

EXECUTIVE SUMMARY

0.1 IMPORTANCE OF COKE IN IRON & STEEL INDUSTRY

Coke is a major input factor in blast furnace which accounts for around 60% of hot metal cost. Coke quality particularly in respect of size fraction, ash content, carbon content, reactivity, granulometry, moisture content, M10 & M40 indices, coke strength after reaction etc. has been the major factor affecting the performance of blast furnaces. Hence it is important to understand the various fundamental aspects of coking and the technologies under precarbonisation, carbonisation and post carbonisation stages. It is also of paramount importance to identify the techno-economic viability of various technologies available in the country as well as in International level and evaluate them under Indian context so that strategies can be evolved for improving quality and productivity of coke from Indian Coals. This will also help in identifying the areas where technology gaps can be bridged at various levels.

0.2 HISTORY & DEVELOPMENT OF COKING INDUSTRY

Coke is basically a solid residue from the destructive distillation of coal. However, coke making is a multistep complex process and present coking scenario is a result of series of development that has taken place since the latter half of 19th century. Starting from beehive oven the present day coke oven is a result of continuous effort to optimise the coking process and introduce innovative ideas to the design of by product ovens e.g. gunflue, half divided, four divided, twin flue, cross over system and others. Considerable developmental efforts towards higher oven capacity by increasing height and width with improvement of silica bricks quality also have taken place world wide. Coke making in the world scenario has come a long way to present level with an annual production of around 350 million tonne in which India's contribution is about 12 million tonne.

In the Indian scenario, coke oven batteries had been built since beginning of this century but the major thrust came when batteries were built in fifties based on USSR, UK and German designs as part

of steel plants. As of now about 3000 ovens are in operation/ construction in coke oven plants. In India today MECON & Otto India are the two organisations who can offer coke oven plants of 4.5 m height without resorting to any foreign support. In the indigenous sector, Otto India is offering coke oven plants on turnkey basis based on the design of its German Collaborator. More than 900 ovens have been built/rebuilt by Otto India so far. MECON on the other hand have its own design for coke oven batteries. Based on its indigenous capability to design, engineer, construct and commission, several MECON design coke oven batteries (upto 4.5 m height) with special features to suit Indian conditions are in successful operation in Indian Steel Plants. Based on Licence agreement with the Soviets, MECON have further widened its capability in design, engineering, consultancy, construction and commissioning of high capacity oven (7m tall) batteries. Based on MECON design, about 680 ovens in various steel plants are working or under construction. An analysis of coke making technology makes it clear that technology development has taken place in the following three parallel paths with specific objectives:

- i) Emergence of new technologies e.g. stamp charging, preheating, selective crushing of coal, partial briquetting of coal, SRC (Solvent refining of coal) with a view to conserve scarce coking coals and to improve productivity in some cases.
- ii) Optimisation of specific throughput capacity of oven and incorporation of innovative designs with a view to minimise number of pushing/charging operations, more of mechanisation and automation thereby improving the overall working atmosphere of coke ovens.
- iii) Introduction of energy conservation such as dry coke cooling technology and pollution control measures thereby making the coke making technology more cost effective and less polluting.

0.3 PERFORMANCE OF COKE OVEN INDUSTRIES

India produces about 6% of world's coke. With expected rise of installation capacity in coming 5 years total coal throughput capacity of Indian coke ovens will become about 36 Mt/yr. Major portion of the coke comes from coke ovens installations in steel industry. To improve overall performance and quality of operation suitable

technologies should be adopted/absorbed from time to time in coke area. To assess the requirement of adoption/absorption of particular technology it is necessary to have indepth study on the effect of various factors affecting the performance of coking industries.

Poor quality and high ash content of Indian coking coal, inconsistent linkage of coal to coke making units, increased number of component in the blend and poor coal stock particularly in monsoon season, have put the coking industry under tremendous pressure. The ash level in coal charge has increased from 17-18% in 60's to 22-24% at present. This has increased ash level in coke to around 28-30% (Figure 2.1). Socio economic problems which have created general indiscipline and industrial unrest along with various operational problems have affected the life of coke oven battery in India.

0.4 STRUCTURE AND STATUS OF INDIAN COKE OVEN INDUSTRY

The basic structure and important facilities available in Indian Steel Plants and other coke oven industries have been described in the report. Several modern technologies have already made their entry in Indian coke oven scene.

7m tall coke oven battery has been commissioned at Bhilai Steel Plant in 1987. PBCC has been implemented and commissioned in June 1990 in Bhilai Steel Plant. TISCO has adopted stamp charging technology & their battery 7 utilising this technology went into operation in January, 1989. VSP coke oven battery with 7m tall ovens has been commissioned in Sept. 1989 with coke dry cooling facilities for the first time in the country. Country's first selective crushing unit with pneumatic classifier also has been introduced at VSP. Some of the facilities are under various stages of implementation in Indian coke oven plants.

Other technologies e.g. solvent refining of coal, formed coke manufacture and others, are still under developmental stage and yet to be implemented in India. However, such innovative measures e.g., mechnisation, automation, emission control etc. have not yet found its impact in full strength in the existing plants. This situation resulted due to limitation for incorporation of some of the facilities in the existing units as well as due to lack of awareness, resource constraints and non availability of the technology indigenously. However, during recent rebuilding of coke ovens and recent planning of new installations these facilities are being incorporated to a limited extent.

0.5 RESEARCH & DEVELOPMENT FACILITIES

Experimental facilities of different degrees are available at Institutions/ organisations like CFRI, (Dhanbad), TISCO, (Jamshedpur), RDCIS, (Ranchi), BSL, (Bokaro) and at a host of foreign organisations. The facilities available in India can be considered quite modern and adequate to evaluate various technologies in the laboratory. However, coordinated approach involving research, engineering in coke oven Industries on the various projects needs to be enhanced.

0.6 STATUS OF ENGINEERING & MANUFACTURING CAPABILITY IN INDIA AND TECHNOLOGY TRANSFER POTENTIAL

In the early part of this century (1907-1918) two integrated steel plants were set up, one at TISCO, Jamshedpur and other at IISCO, Burnpur with the entire assistance from foreign countries. Gradually with the installation of three more steel plants at Rourkela, Durgapur and Bhilai and with expansion work of TISCO in late fifties, Indian Engineers had opportunity to gather experience from observation and association right from the design and engineering stages through construction and commissioning of these plants. In 1959, a consultancy and design organisation for Iron & Steel was set up within, the then Hindustan Steel Ltd (HSL) viz. Central Engineering & Design Bureau (CEDB) (now Metallurgical & Engineering Consultants (India) Limited, MECON). Earlier in 1955, the first steel plant consultancy organisation in India, DASTURCO was also set up in private sector. Otto India is also capable of carrying out engineering for coke oven projects. As such engineering capability exists in India to adopt most advanced technology in coke making.

Parallely with the development of engineering expertise within the country, capability for manufacturing and supply of coke oven equipment and coke oven machines have also developed within the country. Since then a number of collaboration agreements with foreign parties have been effected in the areas of design, engineering, manufacture & supply of coke plant equipment and today know-how of detailed engineering and equipment manufacturing for steel plant including coke ovens is available within the country. Annexure-I gives a broad list of Indian suppliers in the area of coke ovens equipment & machinery.

0.7 MODERNISATION

Under modernisation programmes of some of the plants, the modernisation/replacement of old units by new units with latest technologies is underway to enable achievement/enhancement of production capacity with better products and economics. The need based induction of technology in various areas has been discussed in the report. It is recommended to apply these efforts in other steel plants to bring in modernisation as a continuous process.

0.8 STATE OF ART SCENE

The current technological scenario suggests that the new technologies for iron production have still not reached sufficient levels to eliminate blast furnace route of iron making. Thus coke ovens will continue to exist and the challenge of producing better quality coke for higher sophisticated blast furnaces exist by increased utilisation of inferior quality of coal & optimising cost of production of coke.

Over the last two or three decades blast furnaces have increased considerably both in size and sophistication and these changes have necessitated a high standard of performance of the coke used. Obviously coke oven operators are under constant threat of not reaching upto the desired standard. One of the major problems encountered by Indian coke oven has been the continuous deterioration in quality of coal resulting in coke with high ash content and poor strength. This has contributed to phenomenal high coke rate of Indian Blast furnaces as compared to developed countries. Several technologies have been developed & tried to combat this problem. Technologies which can be considered for improving coke quality are:

- i) Selective crushing of coal.
- ii) Stamp charging of coal.
- iii) Partial brequetting of coal charge (PBCC).
- iv) Preheating of coal charge.
- v) Coke dry cooling process (CDCP).
- vi) Combi-coke process (Combination of preheating & dry cooling).
- vii) Solvent Refining of Coal (SRC).
- viii) Formed coke process.

For proper evaluation purposes the current status of technologies with basic features & latest art of scene in national as well as international fields needs to be analysed. The technologies developed under three broad categories e.g. pre-carbonisation, carbonisation and post carbonisation have been elaborated in the report and summarised below:

A) Pre-carbonisation Technologies

Among the pre-carbonisation technologies, following are gaining more and more importance.

- i) Selective crushing of coal.
- ii) Stamp charging of coal.
- iii) Partial briquetting of coal charge.
- iv) Preheating of coal charge and
- v) Solvent refining of coal.

- i) The selective crushing technology improves the quality of coal blend by ensuring fine crushing and even distribution of harder and mineral matter rich particles leading to homogeneity, and better control in variation of size consistency of coal charge thereby producing good quality coke (M10 index improves by 1.5 to 2 points with respect to a base value of 12 to 14.

The processes based on mechanical type screen (Umbra), electrical heated screen and centrifugal screen could not gain success on commercial scale due to operational and maintenance problems and lower throughput capacities. The process based on pneumatic classifier as developed in Soviet Union has become successful on commercial scale.

- ii) Stamp charging process has been in existence for the last 70 years. Even in India this technology was employed at FCI, Sindri but this did not work successfully due to problems associated with breakage of coal cake. With further development of the technology especially development of stamping machine several plants have come up in late seventies and eighties with the latest one at TISCO, Jamshedpur based on Saarberg Interplan (Germany) technology.

The major benefits which can be derived from stamp charging technique are improvement in bulk density of coal charge (by about 35%), increase in oven throughput (7-15%), coking coal conservation due to use of higher proportion of high volatile and poor coking coal in the blend, improvement of coke quality (M-10 improves by 3-5 points with respect to a base value of 12 to 14), lower coke reactivity, increase in BF coke yield (3 to 4%) etc. At TISCO, operation of stamp charged battery has been stabilised. The improvement on the strength has been reported to be quite substantial (M-10 value of 5.5 has been achieved as against 7.2 for top charged battery). Apart from this, indigenous prime coking coal has been totally eliminated from blend with the use of 80% medium coking coal and 20% imported coal.

- iii) The PBCC process enables partial utilisation of weakly/non-coking coal in the form of briquettes along with coal charge. This process is quite suitable for a country like India which does not have sufficient reserves of good coking coal. Presently there are two main commercialised briquette blend coking process e.g.
 - a) Briquettes blend coking process developed by M/s Nippon Steel Co. (Nihon Otto K.K.) Japan.
 - b) Sumi-coal system developed by M/s Sumitomo Metal Industries Ltd. Japan.

The first PBCC Plant has been installed in 1971 in Tobata Works, Japan. Country's first PBCC plant has been commissioned in June 1990 at Bhilai Steel Plant by M/s Otto India. The Plant is reported to be working successfully giving an improvement of about 1.5 points in M-10 value over a base value of 11

- iv) Preheating of coal before charging enables use of blend containing substantial quantity of poor coking coal. In this process the coal charge is preheated to around 200-250 °C. before charging. Preheating enables increased coal throughput per oven, improves coke quality and enables use of inferior grade coal. Other benefits are overall heat economy and less

thermal stress on oven brickwork. The preheating processes which have been developed on commercial scale are:

- a) Coal-tek system.
- b) Thermocharge system.
- c) Precarbon process.

This technology has not sustained well in the world due to problems associated with handling of preheated coal.

- v) Solvent refining of coal (SRC) is a technology for beneficiation of high ash and poorly coking coals to get a practically ash free low sulphur product in solid and/or liquid form. When compared to other technologies available, SRC serves the dual objective of bringing down blend ash level and improving the coking characteristics of coal blend. It also allows substitution of a portion of prime coking coal by non-coking coal in the coal blend. SRC technology is presently in development stage. Extensive research work has been done for SRC technology in USA, Germany and Japan and semi-commercial plants had been set up. In India developmental work on SRC has been continuing under SAIL-CSIR MISSION Programme. Presently CFRI, a unit of CSIR is planning to install a continuous process development unit (PDU) for generating data and optimising process parameters. Japan International Co-operation Agency (JICA) has been entrusted by Government of India to jointly carry out tests on Indian coal and prepare a preferability report for setting up a 500 tpd SRC demonstration plant in India where MECON, RDCIS & CFRI are assisting JICA for conducting the study.

B) Carbonisation Technologies

Developments of carbonisation technologies have taken place with a view to achieve maximum technological and economical benefits. With highly capital intensive nature of coke ovens, the need was felt to get higher specific throughput per oven which resulted in the emergence of high capacity high throughput ovens. Higher capacity ovens could be achieved by increasing the height and/or width of the ovens. In order to improve the coke output per oven, not only the oven sizes were increased but faster

carbonisation was adopted by increasing flue temperature, narrowing oven width & by adoption of thinner walls. But with very high capacity ovens & very tall ovens the trend is reversed in today's scenario whereby the oven widths are becoming more. At present ovens with height upto 7.85 m/width upto 610 mm and volume exceeding 70 m³ are available based on commercial scale plants installed/under installation. The world trend is clearly towards installation of such high volume ovens, one battery of which replaces 2 to 3 small batteries. Development & features of world's leading designers of coke ovens e.g. (i) Krupp-Koppers, Germany (ii) Koppers Company, USA; (iii) Dr. C. Otto & Co. (now Still-Otto), Germany; (iv) Babcock Woodall-Duckham Ltd, UK; (v) Didier Kogag-Hinselmann; (vi) Carl Still, Recklinghausen, Germany; (vii) CEC Enterprise, France; (viii) Giprokok/TPE, USSR (ix) MECON, India and others have been discussed in the report

C) Post Carbonisation technologies

One of the most significant areas of post carbonisation technologies is dry cooling of coke in an inert atmosphere. In conventional practice hot coke is pushed from the oven and quenched by means of water spray. In wet quenching of coke about 0.36 to 0.42 Gcal heat is lost per tonne of coke. Coke quality also is decreased due to water quenching. The quenching of coke with water also causes pollution problem. Post carbonization technologies are basically aimed at effecting the heat economy of coking process, increasing the coke strength and pollution control.

With a view to effect an economic recovery of sensible heat in hot coke, coke dry cooling technology has been developed and adopted on a commercial scale. This technology has been developed by Giprokoks (USSR), Waagner biro/Krupp-Koppers (Germany), Dr. C. Otto and Carl Still. Out of these technology developed by Giprokoks (USSR) has gained wider acceptance on commercial scale. With a view to introduce latest technology, MECON entered into licence agreement with the Soviets for coke dry cooling technology in 1980. MECON is now offering coke dry cooling plants involving activities from concept to commissioning. Three such plants are being installed at Visakhapatnam Steel Plant, one of which with 4 cooling chambers each of 52-56 t/h

coke cooling capacity has been commissioned in Sept. 1989. During first year of operation of coke dry cooling plant at VSP, the major highlights are:

- i) Improvement in coke quality in comparison to 7m tall battery at BSP.

M-40	6 points
M-10	2 points
- ii) Steam generation 0.53 t/t of coke against a norm of 0.45 t/t of coke
- iii) Thermal efficiency Over 80%
- iv) Chamber availability Over 80%

M/s Kress Corporation, USA has developed recently a coke dry cooling system where instead of pushing into a coke car the hot coke is transferred and supported in a container and preserves it in oven in loaf form during cooling, thereby retaining its natural fissures, porosity and cake cleavage produced during carbonisation process and cooling carried out by circulation of water in the external annular chamber. The first plant of its kind is reported to have been commissioned in the last quarter of 1990. Another development under post carbonisation technologies is combi coke process.

Combi-coke process couples the coke dry cooling and preheating of coal to combine the benefits of both the technologies. Technologies involving Combi-Coke process and development of wet quenching system have been described in the report.

Among the other post carbonisation technologies, coke stabilisation is one of the simplest methods adopted for improving the strength of coke. Coke stabilisation is an operation through which the larger and more friable lumps of coke are reduced to more stable coke lumps of required size range. This is done by mechanical conditioning operation which involves either dropping the coke from predetermined height over an impact plate or subjecting the coke to rotations in large barrel drums or micum drums. The major advantages of coke stabilisation include better coke strength indices and lesser generation of fines during handling.

D) Formed coke process

Good coking coal can be obtained from coal blends containing substantial proportions (70-100%) of poor coking coal (medium & weakly coking coal) and non-coking coal using the technique of formed coke. The first commercial plant was set up in USA by FMC Corporation in 1961. Since then several formed coke plants came into existence with variation in the process scheme. Some of the major formed coke processes are:

- i) FMC formed coke process
- ii) Consol BNR Process.
- iii) Clean coke process
- iv) BF-L process
- v) Ancit process.
- vi) HBNPC process.
- vii) DKS formed coke process.
- viii) CFRI process.

Though there are differences in various processes, the basic process steps can be summarised as

- i) Breaking/crushing of coal to required size.
- ii) Carbonise either lumps or fines to drive out the volatile matter (some of the processes do not require carbonisation before briquetting) resulting in char (carbonised coal fines/crushed carbonised lumps).
- iii) Addition of binder (processed tar) to char or coal fines (some of the processes use coking coals partly as binder instead of tar/pitch).
- iv) Shapping/brequetting the above mixture in processes to give it a particular shape and size, strength and permeability.
- v) Calcine or heat harden the shape/briquettes, cure the same to produce formed coke.

0.9 REPAIR TECHNOLOGIES

In an integrated steel plant coke ovens must continuously produce desired quantity and quality of coke throughout the full campaign

life. But due to problems like nonadherence to the technological operational and maintenance norms, aging of plant and equipment, lack of proper automation and control facilities etc., average life expectancy of coke ovens in India is generally 10 to 15 years as compared to normal life span of about 25-35 years. In Indian conditions damage to refractories especially at oven ends start showing out in 5th or 6th year of operation & in some cases earlier also. Coke ovens repair technology, specially relating to refractory work, play an important role in keeping the good health of the coke oven batteries and extending their life span. The repair to refractory work depends on nature of damage and consists of spraying & patching, pressure dusting etc., repair of end flues by replacing the bricks (after the oven is blanked). If the damage is extensive beyond 6th or 7th flue on either sides then full wall repair is resorted to. In other countries repair techniques like flame guiniting, fusion welding technique (as in Fosbel process) are adopted which has not been effectively utilised in our country. The Fosbel Technique of fusion welding was attempted in Indian coke plants but had only very limited success. RDCIS (SAIL) are working on a programme of indigenous development of ceramic welding. MECON has also carried out some developmental work in this area.

0.10 INNOVATIVE MEASURES & IMPROVEMENTS

During the course of development of coke oven technology and its process various innovations and improvements have taken place in major areas such as

- i) Battery construction with respect to Development of refractory bricks.
- ii) Built in provisions in battery for the economy and uniform distribution of heat.
- iii) Oven equipment e.g.
 - a) Oven anchorage system.
 - b) Oven doors.
 - c) Oven machines.
 - d) Door body and door frame cleaner.
 - e) Gas off take cleaning mechanism.
 - f) Environmental aspect & pollution control equipment.
 - g) Automatic control of heating system.
 - h) Water energy recovery system.

Oven machines and equipment

Major developments have taken place in areas like coke oven machines with single spot operation and improved features/facilities, which enables a number of operations at one setting of the machine, oven doors with improved sealing system (Felxit/zero leak type), door and frame cleaning system, gooseneck cleaning and pollution control system (as part of oven machines) to improve carbonisation conditions, increase life of batter, improve working conditions and improve productivity. These have been elaborated in the report.

Pollution control technologies

The present demand is not only for production with highest level of efficiency but also with greatest possible degree of environmental protection. The water sealing between Ascension pipe lid & frame is adopted to avoid leakage at the Ascension pipe. So also measures like high pressure liquor aspiration system at the gooseneck is aimed at reducing emissions during charging. Coke oven machines incorporate suction devices to control emissions by transferring the particulate & gaseous emissions during charging & pushing to ground stations where they are further handled.

Automation and control of coke making

The most important and difficult parameter for successful control of batter operation is true temperature of ovens. Work has been done at various levels on automation and control of different aspects of coke making including oven temperature.

The report to highlight the development which have taken place at leading Institutions/organisations on this aspect. Emphasis has been given on (i) automation developed by NKK, (ii) automation in Bethlehem, (iii) Carl Still/Estel System (iv) Ecotrol system of Krupp-Koppers, (v) CETCO (coke end temperature control) system, (vi) Otto ABC system etc. These controls through sensing devices and computerisation enables not only avoiding manual operations of heat measurement control hitherto practised, but results in heat economy in ovens ensures proper carbonisations by indicating coke end temperatures and also controls heat input into the ovens taking into account variations in calorific value of fuel, draught, and bulk density of charge.

0.11 TECHNOLOGY ABSORPTION AND GAPS

Utility of any technology is judged by the techno-economic benefits which could be derived through their adoption in a specific location. Adoption of such technologies under Indian context depends upon the merits, state of art scenes and developments in the country and abroad, its relative economics etc. Status of all coke oven related technologies under precarbonisation, carbonisation and post carbonisation stages has been elaborated in the report. A few technologies with latest features have been introduced in some Indian coke oven plants. These are selective crushing of coal, stamp charging of coal, partial briquetting of coal charge, high capacity ovens, equipments & machines with improved features etc. However, such technologies introduced in India have not yet been utilised for the purpose these are meant for, such as utilisations of semi coking coal and non coking coals. Hence the real benefits that can be accrued cannot be assessed at this stage. Nevertheless a beginning has been made & it will be worth while to watch the performance and derive the benefit of the operational experience of these new technologies. A detailed account of various technologies which have been absorbed/under the process of absorption and where gaps exist regarding their absorption have been given in the report. The thrust areas have been identified and recommendations regarding adoption of each technology under Indian conditions have been discussed in the report

0.13 MANPOWER DEVELOPMENT

Manpower development is necessary to improve efficiency and to cater to the needs of new technologies and technological features inducted under modernisation/expansion programmes and new plants installed/proposed to be installed.

It has been recommend that the technologies such as selective crushing of coal, partial briquetting of coal charge (PBCC), stamp charging technology, solvent refining of coal, High capacity High throughput ovens with modern innovative features such as flexit/zero leak doors, single spot oven machines with improved features, door/frame improved mechanical cleaners/hydrojet cleaners, improved ammonia liquor spray nozzles, pollution control units, programmed/auto control heating system, coke dry cooling and formed coke technology may be considered for adoption on broader

scale in our coke oven plants on priority basis. The emphasis has also to be given towards developments of coke ovens repair technologies to improve the life of coke ovens. On line analysis and control of coal blend quality is considered important for improving the quality of coke and performance of coke ovens.

All the technologies can not be adopted altogether in any single plant. The combination of certain technologies will have to be decided based on coke quality requirements, investment capability, impact on cost of production etc. Combination of certain technologies e.g. selective crushing and coke dry cooling can however be considered for adoption in a steel plant as in VSP to derive added benefits. Various technological features e.g. flexit/zero leak doors, single spot oven machines with improved features, doors & frames improved mechanical cleaners/hydrojet cleaners, improved ammonia liquor spray nozzles, pollution control units, programmed/auto control heating systems, on line analysis and control of coal blends, improvement in wet quenching system etc. can be combined as required and adopted in existing plants under modernisation programme and in new plants. SRC and formed coke technologies need development to enable conservation of our coking coal/reduce import of coking coal & enough thrust should be given to develop the same. It can be thus seen that judicious thought has to be given for adoption of new technologies/technological features to meet the need for any plant.

The Research and Development facilities may have to be augmented with adoption of latest technological features and new technologies. It would be necessary to install/augment experimental/pilot testing facilities to test coal blends and assess extent of benefits which can be derived under new technologies such as selective crushing, partial briquetting of coal charge, stamp charging and others.

As regards manufacturing of equipment, capacity and capability of Indian manufacturing firms exist. However, know-how and design of the same for critical equipment and machines shall have to be procured under the technology transfer programmes to enable Indian manufacturers to take up manufacture. This will obviate the need for import of these items and help in import substitution.