Japan International Cooperation Agency (JICA)

Plan and Budget Organization (PBO)
The Islamic Republic of Iran

TECHNICAL COOPERATION ON ANALYSIS OF ENERGY CONSERVATION AND RATIONAL USE OF ENERGY IN THE SOCIAL AND ECONOMIC SECTORS OF THE ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

III. Results of Factory Energy Diagnosis

September 1997

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

Japan International Cooperation Agency (JICA)

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1. RESULTS OF THE STUDY ON THE IRON AND STEEL INDUSTRY

1.1 Results of the Study at Esfahan Steel Company

1.1.1 Plant Outline

(1) Plant name

Esfahan Steel Company

(2) Plant address

Km 45 - Shahrekord Road, Esfahan

(3) Number of employees

11,600

(4) Major product name

Steel bar (Round bars, flat bars, square bars, and deformed round bars),
Shapes (I beams, channels and angles), and
Rails

(5) Production capacity

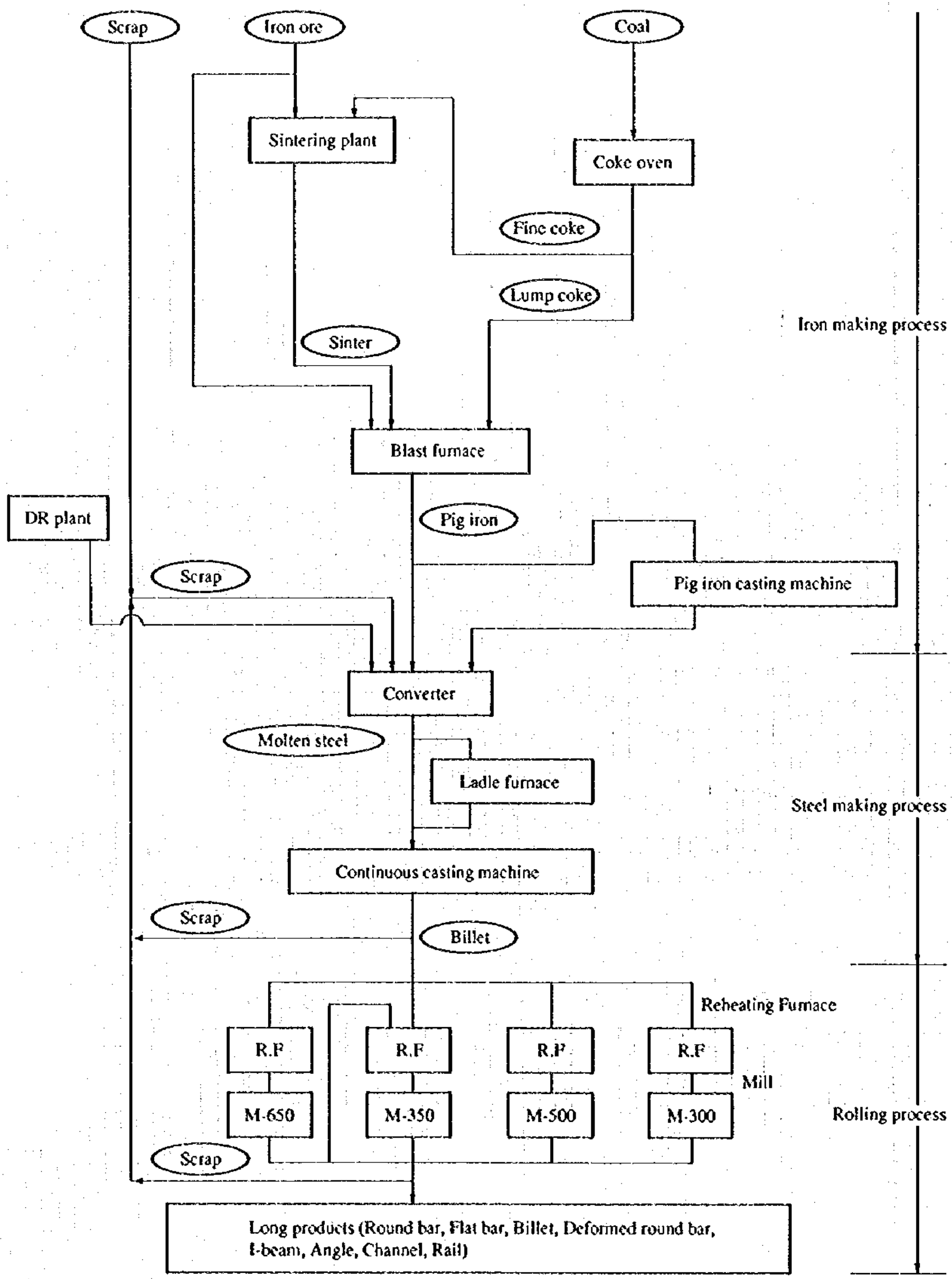
Product 1,900,000 ton/year

(6) Outline of the process

Esfahan Steel has two blast furnaces (1,033 m^3 and 2,000 m^3), three converters (130 t/ch) and four steel bar rolling mills. It is the integrated steel works to produce steel bars, shape steels and rails. The production process flow diagram is shown in Figure 1.1.

Their coke ovens and blast furnaces are being fully operated. This means that their pig iron production capacities are smaller than those of down processes. Therefore, they are now constructing DR (Direct Reduction) plant to make up for them.

Figure 1.1 Production Process Flow Diagram



(7) Plant history

In January 1966, they concluded the contract with the former U.S.S.R.(now the Republic of Russia) to build the iron and steel plants. In 1972, the integrated steel works with an annual production capacity of 550,000 t (the first stage construction) was completed. It was followed by additional contracts with U.S.S.R. In 1988, on completing second stage construction, the annual nominal production capacity of the integrated steel works reached 1,900,000 t, which was practically achieved in 1989.

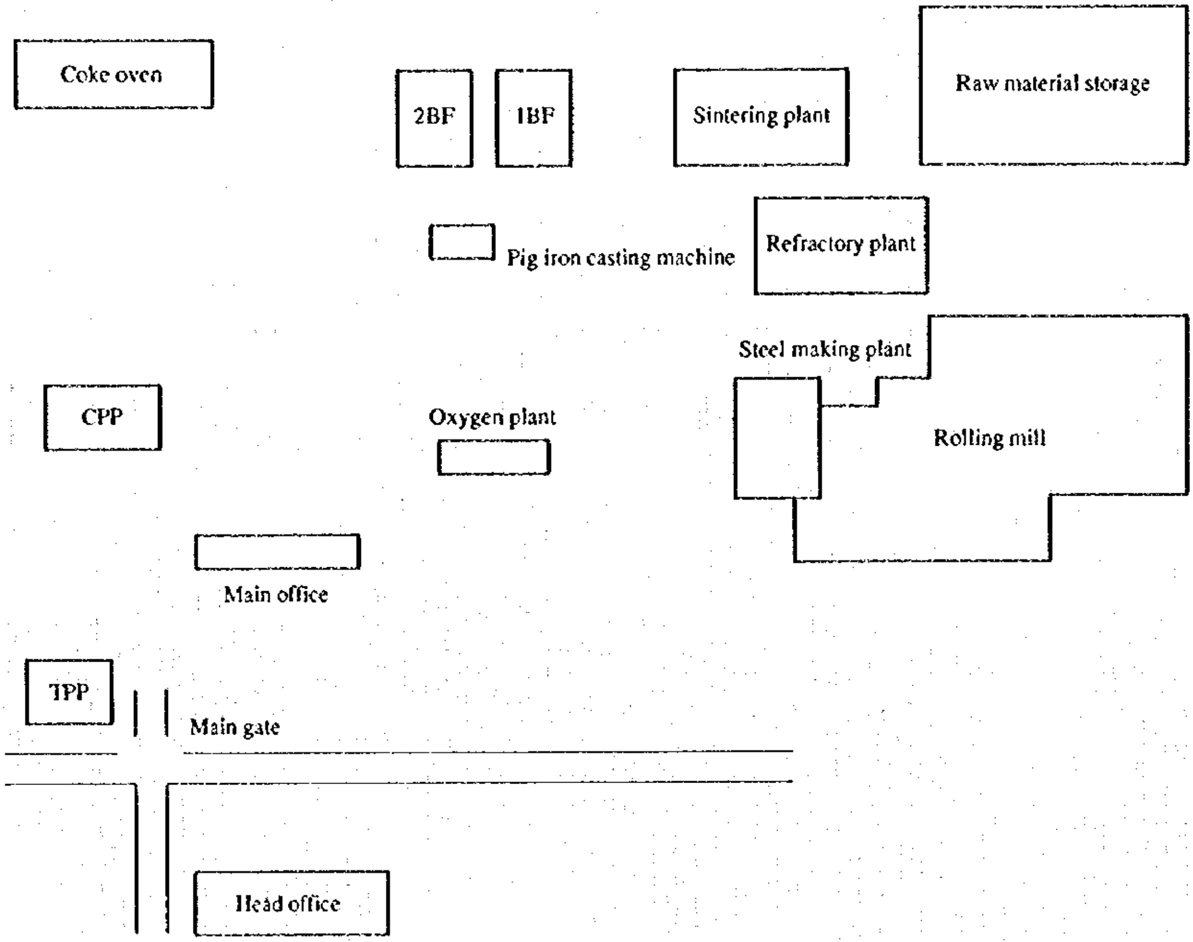
They are now replacing the converters and continuous casting facilities to enhance their production capacity. In their attempt for energy conservation, the waste heat recovery boiler for converters and continuous casting facilities are now being introduced. However, since the ways of operation and their facilities have been little improved, the energy intensity per unit ton of crude steel is much worse than expected.

In 1995 and 1996 when our study was conducted, blast furnaces were of a relining type. Hence, data in 1994 was used.

(8) Plant layout

Figure 1.2 shows the plant layout.

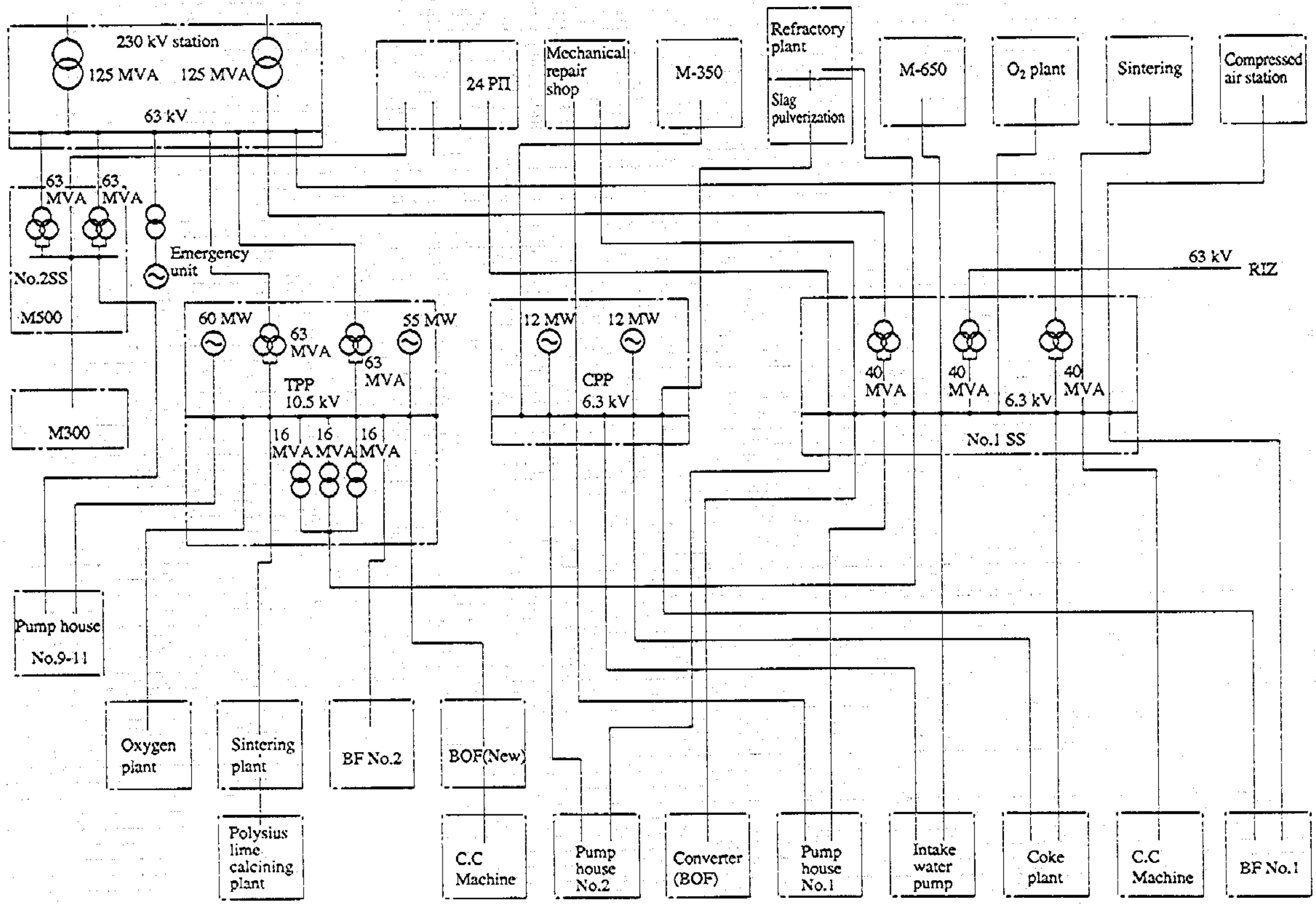
Figure 1.2 Plant Layout



(9) One line diagram

Figure 1.3 shows the one line diagram.

Figure 1.3 One Line Diagram



(10) Outline of major facilities

This integrated steel works was constructed in compliance with the technologies and facilities from the former U.S.S.R. Table 1.1 shows the outline of major facilities.

Table 1.1 Major Equipment

Name	Number	Specifications
Sinter plant	3	75 m^2
Coke oven	2	total 130 cells, 22 t/oven
Blast furnace	2	1,033 m^3, 2,000 m^3
Converter	3	130 t/ch, 2/3 operation
Continuous caster	7	total 2,500,000 t/y
Reheating furnace	4	90 t/h, 60 t/h, 200 t/h, 200 t/h
Rolling mill	4	Bar mill 650,500,300
		Bar and wire rod mill 350
Thermal power plant	3 boilers	100 kg/cm^2, 540 °C, total 2 generators, 115 MW
Central power plant	4 boilers	40 kg/cm^2, 440 °C, 4 blast blower, total 2 generators, 24 MW
Oxygen plant	6	11,000 m^3_N O_2/h
Main transformer	2	125/150 MVA, 230 kV

a. Sintering plant

It consists of three U.S.S.R. made sintering machines with 75 m^2 each. Their annual production capacity in total amounts to 2,516,000 ton. Their production rate based on the operating days in 1994 was 1.46 t/(h·m^2). Although the facilities become too old, they have been well maintained with much operating effort.

b. Coke ovens

They have two batteries of U.S.S.R. made coke ovens with 130 cells in total. The production capacity amounts to 1,150,000 t/y in terms of coke. Their working rate in 1994 was as high as 138.8 percent. Although they held smooth operation, pretty much gas leakage was observed at the doors.

c. Blast furnaces

There are two U.S.S.R. made blast furnaces which have the total furnace inner volume of 3,033 m^3 for two units, with production capacity of 1,925,000 t/y. The production in 1994 amounted to 5,235 t/d in average or 5,417 t/d per operating day. This means that the productivity of iron is 1.79 t/m^3·d (averaged for operating day), which is an outstanding achievement for the blast furnace with low top pressure.

They have to import 40 percent of coal and moreover, they are short of coke due to the coke oven capacity. This leads them to injecting a huge volume of economical domestic natural gas to increase the production of pig iron. The domestic iron ore is used in full.

d. Converters and continuous casting facilities (CC)

Originally, three converters and four continuous casting machines, both from U.S.S.R., were installed. Later, the vessels of converters were replaced with those with the capacity of 130 t/ch by means of Japanese technology, and the continuous casting machines are being replaced by adopting Italian technology. They are now in process of modernization. The tapping frequency comes up to 51 times per day. Troubles and the stop caused by repairing works have been hardly seen, and the production is smoothly going on. The production capacity of CC amounts to 2,500,000 t/y.

e. Rolling mills

They have four U.S.S.R. made rolling mills (M-500, M-300, M-650, and M-350). The production with an annual capacity of 2,150,000 t/y is favorably performed.

Their major products are shapes such as I-beam and channel, and steel bar.

Each rolling mill has its own reheating furnace. The reheating furnaces for M-500 and M-300 are of walking beam type and those for M-650 and M-350 are of pusher type. Their capacities are 900,000 t/y of M-500, 700,000 t/y of M-300, 750,000 t/y of M-650 and 320,000 t/y of M-350.

In relation to the production capacity of CC, M-350 which produces steel bar of 5.5 to 16 mm dia uses the billets produced by M-650.

f. Power plant and blast furnace blower facility

Eighty percent of the electricity consumed in the steel plant is generated by Thermal Power Plant (TPP) and Central Power Plant (CPP). The balance is purchased from outside source. TPP is the exclusive electricity power plant to utilize high temperature and high pressure steam conditions.

CPP is composed of the power plant and the blast blower facilities. It also has a special boiler composed of superheater to superheat 40 kg/cm^2 steam generated as the byproduct from converters.

g. Plant electricity facility

The necessary electricity is normally supplied from two private power generating plants and purchased electricity from two external systems. In addition, they have the gas turbine power generating facility for emergency use.

As shown in the electricity one line diagram in Figure 1.3, the purchased electricity from the first system is provided through 230 kV two lines (Nasac Abad) and stepped down to 63 kV by a 125 MVA transformer. The other purchased electricity from the second line (Riz) received via two 63 kV lines is put in parallel with the first electricity system on the 6.3 kV main line of No. 1 SS. One of private generating power plants is TPP (Thermal Power Plant) to generate with 10.5 kV and the other is CPP (Central Power Plant) to generate with 6.3 kV. TPP supplies electricity from a 60 MW and a 55 MW generators. CPP supplies electric power from two 12 MW generators. Within the whole plant, the electricity from TPP to the related plants is supplied with 10.5 kV, and that from CPP and the purchased electricity via No. 1 SS are provided with 6.3 kV. Both 10.5 and 6.3 kV systems are connected through three 16 MVA transformers located in TPP.

(11) Energy prices

Coal : 55 to 60 US$/t
Natural Gas : 20 Rial/m^3_N
Oil : 20 Rial/kg
Electric Power: 50 Rial/kWh (purchased)
Electric Power: 40 Rial/kWh (private)
BFG : 3 Rial/m^3_N
COG : 8 Rial/m^3_N
1 US$ = 3,000 Rial (As of June 1996)

(12) Study period

a. Preliminary study: October 2 and 3, 1995

b. Plenary study : June 22 to 26, 1996

(13) Members of the study team

a. JICA team

Leader : Norio Fukushima
Process management technology : Seiichiro Maruyama
Heat management technology : Jiro Konishi
Heat management technology : Kenji Kazuma
Electricity management technology: Kazuo Usui
Energy policy : Syin-ya Udo (Preliminary study)
Economic evaluation : Shigeaki Kato (Preliminary study)

b. PBO team

Energy conservation	:	Mr. Mazhari
Energy conservation	:	Mr. Akhavan (Preliminary study)
Micro level energy management	:	Mr. Mianji (Preliminary study)
Macro level energy management	:	Mr. Azizi
Instrumentation	:	Mr. Shayesteh

Mr. Alavizadeh: Advisory Commitee (Preliminary study)

(14) Interviewees

Mr. S. M. Tahaie	:	Senior Energy Manager (Preliminary)
Mr. M. M. Sadeghi	:	Energy Manager (Preliminary)
Mr. J. Hashemijou	:	Power Plant Manager
Mr. H. Ghanoony	:	Electrical Energy Manager (Preliminary)
Mr. H. Bateni	:	Deputy of Electrical Energy Manager (Preliminary)
Mr. M. A. Tabaie	:	Head of Networking & sub-stations
Mr. M. Rafiazadeh	:	Deputy of Power Plant Manager (Preliminary)
Mr. M. Latify	:	Expert Economist (Preliminary)
Mr. M. R. Farghadani	:	Deputy Manager Director
Mr. S. Motamen	:	Product Senior Manager
Mr. H. Fakhari	:	Manager of Technical Department
Mr. M. R. Khosravi Rad	:	Engineer of Technical Department
Mr. H. Z. Motallebi Pour	:	Engineer of Steel Making Department
Mr. M. Yazdan Panah	:	Engineer of Power Plant
Mr. H. Baluchesto	:	Sintering Plant Manageer
Mr. H. Aslani	:	Economic Department Manager
Mr. M. Derakhshani	:	Blast Furnace Manager
Mr. Asnaashari	:	Deputy of Water Treatment Department
Mr. Maherani	:	
Mr. Ghorbani	:	Expert of Economist
Mr. Sadri	:	Deputy of Rolling Mill Department

1.1.2 Energy Consumption

(1) Production and energy consumption

a. Production

This iron and steel works has a nominal production capacity of 1,900,000 t/y. In general, their productive operation is being well performed. Table 1.2 shows the trend of products in quantity. Table 1.3 shows their major products in quantity, 1994.

Table 1.2 Long Product Steel Production (10^6 t/y)

	1991	1992	1993	1994
Production	2.2	2.1	1.95	1.91

Table 1.3 Production in 1994 (10^3 t/y)

Products	Production
Coke	1,033
Sinter	2,368
Pig iron	1,911
Molten steel	1,945
Bloom, billet	1,881
Rolling product	
I-beam	936
Bar	703
Billet	229
Channel	28
Angle and rail	13
Sub total	1,909

b. Operation rate

Table 1.4 shows the operation rates of major facilities which are understood to be on the standard level. The operation rate of sintering facility seems a little lower, because of much downtime due to some operational reasons. As for the blast furnaces, the operation rates look worse than those of Japanese average of 98.6 %. However, their rates are not very much inferior to Japanese average, when we consider their furnace top pressure and productivity of iron.

Table 1.4 Process Available Time Rate

Name		Non Working Time A	Non Working Time B	Non Working Time C	Available Time Rate
Sinter plant		4,583 h	2,553 h	2,030 h	92.3 %
Blast furnace		591	1	590	96.6 %
Rolling mill	650	2,490	1,734	756	91.4 %
	350	1,164	53	1,111	87.3 %
	500	2,795	1,858	937	89.3 %
	300	2,914	2,064	850	90.3 %
Total		9,363	5,709	3,654	89.6 %

Note: Non working time A : B + C
Non working time B : by operational reason
Non working time C : by trouble or maintenance

$$\text{Available time rate} = 1 - \frac{\text{Non working time C}}{\text{Calendar day} \times 24 \times \text{machine number}}$$

c. Yield

The yield is shown in Table 1.5. Although we couldn't completely obtain their data during the study period, we estimate their yield of steelmaking is 89.7 percent and that of rolling stays around 93 to 94 percent. It seems that there may be a room for further improvement.

Table 1.5 Yield of Main Process

Converter	89.7 % Molten steel/(pig iron + scrap)
Rolling mill	94.0 % (Design), 93 ~ 94 % (Estimated)
M-350	92.9 % (Deformed round bar)

d. Energy consumption

Table 1.6 shows the trend of the energy consumption, while Table 1.7 shows the energy consumption and energy intensity per ton of crude steel in 1994.

Table 1.6 Energy Consumption

	Unit	1990	1991	1992	1993	1994
Coal	10^3t	1,161	1,421	1,391	1,317	1,417
Natural gas	10^6m^3	599	696	643	710	705
Diesel oil	10^6L	1,872	2,658		2,184	2,182
Fuel oil	kL				20,301	
Electricity	GWh	872	1,053	1,093	1,052	1,108
In-house generation	GWh	1,161	989	920	852	914

Table 1.7 Energy Intensity in 1994

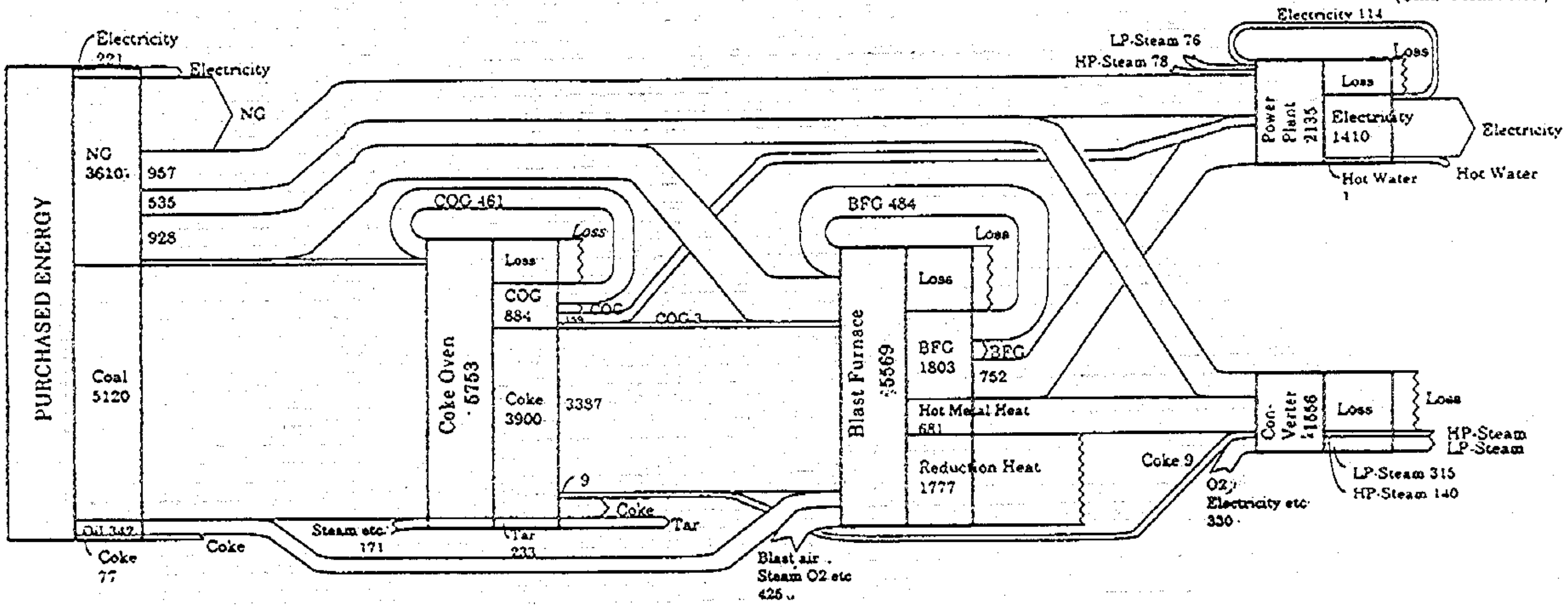
Name	Quantity	Calorific Value	Calorie	Unit Consumption
Coal	1,301.4 × 10^3 ton	7,400 kcal/kg	9,630 Tcal	5,119.9 Mcal/t-steel
Coke	20.5 × 10^3 ton	7,100 kcal/kg	146	77.4
Tar	−48.9 × 10^3 ton	8,800 kcal/kg	−430	−228.7
Oil	71.4 × 10^3 kL	9,000 kcal/L	643	341.8
Electricity	169.8 × 10^6 kWh	2,450 kcal/kWh	416	221.1
Natural gas	707.9 × 10^6 m^3_N	9,593 kcal/m^3_N	6,791	3,610.3
Total			17,196 Tcal	9,141.8 Mcal/t-steel

(2) Energy flow and net energy intensity by process

The energy flow and energy intensity by process are shown in Figure 1.4 and Table 1.8 respectively.

Figure 1.4 Energy Flow

(Unit: Mcal/t-steel)



Energy Consumption

– : Production
Net: (Consumption) – (Production)

(unit: Mcal/t-steel)

	Energy Intensity	Coke Oven	Sintering Plant	Blast Furnace	Converter + CC	Calcining + Dolomite	Rolling Process	CPP TPP GT	O_2 Plant Air Consumption	Others Including Water Plant	Energy Distribution Loss	Equivalent Net Heat Value
Electricity	221	49	131	54	144	26	235	115 –1,190	436	209	13	2,450 kcal/kWh
Blast Air	0			220				–220				175 kcal/m³N
O_2	0			119	116	4	1		–294	19	35	1,700/1,225 kcal/m³N
Air	0				19				–54	35		175 kcal/m³N
NG	3,610	1		928	535	328	815	956		46		9,593 kcal/m³N
COG	0	461 –884	67	3	46		69	159			79	4,091 kcal/m³N
BFG	0			484 –1,803			73	752			494	1,026 kcal/m³N
Tar	–229	–233				4						8,800 kcal/kg
Steam	0	122		32	5 –455	4	6	153	12	120		
Coal	5,120	5,120										7,400 kcal/kg
Cokes	77	–3,900	567	3,387	9	14						7,100 kcal/kg
Oil	342			342								9,000 kcal/l
Hot Water	0							–1		1		
Heat difference	0	–103								103		
Net	9,142	633	765	3,766	420	380	1,200	724	100	533	620	
(%)	100 %	6.9 %	8.4 %	41.2 %	4.6 %	4.2 %	13.1 %	7.9 %	1.1 %	5.8 %	6.8 %	
Indices	t-product/t-steel	0.6919	1.2591	1.0157	1.0000	0.1267	0.9531	(0.5754 MWh/t)	(0.2089 km³N/t)	1.0000	1.0000	

Table 1.8 Energy Intensity by Process

	Energy Intensity/t-steel	Energy Intensity/t-product
Coke oven	633 Mcal/t-steel	915 Mcal/t-coal
Sinter plant	765 Mcal/t-steel	608 Mcal/t-sinter
Blast furnace	3,766 Mcal/t-steel	3,708 Mcal/t-pig
Steel making	420 Mcal/t-steel	420 Mcal/t-steel
Calcining + Dolomite	380 Mcal/t-steel	3,000 Mcal/t-product
Rolling mill	1,200 Mcal/t-steel	1,259 Mcal/t-long product
CPP	455 Mcal/t-steel	5,432 kcal/kWh
TPP	262 Mcal/t-steel	3,152 kcal/kWh
GT-Generation	7.2 Mcal/t-steel	4,650 kcal/kWh
O_2 + Air compressor	100 Mcal/t-steel	
Others	533 Mcal/t-steel	
Loss	620 Mcal/t-steel	
Total	9,142 Mcal/t-steel	

Since each process in the iron and steel works generates (or generates as byproduct) and consumes energy, the energy intensity for each process is defined as the value obtained by subtracting the generated energy from the consumed energy and dividing the value by the product quantity of respective process.

The energy intensity of this works in 1994 is 9,142 Mcal/t-crude steel which consumed 1.6 times more energy than that of Japanese integrated steel works. Although those data on the production quantity, operation rate of facilities and yield are never unfavorable, the energy intensity does not seem to be so good as we have expected. The possible reasons for this are:

a. With their strong intention to increase the production of blast furnaces, they are forced to operate them with higher fuel rate.
This results in poorer energy intensity.

b. Although they recover the waste heat from converters, a good deal of fuel is consumed to heat and dry up ladles and tundishes. This makes the energy intensity worse.

c. The fuel intensity of rolling reheating furnace is too bad.

d. The mutual adjustments of production between relevant processes are essential to minimize energy loss. This is not well carried out.

For example, it is advisable that the production plan and energy distributing plan should be prepared simultaneously. Based on these plans, the operating schedules between related lines should be adjusted in order to consume the most of BFG.

e. There are not a few buffering facilities to absorb the fluctuation of byproduct gas (an example: the thermal power plant (TTP) can burn BFG up to only 25 percent of the boiler load). This compels BFG to be discharged useless when its volume becomes too redundant.

1.1.3 The Status of Energy Management

(1) Setting the target for energy conservation

In this diagnosis, to our regret, we could not obtain information on the target established to improve energy intensity in this works.

We originally thought that they might have less interest in energy conservation in I. R. Iran due to the fact that the prices of domestic energy such as heavy oil, natural gas and electricity were quite inexpensive. This turned out to be a misconception, when we found to our surprise a strong interest in energy conservation by everybody from top management down to workshop supervisors.

On visiting each plant, we were often asked for our views and comments on their energy conservaton efforts and the current situation of energy intensity as well as about energy intensity levels achieved in Japan.

Judging from their serious attitude to cope with the energy conservation issue raised from both top management and staffs, supposedly the macro target (an example: to achieve 5 % of energy conservation in five years) by the Energy Conservation Committee has well been set up.

(2) Systematic action

In response to our question about the action program of the Energy Conservation Committee, they gave us following replies, although, they said, there were few outcomes to be announced.

Energy Conservation Committee

- Action status: At the meeting held once a month, the energy consumption status in each plant is studied.

- Target:
  1) To get their target closer to the international standard of enegy conservation.
  2) To promote energy conservation through technology improvement.
  3) To achieve energy conservation by increasing efficiency through improvement and maintenance activities.
  4) To attempt energy conservation through improvement of process.
  5) To reduce cost through the more intensive management of electricity demand.

The company top management recognize the importance of energy conservation and have in mind the definite target for their plant to get closer to the international standard. However, due to the lack of the overseas information on the operation technology of processes in the iron and steel works and the diagnosis techniques on energy consumption that are helpful for improving processes, they seem to be at a loss how to approach the theme to achieve the energy conservation target.

Since the integrated steel works duly integrate a variety of energy, the organized promotion for energy conservation is mandatory. Followed by the definite top management's policy, all the employees with energy conservation mind should develop the action program of total company-wide movement.

It is needless to say that the Energy Conservation Committee as the core of the movement should have all the employees fully understand the management's policy. Additionally, the project teams consisting of working level staffs may well be organized to study the energy conservation issues encompassing the different processes as well as the common problems for each process.
The study results should be duly reported to the Energy Conservation Committee to have them executed through the management.

In addition, in order to attain the improved operations and facilities in each process, the process engineers must be properly informed of the data on measuring and evaluating the various energy issues so as to understand the real aspects of processes. Doing these works may require four to five experts at least. It is suggested that the selected engineers, one per each process, should be trained to be the experts through actual works.

(3) Data-based management

All the actions must be based on the "Data". The energy consumption records and conditions have to be quantitatively determined as the "Data" and compared to the initially planned figure. At the same time, in case of the wrong discrepancies shown between them, their causes should be investigated to take proper measures and be turned to practical use as the pieces of information to improve the energy intensity. If these systems are completed, the energy management based on the data can be said to be well executed.

Multiple kinds of energy are consumed in this iron and steel works. Daily reports on energy consumption are made in each process, and cumulatively added up to the monthly report to be submitted to the manager of each process.

In case there appear some change of energy intensity in relevant processes, they seem to try to investigate the causes. However, the acquired data do not always seem to be utilized for improving the energy intensity.

All the staffs concerned, not limited to a few of them, should be aware of the acquired data so that the data may serve the energy intensity improvement. It is also necessary to show every day the energy intensity graph to workshop operators to have them think why the energy intensity is changed. In doing so, they will be soon prepared to take necessary measures, in other words, to take part in the energy conservation action program joined by the all concerned.

(4) Education and training of employees

Since the mode of energy consumption is often influenced by people's daily operation, it is essential to teach the operators the proper operation methods with their standards and have them abide by those methods. In addition, various kinds of education and training are necessary. These range from basic knowledge to the middle class knowledge such as the outline of process, structure and function of major equipment, approaches to solve problems and quality control (QC) methods.

It seems that the foreman of each process in this factory is excellent in recognizing relevant issues and getting hold of information, which suggests that their education about the process operations is aptly performed. On the other hand, however, the education to operators in processes for energy conservation seems to be not yet implemented, judging from their ways of using energy.

(5) Equipment maintenance

Any plant is cleaned up. Little steam leakage and insulation peeling can be seen. We are impressed with the plants being well maintained despite their age.

Considering their full capacity operation and difficulty to get spare parts, the maintenance conditions of facilities are well evaluated with fewer break down rates than normally supposed. However, it is a little regrettable to say that there still remain some points to be improved. An example is the BFG volume burnt in TPP (the thermal power plant). Although 80,000 m^3_N/h BFG per a boiler could have been burnt down in the boiler design, only 40,000 m^3_N/h can be burnt (probably since the completion of installation). If the equipment maintenance in each process, together with its improvement, is carried out to get closer to the originally designed figures at least, their energy intensity would become better.

1.1.4 Issues in the Energy Consumption and Countermeasures

(1) The comparison with Japanese new iron and steel works

a. Energy intensity per ton of crude steel

The energy intensity per ton of crude steel of Esfahan Steel (hereinafter referred to as "Esfahan") amounts to 9,142 Mcal/t, which means they consume 1.6 times as much energy as Japanese iron and steel works.

In Japan, they operate the steel works with mainly coal, producing most of electricity and fuel by themselves by using byproduct gas (COG, BFG and LDG), because each process has good energy intensity. On the other hand, in Esfahan, although their blast furnaces operate under high fuel ratio, the energy intensity of each process is so poor that they have to purchase plenty of natural gas from the outer source to make up for the deficiency of their fuel. Therefore, they produce only 50 percent of necessary fuel by themselves.

b. Net energy intensity of each process

Table 1.9 shows the comparison of the energy intensity of each process between Japan's typical new iron and steel works (hereinafter referred to as "JNSW") and Esfahan.

Table 1.9 Comparison of Energy Intensity of Each Process

Process	Product		(PI)	Esfahan Energy intensity (E)	Esfahan PI × E	JNSW Energy intensity (E)	JNSW PI × E
				Mcal/t-p	Mcal/t-s	Mcal/t-p	Mcal/t-s
Coke oven	(Coal)	t	0.6919	916	633	543	376
Sinter plant	Sinter	t	1.2591	608	765	378	476
Blast furnace	Pig iron	t	1.0157	3,708	3,766	3,082	3,130
Steel-making	Crude steel	t	1.0000	420	420	30	30
Rolling mill	Rolling product	t	0.9531	1,259	1,200	617	588
CPP	Power and blast	MWh	0.1693	2,685	455	596	101
TPP	Power output	MWh	0.4029	650	262	–284	–114
GT-Generation	Power output	MWh	0.0032	2,231	7	–	7
O_2 + Air comp.	O_2 product	$10^3 m^3_N$	0.2089	479	100	–83	–17
Calcinig dolomite	(Crude steel)	t	1.0000	380	380	–	380
Others	(Crude steel)	t	1.0000	533	533	538	538
Loss	(Crude steel)	t	1.0000	620	620	133	133
Total	Crude steel	t	1.0000		9,142	–	5,628
Corrections by converter yield			–	–	base	–	–133
Total			–	–	9,142 Mcal/t-crude steel	–	5,495 Mcal/t-crude steel

Note 1: PI = Production ton of each process/crude steel ton
2: Corrections by converter yield are made as follows.
$(376 + 476 + 3{,}130) \times (92.7 - 89.7) / 89.7 = 133$
3: 92.7 is converter yield of Japan and 89.7 is that of Esfahan, at same hot metal ratio.

c. The comparison of energy intensity per ton of crude steel

In calculating the energy intensity per ton of crude steel in JNSW shown in Table 1.9, we set up Σ (PI) × (E) to obtain the value, on assumption that the production ratio of each process would be same as that of Esfahan, and corrected the effect generated by the converter yield.

Thus, on the presumption of producing the same types of products, the comparisons between two parties or previous year and this year may be established. However, upon comparing the energy intensity per ton of crude steel between the two iron and steel works with different product mix, the comparison should be made after the correction of at least the following items.

- Hot metal ratio of converter
- Purchased ratio of coke
- Purchased ratio of sinter
- Secondary rolling product/Primary rolling product

(2) Problems with each process and countermeasures

We would like to describe the problems and improvement plan (or countermeasure) of each process , comparing the energy intensity of correspondent processes in "JNSW". For your reference, the measure to reduce the intensity, examples of the improved operation and equipment together with their outcomes are given on the Guideline.

a. Coke oven (including byproduct plant)

Table 1.10 shows the result of comparing the energy intensity of coke oven at Esfahan with that at JNSW. This table shows the intensity difference of 373 Mcal/t-coal between Esfahan and JNSW. This difference is broken down into following three factors.

intensity difference of fuel	97 Mcal/t
intensity difference of electricity + steam	111 Mcal/t
intensity difference of recovered heat	165 Mcal/t
Total	373 Mcal/t

Table 1.10 Coke Oven Energy Intensity

			Esfahan	JNSW
Consumed energy	Coal	Mcal/t-coal	7,400	7,400
	Fuel	Mcal/t-coal	667	570
	Electricity	Mcal/t-coal	71	91
	Steam	Mcal/t-coal	176	45
	Others		2	2
	Subtotal		8,316	8,108
Generated energy	Coke	Mcal/t-coal	5,637	5,137
	COG	Mcal/t-coal	1,278	1,471
	Tar	Mcal/t-coal	336 (Tar + L. Oil)	306
	L. Oil	Mcal/t-coal		98
	Steam	Mcal/t-coal	–	156
	CDQ gas	Mcal/t-coal	–	9
	Sub total		7,251	7,177
	Heat difference		–149	–388
	Energy intensity	Mcal/t-coal	916	543

Note: Heat difference is calculated by coke oven heat balance as follows.

Heat Balance

Input	Coal	7,400 kcal/kg
Output	Coke	5,637
	COG	1,278
	Tar	336 (Tar + Light oil)
	Light oil	
		7,251
Difference		149

Mass Balance

Input	Coal	1,000 kg/t
Output	Coke	792
	COG (0.483 x 312)	151
	Tar (1.0 x 38.2)	38 (Tar + Light oil)
	Light oil	
		981
Difference		19

1) Analysis of the difference of fuel intensity and countermeasures

Since the fuel intensity at Esfahan is similar to the level in Japan before the Oil Crisis, it is easy to estimate that the improvement plans performed in Japan could be applied. In this diagnosis, we put our priority on the items which are expected to bring about a large improvement effect or those which intensity deviates from the standard level. Thus, we excluded coke oven from our measuring object, and have no measured data on it (such as exhaust gas O_2 measurement). However, now that we are informed of the current intensity, we have prepared the assumed heat balance as given in Table 1.11.

Based on this heat balance, we have figured out how the heat balance will be better modified when the improvement plans are executed. The result is shown in Table 1.12.

Table 1.11 Assumed Heat Balance for Coke Oven

Operation data	
Fuel intensity	668 Mcal/t-coal
Coke generation	794 kg/t-coal
Gas generation	312 $m^3{}_N$/t-coal
Water content in coal	10 %
Fuel calorific value	4,100 kcal/$m^3{}_N$

Assumed operation condition	
Exhaust gas temperature	250 °C
O_2 content in exhaust gas (m = 1.4)	6.4 %
Hot coke temperature	1,100 °C
Generated gas temperature	800 °C

Assumed heat balance		Mcal/t-coal
Heat input	Fuel combustion heat	668
	Sensible heat of charged coal	7
	Sensible heat of moisture in charged coal	3
	Fuel sensible heat	2
	Sensible heat of combustion air	9
	Subtotal	689
Heat output	Hot coke sensible heat	314
	Tar and light oil sensible heat	20
	Sensible heat of generated gas (COG)	99
	Sensible heat of moisture in COG	38
	Evaporation heat of moisture in COG	79
	Furnace body radiation heat	85
	Subtotal	689
		Mcal/t-coal

Table 1.12 Energy Conservation Measures for Coke Oven (Fuel)

Energy Conservation Measures	Assumed Operation Condition						Fuel Intensity	
	Exhaust Gas Temperature (°C)	O_2 Content in Exhaust Gas (%)	Hot Coke Temperature (°C)	Generated Gas Temperature (°C)	Moisture in Coal (%)	Furnace Body Radiation Heat (Mcal/t-coal)	Fuel Intensity (Mcal/t-coal)	Effect (Mcal/t-coal)
Current situation	250	6.4	1,100	800	10	85	668	base
Optimization of combustion air ratio (Operation improvement)	230	3.0	1,100	800	10	85	649	19
Optimization of coking temperature (Operation improvement)	200	3.0	1,050	780	10	76	608	41
Coal moisture control equipment	170	3.0	1,000	750	6	70	540	68
Total								128

Since the working rate of the coke oven at Esfahan is close to 140 %, the fuel intensity becomes higher by as much as 30 Mcal/t than that for the oven with the operation rate of 115 %. They, however, have the advantage to burn COG exclusively. Therefore, we estimate that the intensity may possibly be reduced by their better operation efforts. An example will be that fuel/air ratio should be adjusted and the temperature distribution at the combustion chamber should be adjusted to be uniform. This leads to very little dispersion of the oven temperature and much less dispersion of carbonization time (optimization of oven temperature).

With less dispersion of carbonization time and reduction of troubles of pushing machine, the carbonized coke remaining time gets shorter. Eventually, it will be possible to get down the combustion chamber temperature (optimizing coking temperature) and thereby reduce the fuel intensity.

Although the investment for the coal moisture controlling equipment costs around US$10,000,000, we would like to recommenced the investment, not only for its usefulness for decreasing of energy intensity but also as the effective measure for the expected production increase of 5 to 7 %.

2) Analysis of the difference in electric power and steam intensities and the countermeasure

The electric power intensity at Esfahan is 29 kWh/t-coal. This is not inferior to that of JNSW (the electric power for anti-pollution measures is involved in the case of JNSW). However, the steam intensity of 176 Mcal/t at Esfahan is too inferior to that of 45 Mcal/t at JNSW. Then, taking the 440 °C steam of 40 kg/cm² (G) used for the back pressure turbine into consideration, we added up this heat to the electric power intensity to acquire Table 1.13.

Table 1.13 Comparison of Electricity and Steam Intensity for Coke Oven

	Esfahan	JNSW
Electric power	71 Mcal/t-coal	91 Mcal/t
Electric power + High-pressure steam	161 Mcal/t-coal	91 Mcal/t
Low-pressure steam	86 Mcal/t-coal	45 Mcal/t

All this difference in intensity may be supposedly due to the improper way of using steam. In other words, "the rationalization of steam usage" is mandatory in their coke oven.

The following are some examples of measures for the rationalization of steam usage.

- To reconsider the operation standards or improve the equipment so that the exhaust steam from back pressure turbine may be more effectively used for the process steam.
- To check and improve the radiation heat loss and condensate loss on the 40 kg/cm² (G) 440 °C steam line.
- To check and improve the radiation heat loss and condensate loss on 10 kg/cm² (G) steam line. (to check free blowing off from steam traps)

- To review the heating temperatures

- To recover the waste heat in the coke plant or install the heat exchanger for waste/make-up water, in order to reduce steam consumption.

Although these are some example measures, the improved effects of these are supposed, from our experience, to amount to 30 percent (53 Mcal/t) of the consumed steam.

3) Waste heat recovery

It is needless to say that the difference of energy recovery completely depends on the installation of coke dry-quenching (CDQ) equipment.

4) Summary of recommended countermeasures

The energy conservation measures for the coke oven are summarized in Table 1.14.

Table 1.14 Summary of Energy Conservation Measures in Coke Oven

(Japanese Yen base)

Item	Expected Saving							Total Million yen/y	Invest-ment Million yen	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel			Electricity						
		kL/y	Million yen/y	%	MWh/y	Million yen/y	%				
Optimization of combustion air ratio	19	2,717	46.2	2.3	-			46.2	0	0	O
Optimization of coking temperature	41	5,863	99.7	4.9	-			99.7	200	2.0	O
Review of the steam utilization method	53	7,580	128.9	6.3	-			128.9	0	0	O
Introduction of moisture controlling facilities*1	68	9,725	165.3	8.1	-			165.3	1,000	6.0	O
Introduction of CDQ	(165)	(23,597)	(401.2)	(19.6)	-			(401.2)	(5,000)	(12.5)	×
Total	181	25,885	440.0	21.4 1.4*2	-			440.0	1,200	2.7	

(Iran Rial base)

Item	Expected Saving								Total Million Rial/y	Invest-ment Million Rial	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel				Electricity						
		F.oil kL/y	N.gas $10^3m^3_N$/y	Million Rial/y	%	MWh/y	Million Rial/y	%				
Optimization of combustion air ratio	19	2,717	2,549	314	2.3	-			314	0	0	O
Optimization of coking temperature	41	5,863	5,501	677	4.9	-			677	3,500	5.2	O
Review of the steam utilization method	53	7,580	7,111	875	6.3	-			875	0	0	O
Introduction of moisture controlling facilities*1	(68)	(9,725)	(9,124)	(1,122)	(8.1)	-			(1,122)	(17,500)	(15.6)	In the future
Introduction of CDQ	(165)	(23,597)	(22,138)	(2,723)	(19.6)	-			(2,723)	(87,500)	(32.1)	×
Total	113	16,160	15,161	1,866	13.2 0.9*2	-			1,866	3,500	1.9	

Remarks: The items not to be recommended are not included in the total column.
Saving ratio: saving ratio for energy consumption in a coke oven
(Fuel: 1,098,492.3 Gcal/y, Electricity: 37,619.6 MWh/y)

*1 Effects by the introduction of a moisture control facility do not include the effect of coke production increase.
*2 Saving ratio for the energy consumption (Fuel: 16,780,222.6 Gcal/y, Electricity: 169,672.1 MWh/y) by the entire Esfahan Steel.

Fuel oil (F.oil) price in Japan: 17,000 yen/kL
Energy price on Iran Rial base:
Natural Gas (N.gas): 123 Rial/m^3_N
Electricity: 100 Rial/kWh
Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Calorific value of fuel: F.oil: 9,000 kcal/kL, N.gas (Natural gas): 9,593 kcal/m^3_N
Investment cost is based on that in Japan.

The coal moisture controlling system, also contributing to the coke production increase, is worth while to be invested. This system needs such heat source of 50 Mcal/t as steam etc. However, since the coke oven consumes a large amount of steam, we assume that some portion of it can be effectively used for the system or the waste heat within the coke oven can be recovered. Therefore, we do not add up the additional energy.

On the other hand, we are hesitant to recommend CDQ equipment for Esfahan Steel, because it will make little return on investment, and also from the viewpoint of energy balance.

b. Sintering plant

The comparison of the energy intensity with that of JNSW is shown on Table 1.15, (for the heat balance examples of sintering plant, please refer to Figure 4.4 in Guideline). This comparison table shows that the difference of intensity between Esfahan and JNSW is 228 Mcal/t. The following four points are the major differences. In Figure 4.5 of Guideline, we show the examples of improved intensity. The coke intensity in this case has been decreasing to 42 kg/t from 67 kg/t in five years.

The figure tells us that Japan's coke intensity at sintering plant before the oil crisis was as same as the current one at Esfahan.

Difference in coke intensity	142 Mcal/t (20 kg/t)
Difference in electric power intensity	14 Mcal/t (6 kWh/t)
Difference in fuel etc intensity	45 Mcal/t
Difference in exhaust heat recovery amount	27 Mcal/t
Total	228 Mcal/t

Table 1.15 Sintering Plant Energy Intensity

			Esfahan	JNSW	Remarks
Consumed energy	Coke	Mcal/t	450 (63.4 kg/t)	308 (43.4 kg/t)	
	Electricity	Mcal/t	104 (42.4 kWh/t)	90 (36.6 kWh/t)	
	Fuel	Mcal/t	53	6	
	Others	Mcal/t	–	2	Air and steam
	Subtotal		607	406	
Generated energy	Steam	Mcal/t	–	27	
	Electricity	Mcal/t	–	–	
	Others	Mcal/t	–	–	
	Subtotal	Mcal/t	0	27	
Energy Intensity (Mcal/t)			607	379	

1) Coke intensity difference

The effective sintering area of sintering machine at Esfahan is as small as 75 m^2. This makes the machine inferior to the larger one in terms of electric power intensity. Considering that they have few anti-pollution facilities, it might be natural to think it would be better than that of JNSW but actually it is a little bit worse. One problem with Esfahan is that the bed height of sintering ore is thin. If the permeability between sintering bed is improved and the bed height is increased to 400 mm (targeting 500 mm) at least, they will acquire better yield of sintering. Since we couldn't obtain the performance curve of exhaust fans, we can not estimate how much of capacity margin (for head and shaft horse power) they have. We know a good example of similar capacity machine that the bed height has been made from 300 mm to over 450 mm within the capacity margin of exhaust fans by improving the air permeability to get uniform sintering in the machine. As for the method to improve the permeability, we would like to suggest mini pelletizing of material or segregation charging of material. In addition, CaO mixing may be considered as a measure to increase the average particle size.

Table 1.16 shows some examples of the effective factors and their outcomes for sintering yield.

Table 1.16 Effect of Operation Factors on Sinter Yield (for reference)

Flame front speed	+ 1.0 mm/min	: – 1.8 %
$CaO + 0.5 (SiO_2 - MgO) - 2.5 Al_2O_3$	+ 1.0 %	: + 3.0 %
Combined water	+ 1.0 %	: – 2.0 %
Mean size of raw mix	+ 0.1 %	: + 0.4 %
CaO	+ 1 kg/t-s	: + 0.2 %
Bed height	+ 10 mm	: + 0.4 %
Carbon contents	+ 1 kg/t-s	: + 0.5 %

This table shows that the coke rate will be improved to 5.9 kg/t (42 Mcal/t), because the yield becomes better by 7.2 %, if the bed height increases to 480 mm from 300 mm. There will also be potential room for electric power intensity to be improved by 11 Mcal/t. However, supposing that the motor power consumption may be possibly increased due to the increased draft loss, we assume that the electric power intensity will remain unchanged.

There still remains the difference of 142 – 42 = 100 Mcal/t in coke intensity. We suppose that the difference has been attained from the intention toward low coke rate such as the quantity of CaO for sintering and the use of blast furnace dust (containing carbon) through the effort to improve operation and facility.

2) Electricity power intensity

The oxygen content in the exhaust gas of their sintering machine at Esfahan is 15.8 %. This means the leaked gas volume accounts for 42 %. The main exhaust blowers have made much excessive air suction to make electric power intensity inferior. The preventive measure taken for the leaked air will much improve their electric power intensity.

The clearance between pallet bodies, side walls, seal bars and dead plates of sintering machines and the broken holes on exhaust gas ducts should be protected against the air leakage. Then, if the oxygen content in the exhaust gas is reduced to 14 %, the leaked gas volume will decrease down to 22 % and the main exhaust blower's electric power intensity will be improved by 7 Mcal/t.

Table 1.17 gives the improved electric power intensity by means of the reduction of leaked air volume.

There still remains the difference of 14 – 7 = 7 Mcal/t in electric power intensity. This might be probably caused by the difference in the efficiency of main exhaust blowers and the production yield.

3) Fuel intensity

JNSW is using the direct ignition burner similar to a slit burner to ignite coke uniformly and efficiently. We would like to recommend Esfahan to introduce this method.

4) Waste heat recovery difference

They have no downstream process (secondary rolling mill) and no consumer of steam. Therefore, we would not suggest the recovery of steam from the heat of exhaust gas of sintering machines or exhaust air of sintering cooler at a sintering plant. Although it is possible to recover it as electricity, the profitable return from the recovery is not expected at this class machine with a sintering area of 75 m^2. We will not recommend this method to Esfahan.

5) Summary of energy conservation measures

The energy conservation measures for the sintering plants are shown in Table 1.18.

Table 1.17 Reduction of Air Leakage in Sintering Machine and Exhaust Gas Line

1) Operation condition

Item	Figure	Remarks
Production rate	1.3 t/h·m²	Assumed data
Production	2,340 t/d	
Suction volume of blower	7,500 m³/min	
Total static pressure of blower	–1,100 mmAq	
Static efficiency of blower	0.7	Assumed data
Power of blower	1,926 kW	
Power intensity of blower	19.8 kWh/t	
O_2 content in exhaust gas	15.8 %	Measured data

2) Relationship of O_2 content in exhaust gas and air leakage ratio

	O_2 Content	Air Leakage Ratio
Esfahan steel	15.8 %	42 %
JNSW	12.5 to 14.0 %	5 to 22 %
Pot test in Japan	12 %	0 %

Note 1: Air leakage ratio = ((O_2 content) – 12) / (21 – 12) × 100

Note 2: Pot test in Japan: Pot test of sintering process in a laboratory shows 12 % of O_2 content in exhaust gas without air leakage.

3) Improvement of power intensity

	Existing	After Improved	Difference
O_2 content in exhaust gas	15.8 %	14 %	1.8 %
Air leakage ratio	42 %	22 %	20 %
Suction volume	7,500 m³/min	6,444 m³/min	1,056 m³/min
Power of blower	1,926 kW	1,655 kW	271 kW
Power intensity	19.8 kWh/t	16.8 kWh/t	3.0 kWh/t

Table 1.18 Summary of Energy Conservation Measures in Sintering Plant

(Japanese Yen base)

Item	Expected Saving							Total Million yen/y	Invest-ment Million yen	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel			Electricity						
		kL/y	Million yen/y	%	MWh/y	Million yen/y	%				
Yield increase	42	10,927	185.8	8.3	-			185.8	100	0.5	O
Replacement with a high-efficiency burner	47	12,230	207.9	9.3	-			207.9	200	1.0	O
Development of a low-coke operation technology	100	26,022	442.4	19.7	-			442.4	300	0.7	O
Prevention of leak air	7	-			7,104	71.0	7.1	71.0	30	0.4	O
Steam recovery by waste heat	(27)	(7,026)	(119.4)	(5.4)	-			(119.4)	(1,300)	(10.9)	×
Total	196	49,181	836.1	37.5 2.7*1	7,104	71.0	7.1 4.2*1	907.1	630	0.7	

(Iran Rial base)

Item	Expected Saving								Total Million Rial/y	Invest-ment Million Rial	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel				Electricity						
		F.oil kL/y	N.gas $10^3m^3_N$/y	Million Rial/y	%	MWh/y	Million Rial/y	%				
Yield increase	42	10,927	10,252	1,261	8.3	-			1,262	1,750	1.4	O
Replacement with a high-efficiency burner	47	12,230	11,474	1,411	9.3	-			1,411	3,500	2.5	O
Development of a low-coke operation technology	100	26,022	24,413	3,003	19.7	-			3,003	5,250	1.8	O
Prevention of leak air	7	-				7,104	710	7.1	710	525	0.7	O
Steam recovery by waste heat	(27)	(7,026)	(6,592)	(811)	(5.4)	-			(811)	(22,750)	(28.1)	×
Total	196	49,181	46,139	5,675	37.5 2.7*1	7,104	710	7.1 4.2*1	6,385	10,500	1.6	

Remarks: The items not to be recommended are not included in the total column.

Saving ratio: Saving ratio for energy consumption in a sintering plant (Fuel: 1,192,541 Gcal/y, Electricity: 100,575 MWh/y)

*1 Saving ratio for the energy consumption (Fuel:16,780,222.6 Gcal/y, Electricity: 169,672.1 MWh/y) by the entire Esfahan Steel.

Energy price in Japan:
- Fuel price: 17,000 yen/kL
- Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
- Natural gas (N.gas): 123 Rial/m^3_N
- Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen

Calorific value of fuel: Oil: 9,000 kcal/kL, N.gas (Natural gas): 9,593 kcal/m^3_N

Investment cost is based on that in Japan.

c. Blast furnace

1) Simplified comparison with the blast furnace at JNSW

First of all, the simplified comparison of energy intensity between them is given in Table 1.19.

Table 1.19 Comparison of Energy Intensity in Blast Furnaces (1)

	Esfahan	JNSW
Fuel ratio	Approx. 602 kg/t	450 ~ 550 kg/t
Net energy intensity	3,708 Mcal/t	2,906 ~ 3,226 Mcal/t
Difference	802 ~ 482 Mcal/t-pig	

As shown in the table, there is a big difference of 482 to 802 Mcal/t between them.

In this regard, a wide range of fuel ratio arises because the fuel ratio of blast furnace in Japan is adjusted in view of the total energy balance associated with the whole plant. Consequently, some steel plants appear to have the blast furnace with higher fuel rate.

Blast furnaces are highly energy efficient plant. Since the blast furnace's energy intensity (net energy intensity) is proportionate to its fuel rate, the most effective way to reduce the energy intensity of blast furnace is to decrease its fuel rate. (Refer to Figure 4.11, in the Guideline)

On the other hand, the coke rate, accounting for the major portion of blast furnace fuel rate, fluctuates depending on various factors as shown in Table 1.20. Therefore, the most appropriate operation plans (such as blast temperature, blast volume, top pressure, oxygen injection volume, natural gas injection volume, and fuel rate) should be made up with consideration given to the profiles and various characters of the blast furnace under the given conditions such as pig iron production, raw material and coke strength.

Table 1.20 Coke Ratio vs Operational Factor (for reference)

Si	+ 0.1 %	: + 6.0 kg/t
Slag ratio	+ 1 kg/t	: + 0.2 kg/t
Sinter ratio	+ 1 %	: − 0.6 kg/t
Pellet ratio	+ 1 %	: − 0.5 kg/t
Coke ash	+ 1 %	: + 4.2 kg/t
Blast moisture	+ 1 g/m^3_N	: + 0.5 kg/t
Blast temperature	+ 10 °C	: − 1.0 kg/t
Gas utilization	+ 1 %	: − 6.0 kg/t
Top gas pressure	+ 0.2 kg/cm^2	: − 3.0 kg/t
Hot metal temperature	− 10 °C	: − 0.5 kg/t

2) Operation target of blast furnace at Esfahan: Production increase and energy conservation

The blast furnaces at Esfahan have an unusually high fuel rate, even if their furnace top pressure is taken into our consideration. Their net energy intensity is estimated to consume additional energy of 316 Mcal/t compared with Japanese new blast furnaces, according to Figure 4.11 in the Guideline.

It seems that they were forced to make the fuel rate higher due to the production increase object. However, too high fuel rate causes high furnace temperature, resulting in the unstable furnace situation. Eventually, the troubles for production increase may take place. The efforts for better operation and facility improvement should be often carried out for the possibly lower fuel rate operation. In doing so, they will acquire the favorable production increase and energy conservation (particularly, reduction of coke rate).

Since we couldn't have the opportunity to hear about their hot metal components, slag components and material status, we can not exactly appraise how much their fuel rate would be decreased. We, however, suppose that their fuel rate may be decreased by 50 kg/t at least in view of the slag rate of 300 kg/t and current very low gas utilization efficiency (38.2 %).

The fuel rate is fluctuated in accordance with the parameter shown in Table 1.20. If they expedite the efforts for better operation and facility improvement, such as obtaining uniform distribution of charged materials, with proper attention to the components of materials, by introducing movable armors in order to improve the gas utilization efficiency, and thus, attain the reduced silicon (Si) in hot metal, they will be able to reduce the fuel rate by 50 kg/t to get better energy intensity with blast furnaces in anticipation of production increase.

3) Potential for reducing energy consumption

On the assumption that the blast furnace at JNSW is operated with fuel rate of 550 kg/t-pig, energy intensity will be increased to 3,226 Mcal/t. Accordingly, the difference between the blast furnace at Esfahan and that at JNSW is estimated to be 482 Mcal/t.

Table 1.21 Comparison of Energy Intensity in Blast Furnaces (2)

	Esfahan	JNSW
Fuel ratio	Approx. 602 kg/t	550 kg/t
Net energy intensity	3,708 Mcal/t	3,226 Mcal/t
Difference	482 Mcal/t-pig	

Again, on another assumption that the operation is performed with fuel rate of 602 kg/t, the net energy itensity of blast furnace is supposed not to exceed around 3,392 Mcal/t. It seems to us that the 3,708 Mcal is excessive input of energy from any standpoint. 316 Mcal/t obtained by reducing 3,392 from 3,708 is 44.5 kg/t in terms of coke. This means that there may be some room to reduce the fuel ratio by 50 kg/t.

Table 1.22 gives the comparison example between the blast furnace at Esfahan and that of JNSW by use of PCI (Pulverized Coal Injection).

Table 1.22 Blast Furnace Energy Intensity

			Esfahan	JNSW
Consumed Energy	Coke	Mcal/t	3,335 (469.7 kg/t)	3,051 (429.7 kg/t)
	Oil	Mcal/t	337 (37.4 L/t)	65 (7.5 L/t)
	Natural gas	Mcal/t	914 (95.3 m³N/t)	–
	PCI	Mcal/t	–	657 (88.7 kg/t)
	Subtotal		4,585 (602.4 kg/t)	3,772 (525.9 kg/t)
	Fuel	Mcal/t	480	424
	Blast air	Mcal/t	216 (114 m^3_N/t)	263 (1,145 m^3_N/t)
	Oxygen	Mcal/t	117 (95.3 m^3_N/t)	39 (31.4 m^3_N/t)
	Electricity	Mcal/t	53 (21.6 kWh/t)	65 (26.3 kWh/t)
	Air	Mcal/t	–	9
	N_2	Mcal/t	–	4
	Steam	Mcal/t	32	19
	Total	Mcal/t	5,483 Mcal/t	4,593 Mcal/t
Generated energy	BFG	Mcal/t	1,775	1,377
	Electricity	Mcal/t	–	134
	Total	Mcal/t	1,775	1,511
	Energy intensity	Mcal/t	3,708 Mcal/t	3,082 Mcal/t

4) Improvement of hot stove

Since we excluded their hot stove as well as coke oven from our measuring objects, we have no hot stove data such as oxygen contents in exhaust gas. We, however, have prepared the assumed heat balance as shown in Table 1.23 based on pieces of information acquired on our site survey. We have estimated how the heat balance will change when the improvement is executed. The assumed effects attainable from the improvement together with outcomes are shown in Table 1.24.

Table 1.23 Assumed Heat Balance for Hot Stove

Operation data 96.6.22	
Fuel intensity BFG	486.3 m^3_N/t-pig
Blast temperature	980 °C
Blast intensity (including O_2)	1,236 m^3_N/t-pig
O_2 enrichment	26 %

Assumed operation condition	
Exhaust gas temperature	190 °C
O_2 content in exhaust gas	4.6 % (m = 1.4)

Assumed heat balance		Mcal/t-coal
Heat input	Fuel combustion heat	480
	Cold blast sensible heat	44
	Fuel sensible heat	5
	Combustion air sensible heat	5
	Sub-total	534
Heat output	Hot blast sensible heat	409
	Exhaust gas sensible heat	61
	Furnace body radiation heat	64
	Sub-total	534

Table 1.24 Energy Conservation Measure for Hot Stove (Fuel)

Energy Conservation Measure	Assumed Operaion			Fuel Intensity	
	Exhaust Gas Temperature	O_2 Content in Exhaust Gas	Air Temperature	Intensity	Effect
Present situation	190 °C	4.6 %	30 °C	480 Mcal/t-pig	base
Optimization of combustion air ratio	170	1.0	30	468	12 Mcal/t-pig
Air preheating	165	1.0	140	451	17

5) Summary of conutermeasures

The energy conservation measures for blast furnaces are given in Table 1.25.

Table 1.25 Summary of Energy Conservation Measures for Blast Furnace

(Japanese Yen base)

Item	Expected Saving								Total Million yen/y	Invest-ment Million yen	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel			Electricity							
		kL/y	Million yen/y	%	MWh/y	Million yen/y	%					
Production increase by reducing the fuel rate	388	81,480	1,385.2	10.6	–			1,385.2	500	0.4	O
Low O_2 operation of hot stove	12	2,520	42.8	0.3	–			42.8	10	0.2	O
Air preheater for hot stove	(17)	(3,570)	(60.7)	(0.5)	–			(60.7)	(250)	(4.1)	×
Installation of TRT equipment	(65)	–			(50,641)	(506.4)	(122.2)	(506.4)	(1,000)	(2.0)	×
Total	400	84,000	1,428.0	11.0 4.6*1	–			1,428.0	510	0.4	

(Iran Rial base)

Item	Expected Saving									Total Million Rial/y	Invest-ment Million Rial	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel				Electricity							
		F.oil kL/y	N.gas $10^3m^3_N$/y	Million Rial/y	%	MWh/y	Million Rial/y	%					
Production increase by reducing the fuel rate	388	81,480	76,443	9,403	10.6	–			9,403	8,750	0.9	O
Low O_2 operation of hot stove	12	2,520	2,364	291	0.3	–			291	175	0.6	O
Air preheater for hot stove	(17)	(3,570)	(3,349)	(412)	(0.5)	–			(412)	(4,375)	(10.6)	×
Installation of TRT equipment	(65)	–				(50,641)	(5,064)	(122.2)	(5,064)	(17,500)	(3.5)	×
Total	400	84,000	78,807	9,694	11.0 4.6*1	–			9,694	8,925	0.9	

Remarks: The items not to be recommended are not included in the total column.
Saving ratio: Saving ratio for energy consumption in a blast furnace
(Fuel: 6,782,198 Gcal/y, Electricity: 41,458 MWh/y)

Supplemental note: A blast furnace top pressure recovery turbine (TRT) is, in many cases, installed in a blast furnace having a furnace top pressure of 1.5 kg/cm² and air blow amount of 3,000 m^3_N/min or more. TRT is provided to recover a part of a blast furnace blower power. Therefore, if the power of the blast blower is small, the power to be recovered should naturally be small as in the case of Esfahan Steel.

*1 Saving ratio for the energy consumption (Fuel: 16,780,222.6 Gcal/y, Electricity: 169,672.1 MWh/y) by the entire Esfahan Steel.

Energy price in Japan:
- Fuel price: 17,000 yen/kL
- Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
- Natural gas (N.gas): 123 Rial/m^3_N
- Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Calorific value of fuel: Oil: 9,000 kcal/L, N.gas (Natural gas): 9,593 kcal/m^3_N
Investment cost is based on that in Japan.

The difference of 482 Mcal/t is brought about from the total outcomes of these countermeasures. The effect generated from fuel rate reduction is supposed to amount to 388 Mcal/t.

d. Processes in steelmaking (converter and continuous caster)

The comparison results of energy intensity between their processes in steelmaking and JNSW are shown in Table 1.26.

This table shows that the difference of energy intensity between Esfahan and JNSW is 390 Mcal/t. The following four items cause major differences.

The difference in oxygen intesity (converter)	15 Mcal/t
The difference in electricity intensity	51 Mcal/t (21 kWh/t)
The difference in fuel intensity	235 Mcal/t
The difference in waste heat recovery	101 Mcal/t
Total	402 Mcal/t

Table 1.26 Steel-making Process Energy Intensity

			Esfahan	JNSW
Consumed energy	Oxygen	(converter)	104 (61.3 m^3_N/t)	89 (52.3 m^3_N/t)
	Oxygen	(CC)	12 (6.8 m^3_N/t)	2 (1.2 m^3_N/t)
	Electricity		144 (58.9 kWh/t)	93 (37.8 kWh/t)
	Fuel	(converter)	169	21
	Fuel	(CC)	98	11
	Fuel	(total)	267	32
	Air		19	16
	N_2		–	6
	Argon		–	3
	Steam		5	23
	Coke		9 (1.3 kg/t)	8 (1.1 kg/t)
	Sub total		560 Mcal/t	271 Mcal/t
Generated energy	LDG		–	202
	Steam	(High Pressure)	140	–
	Steam	(Low Pressure)	315	39
	Boiler fuel		314	–
	Sub total		140 Mcal/t	241 Mcal/t
	Energy intensity		420 Mcal/t	30 Mcal/t

1) Improvement of oxygen intensity

Due to very high tapping temperature of 1,700 °C, the oxygen intensity is not so good and yield of crude steel is low. Since they have ladle furnaces at Esfahan, they will not need to have allowance for tapping temperature and thus can lower the temperature remarkably. The improved effect of crude steel yield greatly contributes to the improvement of energy intensity in iron and steel works. Therefore, increasing the improved yield of crude steel should be taken as a target together with the improvement of oxygen intensity.

Since they already own the stirring equipment by inert gas (LDCB), full employment of it will be helpful for reduction of oxygen intensity through improvement of crude steel yield and the improved ratio of hitting the quality standard. The increased yield by 2 % and improved oxygen intensity by 6 m^3_N/t will be tentatively the targets for improvement through better operation effort.

2) Improvement of electricity intensity

Notwithstanding few anti-pollution facilities, their electric power intensity is unexpectedly high. The supplementary natural gas firing in ladle furnaces and waste heat recovery boilers (that means the continuous operation of exhaust fan) may be linked to the increase of electricity intensity. We will suggest suspending the supplementary firing in the waste heat recovery boilers later at Heat Recovery section.

3) Fuel intensity

Strangely enough, the processes in steelmaking shop consume such a large amount of fuel (267 Mcal/t). 70 to 100 Mcal/t is supposed to be enough to cut billets and keep ladles heated. It is highly recommended that the map for fuel consumption in the steelmaking shop be drawn up and the tentative flow meters be installed in an attempt to review their operation standards (heat holding time, and fuel consumption/utilization at heat holding). We suggest that they will exert themselves to overcome this fuel issue. The target to reduce the fuel will be 200 Mcal/t. In addition, it is also necessary to check their natural gas flow meters as described later.

4) Recovery of energy

Although intensity of the recovered energy as steam converters at Esfahan is apparently high, it actually becomes lower after reducing the volume of natural gas for supplementary firing. Their net recovered energy intensity is less than that of JNSW by 101 Mcal/t.

Here are some energy recovery problems at Esfahan.

- Since they try to continuously extract high pressure steam from the batch type converters, they are making supplementary natural gas firing at low efficient waste heat boilers (Thermal efficiency is supposedly 70 %).

- Another issue is that the high pressure steam produced without consideration for the efficiency is superheated with more additional energy. The superheated steam is input into CPP (central power plant) with the steam turbine efficiency of 27 to 28 % only, to generate electric power.

- Even after oxygen blowing is started, the natural gas burners which operators forget to stop firing are found, continuing supplementary firing to generate low pressure steam (the scene was observed in our site survey. Table 1.26 evidently shows the generated low pressure steam of 315 Mcal/t. This means they are firing natural gas during converter operating)

- Because plenty of low pressure steam is generated during oxygen blowing, much of the steam is exhausted in relation with the balances of user plants.

Since the converter gas is fully fired in the waste heat boiler system, the heat absorption rate of the heating surface of the boiler is high. Therefore, if they increase the production at converters (this means the increase of oxygen blowing rate), the life time of the boiler becomes much shorter. Since at Esfahan, the vessels of converters have been completely replaced, we would like to propose that, when the life time of the boilers is finished, they should adopt the gas recovery system.

In the meanwhile, the following are suggested for the operation methods with increased energy recovery ratio. Since the waste heat boiler suddenly increases its steam evaporation volume soon after blowing start of converter, the steam pressure has to be increased to the specified pressure before blowing start in order to secure water and steam volume ratio in the evaporating tubes and reduce the thermal stress of drum steel plate. This specified steam pressure has to be discussed with the boiler manufacturer but we assume it to be around 20 to 25 kg/cm^2 (G). If they suspend extracting high pressure steam, we estimate that their consumption of natural gas will be reduced down to 5 % of current volume (this means 3,080,000 m^3_N/year).

If natural gas is limited to fire at starting up of boiler together with the suspension of extracting high pressure steam, above steam recovery volume will be decreased to around 200 Mcal/t. However, the natural gas volume consumed for supplementary firing is 20 Mcal/t. Therefore, the energy recovery of balanced 180 Mcal/t is expected to increase the recovery volume of 40 Mcal/t in the steelmaking shop. If the natural gas unused in the boilers of converters is supplied to TPP to generate electric power and the low pressure steam is extracted from the steam turbine at TPP in case of necessity, the net energy intensity of TPP will get improved.

5) Summary of countermeasures

The summary of energy conservation measures at steel-making processes is shown in Table 1.27.

Table 1.27 Summary of Energy Conservation Measures for Steel-Making Process

(Japanese Yen base)

Item	Expected Saving							Total Million yen/y	Invest-ment Million yen	Payback Period year	Recommen-dation
	Energy intensity Mcal/t	Fuel			Electricity						
		kL/y	Million yen/y	%	MWh/y	Million yen/y	%				
Improvement of converter yield											O
For a reduction of oxygen	10	–			7,712	77.1	7.0	77.1	0	0	
For a reduction of electricity in the above process	10	–			7,712	77.1	7.0	77.1	0	0	
For a reduction of fuel in the above process	107	22,117	376.0	38.8	–			376.0	0	0	
Reduction of fuel in the steel-making plant	200	41,340	702.8	72.5	–			702.8	0	0	O
Improvement of the boiler auxiliary combustion method	40	8,268	140.6	14.5	–			140.6	0	0	O
Replacement with an exhaust gas recovery equipment	(40)	(8,268)	(140.6)	(14.5)	–			(140.6)	(5,000)	(35.6)	In the future
Total	367	71,725	1,219.4	125.7 3.9*1	15,424	154.2	14.0 9.1*1	1,373.6	0	0	

(Iran Rial base)

Item	Expected Saving								Total Million Rial/y	Invest-ment Million Rial	Payback Period Year	Recommen-dation
	Energy intensity Mcal/t	Fuel				Electricity						
		F.oil kL/y	N.gas $10^3 m^3_N$/y	Million Rial/y	%	MWh/y	Million Rial/y	%				
Improvement of converter yield												O
For a reduction of oxygen	10	–				7,712	771	7.0	771	0	0	
For a reduction of electricity in the above process	10	–				7,712	771	7.0	771	0	0	
For a reduction of fuel in the above process	107	22,117	20,750	2,552	38.8	–			2,552	0	0	
Reduction of fuel in the steel-making plant	200	41,340	38,785	4,770	72.5	–			4,770	0	0	O
Improvement of the boiler auxiliary combustion method	40	8,268	7,757	954	14.5	–			954	0	0	O
Replacement with an exhaust gas recovery equipment	(40)	(8,268)	(7,757)	(954)	(14.5)	–			(954)	(87,500)	(91.7)	In the future
Total	367	71,725	67,292	8,276	125.7 3.9*1	15,424	1,542	14.0 9.1*1	9,818	0	0	

Remarks: The items to be implemented in the future are not included in the total column.
Saving ratio: Saving ratio for energy consumption in a steel-making process
(Fuel: 519,150 Gcal/y, Electricity: 110,556 MWh/y)

*1 Saving ratio for the energy consumption (Fuel: 16,780,22.6 Gcal/y, Electricity: 169,672.1 MWh/y) by the entire Esfahan Steel.

Energy price in Japan:
Fuel price: 17,000 yen/kL
Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
Natural gas (N.gas): 123 Rial/m^3_N
Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen

Calorific value of fuel: Oil: 9,000 kcal/kL, N.gas (Natural gas): 9,593 kcal/m^3_N

Investment cost is based on that in Japan.

e. Rolling processes

The comparison of energy intensity between Esfahan and JNSW is shown in Table 1.28. This table shows that the energy intensity difference between Esfahan and JNSW is 483 Mcal/t. The major difference lies in fuel intensity.

Fuel intensity difference per ton of rolling mill production is 533 Mcal/t.

Table 1.28 Rolling Mill Energy Intensity

	Esfahan	JNSW	Esfahan (final product base)
Production	$2,051 \times 10^3$ t	–	$1,793 \times 10^3$ t
Fuel	878 Mcal/t	345	1,004 Mcal/t final product
Electricity	216 (88.1 kWh/t)	250 (102.2 kWh/t)	247
Oxygen	1	–	1
Steam	5	19	6
Air	–	3	–
Others	–		–
Total	1,100 Mcal/t	617 Mcal/t	1,259 Mcal/t final product

1) Difference in fuel intensity

On their producing 5.5 to 16 mm dia steel bar and angle 80 at Esfahan, they pass twice the rolling process at M-650 and M-350 from the standpoint of production efficiency. Therefore, the net energy intensity per products ton is 1,259 Mcal/t. Since they actually consume twice the fuel and electricity on their passing twice the rolling mills, we do not apply the intensity for per ton of the final product but for the rolling mill output volume (or rolling mill production output) to compare with that of JNSW.

2) Operation situation of rolling mill

Table 1.4 and Table 1.29 respectively show the operation situation of rolling mill and production of each rolling mill.

If the rolling mill operate at 75 % of the nominal capacity, 367 t/h bloom would be possibly treated at M-500, M-300 and M-650. However, with around 263 t/h production capacity at the steelmaking shop, about 28 % (6.8 h/d) of non rolling hours is generated. The actual result in 1994 reveals that non-rolling hours of 7.5 hours per one day per each rolling mill occurred.

Table 1.29 Rolling Mill Production in 1994

	I beam 1000 L	Bar 1000 L	Channel 1000 L	Billet 1000 L	Others 1000 L	Total 1000 L	Working time h	Average t/h	Capacity t/h	Capacity 1000 t/Y
M-500									WB	
	624.9	0	27.9	–	0	652.9	5,965	109.4	200	900
M-300		12 ~ 40ϕ							WB	
	–	473.1	–	0	0	473.1	5,846	80.9	200	700
M-650				258.3					pusher	
	311.4	0	0	112.9	2.7	685.4	6,270	109.3	90	750
M-350		5.5 ~ 16ϕ							pusher	
	–	229.5	0	–	10.5	240.0	7,596	41.1	60	320
Total	936.3	702.6	27.7	371.2	13.2	2,051.4	25,677		550	2,470

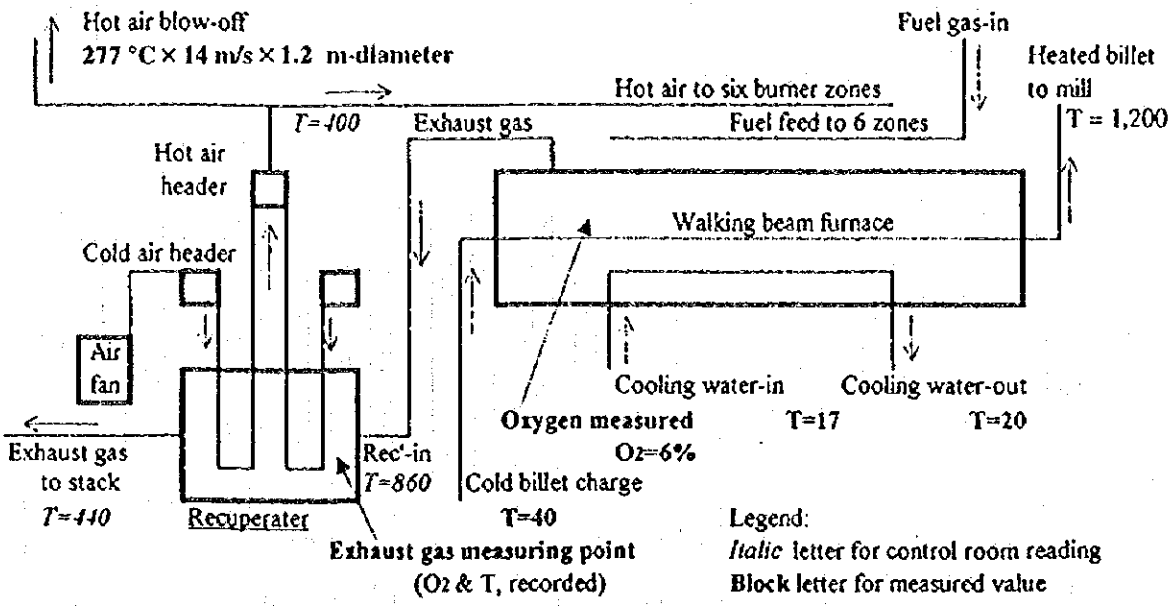
3) Measurement and analysis of continuous reheating furnace (M-500 furnace) for billet.

① Equipment and measuring

This reheating furnace is of walking beam type. The charged billet is transferred to extraction direction by a movable supporting beam at the furnace bottom. Figure 1.5 shows the outline of equipment. The measured values other than those of exhaust gas are also shown on the figure.

Figure 1.6 shows the graphic representation of exhaust gas measurement results.

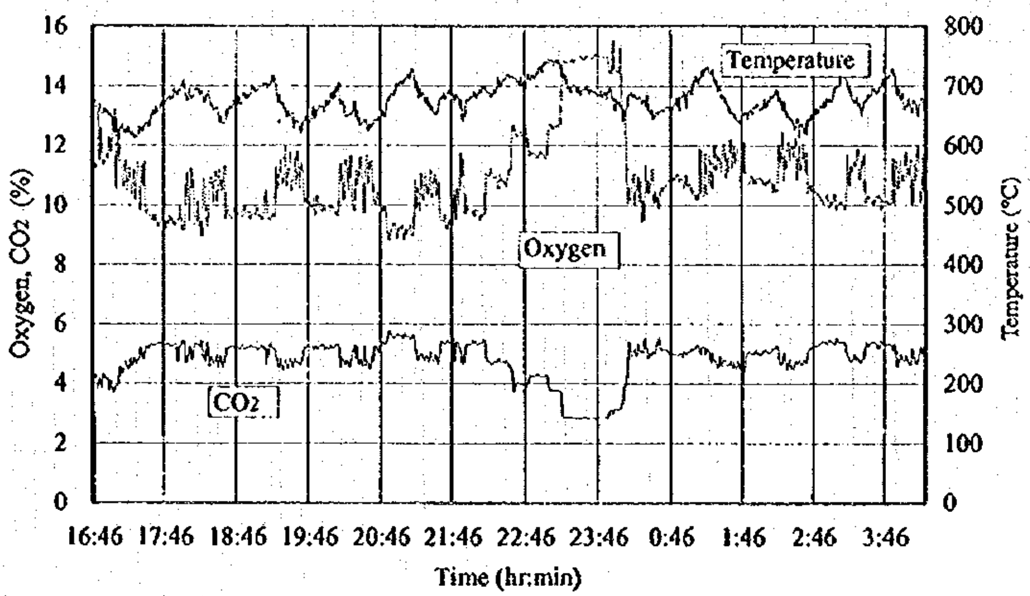
Figure 1.5 Schematic Diagram of M-500 Reheating Furnace



Specification (designed)

Type	Walkign beam, 6 zones	Fuel, designed	N.G/BFG/COG = 14/61/25 %
Product	Bar	Recuperater	Metallic U-tube, 1,345 m²
Nominal capacity	200 t/h	Air-in/out	25/400 °C
Inside dimension	33 L × 13 W × 1.5 H	Gas-in/out	1,000/550-600 °C
Billet charged	200 × 200 × 12,000 mm, 3,750kg		
Heating temperature	1,180 – 1,250 °C	Manufactured	USSR, 1988

Figure 1.6 Oxygen, CO_2 & Temperature, M-500 Furnace (23-June/1996)



The recording of uninterrupted measuring of exhaust gas and operation was carried out from 17.00 till 7.00 in the next morning. However, since there was the time zone during which material charging was suspended, the following analysis, excluding this time zone, should be understood to have been conducted for five hours from 17.00 till 21.00.

② Combustion calculation

The fuel combustion calculation was performed with the spread sheet drawn on a personal computer (PC). By setting up fuel components, air temperature, and oxygen content in exhaust gas on this calculation sheet, the fuel heat value, components of combustion gas, gas volume of each components of combustion gas, combustion air volume, air ratio etc. are represented in the calculated table.

The effect of air ratio adjustment and air preheating can be obtained using the oxygen content in the exhaust gas as parameter.

③ Heat balance and analysis

The premises for our analysis and the calculation results of the heat balance are respectively shown in Tables 1.30 and 1.31.

Table 1.30 Premises in Heat Balance Calculation

Item	Unit	Value	Remarks
Period for calculation		17:00 to 22:00	Five hours, 23-June/1996
Billet charged	t	615.4	Actual value for the period
Fuel gas flow in the period	m^3/5-hrs	15,060	Panel reading summation
Combustion air volume		Calculated on the sheet based on oxygen content.	
For furnace only calculation:			
Oxygen in exhaust gas	%	6.0	Spot measured value at side wall hole
Exhaust gas temperature	°C	860	Panel reading Temperature drop in exhaust duct might be several degrees.
Air temperature	°C	400	Panel reading
For air heater including calculation:			
Oxygen in exhaust gas	%	10.2	Average value of measured record
Exhaust gas temperature	°C	440	Panel reading
Air temperature	°C	30	Assumption
Hot air blow off heat	kcal/h	2,236,917	Spot measured
Cooling water:			
Flow amount	m^3/h	360	Designed value
Temperatute-in	°C	17	Measured, typical value
Temperature-out	°C	20	Measured, typical value

Table 1.31 Heat Balance of M-500 Reheating Furnace (excluding AH)

Heat-in	(Mcal/t)	
Fuel combustion heat	564.3	81.3 %
Fuel sensible heat	0.0	0.0 %
Air sensible heat	101.6	14.6 %
Billet heat content	1.1	0.2 %
Scale generation heat	26.7	3.8 %
Total	693.8	100.0 %
Exhaust gas temperature	860	
Air temperature (burner)	400	

Heat-out	(Mcal/t)	
Billet discharged	187.1	27.0 %
Scale sensible heat	6.6	1.0 %
Exhaust gas sensible heat	381.1	54.9 %
Cooling water	8.8	1.3 %
Emission and miscellaneous heat	110.3	15.9 %
Total	693.8	100.0 %
Oxygen in exhaust gas		10.2 %
Invasion air ratio		54.5 %

The heat balance calculation is made within the extent down to the recuperator inlet where the exhausted gas was measured. The item "others" in the heat balance indicate the calculated values obtained by deduction. The heat radiation from the furnace body is included in this item.

During this measuring period, the charged volume amounted to 123.1 t/h. The necessary fuel calories to heat up steel of one ton or, that is, the fuel intensity was 564,000 kcal/t. During 14 hours of the whole measuring time, the suspension of billet charging took place for two hours. If these hours were included into our calculation, the fuel intensity would be increased to 603,000 kcal/t. Therefore, we would like to recommend the uninterrupted stable operation.

The fuel intensity at the reheating furnace in cold charging is around 400,000 kcal/t in monthly average in Japan. Cold charging means that billet and slab are charged into the reheating furnace at normal temperature.

④ Combustion air blower

The input of the combustion air blower motor were measured. Table 1.32 shows the specifications of the blower.

Table 1.32 Specification of Blower

Air volume	1,100 m³/h
Pressure	633 mmHg
Motor output	800 kW
Motor efficiency	93 %
Rotational speed	1,500 rpm

Table 1.33 shows the measurement results.

Table 1.33 Measurement Data of Blower

	Voltage (kV)	Current (A)	Electric Power (kW)	Power Factor	Load Factor
Maximum	5.76	71.9	649.2	0.875	0.811
Minimum	5.60	67.8	613.4	0.869	0.767
Average	5.68	69.7	630.4	0.871	0.788

From the point of view of electric power, the load did not fluctuate remarkably and the load factor was almost 80 % to indicate that there will not be practically any serious problems.

However, the preheated air was blown out to a considerable extent, suggesting that the air flow rate can be reduced.

4) Improvement of fuel intensity at reheating furnace

The diagnosis results of the reheating furnace and the data obtained in our field survey are summarized into Table 1.34.

Table 1.34 Fuel Intensity in M-500

	Average Production	Fuel Intensity	Yield
Mean value of all the reheating furnaces for 1994	65 % of the maximum value	878 Mcal/t	Unknown
M-500 reheating furnace design value	Product 188 t/h (Charge 200 t/h)	532 Mcal/tp (500 Mcal/t-input)	94 %
M-500 reheating furnace diagnostic result	114.5 t/h (Charge 123.1 t/h)	606 (564 Mcal/t-input)	Assumed to be 93 %

The actual fuel intensity (878 Mcal/t) in the reheating furnaces much exceeded the design value (532 Mcal/t), or even the mean value (564 Mcal/t) during five-hour diagnosis.

① Improvement of production and process control and minimization of fuel consumption for holding heat Reduction target: 212 Mcal/t

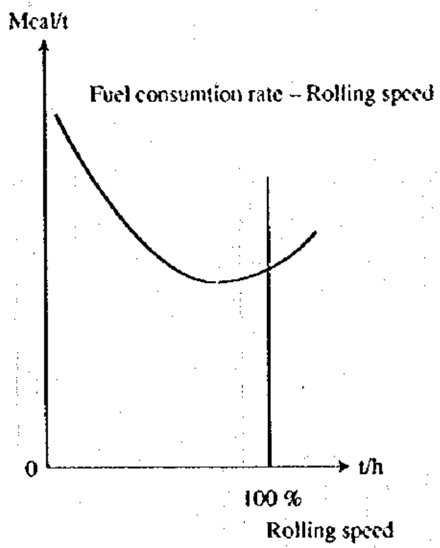
As indicated in Table 1.34 above, there is a big difference in fuel intensity (314 Mcal/t) between 878 Mcal/t of their yearly average and 564 Mcal/t on their uninterrupted operation. This difference is supposed to be raised on such occasions as consuming useless fuel for material waiting time in relation with steel-making and CC capacity or improper matching of the heat pattern at the reheating furnace in case of delayed rolling speed. Therefore, the following countermeasures will be necessary.

①-1 Improvement of production and process control

M-650 (and M-350) should be operated with as constant rolling speed as possible. For this end, we would like to recommend to build the revised production plan in which either M-500 or M-300 may carry out the scheduled shutdown for a certain period.

In other words, the production plan with consideration given to the fuel consumption should be worked out. Figure 1.7 shows the relationship between fuel intensity and rolling speed.

Figure 1.7 Relationship between Fuel Intensity and Rolling Speed



①-2 Improvement of reheating furnace operation

The operation should be performed with the heat pattern corresponding to rolling speed. At the slower rolling speed, fuel should be decreased to protect overheating. The holding and heating up standards should be prepared so that they may operate with minimum holding and heating up loss.

The rolling mill should be operated to discharge billets from the reheating furnace at a specified speed.

② Reduction of fuel intensity to the designing point

Reduction target: 134 Mcal/t

The actual fuel intensity should be reduced to the designed fuel intensity by adopting the following improving measures.

②-1 Installing a partition wall

Unless the partition wall is installed in M-500 reheating furnace, the combustion control (temperature control of bloom) will be difficult, and heat efficiency at low load may possibly be worse.

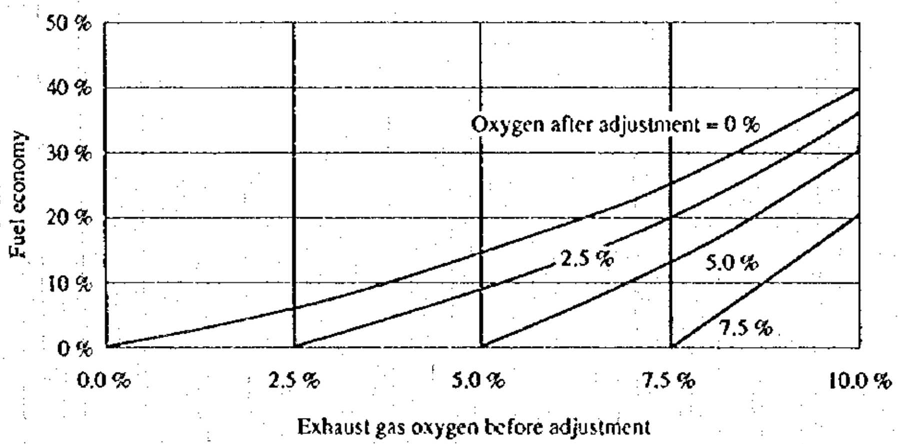
If the partition wall is installed, the heat transition and combustion temperature in each zone will become stable to improve fuel controllability and to allow inputting the optimum volume of fuel.

②-2 Optimization of combustion air ratio

The oxygen content 6 % in the furnace is equivalent to air ratio of 1.4. In Japan, the standard air ratio is 1.25, which means the oxygen content in exhaust gas is equivalent to 4.2 %.

The improved air ratio brings about the fuel saving effect as in Figure 1.8. Now, if the oxygen content is reduced from 6 % to 4.2 % owing to the improved air ratio, fuel will be reduced by 7.4 %.

Figure 1.8 Fuel Economy by Air Ratio Adjustment (M-500 Fuel Gas)
(Exhaust Gas 1,100 °C, Burner Air 400 °C)



The following are necessary for the measures to reduce the air ratio.

- Enhancement of operation management for combustion such as maintenance of burners.
- Tightening of seal in the openings such as the inspection holes.
- Optimization of furnace pressure control.
- Installation of the exhaust gas oxygen measuring meter to monitor the oxygen content in exhaust gas.

②-3 Prevention of heat emission loss

The prevention of heat emission loss will be attained by preventing heat radiation and gas leakage from the inspection doors, by repairing the furnace walls and by stronger heat insulation of the furnace wall.

Table 1.35 shows the calculation for the heat emission from the walls based on the measured and estimated figures on the furnace wall temperature.

Table 1.35 Surface Emission Calculation (M-500 Reheating Furnace)

No.	Ambient Temperature °C	Surface Temperature °C	Emissivity	Area m^2	Heat Transfer Coefficient Convection kcal/h/m²/°C	Heat Transfer Coefficient Radiation kcal/h/m²/°C	Unit Heat kcal/m²/h	Total Heat kcal/h	Remarks
1	30.0	100.0	0.9	367.5	5.143	6.866	841	308,919	Side wall
2	30.0	200.0	0.9	127.4	6.597	10.766	2,952	376,056	Front/back
3	30.0	150.0	0.9	980.0	6.470	8.643	1,814	1,777,364	Roof
4	30.0	100.0	0.9	980.0	1.082	6.866	556	545,230	Bottom
5	30.0	100.0	0.9	377.0	4.493	6.866	795	299,749	Duct to AH
	Total							3,307,318	
	Billet t/h							123.1	
	Emission kcal/t-billet							26,867	

This heat emission amount corresponds to 5 % of the input thermal value of the fuel. The upper wall temperature of furnace body is particularly high.

②-4 Reduction of fuel input in the preheating zone

By installing a partition wall, a heat transfer at the preheating zone will be increased. Thus, the fuel input to the preheating zone is to be decreased. This reduction of the preheating zone fuel lowers the exhaust gas temperature at the furnace end to reduce the exhaust gas loss.

②-5 Proper method to use recuperator

The air flow volume is excessive in order to protect the recuperator and the hot air is blown out. Measuring the velocity and temperature shows that this blown-out amount is equivalent to 18,000 kcal/t.

To feed cold air more than necessary will reduce the preheating air temperature and the calories used for combustion. In general, in an attempt to protect recuperator, cold air will be mixed with the inlet exhaust gas to control the temperature at the highest temperature zone. As a whole, this is helpful for reducing the blower power.

The blowing-out of preheated air is basically caused by high exhaust gas temperature from the furnace. Therefore, in order to avoid this, to reduce the temperature of the preheating zone is essential as described before.

③ Improvement of equipment Reduction target: 50 Mcal/t

③-1 Introduction of fuel gas heat value control

From the standpoints of product yield, product quality improvement and energy conservation, the fuel gas heat value should be controlled at less than ±50 kcal/m^3_N. If the fuel gas heat value becomes stable, the fuel consumption to the reheating furnace will be remarkably reduced.

③-1 Air ratio automatic control including an oxygen content meter

With the same reason as given above, the automatic control of air ratio including an oxygen content meter is necessary together with the improvement of controllability of furnace temperature control and furnace pressure control.

④ Hot charge rolling Reduction target: 70 Mcal/t

If M-650 and M-350 are so arranged at the production planning level as to allow hot charging, the hot charging can be carried out soon after the communication arrangement between the rolling sections. We would like to recommend them to try around 25 % of hot charging as a target after studying the handling method, even at as low temperature as 300 °C.

Then, hot charging can be recommended also for M-300. If they build the production plan to well combine M-300 with CC, they can set up 50 % of hot charging ratio as a target.

The action program will be to achieve 30 % of hot charging in the whole lines as the final target in an attempt to reduce the fuel intensity down to 350 Mcal/t. However, in order to reduce it to 350 Mcal/t, the holding furnace to tentatively store the billets will be supposedly necessary, because those blooms produced by the continuous caster should be collected to a certain lot.

⑤ Improvement of yield Improvement target: 3 %

Since the yield is an index to show the entire technical level of rolling, the improvement of operation should be conducted so as to increase the current level (estimated yield: 93 %) by 3 % at least.

Unless the analysis for the causes of reduced yield is made, no specific suggestions can be given, but the following actions will be necessary.

- To prevent overheating at reheating furnace
- To extract billets at a constant temperature level (constant rolling temperature)
- To well manage the caliber
- To reduce crop loss
- To investigate the causes of miss rolling and countermeasures
- To investigate the causes of rejected products and countermeasures

5) Summary of countermeasures

Summary of energy conservation measures at rolling processes is given in Table 1.36

Table 1.36 Summary of Energy Conservation Measures for Rolling Process

(Japanese Yen base)

Item	Energy intensity Mcal/t	Expected Saving: Fuel kL/y	Fuel Million yen/y	Fuel %	Electricity MWh/y	Electricity Million yen/y	Electricity %	Total Million yen/y	Invest-ment Million yen	Payback Period Year	Recommen-dation
Improvement of production/ process management	212	47,782	812.3	24.0	–			812.3	0	0	O
Review of the reheating furnace operation method and the installation of a partition wall	134	30,202	513.4	15.1	–			513.4	50	0.1	O
Fuel gas calory control and automatic control of the reheating furnace air combustion ratio	50	11,269	191.6	5.7	–			191.6	50	0.3	O
Improvement of hot charge ratio	70	15,777	268.2	7.9	–			268.2	50	0.2	O
Improvement of yield	34	6,085	103.5	3.1	5,948	59.5	3.3	163.0	0	0	O
Total	500	111,115	1,889.0	55.7 6.0*1	5,948	59.5	3.3 3.5*1	1,948.5	150	0.1	

(Iran Rial base)

Item	Energy intensity Mcal/t	Expected Saving: Fuel F.oil kL/y	Fuel N.gas $10^3m^3_N/y$	Fuel Million Rial/y	Fuel %	Electricity MWh/y	Electricity Million Rial/y	Electricity %	Total Million Rial/y	Invest-ment Million Rial	Payback Period Year	Recommen-dation
Improvement of production/ process management	212	47,782	44,828	5,514	24.0	–			5,514	0	0	O
Review of the reheating furnace operation method and the installation of a partition wall	134	30,202	28,335	3,485	15.1	–			3,485	875	0.3	O
Fuel gas calory control and automatic control of the reheating furnace air combustion ratio	50	11,269	10,572	1,300	5.7	–			1,300	875	0.7	O
Improvement of hot charge ratio	70	15,777	14,802	1, 821	7.9	–			1,821	875	0.5	O
Improvement of yield	34	6,085	5,709	702	3.1	5,947	595	3.3	1, 297	0	0	O
Total	500	111,115	104,246	12, 822	55.7 6.0*1	5,948	595	3.3 3.5*1	13,417	2,625	0.2	

Remarks: The items not to be recommended are not included in the total column.
Saving ratio: Saving ratio for energy consumption in the rolling process (Fuel: 1,815,146 Gcal/y, Electricity: 180,421 MWh/y)

*1 Saving ratio for the energy consumption (Fuel: 16,780,222.6 Gcal/y, Electricity: 169,672.1 MWh/y)

Energy price in Japan:
- Fuel price: 17,000 yen/kL
- Electricity price: 10 yen/kWh

Energy price on Iran Rial base:
- Natural gas (N.gas): 123 Rial/m^3_N
- Electricity: 100 Rial/kWh

Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen

Calorific value of fuel: Oil: 9,000 kcal/kL, N.gas (Natural gas): 9,593 kcal/m^3_N

Investment cost is based on that in Japan.

f. Energy facility and others

Table 1.37 shows the comparison between Esfahan and JNSW. In this sector, there is a big difference of 1,328 Mcal/t-steel. This may be caused by the differences in the modernization progress and energy distribution loss.

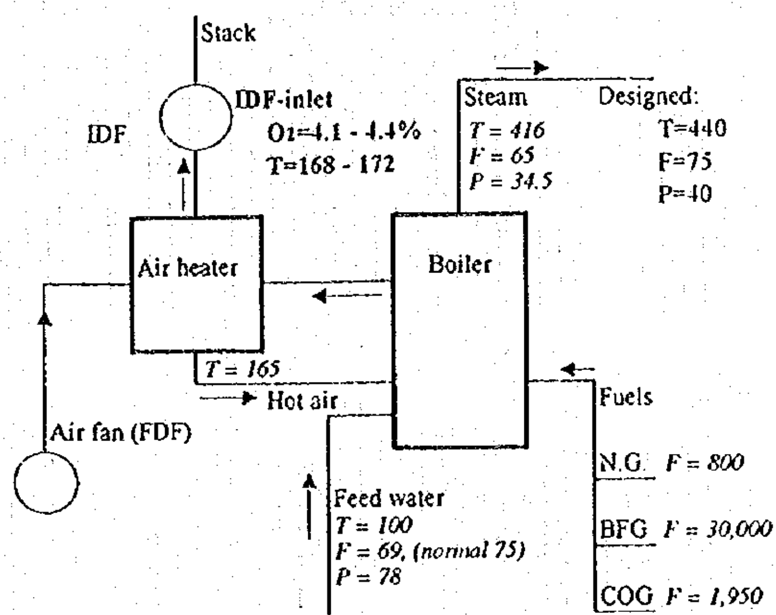
Table 1.37 Comparison of Energy Intensity in Energy Plant, etc.

	Unit	Esfahan	JNSW	Difference
CPP (Blast & power plant)	Mcal/t-steel	455	101	354
TPP (Thermal power plant)	Mcal/t-steel	262	−114	376
Oxygen plant	Mcal/t-steel	99	−17	116
Others	Mcal/t-steel	533	538	−5
Energy distribution loss	Mcal/t-steel	620	133	487
Total	Mcal/t-steel	1,969	641	1,328

1) Central power plant (CPP)

The measured values for CPP No. 3 Boiler are given in Figure 1.9.

Figure 1.9 Measured Data of CPP No. 3 Boiler



F: Flow rate (m^3/h)
T: Temperature (°C)
P: Pressure (kg/cm² (G))

Legend:
Italic letter for control room reading
Block letter for measured valuer

The measured oxygen content of 4.2 % in exhaust gas is equivalent to 1.4 of air ratio, which is a little higher than Japanese standard 1.2 to 1.3 (equivalent to oxygen content about 3 % in exhaust gas).

Table 1.38 gives the comparison between Esfahan and JNSW.

The surprising difference of 354 Mcal/t-steel arises because the steam condition at Esfahan plant is as low as 40 kg/cm² (G) at 440 °C and because they use a small blast furnace blower of low efficiency centrifugal type.

The steam condition of the CPP at JNSW is as high as 90 kg/cm² (G) at 510 °C. In order to obtain high energy efficiency, the back pressure turbine is used for generating electricity. The outlet steam from the turbine is delivered to the works as process steam.

Table 1.38 Energy Intensity of CPP

		Unit	Esfahan	JNSW
Consumed Energy	Fuel	kcal/kWh	4,092	2,858 (including blast air)
	Electricity	kcal/kWh	244 (0.0994 kWh/kWh)	244 (0.0914 kWh/kWh)
	Steam (HP)	kcal/kWh	460	544
	Steam (LP)	kcal/kWh	340	237
	Air + N_2	kcal/kWh		1
	Sub-total	kcal/kWh	5,135	3,864
Generated Energy	Electricity	kcal/kWh	1,153 (0.4706 kWh/kWh)	651 (0.2657 kWh/kWh)
	Blast air	kcal/kWh	1,297 (7.414 m^3_N/kWh)	1,799 (7.822 m^3_N/kWh)
	Steam	kcal/kWh	–	818 (1.169 kg/kWh)
	Sub-total	kcal/kWh	2,451	3,268
Energy intensity		kcal/kWh	2,685	596
Power output	Electricity		149,900	(80,207)
	Blast air		168,611	(221,697)
	Sub-total		318,511 MWh	(301,904 MWh)
Energy intensity		Mcal/t-steel	455 Mcal/t-steel	101 Mcal/t-steel
Note: Equivalent Wh of blast air			71.4 Wh/m^3_N	93.88 Wh/m^3_N

① Energy conservation by operation improvement

We would like to recommend implementing the method given in Guideline, because the plant efficiency is expected to be improved by 1 to 3 %. In our recommendation, if their air ratio is well adjusted to Japanese standard, 0.5 % fuel saving can be attained in calculation.

After promoting energy conservation in the entire plant, they are expected to suspend the operation of the electric generating turbine at CPP. Electric power conservation will be described in Item g.

If their steam condition is changed to the rated value of 40 kg/cm² (G) at 440 °C from currently measured conditions of 34.5 kg/cm² (G) at 416 °C, the turbine efficiency (as condensing turbine) will be improved by around 3 %.

② Modernization of equipment

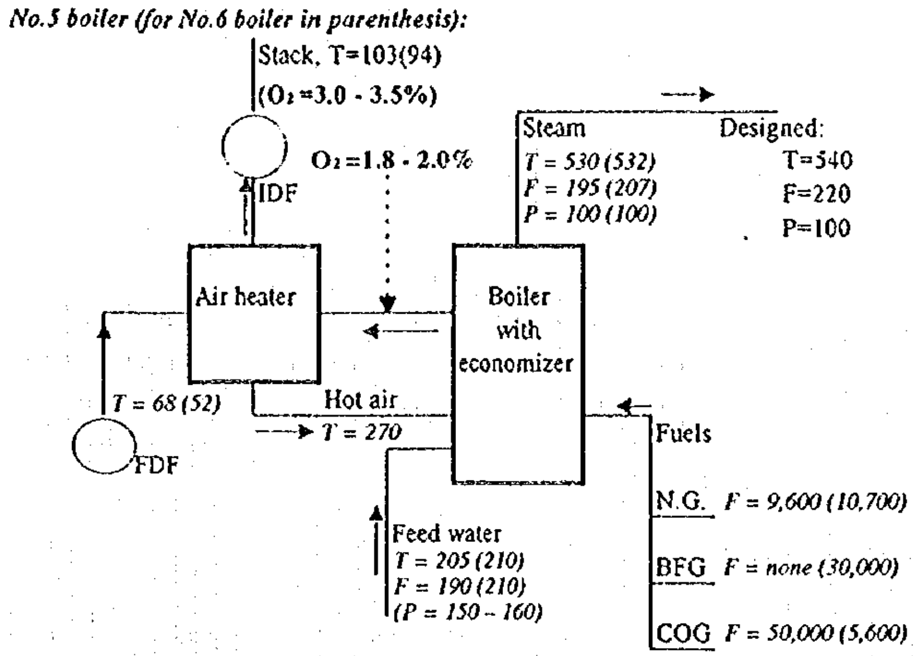
If natural gas price is higher in the future or their boilers become deteriorated, they had better alternatively use the motor driven axial blower to simultaneously attain rationalization as well as energy saving.

Meanwhile, CPP is recommended to serve as the exclusive steam station for the blast furnace blower. Our recommendation is that the power generation and the adjusting function of process steam should be exclusively performed by TPP.

2) Thermal power plant (TPP)

Fig 1.10 shows the measured data of the boilers and the operation data recorded at their control room.

Figure 1.10 Measured Data of TPP Boilers



F: Flow rate (m^3/h)
T: Temperature (°C)
P: Pressure (kg/cm^2 (G))

Legend:
Italic letter for control room reading
Block letter for measured values

The oxygen content in exhaust gas is 1.1 in terms of air ratio. This means that they are being well operated.

For their information, Japan's Energy Conservation Law specifies the air ratio of boiler exhaust gas to be 1.2 to 1.3.

The indicated exhaust gas temperature at their control room was about 100 °C. We are afraid this indication seems too low from averaged standard. It is necessary for them to check if the measured point of temperature indicator is well located or not.

Comparison with JNSW is given in Table 1.39. The difference of 375 Mcal/t-steel has been also generated in this plant. This may be also caused by the extent of modernized equipment.

There are two functions in the energy sector of the integrated steel works. One is to produce and supply necessary energy with high efficiency, and the other is to make best use of the surplus energy (by-product gas, steam etc.) from the works. Although TPP should satisfy both simultaneously, TPP doesn't have the second function. It may well be said that TPP is a kind of deficient power plant. It should be soon renovated to burn BFG corresponding to 50 % of the boiler load at least.

Table 1.39 TPP Energy Intensity

			Esfahan		JNSW	
Consumed Energy	Fuel	kcal/kWh	2,877		2,164	
	Electricity	kcal/kWh	182	(0.0742 kWh/kWh)	127	(0.0518 kWh/kWh)
	Steam	kcal/kWh	44		6	
	Air + N_2	kcal/kWh	0		1	
	Sub-total	kcal/kWh	3,103		2,298	
Generated Energy	Electricity	kcal/kWh	2,450	(1 kWh/kWh)	2,450	(1 kWh/kWh)
	Steam	kcal/kWh	0		132	
	Hot water	kcal/kWh	3		0	
	Sub-total	kcal/kWh	2,453		2,582	
Energy intensity		kcal/kWh	650		−284	
Energy intensity		Mcal/t-steel	262		−114	

① Improvement of operation and facilities

Our diagnosis results reveal that the oxygen content in boiler exhaust gas is low enough. However, in order to maintain this level, it is advisable to install oxygen meter and to persistently control the oxygen content in exhaust gas with the meter. The volume of BFG to be burnt was 80,000 m^3_N/h from the designed point but 40,000 m^3_N/h only is burnt. We would like to recommend that the soonest improvement should be made to burn the surplus BFG on the days when the rolling mills are not operating for maintenance. This action will be helpful to reduce the natural gas consumption.

② Modernization of facilities

In an attempt to concentrate such functions as absorbing the fluctuation of by-product gas and steam on TPP, the more efficient power plant is recommended to be additionally built. We propose that CPP boilers are to be suspended in the future and the blast furnace blower should be driven by electric motor.

Refer to the Guideline for the modernization plans.

3) Oxygen plant

The comparison table of oxygen plants is shown on Table 1.40.

The efficiency difference between oxygen plants is 116 Mcal/t in terms of 1 ton of crude steel. Japan's oxygen plants supply also nitrogen and compressed air. Therefore, the consumed electricity kilowatts divided by the generated quantities of oxygen gets the intensity of 0.75 to 0.78 kWh/m^3_N. However, after the correction by deducting the consumed electricity for producing nitrogen and compressed air, the value for a recent plant will be 0.600 kWh/m^3_N or below.

Table 1.40 O_2 Plant Energy Consumption

			Esfahan	JNSW
Consumed energy	Electricity	$kcal/m^3_N$	1,823 (744 Wh/m^3_N)	1,896 (774 Wh/m^3_N)
	Steam	$kcal/m^3_N$	60	29
	Air + N_2	$kcal/m^3_N$	–	35
	Sub total	$kcal/m^3_N$	1,883	1,959
Generated enetgy	Oxygen (H)	$kcal/m^3_N$	652	1,170
	Oxygen (L)	$kcal/m^3_N$	755	382
	Nitrogen	$kcal/m^3_N$	–	168
	Air	$kcal/m^3_N$	–	279
	Argon	$kcal/m^3_N$	–	43
	Sub total	$kcal/m^3_N$	1,407	2,042
Energy intensity		$kcal/m^3_N$	475	–83
Energy intensity		Mcal/t	99	–17

Note: Equivalent calorie Oxygen High pressure: 1,700 $kcal/m^3_N$
Low pressure: 1,225 $kcal/m^3_N$
Nitrogen : 270 $kcal/m^3_N$
Electricity : 2,450 $kcal/m^3_N$

① Improvement on operation and facilities

The power consumption of the air compressors of the oxygen plant takes about 28 % of the total power consumption of the iron and steel works. Table 1.41 shows the specifications of the air compressors.

Table 1.41 Specification of Air Compressor

Type	Centrifugal type			
Discharge pressure	5.5 kg/cm^2 (G)			
Suction pressure	0.84 kg/cm^2			
Air volume	65,000 m^3_N/h			
Motor output	9,000 kW	Voltage	10.5 kV	4 units
			6.3 kV	2 units

There are six air compressors, of which three (No. 1, No. 3 and No. 4) were observed for power consumption. Table 1.42 summarizes the results of measurement.

Table 1.42 Measurement Data of Air Compressor (No. 1, No. 3 and No. 4)

	No. 1	No. 3	No. 4	Mean
Electric power (kW)	6,215	5,368	5,356	5,646
Power factor	0.977	0.858	0.848	-
Utilization factor	0.69	0.60	0.60	0.63
Discharge pressure (atg)	5.33	5.20	5.47	5.33
Air volume (m^3/h)	69,500	66,670	64,870	67,010
(in terms of m^3_N/h)	50,450	(48,390)	(47,090)	(48,640)
Theoretical power				3,393
Efficiency (%)				60.1

The theoretical power consumption of each air compressor was determined by the equation below, assuming that the atmospheric pressure of Esfahan is to be equal to 627 mmHg (0.825 kg/cm^2).

$$Lth = \frac{(\alpha+1)K}{K-1} \cdot \frac{P_s Q_s}{6,120} \cdot \left\{ \left(\frac{P_d}{P_s} \right)^{\frac{K-1}{K(\alpha+1)}} - 1 \right\}$$

here

Lth: Required theoretical power (kW)

α : Number of intercoolers

K : ratio of specific heat of air

P_s : Suction pressure (kg/m^2)

P_d : Pressure (kg/m^2)

Q_s : Volume of air at suction (m^3/min)

From the results, if the air compressors are operated with an efficiency of about 60 % and the running efficiency of the motors is 90 %, then the compressor themselves are operated with an efficiency of about 67 %. On the day of the survey, all the six oxygen plants were running but slightly short of the oxygen demand of the iron and steel works, 50,000 $m^3{}_N$/h. Therefore, if the oxygen yield is 17 %, it may be safe to assume that the consumption of feed air per plant was less than 49,029 $m^3{}_N$/h. We believe that the estimate of 48,640 $m^3{}_N$/h in Table 1.42 is correct.

The energy intensity per 1 $m^3{}_N$ of compressed air is 0.116 kWh/$m^3{}_N$ and that of oxygen is 0.683 kWh/$m^3{}_N$. Under Japanese atmospheric conditions, they are equivalent to 0.108 kWh/$m^3{}_N$ and 0.634 kWh/$m^3{}_N$ respectively.

The poor energy intensities are attributable to the fact that all the six air compressors are operated. If only five of them are operated without modifying the rate of oxygen generation, they will be improved to the following levels.

Electirc power intensity of air compressor: 0.116 → 0.102 kWh/$m^3{}_N$-Air
(0.095 kWh/$m^3{}_N$-Air after correcting for the atmospheric pressure)

Electric power intensity of separator: 0.683 → 0.602 kWh/$m^3{}_N$-O_2
(0.559 kWh/$m^3{}_N$-O_2 after correcting for the atmospheric pressure)

Thus, the electric power intensity can be reduced by about 10 % by operating the air compressors at the design point. Then, a 5 %* of annual average power saving can be expected.

* 13,080 MWh/y (= 261,604 MWh/y × 0.05)

It is recommended that the intensity be regularly measured by referring to the Guideline and that the specifications provided at the time of purchase be maintained.

② Modernization of facilities

The oxygen plant has to be operated with high efficiency machines in the future in terms of feed air compressors, oxygen compressors and separators. Table 1.43 shows some of the data obtained as a result of the diagnosis.

Table 1.43 Operation Data of O_2 Plant

		Result of the Study	JNSW
Air volume	A	48,640 m^3_N/h	144,000m^3_N/h
Presumed oxygen generation	B	8,269 m^3_N/h	23,800 m^3_N/h
Electric power for air compressor	C	5,646 kWh/h	10,401 kWh/h
Electric power intensity (C/A)		116 Wh/m^3_N Air	74.4 Wh/m^3_N Air
Presumed electric power intensity (C/B)		0.683 kWh/$m^3_N O_2$	0.437 kWh/$m^3_N O_2$
Suction air temperature		Assumed to be 32 °C	20 °C

Information obtained at preliminary diagnosis

	Esfahan	JNSW
Electric power intensity for separator	0.680 kWh/$m^3_N O_2$	0.500 kWh/$m^3_N O_2$
Electric power intensity for oxygen compressor	0.230 kWh/$m^3_N O_2$	0.165 kWh/$m^3_N O_2$

4) Other facilities

Table 1.44 compares the other facilities with those at JNSW.

While no significant difference is observed between them on a crude steel per ton basis, the electric power intensity of the water facilities needs reduction.

The power consumption in the first pump station selected for diagnosis was observed. There are four return pumps (No. 12, No. 13, No. 14 and No. 15) in the first pump station, of which No. 13, and No. 14 and No. 15 were operating during the observation.

Table 1.45 shows the specifications of the pumps.
Table 1.46 shows the measurement results.

Table 1.44 Energy Consumption of Others

unit: Mcal/t-steel

		Esfahan	JNSW
Consumed Energy	Electricity (water)	194 (79.1 kWh/t)	76 (31.1 kWh/t)
	Electricity (other)	15 (6.3 kWh/t)	89 (36.2 kWh/t)
	Oxygen	19	10
	Air + N_2	–	1
	Steam	120	4
	Fuel	46	33
	Air to production process	35	–
	(Subtotal)	(430)	(213)
	Heat difference	103	325
Energy intensity	Mcal/t-steel	533	538

Note: Heat difference: Table1.3, 1.7 and 1.10. 149 × 1,301,400 ÷ 1,880,982 = 103

Table 1.45 Specification of Pump

Head	20 m
Flow rate	4,100 m^3/h
Motor output	320 kW
Motor efficiency	92.6 %
Rotational speed	735 rpm

Table 1.46 Measurement Data of Pump

	No. 13	No. 14	No. 15	Average
Electric power (kW)	290.6	301.5	316.3	302.8
Discharge pressure (kg/cm^2)	2.5	2.35	2.3	2.38
Flow rate (m^3/h)	3,250	3,090	2,300	2,880
Pump efficiency	76	71	50	67

While the efficiency of the pumps shows some extent of deviation, the operation of No. 14 pump was meausured for flow rate by means of an ultrasonic instrument. We may be safe to assume that the measured values are typical for the pumps.

According to the obtained data, No. 15 and No. 14 pumps were operating poorly. They have to be serviced immediately to recover the original capacity (e.g., by replacing the impeller ring).

Since the pumps have an Ns (specific speed) value of about 640, they will operate with an efficiency of about 85 % at the design point.

To reduce the electric and head power for the pump, firstly, it is recommended to find out the correct demand and head for water, and to make the number of operating pumps and the specification match them. If they cannot be determined first hand, reduce the supply rate gradually by 5 %, 10 %, 15 % and so on to decide the minimum flow rate not to affect plant operaion and obtain an estimated resistance curve.

Seeing the fact that the electric power conservation of the pumps should be based on reduction of the demand for water, the water consumption of large water consuming facilities have to be minimized. Once the minimal consumption rates are defined, the capacity of each of the pumps, the number of pumps to be operated and the method of controlling them have to be defined accordingly. In other words, the pumps have to be operated at their specified point.

If the pumps are currently operating to supply excessive water, the impellers of the pumps may be cut to reduce the power consumption.

According to our observations, the three pumps were supplying water at a rate of $2,880 \times 3 = 8,640\ m^3/h$ but the discharge pressure was as high as 2.3 to 2.5 kg/cm^2 (G). This may be probably because the discharge valves were slightly closed. Therefore, the demand may probably be met by operating the two pumps by restoring the specified values for the gap of the impeller rings of the pumps. If the discharge valves of the pumps are fully open, it means that process requires high pressure that is as high as 2.3 to 2.5 kg/cm^2 (G) and the cause of this has to be further looked into in order to reduce the pressure to the normal level of 2.0 kg/cm^2 (G).

The power consumption of the water facilities does not seem to have any fluctuations throughout the year because the yearly average is close to the average during our diagnos. Since water is used mostly as cooling water, it may be necessary to change the mode of operation of the facilities at least in summer and in winter.

5) Energy distribution loss

Table 1.47 shows a comparison with JNSW.

There is a clear difference between their values and the JNSW values. The following items require improvement, considering that no BFG and COG gas holders are provided.

Table 1.47 Energy Distribution Loss

	Esfahan	JNSW	Remarks
Electricity	13 Mcal/t-steel	19 Mcal/t-steel	
O_2	35	4	
COG	79	64	
BFG	494	5	
Steam	0*	26	
Others	0*	15	LDG etc.
Total	620 Mcal/t-steel	133 Mcal/t-steel	

*: The data could not be obtained.

① Improvement on operation

①-1 High rate of oxygen loss due to dispersion

A tight communication link has to be established with the steelmaking shop in order to motivate them to unify the tap-to-tap time of the converters and reduce the current dispersion level of 13.7 % down to about 6 %.

No data on steam loss is available in their report on energy distribution.

The generated volume and the consumed volume of steam will not agree because steam is inevitably accompanied by condensing loss and unmeasurable situations. The difference between them has to be checked on a monthly basis and the meters and the traps have to be serviced if any abnormality is observed.

①-2 Natural Gas

Although natural gas is very clean, small metering errors may occur and the metering differences between purchased and consumed volumes should not be allocated to the consumers in a businesslike manner. While the purchased volume may be currently corrected by the responsible staff members to compensate the differences of pressure and temperature, the consumption of natural gas in steelmaking shop is unusually high. Therefore, we recommend to check the meters on the purchasing point.

② Modernization

We propose to install BFG 50,000 m^3 and COG 30,000 m^3 gas holders because of their advantages that become apparent particularly when the price of natural gas is higher.

A high loss rate of by-product gas due to dispersion can discourage any energy conservation efforts. In other words, energy conservation will be boosted by installing them under the political consideration.

6) Supply and demand of electric power

Table 1.48 shows the average power consumption in 1994 and the average power consumption obtained by us during the site surveys. It will be seen that the loads of the oxygen plant, converters, and rolling mills fluctuate remarkably.

In view of the fact that the load of the oxygen plant is particularly remarkable, the blast furnace and the converters have to be operated on a stable basis in order to level off the peak load.

7) Summary of the recommended measures

Table 1.49 summarizes the proposed energy conservation measures in the energy facilities.

Table 1.48 Electricity Balance

(Supply)	1994 year		June 23 – June 24 (24H)		
ITEM	total (MWh)	average (MW)	total (kWh)	average (MW)	MW difference
CPP production	149,900	17.1	274,680	11.4	-5.7
TPP	757,981	86.5	2,439,000	101.6	15.1
gas	6,139	0.7	0	0.0	-0.7
Generation total	914,019	104.3	2,713,680	113	9
Riz	77,409	8.8	334,015	13.9	5.1
Nasac	198,998	22.7	483,840	20.2	
Purchase total	276,407	31.6	817,855	34.1	
Total	1,190,426	135.9	3,531,535	147.1	11.3

(Consumption)	1994 year		June 23 – June 24 (24H)		
ITEM	total (MWh)	average (MW)	total (kWh)	average (MW)	MW difference
Agglomeration	100,514	11.5	308,544	12.9	1.4
Raw material stock	11,016	1.3	29,685	1.2	0.0
Total of aglomeration	111,531	12.7	338,229	14.1	1.4
Coke oven plant	37,622	4.3	105,100	4.4	0.1
Aspiration	0	0.0	28,128	1.2	1.2
Slag of blast furnace	735	0.1	1,278	0.1	0.0
Furnace No. 1	18,323	2.1	22,497	0.9	-1.2
Furnace No. 2	20,659	2.4	45,000	1.9	-0.5
Air	1,586	0.2	3,458	0.1	0.0
Total of blast furnace	41,304	4.7	100,361	4.2	-0.5
Casting	17,197	2.0	114,837	4.8	2.8
Converter	77,623	8.9	213,792	8.9	0.0
Scrap	684	0.1	1,839	0.1	0.0
Scrap crashing	384	0.0	1,032	0.0	0.0
Production	8,869	1.0	23,354	1.0	0.0
Continuous	6,120	0.7	28,980	1.2	0.5
Total of convertor	110,877	12.7	383,834	16.0	3.3
Azar Co. (Lime calcining plant)	19,692	2.2	125,036	5.2	3.0
Roll 300	55,837	6.4	161,652	6.7	0.4
Roll 500	50,363	5.7	96,152	4.0	-1.7
Roll 650	56,029	6.4	100,414	4.2	-2.2
Roll 350	18,399	2.1	45,822	1.9	-0.2
Total of roll	180,628	20.6	404,040	16.8	-3.8
O_2 workshop	30,666	3.5	45,760	1.9	-1.6
O_2	261,694	29.9	997,542	41.6	11.7
Compressor	42,215	4.8	80,388	3.3	-1.5
Total of O_2 workshop	334,575	38.2	1,123,690	46.8	8.6
Abband dam	9,873	1.1	34,272	1.4	0.3
Physical water	4,957	0.6	15,109	0.6	0.1
Water treatment	154	0.0	242	0.0	0.0
Cyclic water	133,844	15.3	360,307	15.0	-0.3
Total of water	148,828	17.0	409,930	17.1	0.1
Total of mechanical engineering	12,906	1.5	35,829	1.5	0.0
CPP	31,671	3.6	78,240	3.3	-0.4
TPP	56,231	6.4	172,840	7.2	0.8
Gas PP	76	0.0	15	0.0	0.0
Chemical treatment	764	0.1	2,032	0.1	0.0
Total of power plant	88,741	10.1	253,127	10.5	0.4
Civil department	24,868	2.8	76,538	3.2	0.4
Shahr Foolad Co.	32,796	3.7	62,270	2.6	-1.1
Takavar Co.	13,662	1.6	30,270	1.3	-0.3
Others	22,541	2.6	83,281	3.5	0.9
Loss in distribution line	9,855	1.1	0	0.0	-1.1
Total	1,190,426	135.9	3,531,535	147.1	11.3

Table 1.49 Summary of Energy Conservation Measures in Energy Utilization Facilities

(Japanese Yen base)

		Expected Saving										
Item		Energy intensity Mcal/t	Fuel kL/y	Fuel Million yen/y	Fuel %	Electricity MWh/y	Electricity Million yen/y	Electricity %	Total Million yen/y	Investment Million yen	Payback Period Year	Recomendation
CPP	Low O_2 combustion and enhancement of the vacuum degree of the condenser	21	4,341	73.8	0.9	-			73.8	10	0.1	O
	Modification to an electric blower and increasing the efficiency of the blast furnace blower	(282)*1	(58,290)	(990.9)	(11.8)	-			(990.9)	(3,500)	(3.5)	In the future
TTP	Multi-purpose power generating turbine											
O_2 plant	Air compressor Improvement of the operation method	17	-			13,167	131.7	4.1	131.7	0	0	O
	Increasing the efficiency of the air compressor	(51)	-			(39,501)	(395.0)	(12.3)	(395.0)	(2,500)	(6.3)	In the future
Energy	BFG, COG holder	(504)	(104,178)	(1,771.0)	(21.1)	-			(1,771.0)	(800)	(0.5)	In the future
Supply loss	Reduction of oxygen supply loss	15	-			11,286	112.9	3.5	112.9	0	0	O
Waster facilities	Improvement of the water pump operation method	17	-			13,080	130.8	4.1	130.8	10	0.08	O
Total		70	4,341	73.8	0.9 0.2*3	37,533	374.7	11.7*2 22.1*3	443.5	20	0.04	

(Iran Rial base)

		Expected Saving											
Item		Energy intensity Mcal/t	Fuel Oil kL/y	Fuel N/gas $10^3m^3_N/y$	Fuel Million Rial/y	Fuel %	Electricity MWh/y	Electricity Million Rial/y	Electricity %	Total Million Rial/y	Investment Million Rial	Payback Period Year	Recomendation
CPP	Low O_2 combustion and enhancement of the vacuum degree of the condenser	21	4,341	4,073	501	0.9	-			501	175	0.3	O
	Modification to an electric blower and increasing the efficiency of the blast furnace blower	(282)*1	(58,290)	(54,687)	(6,626)	(11.8)	-			(6,626)	(61,250)	(9.2)	In the future
TTP	Multi-purpose power generating turbine												
O_2 plant	Air compressor Improvement of the operation method	17	-				13,167	1,317	4.1	1,317	0	0	O
	Increasing the efficiency of the air compressor	(51)	-				(39,501)	(3,950)	(12.3)	(3,950)	(43,750)	(11.1)	In the future
Energy	BFG, COG holder	(504)	(104,178)	(97,738)	(12,022)	(21.1)	-			(12,022)	(14,000)	(1.2)	In the future
Supply loss	Reduction of oxygen supply loss	15	-				11,286	1,129	3.5	1,129	0	0	O
Waster facilities	Improvement of the water pump operation method	17	-				13,080	1,308	4.1	1,308	175	0.1	O
Total		70	4,341	4,073	501	0.9 0.2*1	37,533	3,754	11.7 22.1*1	4,255	350	0.1	

Remarks: The items to be implemented in the future are not included in the total column.
Saving ratio: Saving ratio for energy consumption in energy utilization facilities (Fuel: 4,503,066 Gcal/y, Electricity: 320,150 MWh/y)

*1 500 Mcal/t-steel – 89 kWh/t-steel × 2.45 Mcal/kWh = 282 Mcal/t-steel
*2 -11.7 % shows energy saving ratio in energy utilization facilities.
*3 Saving ratio for the energy consumption (Fuel: 16,780,222.6 Gcal/y, Electricity: 169,672.1 MWh/y)
22.1 % shows energy saving ratio for purchased power in the Works.

Energy price in Japan:
Fuel price: 17,000 yen/kL
Electricity price: 10 yen/kWh
Energy price on Iran Rial base:
Natural gas (N.gas): 123 Rial/m^3_N
Electricity: 100 Rial/kWh
Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Calorific value of fuel: Oil: 9,000 kcal/kL, N gas (Natural gas): 9,593 kcal/m^3_N
Investment cost is based on that in Japan.

h. Summary of the proposals

Table 1.50 summarily shows the proposals for power energy conservation.

Table 1.50 Summary of Proposals

(Japanese Yen base)

Process, Utilities	Expected Saving						Total	Investment	Payback
	Fuel			Electricity			Million	Million	Period
	kL/y	Million yen/y	%	MWh/y	Million yen/y	%	yen/y	yen	Year
Coke oven	25,885	440.0	1.4	-			440.0	1,200	2.7
Sintering plant	49,181	836.1	2.7	7,104	71.0	4.2	907.1	630	0.7
Blast furnace	84,000	1,428.0	4.6	-			1,428.0	510	0.4
Steel-making process	71,725	1,219.4	3.9	15,424	154.2	9.1	1,373.6	0	0
Rolling process	111,115	1,889.0	6.0	5,948	59.5	3.5	1,948.5	150	0.1
Utility facilities	4,341	73.8	0.2	37,533	374.7	22.1	448.5	20	0.04
Total	343,247	5,886.3	18.6	66,009	659.4	38.9	6,545.7	2,510	0.4

(Iran Rial base)

Process, Utilities	Expected Saving							Total	Investment	Payback
	Fuel				Electricity			Million	Million	Period
	F.oil kL/y	N.gas $10^3m^3_N$/y	Million Rial/y	%	MWh/y	Million Rial/y	%	Rial/y	Rial	Year
Coke oven	16,160	15,161	1,866	0.9	-			1,866	3,500	1.9
Sintering plant	49,181	46,139	5,675	2.7	7,104	710	4.2	5,675	10,500	1.6
Blast furnace	84,000	78,807	9,694	4.6	-			9,694	8,925	0.9
Steel-making process	71,725	67,292	8,276	3.9	15,424	1,542	9.1	9,818	0	0
Rolling process	111,115	104,246	12,822	6.0	5,948	595	3.5	13,417	2,625	0.2
Utility facilities	4,341	4,073	501	0.2	37,533	3,747	22.1	4,255	350	0.1
Total	343,247	324,842	39,956	18.6	66,009	6,594	38.9	46,550	43,400	0.9

Remarks: For the items to be improved in each process and utility, please refer to the table mentioned above.

Investment cost is based on that in Japan.