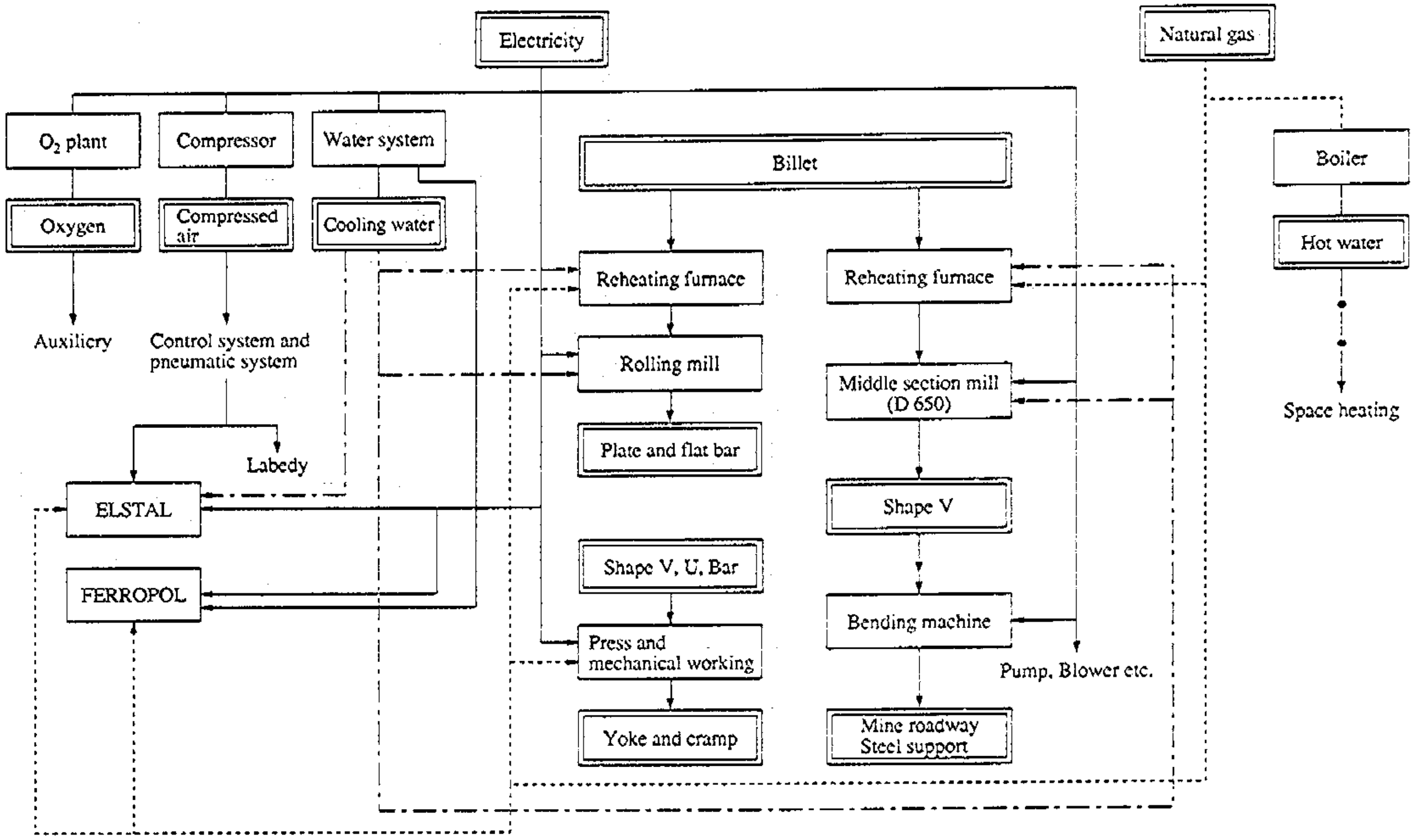
(5) Energy flow

Most part of the purchased energy is occupied by electricity (36 %) and natural gas (62 %). Electricity is used not only for the rolling mill and press machine but also for the compressed air plant, cooling water system, and oxygen plant. The generated compressed air, cooling water, and oxygen are supplied to each plant.

The sensible heat of the cooling water for the ELSTAL's electric arc furnace is recovered in the state of hot water. Since Huta Labedy supplies electricity, natural gas, cooling water, and compressed air to ELSTAL (electric arc furnace) and FERROPOL (bar steel mill), which are the affiliates located on the company's same premises, the energy intensity of Labedy is calculated in due consideration of these factors.

Figure 1.1.4 shows the energy flow.

Figure 1.1.4 Energy Flow



1.1.3 Energy Management Status

(1) Setting the energy conservation target value

a. Target setting

No specific target value has not been set for the entire factory. Presently, each mill has a plan to clarify the costs including the energy cost and proceed with restructuring so that each mill will be based on the self-supporting profit system.

b. Problems in promotion of energy conservation

Since measuring instruments including flowmeters are insufficient, efforts are being made to increase them.

The market trend is hard to forecast, thus making investment for energy conservation difficult.

(2) Systematic activities

a. Setting up a section dedicated to energy conservation

A particular section is not available, but Energy Department is in charge of energy conservation.

A temporary working group is provided as required for cost reduction or facility restructuring. For example, a particular group was available for examination to replace the open-hearth furnace with an electric furnace.

b. Setting up an energy conservation committee

Not provided. However, since restructuring is one of the important issues for the company, reduction of costs (including the energy cost) is always picked up by the manager meeting in the company.

c. Stance of the management towards energy conservation

To let the company survive, efforts are being made to enhance the competitive force. The energy conservation activities are regarded to be important as one of them.

d. Personnel evaluation system

People who brought merits to restructuring or cost reduction are highly evaluated.

(3) Data-based management

a. Grasping the energy consumption

Cost management by process is being performed. They keep good track of electricity and gas. There are only a few flow meters available for cooling water, making it impossible to grasp actual water consumption by each section and the cost for water consumption is shared by each mill based on the company's rule.

b. Grasping the energy consumption for each major facility

Since there are only a few flow meters provided for hot water/cooling water and compressed air, the data on actual consumption is unavailable, and therefore the consumption shown in the cost sheet may be different from the actual value. However, they keep track of electricity and gas for each major facility, and thus 90 % or more energy is managed by the meters.

c. Grasping the energy intensity for major products

They keep track of, and manage the energy intensity for major products.

d. Installing measuring equipment

At some places, measuring equipment for cooling water, hot water, or compressed air is not installed. Installation and management of such measuring instruments at the earliest possible time are recommended.

e. Production management and cost management

Cost management is strictly being performed. However, the energy intensity by product type is not grasped well. It does not seem that process control is being performed to minimize the energy cost.

(4) Training and education of employees

a. Commendation system

A commendation system is available.

(5) Plant engineering

Restructuring of the plant is now under way. There are many old facilities and a few latest facilities used together, old ones of which seem to be maintained well.

Although the rolling mill consuming a large amount of energy is incredibly old, investments are made on the equipment necessary for cost reduction by such means as replacing the combustion control system. This suggests that this plant may be called a well-managed plant.

1.1.4 Problems and Countermeasures related to the Use of Energy

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

Major products of this factory are billet, steel supports (mining beams), flat bars, and sheets. Comparison of energy consumption by product shows that the processes for producing the beam and cramps consume 49.4 % of the total energy, followed by the billet production process 14.9 %, the production processes for the flat bars and sheets 14.2 %, and other processes 21.5 %. Along with abolition of the open-hearth furnace, the billet ingot process has been shut down.

As for the mining beam bending and cramp manufacturing processes, data of the year that showed the best intensity of the Labedy factory in the past five years is used and the reference values are shown in parentheses. For others, the values for Labedy in 1996 are used unchanged.

Table 1.1.9 Comparison of Energy Intensity

Production Process	Unit	Production	Labedy	Excellent factory	Difference
Mining beam and cramp	MJ/t-product	209,358	2,374	1,917	457
Middle section mill	MJ/t-shape	200,500	2,206	1,768	438
Beam bending	MJ/t-product	193,500	93	(93)	–
Yoke and cramp	MJ/t-product	15,358	2,391	(1,878)	513
Flat plate and sheet	MJ/t-product	28,564	5,031	2,101	2,930
Billet (Large section mill)	MJ/t-billet	38,600	3,880	0	3,880
Water system	$MJ/10^3 m^3$	$10,814 \times 10^3$	2,415	0	2,415
Air compressor	MJ/m^3_N	$40,468 \times 10^3$	523	0	523
Hot water boiler	MJ/MJ	73,998 GJ	0.329	0.255	0.074
Others	MJ/t-product	237,992	605	(605)	–
Total	MJ/t-product	237,992	4,238	2,626	1,610

Note: It is assumed that the V-shape/steel support production ratio of this plant is equivalent to that of the excellent factory.

Note: Cooling water is evaluated to be 1 m^3 = 0.253 kWh = 2595.8 kJ and compressed air to be 1 m^3_N = 0.102 kWh = 1047.6 kJ.
Although the hot water boiler is not used at excellent factory, it is assumed to have the same efficiency as that of the gas-fired steam boiler. Therefore, its heat efficiency is regarded to be 90 %.

According to Table 1.1.9, it can be seen that the energy conservation potential of Labedy is approximately 38 %. In contrast, the large section mill has been shut down in 1997. Since the potential has been reduced by 600 MJ/t (14.9 %), the substantial energy conservation potential will be 23 %.

Energy conservation potential for compressed air can simply be calculated as follows:

Energy conservation potential for an air compressor = Production volume of compressed air (m^3_N/y) × (0.144 – 0.102) (kWh/m^3_N)

Energy conservation potential of compressed air for a middle section mill = Production volume of middle section mill (t/y) × (31.7 – 25.0) (m^3_N/t) × 0.102 (kWh/m^3_N)

where:
Electricity intensity for manufacturing compressed air : 0.144 kWh/m^3_N
Compressed air intensity of a middle section mill : 31.7 m^3_N/t
Compressed air intensity of rolling mill of excellent factory : 25 m^3_N/t

(2) Estimating the energy conservation potentials

Steps for energy conservation are categorized into the following three steps to sort out and examine its energy conservation potential:

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

A. Estimation of energy conservation potential by process

Table 1.1.10 lists the net energy consumption for each process in decreasing order of the amount.

Table 1.1.10 Energy Consumption by Process

Unit: GJ/y

Process	Consumed energy	Generated energy	Net consumption	Ratio
a. Middle section mill	442,230	0	442,230	43.9
b. Large section mill	149,766	0	149,766	14.9
c. Plate mill	143,715	0	143,715	14.2
d. Energy system	216,060	144,427	71,633	7.1
(Water system)	(54,188)	(28,071)	(26,117)	(2.6)
(Air compressor)	(63,515)	(42,358)	(21,157)	(2.1)
(Hot water boiler)	(98,357)	(73,998)	(24,359)	(2.4)
e. Mining beam works	55,854	0	55,854	5.5
(Beam bending)	(17,945)	(0)	(17,945)	(1.8)
(Yoke and cramp)	(37,909)	(0)	(37,909)	(3.7)
f. Others	145,173	0	145,173	14.4
Total	1,152,797	144,427	1,008,370	100

a. Middle section mill

a1. Difference due to external factors

There is no significant difference found in external factors.

a2. Difference due to technical factors

Table 1.1.11 shows comparison of the energy intensity of LABEDY for the fiscal year 1996 with that of the excellent factory.

Table 1.1.11 Comparison of Energy Intensity of Middle Section Mill in 1996

	Unit	Labedy	Excellent factory
Fuel	MJ/t-product	1,534 (42.7 m^3_N/t)	770
Steam	MJ/t-product	–	75
Electricity	MJ/t-product	607 (59.1 kWh/t)	923 (90 kWh/t)
Compressed air	MJ/t-product	33 (*3.2 kWh/t)	
Cooling water	MJ/t-product	32 (*3.1 kWh/t)	
Total	MJ/t-product	2,206	1,768 MJ/t

(Note) * means equivalent calorie in kWh.

1) Middle section mill in Labedy

The billets of 165 × 140 × approx. 6 m length (177 kg/m) produced by the separate company ELSTAL are received, heated and rolled into V-type section (21 to 35.9 kg/m) using the middle section mill. The rolling time in 1996 is 6,171 h, which is equivalent to approximately 70 % of the annual opertion rate.

2) Improving the yield

The rolling yield is as good as 94.4 %, which still allows for further improvement. By increasing the yield up to around 97.0 %, energy intensity can be improved by 59 MJ/t (Fuel: 41 MJ/t, Electricity: 18 MJ/t).

In order to improve the product yield, firstly it is necessary to keep daily record and control of each amount of crops, product crop loss, miss roll and unacceptable products, which have a large influence on the yield. Next, measures to reduce such problems should be considered and examined starting with the one which occupies a larger percentage, and thus brought into action.

During our study in Poland, the rolling mill was shut down, and the actual situation of crops and odd ends could not be observed. However, judging from the fact that a considerable amount of products from miss roll were left around, it seemed to us that it would be the first step for this factory's improvement of product yield to reduce miss roll. For this end, the date of ocurrence of miss roll, size, No. of miss roll, occurrence status, causes and countermeasures should be surveyed, examined and recorded to improve the facilities in cooperation with personnel in charge of maintenance.

3) Fuel intensity

Fuel intensity is 1,534 MJ/t (366 Mcal/t), which is considerably favorable. As shown also in O_2 4.1 % (air ratio: m = 1.22) obtained as the result of the exhaust gas analysis at our simplified energy audit, the combustion control of the reheating furnace is maintained at a nearly favorable level, although it allows for some improvement.

If hot charge rolling is available, a substantial energy conservation can be expected. Hot charge rolling will be described in more detail in item ⑤. In this section, the target energy intensity is 1,381 MJ/t (330 Mcal/t) without hot charge rolling taken into account. The improvement target will be as follows:

1,534 MJ/t – 41 MJ/t – 1,381 MJ/t = 112 MJ/t (27 Mcal/t)
41 MJ/t : For yield improvement (equivalent to 2.6 %)

① Improving the heat holding criterion: 25 MJ/t (6 Mcal/t)

The furnace heat holding criterion for billet waiting or rolling mill inspection should be reviewed and the fuel used for heat holding should be reduced.

In rolling mills, generally a large amount of energy is used for raising and holding the heat in the reheating furnace. Using the following methods, the actual situation regarding energy use should be first studied, and then the improvement measures examined and implemented, thereby to reduce fuel consumption.

- Keep record of heat holding/raising
  The example of the record is shown in Section c. steel plate mill.

- Set up criteria for heat holding/raising, and thus follow up the result. Always check the fuel intensity for heat holding/raising, to review the criteria. Survey the causes and consider the measures when any deviation from the criteria should arise.

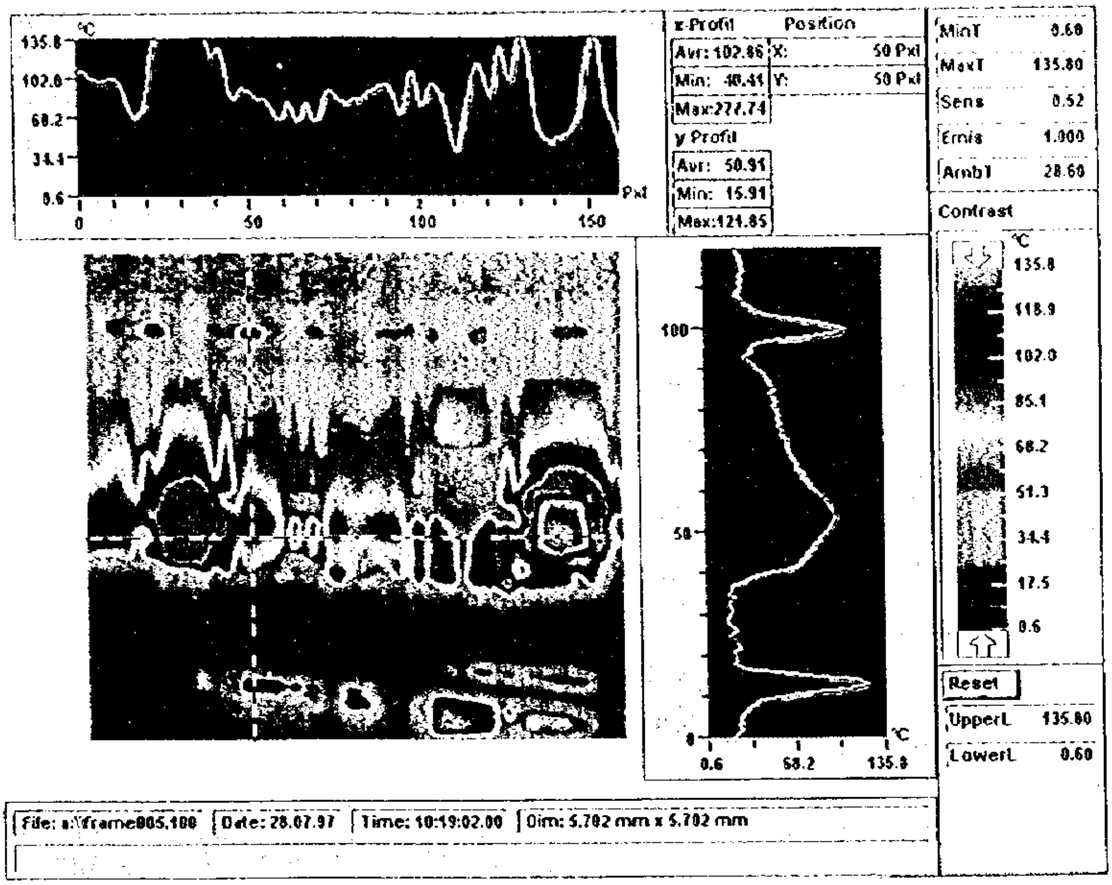
- Notify the reheating furnace operator about the scheduled time for starting and stopping of the reheating furnace at as early time as possible, in addition to the above item. Also try to be punctual so as to eliminate the waste of fuel. It is advisable to keep record of energy loss involved in starting/stopping the furnace.

② Reinforcing heat insulation of the reheating furnace by ceramic fiber: 63 MJ/t (15 Mcal/t)

Since the heat radiation loss and heat capacity can be reduced by installing ceramic fiber, the heat loss caused by temporary shutdown of heating due to the failure of the electric arc furnace (billet waiting) or rolling mill maintenance, heat holding for the furnace, etc, can be greatly reduced.

The result of our survey of this factory revealed that for the outer surface of the furnace, the furnace wall surface temperature does not feel high in general but there is a high temperature portion around the inspection hole on the side wall as shown in Figure 1.1.5. Therefore, heat insulation should be reinforced. This should be coped with at an earliest possible time.

Figure 1.1.5 Thermal Image of Inspection Hole of Reheating Furnace



x-Profil
Avr: 102.86
Min: 40.41
Max:277.74

Position
X: 50 Pxl
Y: 50 Pxl

y Profil
Avr: 50.91
Min: 15.91
Max:121.85

MinT 0.60
MaxT 135.80
Sens 0.52
Emis 1.000
AmbT 28.60

UpperL 135.80
LowerL 0.60

File: a:\frame005.100
Date: 28.07.97
Time: 10:19:02.00
Dim: 5.702 mm x 5.702 mm

③ Improving the air ratio: 28 MJ/t (7 Mcal/t)

Figure 1.1.6 shows the result of measuring the exhaust gas on the shape rolling mill reheating furnace. The measurement point was the inlet of the air preheater. The preheated air temperature is 350 °C.

Figure 1.1.6 Exhaust Gas Measurement of Shape Steel Rolling Mill Furnace
(Measured at the air preheater gas inlet)

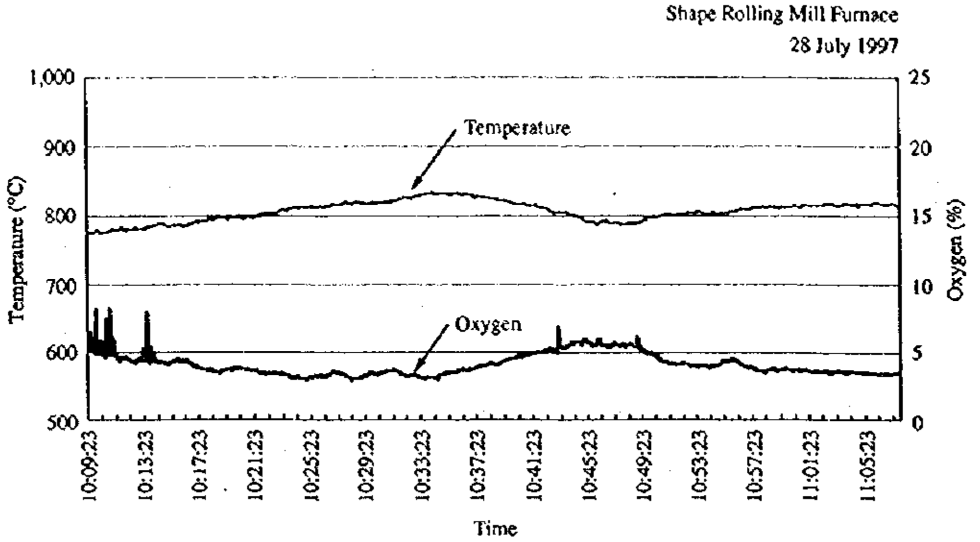


Table 1.1.12 shows the result of combustion calculation by the average value of the measured values. As shown in this table, the air ratio is 1.22 upon measurement. If the air ratio is maintained at the minimum value (1.15) during measurement, fuel consumption is logically reduced by 1.8 %.

Table 1.1.12 Fuel Reduction Effect by Air Ratio Control (Shape steel reheating furnace)

Preconditions	
Fuel gas	
Net heat value (kJ/m^3_N)	35,930
Net heat value (kcal/m^3_N)	8,582
Combustion air temperature	350
Exhaust gas temperature	808
Furnace infiltrating air ratio	0 %

Notes: The measuring point: Before the air preheater
The temperature after air heating is assumed based upon the AH heat balance.
Exhaust gas temperature means the exhaust gas temperature before air preheating.

Calculation Result

	Theoretical Combustion	Current Air Ratio	Air Ratio after Improvement
Exhaust gas oxygen	0.0 %	4.1 %	3.0 %
Air ratio	1.00	1.22	1.15
Air flow rate (m^3/kg)	9.7	11.8	11.2
Exhaust gas volume (m^3/kg)	10.7	12.8	12.2
Exhaust gas heat loss ratio (to fuel heat)		27.0 %	25.7 %
Fuel saving rate			1.8 %

Notes: For air ratio improvement, the minimum values of the measured O_2 values are listed.
The exhaust gas loss ratio is the exhaust gas heat loss ratio after air preheating.

By maintaining O_2 in the exhaust gas at 3 % (1.15 as the air ratio), the fuel intensity can be improved by 1.8 %.

④ Air preheater (cleaning of the recuperator)

Energy intensity for recovery can be maintained at a favorable level by performing simple heat balance for the air preheater on a regular basis and implementing management for cleaning the recuperator when the heat recovery rate declines.

The temperature of the exhaust gas after air preheater was 406 °C with the panel meter. According to the calculation based on the heat balance of the air preheater, however, the temperature was found to reach as high a level as 550 °C. One of the possible causes is that cold air may leak in the high temperature exhaust gas side in the air preheater. Therefore, the air preheater should be checked for any leakage by measuring oxygen content in the exhaust gas at the outlet of the air preheater.

For reference, the exhaust gas temperature t_{2g} at the outlet of the air preheater was obtained based on the following formula:

$$t_{2g} = \frac{C_{p1g}}{C_{p2g}} \times t_{1g} - \frac{Q_a\left(t_{2g}\, C_{p2a} - t_{1a}\, C_{p1a}\right)}{Q_g\, C_{p2g}} = 834 - 277 = 557\ °C$$

where

Q_a : Air flow rate 11.848 $m^3{}_N/m^3{}_N$-fuel

Q_g : Exhaust gas flow rate 12.863 $m^3{}_N/m^3{}_N$-fuel

C_{pa}: Air specific heat 0.3094 at 28 °C, 0.3171 at 350 °C

C_{pg}: Exhaust gas specific rate 0.3515 at 808 °C, 0.3405 at 557 °C

t_{2a} : Preheated air temperature (at the outlet of an air preheater): 350 °C

t_{1a} : Air temperature (at the inlet of the air preheater): 28 °C

t_{2g} : Exhaust gas temperture (at the outlet of the air preheater): Temperature obtaind by calculation

t_{1g} : Exhaust gas temperture (at the inlet of the air preheater): 808 °C

⑤ Hot charge rolling:

Taking it into consideration that billets are produced by another company, which is located away from the mill, the potential for hot charge rolling is estimated at approximately 50 %.

Hot charging of 1/2 of the total billets to be charged at an average temperature of 500 °C allows the fuel intensity to be reduced by 167 MJ/t (40 Mcal/t).

It is most advisable to implement hot charge rolling because it can bring about a substantial effect. The most practical method for the transportation of billets may be the use of a heat insulation box by track between the electric arc furnace shop and the middle section mill.

When this system is adopted, this heat insulation box is useful to absorb the difference of production speed between the electric arc furnace shop and the middle section mill.

4) Electricity intensity

Electricity intensity of the middle section mill in Labedy is 65.4 kWh even when the values obtained as a result of conversion from compressed air and cooling water into electricity are added. This is a preferable intensity comparable with that (65 kWh) of the rolling mill with the best intensity among electrical furnace companies in Japan. The fact that this mill is a simple 2-stand rolling mill and cooling water intensity is low (12.4 m^3/t) contributes to this good electricity intensity.

To improve the electricity intensity of the rolling mill, there is a way that brings the rolling productivity (t/h) to the maximum in the rolling mill motor capability range. Judging from the actual operation results, it is presumed that the rolling productivity is very close to the maximum presently.

b. Large section mill

Since the continuous casting facility was installed for replacing the open-hearth furnace with an electric furnace, the operation of the open-hearth furnace has been shut down since April, 1996.

This is one of results of the Huta Labedy's modernizing plan.

c. Steel plate mill

c1. Difference due to external factors

Since flat bars and sheets with various sizes are produced in a small amount, this mill is not comparative with mills that produce large amounts of few product types.

Therefore, comparison will be made in the next section by selecting a mill using a similar production form in the excellent factory.

c2. Difference due to technical factors

Table 1.1.13 Comparison of Energy Intensity of Plate Mill

	Unit	Labedy	Excellent Factory
Fuel	MJ/t-rolled product	3,751 (848 Mcal/t)	1,424 (340 Mcal/t)
Electricity	MJ/t-rolled product	970 (94.5 kWh/t)	677 (66 kWh/t)
Compressed air	MJ/t-rolled product	212 (20.6 kWh/t)	
Cooling water	MJ/t-rolled product	79 (7.8 kWh/t)	
Oxygen and others	MJ/t-rolled product	19 –	
Total	MJ/t-rolled product	5,031 (1,153 Mcal/t)	2,101 (502 Mcal/t)

1) Labedy's rolling facility

A universal mill produces flat bars and sheets by reverse rolling. The maximum rolling capability is 8 t/h (universal mill motor: 750 kW) and the reheating furnace is 2.7 m (width) × 14.4 m (length).

The rolling time is 5,480 hours and the rolling yield is 87.5 % in 1996 as shown in Table 1.1.14.

Table 1.1.14 Rolling Time of Steel Plate Mill

Calendar hour		8,784 h/1996	
Scheduled maintenace	Rolling stop by other reason	Inspection, Trouble, etc	Rolling time
592 h	2,560 h	152 h	5,480 h

2) Yield improvement: Fuel 104 MJ/t, Electricity 3.4 kWh/t

The billet size is small, that is; the maximum length of the charged billet is 2.45 m, the billet unit weight is presumably 300 to 400 kg (average) and the maximum length of the product that can be rolled by the universal mill is 12 m. Taking this fact into consideration, the yield 87.5 % can be said to be a fairly good level. The result of our survey of the rolling mill revealed that there may be some room for improvement of the product yield, that is, in terms of reducing the crop loss, and product crop loss. It is thus advisable to make further effort for reducing the aforementioned factors. With regard to the product yield, even if the improvement is implemented, 90 % is presumed to be the upper limit of the attainment.

If a yield of 90 % can be achieved, the fuel intensity can be improved by 104 MJ/t (25 Mcal/t), and the electricity intensity by 35 MJ/t (3.4 kWh/t).

3) Fuel intensity

The fuel intensity in 1996 was 3,751 MJ/t-product (896 Mcal/t-product).

In contrast, according to the site tour and the monthly reported values in 1996, the fuel intensity in the normal operation (rolling productivity: 5.21 t/h) is assumed to be around 2400 MJ/t-billet = 2,743 MJ/t-product (655 Mcal/t) = 76.3 m^3_N/t. Since natural gas consumption in a year (8,784 hours = 366 days in 1996) was 2,982.2 × 10^3 m^3_N, the natural gas consumption in the rolling time (5,480 hours) and non-rolling time (2,712 hours) can be presumed as follows:

- Fuel consumption in the time of rolling hours = 2,180.7 × 10^3 m^3_N (398 m^3_N/h) (=2,743 MJ/t × 28,564 t/y ÷ 35.93 MJ/m^3_N)

- Fuel consumption in the time of non-rolling hours = 801.5 × 10^3 m^3_N (296 m^3_N/h)

The above-described result of our consideration and examination showed that the reheating furnace of this rolling mill involves the following major problems to be resolved.

- During non-rolling time, i.e. during the heat raising/holding time, an incredibly large amount of fuel is presumably consumed, and thus the enrgy intensity alone amounts to as much as 1,008 MJ/t (241 Mcal/t). In case of the excellent factory, on the other hand, even such a furnace as requires frequent start/stop operations for heating as many times as 22 times a month consumes only 85 MJ/t in terms of actual result.

- The fuel intensity during normal rolling excluding heat holding/raising in this factory is estimated at 2,743 MJ/t (655 Mcal/t), while in the excellent factory, the fuel intensity of the rolling mill of the same scale which heats and rolls cold billets is 1,942 MJ/t (464 Mcal/t). This means that LABEDY consumes fuel more than required by as much as 41 %.

The result of our examining causes and factors of these problems showed that:

- This rolling mill is forced to be stopped due to various factors such as the shortage of billets and waiting for product shipping

- Although a rolling schedule is available, it is frequently changed.

- The rolling schedule is vague and not specifically planned(e.x.: rolling starts next morning) and according to the schedule, heat raising operation is started early in the morning.

- No operation criteria for low productivity operation is specified, nor is any countermeasure taken. (only rely on furnace temperature control)

Although there was only a limited short time for factory survey, and thus no detailed information was made available, it was concluded that in order to improve the energy intensity it would be practical and effective in terms of cost-benefit to first implement the measures ①, ②, and ③ and at the same time proceed with the measures ④ and ⑤. In addition, it is recommended to keep daily record regarding the following items, collect the data monthly and identify the actual situation of energy use so as to grasp the fuel consumption required for heat rasing/holding, and review and examine the improvement methods.

Example of Recording Heat Raising/Holding

Date		Heat raising		Heat holding	
		Heat raising time	Fuel consumption	Heat holding time	Fuel consumption
December 1	Waiting for billet	–		8:00 – 10:00	200m^3_N
December 2	Heat raising after maintenance of the rolling mill	18:00 – 21:00	600 m^3_N		
Total for Decamber	No. of times for heat raising 25 times No. of times for heat holding 100 times Production volume 2,200 t	125 h	15,000 m^3_N (6.8 m^3_N/t)	200 h	40,000 m^3_N (18.2 m^3_N/t)

The following items are considered to be the recommendable measures for reducing the fuel intensity of the reheating furnace. If these measures are implemented, the fuel intensity can be reduced to 2,111 MJ/t (504 Mcal/t) without any increase in the yield taken into account.

① Improving the process control and reheating furnace heat holding/heat-up criterion: 670 MJ/t (160 Mcal/t)

Process control should be performed so that the rolling mill can run continuously for a long time. If rolling should be stopped inevitably, the stop time should be forecast accurately and observed.

At the same time, it is advisable to determine the heat holding criterion and heat-up criterion, control the amount of fuel to be used during the stop, and minimize the fuel for heat holding and heat-up.

② Improving the reheating furnace operation to adapt to the low load: 431 MJ/t (103 Mcal/t)

Fuel charging criterion at the low load should be specified and management of O_2 content in the exhaust gas should be enhanced.

③ Heat insulation by ceramic fiber: 251 MJ/t (60 Mcal/t)

Since the heat radiation from the furnace body and accumulated heat in the insulation material can be reduced, the fuel consumption required not only for operation but also for heat holding and heat-up can be reduced.

④ Adjusting the air-fuel ratio: 63 MJ/t (15 Mcal/t)

Figure 1.1.7 shows the result of measuring the exhaust gas on the plate mill reheating furnace. The measurement point was the inlet of the air preheater. The preheated air temperature is 250 °C.

Figure 1.1.7 Exhaust Gas Measurement of Plate Steel Rolling Mill Furnace (Measured at the air preheater gas inlet)

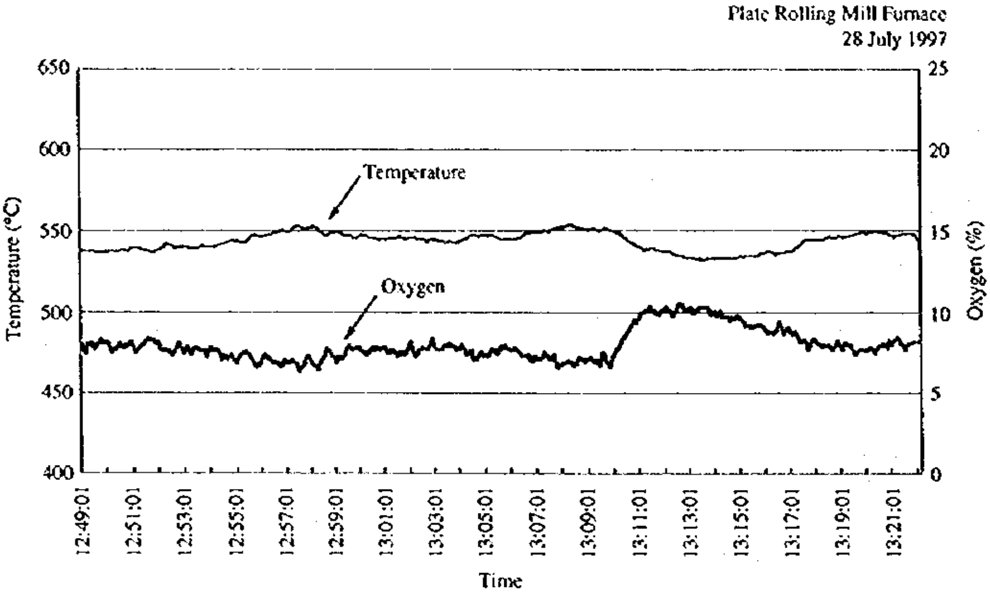


Table 1.1.15 shows the result of combustion calculated using the average value of the measured values. As shown in this table, the air ratio is 1.55 upon measurement. If the air ratio is maintained at the minimum value (1.39) provided during measurement, fuel consumption is logically reduced by 2.3 %.

Table 1.1.15 Fuel Reduction Effect by Air Ratio Control (Steel plate reheating furnace)

Preconditions	
Fuel gas	
Net heat value (kJ/m^3_N)	35,930
Net heat value (kcal/m^3_N)	8,582
Combustion air temperature	250
Exhaust gas temperature	544
Furnace infiltrating air ratio	0

Notes: The measuring point: Before the air preheater
The temperature after air heating is assumed based upon the AH heat balance.
Exhaust gas temperature means the exhaust gas temperature before air preheating.

Calculation Result	Theoretical Combustion	Current AR Condition	After AR Improvement
Exhaust gas oxygen	0.0 %	8.0 %	6.4 %
Air ratio	1.00	1.55	1.39
Air flow rate (m^3/kg)	9.7	15.1	13.5
Exhaust gas volume (m^3/kg)	10.7	16.1	14.5
Exhaust gas heat loss ratio (to fuel heat)		20.4 %	18.5 %
Fuel saving rate			2.3 %

Note: For air ratio improvement, the minimum value of the measured O_2 values is used.
The exhaust gas loss ratio is the exhaust gas heat loss ratio after air preheating.

The fuel intensity can be reduced by 5.3 % by adjusting O_2 in the exhaust gas (8.0 %) to 6.4 %.

⑤ Reinforcement of sealing at the front/rear opening of the furnace: 85 MJ/t (20 Mcal/t)

As a result of observing the operation status, it was found that the length of the bloom charged in the furnace was smaller compared with the furnace width, allowing a large amount of air to enter through the gaps at both ends of the bloom. Also, the charging door has a too large gap on the slab, and as a result, the volume of entering air may increase. The problem of the infiltrating air can be analyzed through exhaust gas measurement at the no-infiltrating zone of the furnace.

Clearances are provided between the furnace front/rear door and billet and between the billet and furnace walls; the fuel intensity can be improved by approximately 3 % by improving the furnace internal pressure adjusting method and providing the curtain to minimize the opening.

4) Electricity intensity: (20 kWh/t)

It is strange that the electricity intensity is at a bad level of 94.5 kWh/t although this rolling mill is simple because one universal mill performs reverse rolling. The only way for improving the electricity intensity is to increase the rolling productivity (t/h). Therefore, the rolling productivity should be maximized by minimizing the number of rolling passes within the allowable output range of the rolling mill motor.

As shown in Table 1.1.16, in 1995, the electricity intensity of 73.6 kWh/t-product was achieved with the rolling productivity of 6.3 t/h, suggesting that improvement of electricity intensity by about 20 kWh/t will be made possible by increasing the rolling productivity.

Table 1.1.16 Relationship between Rolling Productivity and Electricity Intensity

	1995	1996
Rolling productivity	6.3 t/h	5.2 t/h
Electricity intensity	73.6 kWh/t	94.5 kWh/t
cf. Fuel intensity	3,105 MJ/t	3,751 MJ/t
cf. Rolling time	5,824 h	5,480 h

B. Utilities (heat utilization facilities)

1) Measurement in the boiler room

This factory has three state-of-the-art hot water boilers with gas combustion to supply hot water for process and heating. Table 1.1.17 shows the outline of these facilities. With regard to these boilers, which are modern facilities, there is no point in particular to be picked up.

Table 1.1.17 Outline of the Hot Water Boiler

Type	Package Type Hot Water Boiler	3 Units
Capacity	4 MW/unit	
Year of installation	1996	
Fuel	Gas/heavy oil selectable	Always gas-fired
Manufacturer	Babcock-Omnimal	
Exhaust gas temperature	90 °C	100 °C at our survey

In addition to the hot water boilers, the equipment that recovers heat from the cooling water for the electric furnace in the steel-making company ELSTAL on the same premises via a heat exchanger and supplies the heat to the hot water system has been running since 1997. However, heat is excessive in the non-heating season.

In the auxiliary equipment room adjoining the hot water boilers, the hot water branch header and heat exchanger are provided, and many valves have been installed without heat insulation. Table 1.1.18 shows the result of heat radiation calculation based on the approximate number of valves based on the factory survey result to estimate the possible allowance for energy conservation.

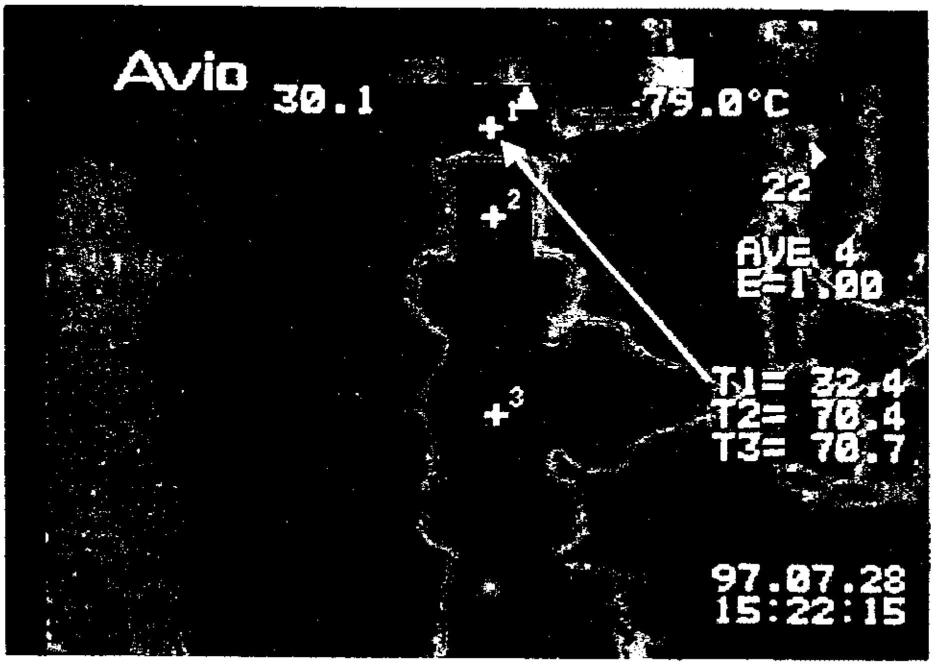
Table 1.1.18 Heat Radiation from Valves in the Auxiliary Machinery Room for Hot Water Boilers

Installation place	Environmental temperature	Surface temperature	Nominal diameter	Equivalent length	Assumed No. of units installed	Radiation amount
	(°C)	(°C)	(mm)	(m)		(kcal/h)
Hot water boiler auxiliary equipment room	28	90	300	1.91	10	13.372
Hot water boiler auxiliary equipment room	28	90	200	1.68	20	16,012
Hot water boiler auxiliary equipment room	28	90	100	1.27	30	9,594
Hot water boiler auxiliary equipment room	28	90	50	1.11	40	5,918
Total						44,896

If heat insulation is applied to these valves, heat radiation will be reduced to approximately 10 %.

The high-temperature portion to which heat insulation is not applied can be visually represented by using an infrared thermal imaging system. Figure 1.1.8 shows an example.

Figure 1.1.8 Thermal Image of the Non-insulated Valve (Boiler auxiliary equipment room)



C. Utilities (electricity utilization facilities)

c1. Difference due to external factors

Nothing in particular.

c2. Difference due to technical factors

Assuming that the energy for cooling water and compressed air are each evaluated as follows,
1 m^3 = 0.253 kWh = 2,596 kJ,
1 m^3_N = 0.102 kWh = 1,048 kJ,
and that the thermal efficiency of the gas-fired hot water boiler is 90%,
the net consumption of LABEDY's energy utilization system is as shown in Table 1.1.19.

Table 1.1.19 Net Energy Consumption in Energy System

Process	Unit	Consumed Energy	Generated Energy	Net Energy Consumption
Cooling water	GJ/y	54,188	28,071	26,117
Compressed air	GJ/y	63,515	42,358	21,157
Hot water-Boiler	GJ/y	98,357	73,998	24,359
Total	GJ/y	216,060	144,427	71,633

7.1 % is obtained by dividing the net energy consumption 71,633 GJ obtained from this table by LABEDY's actual value. (See Table 1.1.10) The energy intensity of Labedy can be improved by 7.1 % (301 MJ/t-product) by making the energy system more efficient.

1) Reducing electricity for water systems such as cooling water: 0.146 kWh/m^3

As the features of Huta Labedy, the water intensity per ton-product is as low as 24.3 m^3/t, whereas the electricity intensity per 1 m^3 of water is 0.488 kWh/m^3, which is extremely bad.

The reasons that the electricity intensity for the cooling water system is bad are presumed to be as follows:

- The cooling water pump is far away from the plant using the cooling water or the same pump is used to feed water to the plant that is far away and to the plant that is closer.
- Since the pump specifications are too much different from the required specifications, the pumps are operated with small opening of the discharge valve.
- The cooling tower fans are run longer than required.
- The water system uses an open cycle.

Although detailed survey could not be carried out in this factory energy audit, comparison with excellent factory of a similar level shows that the electricity intensity can be improved by approximately 30 % through the effort for energy consumption by considering the following measures.

① Investigating and reducing of the required cooling water volume

The reason why the volume of water is required for each process should be examined in consideration of the inlet/outlet temperature difference, flow speed, etc. and the cooling water volume should be reduced.

② Examining the optimum water delivery system

Specifications of the water delivery pump, cooling tower water feed pump, etc. should be reviewed and addition of pumps to the necessary locations (e.g. the middle section mill) and abolition of pumps (e.g. cooling tower water feed pump) should be examined so that the sum of the pump shaft horsepower in the system will be minimal. If flow rate variation in the production processes is large, variable speed control of the pump with an inverter unit should also be considered.

③ Examining the running schedule that always minimizes the number of pumps being operated

The water delivery plan and cooling water pump running schedule should be made for the probable shutdown of each process (e.g. stop for maintenance) so that unnecessary pumps will not be operated.

④ Recovering the pump performance

If the pump efficiency is degraded, the pump performance should be recovered by maintenance.

⑤ Reducing the extra capacity of the pump

By replacing the pump impeller or reducing the diameter of the pump impeller, the pump's extra specifications should be modified.

⑥ Automation should be achieved so that the cooling tower fan will be started/stopped depending on the cooling water temperature.

2) Reducing the air compressor electricity: 0.019 kWh/m^3_N

Electricity used by air compressors in 1996 was 5,830 MWh and the air flow rate in that year was 40,468 × 10^3 m^3_N. Therefore, the feed air intensity was 40,468/5,830 = 6.94 m^3_N/kWh, which is low. In some cases, the feed air intensity in Japan has reached 9 m^3_N/kWh. In this energy audit in LABEDY, electricity used was assumed to be 640 kW for feed air of maximum 5,400 m^3_N. In this case, the intensity is also 8.44 m^3_N/kWh, thus producing a good result. However, judging from the fact that electricity consumption hardly changes also for feed air of 3,500 m^3_N under low load and thus results in energy loss, the air compressor control system may be inappropriate. For a turbo compressor, efficient operation is allowed for up to 70 % of the load by adopting suction vane control. Therefore, improvement of the control method should be considered.

Energy intensity improvement up to 8 m^3_N/kWh can be expected by improving the control system.
Electricity saving: 5,830 - 40,468/8 = 772 MWh.
Therefore, improvement of electricity intensity is: 772/40,468 = 0.019 kWh/m^3_N.

The reason why the electricity intensity is extremely bad is that the Labedy's system cannot cope with the compressed air demand variation in each process. Therefore, a suction vane control system should be installed on the compressor to cope with the fluctuation in the demand, so that both electricity consumption and eelctricity intensity can be improved when the flow rate is low.

The first thing to do in examining the energy system is to check the demand variation and to select the system that is most efficient throughout the year. High efficiency of each component does not simply lead you to the best selection.

3) Fuel saving for the hot water boiler: 20,811 GJ/y

Heat efficiency of the existing hot water boiler is 84.4 %, which is not bad. Recovering the excess exhaust heat in the factory allows the efficiency to be be further improved, and fuel consumption to be reduced.

The middle section mill is suitable for the target equipment for exhaust heat recovery. Assuming that heat recovery is implemented for 7 months annually excluding the summer season, energy conservation of 6,121 GJ/y can be achieved.

$$200{,}500\ \text{t/y} \times 25\ \text{Mcal/t} \times 0.5 \times 4.1868 \times \frac{1}{1{,}000} \times \frac{7}{12} = 6{,}121\ \text{GJ/y}$$

The above equation was based on the assumption that 50 % of the exhaust gas heat generated woud be recovered.

The fuel intensity of the reheating furnace in the middle section mill requires 250 Mcal/t even after hot charge rolling is introduced. Since the exhaust heat is at least 25 Mcal/h, the above result can be recovered:

Additionally, Labedy has conducted heat recovery from cooling water for the electric furnace since 1997; thus the following heat value can be obtained:

$$200{,}500\ \text{t/y} \times 60\ \text{Mcal/t} \times 0.5 \times 4.1868 \times \frac{1}{1{,}000} \times \frac{7}{12} = 14{,}690\ \text{GJ/y}$$

4) Electricity saving for lighting (Step 1)

Current electricity consumption by mercury lamps and energy conservation potential in the entire factory are estimated as follows:
Basic power consumption in the factory is approximately 6,000 kW. As a result of the survey of this factory, lighting electricity is estimated at 5 % of the entire electricity consumption, and it is thus presumed to be about 300 kW.

Most of these lighting uses mercury lamps and color-rendering properties have almost no problem; therefore, energy conservation can presumably be achieved by changing the mercury lamps into sodium lamps (including the locations where lamps are already converted into mercury lamps or where illuminance is insufficient).

In our view based on the result of this survey, it will be possible to replace approximately 70 % of the mercury lamps to sodium lamps and thereby achieve 40 % of energy conservation.

Electricity saving: 300 × 0.7 × 0.4 × 8.760 = 736 MWh

5) Electricity saving for the transformer

For energy losses from 28 transformers whose data was obtained from POLESCO, examination was made according to Table 1.1.20.

As a result, it is considered that there is a possibility for energy conservation by replacing three transformers of low efficiency in the middle section mill D650.

Table 1.1.20 Transformer Energy Loss

Name of equipment	Primary /Secondary (kV)	Transformer capacity (kVA)	No load loss (kW)	Full load loss (kW)	Total loss (kW)	Full load efficiency (%)	Maximum efficiency (%)	Best efficiency (%)	Δ Efficiency (%)	Payback year (Japan)	Payback year (Labedy)	Possibility	Load maximum efficiency (%)	L.F at maximum efficiency (%)
110 kV receiving	115/6.3	16,000	16.25	96.402	112.652	99.30	99.51	99.5	-0.008	-	-	×	6,569	41.1
Compressor TR1	6/0.4	1,000	1.668	10.148	11.816	98.83	99.18	99.1	-0.084	-	-	×	405	40.5
Compressor TR2	6/0.4	1,000	1.668	10.148	11.816	98.83	99.18	99.1	-0.084	-	-	×	405	40.5
Compressor TR3	6/0.4	200	(1.1)	(3.8)	(4.9)	(97.61)								
Medium mill D750 TR1	6/0.4	250												
Medium mill D750 TR2	6/0.5	800	1.86	11.23	13.09	98.39	98.87	99.05	0.180	15.6	61.0	×	326	40.7
Medium mill D650 TR1	6/0.5	800	3.6	13.2	16.8	97.94	98.31	99.05	0.744	2.9	11.5	Δ	413	52.2
Medium mill D650 TR2	6/0.5	800	3.6	13.2	16.8	97.94	98.31	99.05	0.744	2.9	11.5	Δ	413	52.2
Medium mill D650 TR3	6/0.5	800	3.6	13.2	16.8	97.94	98.31	99.05	0.744	2.9	11.5	Δ	418	52.2
Medium mill D650 TR4	6/0.5	800	2	10.954	12.954	98.41	98.84	99.05	0.207	12.9	50.4	×	342	42.7
Beam TR1	6/0.5	1,000	1.916	10.917	12.833	98.73	99.09	99.1	0.006	425.1	1661.6	×	419	41.9
Beam TR2	6/0.4	250	0.813	3.63	4.443	98.25	98.64	98.8	0.156	15.5	60.6	×	118	47.3
Ingot LAB. TR	6/0.4	315	0.789	5.1	5.889	98.16	98.74	98.85	0.108	27.0	105.1	×	124	39.3
Ingot DYRCK. TR	6/0.4	250	0.819	3.612	4.431	98.26	98.64	98.8	0.157	15.2	59.6	×	119	47.6
Ingot TR1	6/0.525	1,000	2.2	10.966	13.166	98.70	98.03	99.1	0.073	35.0	136.9	×	418	44.8
Ingot TR2	6/0.525	1,000	2.2	10.966	13.166	98.70	99.03	99.1	0.073	35.0	136.9	×	418	44.8
Ingot TR3	6/0.4	250	0.813	3.612	4.425	98.26	98.65	98.8	0.152	15.8	61.7	×	119	47.4
Pump TR1	6/0.5	800	1.62	9.222	10.842	98.66	99.04	99.05	0.007	386.5	1511.7	×	335	41.9
Pump TR2	6/0.5	800	2.5	11.1	13.6	98.33	98.70	99.05	0.350	6.9	26.9	×	380	47.5
Plate mill TR1	6/0.525	500												
Plate mill TR2	6/0.525	500												
Plate mill TR	6/0.23	125												
Welding Kiosk TR1	6/0.4	315	0.99	5.2	6.19	98.07	98.58	98.85	0.270	9.7	37.9		137	43.6
Welding Kiosk TR2	6/0.4	400	0.972	5.435	6.407	98.42	98.86	98.9	0.036	74.6	291.8		169	42.3
Welding Zbyt TR1	6/0.5	500	1.46	7.7	9.16	98.20	98.68	98.94	0.263	10.0	38.9		218	43.5
Welding Zbyt TR2	6/0.4	400	1.242	5.21	6.452	98.41	98.74	98.9	0.156	15.0	58.6		195	44.8
Welding Blach TR1	6/0.5	800	1.7	9.095	10.795	98.67	99.03	99.05	0.023	112.6	440.0		346	43.2
Welding Blach TR2	6/0.4	1,000												
Best of Poland		1,000	1.65	9	10.65	98.95	99.24						423	42.8

6) Motor capacity check

Table 1.1.21 shows the current measurement result. According to this result, the load currents for 75 kW of the reheating furnace air fan and 70 kW of the water feed pump for the cooling tower are lower than 70 % of the rated current. Therefore, energy conservation may be achieved by selecting the optimum capacity of the motor. However, this measurement was made at spots. The degree of water flow rate variation should be measured and long-term forcasting of the plant operation (including reduction in the water volume) should be considered for examination (including the use of the inverter).

Table 1.1.21 Result of Current Measurement

Name of equipment	Kind of motor	Motor output (kW)	Actual input (kW)	M.O/A.I ratio	Rating current (A)	Actual current (A)	IA/IR ratio (%)	Control method	Speed control
Pump to tower (clear)	Induction	150	–	–	225	184	81.78		
Pump to factory (clear)	Induction	125	–	–	175	123.7	70.69		
Pump to factory (clear)	Induction	125	–	–	175	124.4	71.09		
Pump to factory (dirty)	Induction	70	–	–	128	74.8	58.44		
Pump to factory (dirty)	Induction	70	–	–	102	69.1	67.75	Frequency	Invertor
Fan for heating furnace	Induciton	75			102	60.1	58.92		
Plate roll mill	Induction	750			112	60–90			

Electricity savings of 75 kW and 70 kW of motors by variable speed control with inverter units are as follows:
(70 × 0.584 + 75 × 0.589) × 8,750 × 0.9 × 0.2 = 134 MWh/y
where operation rate is 90 %.

D. Mining beam and cramp fabrication mill

According to the trend of the electricity intensity in the past five years, the best data in 1992 will be the feasible and reliable improvement target value.

In 1992, the electricity intensity of the yoke and cramp fabrication mill was 108.9 kWh/t.
The best way for reducing the electricity intensity of the fabrication mill is to increase the operation performance (t/h). Therefore, the operation performance should be selected as the management parameter and its increase/decrease factors should be investigated and improved. As a result, the electricity intensity will be improved by 50 kWh, if 108.9 kWh/t can be continuously achieved.

E. Others

We had no time enough to observe the energy use status of others in this energy audit. As the reason why the energy consumption by others is large, the following factors can be presumed:

- While the amount of production is small, the site area is too large. Additionally, mills, offices, and maintenance shops are distributed in a wide area.

- Since some roof-high buildings are fully heated, the heating efficiency is low.

For restructuring of the factory, not only making each process best but also reconsidering the layout of the entire plant and making the factory compact are required.

1) Centralizing the factories: 16,879 GJ/y

Before implementation of restructuring, the layout of each plant should be examined. The plant should be concentrated into one location as much as possible and the offices and maintenance shops should be unified at one location.

Since the ELSTAL's electric furnace has been improved to the state-of-the-art one and also CC is available, the layout should be determined so that the material flow cost will be minimized and the new plants should be built sequentially according to the layout, thus to centralize the factories.

This centralization will allow the hot water for heating to be reduced by approximately 1/3. Besides, effective arrangement of personnel, electricity saving for cooling water and compressed air, and reduction in losses of electricity and compressed air can be expected.

2) Reviewing the heating plan

The heating energy consumption is 2,853 MJ/m²/year (681 Mcal/m²/y) per total floor area and 311 GJ/t per ton-product.

Since the heating efficiency for a large building is extremely low, the operating area for operators should only be heated or review of the heating plan including circulating the heat on the top part of the building to the bottom part is required.

(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 1.1.22.

Table 1.1.22 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_2	Dust
Step 0	8,162	1.0	128.6	0.2
Step 1	3,291	0.6	51.8	0.1
Step 2	1,230	0.8	19.2	0.1
Step 3	3,225	0.2	50.8	0.1
Step 1-3	7,747	1.7	121.9	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 1.1.23. Furthermore, the payback period required to recover investments in energy conservation including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 1.1.23 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ PBP	Economical PBP
Step 0	2,374	40.1	2,414	0	0.00	0.00
Step 1	1,117	16.2	1,134	57	0.05	0.05
Step 2	848	6.2	855	2,853	3.34	3.36
Step 3	795	15.8	811	1,429	1.76	1.80
Step 1-3	2,761	38.2	2,799	4,339	1.55	1.57

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

As evident from this Table 1.1.23, 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.
Although the payback period is small for Step 3 at this factory, it should be noted that the improvement item includes changes to the production process such as hot charges, and thus, the establishment of technical management is required.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 1.1.24.

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 1.1.9. The relationship between energy conservation potential, the period to recover the investment, and the investment cost is shown in Figure 1.1.10.

Table 1.1.24 Summary of Energy Conservation Potential

Electricity: 0.172 PLN/kWh Natural gas: 0.514 PLN/m³N
1 PLN = 30 yen (36.5 MJ/m³N)

Item	Energy Conservation Potential							Investment	Payback period
	Fuel			Electricity			Total		
	GJ/y	10^3 PLN/y	%	MWh/y	10^3 PLN/y	%	10^3 PLN/y	10^3 PLN	year
Step 0 (In progress)									
1. Shutdown of large-sized mills (conversion from the current open hearth furnace to an electric furnace)	127,986	1,802	18.8	2,123	365	5.7	2,167	0	0
2. Heat recovery from the electric furnace cooling water	14,690	207	2.2				207	0	0
Subtotal	142,676	2,009	21.0	2,123	365	5.7	2,374	0	0.0
Step 1									
3. Middle-section mill: Improving the rolling yield	8,220	116	1.2	361	62	1.0	178	0	0
4. Middle-section mill: Improving the air ratio of the reheating furnace	5,614	79	0.8				79	0	0
5. Middle-section mill: Improving the heat holding standards	5,012	71	0.7				71	0	0
6. Plate mills: Improving the yield	2,970	42	0.4	97	17	0.3	59	0	0
7. Plate mills: Enhancing the process control and improving the reheating furnace heat holding and heating up standards	19,138	270	2.8				270	0	0
8. Plate mills: Upgrading the standards for operation of the reheating furnace under low load	12,311	173	1.8				173	0	0
9. Plate mills: Improving the air ratio of the reheating furnace	1,800	25	0.3				25	0	0
10. Plate mills: Reinforcing the sealing for the openings	2,342	33	0.3				33	57	1.7
11. Plate mills: Improving the rolling productivity (t/h)				571	98	1.5	98	0	0
12. Clamp shop: Improving the production productivity (t/h)				768	132	2.1	132	0	0
Subtotal	57,407	808	8.4	1,797	309	4.9	1,118	57	0.1
Step 2									
13. Middle-section mills: Reinforcing the insulation of the reheating furnace with ceramic fiber	12,631	178	1.9				178	857	4.8
14. Plate mills: Reinforcing the insulation of the reheating furnace with ceramic fiber	7,169	101	1.1				101	571	5.7
15. Ligthing: Changing to the sodium lights				736	127	2.0	127	432	3.4
16. Promoting the electricity saving for the cooling water system				1,579	272	4.3	272	571	2.1
17. Improving the control method of air compressor				772	133	2.1	133	286	2.2
18. Motor revolution control by an inverter				134	23	0.4	23	124	5.4
19. Reinforcing heat insulation of steam valves	1,334	19	0.2				19	68	3.6
Subtotal	21,134	298	3.1	3,221	554	8.7	852	2,909	3.4
Step 3									
19. Middle-sec. mill: Introducing the hot charge rolling method	33,483	472	4.9				472	857	1.8
20. Middle-sec. mill: Recovering the hot water heat from the reheating furnace exhaust gas	6,121	86	0.9				86	571	6.6
21. Centralizing the mills (Reviewing the layout)	16,879	238	2.5				238	0	0.0
Subtotal	56,483	795	8.3				795	1,429	1.8
Total (No. 1, 2, and 3 steps)	135,024	1,901	19.9	5,018	863	13.6	2,765	4,395	1.6

Notes: Centralization of mills (reviewing the layout) is the issue to be considered when restructuring of the entire factory is to be implemented. Thus, only energy conservation potential due to a layout change was estimated here.

As of 1996: Fuel consumption: 679,979 GJ/y
Electricity consumption: 36,940 MWh/y (378,929 GJ/y)
Total: 1,058,908 GJ/y

Figure 1.1.9 Labedy Energy Conservation Potential

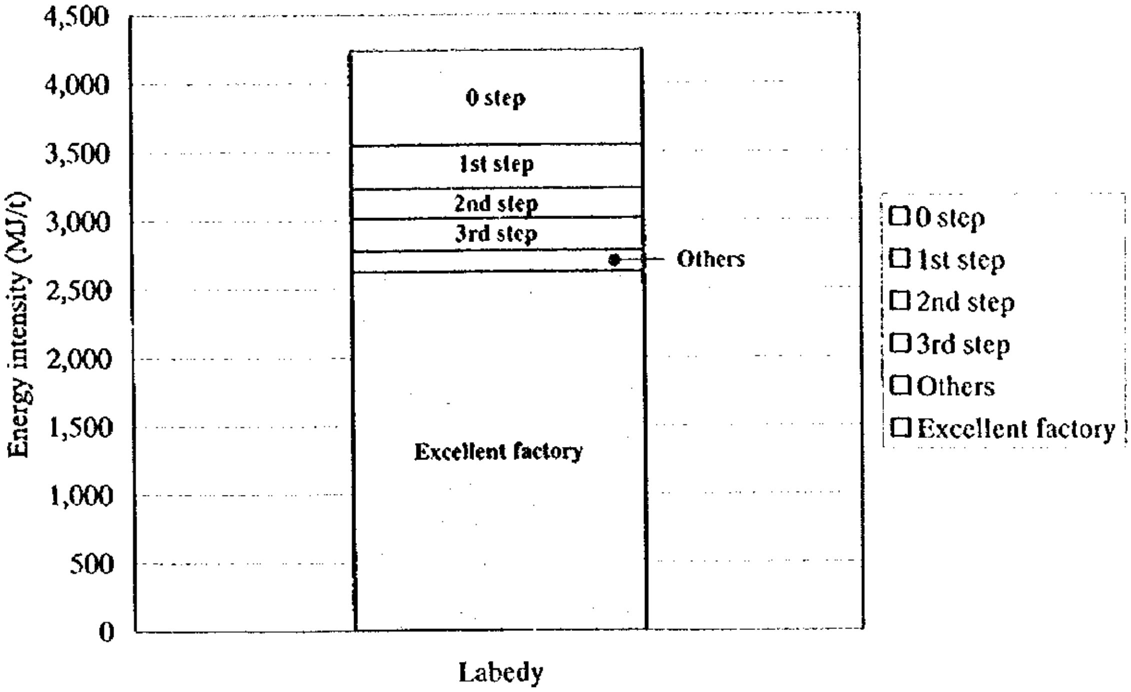
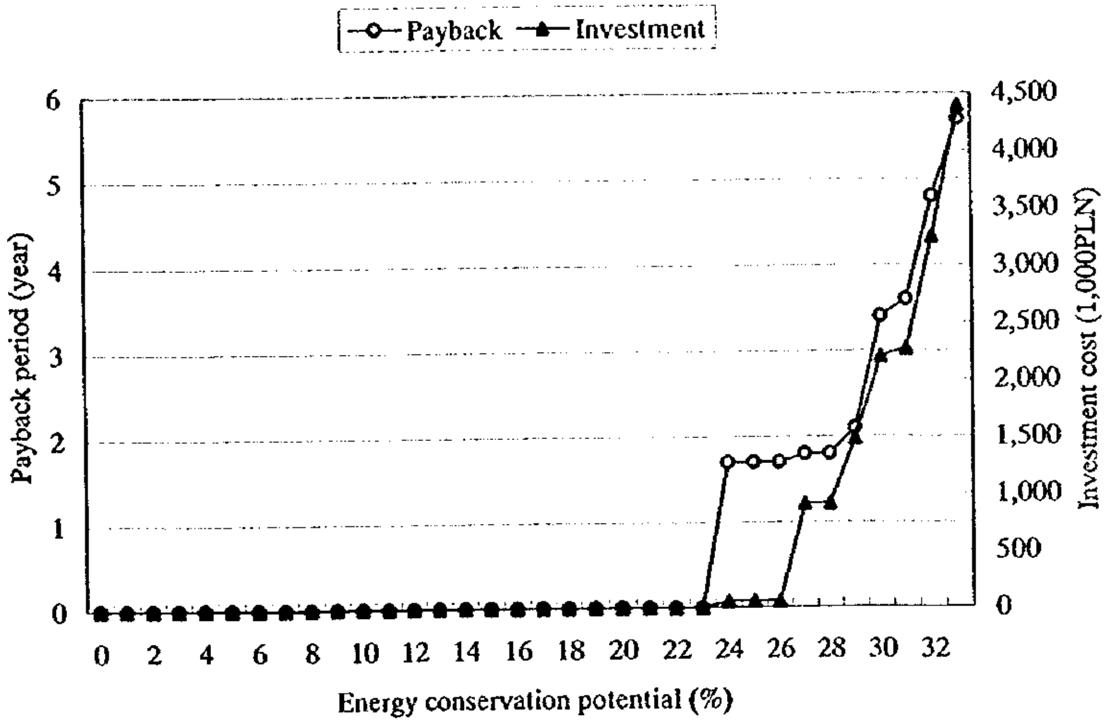


Figure 1.1.10 Labedy Energy Conservation Potential



1.2 Results of the Study at the Huta Ostrowiec Plant

(1) Study period: July 30 to August 1, 1997

(2) Members of the study team

a. JICA Team

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

b. Local consultants

POLESCO Investment SA
Mr. Piotr Bortnowski: Vice President
Dr. Tadeusz Kruczek: Heat management
Dr. Marcin Szega : Heat management
Dr. Joachim Bargiel : Electricity management

(3) Interviewees

Eng. Hieronin Balcerczak : Chief of Energy Department
M. Sc. Eng. Stanislaw Fabianski : Head of Steel Department
M. Sc. Eng. Janusz Pichor : Head of Forging Shop
M. Sc. Eng. Leszek Nawrot : Head of Rolling Mill
M. Sc. Eng. Janusz Kwiatkowski: Head of Energy Department
M. Sc. Eng. Wieslow Gradziel : Head of Energy Section of Rolling Mill
M. Sc. Eng. Andrzei Trzcinslci : Head of Electrical Department
M. Sc. Eng. Krzysztol Nowak : Head of Automatic Section
Eng. Stonislow Kaslnele : Head of Compressor Station
Eng. Karirmerz Slarek : Head of Pump Station
Eng. Bolestow Pawlok : Electricity
Mr. Edward Kosciokek : Economist

1.2.1 Profile of the Plant

(1) Plant name: Huta Ostrowiec

(2) Address: 27-400 Ostrowiec Sw. ul. Samsonowicza 2

(3) No. of employees: 4,151

(4) Major products: Deformed bar and forged products

(5) Production capacity:

Deformed bar : 600,000 t/y
Forged products: 50,000 t/y

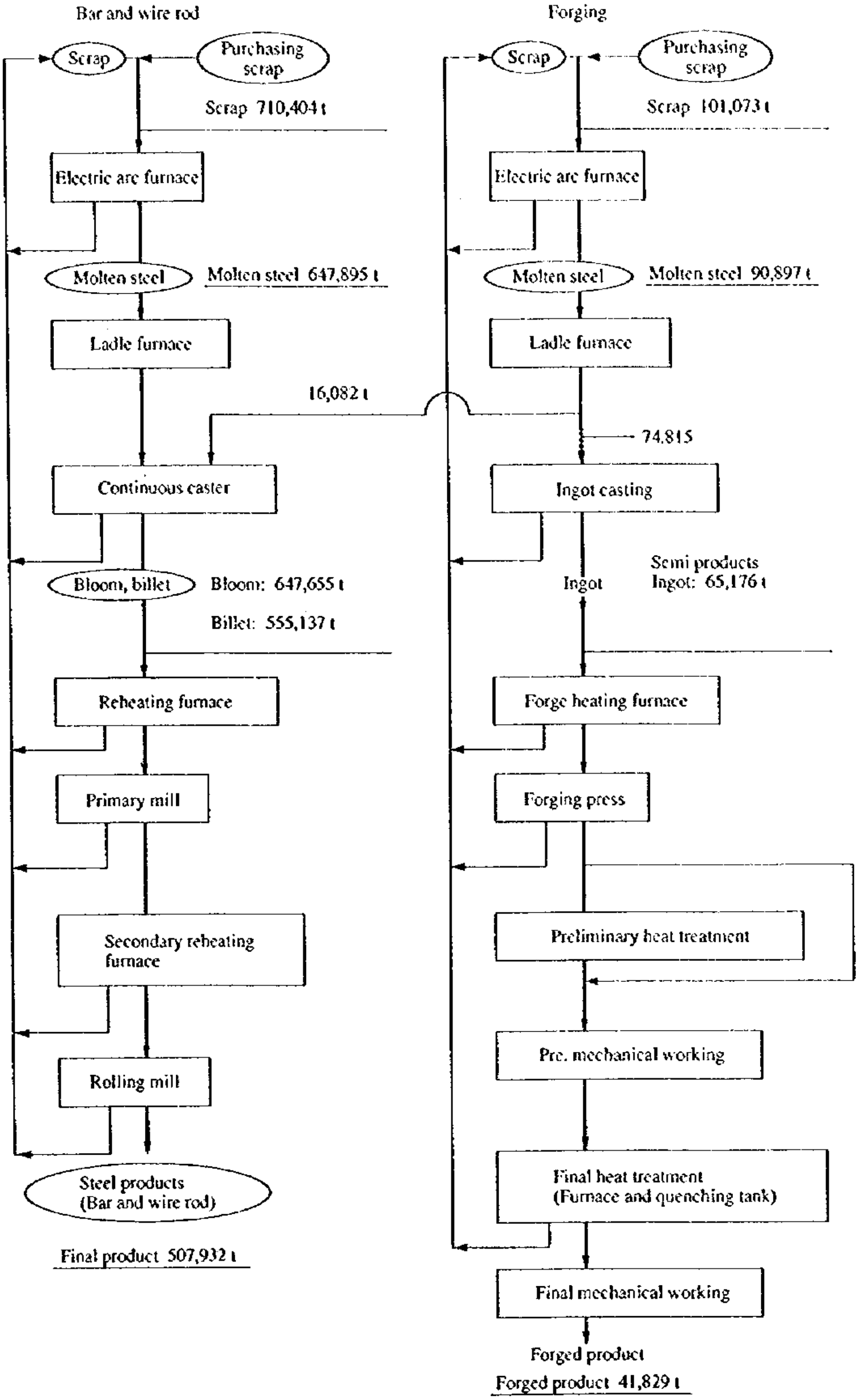
(6) Overview of the process

Huta Ostrowiec, which has the electric furnace shop, rolling mill, and forging shop, is what is called an electric furnace plant that produces deformed bars and forged products such as the crank shaft and propeller shaft for ships. Figure 1.2.1 shows the process flow.

(7) History of the plant

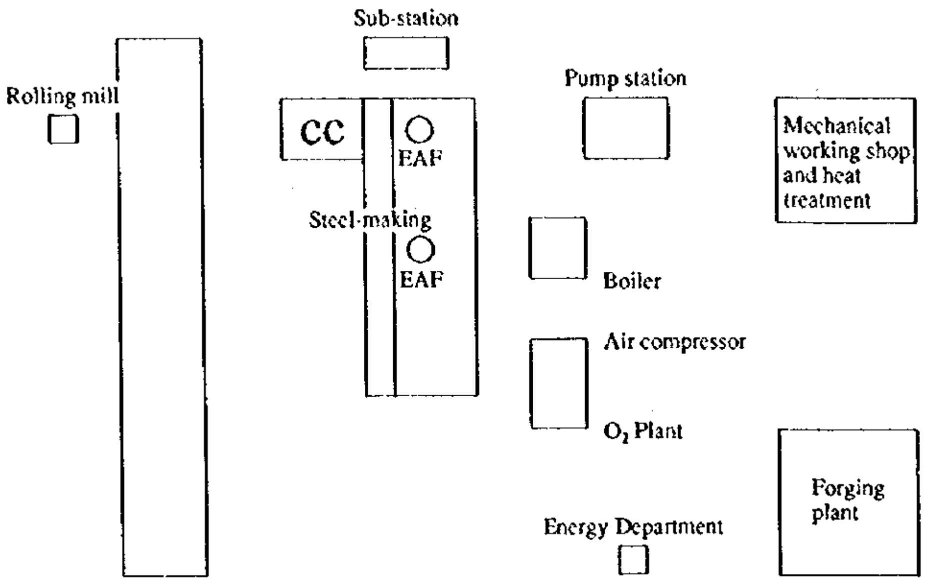
This company was founded in 1913 and the steel-making plant was built at the current location after the World War II. This plant introduced the first continuous casting equipment in Poland. Presently, modification of the rolling plant and continuous casting equipment has been started and restructuring is currently in progress. This plant has acquired ISO 9001 certification. The forged products are approved by the Lloyd Ship Class Association, etc. and this plant is focusing on product quality control.

Figure 1.2.1 Process Flow



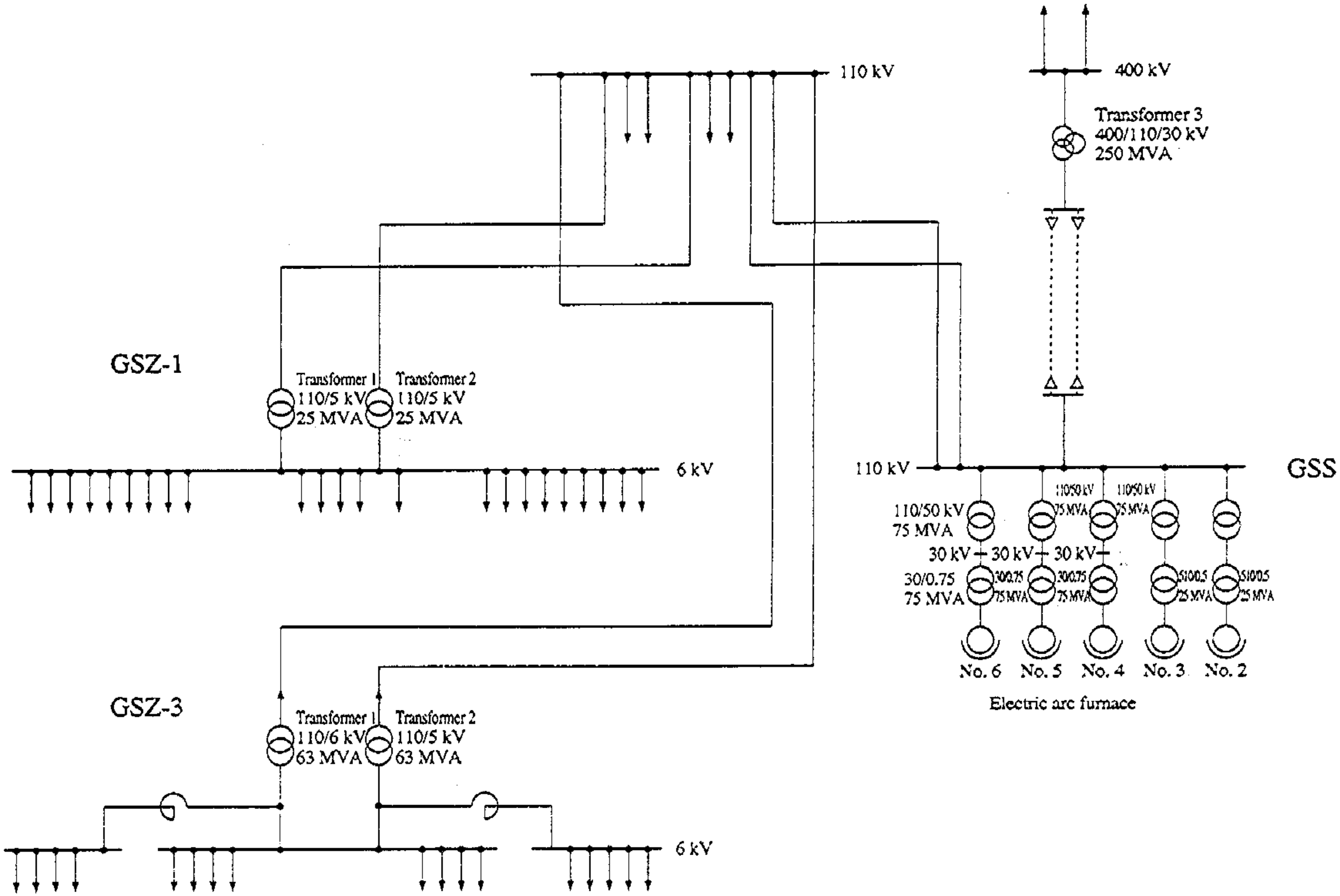
(8) Plant layout

Figure 1.2.2 Plant Layout



(9) One line diagram

Figure 1.2.3 One Line Diagram



(10) Outline of major equipment

Table 1.2.1 Major Equipment

Process	Equipment	Number	Specification
Bar and wire rod line			
Steel-making	Electric arc furnace	2	140 t/ch-EBT, 75 MVA
	Ladle furnace	1	140 t/ch 75 MVA
	Continuous caster	2	4 strands/each, 220 × 220 Bloom
Rolling mill	Reheating furnace	1	200 t/h, 12.6 m × 25.0 mL
	Secondary reheating furnace	1	180 t/h, 18 m × 13 mL
	Bar mill	1	200 t/h, product 8 ~ 32 mmϕ Maximum rolling speed 20 m/s Full continuous bar mill
Forging line			
Steel-making	Electric arc furnace	1	70 t/ch-EBT, 25 MVA
	Ladle furnace	1	70 t/ch 25 MVA
	Degassing process	1	
	Ingot caster	–	Bottom pouring
Forging shop	Forge heating furnace	28	Batch type
	Forging press	5	8,000 ~ 800 t
	Mechnical working shop	1	
	Heat treatment furnace	–	Batch type

(11) Energy prices

Table 1.2.2 Energy Price and Heat Value

	Energy Price		Heat Value
Electricity	127.58 PLN/MWh	(Jun. 1997)	10,258 kJ/kWh
Natural gas	0.4798 PLN/m^3_N (13.5 PLN/MJ)	(Jun. 1997)	35,532 kJ/m^3_N
Gasoline	1.7 PLN/L	(Jun. 1997)	–
Hot water	12.05 PLN/GJ	(Apr. 1996)	–
Steam	13.14 PLN/GJ	(Jun. 1996)	–
Coke			27,100 kJ/kg

1.2.2 Energy Consumption Status

(1) Trend of production

Table 1.2.3 Trend of Production

	Unit	1993	1994	1995	1996
Deformed bar	t	388,839	529,386	485,759	507,932
Forged product	t	44,401	55,182	48,107	41,829
(Crude steel)	t	(496,177)	(645,277)	(723,419)	(712,831)

(2) Trend of energy consumption

Table 1.2.4 Trend of Energy Consumption

	Unit	1993	1994	1995	1996
Fuel oil	kL	42,674	38,424	0	0
Natural gas	$10^3m^3_N$	50,257	41,133	84,063	83,395
Electricity	MWh	503,774	410,653	634,620	624,829
Steam and hot water	GJ	526,100	553,642	490,737	455,901
Liquid oxygen	t	–	–	393	1,722

(3) Trend of energy consumption and energy intensity

Table 1.2.5 Trend of Energy Consumption and Energy Intensity

	Unit	1993	1994	1995	1996
Fuel oil	GJ	1,677,088	1,510,063	0	0
Natural gas	GJ	1,785,732	1,461,538	2,986,927	2,963,191
Electricity	GJ	5,167,714	4,212,478	6,509,932	6,409,496
Steam and hot water	GJ	526,100	553,642	490,737	455,901
Liquid oxygen	GJ	–	–	4,233	18,546
Total		9,156,634	7,737,721	9,991,829	9,847,134
Energy intensity	MJ/t-crude steel	18,454	11,991	13,812	13,814
	(Mcal/t-crude steel)	(4,408)	(2,864)	(3,299)	(3,299)

Electricity equivalent calorie: 2,450 kcal/kWh
Liquid oxygen equivalent calorie: 10,770 kJ/kg

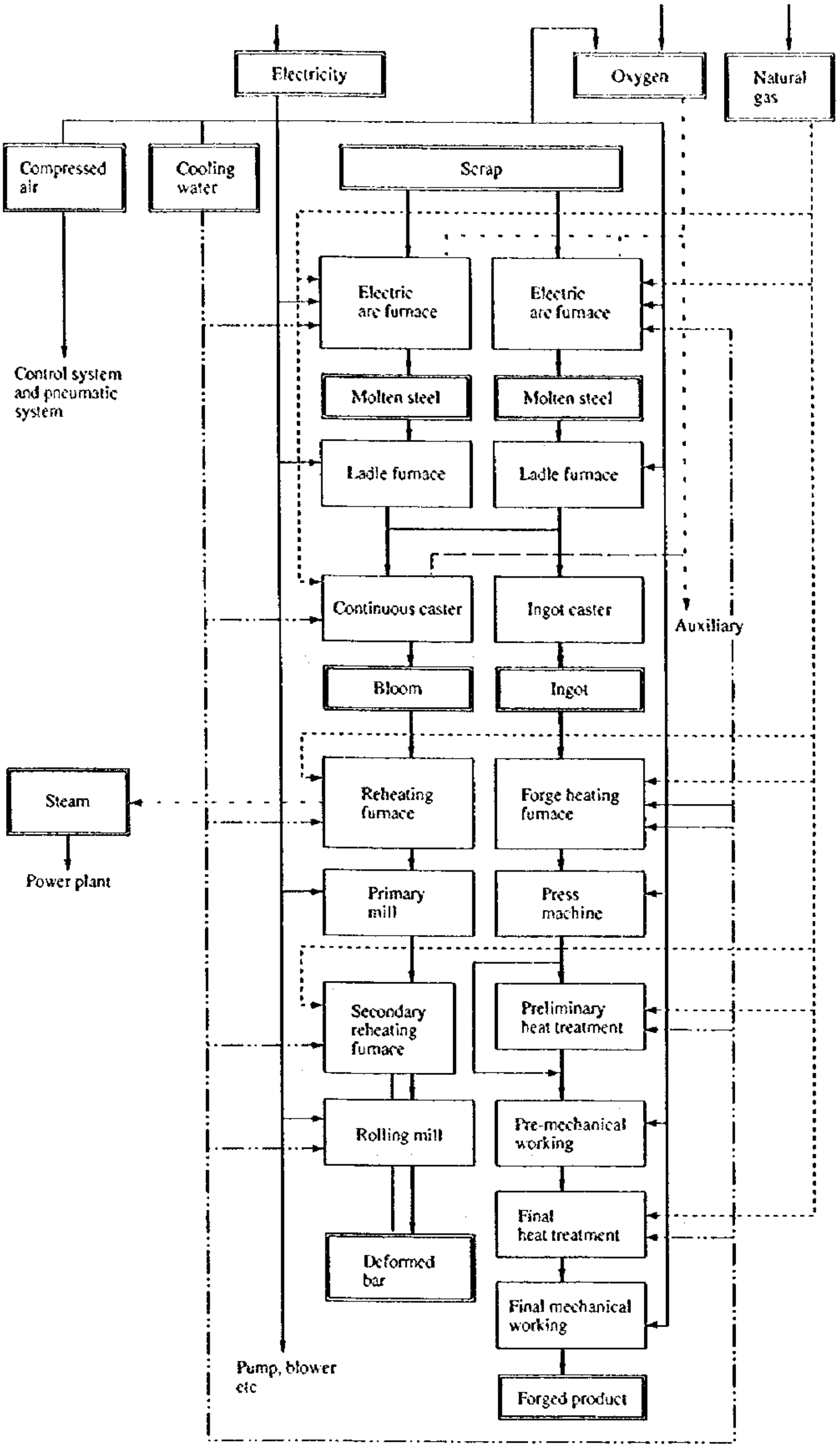
(4) Percentage of the energy cost in the sales cost

The proportion of energy cost to production cost is approximately 18.7 % at this factory

(5) Energy flow

The major portions of the purchased energy consist of electric power (65 %) and natural gas (30 %), while steam and hot water are also all purchased. Besides its use by rolling mills and electric furnaces, electric power is also used at the oxygen plant, compressed air plant, and the cooling water system. Oxygen, nitrogen, compressed air, and cooling water are supplied and used at each plant. Natural gas is used at each plant as direct fuel. Additionally, an evaporating cooling system is adopted for cooling the skids at the reheating furnace in the rolling mill, with its generated steam sent to and used at the adjacent power generation plant. The energy flow is shown in Figure 1.2.4.

Figure 1.2.4 Energy Flow



1.2.3 Energy Management Status

(1) Setting the energy conservation target

a. Setting the target value

The target value for the entire plant has not been set yet. However, the energy intensity target value is available for each process.

b. Problems in the promotion of energy conservation

While the lack of funds poses the foremost obstacle, with the introduction of outside capital and ESCO business, the policy for energy conversion processes (example: oxygen plant) will be shifted from low efficiency in-house facilities to outsourcing, passing expectations for energy conservation gains to other dedicated companies. This should not involve any technical difficulties.

(2) Systematic activities

a. Setting up the department dedicated to energy conservation

This department is not provided. The Energy Department leads each department and evaluates the activity result of the departments.

b Setting up the energy conservation committee

Not provided.

c. Top management's stance

To successfully compete with other companies and imported products, cost reduction and promotion of restructuring are considered to be the top-priority issues. Energy conservation is regarded to be one of such important themes.

d. Personnel evaluation system

There is no system that will pick up the energy conservation activities alone to reflect them into personnel evaluation. However, an evaluation system that awards individuals with proven contributions to promoting cost reductions and restructuring is in place.

(3) Data-based management

a. Grasping the energy consumption

They keep track of the energy consumption.

b. Grasping the energy consumption for each major equipment

The main equipment are provided with meters, through which they keep track of the energy consumption.

c. Grasping the energy intensity for major products

They keep track of the energy intensity for major products by process and by energy sources.

The overall energy intensity is not available.

d. Installing measuring instruments

Measuring instruments are provided for each major facility.

e. Production management and cost management

Production management and cost management are performed.

However, they have not yet reached a level that enables implementation of process management (adjustments between processes) that minimizes energy cosumption.

(4) Training of employees

a. Commendation system

A commendation system is provided to award a person with money for his/her contribution to cost reduction, thus achieving a result.

(5) Plant engineering

a. Scheduled maintenance system

An annual maintenance schedule is provided for plant engineering in a scheduled manner.

However, because the facilities are aging, they require a lot of work which takes up a lot of time, lowering their operation rates as a consequence. There is a need to study ways to carry out equipment improvements in a well planned manner, shortening work periods, and increasing annual production, as well as reducing the cost of such works.

b. Plant engineering status

In general, the equipment are maintained and managed well.

1.2.4 Problems and Countermeasures related to the Use of Energy

1.2.4.1 Comparison of energy intensity with the excellent factory

Major products of this plant are deformed bars and forged products. The deformed bar production process takes up 68 % of total energy consumption, while the forged product production process consumes 25 % of the energy, and others consume 7.0 %. Since the energy intensity of the forged products production process greatly differs depending on the product being produced, comparison with other companies is not so significant. However, the average value of companies having a batch furnace is shown in the parentheses for reference as shown in Table 1.2.6.

Table 1.2.6 Comparison of Energy Intensity

		Unit	Ostrowiec	Excellent factory	Difference
Deformed bar production proces		MJ/t-deformed bar	12,080	7,128	4,952
EAF and continuous casting		MJ/t-molten steel	7,069	5,147	1,922
Rolling mill	(507,932 t)	MJ/t-deformed bar	4,159	1,768	2,391
Forged product		MJ/t-product	55,067	(34,351)	20,716
EAF and ingot casting		MJ/t-molten steel	9,429	6,856	2,573
Forging plant	(41,829 t)	MJ/t-product	38,202	(22,088)	16,114
Total	(549,761 t)	MJ/t-product	15,351[*1]	(9,199)	6,152
(Note) Continuous casting yield		%	97.54	99.0	
Rolling mill yield		%	91.50	97.0	
Forged product/molten steel		%	55.91	(55.91)	

As mentioned above, it is generally difficult to compare energy intensities of forging plants since intensity differs greatly depending on the type, size, and quality, etc. of the product, and thus, the energy conservation potential of this factory's production process was estimated without counting the energy intensity of the forging plant, and results are as shown below.

$$\left\{\frac{549,761\times 6,152-(38,202-22,088)\times 41,829}{15,351\times 549,761}\right\}\times 0.93\times 100=29.8\ \%$$

As a measure of comparison, if improvement of energy intensity could be achieved at the forging plant to a level equivalent to the Excellent company, its energy conservation potential would be as follows.

$$\frac{6,152}{15,351}\times 0.93\times 100=37.3\ \%$$

It should be noted that the previously mentioned "7 % for other processes" was not included in this calculation.

1.2.4.2 Estimation of the energy conservation potential

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

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

(1) Estimation of energy conservation potential by process

Table 1.2.7 lists the processes in this plant in decreasing order of net energy consumption.

Table 1.2.7 Energy Consumption by Process

Unit: GJ/y

Process	Energy consumption	Energy generation	Net consumption	Percentage (%)
a. Electric arc furnace (140-ton) and continuous caster	4,580,103	0	4,580,103	46.5
b. Rolling mill	2,112,398	0	2,112,398	21.5
c. Forging equipment	1,597,958	0	1,597,958	16.2
d. Electric arc furnace (70-ton) and ingot-making equipment	857,056	0	857,056	8.7
e. Others	506,576	0	506,576	5.2
f. Oxygen plant	232,222	100,131	132,091	1.3
g. Air compressor	156,542	115,747	40,795	0.4
h. Water system	304,191	289,099	15,092	0.2
Total	10,347,045	504,977	9,842,068	100

a. Electric furnace (140-ton) and continuous caster (CC)

a1. Difference due to external factors

There is no particularly large difference. However, the following points can be made.

- One of Japan's representative electric arc furnace companies (excellent factory) stops their furnaces for 14 hours when the electricity rate is high during the weekday daytimes, and thus operates in a peculiar arrangement in order to reduce manufacturing costs.

- On the other hand, this stopping of the furnace invites a rise in the rate of energy loss, which in turn is a factor that worsens energy intensity.

a2. Difference due to technical factors

1) Comparison of energy intensity with the excellent factory

Table 1.2.8 compares the energy intensity of this factory in 1996 with that of the excellent factory. The energy intensity of the excellent factory shown in the table can be further improved by a small amount, if it chooses to ignore its manufacturing cost and does not stop its furnaces.

Table 1.2.8 Comparison of Energy Intensity with Steel-making Plant in 1996

	Unit	Ostrowiec		Excellent factory	
Electricity (Total)	Unit	6,099	(595 kWh/t)	4,411	(430 kWh/t)
EAF + LF	MJ/t-steel	5,674	(553 kWh/t)	3,488	(340 kWh/t)
CC and auxiliary equipment	MJ/t-steel	425	(42 kWh/t)		(90 kWh/t)
Compressed air	MJ/t-steel	65	(*6 kWh/t)		
Oxygen and argon	MJ/t-steel	149	(*15 kWh/t)		
Cooling water	MJ/t-steel	170	(*17 kWh/t)		
Natural gas	MJ/t-steel	586	(* 16 m^3_N/t)		
Carbon and Aluminum	MJ/t-steel	?		435	
Oil and others	MJ/t-steel	–		301	
Total	MJ/t-steel	7,069	(1,688 Mcal/t)	5,147	(1,229 Mcal/t)

(Note) * means equivalent calorie in kWh and equivalent heat values of these types of energy are as follows:

- Compressed air $1\ m^3_N = 1.0467$ MJ = 0.102 kWh
- Oxygen $1\ m^3_N = 6.6989$ MJ = 0.653 kWh
- Argon $1\ m^3_N = 15.386$ MJ = 1.500 kWh
- Cooling water $1\ m^3 = 2.5928$ MJ = 0.253 kWh

2) Comparison of operation indexes for the electrical furnace and ladle furnace

Most part of energy consumption in the steel-making process is occupied by the electric furnace and ladle furnace.

For the electricity intensity of the electric furnace and ladle furnace at Ostrowiec, the tap-to-tap time has been recently reduced to 114 minutes (120 minutes in 1996) as a result of carbon injection, and the electricity intensity has been improved from 553 kWh/t to 509 kWh/t. Comparison between the recent Ostrowiec data and excellent factory data is shown in Table 1.2.9.

Table 1.2.9 Comparison of Energy Intensity of Electric Arc Furnace (EAF) and Ladle Furnace (LF)

	Ostrowiec		Excellent factory		Remarks
Capacity	EBT 140 t/ch		EBT 50 t/ch		
Transformer capacity	75 MVA		35 MVA		
Tap-to-tap	EAF 114 min		EAF 56.1 min		
Tapping weight	123 ~ 125 t/ch		65 t/ch		
Tapping temperature	1,600 °C		1,625 °C		
Electricity EAF	1,247	(474 kWh/t)	<292> 833	(340 kWh/t)	2,450 kcal/kWh
LF	<438>	(35 kWh/t)	0	(0)	
Oxygen	40	(25 m^3_N/t)	53	(33 m^3_N/t)	1,600 kcal/m^3_N
Carbon injection	49	(7 kg/t)	83	(Carbon: 9.8 kg/t)	7,055 kcal/kg
				(Al dross: 4.7 kg/t)	2,963 kcal/kg
Oil injection	0	(0)	27	(3 L/t)	8,900 kcal/L
Electrode consumption	22	(2.83 kg/t)	13	(1.7 kg/t)	7,837 kcal/kg
Total	<549> 1,358		<468> 1,009 Mcal/t		Difference <81> 349 Mcal/t

(note) < > is calculated as equivalent calorie, 1 kWh = 860 kcal

3) Improving the energy intensity

Since the capacity of the electric furnace at the excellent factory for comparison is nominally as small as 50 tons/ch (actually 65 tons/tapping), Ostrowiec has a smaller percentage of the energy loss for the 140-ton/ch furnace, and it should naturally be superior in terms of intensity. Although oxygen consumption is 25 m^3_N/t and carbon injection is as much as 7 kg/t, the electricity intensity is higher by 30 to 50 kWh/t than that of the electric arc furnace in the Japanese excellent factory. However, the capacity of the electric furnace does not match that of the continuous caster or the rolling mill; therefore, the tap-to-tap time cannot be reduced, thus resulting in poorer intensity. To reduce the tap-to-tap time, operation of the electric furnace should be improved, and the operation of the electric furnace should be matched with the continuous caster and rolling mill.

Since Ostrowiec has a ladle furnace (LF), it would be advisable for them to fully utilize the capacity of the LF, and eventually reduce tap-to-tap time to under 70 minutes, by improving their facility and operation to operate with 1 electric furnace (140 t) + 1 LF + 2 CC.

Reducing tap-to-tap time will mean to increase productivity of the furnace. Thus, while replacing electricity with fuel, energy input should be increased to raise melting speed per unit of time, which will reduce tap-to-tap time, and at the same time, the relative amount of energy loss due to furnace cooling loss and radiation heat loss should be reduced.

Tables 1.2.10 and 1.2.11 respectively show the energy conservation effect of the alternative energy and the relationship between the tap-to-tap time and electricity intensity.

Table 1.2.10 Effect of the Alternative Energy on Electricity Conservation

	Available range	Replacement ratio
Oxygen	$0 \sim 20$ m^3_N/t	5.5 kWh/m^3_N
	> 20 m^3_N/t	2.7 kWh/m^3_N
Oil	0 ~ 5 L/t	9.0 kWh/L
Natural gas		8.5 kWh/m^3_N
Coke		3.0 ~ 8.3 kWh/kg
Aluminium dross	5.0 kWh/kg	
Scrap preheating	20 ~ 40 kWh/t	

Table 1.2.11 Relationship between Tap-to-Tap Time and Electricity Intensity

Tap-to-tap time	Electricity intensity
180 min	550 ~ 600 kWh/t
120 min	480 ~ 520 kWh/t
90 min	430 ~ 470 kWh/t
70 min	380 ~ 420 kWh/t
60 min	360 ~ 400 kWh/t

Specific measures to reduce tap-to-tap time of the furnace, and improve electricity intensity, are listed below.

- It is recommended that implementation of measures that enable utilization of LF be given priority.

Since this factory possesses a LF, tapping of steel at low EAF temperature will become possible by fully utilizing the temperature rise and heat insulation features of its LF.
This measure will allow a drastic reduction in tap-to-tap time.

- Installation of a scrap preheating device: 20 kWh/t (20 to 40 kWh/t)

Use the exhaust gas from the EAF to preheat the scrap that is charged.
While there are large effects such as the recovery of waste heat, and reduction in melting energy at the EAF, factors like the required amount of time for preheating should be studied carefully upon installing facilities so that the scale of the measure matches capacity of the EAF.

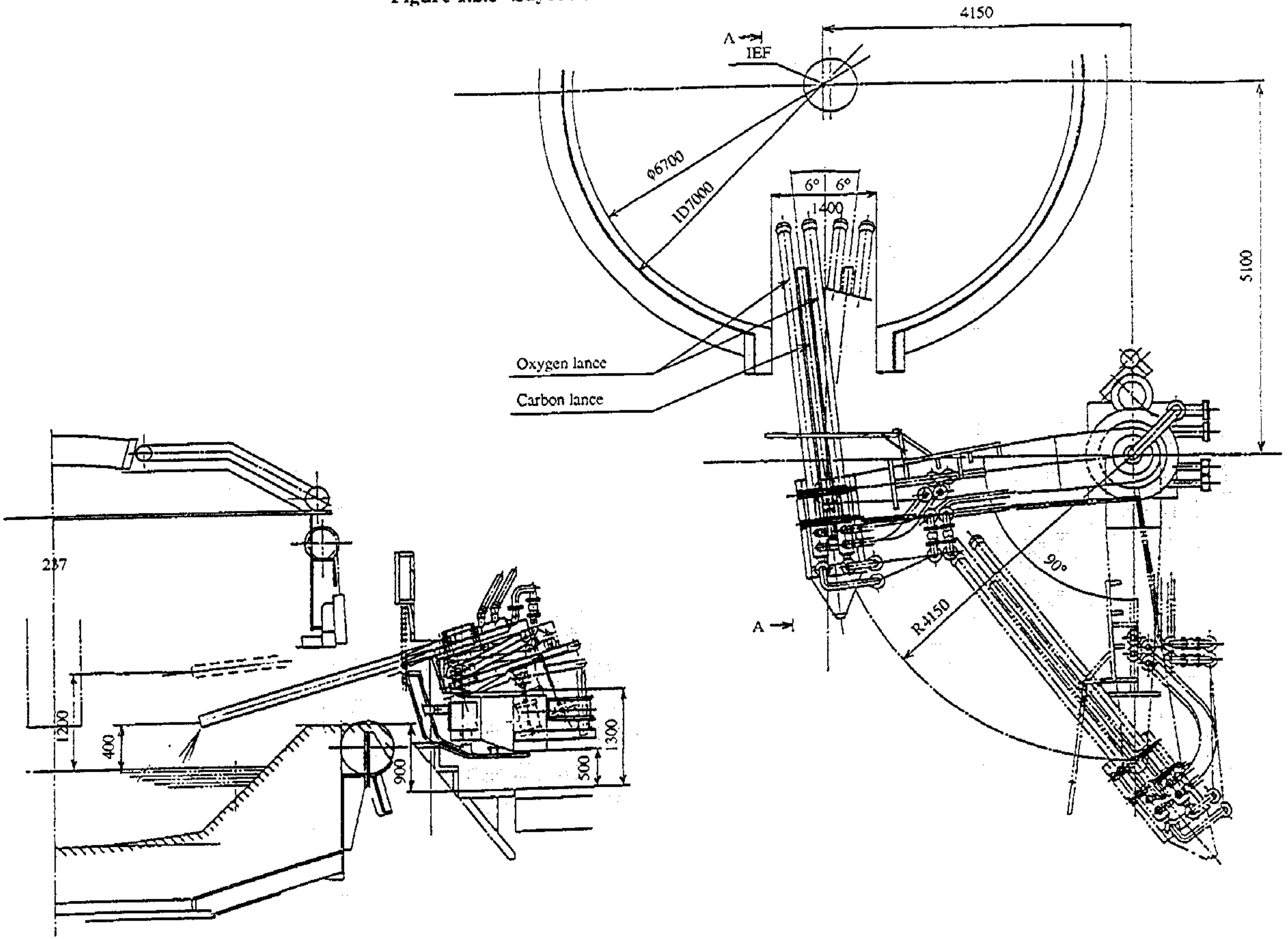
- Installation of natural gas burner device	0 → 4 m^3_N/t	65 kWh/t
(Oxygen consumption	0 → 8 m^3_N/t)	
- Increase of carbon injection	7 → 12 kg/t	
- Maintain O_2 blowing at the current level	25 → 25 m^3_N/t	

Because O_2 blowing applied to EAF has significant effects such as cutting the charged scrap, enhancing melting speed due to the cutting, and enhancing combustion of the carbon material inside the furnace, the number of furnaces using O_2 is on the rise in recent years.

In this factory, 8 m^3_N/t of oxygen is newly added to accommodate natural gas blowing.

A water cool type O_2 blowing facility is shown in Figure 1.2.5 for reference.

Figure 1.2.5 Layout of Water Cooled Lance Equipment



4) Electricity saving measures for the auxiliary equipment of the electric furnace

Additionally, the following measures are provided for electricity saving of the auxiliary equipment of the electric furnace:

- Improving the electricity intensity of the auxiliary equipment as a result of reducing the tap-to-tap time: 10 to 15 kWh/t
- Improving the electricity intensity by variable speed control or pole change control for the dust collector blower: 3 to 5 kWh/t

b. Rolling mill

b1. Difference due to external factors

As with electric arc furnaces, rolling mills at the electric arc factory in Japan are also stopped for 14 hours (8:00 to 22:00) during the daytime on week days, worsening energy intensity. For this reason, various improvements in facilities and operation are implemented to maintain favorable fuel intensity at the reheating furnace. Currently, energy intensity is at a level shown in Table 1.2.12.

b2. Difference due to technical factors

Table 1.2.12 Comparison of Energy Intensity in the Rolling Mill

Unit: MJ/t

	Ostrowiec	Excellent factory
Fuel	2,437 (69 m^3_N/t)	770
Steam	41	75
Electricity	1,420 (138 kWh/t)	
Compressed air	52 (*5 kWh/t)	923 (90 kWh/t)
Cooling water	208 (*20 kWh/t)	
Total	4,159	1,768

(Note) * indicates the energy intensity in terms of electricity.

1) Rolling mill at Ostrowiec

The rolling mill at Ostrowiec receives the 220 × 220 bloom to be rolled from the continuous caster. The rolling mill is provided with a secondary heating furnace to reheat the rolled material in the middle of rolling.

It is more efficient to produce blooms of 220 × 220 in size when productivity of only the CC is considered. However, for rolling mills that produce 8 ϕ to 32 ϕ deformed bars, the billet size is generally about 120 × 120, which is desirable since the intermediate reheating process becomes unnecessary. Thus, Ostrowiec has started modification of the continuous caster for production of 120 × 120 billets and modification of the rolling plant to allow receiving the billets. Yet, to reduce the work period of modifying the rolling mill, it is planned not to eliminate the secondary reheating furnace, but to leave it as it is.

According to the current operation performance, the yield is lower although a large 220 × 220 × 11.7 m bloom is used as the material. Hence, the themes for the rolling process are improvement of the fuel intensity and improvement of the yield.

Table 1.2.13 Comparison of Products

		Ostrowiec	Excellent Factory
Bloom/Billet	Section	220 × 220 mm	120 × 120 mm
	Length	11.7 m	4.2 m
Cf. product		8 mmϕ ~ 32 mmϕ	10 mmϕ ~ 32 mmϕ (6 mmϕ ~ 51 mmϕ)
Cf. Rolling mill yield		91.5 %	97 %

2) Improvement of the yield

Electricity intensity: 94 MJ/t (9.2 kWh/t)
Fuel intensity : 138 MJ/t (33 Mcal/t)

As there are many miss roll and scale loss, and rolling yield is as low as 91.5 %, the causes of this reduced yield should be investigated, analyzed, and improved, and the yield should be raised to about 97 %. If yield is improved to the level of excelletn factory or 97 %, fuel intensity will be improved by 138 MJ/t.

Since improved product yield will also contribute to reduction in energy used by the electric arc furnace + CC process, the energy intensity per production ton including that of the electric arc furnace, CC, and rolling will be improved from 12,080MJ/t to 11,395MJ/t, which will be a 5.67 % improvement.

Improvements should be made so that rate of miss roll is lowered to the level of excellent factory, or under 0.5 %. Taking only electricity as an example, when the amount of reduction in electricity for the electric arc furnace, CC, and rolling process is calculated, it becomes as follows. Here it should be noted that the values of compressed air, oxygen, argon and cooling water produced by means of electric power are added in terms of electricity.

Rolling process: $163\ \text{kWh/t}\left\{1-\frac{0.915}{0.97}\right\}=9.2\ \text{kWh/t - product}$

Electric furnace + continuous caster process:

$$616\ \text{kWh/t}\left\{\frac{1}{0.915\times0.9754}-\frac{1}{0.97\times0.9754}\right\}+16\ \text{kWh/t}\left\{\frac{1}{0.915}-\frac{1}{0.97}\right\}$$
$$=40.1\ \text{kWh/t - product}$$

where

0.974 is the yield of CC,
163 kWh/t is the electricity intensity of the rolling process [kWh/t-product],
16 kWh/t is the electricity intensity of the CC process [kWh/t-billet], and
616 kWh/t is the electricity intensity of the electric arc furnace process. [kWh/t-molten steel]

Total 9.2 + 40.0 = 49.2 kWh/t-product

Similarly, a reduction in the consumption of fuel and steam is obtained as follows:

The fuel and steam intensity in the rolling department is 2,478 MJ/t-product,
the fuel intensity in the CC department is 84 MJ/t-billet, and
the fuel intensity in the EAF department is 502 MJ/t-molten steel.

Therefore,

the effect on the rolling department alone is 2,478 MJ/t × 0.05670 = 140.5 MJ-product,
the ripple effect on the CC department is 84 MJ/t × 0.0620 = 5.2 MJ/t-product,
the ripple effect on the EAF department is 502 MJ/t × 0.06353 = 31.9 MJ/t-product.
The overall effect on the three departments is 178 MJ/t-product.

Hence, the total reduction in energy consumption can be obtained as follows:

The energy intensity of the rolling department is 4,159 MJ/t-product,
the energy intensity of the CC department is 248 MJ/t-billet, and
the energy intensity of the EAF department is 6,821/MJ/t-molten steel.

Therefore,

the effect on the rolling department alone is 4,159 × 0.05670 = 235.8
the ripple effect on the CC department is 248 × 0.0620 = 15.4
the ripple effect on the EAF department is 6,821 × 0.06353 = 433.3
Total: 684.5 MJ/t ≒ 684 MJ/t

3) Improvement of the fuel intensity

The dimension (furnace width × furnace length) of the reheating furnace at Ostrowiec is 12.6 m × 25 m. Compared to the same type of furnace at excellent factory, this furnace has problems such as heat insulation. If the improvements mentioned later are implemented, energy intensity is estimated to improve to 1,256 MJ/t-bloom (300 Mcal/t-bloom). When this is converted to per ton of product, assuming a rolling yield of 97 %, it becomes 1,295 MJ/t-product.

The rolling mill at Ostrowiec has a secondary reheating furnace in the rolling line. If this secondary reheating furnace consumes fuel of approximately 335 MJ/t, the target of intensity improvement that can be achieved without hot charge rolling is as follows:

$$\left(2{,}437\ \text{MJ/t} - \underset{\substack{\text{Yield}\\ \text{improvement}\\ \text{(already calculated)}}}{\underline{138\ \text{MJ/t}}}\right) - \underset{\substack{\text{Standard}\\ \text{intensity}\\ \text{of reheating}\\ \text{furnace}}}{\underline{1{,}295\ \text{MJ/t}}} - \underset{\substack{\text{Standard intensity}\\ \text{of the secondary}\\ \text{reheating furnace}}}{\underline{335\ \text{MJ/t}}} = 669\ \text{MJ/t}\ (160\ \text{Mcal/t})$$

To reduce the intensity, the following measures can be taken:

- Reduction of equipment troubles and miss roll rate, and improvement of the heat holding criterion	: 170 MJ/t (41 Mcal/t)
- Reinforcement of heat insulation by ceramic fiber	: 73 MJ/t (17 Mcal/t)
- Reduction of the radiated heat by reinforcing the blocking of the opening	: 49 MJ/t (12 Mcal/t)
- Optimization of the combustion air ratio	: 377 MJ/t (90 Mcal/t)
Sub-total	: 669 MJ/t (160 Mcal/t)

- Hot charge rolling: 335 MJ/t (80 Mcal/t)

Almost all deformed bar producing rolling mills in excellent factory perform either hot direct rolling (HDR) or hot charge rolling (HCR). With its CC and roll mill right next to each other, Ostrowiec has the conditions to carry out HCR. Fuel intensity of rolling mills at excellent factory performing HCR is between 628 MJ/t (150 Mcal/t) and 921 MJ/t (220 Mcal/t), and it goes without saying that the temperature of the billet charged into the reheating furnace is higher, that plant's fuel intensity becomes better.

If the target for fuel intensity at Ostrowiec is set at the level at excellent factory, or 921 MJ/t, the hot charge rate will have to be raised to 75 % with average billet temperature at 500 °C. Judging from our visit to the Ostrowiec plant, this target seems easily achievable, and we hope it is implemented.

However, there is a gap between the productivity of the continuous caster and the rolling productivity (i.e. the rolling productivity (t/h) varies depending on the diameter of the deformed bar), the heat holding furnace is required.

- Recommendation to modification of the reheating furnace

  Although there are plans to eliminate the reheating furnace currently in use, and to install a new one, planning and improvement should be carried out along the following line of thought for the reheating furnace, regardless of currently existing one or new furnace, to improve the fuel intensity upon reheating cold billets to about 1,256 MJ/t-billet (300 Mcal/t-billet).

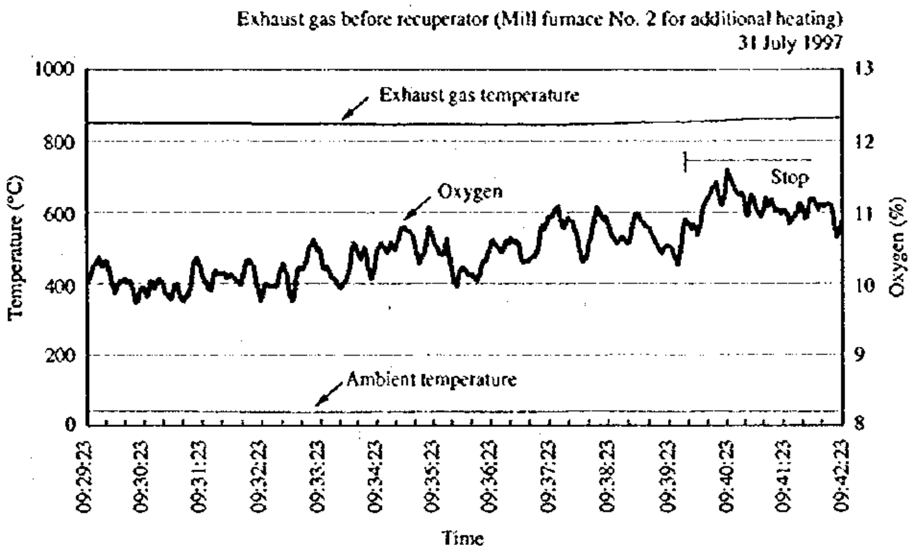
  - Heat insulation with ceramic fiber

  - The reheating furnace should be divided into about 5 zones, enabling preheating, reheating, and soaking to be carried out independently, and partition walls should be installed so that the combustion temperature of each zone can be measured accurately, and the furnace should be structured in a way that minimizes the amount of input energy required.

- Improving the air ratio for the secondary reheating furnace

  Figure 1.2.6 shows the results of the measurement of the exhaust gas from the secondary reheating furnace. Measuring point was at the inlet of the recuperator.

Figure 1.2.6 Exhaust Gas Measurement of the Secondary Reheating Furnace



Combustion calculation was performed using these measured values for calculating the possible air ratio improvement effect. The results are shown in Table 1.2.14. 1.5 minutes after starting the measurement, the rolling mill stopped due to a trouble, which lowered the combustion rate of this furnace, which was put in the heat holding status. Figure 1.2.6 shown above contains this period, but for the calculation, we used the data before rolling was stopped. As shown in this table, 14.7 % fuel saving can be achieved through air ratio control.

Table 1.2.14 Effect of Air Ratio Improvement of the Secondary Reheating Furnace

Preconditions	
Fuel gas	
Net heat value (kJ/m^3_N)	35,532
Net heat value (kcal/m^3_N)	8,487
Combustion air temperature	330
Exhaust gas temperature (Before air heating)	850
Exhaust gas temperature (After the assumed air heating)	606
Furnace infiltrating air ratio	0 %

Notes: The measuring point is in front of the air preheater.
The temperature after air heating is assumed based on air heating balance.

Calculation Result	Theoretical Combustion	Current Air Ratio	Air Ratio after Improvement
Exhaust gas oxygen	0.0 %	10.0 %	5.9 %
Air ratio	1.00	1.82	1.35
Air flow rate (m^3/kg)	9.6	17.5	13.0
Exhaust gas volume (m^3/kg)	10.6	18.5	14.0
Exhaust gas heat loss ratio (to fuel heat)		42.6 %	32.6 %
Fuel saving rate			14.7 %

Notes: The air ratio improvement percentages are the reference values based on the judgement creteria in Japan.
The exhaust gas loss ratio means the exhaust gas heat loss after air preheating.

For the calculation, we used the data obtained before rolling was stopped.

Table 1.2.15 shows the specifications of the secondary reheating furnace.

Table 1.2.15 Specifications of Secondary Reheating Furnace

Items	Specifications
Type	Walking beam type
Capacity	Maximum 180 t/h
	100 t/h for measurement period
Furnace dimension	18 m-W × 12.2 m-effective length
Charged material	Bloom, (105 – 130) mm × (15,000 – 17,400) mmL
Fuel	Natural gas
Burner capacity	20 MW
Cooling water	135 m^3/h

- Recommendation to the secondary reheating furnace

  - The current retrofitting plan is to leave the secondary reheating furnace unchanged in order to shorten the work period. Yet, leaving this furnace as it is and extending the use of the existing rolling mill involve many problems in terms of material handling, energy conservation and yield. However, taking into account the fact that a reheating furnace in the rolling mill, roller tables, etc. have already been newly installed, it is most unlikely that an immediate renovation of the rolling line at this point of time will produce any significant benefit. Therefore, we would strongly recommend the following measures to be taken instead:
    - to extend the length of the reheating furnace in the rolling mill so as to improve the fuel intensity at such time when the furnace and the mill will become superannuated,
    - to eliminate the secondary reheating furnace, and
    - to modernize the production line into a more linear arrangement.

    Additionally, the energy conservation effect from the elimination of the secondary reheating furnace is estimated at about 167 - 335 MJ/t for fuel intensity and about 10 kWh/y for electricity intensity.

  - After the new billet CC (120 × 120) and new reheating furnace are complete, the existing secondary reheating furnace will only be used as a reheating furnace. The fuel intensity of the current facility is estimated to be about 335 MJ/t (80 Mcal/t).

    Therefore, improvements such as changing the lining to ceramic fiber, or coating with ceramic fiber, should be studied to minimize radiation heat loss and structural heat losses, as a way to improve energy intensity to under 167 MJ/t (40 Mcal/t).

4) Improvement of the electricity intensity

- Modification of the continuous casting process and rolling process: Improvement by 40 kWh/t

  When the modification planned by Ostrowiec is completed, the electricity intensity is expected to be improved by approximately 40 kWh/t.

c. Forging shop

The energy intensity of the forging shop varies very much depending on the product being produced and the production volume. Therefore, it is hard to presume the energy conservation potential by simply comparing the energy intensity of the excellent factory. In this simplified factory energy audit, the energy conservation potential is to be estimated on the basis of the results from the short-time factory tour and the forging furnace's exhaust gas O_2 analysis.

1) Forge heating furnace

The fuel intensity of the forge heating furnace is 15, 229 MJ/t (3,637 Mcal/t-ingot), which is incredibly poor. If it is assumed that the weight of the heat insulation material and supports (cast steel) of the heating furnace platform car is same as that of the ingot and the heat efficiency of the heating furnace having the air preheater is 15 %, the fuel intensity will be 11,166 MJ/t (2,667 Mcal/t). This shows that the fuel intensity at Ostrowiec is extraordinarily poor.

The results of our simplified factory energy audit suggest the following possible causes.:

- As evident from Table 1.2.16, because there is a lot of air invading the heating furnace, the air-fuel ratio has reached 2.5. If this could be lowered to 1.35, a 16.4 % reduction in fuel consumption can be attained.

  There are many problems such as poor sealing between the cart and heating furnace, and poor sealing of the heating furnace door. Improvements should be made immediately from the areas where possible.

- The operation rate of the heating furnace is low.
  For example, even the annual operation rate of the No. 18 furnace whose operation rate is high is as low as 46.5 %.

  The number of heating furnaces is excessive compared to the quantity of casting performed. The number of furnaces in operation should be streamlined, and operation rates raised to about 70 %.

- The control of air-fuel ratio is poor.

- The use of ceramic fiber for heat insulation of the heating furnace is behind schedule (significant structural heat loss)

Ostrowiec is proceeding with the use of ceramic fiber, which has so far been achieved by approximately 30 %.

Although there may be problems of funding, we recommend immediate action. Ceramic fibers produce positive effects like reduction of structural heat losses, and radiation of heat loss, and they enable about 40 % reductions in fuel consumption, and therefore, they should be implemented as soon as possible.

For the reason mentioned above, as steel heating time gets longer, energy losses such as radiation heat, and exhaust gas sensible heat, etc., become relatively greater, resulting in worsened fuel and power intensities.

Hence, to improve the fuel intensity of the heating furnace, the following should be carried out:

① Entry of air should be minimized and a low air-fuel ratio should be maintained even though the load is small.

If the measure mentioned above is implemented, and the air fuel ratio is lowered from 2.5 to 1.35, there will be an energy conservation effect as described below.

15,229 × 0.164 = 2,497 MJ/t

Expected effect: 2,497 MJ/t (596 Mcal/t-ingot)

② The required heat value should be minimized.

Expected effect: 4,075 MJ/t (973 Mcal/t-ingot)

- Process control is required so that the ingot at a higher temperature can be charged in the heating furnace.
- The heat insulation material of the heating furnace should be replaced with ceramic fiber.
- Process control is required so that the operation rate of the heating furnace will be increased.

As a result, it is expected that the fuel intensity will be improved by 6,496 MJ/t (1,551 Mcal/t) from 15,229 MJ/t to 8,733 MJ/t-ingot (2,086 Mcal/t). This measure will shorten the steel ingot retention time inside the heating furnace, and since that reduces operating time of the furnace per unit weight of steel ingot, required power for fans and other facilities will simultaneously decrease, and their operating times will shorten, resulting in a 6 to 10 % improvement in power intensity.

Exhaust gas measurement and analysis of No. 18 heating furnace

The forging shop is equipped with 56 large and small heating furnaces. Of these, the exhaust gas composition at the No.18 furnace for the large scale 8,000 t press machine was measured. This furnace for heating large size forging materials is operated in the batch system. Combustion started at the time 15:00 on the day before the measurement day and finished at 12:30 on the measurement day. Measurement was sequentially performed on the exhaust gas before and after the recuperator during the period from 10:59 to 11:30. This period fell on the soaking period and the fuel consumption was approximately 2/3 of the maximum. The measurement result for the recuperator's outlet is shown in Figure 1.2.7, while the result for its inlet is shown in Table 1.2.17.

Figure 1.2.7 Exhaust Gas Measurement of No. 18 Heating Furnace

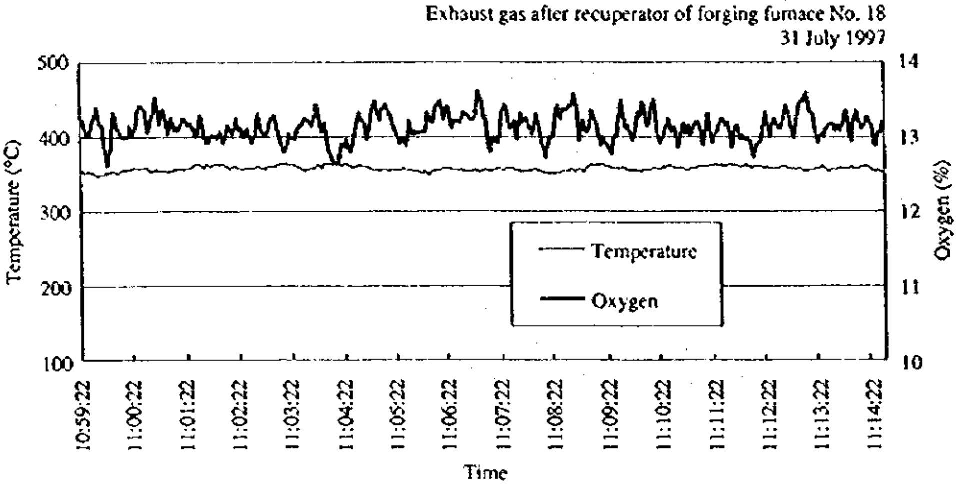


Table 1.2.16 shows the results of calculating the possible air ratio improvement results using the measured values.

Table 1.2.16 Air Ratio Improvement Effect of No. 18 Heating Furnace

Preconditions	
Fuel gas	
Net heat value (kJ/m^3_N)	35,532
Net heat value ($kcal/m^3_N$)	8,487
Combustion air temperature	34
Exhaust gas temperature (Before air heating)	358
Furnace infiltrating air ratio	0 %

Notes: The measuring point is at the back of the air preheater.

Calculation Result

After recuperator	Theoretical Combustion	At Current Air Ratio	At Air Ratio Improvement
Exhaust gas oxygen	0.0 %	13.10 %	5.9 %
Air ratio	1.00	2.50	1.35
Air flow rate (m^3/kg)	9.6	24.1	13.0
Exhaust gas volume (m^3/kg)	10.6	25.1	14.0
Exhaust gas loss ratio (to fuel heat)		31.3 %	17.8 %
Fuel saving rate			16.4 %

Notes: The air ratio improvement percentages are the reference values based on the judgement criteria in Japan.

As shown in this table, controlling the air ratio can achieve a 16.4 % fuel saving effect. However, these results are based on the measurement during only one phase of period in the furnace batch system operation. This requires further measurement and analysis throughout the entire period.

Table 1.2.17 Exhaust Gas Measurement before the Recuperator

Exhaust gas oxygen	Exhaust gas temperature	Air ratio	Exhaust gas temperature after the recuperator	Air temperature
12.3 %	841	2.27	504 (Operation chart) 483 (Calculated value)	451 (Chart)

As shown in Figure 1.2.7 and Table 1.2.17, oxygen content of the exhaust gas before the recuperator is lower than that after the recuperator. This suggests that there is a possibility of air leaking to the gas side, which requires more accurate measurements.

The components of the fuel gas used for the above-mentioned calculations are as shown in Table 1.2.18. Table 1.2.19 shows the specifications of this heating furnace.

Table 1.2.18 Fuel Gas Components

Gas components	CO_2	H_2	CH_4	C_2H_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	O_2	H_2O
Wet volume	0.1 %	-	97.9 %	-	0.4 %	0.1 %	0.1 %	1.4 %	0.0 %	-

Table 1.2.19 Specifications of No. 18 Heating Furnace

Items	Specification
Type	Bogie-type furnace
Capacity	Maximum 90 t/cycle (40 t/cycle in measurement period)
Fabricator	Biprohut
Furnace dimension	2.4 m-W × 8.5 m-effective length
Fuel	Natural gas
Burner capacity	4,320 kW

2) Heat treatment furnace

The fuel intensity of the heat treatment furnace is as poor as 6,407 MJ/t (1,530 Mcal/t-product). The fuel intensity in heat treatment is 250 to 760 Mcal/t-input on a basis of loaded tons. This heat process also has room for improvements in terms of air fuel ratio, and applying ceramic fiber to reinforce heat insulation, and thus, substantial improvements in energy intensity can be expected. While an improvement in air fuel ratio can be expected to achieve 1,018 MJ/t in energy conservation, improvements such as implementing heat insulation using ceramic fiber can result in 1,714 MJ/t, bringing the total to about 2,732 MJ/t, and thus, it is estimated that energy intensity can be improved to about 3,635 MJ/t (878 Mcal/t).

d. 70-ton electric furnace and ingot casting shop

Compared with the excellent factory, this plant allows for improvement by approximately 27 %.

Because transformer capacity is small, reduction to about 90 minutes is believed to be the limit for tap-to-tap time. By implementing an energy conservation measure similar to the one described in Paragraph a-1 for the 140 t electric arc furnace, an approximately 10 % improvement in energy intensity is estimated to be possible.

e. Oxygen plant

They have a plan to invite an oxygen supplier's plant BOC to move into the company's factory, from which oxygen is to be purchased so that the in-house inefficient plant can be stopped. If this plan is implemented, energy intensity at Ostrowiec will be improved as follows:

As shown in Table 1.2.7, the net energy consumption of the oxygen plant is 132,091 GJ/y, which is the resultant benefit produced by purchasing oxygen from BOC. The current energy consumption of the oxygen plant based on the Ostrowiec operation data is as follows:
Steam : 19,740 GJ/y
Electricity : 202,852 GJ/y (19,775 kWh/y)
Cooling water: 9,630 GJ/y (3,710,000 m^3/y × 2.5958)
Total : 232,222 GJ/y

Therefore, savings in the steam and electricity through the purchase of oxygen from BOC are as follows:
Steam : 132,091 × 19,740/232,222 = 11,228 GJ/y
Electricity : 132,091 × 212,482/232,222 = 120,863 GJ/y = 11,782 MWh/y

f. Others

The purchase of hot water and steam constitute 4.89 % of total energy consumption. Since Ostrowiec owns a hot water piping network, 1.7 % of this 4.89 % can be reduced by facilitating waste heat recovery (energy purchase will decrease to 3.19 %).

This should be positively implemented since hot water heat recovery requires a relatively low construction cost.

Processes allowing heat recovery are as follows:

1) Waste heat recovery from the reheating furnace in the rolling mill (steam)

Even if fuel intensity is improved to 220 Mcal/t-product, there will still be a 22 Mcal/t exhaust gas loss, and since at least about 50 % of this is recoverable, 11 Mcal/t of heat can be recovered.

$$500{,}000\ \text{t/y} \times 11\ \text{Mcal/t} \times 4.1868 \times \frac{1}{1{,}000} = 23{,}027\ \text{GJ/y}$$

2) Recovery of waste gas heat from the electric furnace (140-ton) (steam)

Since the exhaust gas of an electric arc furnace possesses 80 to 90 Mcal/t of sensible heat even after preheating scrap, if 40 % of this is recoverable, the following amount of waste heat can be recovered.

$$650{,}000 \times 80 \times 0.4 \times 4.1868 \times \frac{1}{1{,}000} \fallingdotseq 87{,}085\ \text{GJ/y}$$

3) Recovery of cooling water heat from the electric furnace (140-ton) (hot water)

Since the waste water for cooling an electric arc furnace contains 60 to 70 Mcal/t of sensible heat, if 50 % of this is recovered, the following amount of waste heat can be recovered.

$$\frac{7}{12} \times 650{,}000 \times 60 \times 0.5 \times 4.1868 \times \frac{1}{1{,}000} = 47{,}624\text{GJ/y}$$

As a result, heat recovery of 157,736 GJ/y is possible.

B. Utilities (heat utilization facilities)

1) Recording by means of an infrared thermal imaging system

Figure 1.2.8 and Figure 1.2.9 show the images of the high-temperature zones of the secondary reheating furnace and the forging heating furnace by the use of an infrared thermal imaging system The figures show the image of the high-temperature zone in the periphery of the side surface for the secondary reheating furnace and that before the recuperator for the forging heating furnace. The use of this system allows a visual understanding of a high-temperature zone, thus making it easier to know the zone requiring further heat insulation. Moreover, it is possible to know any breakage of the insulating material of the inside which cannot be seen from the outside.

Additionally, measurement results at this facility are reflected in the recommendations and energy conservation potential calculations in each facility item.

Figure 1.2.8 Thermal Image of the Side Surface of Inspection Hole of the Secondary Reheating Furnace in Rolling Mill

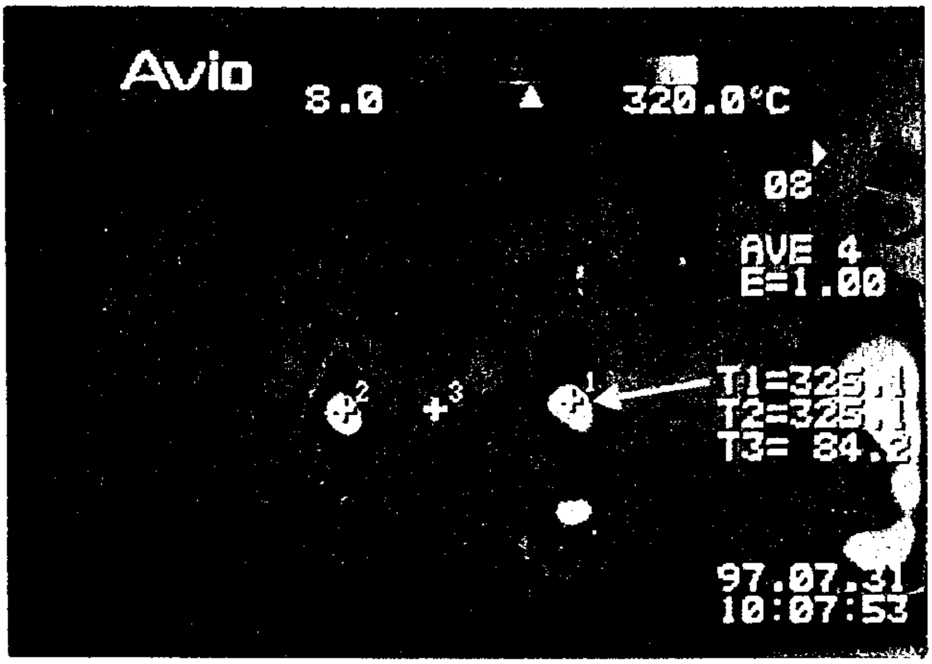
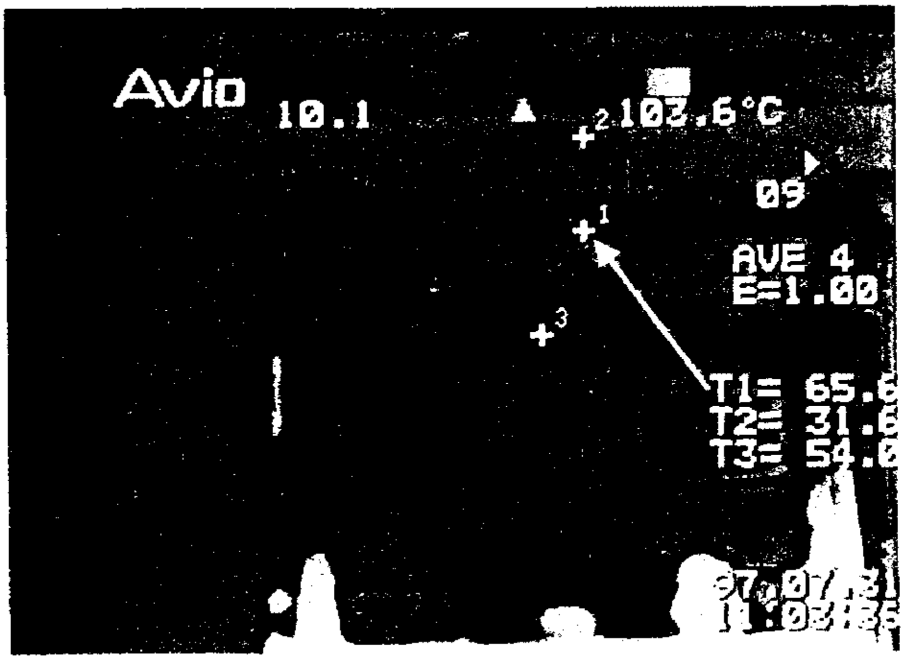


Figure 1.2.9 Thermal Image of the Recuperator Outer Wall of the Forging Heating Furnace



C. Utilities (electricity utilization facilities)

1) Lighting (Step 2)

The number of mercury lamps at each factory is estimated to be about as follows, according to investigation results.

Forging shop : Approximately 200 lamps
Steel-making shop: Approximately 500 lamps
Rolling mill : Approximately 2,300 lamps
Total : Approximately 3,000 lamps

For these, there is almost no problem in color rendering properties. Therefore, replacement with sodium lamps (though there are the positions where illuminance is poor) will be an aid to energy conservation. Since about 80 % of the above is estimated to be convertible to sodium lamps, provided that converting mercury lamps to sodium lamps has an energy conservation effect of 40 %, the following result can be obtained.

3,000 lamps × 0.8 × 400 W × 0.4 = 384 kW

Electricity saving in a year: 384 kW × 8,760 h = 3,360 MMh

2) Motor

① Pump (Step 2)

The annual electricity consumption for pumps is 26,000 MWh. Results of the investigation revealed that the flow of cooling water is not adequately controlled, and an excessive amount of water is being used. Optimal flow rate and water pressure for each facility should be grasped and adjusted, adjustments to cooling water volume rates should be made between summer and winter, water quantity should be adjusted according to differences in operation rates, water flow rate should be adjusted when equipment are stopped, and other adjustments should be carried out meticulously as part of an effort to achieve energy conservation. Moreover, it cannot be overstressed that energy conservation measures such as reducing the number of pumps, and introducing a variable speed control, and others based on results created by these adjustments should be devised.

If these measures are taken, at least a 10 % energy conservation should be possible.

26,000 MWh × 0.1 = 2,600 MWh

② Dust collecter blower

On the day of the survey, the state of facility use of the dust collector blowers was a 67 to 73 % operation rate for the 4 units for the 140 t furnace, 69 to 80 % for the 2 units for the 70 t furnace, and thus, it was revealed that they are running with plenty of allowance. The amount of dust generated by an electric arc furnace fluctuates greatly from right after start of operation to end of smelting. Thus, by carrying out modifications so that the blower's rotation can be controlled in accordance with the rate of dust being generated by the electric arc furnace, it becomes possible to save a substantial amount of energy. Although no concrete recommendations can be made here, since the factory initially planned for our survey changed, and the matter could not be investigated adequately, we hope the state of operation and dust generation will be investigated thoroughly in the future, and consideration will be given to introducing such a system.

3) Air compressor

The annual electricity power consumption by air compressors is approximately 15,000 MWh for oxygen generation and approximately 15,000 MWh for general purposes. Air compressors for oxygen generation are excluded from our study subjects because their planned updating is now under way. Unfortunately, the general purpose reciprocate type air compressors were either undergoing overhaul or repairs, and measurements could not be conducted on the day of our survey, and thus, we are not in a position to provide concrete recommendations. Therefore, measurements need to be taken again under normal conditions in the future.

4) Transformer

The iron loss of the 63 MVA transformer was 63.33 kW and the full-load copper loss was 255 kW according to the test certificate. Thus, the maximum efficiency of this transformer is 99.6 % of that at 31.4 MVA. The iron loss of the 25 MVA transformer was 26.625 kW and the full-load copper loss was 123.624 kW according to the test certificate. Therefore, the maximum efficiency of this transformer is 99.5 % of that at 11.6 MVA. Although the current load status should be checked, the energy conservation effect will not be admitted.

(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 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 1.2.20.

Table 1.2.20 Emission Improvement by Energy Conservation Measures

Measure	Reduction [ton/year]			
	CO_2	SO_2	NO_2	Dust
Step 0	6,059	16.2	92.2	0.9
Step 1	27,647	3.7	435.4	0.6
Step 2	12,634	5.7	198.1	0.5
Step 3	18,724	1.3	295.1	0.3
Step 1-3	59,005	10.7	928.7	1.4

Reduction includes emission from fuel and electricity.

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

The result of calculating the amounts of reduction in pollutant emission, for the energy conservation items that were proposed based on our factory survey, and the corresponding reductions in emission fees, is shown in Table 1.2.21. Furthermore, the length of time required to recover investments in energy conservation including the effect of reduced emission fees, and the payback period based only on fuel reductions, are listed together in this table.

Table 1.2.21 Payback Period Improvement by Emission Fee Reduction

Measures	Energy cost advantage	Emission fee advantage	Total advantage	Investment	Eco-Environ. PBP	Economical PBP
Step 0	16,029	33.6	16,063	0	0.00	0.00
Step 1	13,982	136.0	14,118	6,857	0.49	0.49
Step 2	6,886	63.1	6,950	20,829	3.00	3.02
Step 3	4,748	91.8	4,840	13,143	2.72	2.77
Step 1-3	25,617	290.9	25,907	40,829	1.58	1.59

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

As evident from this Table 1.2.21, the reduction in emission fee is only a few percents at most compared to reduction in energy cost, and thus, the effect of reduced emission fees on the investment recovery period is also negligible.

Although the payback is small for Step 3 at this factory, it should be noted that the improvement item includes changes to the production process such as hot charges, and thus, the establishment of technical management is required.

b. Summary of Energy Conservation Potential

The energy conservation potential of this factory is shown in Table 1.2.22.

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 1.2.10. The relationship between energy conservation potential, the payback period, and the investment cost is shown in Figure 1.2.11.

Table 1.2.22 Summary of Energy Conservation Potentials

Electricity: 0.172 PLN/kWh Coke: 400 PLN/t (27.1 GJ/t) Natural gas: 0.514 PLN/m^3_N (35.5 MJ/m^3_N) Steam: 13.14 PLN/GJ (28 GJ/t)
1 PLN = 30 yen

Item	Energy Conservation Potential							Investment	Payback period
	Fuel			Electricity			Total		
	GJ/y	10^3 PLN/y	%	MWh/y	10^3 PLN/y	%	10^3 PLN/y	10^3 PLN	year
Step 0 (Under construction or planning)									
1. EAF: Carbon injection and natural gas injection (Tap to tap time reduction)				42,114	7,244	6.7	7,244	-	-
Injecting natural gas (4 m^3_N/t)	Δ92,000	Δ1,332	Δ2.7						
Increasing the coke injection (5 kg/t)	Δ87,790	Δ1,296	Δ2.6						
Increasing the volume of oxygen for natural gas combustion (8 m^3_N/t)				Δ3,385	Δ582	Δ0.5	Δ582	-	-
2. CC process and rolling mill improvement				20,318	3,495	3.3	3,495	-	-
3. Changing the insulating material for the forge-heating furnace to ceramic fiber, and so on(Including the enhancing of the process control)	265,592	3,845	7.7				3,845	-	-
4. Purchasing oxygen from BOC (Oxygen supplier)	11,228	163	0.3	11,782	2,027	1.9	2,190	-	-
Subtotal	97,030	1,380	2.8	70,829	12,184	11.3	16,192	-	-
Step 1									
5. Reducing the tap-to-tap time of 140t EAF (Reducing the electricity consumption for auxiliary equipment)				6,479	1,114	1.0	1,114	0	0
6. Rolling: Improving the yield	90,920	1,316	2.7	24,969	4,298	4.0	5,614	0	0
7. Rolling: Decreasing the equipment failure/miss roll rate and improving the heat holding standards	86,348	1,250	2.5				1,250	0	0
8. Rolling: Optimizing the air ratio of the reheating furnace	191,490	2,773	5.6				2,773	0	0
9. Optimizing the air-fuel ratio of the forge-heating furnace and taking a preventive measure against ingress of air, such as improvement of door sealing	162,744	2,356 0	4.8	1,499	258	0.2	2,614	4,000	1.5
10. Optimizing the air ratio of the forging heat treatment furnace and improving the sealing	42,582	617	1.2				617	2,857	4.6
Subtotal	574,084	8,312	16.8	32,967	5,670	5.3	13,982	6,857	0.5
Step 2									
11. 140t EAF: scrap preheating equipment (20 kWh/t)				12,957	2,229	2.1	2,229	5,714	2.6
12. 70t EAF: Scrap preheating equipment (30 kWh/t)				2,727	469	0.4	469	1,429	3.0
13. Rolling: Providing the primary reheating furnace with ceramic fiber insulation	37,079	537	1.1				537	1,143	2.1
14. Rolling: Providing the secondary reheating furnace with ceramic fiber insulation	84,825	1,228	2.5				1,228	1,429	1.2
15. Rolling: Improving the opening of the reheating furnace (prevention of infiltrating air)	24,889	360	0.7				360	143	0.4
16. Improving the heat insulation for the forge-heating furnace and process control	71,695	1,038	2.1				1,038	5,714	5.5
19. Lighting: Using sodium lamps				3,360	578	0.5	578	1,971	3.4
20. Controlling the pump revolution				2,600	447	0.4	447	1,237	2.8
Subtotal	218,488	3,163	6.4	21,644	3,723	3.5	6,886	18,780	2.7
Step 3									
21. Rolling: Improving the hot charge rolling rate	170,157	2,464	5.0				2,464	7,143	2.9
22. Installing an exhaust gas boiler for the roll reheating furnace	23,057 (Steam)	334	0.7				334	1,714	5.1
23. Installing an exhaust gas boiler for the electric furnace	87,085 (Steam)	1,261	2.5				1,261	3,429	2.7
24. Heat recovery from the electric furnace cooling water	47,624 (Hot water)	690	1.4				690	857	1.2
25. Abolition of the secondary reheating furnace for the rolling mill	{84,824}								
Subtotal	327,923	4,748	9.6				4,748	13,143	2.8
Total (Steps 1, 2, and 3)	1,120,495	16,224	32.8	54,611	9,393	8.7	25,617	38,780	1.5

As of 1996: Fuel consumption: 3,419,092 GJ/y
Electricity consumption: 626,637 MWh/y (6,428,042 GJ/y)
Total: 9,847,134 GJ/y

Figure 1.2.10 Ostrowiec Energy Conservation Potential

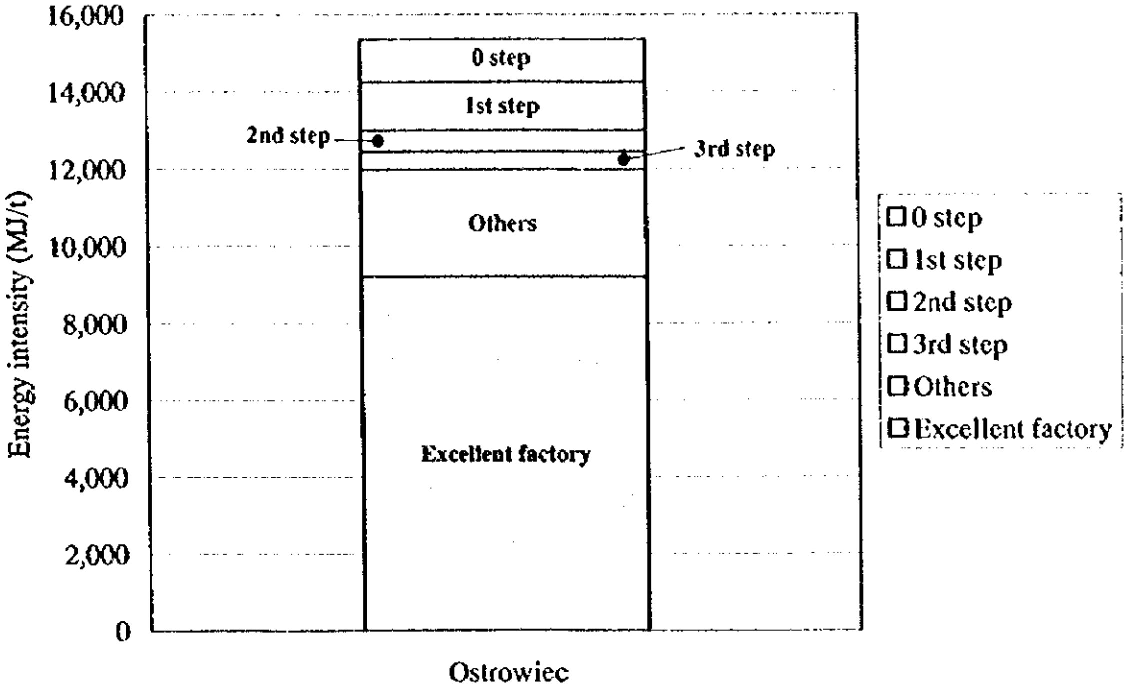


Figure 1.2.11 Ostrowiec Energy Conservation Potential