No. 2

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

IV. Guideline

September 1997

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

Japan International Cooperation Agency (JICA)

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IV. GUIDELINE

1. CHARACTERISTICS OF THE DOCUMENT

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Governmental organs in charge of the promotion of energy conservation are expected to take a leading position in proceeding with factory energy diagnosis and training of factory engineers which are necessary for promotion of future energy conservation activities in the factories in I.R. Iran.

To proceed with these activities, it is necessary to prepare a guideline which will be useful to engineers involved in the activities.

The document contained in this report describes the technical items which will be helpful in working out the guideline, with particular attention paid to the following:

(1) The document shall provide the description which is useful to the engineers of governmental organs in charge of the promotion of energy conservation as ① manual for diagnostic instruction, ② textbook for the seminar, or ③ data to determine the progress of factory rationalization or streamlining.

(2) The document shall be described in such a way that it can be understood by the engineers four or five years after graduating from universities or colleges, even if they are not currently engaged in the relevant field of the industry.

(3) In order to ensure that the range of the description items conforms to the current situation of the industry in I.R.Iran, the description shall be restricted to the items related to the process in the factories under the current study, and shall include basic items, numerical values for reference, and the technique and cases for energy conservation.

It is expected that this document will be used as a reference when the guideline is worked out by governmental organs in charge of the promotion of energy conservation, and will be improved by adding the information which will be collected through unique factory diagnosis.

2. FACTORY ENERGY DIAGNOSIS METHOD

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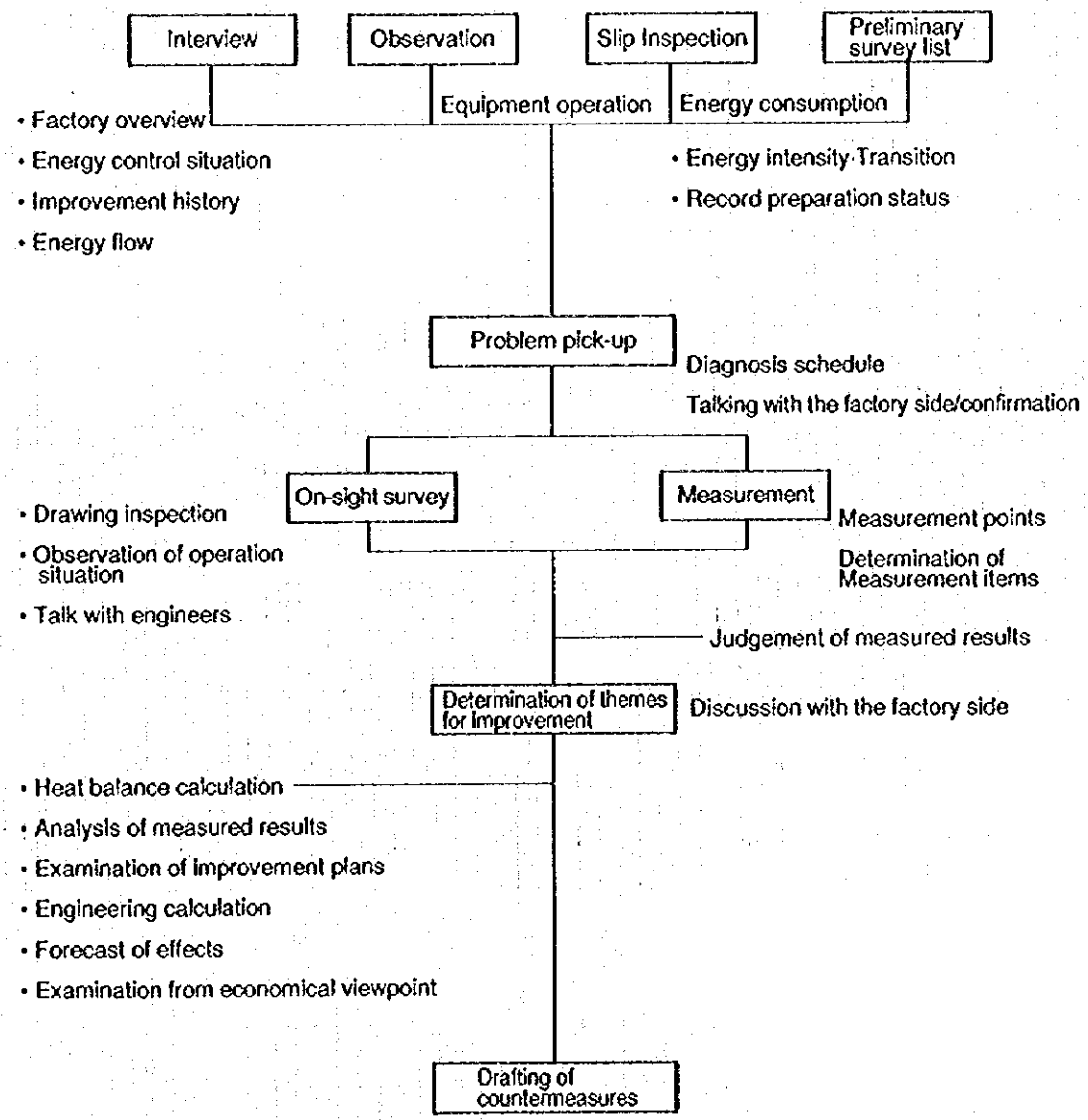
2.1 Factory Diagnostic Procedure

Figure 2.1 shows the general procedure for factory survey:

Figure 2.1 Flowchart of Factory Energy Diagnosis



(1) Factory overview

It is necessary to get correct information on the understanding and enthusiasm of the management persons for energy conservation, the efforts made in the past and the points considered as problems by the factory.

a. Factory overview (factory name, type of industry, capital, number of employees, organization, history, share and position in the industry)

b. Trend of the production volume of major products for the last five years

c. Trend of the energy consumption for the last five years

d. Production process chart of major products

e. Type, capacity and operating conditions of energy consuming equipment such as boilers

f. Energy flow

g. Electric power one line diagram and power receiving equipment

h. Factory layout

i. Items which the factory considers as problems and wishes to be studied

j. Items for energy conservation actions taken in the past

k. Items for energy conservation actions to be taken in future

l. Economic environment for the industry and the factory, and the factors inhibiting the promotion of energy conservation measures

(2) Working out the diagnostic program

a. General observation of the factory should be conducted while listening to the explanation of the factory persons, and the outline of the following points should be grasped by checking the preliminary questionnaire, energy consumption and production record:

- Problems of the equipment and operation
- Points which should take priority in diagnosis
- Technical level of the factory
- Deterioration and maintenance of the equipment
- Trend of utilization rates
- Energy unit consumption rate and its transition

b. Determining the diagnostic program

- Equipment or processes which should take diagnostic priority
- Measuring point, measuring items and measuring time
- Sharing the works

c. Explaining the diagnostic program to the factory to get understanding and cooperation about the following items:

- Adjustment with the production program
- Preparing the holes for installation of measuring sensors or taking samples
- Preparation of power supply

(3) Measurement and study to be implemented according to the diagnostic program

- Selection and arrangement of the measuring equipment
- Entering the set conditions in the measuring equipment
- Monitoring to see if the adequate data have been gained or not

- Detailed structure and dimensions of the equipment according to equipment drawings or actual measurement

- Determining the problems by observation of the operation

- Hearing from engineers

- Data required to evaluate the economic effect of the improvement plan (Study of the energy price, fund and cost)

(4) When the measurements have been obtained, items should be described in the report to propose improvement measures after the analysis, be picked up and be explained to the factory people to confirm such items.

(5) Study of improvement proposal

Based on the data entered in the check list, measurement record chart, data floppy, and drawings, heat management as well as electric management including calculation of heat balance, heat transfer and fluid conveyance power should be analyzed, and study should be made to seek ways for energy conservation by modification or addition of the equipment, thereby working out the plan best suited to the current situation of the factory.

On the basis of this plan, the approximate cost and expected effect required for improvement should be calculated, and economic evaluation of various improvement proposals should be made according to the common indices or techniques, thereby determining feasibility and priority.

A study should be made of the impact accompanying these improvement measures, showing the points to be noted for implementation.

2.2 Points to be Noted for Diagnosis

In Japan, the Ministry of International Trade and Industry (MITI) provides the items to be standard for judgment when the factory manager of the factory plans rationalization in the use of energy within the technically and economically feasible range.

According to this provision, the energy conservation technique is classified into seven categories as given below, showing the conformance criteria and target level for major items:

I. Rationalization of fuel combustion
II. Rationalization of heating, cooling and heat transfer
III. Prevention of heat loss due to heat radiation and transfer
IV. Waste heat recovery and reuse
V. Rationalization in conversion of heat into power
VI. Prevention of electric heat loss due to resistances
VII. Rationalization in conversion of electricity into power

Thus, these items provide a guideline for diagnosis of energy conservation. The following gives the confirmation criteria in the Japanese standards by way of reference.

The following also introduce examples of rationalization and improvement measures for each item:

I. Rationalization of fuel combustion

Table 2.1 Standard Air Ratio for Boilers

Classification	Load factor (%)	Solid fuel		Liquid fuel	Gas fuel	Blast furnace gas and other by-product gases
		Fixed bed	Fluidized bed			
Large-sized boiler for electric utilities	75 - 100	–	–	1.05 - 1.2	1.05 - 1.1	1.2
Other boilers						
30 t/h or more	50 - 100	1.3 - 1.45	1.2 - 1.45	1.1 - 1.25	1.1 - 1.2	1.2 - 1.3
10 to 30 t/h	50 - 100	1.3 - 1.45	1.2 - 1.45	1.2 - 1.3	1.2 - 1.3	–
5 to 10 t/h	50 - 100	–	–	1.3	1.3	–
< 10 t/h	50 - 100	–	–	1.3	1.3	–

Table 2.2 Target Air Ratios for Boilers

Classification	Load factor (%)	Solid fuel		Liquid fuel	Gas fuel	Blast furnace gas and other by-product gases
		Fixed bed	Fluidized bed			
Large-sized boiler for electric utilities	75 - 100	–	–	1.05 - 1.1	1.05 - 1.1	1.15 - 1.2
Other boilers						
30 t/h or more	50 - 100	1.2 - 1.3	1.2 - 1.25	1.05 - 1.15	1.05 - 1.15	1.2 - 1.3
10 to 30 t/h	50 - 100	1.2 - 1.3	1.2 - 1.25	1.2 - 1.25	1.2 - 1.25	–
5 to 10 t/h	50 - 100	–	–	1.2 - 1.3	1.2 - 1.25	–
< 10 t/h	50 - 100	–	–	1.2 - 1.3	1.2 - 1.25	–

Table 2.3 Standard Air Ratio of Industrial Furnaces
(Except for solid fuel furnace or the furnace of below 500 Mcal/h)

Classification	Continuous type	Intermittent type
Metal melting furnace for casting	1.30	1.40
Continuous billet heating furnace	1.25	
Other metal heating furnace	1.25	1.35
Metal heat treating furnace	1.25	1.3
Petroleum heating furnace	1.25	
Thermal cracking furnace and reforming furnace	1.25	
Cement kiln	1.30	
Lime kiln	1.30	1.35
Drying oven (only the burner section)	1.30	1.50

Table 2.4 Target Air Ratio for Industrial Furnaces
(Except for solid fuel furnace or the furnace of below 500 Mcal/h)

Classification	Continuous type	Intermittent type
Metal melting furnace for casting	1.25	1.3
Continuous billet heating furnace	1.2	–
Other metal heating furnace	1.2	1.3
Metal heat treating furnace	1.2	1.3
Petroleum heating furnace	1.25	–
Thermal cracking furnace and reforming furnace	1.25	–
Cement kiln	1.25	–
Lime kiln	1.25	1.35
Drying oven (only the burner section)	1.3	1.5

I-1	Selection of burners	Type, capacity, turndown ratio Maintenance, tip worn
I-2	Improvement in atomization	Fuel temperature, viscosity Volume of atomizing air and steam Fuel pressure Dispersion reagent, emulsion
I-3	Prevention of air entry	Furnace pressure control, Narrowing of the aperture, master/slave door, seal improvement, Reduced opening time

I-4	Fuel-air ratio control improvement	O_2 control, CO control, Cascade control, Cross limit control
I-5	Load stability, distribution of small-sized boilers, and control of the number of units	Load distribution improvement and control of the number of units, Steam accumulator
I-6	Combustion temperature rise	Combustion by oxygen enrichment, Gas atomization,
I-7	Complete combustion at a low temperature	Combustion by catalyst Fluidized bed combustion

II. Rationalization of heating, cooling and heat transfer

II-1	Heating by industrial furnace	
II-1-1	Optimization of heating temperature	Setting the work standards,
II-1-2	Heat pattern improvement	Temperature distribution, temperature rise speed, In-furnace gas flow
II-1-3	Load optimization	Furnace floor load, Load distribution to more than two equipment, Load leveling
II-1-4	Material loading method improvement	
II-1-5	Furnace shape improvement	
II-1-6	Reduction in calorific heat of furnace body and transfer tool	Reduced weight
II-1-7	Flame emissivity improvement	
II-1-8	Direct heating	Improvement by modification into direct heating furnace, Submerged combustion, Direct resistance heating Far infrared heating, Microwave heating, Induction heating Dielectric heating

II-2 Heating by steam

II-2-1 Optimization of steam pressure

II-2-2 Air purging

II-2-3 Direct steam blow-in method improvement

II-3 Heat transfer

II-3-1 Reduction in resistance for heat transfer	Prevention of scale, sludge and frost from growing on heat transfer surface, Boiler water quality control, chemicals supply, blowing optimization, Removing condensed film, defrosting, Cleaning, soot blowing, filter cleaning
II-3-2 Improvement of heat transfer coefficient	Air flow rate increase, heating by jet flow, high-speed burner, Fluidized heat transfer, Atomized mist cooling
II-3-3 Heat exchange system	Optimization, Increase in unit numbers
II-3-4 Heat exchanger	Use of material with high heat conductivity Heat transfer tube shape Heat transfer tube arrangement Expanded heat transfer surface, fin plate, Buffer plate, turbulence accelerator

II-4 Operation

II-4-1 Optimization of start and stop time	Use of remained pressure of boiler

II-4-2	Reduction in load	Air conditioning temperature, rate of air circulation optimization, Use of potential heat in the preceding process, Reduction in process wait time Reduction in empty furnace time, lot concentration Optimization of distillation column reflux ratio, selection of feed/extraction tray
II-5	Process	
II-5-1	Improvement of control method	Reduction of margin
II-5-2	Introduction of automated system	
II-5-3	Cascade use of heat	Multi effect evaporator, steam re-compression Increase in the number of distillation tower trays Plant integration Pooling of energy among plants
II-5-4	Change of separation method	Mechanical separation Separation by membrane Adsorption Extraction and super-critical extrac-tion
II-5-5	Layout change	Reduction in transport distance Avoiding the complicated transports Reduction in idle operation time by reduced transport distance
II-5-6	Mitigation of reaction conditions	Catalyst improvement Chemicals improvement Bio reactor
II-5-7	Change of product standards	Avoiding the excessively high quality product Materials requiring no heat treatment in the next process

II-5-8	Change of materials	Recycling
II-5-9	Scale up	Reduction of operating time by increased electric power
II-5-10	Introduction of continuous operation	
II-5-11	Introduction of higher speed	
II-5-12	Omission of some processes	Hot charging
II-5-13	Use of highly efficient equipment	

III. Prevention of heat loss due to heat radiation and transfer

Table 2.5 Standard Temperatures of Furnace Outer Walls
(except for the rotary furnace and the furnace with the capacity of 500 Mcal/h or less, outer air temperature 20 °C)

Temperature inside the furnace (°C)	Temperature outside the furnace wall (°C) Ceiling	Side wall	Hearth contacting with the outer air
1,300 °C or more	140	120	180
1,100 °C or more but less than 1,300 °C	125	110	145
900 °C or more but less than 1,100 °C	110	95	120
Less than 900 °C	90	80	100

Table 2.6 Target Temperatures of Furnace Outer Walls
(except for the rotary furnace and the furnace with the capacity of 500 Mcal/h or less, outer air temperature 20 °C)

Temperature inside the furnace (°C)	Target temperature of furnace outer wall (°C) Ceiling	Side wall	Hearth contacting with the outer air
1,300 °C or more	120	110	160
1,100 °C or more but less than 1,300 °C	110	100	135
900 °C or more but less than 1,100 °C	100	90	110
Less than 900 °C	80	70	90

III-1	Prevention of leakage	Inspection, repair at earlier stage, Selection and maintenance of steam trap Improved seal for the rotary section and joint
III-2	Reduction in heat release area	Improvement of piping route Removal of unnecessary piping Closing of the master valve for unnecessary piping and putting blind plate
III-3	Heat insulation	Improved heat insulation for flange and valve, Use of heat insulation material with low heat conductivity Reduced thermal emissivity of the cover Installation of covers or lid Maintenance of heat insulations Reduced weight of heat insulation material for batch furnace (Specific bulk weight should be less than 1.3.)
III-4	Prevention of gas flowing into the furnace and radiation loss	Reduced aperture size, closing, installation of the door Reduced door open/close time
III-5	Optimization of boiler blow volume	

IV. Waste heat recovery and reuse

Table 2.7 Standard Exhaust Gas Temperatures for Boilers (unit: °C)
(Load factor: 100% at the outer temperature of 20 °C)

Classification of evaporation	Solid fuel		Liquid fuel	Gas fuel	Blast furnace gas and other by-product gases
	Fixed bed	Fluidized bed			
Large-sized boiler for electric utilities	–	–	145	110	200
Other boilers					
30 t/h or more	200	200	200	170	200
10 to 30 t/h	250	200	200	170	–
5 to 10 t/h	–	–	220	200	–
< 10 t/h	–	–	250	220	–

Table 2.8 Target Exhaust Gas Temperatures for Boilers (unit: °C)
(Load factor: 100% at the outer temperature of 20 °C)

Classification of evaporation	Solid fuel		Liquid fuel	Gas fuel	Blast furnace gas and other by-product gases
	Fixed bed	Fluidized bed			
Large-sized boiler for electric utilities	–	–	135	110	190
Other boilers					
30 t/h or more	180	170	160	150	190
10 to 30 t/h	180	170	160	150	–
5 to 10 t/h	–	300	200	180	–
< 10 t/h	–	320	220	200	–

Table 2.9 Standard Waste Heat Recovery Ratio for Industrial Furnaces

Gas temperature at furnace outlet (°C)	Waste heat recovery rate (%)		
	> 20 Gcal/h	5 -20 Gcal/h	1 - 5 Gcal/h
< 600	25	25	–
600 - 800	35	30	25
800 - 900	40	30	25
> 900	45	35	30

Table 2.10 Target Waste Heat Recovery Ratio of Industrial Furnaces

Gas temperature at furnace outlet (°C)	Waste heat recovery rate (%)		
	> 20 Gcal/h	5 -20 Gcal/h	1 - 5 Gcal/h
< 600	30	30	–
600 - 800	35	30	25
800 - 900	40	35	30
> 900	50	40	35

IV-1 Waste energy

- Exhaust gas, exhaust air
- Waste water, waste liquid
- Condensate
- High-temperature solids (red hot cokes)
- Mechanical energy (water head)
- Waste pressure (blast furnace, fluid coker)
- By-product gas (steel converter)
- Coldnees (liquefied natural gas)
- Natural energy (solar light, heat and outer air temperature)

IV-2 Purpose of use	Heating of material and raw materials Preheating of combustion air or feed air Preheating the boiler feed water Preheating the fuel (oil) Steam generation Power generation, electric power generation Air conditioning District heat supply Refrigeration Fish culture Heating of green house Snow melting
IV-3 Means	Heat exchanger and fluidized bed Heat pipe Heat pump Use of heat medium Waste heat boiler Reduced pressure type recovery boiler Turbine (organic solvent and steam) Total enthalpy heat exchanger Regenerative burner

V. Rationalization in conversion of heat into power

V-1 Improvement of energy efficiency	Improvement of steam conditions Combined system Cogeneration Power recovery of steam pressure reduction

V-2 Rationalization in power plant	Improvement of turbine and nozzle shape Condenser vacuum control (cleaning, water temperature and leakage) Power plant operation Variable pressure operation Control of the number of auxiliary equipment, speed control Optimization of back and extraction pressure Peak shift (use of electric power during mid-night hours and on holidays, heat storage)
V-3 Direct power generation	Fuel cell
V-4 Engine efficiency improvement	
V-5 Rationalization of steam ejector	Optimization of the number of steps and steam pressure Conversion to vacuum pump

VI. Prevention of electric heat loss due to resistances

VI-1 Power transmission	
VI-1-1 Increase in voltage	
VI-1-2 Reduction in temperature	
VI-1-3 Conversion into DC power	
VI-2 Wiring	
VI-2-1 Minimizing the wiring length	Power receiving substation equipment Sub-station system, load arrangement improvement, Wiring route improvement
VI-2-2 Wiring system improvement	
VI-2-3 Selection of wire diameters	
VI-2-4 Balancing loads between 3-phase	

VI-3 Transformer	
VI-3-1 Optimum capacity	
VI-3-2 Load distribution, control of the number of operating units	
VI-3-3 Wire connection method	
VI-3-4 Disconnected when not in use	
VI-4 Electric equipment	Reduced contact resistance
VI-5 Power factor improvement	Installation of phase advance capaci-tor, load interlocking ON/OFF Optimization of load factor of equipment
VI-6 Operation	Use of synchronous generator
VI-6-1 Maximum power control	Load leveling Demand control
VI-6-2 Optimization of circuit voltage	
VI-7 Use of the equipment with minimum loss	Superconductivity

VII. Rationalization in conversion of electricity into power

VII-1 Motor	Use of highly efficient motor Optimum capacity
VII-2 Power transmission	Transmission device improvement, Lubrication control, Belt (material and relaxation adjustment)
VII-3 Operation	Prevention of idle operation, inter-mittent operation, Maintenance of optimum voltage, Intermittent charge for electric precipitator

VII-4 Fluid transport	Reduction in flow rate (leakage prevention)
VII-4-1 Load reduction	Reduction in pipe resistance (rationalization of pipe route and cleaning) Reduction in suction temperature Change of transport method Highly efficient equipment, impeller, variable blade
VII-4-2 Optimization of equipment capacity	Impeller cut
VII-4-3 Control	Speed control (VVVF, clutch, pole change) Control of the number of units
VII-5 Energy recovery	Regenerative braking
VII-6 Electric heating	
VII-6-1 Load reduction	Hot charge Furnace loading method, power input method improvement Reduction in contact resistance
VII-6-2 Highly efficient equipment	Higher efficiency of Frequency converter Direct heating (direct electric conduction, induction heating, dielectric heating, microwave heating, plasma heating)
VII-6-3 Comparison with combustion heating	

VII-7 Air conditioning

VII-7-1 Load reduction	Building shape, structure, direction, surroundings, Prevention of outer air from entering (automatically operated door, curtain) Optimization of volume and frequency of air circulation Heat insulation Separation of heat generating bodies, isolation of illumination heat sources, Local air conditioning, Zoning (change of air conditioning requirements according to the location) Room heating by far infrared radiation
VII-7-2 Ventilation	Filter cleaning, Reduced duct resistance Fan speed control Increased size of humidifier nozzle
VII-7-3 Improved control	Return water temperature control
VII-7-4 Operation control	Water quality control for cooling tower Cleaning of heat exchanger

VII-8 Illumination

VII-8-1 Optimum illuminance	
VII-8-2 Interior	Wall color
VII-8-3 Improved equipment layout	
VII-8-4 Use of sun light	
VII-8-5 Turning off the unnecessary lights	

VII-8-6 Illumination control	
VII-8-7 Fixtures cleaning	
VII-8-8 Lamp replacement at proper intervals	
VII-8-9 Use of highly efficient equipment	Lamp, Stabilizer and High-frequency lighting up
VII-9 Electrolysis	
VII-9-1 Reduced contact resistance	
VII-9-2 Reduced voltage	Reduction of overvoltage Improvement of electrodes
VII-9-3 Operating condition control	Bath temperature, concentration, distance between electrodes

3. ENERGY MANAGEMENT

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In order to achieve higher efficiency and level in energy consumption as well as productivity and quality, the first requirement is to use the appropriate and well-maintained equipment according to the purpose and to handle them properly. The most effective way for energy conservation is to reduce the number of the equipment troubles and to ensure higher product yields.

The second requirement is to consider if there is any room for improvement in the current equipment and operation method, and to make constant efforts to reach a higher level through repeated studies and factory experiments.

To achieve this, the management people of the factory and the engineers as well as all the operators working in the first front of the site are required to make an concerted effort. It is not too much to say that the success of the campaign depends on the willingness of all the employees of the company, and the factory management to encourage the willingness of these employees is the key to the success. Energy management can be defined as "an organized effort to achieve energy conservation".

3.1 Defining the Management Policy

Because of deeper recognition of the energy situation and requirements for improved factory profit, the factory management and supervising people have come to be greatly interested in energy conservation issues. In order to start the energy conservation activity as a campaign involving all the members of the factory, it is necessary to demonstrate a strong determination of the top management to achieve the goal as a company policy. It is essential to show a quantitative target in terms of percentage of energy to be reduced for each ton of product, and the deadline by which this target must be achieved, as well as such restrictive items as the upper limit of the annual investment and the investment recovery period. When the top management has defined a direction in which the factory is moving forward, the employees can be convinced that they are working in the direction desired by the top management of the company. Since all the factory members are making efforts in the same direction, cooperation among them will become very smooth.

The target of the management is shown as an overall goal, so each division in the factory should set up concrete, detailed targets regarding the items for which it can take actions within the scope of their responsibility to achieve the goal set up by the top management, and should make efforts to reach such targets. Since such targets are given in a familiar form which is easily understandable, they will be effectively conveyed to every member of the factory to get positive cooperation.

When the targets broken down for each division are to be set up, they will be studied in the committee (discussed later) to see if such individual targets meet the overall goal or not. It is also important to bring up rivalry in a good sense in the factory so that each division should set up higher level to make further efforts in challenging it.

3.2 Setting up the Organization to Promote the Energy Conservation Campaign

In the campaign such as energy conservation campaign where a great number of people pertaining to different classes join, it is necessary to appoint some persons who will take care of the overall progress of the activities. In the case of a small-sized factory, individuals may take up this responsibility. However, in the case of a large-sized factory, a special-purpose section may be organized for this purpose.

In any case, this section, as staff members of the plant manager, is required to pay attention to the progress of energy conservation campaign. If there is any delay in the progress, it should check the causes for such delay and should make efforts to remove such causes.

To be concrete, the duties of this section comprises having a correct information on the energy consumption situation, comparison with the original schedule, collection and checking of improvement proposals, distribution of improvement budgets, progress control of the improvement works, evaluation of the results, working out of the education and training program, and preparation for the meeting of the committee.

The committee is effective in ensuring a smooth communication and deep understanding among various divisions such as production, sales, material purchase, equipment maintenance, accounting so that the effective actions will be taken. In this meeting, impact of the energy conservation measures upon each division should be discussed, and it should be confirmed that energy conservation measures do not adversely affect the profits of the entire factory.

The committee should be headed by the factory manager having authority and responsibility for production, or a person having an equivalent authority and responsibility. Otherwise, the meeting will end up determining nothing and implementing nothing.

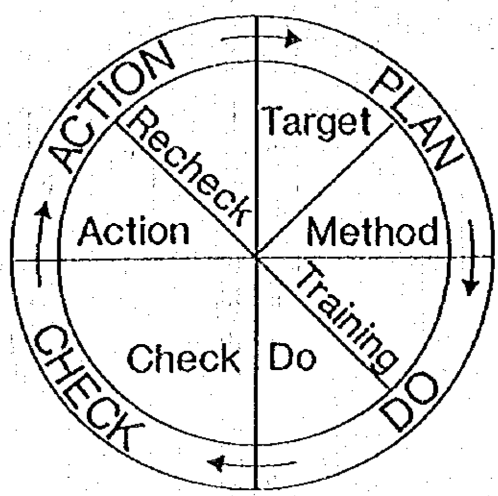
No matter how excellent an idea for the energy conservation countermeasures are based on, it will not lead to good results, unless the operators have a deep understanding of the meaning and put it into practical use in the daily works. In some cases, the QC circle (a small circle for activities) is effectively used for energy conservation with good results. The QC circle is to improve the human relations at the job site and to provide a joy of positive works by making use of the positive willingness which is essentially built in humans. Until workers recognize that the QC activities are useful and necessary for each of them, however, it is necessary to take some means as education or incentives which will facilitate promotion of the activities. It should be noted that the workers in the front line are always in contact with the energy-consuming equipment, and are in a position to feel most sensitively the phenomena which may occur according to changes of operating conditions. It will be very effective if it is possible to use information of these people and to pick up improvement actions from them.

3.3 Scientific and Organized Activities

To go ahead with the energy conservation campaign, it is essential to have correct information on the energy consumption. It will be impossible to work out an effective strategy if there is no data showing the change of the unit consumption rate to production volume, and the differences according to the equipment, product types and material types. It is not too much to say that the factory data contains a huge amount of suggestions for improvement. If the data area checked with awareness to solve problems, it is possible to find out ways for improvement. Install measuring instruments at the required positions, and record readings. Analyze the information on a periodic basis, and try to find out meaning in the information. In this case, the data should be processed in a statistical method, and be careful to detect significant differences.

When the improvement program is implemented, be sure to follow up the results. Efforts should be made to improve the work quality according to PDCA circle advocated by Dr. Deming. As shown in Figure 3.1, the PDCA circle comprises the following processes; to determine a method regarding an improvement item (PLAN), to train oneself in that method and to put it into practice (DO), to confirm the result (CHECK), and to evaluate the result and to standardize it if satisfactory, and to take corrective actions if not satisfactory (ACTION). If the goal in one step has been achieved, PDCA efforts will be made to achieve the goal in the next step. This method is useful in improving the work quality in every aspect including energy conservation activities.

Figure 3.1 PDCA Circle



In the first stage of selection of the theme in the PLAN phase, the items which should be improved can be easily found out. The improvement proposal system must by effectively used. Proposals may be given by any of the individual workers, QC circles, or staff members. The proposals should not be left unchecked. Immediately they must be brought to the meeting of the committee for review. Advice may be given to some proposals or may be partially modified; in this way, they should be taken up for implementation if possible. Some award should be given to the proposals. It is important to give official commendation to the proposal which has been adopted with excellent results, thereby encouraging the employees to take greater interest in the energy conservation campaign. For proposals which could not be adopted, it is necessary to explain the reason and to lead them for better proposal.

In the DO phase, it is necessary to explain the purpose of the improvement and concept of improvement program to all the factory people and to call for their cooperation to achieve the goal. Lead them so that they will report even minor abnormalities, and fine adjustment can be made smoothly in order to ensure successful activities.

The results should be checked on a periodic basis and reported to the committee or superiors, as well as to the workers in order to encourage them to take greater interest in the activities. In this case, it is important to define the criteria from the beginning, which should not be changed easily on the way.

In the ACTION phase, if the excellent results can be expected by executing the improvement plan, it should be incorporated in work standards to make sure. The required measures should also be taken for the equipment. This procedure is intended not to give much load to the operator in the normal operator, and is essential to ensure continued improvement activities.

If the considerable results can be obtained on a continued basis, the process should be described and should be made public to serve as a good example for other groups. At the same time, official commendation should be given to the related persons, thereby encouraging their further efforts.

3.4 Providing Education and Information

Even if the employees are willing to cooperate, the improvement program cannot be implemented smoothly without information on how to solve the problem. Their interest in the activities will be increased if they can make proposal in addition to pointing out problems.

For this purpose, intra-company education is very important. Seminars are held and guideline manuals are distributed. Even if the staff members are sent to seminars sponsored by external organizations, the results will be much reduced if the information gained from such an event is restricted to these participants, without being conveyed to the other staff members and general operators.

The participants in the external seminars should convey the knowledge in the intra-company seminars when they have came back to their own factory. This will raise the general level of the factory, and will also confirm their knowledge.

The improvement movement will also be encouraged by active exchange of information with the employees of rival companies, material suppliers and product vendors. Of course, it is necessary to compete among companies. Exchange of technical information on the give-and-take basis to some extent will raise the level of the industry and strengthen international competitiveness, thereby contributing to mutual benefits. For example, to disclose the unit consumption rate will motivate competition. Furthermore, problems can be picked up from different angles by getting advice and diagnostic comments from public organizations, consultants and university professors.

4. ENERGY CONSERVATION IN THE STEEL INDUSTRY

4. ENERGY CONSERVATION IN THE STEEL INDUSTRY

4.1 Introduction

Iron and steel-making plants include the following three types:

(1) Integrated steel works where iron ores are processed to make pig iron by a blast furnace, which is processed into steel and further into steel products such as steel sheets, bar steels, etc.

(2) Steel works where DRI (Direct-reduced iron) is made by a direct-reduction method and processed into steel by an electric furnace and further into steel products.

(3) Electric furnace plants where DRI and steel scraps are molten by an electric furnace to make steel without using a blast furnace or a direct reducing furnace.

An integrated steel works has several features. The largest one must be that the steel works as a whole has a rational and economical production system. For example, since the molten pig iron produced by a blast furnace can be charged into a converter in the subsequent steel making process, without being cooled, the heat loss is small and the operational efficiency is high. All the gases evolved from the blast furnace, converter, coke oven, etc. can be perfectly used as energy sources in the steel works. The slag separated in the production of pig iron and steel can be used for preparing cement, concrete aggregate, etc.

In addition, shops where various types of steel products are manufactured are located in the same area. This is also advantageous in terms of transportation cost.

On the contrary, a direct reducing steel works or an electric furnace plant has such features as being relatively small in equipment and other capital costs, and being easy in quick change of operation, to be suitable for producing many kinds in small quantities.

This chapter describes energy conservation measures for each process in integrated steel works.

4.2 Implementing Energy Conservation in Integrated Steel Works

Integrated iron and steel works have also energy integrated. It is, therefore, necessary to make an effective control of production, equipment and energy as well as to proceed with energy conservation for each process.

4.2.1 Energy Conservation for each Process

(1) Stabilization of operation and equipment

An integrated steel works does not show its power until each process operates smoothly. If a part of the equipment should go out of order or cause a trouble, it will affect the entire plant, adversely influencing the energy intensity. Thus, it is essential to stabilize the operation and equipment.

Particularly the stabilization of the operation of a blast furnace, which is the core of an integrated steel works, is most indispensable for energy conservation activities.

(2) Minimization of blast furnace fuel rate and selection of a cheap fuel

A blast furnace, which consumes a large amount of energy, requires minimization of the fuel rate (for example reducing it to 450 kg/t-pig or less), and equipment and operation techniques which will allow shifting the blast furnace fuel to cheaper energy in accordance with the fluctuation in energy prices.

(3) Enhancement of yield

Yield is not merely one of the important indexes for production activities in each process, but also it is important in terms of energy conservation because its enhancement contributes directly to the improvement of energy intensity.

(4) Improvement of operation and equipment

Energy intensity for each process is to be decreased by means of individual ideas and originality given below.

- Improving the productivity (t/h)
- Enhancing the combustion control (exhaust gas O_2 control or charge heat control)
- Reducing the fuel by enhancing of air preheating
- Improving the heating or combustion patterns including the improvement of heating patterns for the reheating furnace

- Reducing the required heat through decreasing slab extracting temperatures, etc.

- Decreasing the radiation heat loss from the furnace (reinforcement of heat insulation)

- Reducing the infiltration of air into the furnace (prevention of air leakage)

- Preventing the idle rotation of pumps, motors, etc. (to stop the rotating machines during non-operating time)

- Optimizing the capacity for pumps, fans, etc. (impeller cut)

- Reviewing the utility pressure such as reduction of air pressure for control, etc.

- Reducing the volume of cooling water and fuel for holding heat for the furnaces etc.

- Centralized rolling (to roll the steel of similar energy intensity collectively during a certain period of time)

4.2.2 Energy Conservation by Minimization of the Total Energy Cost of a Steel Works

In order to minimize the energy cost per ton of product with consideration given to the energy balance of a steel works, it is necessary to coordinate the control of blast furnace fuel rate, production control and energy management efficiently.

(5) Optimization of blast furnace fuel rate

A blast furnace has the greatest influence on the energy balance of a steel works. Increasing or decreasing the fuel rate for the blast furnace to minimize the energy cost of the steel works is one of the high-level operation techniques.

(6) Prevention of energy dissipation loss and energy center

A demand and supply balance should be taken to balance the generation and the use of energy in order to prevent the energy dissipation loss as well as to adjust the maintenance date for each process and the production schedule, thus minimizing the energy dissipation loss.

Diverse kinds of energy are used in large amounts in steel works, and moreover the generated and utilized amounts vary from one moment to another. Hence an energy center has been set up to perform an efficient demand and supply adjustment by a small number of people, and now conducts a centralized management of energy, and the center has also a predicting system interfacing with production information.

(7) Enhancement of energy buffer equipment

By-product gases and steams generated in the steel works differ in the amounts of generation and utilization. To absorb these fluctuations, it is necessary to have an optimum buffer equipment capacity.

(8) Production control system with a view to energy minimum

There are many processes in steel works, but if these processes are to be individually operated in their own way in an integrated steel works which is dependent on the recirculation of by-product gases, it will be extremely difficult to adjust the energy demand and supply, and in addition, less visible losses will occur in various sectors resulting in the aggravation of energy intensity. To cope with this situation, a steel works should place the first priority on the achievement of the production schedule, and set up the inter-process production control system which will also allow the target of energy intensity to be attained at the same time.

(9) Effective utilization of the sensible heat from the slabs in the preceding process

The introduction of a continuous casting equipment is commonly known as an example of using effectively the slab sensible heat from the preceding process. Recently the slabs made by the continuous casting equipment are charged into the rolling reheating furnace at a temperature as high as possible, thereby to reduce the fuel intensity of the reheating furnace. Realizing this at a high level (direct rolling) requires the synchronization of converter —CC— (to satisfy the software and hardware requirements) rolling, and the technique for manufacturing high-quality CC slabs and CC blooms.

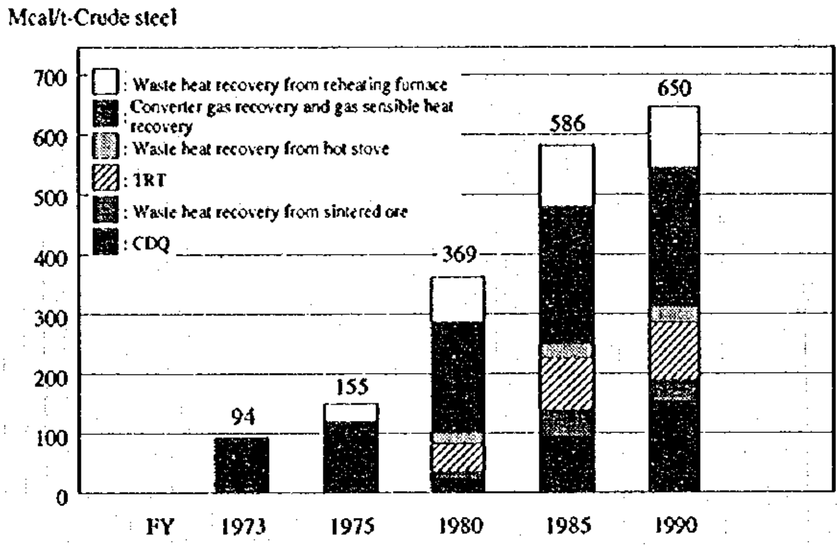
4.2.3 Waste Energy Recovery and Modernization of the Process

A steel works involves high-temperature processes, and consumes a large amount of energy including not only fuels but also electricity, oxygen, blast blower, etc. Thus, in order to remarkably improve the energy intensity, it is indispensable to modernize the waste energy recovery, the process and energy equipment.

(10) Recovery of waste energy

The amount of waste heat recovered in Japan is 650 Mcal/t as shown in Figure 4.1, and exceeds 12 % of the net energy amount used, demonstrating a significant result.

Figure 4.1 Trend of Recovery Quantities of Waste Energy in the Integrated Steel Works in Japan



Waste energy recovery techniques which will bring about a substantial result include the following:

- CDQ (Coke Dry Quenching)
- TRT (Blast furnace Top pressure Recovery Turbine)
- Recovery of converter gas and gas sensible heat
- Recovery of waste heat from the reheating furnace
- Recovery of waste heat from the sintering machine

However, these techniques call for a large amount of investment; therefore it is advisable to start with the one likely to produce a larger improvement effect after some improvements such as those of operation, synchronization of the processes (control of production schedule), etc. in consideration of the energy balance of the entire works.

Before planning the production schedule and determining the form in which energy is recovered (electricity or steam), consideration should be given on the utilization method of the recovered energy (countermeasure for the non-operating time), stability of the recovered energy, the characteristic of the plant to recover the waste heat, properties of waste heat, etc.

Recovering the waste heat to be recirculated for such a purpose as air preheating has achieved comparatively good results and is economically feasible.

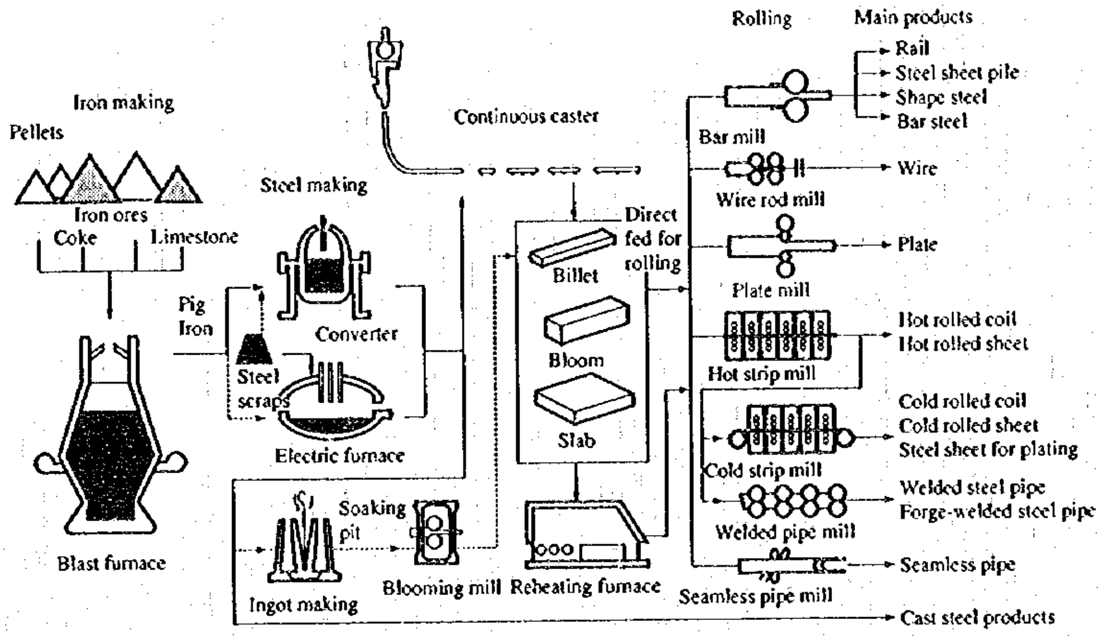
(11) Modernization (concatenation) of processes and efficiency enhancement of energy equipment

In the past there emerged innovative energy conservation processes — open hearth furnace, converter, blooming and CC. In the future, modernization and energy efficiency enhancement are expected to be effected for processes and energy equipment.

4.3 Outline of Major Processes in an Integrated Steel Works and Themes of Energy Conservation

Figure 4.2 shows the flow of raw materials and products in an integrated steel works.

Figure 4.2 Flow of Raw Materials and Products in the Integrated Steel Works



*Fed to surface treatment equipment, to be made into the products such as electrolytic tin plated steel, electrogalvanized steel, zinc hot dipped steel, etc.

4.3.1 Sintering Equipment

(1) Sintering process

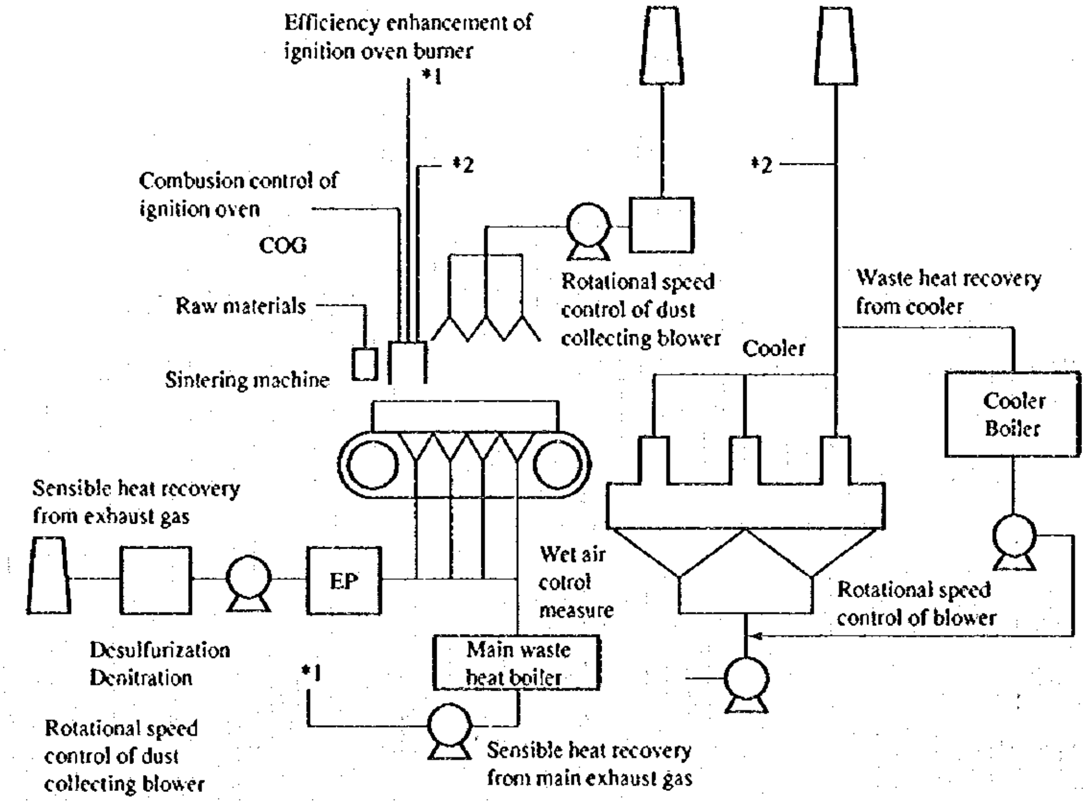
Iron ore is sintered to ensure the permeability in the blast furnace, accounting for 70 % or more of the charged material.

Sintered ore is prepared by burning and solidifying iron ore powder, coke and limestone, and the sintering process consists of a sintering machine and a sintering cooler. The sintering machine carries the raw materials using a conveyor, and gets them ignited with air supplied by an induced draft fan. The sintered ore delivered from the sintering machine is air-cooled by the sintering cooler, and then fed to the blast furnace.

The energy consumption in the sintering process accounts for about 9 to 10 % of all the energy consumption in the integrated steel works.

Figure 4.3 shows the flow and energy conservation measures of the sintering process.

Figure 4.3 Flow and Energy Conservation Measures of the Sintering Process



(2) Energy conservation by improvements of operation and equipment

a. Coke breeze

Coke breeze occupies the largest energy intensity in the sintering machine. The energy intensity of coke breeze, which was 60 to 65 kg/t, has decreased to a 40 kg/t to 45 kg level as a result of taking measures for improvement of the yield, enhancing thicker bed height operation, etc.

Two important measures for the improvement of the yield are to obtain a sufficient strength by conducting homogeneous sintering in the sintering machine through the homogenization of material charge and permeability of the sintering bed, and to prevent the crushing and degradation of the product during its transportation.

Taking measures such as improvement of permeability, optimization of the coke breeze grain composition, etc. will allow a thicker bed height operation, and improve the yield and increase the productivity.

b. Electric power

The foregoing measures contribute directly to reducing electricity intensity.

The electricity intensity actually decreased to about 20 kwh/t by means of preventing the wind leak by reinforcing the seal around the sintering machine, enhancing the efficiency of the blower impeller, cutting the impeller, and controlling the rotational speed of the blower in addition to the above-mentioned measures. Consequently, however, a dust collector, desulfurizing equipment etc., for pollution-preventive measures have come to be required, which results in the electricity intensity increasing to 35 to 45 kwh/t.

c. Fuel for the ignition furnace

The fuel intensity is reduced to 6 Mcal/t by lowering the air combustion ratio of the ignition furnace, optimization of the ignition furnace pressure control and improvement of the ignition furnace burner (adoption of a line burner).

(3) Energy conservation by recovery of waste heat

The waste heat from the sintering process includes mostly exhaust gas sensible heat (approx. 85 Mcal/t) from the sintering machine body and the exhaust gas sensible heat (approx. 180 Mcal/t) from the sintering cooler. The former is recovered from the sensible heat of the exhaust gas (250 to 400 °C) in the proximity of the ore discharge section of the sintering machine itself, to be used for recovering the steam or preheating the material and the air for the ignition furnace, etc. On the other hand, the latter is recovered as steam or electricity from the sensible heat of the high-temperature exhaust gas (250 to 400 °C) from the cooler by means of a power-generating system which double-flashes the recovered steam or hot water. Supposing that the temperature of the sintered ore is 700 °C, the temperature (with 0 °C as a reference temp.) of the sintered ore is 180 Mcal/t. However, since only the high-temperature zone waste of the sintering cooler is recovered, the recovery rate is around 65 Mcal/t sinter when 10ata saturation steam is recovered.

Figure 4.4 shows the heat balance in the sintering process, and Figure 4.5 shows the tansition of energy intensity, which is an example of a sintering plant which succeeded in reducing the coke intensity immediately after the oil shock.

Figure 4.4 Heat Balance in the Sintering Process (an example)

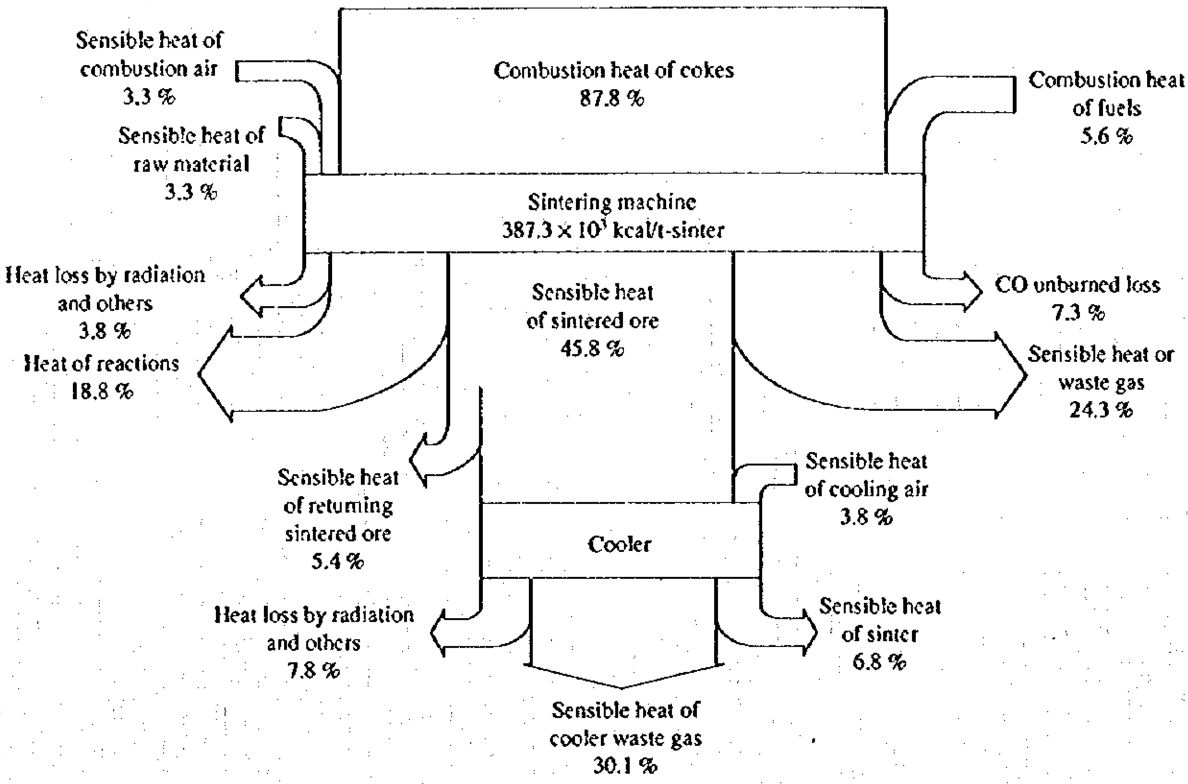
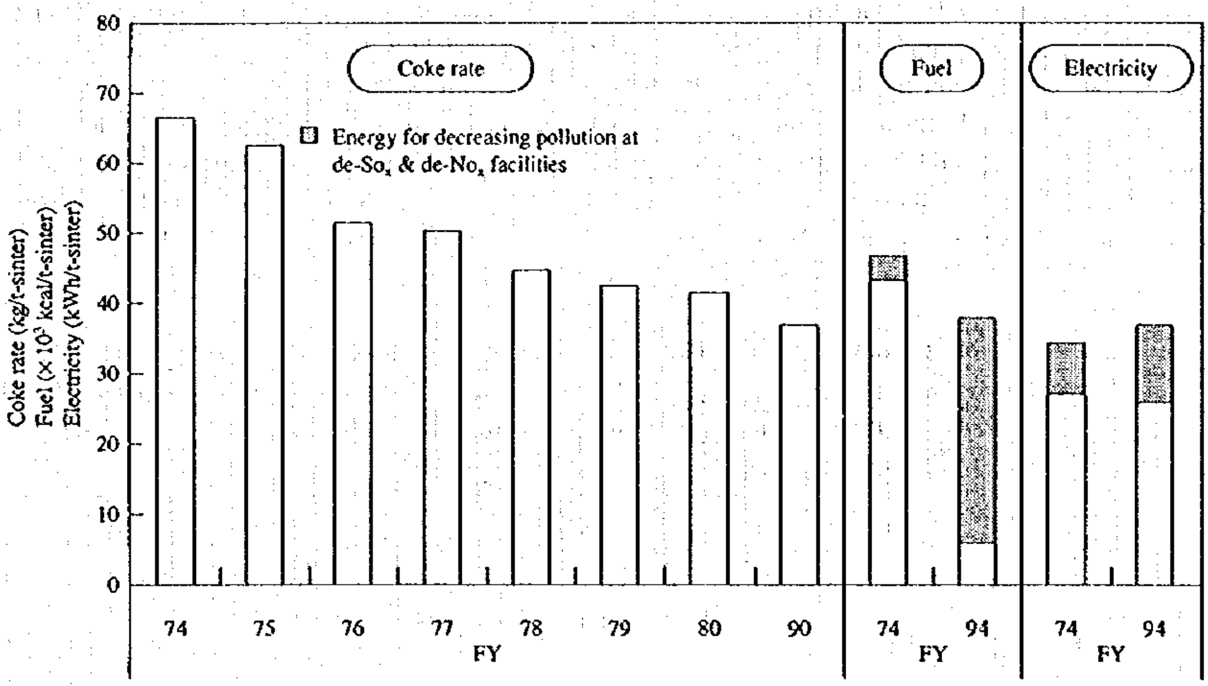


Figure 4.5 Transition of Energy Intensity at a Sintering Plant in Japan



4.3.2 Coke Oven

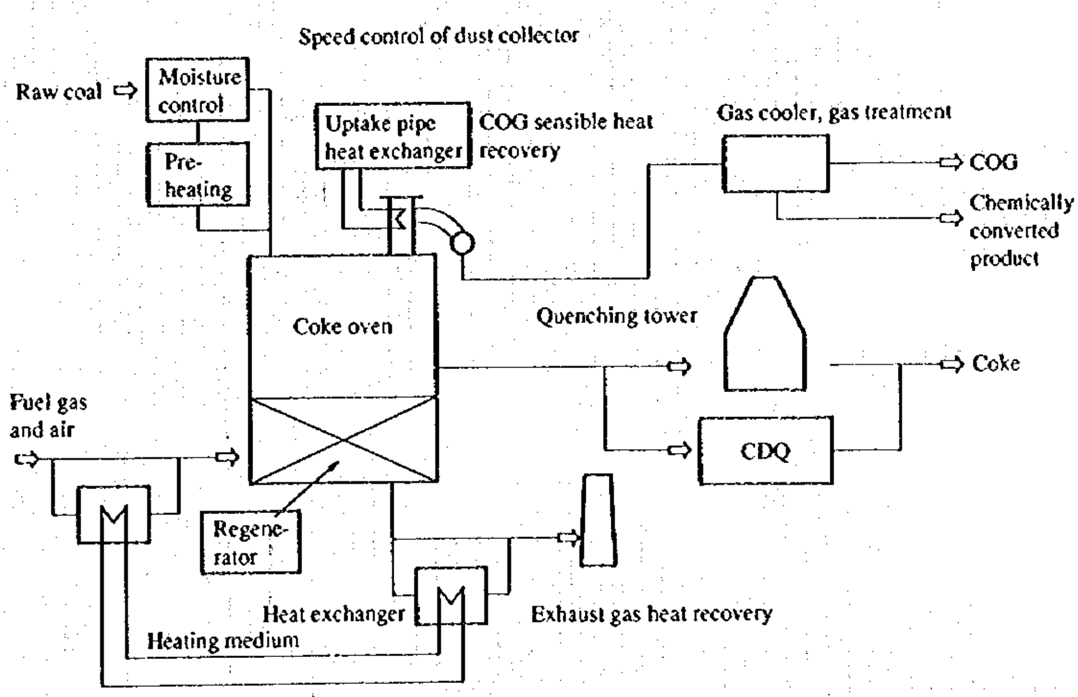
(1) Coke process

In the coke process, raw coal is carbonized in a coke oven to produce the coke for reducing the iron ore. The coke oven has carbonization chambers and combustion chambers arranged alternately on a regenerator. The raw coal is adjusted, ground, mixed and carried to be charged into the carbonization chambers, and usually in 15 to 20 hours, carbonization is completed to deliver hot coke. The coke is quenched into a product in a quenching tower. The product is sieved and fed on a belt conveyor into a blast furnace.

The energy in the coke process is mainly consumed for heating the raw coal and carbonization. Recently, waste heat recovery such as CDQ is widely adopted, and the energy consumption accounts for 5 to 6 % of the overall energy consumption in integrated steel works.

Figure 4.6 shows a flow diagram and energy conservation measures of the coke coking process.

Figure 4.6 Flow and Energy Conservation Measures of the Coking Process



(2) Energy conservation by improvements of fuel and equipment

a. Fuel

The fuel for carbonization occupies most of the energy intensity.

The fuel intensity was around 650 Mcal/t-coal; but it has decreased to as low as 550 Mcal/t-coal after the following improvements.

- Enhancement of combustion control (control of the oxygen concentration in the exhaust gas)

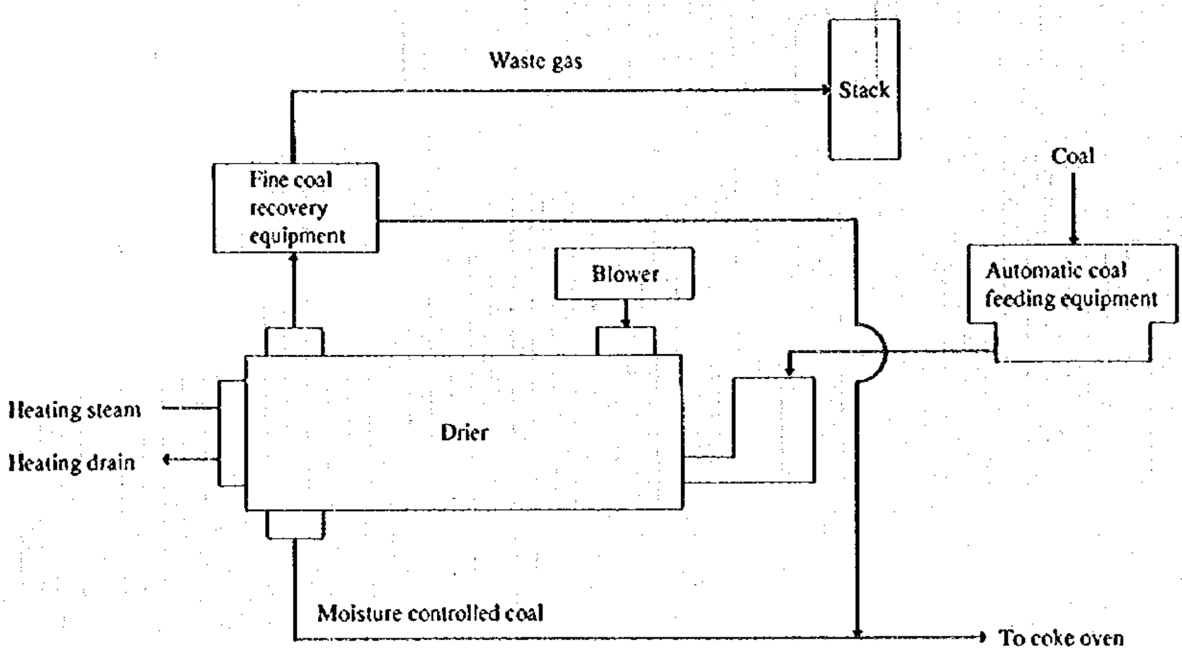
- Adoption of automatic combustion control using a computer on the basis of the coke oven operating schedule (operation rate) including furnace temperature control, as well as proper maintenance of the furnace temperature distribution for an even carbonization of coal to minimize the disparities in the unfiring time and carbonization time.

- Coal moisture control system preheats and dries the raw coal water content of about to 5 to 7 % by heat sources of steam or the plant waste heat, etc., before charging the raw coal into the coke oven, and can decrease the heat consumption for carbonization. This can also improve the productivity.

  The moisture control system brings about a fuel reducing effect of about 75 Mcal/t, allowing an approximately 5 % production increase.

Figure 4.7 shows a flow of the coal moisture control equipment.

Figure 4.7 Flow of a Coal Moisture Control System



b. Electricity

The concept of rotational speed control may be introduced into the blower of the dust collector.

(3) Energy conservation by waste heat recovery

a. CDQ (coke dry quenching)

Coke dry quenching (CDQ) equipment quenches the hot coke delivered from the coke oven, continuously by a circulating inert gas, and recovers the heat as steam (250 to 510 °C) from a high-temperature circulating gas by a waste heat boiler. The temperature of the hot coke is higher than 1000 °C, to allow recovery as high pressure steam, and so recovery as electricity can also be effected by using an existing power generator or a newly installed power generator attached to CDQ. The heat recovered by CDQ amounts to 200 to 300 Mcal per ton of coke. A part of the circulating gas was released in CDQ, but recently it is recovered as fuel, and the recovery rate amounts to 20 Mcal/t-coke (gas calory 850 kcal/Nm^3).

Figures 4.8 and 4.9 show an example of heat balance of coke oven and the processing sheet, respectively.

Figure 4.8 Heat Balance of a Coke Oven (an example)

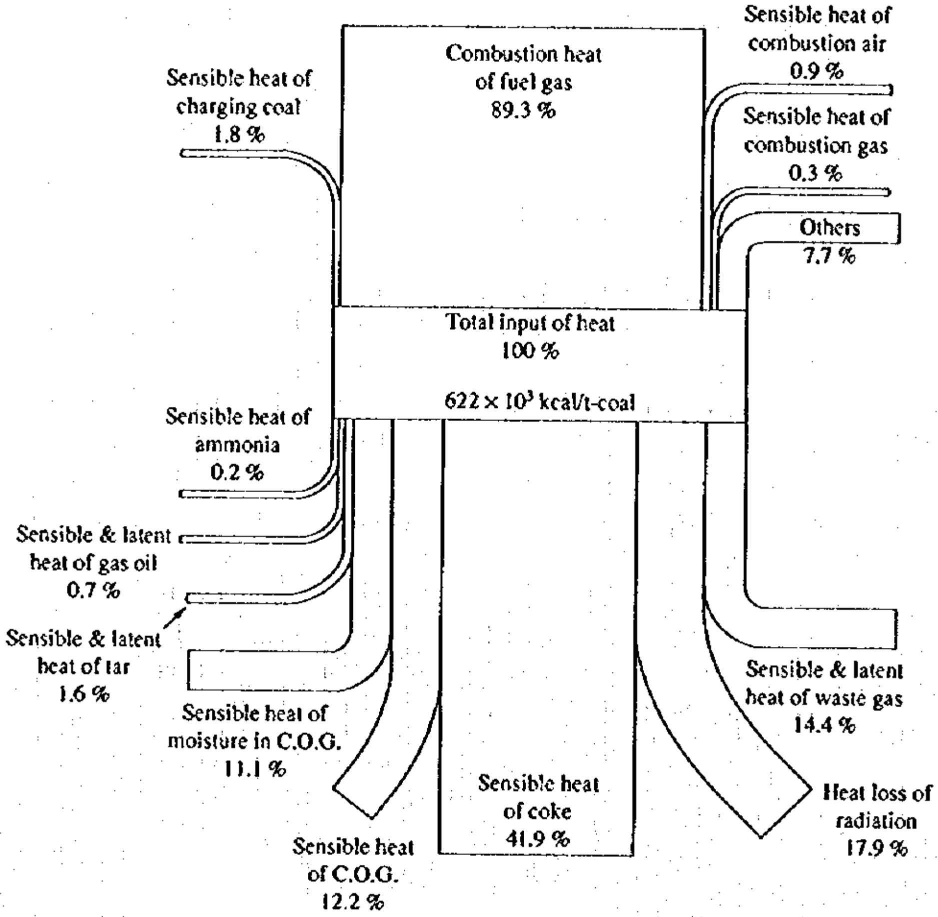
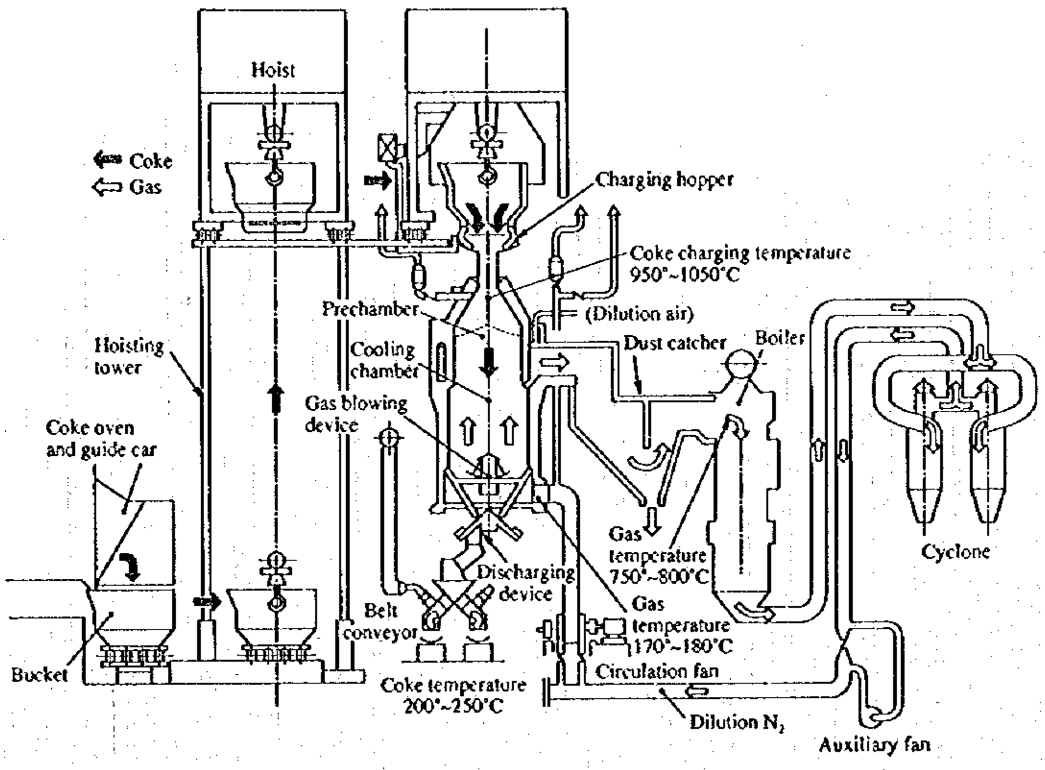


Figure 4.9 General Arrangement and Process Flow Sheet for CDQ



b. Recovery of coke oven gas (COG) sensible heat

Riser tube type heat exchangers are now commercially available for recovering a part of the sensible heat (110 Mcal/t-coal at 0 °C as a reference) of the generated COG of a temperature as high as 800 °C. However, they are not so widely used for economical reasons because a coke oven is divided into a lot of chambers. Since the generated COG is cooled by a gas cooler, feedwater for the CDQ boiler is, in some cases, preheated in the gas cooler, to recover the heat of 19 Mcal/t-coal.

4.3.3 Blast Furnace

(1) Blast furnace process

In the blast furnace process, pig iron is produced using iron ore, and sintered ore prepared by pretreating the iron ore, as the raw materials and using the coke charged simultaneously, and heavy oil, natural gas, pulverized coal, etc. injected in from the tuyere, as a melting heat source and a reducing material.

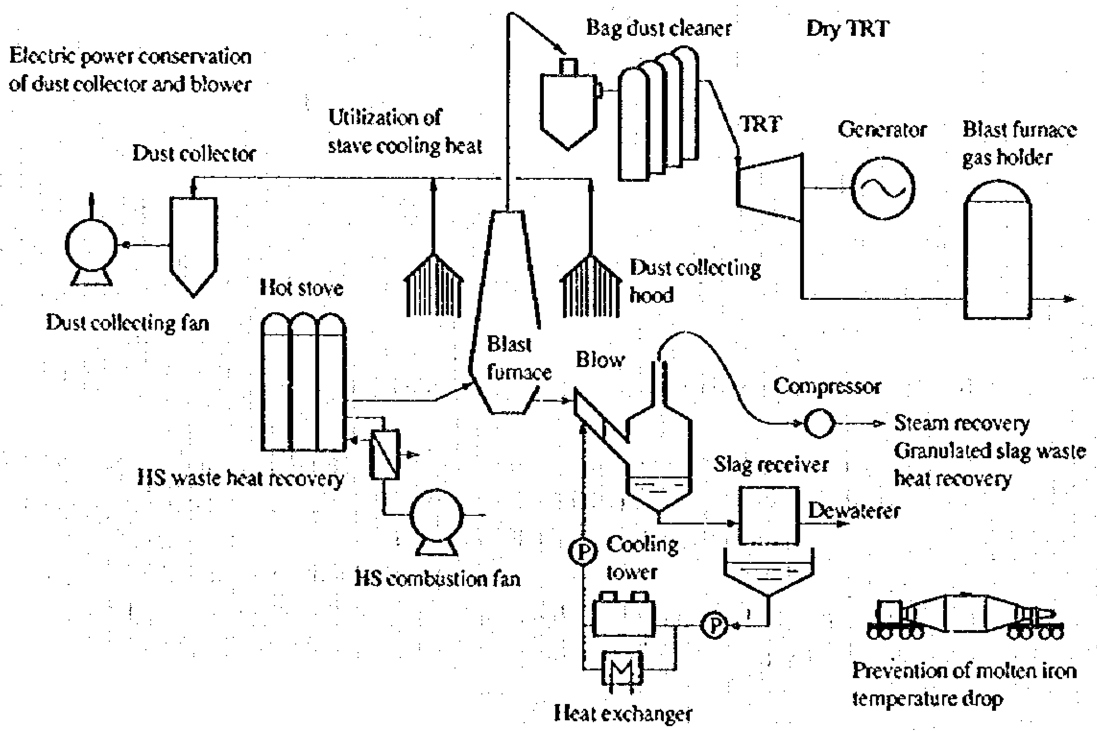
The raw materials, coke, etc. supplied from the top of the blast furnace make reduction reaction with the hot air blown in from many tuyeres formed in the lower part of the furnace, and the molten iron produced is collected at the furnace bottom. It is taken out of the furnace through a tap hole. The impurities in the iron ore are taken out as molten slag.

On the other hand, as a result of the above reaction, blast furnace gas (BFG) is discharged from the furnace top, and is dedusted, to be effectively used as a fuel.

In the iron making process, the energy (approx. 1750 Mcal/t pig) used for melting and reducing the iron ore is enormous, and accounts for 57 % of the overall energy consumed for iron making. In recent years, to reduce the coke rate of the blast furnace and to extend the life of the coke oven, PCI injection technique is increasingly adopted, and pulverized coal of 100 to 200 kg/t-pig is injected.

Figure 4.10 shows a processing flow and energy conservation measures.

Figure 4.10 Flow and Energy Conservation Measures of the Iron Making Process



(2) Energy conservation by improvement of operation and equipment.

a. Fuel rate (Coke, etc.)

The blast furnace consumes coke, heavy oil, pulverized coal and natural gas as energy for reducing and melting the iron ore, and the fuel intensity is called fuel rate.

Decreasing the fuel rate or controlling the fuel rate is one of the important techniques for blast furnace operation. More specifically, the fuel rate and the net energy consumption have been reduced by improving the gas availability ($CO/CO + CO_2$) through optimization of the furnace top charge distribution, decreasing the heat loss of the furnace body (i.e. heat insulation of the tuyere), and increasing the air blasting temperature and the treated ore ratio. (Some actual results show that the fuel rate decreased to as low as 420 kg/t)

In recent years, a blast furnace has come to be regarded more as a gas generating furnace and operated under such conditions as to minimize the energy cost of the entire steel works.

Figures 4.11 and 4.12 show blast furnace fuel rate vs. blast furnace net energy consumption, and the heat balance of a blast furnace, respectively.

Figure 4.11 BF Fuel Rate vs BF Energy Intensity

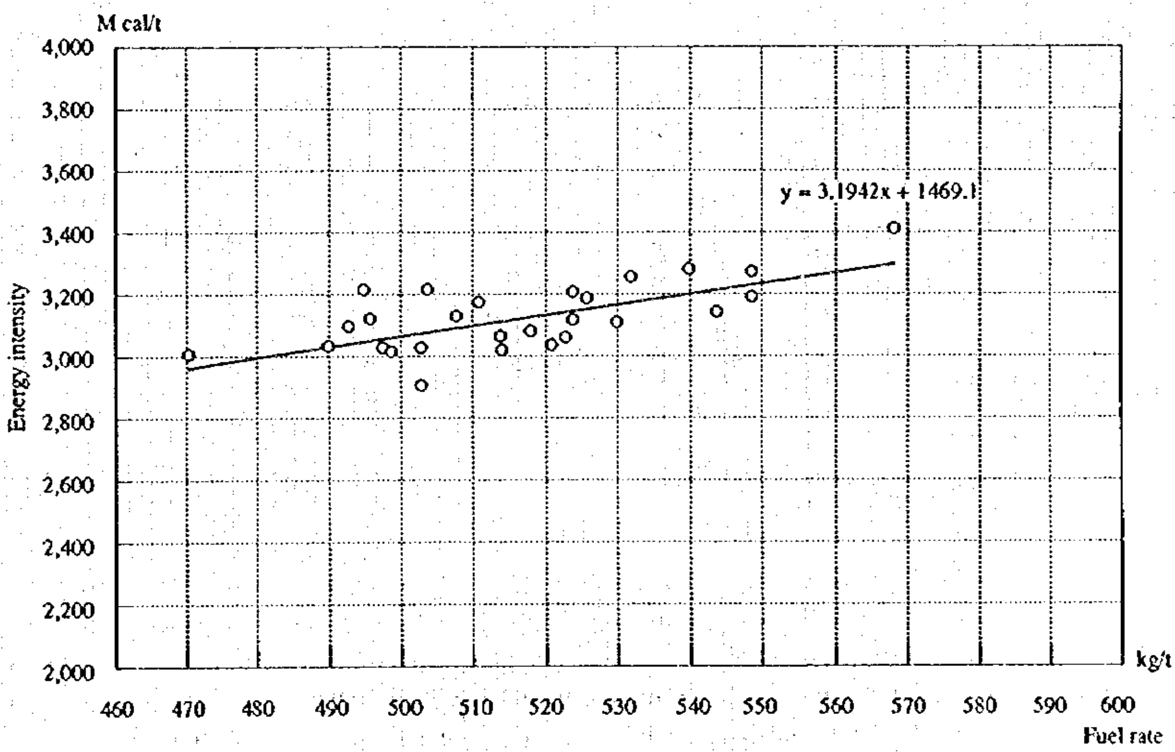
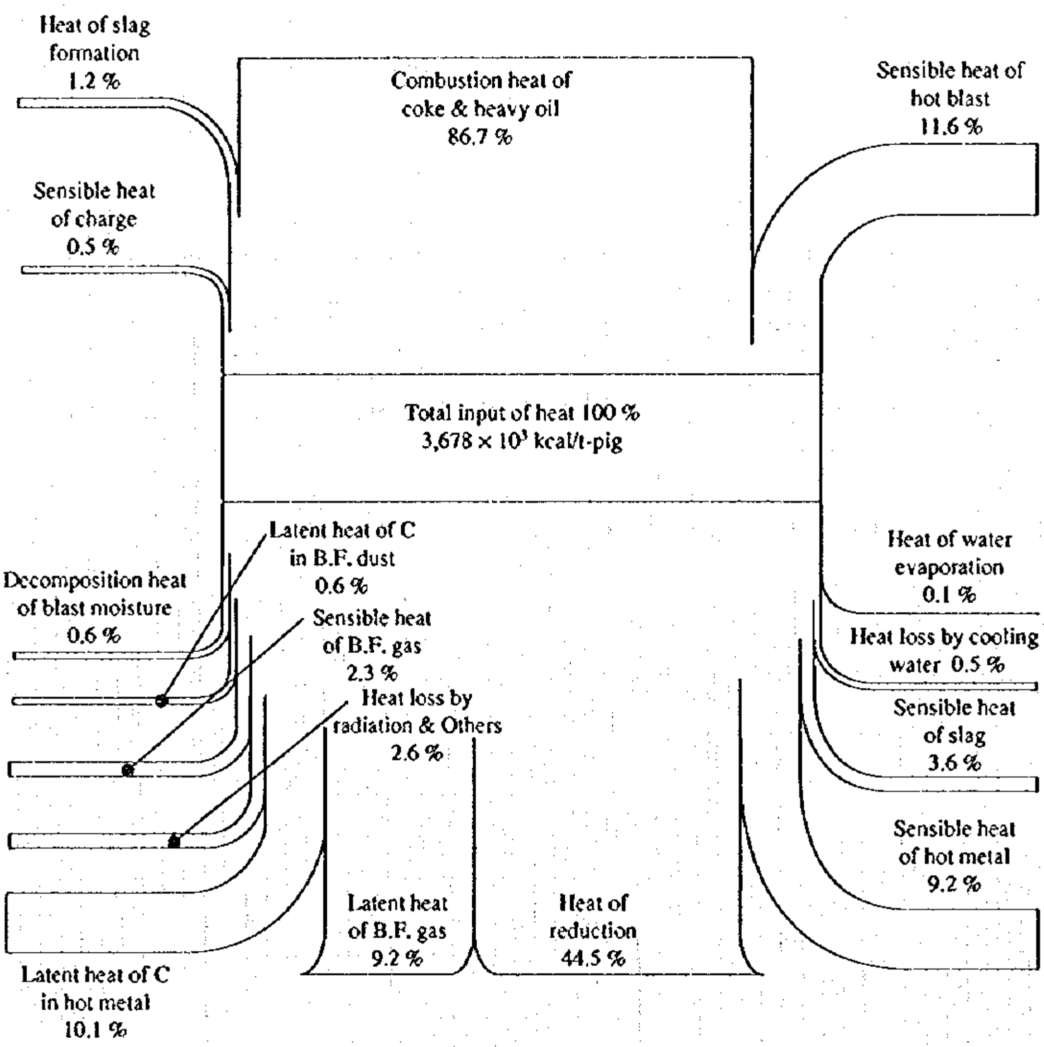


Figure 4.12 Heat Balance of a Blast Furnace (an example)



b. **Fuel (Hot stove)**

Fuel intensity can be about 2 % decreased by improving the burners; introducing the staggered parallel blowing method; controlling the charge heat amount by means of a computer; controlling low O_2 combustion; preventing the generation of uncombusted CO gas by improvement of control method of fuel gas valves and air valves; and improving high-calory gas combustion, etc. at air preheating.

c. **Electricity**

Impeller cutting should be performed for pumps and fans to obtain a proper capacity, and the concept of rotational speed control should be introduced for the dust collecter fan, etc. to increase the air volume only when required, thereby leading to electricity conservation.

- Air volume control of the cast house dust collector

- Air volume control of the hot stove combustion fan and the optimization of the capacity

- Rotational speed control of cooling water and dust collecting water pumps and the optimization of the capacity.

(3) Energy conservation by waste heat recovery

a. T.R.T (Blast furnace top gas pressure recovery turbine)

Nearly 100 % of Japanese steel works adopt T.R.T. — most popular in Japan as waste heat recovery equipment — which recovers the top gas pressure energy of a blast furnace operating under a pressure of 1.5 to 3 kg/cm^2 (called high-pressure operation) as electricity by an expansion turbine. Wet-process TRT, which is capable of recovering about 45 % of power consumed by a blast blower, can recover electricity of 35 to 50 kWh (85 to 120 Mcal/t) per ton of pig iron. Dry-process TRT can recover electricity of 40 to 55 kWh/t (100 to 135 Mcal/t).

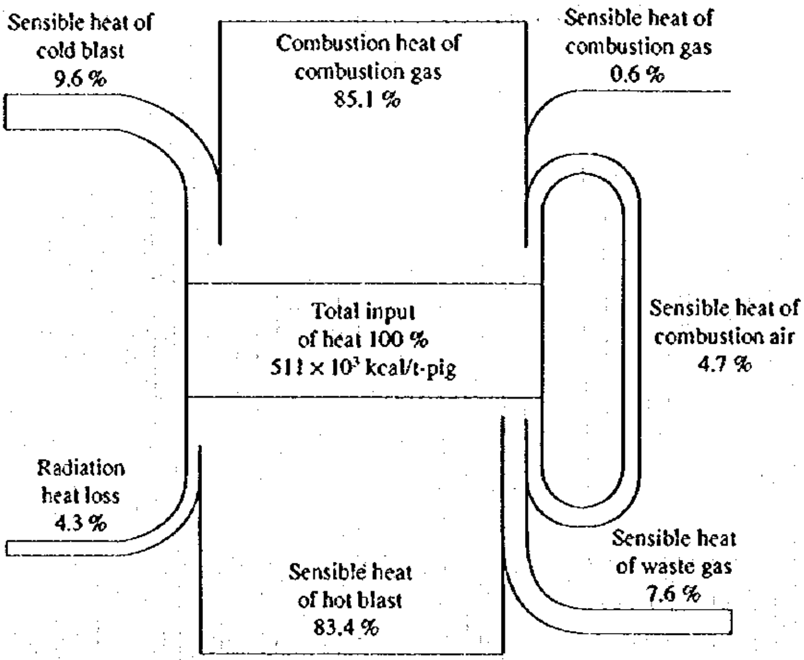
b. Waste heat recovery from a hot stove (Air preheating)

The sensible heat of exhaust gas from a hot stove, which is only 250 °C in temperature but large in quantity, can be utilized for preheating combustion air (also combustion gas) by a rotational heat exchanger or a one using a heating medium.

The adoption ratio in Japan is nearly 100 %. The heat efficiency of a hot stove, which was about 80 % at most, is about 4 % increased by installation of an air preheater, thus improving the fuel intensity by 20 to 25 Mcal/t.

Figure 4.13 shows a heat balance example of a hot stove.

Figure 4.13 Heat Balance of a Hot Stove (an example)



4.3.4 Steel Making

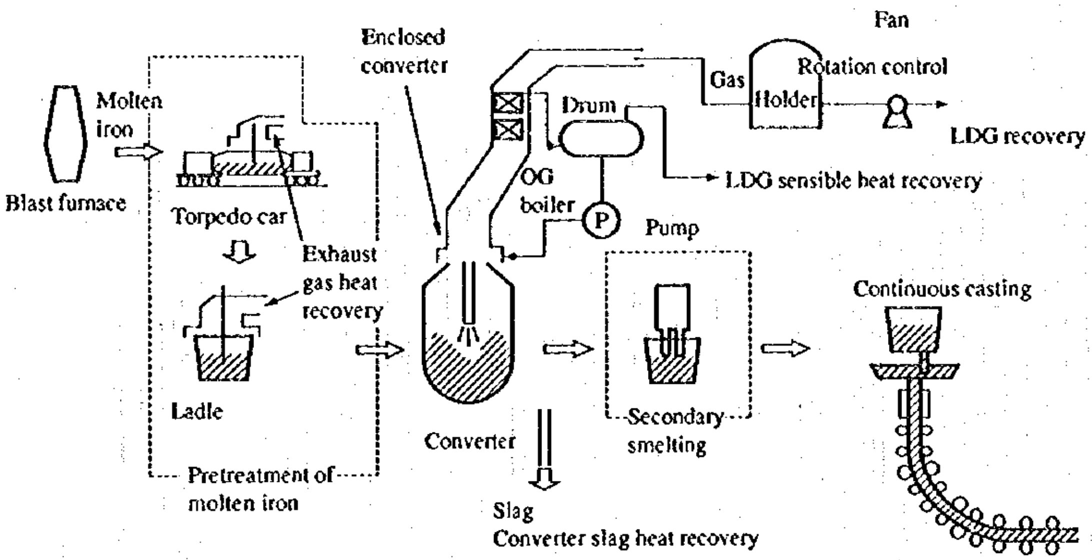
(1) Steel making process

In the steel making process, impurities such as carbon, silicon and sulfur are removed from molten iron by a converter and a smelter, to make steel which is then made into slabs by a continuous caster.

Molten iron is delivered at about 1,500 °C and charged into a converter at about 1,350 °C, to bring in sensible and latent heat of about 700 Mcal/t-crude steel. The oxidation reaction heat of each element (C, Si, etc.) in the molten iron and the sensible heat of the molten iron are converted into the sensible heat of molten steel and molten slag and the sensible and latent heat of exhaust gas.

Figure 4.14 illustrates the flow and energy conservation measures of the steel making process.

Figure 4.14 Flow and Energy Conservation Measures of the Steel Making Process



(2) Energy conservation by improvement of operation and equipment

In the steel making process the continuous casting ratio has achieved the most remarkable result in terms of energy conservation. In Japan, the continuous casting ratio, which was only about 27 % in 1974, exceeded 93 % in 1986, and reached 98 % in 1995. Omission of some processes and improvement of the yield have resulted in the energy intensity of 150 to 200 Mcal/t steel.

A converter — the main equipment of a steel-making plant — is usually operating at the rate of a half or two-thirds of the full availability and yet at batch. In addition to a large amount of oxygen consumed in a steel making plant, fuel is used for the heat holding and drying of the converter, ladle, caster, etc., and electricity is used as a power source for pumps and fans.

Since a great amount of high-temperature gas (including 90 to 95 % CO) is generated in a converter because of oxidation reaction of C, Si, etc. in the molten iron occurring along with smelting, the sensible heat and the latent heat are recovered. The gas recovering methods include recovery of steam by a converter waste heat boiler or recovery of a converter gas (LDG) as fuel by a gas recovering device. This results in the net energy consumption being nearly 0 (zero).

Recently, however, to improve the quality of steel, the rate of secondary smelting has increased, consuming the net energy of 50 to 100 Mcal/t.

a. Oxygen

Oxygen is mainly used to eliminate impurities such as C, Si, etc. in the molten iron. The measures to improve the oxygen consumption rate are:

- to reduce the re-smelting rate,

- to reduce the content of silicon in the molten iron (this effort to be made in the blast furnace process),

- to decrease the steel outlet temperature as much as possible for increasing the yield,

- to increase the oxygen efficiency by blowing in and agitating an inert gas from the bottom of the converter, etc.,

It is equally important to operate the converter at as constant pitch as practicable and to ensure a smooth communication with the oxygen plant in order to decrease the oxygen dissipation loss.

b. Electricity

Idle time should be reduced by stopping the pumps and fans when a converter and a continuous caster (CC) are to be stopped for the period of time exceeding a specified time. At the same time, such measures should be taken as checking the capacity in terms of the propriety and replacing it with a smaller one when necessary.

As for a dust collector, such measures as fan air volume control, damper automatic change-over, etc. are available for collecting a required amount of dust at a necessary timing.

c. Fuel

Fuel, which is used for heat holding, drying, etc. of ladle and tundish, can be reduced by studying the actual situation and reviewing the heat holding and drying standards. In this regard, it should be noted that the absolute use amount and the energy intensity tend to increase particularly at reduction in production.

In case a waste heat boiler is available, it needs to be combusted additionally by heavy oil or natural gas when steam pressure drops during a non-blowing-smelting time of a converter. Auxiliary combustion should be completed at a good timing by the start of the subsequent blowing-in to reduce the amount of additional fuel with the target at about 20 Mcal/ton or less at the two-third operation of a converter.

d. Improvement of yield

Increasing the yield of a converter, or a continuous caster (CC) contributes greatly to improving the energy intensity. For a converter, the steel outlet temperature should be reduced as much as possible to improve the appropriateness of the components. For a continuous caster, such measures as improvement of the continuous casting ratio should be taken.

(2) Energy conservation by recovery of waste heat

a. Coverter waste heat boiler (combustion type)

A converter waste gas occurs in the smelting process by blowing in oxygen. The gas contains about 95 % CO and about 100 g/m^3_N of dust, and generates a large amount of sensible heat of a temperature of approx. 1500 °C. In order to cool this gas and collect the dust, a method to combust a waste gas at the furnace outlet once and recover it as steam (by a waste-heat boiler) was first developed.

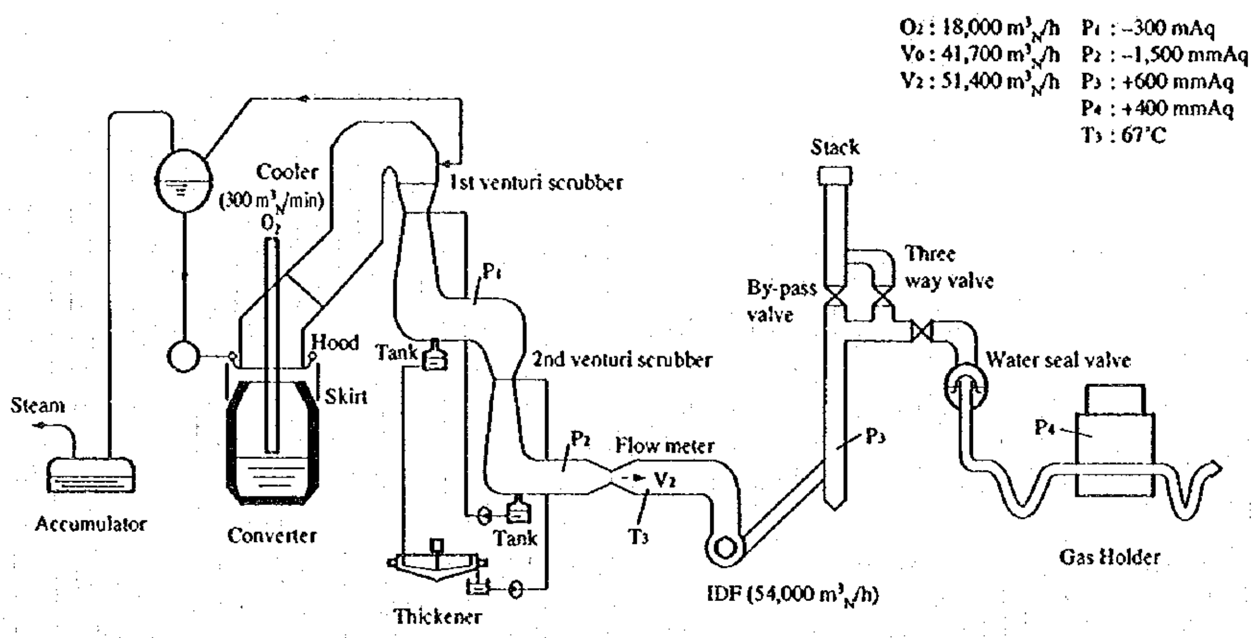
However, this waste heat boiler involved such problems as high construction cost, maintenance cost, only about 200 Mcal/t rate of heat recovery, and the difficulty in demand and supply adjustment with the consuming part due to batch-wise generation of recovered steam.

b. Recovery of converter gas (Non-combustion type)

Since the gas-recovery method was put to practical use in 1960's it has come to occupy the main position in the waste heat recovery of a converter, achieving a recovery rate of about 90 to 100 m^3_N (to be calculated in 2000 kcal/m^3_N). In recent years, some plants have come to adopt a method to reconfigure a part of gas recovery system into a boiler to recover the sensible heat, and achieves 240 Mcal/t or more of recovered heat.

Figure 4.15 shows the flow diagram of a converter gas recovery system.

Figure 4.15 Flow Diagram of a Converter Gas Recovery System



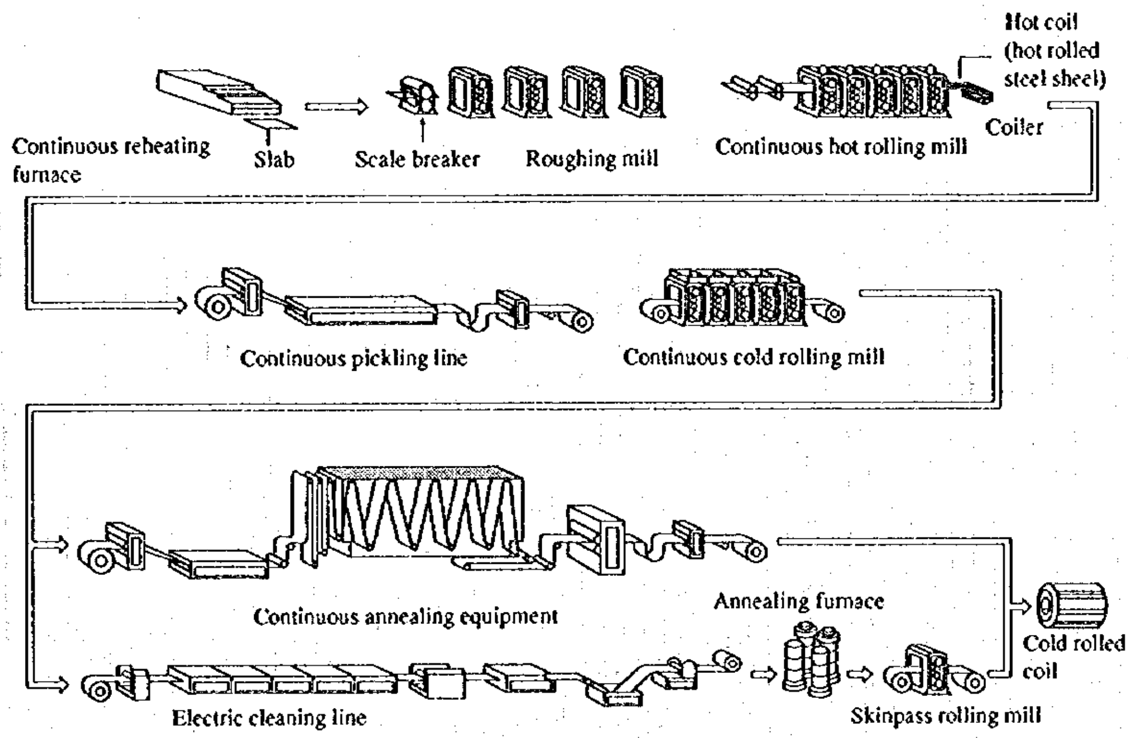
4.3.5 Rolling

(1) Rolling process

In the rolling process, a slab, bloom, or billet is heated up to a specified temperature, then rolled by a rolling mill and processed into a specific shape and size. The rolling process is categorized into the primary hot rolling for manufacture of steel plates, shape steels, bar steels, wire rods, and the secondary cold rolling for hot dipping, electroplating and manufacture of welded steel pipes, butt-welded steel pipes and seamless steel pipes.

Figure 4.16 shows an example of steel sheet (cold-rolled steel sheet) manufacturing process. In the first hot rolling process, the heated slab is rolled into a thin hot strip coil through the roughing mill and the finishing mill, and then tempered into a hot coil while being cooled by scattering water. After removing the scales on the surface by acid cleaning, the sheet is further subjected to thickness reduction by the cold rolling mill and to compositional adjustment. Then the sheet is passed through the continuous annealing system to be processed by soaking, annealing, and quenching for having the processability improved, and then cold-rolled into a steel sheet. The cold-rolled steel sheet may be further subjected to plating, etc. for each specific application.

Figure 4.16 Cold Steel Sheet Production Process



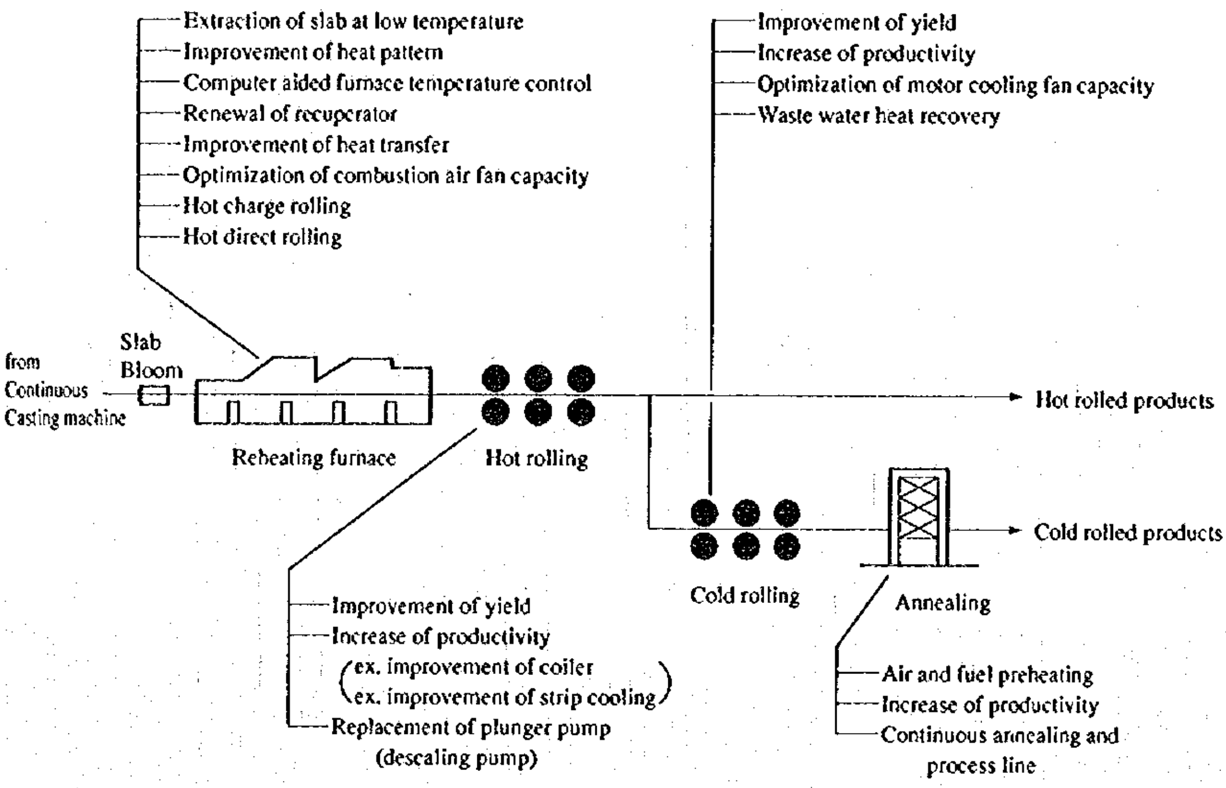
The process for manufacturing steel bars such as shape steels, bar steels, rod steels, etc., steel plates, and steel pipes also consists of such processes as forming processing, welding, heat-treatment, etc. as required.

Energy intensity in the rolling process is 546 Mcal/t in the primary rolling, and 660 Mcal/t in the secondary rolling, accounting for 13 to 15 % of the energy consumption of an integrated steel works.

This section describes mainly energy conservation measures in the primary rolling process.

Figure 4.17 shows a flowchart and energy conservation measures of the rolling process.

Figure 4.17 Flow and Energy Conservation Measures of the Rolling Process



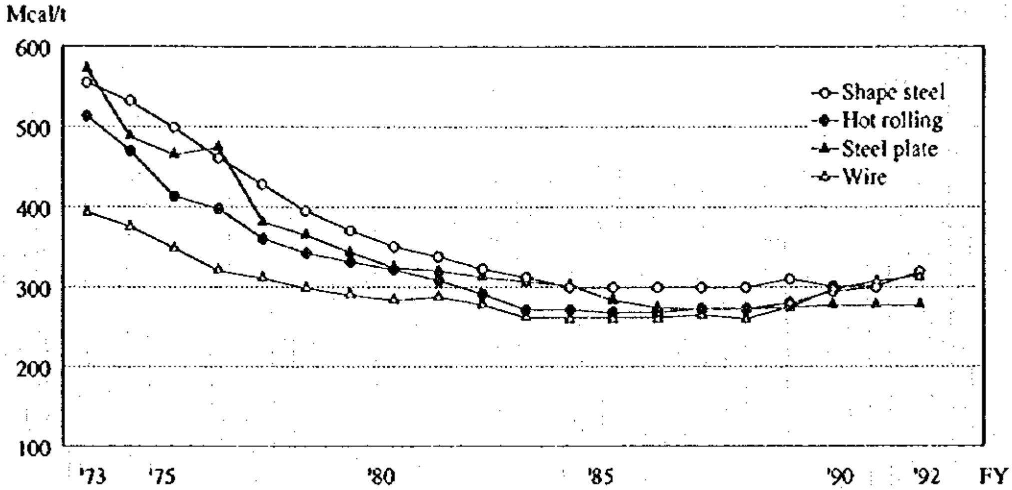
(2) Energy conservation by improving operation and equipment

Fuel accounts for approximately 50 % of the energy consumed in the rolling process, while electricity and steam occupy the rest. Energy conservation measures actually implemented in the primary rolling process include efficiency enhancement of heating and diverse efforts in processes such as rolling, annealing, heat-treatment. Moreover, in the rolling process involving many repetitions of heating and cooling processes, the losses arising from these processes must be reduced as much as possible. This requires energy conservation measures in terms of integration, omission, and concatenation of processes.

a. Fuel (An example of reheating furnace)

Figure 4.18 shows the changes in fuel intensity of a reheating furnace.

Figure 4.18 Trend of Fuel Intensity of a Reheating Furnace



- Reduction of heat loss

Effective measures to reduce the waste gas heat loss, which occupies the largest portion of various types of heat loss in the reheating furnace are:

- to reduce the exhaust gas amount (control of the oxygen concentration in the exhaust gas,

- to decrease the exhaust gas temperature (optimization of heat patterns, introduction of a computer for that purpose, etc.) and at the same time,

- to take such equipment improvement measures as extension of the furnace length,

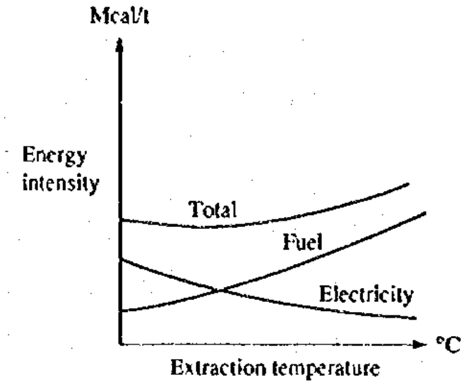
Measures to reduce the cooling water heat loss include reinforcement of heat insulation (double heat insulation) of the skid pipe, increasing the size of skids, crosses and posts to reduce their numbers, prevention of vibration, prevention of heat-insulating materials from dropping, etc. Reduction of the heat capacity of the furnace wall utilizing ceramic fiber and enhancement of heat insulation are available for decreasing the radiation heat of the furnace body.

- Low-temperature extraction, etc.

Extracting a slab from the reheating furnace at a low temperature tends to decrease the fuel intensity but increase the electricity intensity. Considering these influences and skid marks, the slab should be extracted at as low temperature as possible.

Fuel intensity is reduced by 3 to 5 Mcal/t for every 10 °C drop in the temperature as shown in Figure 4.19.

Figure 4.19 Relationship between Energy Intensity and Extraction Temperature



- Enhancement of heat recovery

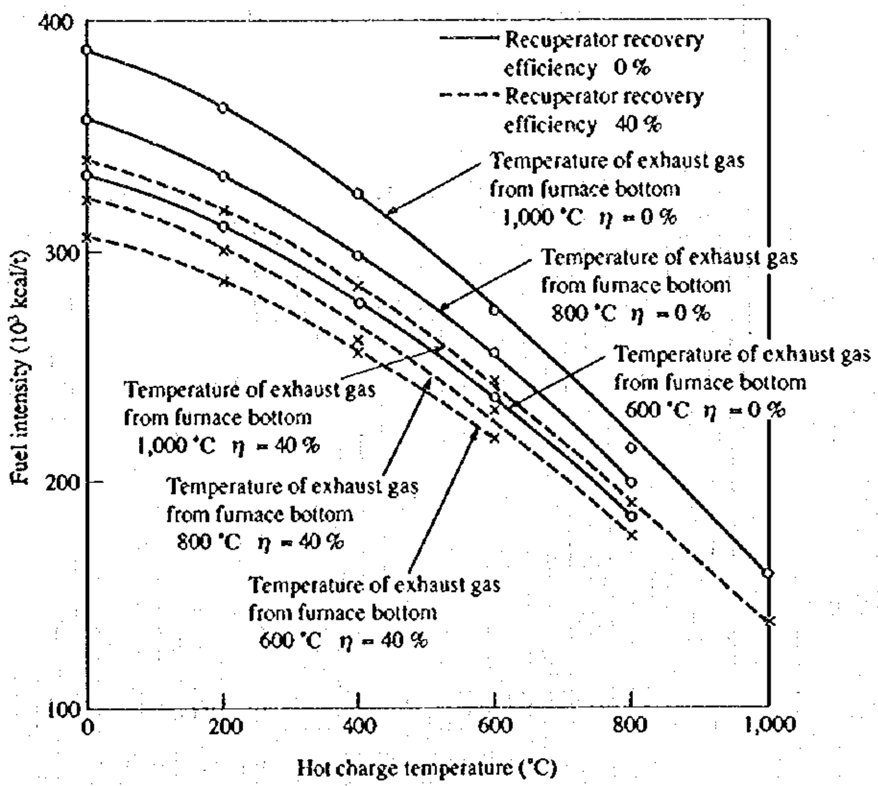
A dirty heat-conducting surface of an air preheater (recuperator) will degrade extremely its performance and exert an adverse effect on fuel intensity. Therefore, simple heat balance should be periodically performed to maintain the temperature efficiency at the initial installation. If any problem is found, the preheater must be reinforced or replaced.

- Improvement of hot charge ratio

The fuel intensity of the reheating furnace will be remarkably improved by charging the hot slab from the continuous casting process or the blooming process into the reheating furnace, or by direct-rolling if possible in terms of the layout (The adoption ratio in Japan is 60 %). Supposing that 100 % of the CC material could be direct-rolled, the fuel intensity will be 100 Mcal/t or less even if the heat by an edge heater is added.

Figure 4.20 shows an effect of hot charge rolling (an example of trial calculation).

Figure 4.20 Effect of Hot Charge Rolling (an example)



- Heat balance example

Table 4.1 shows an example of heat balance of hot-rolling reheating furnace into which only cold slabs are charged.

Table 4.1 Heat Balance of a Reheating Furnace

Charged slab temperature: cold

(Example 1)

Heat Input	Mcal/t	(%)	Heat Output	Mcal/t	(%)
Combustion heat of fuel	330.3	(94.2)	Heat content of extracted slab	195.3	(55.7)
Sensible heat of fuel	0.2	(0.1)	Sensible heat of scale	5.2	(1.5)
Heat content of charged slab	0	(0)	Sensible heat of exhaust gas	82.7	(23.6)
Scale formation heat	20.0	(5.7)	Heat of cooling water	11.1	(3.2)
			Heat loss	56.2	(16.0)
Heat recovered by recuperator	(34.9)	((10.0))	Heat recovered by recuperator	(34.9)	((10.0))
Total	350.5	(100)	Total	350.5	(100)

Overall heat efficiency = {195.3/(330.3 + 0.2 + 20)} × 100 = 55.7 %
Furnace effective length and width: 29.8 L × 9.28 W (m)
Nominal capacity: 170 t/h

(Example 2)

Heat Input	Mcal/t	(%)	Heat Output	Mcal/t	(%)
Combustion heat of fuel	318.7	(97.6)	Heat content of extracted slab	194.8	(59.7)
Sensible heat of fuel	0	(0)	Sensible heat of scale	2.1	(0.6)
Heat content of charged slab	0	(0)	Sensible heat of exhaust gas	33.3	(10.2)
Scale formation heat	8.0	(2.4)	Heat of cooling water	43.8	(13.4)
			Heat loss	52.7	(16.1)
Heat recovered by recuperator	(62.7)	((19.2))	Heat recovered by recuperator	(62.7)	((19.2))
Total	326.7	(100)	Total	326.7	(100)

Overall heat efficiency = {194.8/(318.7 + 8.0)} × 100 = 59.6 %

(Example 3)

Heat Input	Mcal/t	(%)	Heat Output	Mcal/t	(%)
Combustion heat of fuel	462.1	(90.5)	Heat content of extracted slab	206.8	(40.5)
Sensible heat of fuel	0.6	(0.2)	Sensible heat of scale	5.5	(1.1)
Heat content of charged slab	0	(0)	Sensible heat of exhaust gas	195.0	(38.2)
Scale formation heat	20.0	(3.9)	Heat of cooling water	65.0	(12.7)
Sensible heat of atomizer	27.7	(5.4)	Heat loss	38.1	(7.5)
Heat recovered by recuperator	(51.1)	((10.0))	Heat recovered by recuperator	(62.7)	((19.2))
Total	510.4	(100)	Total	510.4	(100)

Overall heat efficiency = {206.8/(462.1 + 0.6 + 20.0 + 27.7) } × 100 = 40.5 %

b. Electricity

In order to reduce the electricity for rolling, the consumption characteristics for rolling should be studied to first adopt a method which will produce a greater effect. The following items will be empirically proposed, which will be also effective for the secondary rolling process.

- Since the electric power consumption for rolling is generally proportional to the rolling time, rolling productivity (t/h) should be enhanced.

- The capacity of a fan for a reheating furnace, a cooling fan for a rolling motor, pump, etc. should be checked to lower the capacity.

- Equipment should be improved so as to stop an auxiliary equipment during the non-rolling time including also lighting time.

- The operation efficiency of a pump or a fan should be checked, and if it is found low, it should be replaced with a one of higher efficiency.

c. Steam

A large amount of steam is used in the secondary rolling process including an acid-pickling line, cleaning line, etc. In many successful cases, however, by adopting the most appropriate measure through measuring the steam flow rate and studying the consumption characteristics, the consumption rate could be reduced by about 70 %. (In some actual cases, rather simple improvement measures are taken such as installation of a heat exchanger for waste water and makeup water, the use of water for cascade, etc.)

(3) Energy conservation by waste heat recovery

a. Air preheating

Since slabs need to be heated to a high temperature in order to obtain a high-temperature flame, an air preheater should naturally be installed. Heat exchangers suitable for even small furnaces are commercially available.

b. Fuel gas preheating

To conduct a drastic waste heat recovery, fuel gas was, in some cases, pre-heated.

c. The sensible heat of the skid cooling water can be recovered as hot water. Consideration must be also given to the purpose for which it will be utilized. When a reheating furnace boiler is installed, the recovered water will be used as a feedwater preheater.

d. Boiler for a reheating furnace

Energy conservation measures should be made after considering a possible effect of the waste gas reduction based on fuel consumption reduction efforts such as fuel gas preheating, hot charge, etc.

(4) Integration, omission and continuation of processes

The rolling process consists of repeated heatings and coolings. Therefore, the ultimate energy conservation results from integration connection, omission and continuation of processes.

The following constitute typical energy conservation techniques in the rolling process.

- Direct combination of the acid cleaning process and the cold rolling process

- Continuation of cleaning → annealing → tempering → purification processes (continuous annealing equipment)

- Continuation of the plating processes (Continuous plating equipment)

(5) Improvement of the yield

Improvement of the yield in the rolling process leads directly to the increase in production, and thus it can be said to be a rolling technique itself. The following operation efforts for the entire rolling line will result in the improvement of the yield:

- to maintain an even and optimum rolling temperature of slabs extracted from the reheating furnac,

- to prevent the occurrence of surface flaws by the optimum roll pass design, maintenance control, etc,

- to prevent overheating in the reheating furnace (prevention of excessive scale loss),

- to minimize the crop loss.

4.3.6 Energy Equipment

(1) Functions of the energy department

The energy department in a steel works has two functions: to convert an excessive energy in the steel works (e.g by-product gas such as BFG) into an energy required for that plant (e.g electricity, oxygen, blast air, etc.), and to perform economically a demand and supply control of utilities used in the plant such as electricity, fuel, water, compressed air, oxygen, nitrogen.

The net energy consumed in the energy department is approximately 7 to 9 %.

(2) Energy conservation by improvement of operation and equipment

Since pumps and blowers among various energy equipment are commonly used, they will be dealt with together here. Energy conservation measures will be mentioned for each equipment.

a. Fuel (Fuel supply system)

- To decrease the distribution loss of by-product gas (installation of a most appropriate buffer to prevent the distribution loss of a by-product gas).
  - by installation and addition of a gas holder or addition of a power-generating plant
  - by installation of a burner which will allow combustion of more than one kinds of fuel on a boiler or a reheating furnace to make effective use of an excessive by-product gas (thereby to make the plant operate to the maximum with only a by-product gas).
- To improve the function of the energy center (by minimization of energy cost).
- To stabilize the calory of the gas to be fed to each process.

(Boiler)

- To enhance the combustion control (control of the oxygen concentration in exhaust gas) — hysteresis improvement of an air control system, reduction of air leakage, etc.
- To install, add or replace an air preheater and to improve the seal mechanism.
- To reduce the boiler blow-down water.

(Steam turbine)

- To enhance the control of the vacuum of the condenser or install a continuous cleaning equipment for a condenser tube.

- To maintain the cooling capacity of the cooling tower for the condenser cooling water.

- To enhance the efficiency of steam turbine.

- To replace a sealing equipment in the steam turbine (recovery of the performance through maintenance).

- To shorten the periodic maintenance interval.

(Blast blower)

- To decrease the pressure loss of a suction filter.

- To modify a blower to match it to the blast furnace operation (reduction of stages)

b. Electricity (Power distributing/receiving equipment)

- To reduce the power distribution loss (review of the capacity of the transformer for power distribution reception)

- To keep the power factor at 100 % in power receiving station.

- To reduce the electricity for power receiving demand (Enhancement of the function of the energy center).

(Feedwater equipment)

- To reduce No. of operating pumps through reviewing the feedwater amount.

- Intermittent operation of cooling tower fans.

- To review the feedwater pressure (by impeller cutting).

- To improve the feedwater pressure controlling method (by adoption of an inverter).

- To separate each different feedwater pressure system or to install a booster pump.

(Fuel equipment)

- To integrate or abolish the fuel gas blowers (e.g. to combine the blowers which supply fuel to each consuming device at each different gas calory, thereby reducing the number of operating blowers).

- To improve the pressure control method (by adopting an inverter).

(Oxygen plant)

- To prevent the dissipation of oxygen (by enhancing the linking with the converter operation) (by enhancing the demand-supply control function by installing a liquid oxygen, or liquid nitrogen manufacturing equipment) (by enhancing oxygen generating capacity by parallel installation of feed air compressors)

- To adopt a molecular sieve.

- To modify an air compressor (by replacing it with a higher efficiency impeller and adopting a suction vane control)

- To reduce the pressure loss of the suction filter.

(Pump and blower)

- To optimize the capacity (Impeller cutting for the reduction of excessive capacity, etc.).

- To introduce the rotational speed control.

- To prevent idle rotation.

c. Steam for the steel-making process

(Steam feeding equipment)

- To reduce the loss in steam supply; to reduce the radiation heat loss (by changing the piping trap from the disk type to the free-float type to reduce the number of traps and reinforce the heat insulation of uncovered pipes and valves).

- To recover steam drain.

(Steam generating equipment)

- To improve the boiler load factor by installation of an accumulator (by reducing operating boilers).
- To improve the utilization rate of steam turbine extraction steam.

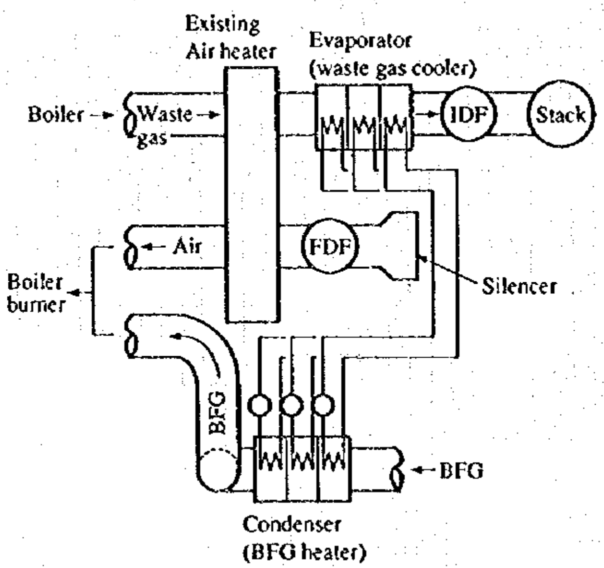
(3) Energy conservation by waste heat recovery

a. Fuel

As an example of energy equipment waste heat recovery, there is a preheater of fuel BFG by the use of boiler waste gas. Since BFG is low in calory (800 kcal/m^3_N or below in Japan), the boiler efficiency is nearly 86 %, which can be increased up to 90 % by installing a preheater for BFG.

Figure 4.21 shows the example.

Figure 4.21 Effect and Flow of a Fuel Gas Preheater (an example)



Data at 75 % Load

Waste gas flow	380,000 m^3_N/h
Waste gas inlet temp	194 °C
Waste gas outlet temp	133 °C
BFG flow	205,000 m^3_N/h
BFG inlet temp	40 °C
BFG outlet temp	160 °C

b. Electricity

When a pressure reducing valve is used for the supply line of steam for industrial use, the electricity can be recovered by installing a back-pressure turbine.

(4) Modernization and efficiency enhancement of energy equipment

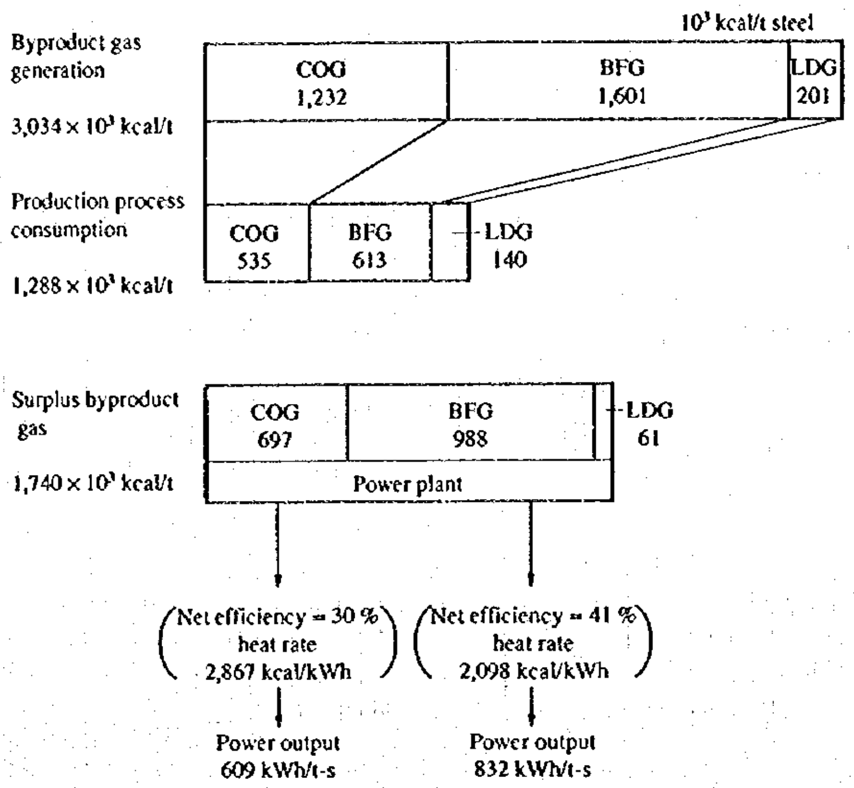
In a steel works, various kinds of energy conversion are performed in the power-generating plant, the oxygen plant, blast furnace blowing plant, etc., to supply a great amount of energy to each process.

Conventionally these plants were regarded as an auxiliary equipment of a steel works, and their conversion efficiency was considered much less important. However, improving the energy conversion efficiency has contributed to a great reduction in energy intensity of an integrated steel works, thus leading to the efficiency enhancement of energy equipment.

a. Reduction of energy intensity by improving the power-generating efficiency (For consideration).

Figure 4.22 shows an example where higher efficiency in power-generation contributes to improvement of energy intensity. This figure shows excessive gas amounts (consumption rate) in a modern steel works. Generating power at a net efficiency (efficiency at the power distribution end) of 41 % will allow the 832 kwh/t required in a steel works to be all self-supplied by an excessive gas, demonstrating that it can fully cope with the increase of product quality.

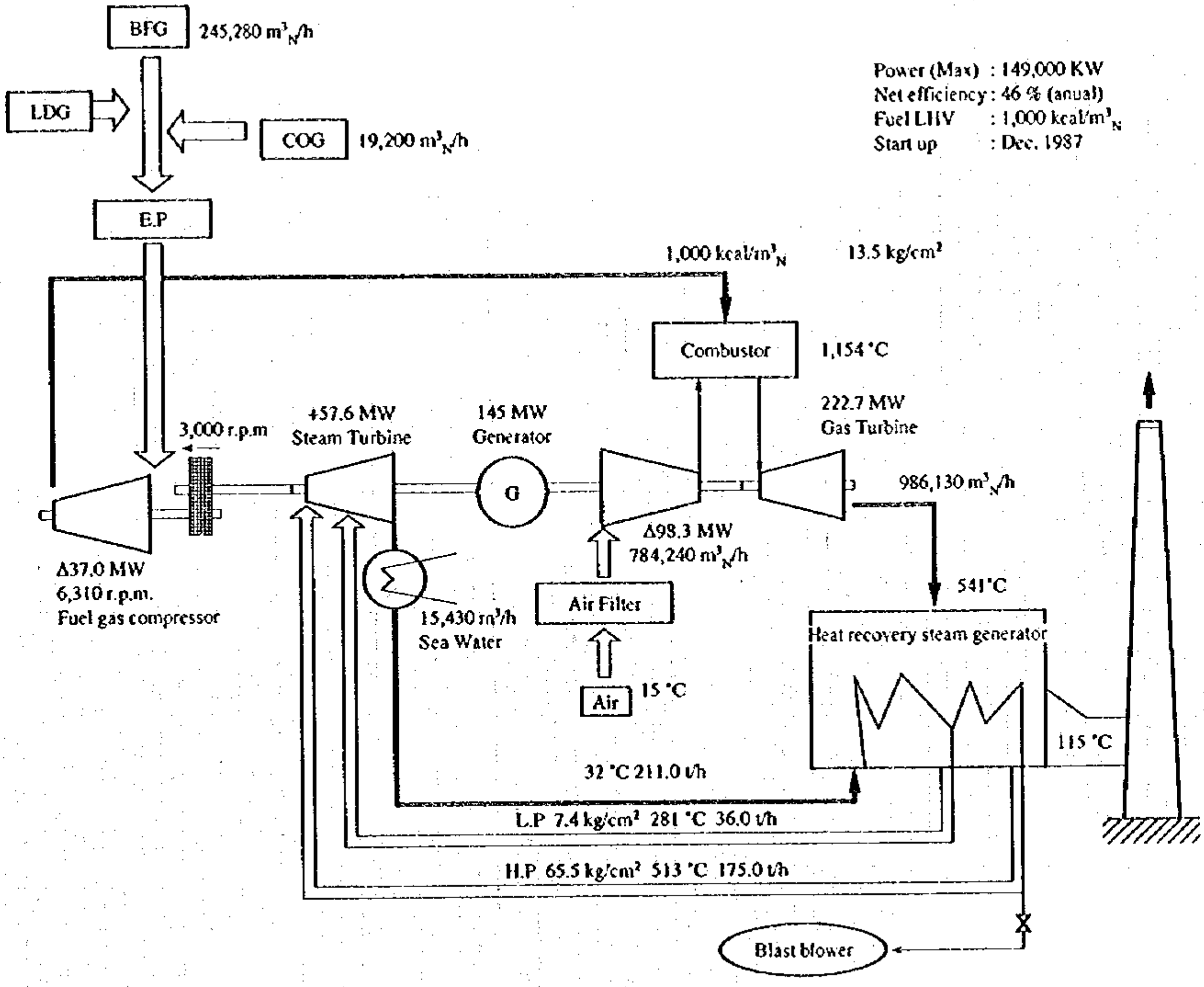
Figure 4.22 Effect of a High Efficiency Power Plant (an example)



b. Gas turbine combined cycle power generation

In some cases, a gas turbine combined cycle power generating equipment of 46 % power generating efficiency was introduced, contributing to improvement of energy intensity in spite of the use of low-calory fuel gas of 1,000 kcal/m^3_N. Figure 4.23 shows the flowsheet.

Figure 4.23 Flow Diagram of a Gas Turbine Combined Cycle Plant



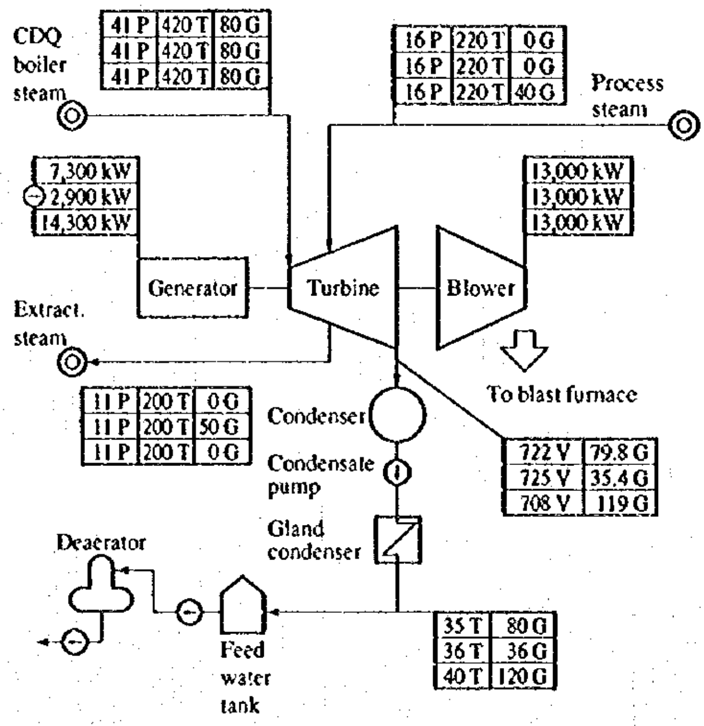
c. Multi-purpose power generation

Since the waste heat from a steel works has a high temperature, it can easily be recovered as steam in terms of economy, which is utilized as processs steam. The demand for process steam on the other hand tends to decrease along with the progress of energy conservation. As the waste steam rate increases against the steam demand rate, the surplus of steam occurs seasonally or on the maintenance day of a large energy-consuming equipment. On the other hand, when a waste steam generating plant enters into maintenance, steam will be insufficient.

To cope with these situations, it will be necessary to install steam demand-supply control equipment such as mixed-steam/extraction steam/condensing turbines for power generation, etc.

Figure 4.24 shows an example of this turbine.

Figure 4.24 Heat Balance of a Mixed and Extraction Steam Turbine



P : pressure (kg/cm² abs.)
T : temperature (°C)
V : vacuum pressure (mmHg)
G : flow rate (t/h)
kW: output (kW) or shaft power (kW)
⊖ : Required power of motor
Upper line value : blast furnace air supply and power generation with CDQ boiler steam (80 t/h)
Middle line value: maximum extraction (50t/h)
Lower line value : maximum mixing (40t/h)

d. High effficiency oxygen plant

Enhancement of oxygen plant efficiency involves the following three points, and it is expected that a plant will be enlarged in scale through integration or be gradually replaced by a high efficiency plant. The target at present is 0.45 to 0.50 kwh/m^3_N for electricity intensity for manufacturing oxygen and 0.15 to 0.17 kwh/m^3_N for oxygen distribution electricity intensity.

- Air compressor: To improve the electricity intensity by adoption of a high-efficiency impeller, suction vane control, a high-efficiency heat exchanger, and an axial flow compressor.

- Air separating equipment: To reduce as much as possible the suction pressure of an air compressor.

  To maximize the fluctuation in the oxygen generation amount in order to reduce the dissipation loss.

- Oxygen compressor: To adopt a high-efficiency impeller, suction vane control, and a high-efficiency heat exchanger.

c. Blast blower

Axial flow compressors are mainly used, and high-efficiency stator blade control of a wider blowing range is adopted. A blast blower combining a centrifugal compressor and an inter-cooler may be possible, but a comparative consideration of these two methods in terms of the efficiency of the centrifugal compressor, electricity consumed in the cooling tower and reduction of fuel consumption in the hot stove reveals that the adoption of an axial flow compressor will bring about a greater effect of energy conservation for the entire plant.

Conventionally a steam turbine was, in some cases, employed as a driver, but in the future it will tend to be replaced by a motorized blast blower from the viewpoint of efficiency and labor saving.

4.4 Output of Energy Consumption in the Japanese Iron and Steel Industry

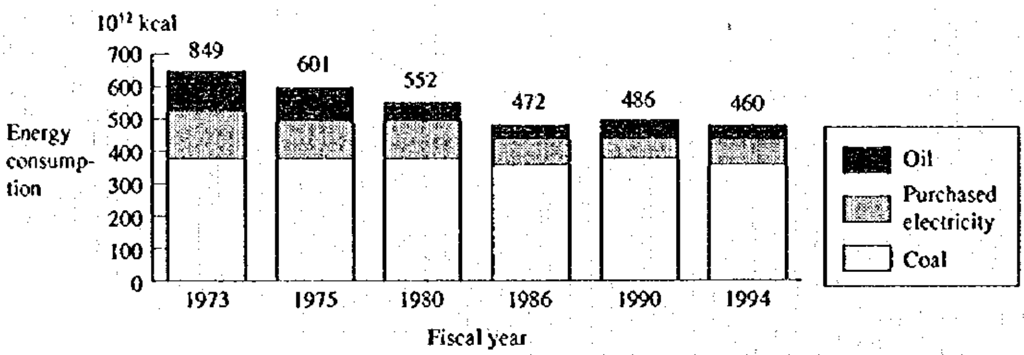
4.4.1 Features of Energy Consumption in Japanese Iron and Steel Industry

The iron and steel industry is the largest energy consuming industry which accounts for 11.7 % (51.0 million kl of oil equivalent, FY 1994) of Japanese energy consumption.

The consumption percentages of respective energy sources in the entire iron and steel industry are 77.9 % of coal, 15.0 % of purchased electricity and 7.1 % of oil in FY 1994 showing a large drop in the oil fuel consumption percentage from 21.3 % of FY 1973.

Figure 4.25 shows the changes in energy consumption of respective energy sources in Japanese iron and steel industry.

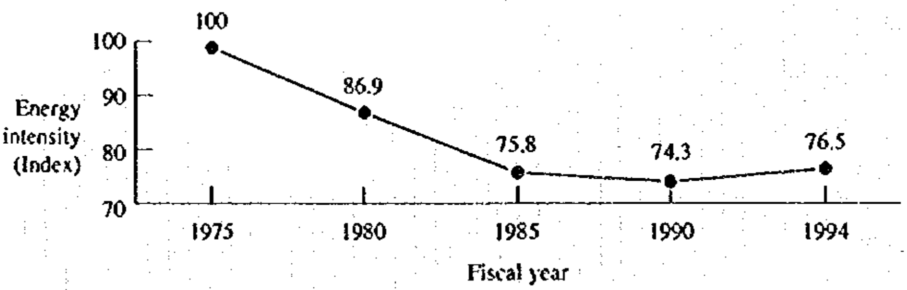
Figure 4.25 Changes in Energy Consumption of Respective Energy Sources in the Integrated Steel Works



4.4.2 Energy Conservation Level in the Iron & Steel Industry

Figure 4.26 shows the changes in energy intensity (index) of Japanese iron and steel industry.

Figure 4.26 Change in Energy Intensity (Index) in the Integrated Steel Works

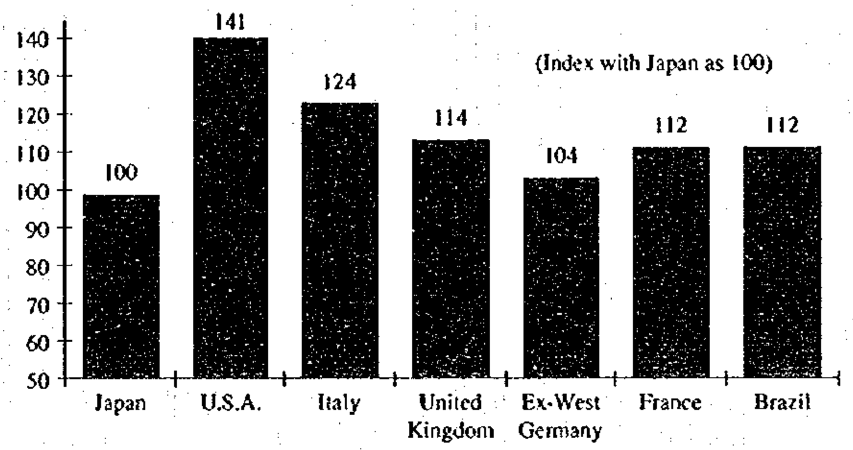


The energy intensity per ton of crude steel dropped to 76.5 in FY 1994 with that in FY 1975 as 100.

The energy intensity in Japanese iron and steel industry tends to level off recently, but compared to the energy intensity in major steel making nations in the world, with the specific consumption rate of Japan as 100, USA shows the highest consumption level of 141 being followed by 124 of Italy, 112 of France, 112 of Brazil and 104 of ex-West Germany. Japan remains at the highest level in the world in the energy consumption efficiency.

Figure 4.27 shows energy intensity in the major steel-making countries.

Figure 4.27 Energy Intensity (Index) of Major Steel-making Nations (1991)



4.4.3 Energy Intensity in an Integreted Steel Works

At present, an average integrated steel works consumes 5,500 to 5,800 Mcal of energy per ton of crude steel.

Percentages of respective energy consumption items in an integrated steel works consuming 5,680 Mcal of energy per ton of crude steel ore, for example, 30.8 % for reduction of iron ore (endothermic reaction), 22.6 % for electricity used for rolling, blowers, pumps, lighting, etc., 13.0 % for exhaust gas sensible heat, 11.1 % for steel product sensible heat, etc., 3.6 % for slag sensible heat and 18.9 % for cooling water, etc. Hence, the ratio of waste energy to be recovered accounts for 46.6 % (2,560 Mcal/t) of the entire energy used.

Meanwhile, as shown in Figure 4.1, the recovered waste heat increased by 556 Mcal/t in 1990 as compared with that in 1973, and the increase accounts for 9.8 % of the entire energy used.

4.4.4 Energy Conservation Measures in an Integrated Steel Works

The energy conservation measures in the iron and steel industry can be classified into the following three major categories:

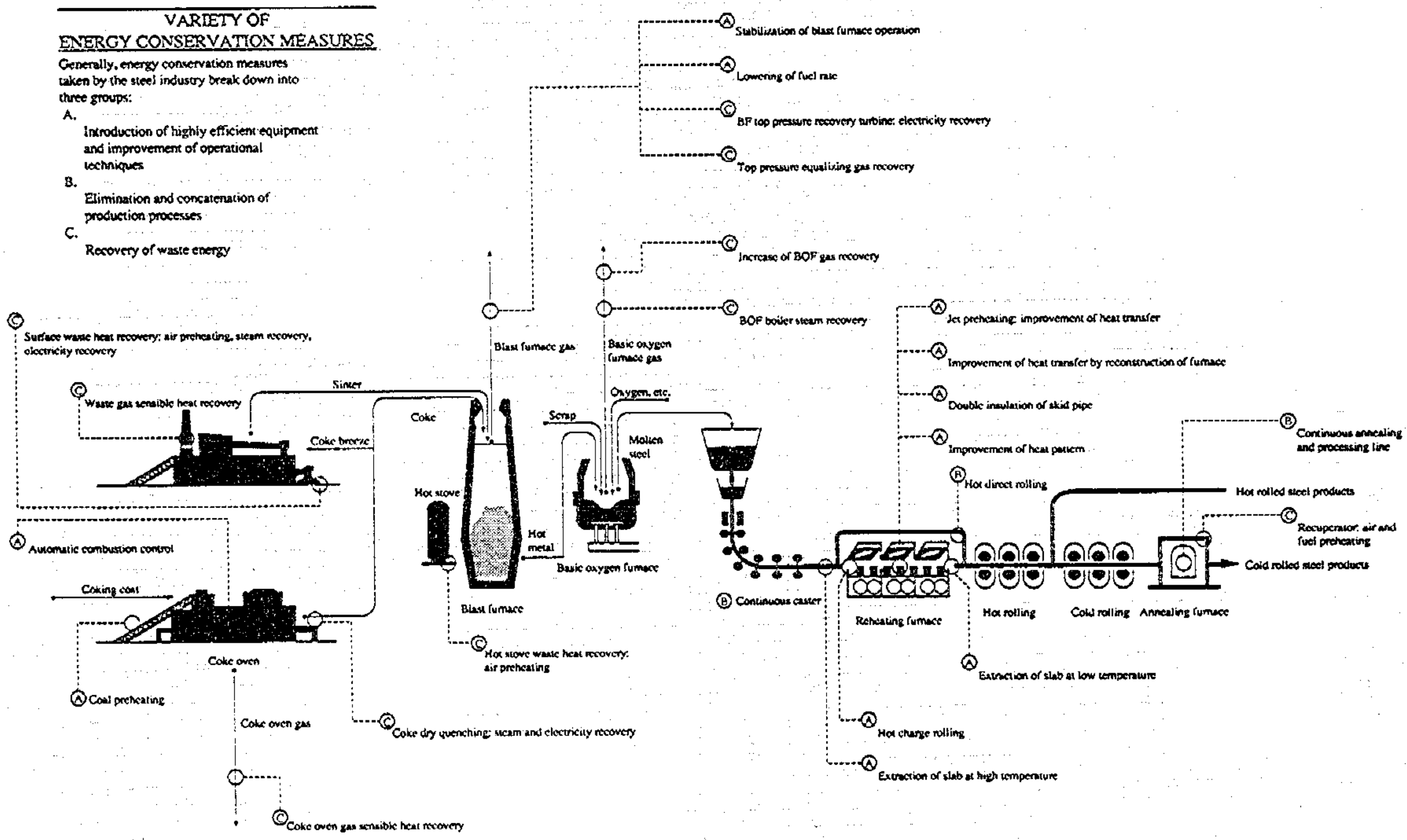
① Introduction of more efficient equipment and improvement of operation
② Omission and concatenation of production steps
③ Recovery of waste energy

After the first oil crisis in 1973, energy conservation measures were taken mainly by improving the operation till the sudden energy rise due to the second oil crists in 1979, and in the period of sudden energy price rise after the second oil crisis, energy conservation measures were taken mainly by adopting more efficient equipment including the introduction of waste energy recovery equipment, to achieve a large energy conservation of about 20 % in FY 1985.

Figure 4.28 shows the typical energy conservation measure taken since 1973.

The total amount invested in energy conservation equipment in the steel-making industry for the period from 1982 to 1993 amounts to 1.5 trillion yen, accounting for 15.5 % of the total investment amount of the steel-making industry in the same period.

Figure 4.28 Energy Conservation Measures in the Integrated Steel Works



4.4.5 Energy Conservation Rate in Each Process

Table 4.2 shows the net energy intensity of each process in a Japanese integrated steel works and Table 4.3 shows the main energy intensity of each process.

Table 4.2 Energy Intensity of Each Process (an example)

Plant		Net Consumption	Remark
Sinter plant	(per Sinter t)	378 Mcal/t	
Coke oven	(per Coal t)	443	excluding DH
By-product plant	(per Coal t)	100	
Blast furnace	(per Pig iron t)	3,082	
Converter and Continuous casting	(per Crude steel t)	30	
Rolling mill (primary)	(per Rolled product t)	546	
Others	(per Crude steel t)	538	including DH'
Power and Blower plant	(per Equivalent kWh)	596	
Power plant	(per Power output kWh)	-284	
Oxygen plant	(per Produced Oxygen m^3_N)	-83	
Energy distribution loss	(per Crude steel t)	133	

Note: DH and DH' are calculated as follows

$$DH = \frac{\text{(Input energy for coking)} - \text{(Output energy of coke oven)}}{\text{Charging coal}}$$

$$DH' = DH \times \frac{\text{Coal}}{\text{Crude steel}}$$

Table 4.3 Main Energy Intensity of Each Process (an example)

Coke Plant	Coke oven fuel per ton-coal	513 Mcal/t
	Coke oven electricity per ton-coal	25 kWh
Sinter Plant	Coke rate per ton-sinter	45 kg/t
	Electricity per ton-sinter	37 kWh/t
	Fuel per ton-sinter	6 Mcal/t
	Recovered steam per ton-sinter	27 Mcal/t
Blast Furnace	Fuel rate per ton-pig iron	526 kg/t
	Blast air per ton-pig iron	1,145 m^3_N/t
	Electricity per ton-pig iron	26 kWh/t
	Hot stove fuel per ton-pig iron	424 Mcal/t
	Recovered BFG per ton-pig iron	1,377 Mcal/t
	Recovered electricity per ton-pig iron	55 kWh/t
Converter	Oxygen per ton-crude steel	52 m^3_N/t
	Fuel per ton-crude steel	21 Mcal/t
	Electricity per ton-crude steel	27 kWh/t
	Recovered gas per ton-crude steel	202 Mcal/t
	Recovered steam per ton-crude steel	39 Mcal/t
Rolling Mill (primary)	Fuel per ton-rolled product	281 Mcal/t
	Electricity per ton-rolled product	103 kWh/t
Power Plant	Fuel per net output	2,286 kcal/kWh
	Fuel per kWh-output	2,164 kcal/kWh
Energy Distribution Loss	BFG bled per ton-crude steel	5 Mcal/t
	COG bled per ton-crude steel	64 Mcal/t
	O_2 bled per ton-crude steel	4 Mcak/t