The process of steelmaking in the twenty first century has addressed energy optimisation and environment as two of the top priority issues, given the fast depleting natural resources of planet earth and the alarming negative effects of global warming. Thus, given this critical scenario, the most question that inevitably comes to mind is: What exactly is the Indian steel industry doing to keep pace with global trends as far as energy optimisation and environmental controls are concerned?

This paper seeks to elaborate upon some of the measures taken by Indian steelmakers to optimise energy as also the steps adopted by them to combat pollution.

The Need to Save Energy in the Steel Industry

To begin with, why do steelmakers need to save and optimise on their energy resources? It is already established that the carbon present in the coal required for iron and steel production is mandatory, for the reduction of iron ore. Therefore, as long as coal remains indispensable as the reducing agent, it becomes compulsory for any steelmaker to reduce the consumption of energy, including that of coal, in order to cope with global warming.

Moreover, the smelting and refining processes, which involve cokke ovens, the BF and the BOFs, generate heat and pressure, which are recoverable as steam and electric power. Representative examples of practical recovery techniques include dry quenching at coke ovens and the top-pressure recovery at blast furnaces. The former involves quenching coke with nitrogen gas instead of water, enabling the sensible heat of the high-temperature coke to be efficiently recovered and utilized for steam generation. The latter example generates electric power by driving a turbine with the pressure of the exhaust gas from the top of the BF. The sensible heat of the exhaust gas produced in the BOF is also effectively recovered and used as fuel gas.

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One of the most effective ways to save energy is to eliminate obsolete processes and to continue with specific operating processes with proven energy saving records. One such notable example would be the change from ingot making -- slabbing to continuous casting, which has reduced the fuel required for soaking the ingot and power for operating the slabbing mill. Adoption of hot charge rolling or hot direct rolling of continuously cast slabs, which reduce fuel consumption for reheating; and the change from batch annealing to continuous annealing are two other examples of operating processes, which have enabled most steel works to reduce their energy consumption considerably.

In countries where steel scrap is abundantly available, scrap oriented EAF-based steelmaking is likely to contribute more towards energy savings in future. This is more likely in the case of coal-based new melting furnaces where the scrap route does not require the energy intensive iron ore reduction process which accounts for about 70 per cent of total energy needed to produce steel through the BF-BOF route.

Furthermore, the improved quality and properties of steel products contribute greatly to energy saving. For instance, high strength steel sheets for automotive applications reduce fuel consumption by making it possible to decrease the weight of the car body. Steel materials widely used in machinery and equipment which are to generate or consume electricity also make an important contribution to energy saving. Gas turbines, for example, operate more efficiently at higher applied gas temperatures. The heat resistance of steel materials used for the
turbine blades and rotor shafts determines this gas temperature. The development of higher heat-resistant super alloys and stainless steels is therefore closely associated with increased generating efficiency. It has already been mentioned that a lower iron loss in electrical steel sheet increases power conversion efficiency. Improved corrosion resistance in weatherproof and surface-treated steels, as well as longer life in bearing steels, contribute greatly to energy saving by extending the life cycle of equipment fabricated from these materials.

Historically speaking, following the first oil crisis, the global steel industry made full use of the world's most advanced technologies to achieve energy savings of approximately 20 per cent during the 1970s and 80s. The industry's efforts to save energy focused on improving productivity through the elimination and integration of certain production processes such as the development of continuous casting and continuous annealing etc and the introduction of largescale waste energy recovery equipment.

It was, however, during the 1990s that the concept of waste energy recovery equipment was reinforced and higher efficiency in the operation of implant power generation equipment was achieved. It was also during this decade that plastic waste materials were also effectively utilised.

A possible energy saving setup in an integrated steel plant is shown in Figure1.

Energy Optimisation in Indian Steel Plants: An Introduction

In any integrated Indian steel plant, operating on the BF-BOF route, the iron making operations comprise the blast furnace, coke ovens and sinter plant, which in their totality consume about 65 per cent of the total energy. The blast furnace alone consumes about 52 to 56 per cent of the total energy out of which nearly 90 per cent of the heat input to the BF is contributed by coke and coal. Therefore, the coke consumption rate is a very important factor, which determines the level of energy consumption by an integrated steel plant. The balance 35 per cent of the total energy is consumed by the rest of the steel plant (i.e. non-ironmaking operations) which includes steelmaking (about 6 per cent), rolling mills (about 15 per cent) and auxiliary shops & facilities (about 14 per cent).

In Indian integrated steel plants, the Specific Energy Consumption (SEC), which varies between 6.9 to 10.0 GCal/tc, is very high compared to the average figure of 4.6 to 5.6 GCal/tc achieved by the advanced countries.

With regard to energy optimisation, Indian steel plants have started emphasising more on installation of new equipment with clean and energy saving technologies as also recycling of wastes generated within their premises, thus contributing to better performance figures.

Several integrated steel plants operating on the BF-BOF route have installed high productivity blast furnaces with bell-less top charging, high top pressure, with top gas recovery turbine and waste heat recovery in stoves for preheating of air; coke dry quenching for coke oven batteries; BOF converter gas recovery system in steel making (energy recovery 0.14 GCal/ton of liquid steel).

These in their totality have yielded some very positive results. For example, SAIL has reported the lowest overall energy consumption at 7.5 GCal/tc in 2002-2003, which marks a 3 per cent decline over the previous year. This, hearteningly, is despite an increase in the production of quality steels, which consume higher energy. Tata Steel, similarly, in its energy policy, has adopted a strategy to reduce overall specific energy consumption at the rate of 1 per cent per annum by improved operational and energy efficient processes with emphasis on the minimum use of petroleum fuels. Tata steel has also augmented its captive power generation to become nearly self sufficient in power for uninterrupted plant operations.

The thrust today is also more on energy recovery from waste heat including generation of power from dry coke quenching; recovery turbine for high top pressure blast furnaces; preheating of combustion air utilising the flue gas heat in hot blast stoves; recovery of BOF gas for use as a by-product fuel; utilising Corex flue gas for generation of power and utilisation of DR plant rotary kiln exit gas for generation of power etc. Several steel plants have even set up their own captive power units to combat the ever-increasing tariff of the public utility power system. This is predicted to substantially reduce the cost of energy which currently constitutes 30 to 33 per cent of the total cost of production of Indian steel, whereas in the USA, UK,
France and Germany, it is 24.1, 19.8, 22.1 and 23.4 per cent, respectively. Evaporative cooling systems for rolling mill heating furnaces as also for recuperators have been gainfully operated.

Forms of energy used in Indian steel plants are presented in Table 1 below:

<table>
<thead>
<tr>
<th>Fuels</th>
<th>BF-BOF Route</th>
<th>DR-EAF Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coking coal - Coke</td>
<td>Non-coking coal</td>
<td>Non-coking coal for coal based DR-plants</td>
</tr>
<tr>
<td>Non-coking coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>By-product fuels:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Coke-oven gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Blast-furnace gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• BOF converter gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Coal tar/crude tar</td>
<td>Petroleum fuels:</td>
<td></td>
</tr>
<tr>
<td>Petroleum fuels:</td>
<td>• Light Diesel Oil</td>
<td>Natural gas (for gas-based DR plants)</td>
</tr>
<tr>
<td>• HSD</td>
<td>• HSD</td>
<td></td>
</tr>
<tr>
<td>• Fuel oil</td>
<td>• Fuel oil</td>
<td></td>
</tr>
<tr>
<td>• LPG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electric power</th>
<th>BF-BOF Route</th>
<th>DR-EAF Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased</td>
<td>Captive generation</td>
<td>Captive generation (for larger plants)</td>
</tr>
<tr>
<td>Captive generation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Energy Optimisation and EAF-based Steelmaking: The Indian Scenario**

Even though 43 per cent of Indian steel is produced through the EAF route, the EAF-based steel industry in India is faced with spiraling energy prices, which has caused many small/medium scale EAF units to shut down. In India, the EAF is a highly energy intensive process due to the utilisation of 100 per cent cold charge. The electricity consumption is as high as 600 Kwh/t as compared to a world average of 416 Kwh/t.

However, DR-EAF route plants (specially those with gas based DR plants) generally consume less energy and are less polluting than plants operating on the BF-BOF route. Thus, productivity of EAF units in developed countries has increased with corresponding reduction in energy consumption. Some Indian plants have adopted modern technologies but, in general, there is a wide gap in the technology pursued by Indian EAF plants as compared to their foreign counterparts.

In DR plants, however, the gas based plants have an SEC of 2.5 to 3.45 GCal/ton and coal based plants have a higher SEC in the range of 3.8 to 5 GCal/ton. In EAF plants, the SEC varies between 1.5 to 2.0 GCal/ton.

India is the second largest producer of DRI in the world with an annual production of 5.6 million tons. DRI is produced in India both through gas-based reduction route and through coal based reduction route. The gas based processes have low energy consumption while coal based processes utilising rotary kilns have the disadvantage of high energy consumption. There are several Indian processes of DRI using rotary kilns such as OSIL, TDR and JINDAL.

The differential rates of power tariffs and the lack of rationalisation in power costs which vary from state to state is yet another problem that plagues the Indian EAF Industry as also Induction furnace operators. According to published figures, the power tariffs to integrated steel plants comes to Rs 700/- per ton of steel produced whereas in case of electric steelmaking, it is as high as Rs 5000/- per ton!

A few large scale, gas-based, DRI-EAF units have resorted to certain energy conservation measures such as the deployment of UHP transformers, twin shell steel melting by using hot metal and DRI, use of hot DRI, increasing the DRI/scrap ratio and improved emission control. To quote one such example, Ispat Industries Ltd (IIL), at its plant in Dolvi, Maharashtra, has utilised liquid hot metal from its blast furnace along with sponge iron in a 70:30 ratio thus reducing the power consumption in the EAF. Further, IIL has also achieved a total energy saving of around 10,00,000 Kwh/month due
to efficient use of cooling tower fans; modifications in fan blades; economical use of utility pumps & lighting; LCP; and conversion of its AC system to AHU. IIL has also advantageously utilised thin slab castering technology.

The Environment and Indian Steel: A Historical Overview

It is disheartening to note that the Central Pollution Control Board has identified the Indian iron and steel industry as one of the 17 categories of highly polluting industries. This is more so as prior to 1980, the primary technological consideration for Indian steel making was the volume of production while the concern of Indian steelmakers towards energy savings and environmental protection was somewhat limited. The regulatory requirements were confined within the safety aspects as required by the then Factory Regulations and to some extent on the discharge of waste water.

As such, there were no specific regulations on the allowable emission load, wastewater characteristics, occupational health status of the workers, community health and safety aspects. The steel making process in some of the integrated plants were energy intensive, recorded a significantly high load of dust emissions, excessive water consumption and poor working conditions. The siting criteria for the steel plant other than raw materials, transport and power linkages, was then governed by the availability of unlimited water from a nearby perennial stream which also served as the receiving body for wastewater. Adequate land was also available for dumping solid wastes for years together. Both resulted in causing sufficient damage to the localised land environment, ecological settings and associated water bodies.

The Winds of Change

The scenario, however, changed dramatically in the Seventies when the global energy crisis surfaced due to a hike in petroleum prices and the historic United Nations Conference on the Human Environment held in Stockholm in 1972.

These two events were the main drivers for a total concept change in the industrial development all over the world and India, too, came into its ambit. The steel industry felt the urgent need for energy optimisation and the Government of India, being a signatory to the Stockholm Convention amended the Constitution of India in 1976 by inserting specific provisions depicting that the State "shall endeavour to protect and improve the environment and to safe guard forests and wild life of the country".

Subsequently, The Environment (Protection) Act came into force in 1986 in India. This led the Indian Steel and other manufacturing industries including mining to give due stress on energy conservation and environment protection by preventing and controlling environmental pollution. Thus, community development programmes became a part of the overall Indian environment management programme.

Initially, the Indian Steel industry was reluctant to comply with environment protection regulations as stipulated by law due to various reasons like shortage of requisite capital, space constraints, obsolete technology etc. However, with a rapidly changing mindset brought about by stringent legislation, modernisation of the integrated steel plants was taken up in phases by fresh injection of capital to give thrust to five specific areas namely, (i) energy conservation (ii) water conservation (iii) air pollution control; (iv) solid waste utilisation instead of land filling and (v) technology upgradation.

As said earlier, under the relevant provisions of the Environment (Protection) Acts and Rules, the iron and steel industry in the country is categorised as one of the scheduled polluting industries. Thus, to set up any green field steel plant or brown field expansion or modernisation of an existing steel plant, the project proponent is required to carry out environmental impact assessment (EIA) and environmental risk assessment (ERA) which would be evaluated by the project affected persons (PAPs) and a Government appointed Expert Committee for approving the project. Moreover, an operating steel plant is under constant surveillance by the State and Central Regulating Authorities to check whether the pollution load on the plant is well within the allowable norms in terms of discharge to the environment.

The following Tables, 2 and 3 indicate the present allowable pollution norms applicable for the steel industry:
TABLE 2 AMBIENT AIR QUALITY
ANNUAL AVERAGE PERMISSIBLE POLLUTION LEVEL (MCG/CU M) (I)

<table>
<thead>
<tr>
<th>Area</th>
<th>SPM (II)</th>
<th>RPM (III)</th>
<th>SO2</th>
<th>Nox</th>
<th>Pb</th>
<th>CO (6 hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>360</td>
<td>120</td>
<td>80</td>
<td>80</td>
<td>1.0</td>
<td>5000</td>
</tr>
<tr>
<td>Residential, Rural &amp; other areas</td>
<td>140</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>0.75</td>
<td>2000</td>
</tr>
<tr>
<td>Sensitive</td>
<td>70</td>
<td>50</td>
<td>15</td>
<td>15</td>
<td>0.50</td>
<td>1000</td>
</tr>
</tbody>
</table>

Notes:  (1) Figures are annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.
(2) SPM Suspended particulate matters.
(3) RPM Respirable particulate matters

TABLE 3 SALIENT CHARACTERISTICS OF TREATED WASTE WATER AS PER REGULATIONS

<table>
<thead>
<tr>
<th>Plants</th>
<th>Parameters</th>
<th>Max. allowable limits (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke oven effluent</td>
<td>pH 6</td>
<td>6 to 8 (no unit)</td>
</tr>
<tr>
<td></td>
<td>Suspended solids</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Phenol</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Cyanide</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>BOD (5 days at 20°C)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Ammoniacal nitrogen</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Oil &amp; grease</td>
<td>10</td>
</tr>
<tr>
<td>Other plants like</td>
<td>pH</td>
<td>6.0-9.0</td>
</tr>
<tr>
<td>Sinter plant,</td>
<td>Suspended solids100</td>
<td>100</td>
</tr>
<tr>
<td>Blast furnace,</td>
<td>Oil &amp; grease</td>
<td>10</td>
</tr>
<tr>
<td>Steel melt shop and mills</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The permissible pollution levels stated above are subject to variations depending on the environmental needs at the local, regional and national levels.

Some Emerging Trends

Broadly speaking, in the last decade, the Indian steel industry has realised that in order to sustain itself and to compete globally, it can no longer ignore environmental considerations. Moreover, since the enactment of the Environment (Protection) Act in 1986 and subsequent formulations of rules, the Indian steel industry (mainly the major players like SAIL, Tata Steel and Rashtriya Ispat Nigam Ltd) adopted a three pronged strategy in their efforts at pollution control at their respective steel works and mines. The strategy included:

- Conducting an environmental audit to ascertain the existing status, identifying the areas of attention and prioritising those areas for short, medium and long-term addressal through appropriate mitigating measures.
- Modernisation and technology upgradeation of the steel works (like phasing out Open Hearth Furnaces, Ingot casting and replacement by the BOFCC route). Many new pollution control devices were installed which were integrated to the existing iron and steelmaking process involving absorption of an estimated 812 per cent of the capital outlay.
Formation of dedicated and specialised Environment Management Divisions at corporate and plant levels and conduction of training and HRD programmes across the plants and mines. A very important aspect was the introduction of inhouse pollution monitoring and environmental awareness training.

EMS ISO 14001
Some of the integrated steel plants such as RINL, SAIL and Tata Steel have taken some very bold steps towards efficient environmental management by adopting comprehensive environmental management systems (EMS) in accordance with ISO-14001 standards. This has led to substantial improvement in conservation of raw materials, energy and water, reduction in wastewater discharge, quality improvement in air emissions and effective solid wastes recycling within the plant for gainful reuse. Tata Steel, which is the first Indian steel major to be awarded the ISO 14001 certificate for being a virtual zero emission plant, is one such notable example.

Life Cycle Impact Assessment (LCA)
The environment Regulating Authority has also advised integrated steel plants to undertake LCA studies for their operational units, from the mines to the finished steel stage. LCA analysis was done at the Visakhapatnam Steel Plant of RINL during the period, 1999 to 2001, by using Ecobilan software as used by the IIISI to carry out life cycle inventory (LCI) analysis on a global basis.

Corporate Responsibility for Environmental Protection (CREP)
In March 2003, the Union Ministry of Environment and Forests, Government of India and the Indian steel industry, entered into a landmark understanding to frame a charter on Corporate Responsibility for Environmental Protection (CREP). This charter envisages a voluntary control of pollution through responsible operations complying with the notified norms and charter guidelines and aims to achieve the following:
- To rebuild at least 40 per cent of the coke oven batteries in the next 10 years (by December 2012) within the allowable emission norms for door leakage, charging emissions and coke dry quenching.
- To reduce fugitive emissions by 30 per cent by March, 2004 and 100 per cent by March, 2008 (including installation of secondary dedusting facilities) in steelmelt shops.
- Direct injection of auxiliary fuel in all blast furnaces by June, 2013.
- Utilisation of Steelmelt Shop/Blast Furnace slag as per the following schedule:
  - By 2004 70%
  - By 2006 80%
  - By 2007 100%
- Charge of tar sludge from the electrostatic tar precipitator to coke oven by June, 2003.
- To reduce specific water consumption to 5 cu m/tcs for long products and to 8 cu m/tcs for flat products by December, 2005.

In accordance with the CREP guidelines, the Indian steel industry, on its part, is expected to initiate steps whereby it can recover energy from Blast Furnace (BF) top gas; start using tarfree runner linings; deducting cast houses at tap holes, runners, skimmers, ladles and charging points; suppress fugitive emissions using nitrogen gas or other inert gases; study the possibility of slag and fly ash transportation back to the abandoned mines; process waste containing flux and ferrous wastes through waste recycling plants; implement rainwater collection; reduce green house gases by reduction in
(a) Waste heat recovery;
(b) Reduction in power consumption;
(c) Use of byproduct gases for power generation; and
(d) Promotion of energy optimisation technology including energy audit.

Recycling of Waste Generated by the Indian Steel Industry
The Indian integrated steel plants generate about 11 million tons of solid wastes every year. Slags generated from the blast furnaces and the BOF are generally about 85 per cent of total wastes. Therefore, efforts have been made to utilise these slags since the early days.

*BF Slag:* Slag generated by a majority of Indian blast furnaces is being extensively used in plant all
and township road networks. Moreover, the Indian Roads Congress (IRC) and the Bureau of Indian Standards have accepted air-cooled BF slag generated by SAIL plants as a substitute for stone aggregate/chips for road making. A directive has been issued by the National Highway Authority Division, Ministry of Surface Transport to use the BF slag in all future road construction activities of the Government of India. It is also reported that air cooled BF slag is being used extensively as an aggregate in all types of concreting operations and as a trickling filter medium for waste water treatment. Also, a large portion of the slag is granulated for use in cement making.

**BOF Slag:** The average inplant reuse of BOF slag is about 30 per cent of production. At present, BOF slag recycling through blast furnace and sinter plant varies from 12 to 45 per cent in individual SAIL plants. The BOF slag has proved to be an effective railway ballast. This slag is being extensively used for internal railway networks in SAIL plants.

Due to scarcity of raw materials for refractory use and restrictions on land filling, the reuse of refractory materials has gained importance. Nowadays, a large portion of the dolomite based refractory from converters and transfer ladle linings is fed, after processing, to the sinter plant because of the calcium and magnesite it contains. The Research and Development Cell for Iron & Steel (RDCIS) of SAIL has developed some technologies for reuse/recycling of the refractories, which are:

- Salvaged MgO/C can be reused for production of carbonaceous mixes.
- Fire clay/high alumina refractories can be used to produce different grades of castable and mortar.
- High alumina castable can be made out of salvaged slide gate refractories like plate, nozzle etc.

**New Environmental Initiatives Taken by Some Private Indian Steelmakers**

While speaking of the initiatives taken by some leading Indian steelmakers in the private sector, it may be mentioned that Jindal Vijaynagar Steels Ltd (JVSL) is the first Indian steel plant to implement OSHAS 18001 Safety Management System and acquire OSHAS18001 Certification. It is also the first Indian steel unit to utilize carbon trading facilities approved by the Kyoto Protocol and has already submitted its application for host country endorsement. JVSL, moreover, utilises 100 per cent of its COREX sludge at its pelletisation plant and also has to its credit 100 per cent utilisation of bag house dust. Lime fines generated by the plant are converted into briquettes and subsequently reused in the BOF while part of the BOF slag is used as coolant in the Corex furnace. Among the other Indian plants that have also been awarded ISO 14001 certification are Essar Steel and Jindal Steel and Power Ltd at Raigad.

**Concluding Remarks**

Today as we enter the fourth year of the new century, we need to remind ourselves that the future of mankind depends greatly on the availability and consumption of various forms of energy. What is alarming is the fact that 90 per cent of the energy consumed comes from fossil fuels: oil, gas and coal which are non-renewable. Thus in view of the ever increasing demand for energy, specially in the developing countries, it is a million-dollar question as to how long the conventional energy sources will last.

India consumes about 5 per cent of the global energy of which 54 per cent is consumed by the country's industrial sector. The Indian steel sector alone consumes about 10 per cent of the total energy in the country as against a global average of 4 per cent. This, therefore, calls for a situation where the Indian steel industry seriously needs to reorganise its priorities as far as energy optimisation and conservation are concerned.

It is encouraging to note, however, that the Indian steel industry is now all too familiar with such phenomena as climatic change, green house effect, global warming, acid rain, the impending energy crisis etc. However, in the process of implementation, economic hurdles like the availability and cost of capital come in the way, which can be tackled through stringent legislation where the total cost needs to be shared by all, that is suppliers, vendors, customers etc partly voluntarily or maybe through an effective control system and where also the polluter is made to pay for the damage he does to the environment.

Consequently, the steel industry all over the world is constantly on the lookout for ways and means of lowering the impacts on the environment and India
is no exception to the rule. It is also well known that the more energy a plant or process uses, the greater is the pollution. Therefore, all over the world, the accent today is on “clean technologies” with high degree of recyclability rather than “cleaning up technologies”. And if it is sustained, then that only would be the saviour of planet earth.

List of Selected References:
FIG 1. POSSIBLE ENERGY-SAVING SETUP IN AN INTEGRATED STEEL PLANT

- COKE OVENS
  - Coke breeze for sintering
  - Coke sensible heat recovery, coal pre-heating, etc.
  - Coke dry quenching (cooling) and electric power recovery

- SINTER PLANT
  - Sinter-based heat recovery, air pre-heating, steam or electric power recovery

- BLAST FURNACE
  - BF top pressure recovery turbine (TPTR), electric power recovery
  - Hot stove waste heat recovery air & BF gas pre-heating

- BASIC OXYGEN FURNACE
  - BOF gas, increase of recovery

- CONTINUOUS CASTING MACHINE
  - Reduction of fuel consumption
  - Recuperator or regenerative burner
  - Jet pre-heating, improvement of heat transfer
  - Improvement of heat transfer by reconstruction of furnace
  - Double circulation of skin pipe
  - Improvement of heat pattern

- REHEATING FURNACE
  - Hot direct rolling (HDR), reduction of fuel consumption
  - Slab discharging at lower temperature
  - Slab charging at higher temperature (HCR), reduction of fuel consumption

- HOT ROLLING, COLD ROLLING

- ANNEALING FURNACE
  - Continuous hardening and processing line
  - Recuperator, combustion air, fuel pre-heating