SESA ENERGY RECOVERY COKEMAKING:
COKE TECHNOLOGY FOR THE FUTURE

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INTRODUCTION

Coke is primarily consumed in the steel industry through the blast furnace route that accounts for 75% of the world coke production. There was a belief that emerging technologies such as those based on DRI/ Smelting would make coke dependent blast furnaces obsolete. However, as yet there does not appear to be any proven alternatives, which are likely to replace blast furnace in the foreseeable future. This means coke ovens would continue to exist. Fundamentally there are two met coke production processes: Byproduct Recovery Cokemaking and Energy Recovery/ Nonrecovery Cokemaking.

In the last century the by-product oven that produces both coke and byproducts such as tar, pitch, benzol and ammonium sulphate had been the dominant cokemaking technology. However, environmental concerns, occupational health & safety and reduced value for byproducts as well as competition from the petrochemicals have led tonnes coke capacity. Earlier the US EPA had only recommended the energy recovery technology as the acceptable alternative. In India the Central Pollution Control Board has also recommended adoption of nonrecovery ovens as a pollution control alternative.

At the moment increasingly stringent environmental regulations have made it imperative for any future capital investment in cokemaking to take these factors into consideration and this has swung the thinking in favour of the more environment-friendly energy recovery cokemaking processes.

Sesa have, over the last decade, developed an energy recovery cokemaking technology that has been developed to incorporate the latest automation, making it suitable for the western market and entirely compliant with the latest US EPA. We believe that it is the cokemaking technology most suited for the future, provided, of course that the use of the coke oven gas can be dispensed with.

WORLD MET COKE SECNARIO

Recent years have witnessed unprecedented growth in global steel consumption, particularly since 2001. The world crude steel production has crossed the billion-ton mark to 1056 million metric tonnes in 2004 and is poised to scale new heights in the coming years. The share of crude steel produced from the integrated steel plants has also increased, from 61 to 64% with stepping up of the hot metal production from 570 in 2001 to 709 million tonnes in 2004. Around 10% rise in the output of hot metal is expected by the end of the current financial year.

The coke production in India stood little over 19 million tonnes in the year 2004, which saw the hot metal and crude steel production a level of 25 and 33 million tonnes respectively. The conventional byproduct recovery coke ovens account for about 85% of the Indian met coke production and the balance comes from nonrecovery coke plants. The Indian economy is growing at a pace never seen before. The Indian steel demand is projected to be more than doubled by 2012 on a conservative basis and that means coke requirement would also follow the same trend.

The boom in the export prices of coke in 2004 has on the one hand has made Russia, Ukraine, Poland enhance their coke production and on the other hand USA and India to invest in additional cokemaking capacity. Meanwhile, the new plants are being set up in China and are being commissioned. While Chinese coke making capacity is 260 million tonnes, its domestic coke demand expected to be of the order of 220 million tonnes in 2005. This has led to a mismatch in the supply-demand of coke resulting in drop in coke prices to a level where buying coke has become cheaper than importing coking coal and produce coke. However, this is a temporary situation. The coking coal prices, which were jacked up out of all proportions, are likely to ease out early next year when the coal contracts are finalized with concomitant market correction. This would make coke making profitable in tune with surging global steel demand.

BY PRODUCT RECOVERY COKEMAKING

In byproduct cokemaking, gases evolved during the carbonization are cooled, and various primary chemicals like ammonia, tar and benzol are recovered. Purified coke

The coal is charged into the narrow, rectangular, refractory coking chamber "slot type" ovens. The chamber is also equipped with a gas collecting system for the removal of the volatile matter distilled from the coal. The raw coke oven gas is collected and subsequently stripped of certain chemicals. The relatively large amount of gas remaining after the chemicals are stripped is available for use as a high-grade industrial fuel

The coking chamber and its coal charge are heated by heating walls located on each side of the coking chamber. The heating walls contain a series of vertical heating flues in which a fuel gas is burned. A regenerative system is provided for preheating the air being supplied for combustion in the heating flues.

ENERGY-RECOVERY COKEMAKING

In the energy-recovery cokemaking process, volatiles evolved during coal carbonization, are not recovered as by-products but are combusted completely in presence of controlled quantity of air and the heat of the volatiles of evolving gases is utilized for coking the coal mass into coke and thus no external heating is required. The higher level of heat importantly is used to break up the potentially polluting hydrocarbons into the constituent combustible compounds and to burn them thus avoiding the potentially hazardous pollution. The heat consequent to combustion is only partially utilized during the process. The direction of heat transfer is in the vertical direction in energy-recovery cokemaking as against the horizontal direction in the case of by products recovery cokemaking process. While the energy-recovery coke ovens operate under negative

TABLE 1: COMPARISON OF BYPRODUCT VIS-À-VIS NONRECOVERY COKEMAKING PROCESSES

BY PRODUCT RECOVERY	NON RECOVERY
• Oven chambers are kept under slight positive pressure.	• Oven chambers are kept under slight negative pressure or suction.
• Oven shape is taller than wider	• Oven shape is much wider than higher
• Generates excessive air emissions including toxic and carcinogenic compounds.	• Free from air pollution. No toxic and carcinogenic compounds.
• Gas is cooled resulting in generation of condensate. Water is used to control emissions, recovery of by products and coke quenching.	• Uses water only as makeup for coke quenching
• Excessive generation of effluents.	• No effluents, quenching water is recycled.
• Solid waste generation in byproducts processing.	• No solid waste generation.
• Maximum achievable coke temperature, lower than non-recovery coke ovens.	• Maximum achievable temperature higher than by product ovens
• Susceptible to wall pressure.	• No wall pressure since coal charge resting on the oven sole is barely in contact with oven walls and has large unrestricted surface area.
• Possibility of oven damage due to sticker.	• No possibility of oven damage due to stickers.
• Shrinkage characteristics of coal charge relevant.	• Shrinkage characteristics of coal charge irrelevant.
• Coke quality inferior to that obtained from non-recovery coke oven.	• Ability to heat coke at higher temperature than by product. Product coke with improved quality with respect to cold and hot strength properties.
• Productivity is mainly controlled by changes in coking period through changes in temperature. Any changes in productivity affect coke quality.	• Can adjust productivity and pushing / charging schedules independently. Coke quality unaffected by change in pushing/charging schedule.
• Limited flexibility to coal quality usage.	• High degree of flexibility to coal quality usage.
• High operating cost.	• Low operating cost.
• High capital investment.	• Low capital investment.

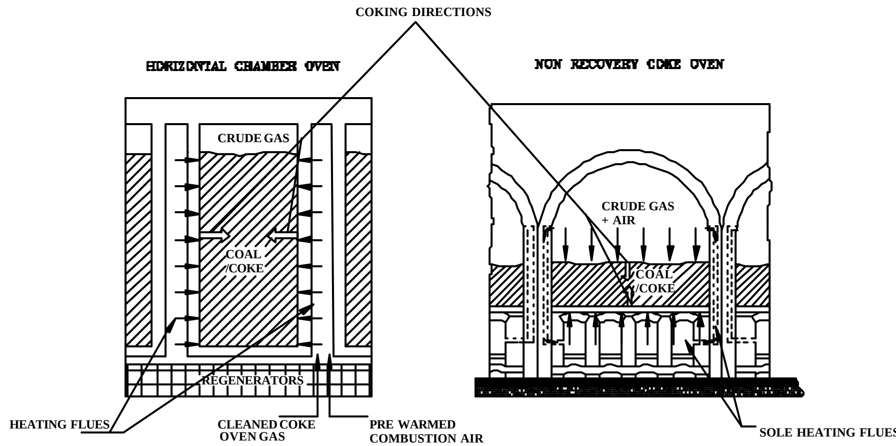


FIG 1: SCHEMATIC COMPARISON OF BYPRODUCT RECOVERY & NONRECOVERY OVENS

COKE YIELD

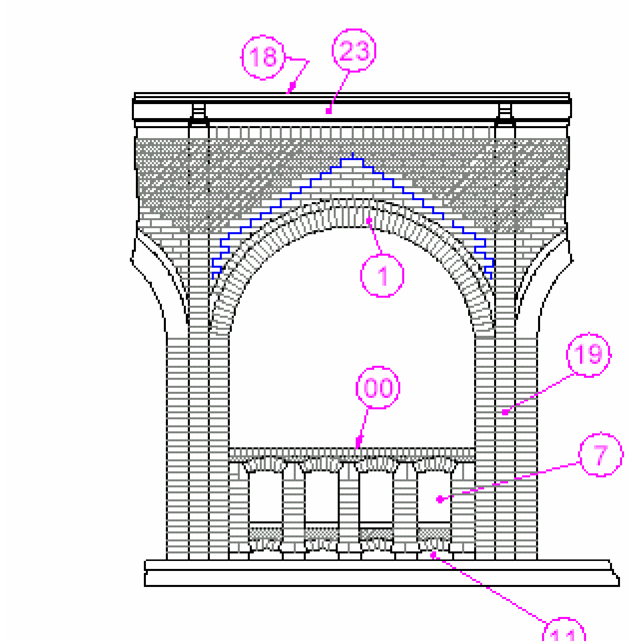
Byproduct ovens have higher coke yield than the energy recovery ovens since there is no burning loss. On the other hand 3-5 % burn-off in the energy recovery ovens is not a real loss as the energy from coal burning increases the power generation**.** With Sesa's most recent development on in-situ desulphurisation burning loss can be maintained below 1%.

COKE QUALITY

Both processes produce high quality met coke as long as appropriate coal blends are the battery operation. The potential of the heat recovery in the nonrecovery process, as clean electricity generation, makes the process viability less susceptible to the vagaries of coal price fluctuations owing to the credits from power generation.

SESA COKE OVENS

The coke plant at Amona, Goa consists of 84 ovens of the Sesa Energy recovery Coke Oven design with an annual capacity of 280,000 TPA. The width and length of the Sesa oven chambers are 2.75 meters and 10.76 metres respectively. The cross section of Sesa Oven is depicted in **Fig 2**. Each oven with a coal charge height 1.18 meters weighing 26 tonnes operates on a coking cycle of 48 hrs. There are four stacks with 21 ovens connected to each. A view of the Sesa Coke Ovens is shown in **Fig 3**.



Coking starts by means of heat retained in the brickwork from the previous coal charge. The evolving volatiles are mixed with air drawn (Primary air) into the free space of oven and are combusted. The products of combustion heat the coal mass and the oven dome, which radiates heat to coal mass. The heat of the combusted volatiles is used by allowing it to pass through the downcomers in the side walls into underflues where additional air (Secondary air) input from the lower sides of the oven assists in the continuation of the combustion to provide heat from the bottom of coal charge leading to a higher coking rate, and a more complete combustion of volatiles. Coking proceeds from the top of the charge in the direction of oven floor and also from the bottom of oven to the center of the coal mass.

Complete combustion of the escaping hydrocarbons, if any, is achieved by providing air (Tertiary air) in the common flue where the flue gases from individual ovens of each battery of ovens is drawn through feeder flues. The openings of the feeder flue are varied by adjusting the individual oven dampers, depending on their distance from the stack, so as to maintain a uniform negative pressure in all the ovens of the battery. The hot common stack generates the negative pressure in the common flue.

preparation plant, wet quenching tower and a single line of coke cutting and screening plant.

The Seas Ovens are equipped with conventional top charging and are can be operated on sequence charging mode. This ensures gradual feeding of coal charge into the oven and consequent gradual displacement of air from the oven thus helping in maintaining the steady negative pressure in the ovens, which eliminates charging emissions.

FOUNDATION AIR COOLING & RECOVERY OF HEAT

One of the unique features of Sesa cokemaking is the cooling of the oven foundation. While protecting the foundation of the ovens from excessive temperature, it also helps in improving energy by capturing the process heat and its recovery through primary, secondary and tertiary air usage for combustion of the evolving volatiles during the coking process.

The Sesa energy recovery cokemaking technology was displaced by the Ministry of Steel at the exhibition organized in 2003 by the Ministry of Environment & Forests in New Delhi to demonstrate India's contribution to the Kyoto Protocol and the development of CDM technologies in India. With the power plant the Sesa technology is entitled to carbon credits under the Kyoto protocol.

JSW COKE PLANT

CRS and particularly M10. However, this equipment needs a higher degree of automation and this has yet to be fully commissioned at JSW.

COMPACTED CHARGING

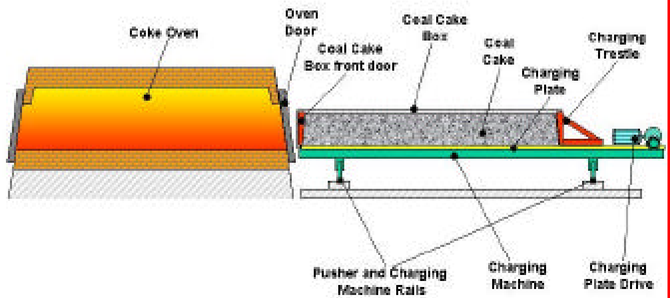
VeCon of Germany has developed compacted charging technology for the Sesa coke ovens and has an exclusive arrangement with Sesa in this respect.

In terms of the resultant coal density and processing steps, the compacted charging is similar to the conventional stamp charging. However, stamp charging for the squat horizontal compacted coal slab results in particle displacement rather than compaction. Also in the hydraulic stamping of the coal cake air displacement is restricted and the compaction is not adequately achieved. The bottom vibration based technique has been found to produce the best results in the compaction of the squat horizontal cake provided the duration of vibration is controlled to avoid particle segregation, and hence it is important that the process needs to be adequately automated.

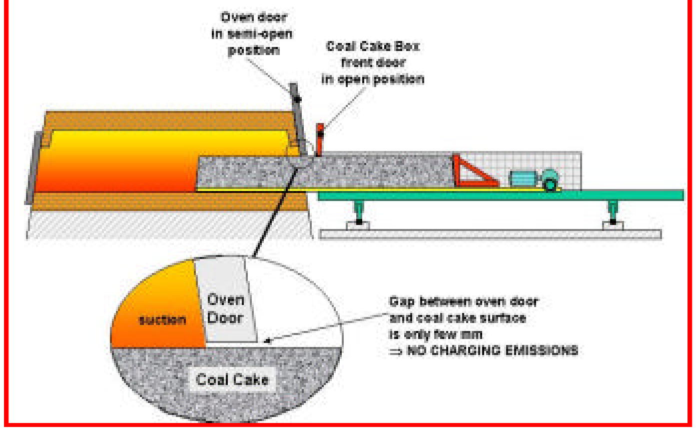
The stamp charging technique is widely used in Europe and at Tata Steel in India to upgrade inferior domestic coking coal and to facilitate its blending with imported hard and semisoft coking coals to produce an acceptable blast furnace grade coke at a lower cost. In addition Stamp charging also results in a higher productivity of the coke ovens.

The density of this coal cake is typically 1140 kg/m^3 against 780 kg/m^3 for top charging with water content 6 to 8%. This corresponds to 45% increase in bulk density. The coal cake can be charged within one minute, thereby avoiding significant oven heat loss

THE ESSENTIAL PARTS OF A COMPACTED CHARGING MACHINE



SITUATION DURING CHARGING OF THE COAL CAKE



SITUATION DURING REMOVAL OF THE CHARGING PLATE

The conclusions of the industrial trials conducted in 2001 can be stated as follows:

1. Compact charging produced higher quality coke.
2. Many characteristic advantages of stamp charging are reproduced in the energy recovery coke process such as CSR and CRI, and most importantly M10.
3. The increase of the charge bulk density up to 45% by the compact charging did not adversely affect the coking time, with a reduction in coal cake height from 1.18 metres to 0.95 metres, thereby increasing the throughput by 28%.
4. The range of suitable coals would be enlarged with the compact charging as its use in the energy recovery process has no restrictions concerning coal expansion and wall pressure, unlike the slot oven in the conventional recovery coke process.
5. The advantages of the compacted charging in shortening the charging time were evident: minimizing the heat loss and leakage of fumes.
6. The compact charging opens a new opportunity of automation in charging, thereby lowering the overall operating cost.

TRIALS WITH SEMI-SOFT USAGE IN COAL BLEND

In 2004, full-scale industrial trials were conducted by making a makeshift arrangement for stamp charging at Amona; Goa, to quantify the effect of compacted charging on coke quality. These trials involved carbonization of different coal blends, incorporating weakly coking coals: soft/semisoft/semi-hard, their usage varying from 50 to 60%. The coals used in the trials are summarized in **Table 2**

TABLE 2 TYPICAL CHARACTERISTICS OF COAL USED AND COKE BREEZE

Parameters	Riverside	Grootegeluk	Tahmoor	Burton	Metropolitan	K 9	Norwich	Coke

The blend composition and resultant coke are given in **Table 3**:

TABLE 3 COMPOSITION OF COAL BLEND & RESULTANT COKE QUALITY

‘%

Coal Source	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5	Blend 6
Riverside	47	40	42	40	40	42
Metropolitan	21		17			20
Tahmoor	20	30	17	30	30	21
Norwich Park					30	
Burton Ss		30		23		
Coke Breeze			7	7		
Grootegeluk			5			5
K-9	12		12			12
Coke Properties						
M10	5.8	6.3	6.5	7.2	7.2	5.4
M20	92.5	92.4	92.7	92.0	92.3	93.1
CSR	66.7	69.6	68.2	65.2	65.7	72.7
CRI	23.2	21.2	23.3	22.1	24.6	22.8

It may be seen that blends with 53-60% weakly coking coal produce coke characterizing CSR of 69.0 $\pm$ 3.7 using compacted charging.

OPTIMIZATION OF CAPITAL COST

Capital costs of the SESA technology are minimized by:

- Use of alumina bricks and special shapes.
- Less number of ovens due to higher bulk density of coal charge.
- Manufacture of cars and compacting station components in India although

USE OF ALUMINA REFRACTORIES IN SESA OVENS

The use of silica bricks in coke oven forms a mindset of coke makers who are used to the conventional by product ovens for more than a century. It is more a matter of faith in the practice of its use rather than a logical deduction on technological reasoning of the specific duty involved. The aspect of alumina bricks has come up for much debate and it might be worthwhile discussing the same here:

- The fundamental differences in the Non-recovery coke making in beehive type ovens and By-product coke making in conventional slot ovens are the conditions prevailing. Though coking is done in absence of air, a portion of oven above the coal charge in non-recovery ovens is subjected to an oxidizing atmosphere as against slot ovens where the atmosphere is very non-oxidizing. Thus conditions in the oven assume special significance as a guiding factor for the selection of refractories. Refractory brickwork in non-recovery oven are likely to be subjected to more thermal shocks as compared to slot ovens and hence alumina refractory bricks are ideally suitable as is well known that alumina bricks have better resistance to thermal shock and Spalling and are therefore more versatile for this application. Higher alumina bricks (with alumina 61%) are superior to silica bricks with respect to compressive strength, bending strength, co-efficient of thermal expansion and modulus of elasticity as can be seen:

	High Alumina	Silica
	61%	93%

mass of cold coal can lower the temperature condition of the oven over this range, particularly when pushing is delayed, as can happen in actual practice.

Shown in **Fig 5** is a detailed graph of Allotropic changes in silica minerals in Silica bricks

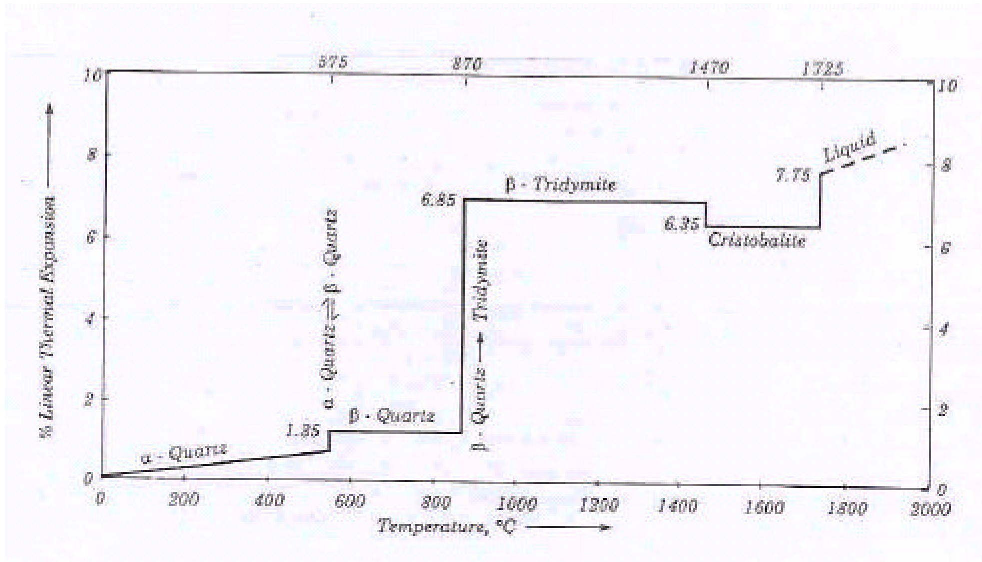


FIG 5 ALLOTROPIC CHANGES IN SILICA WITH ASSOCIATED THERMAL EXPANSION

- Silica has less thermal resistance. When quickly heated or cooled, silica loses its mechanical strength fully and cracks or breaks, which is explained by sharp changes in volume resulting from the phase change (conversion of one crystal form into another.

- The use of silica bricks in vertical slot ovens is preferred due to its higher thermal brick at O.5 % max as against 1.5% max specified by other designs and as a result, due to damage to refractory, life of such installations is very poor.

- In non-recovery oven the heating of the coal is by radiation from the top and bottom heating is by conduction through the sole from the under flues. On the other hand, in the case of slot ovens, oven walls are heated by the external gas and heat transferred through the refractory walls.

- Some non-recovery ovens have successfully used silica bricks but in those ovens it is critically important to ensure that the oven brick temperatures at the time of coke pushing followed by coal charging at no time are permitted to cross the critical 850^0C region for any reason.

SIZE OF OVENS

The small sized oven has the advantage that it can use the very sturdy semicircular classical Roman arch which is a well proven sound structural feature of the Sesa ovens instead of the half arch which results in an element of side thrust and therefore needs thicker oven walls. More importantly, the smaller length of the underflues labyrinth facilitates the more uniform heating of the coal mass above.

LOWER OPERATING COSTS

The operational (including maintenance, water and electricity) costs in India are low in

BURNING LOSS

In the Sesa ovens, it is of the order of 3% and can be reduced to below 1% by in-situ desulphurisation technology developed by the Sesa. In this, coal cake with a special coating forms a part of the cake preparation process. Some competitive technologies offer in the range of 3~4% and some others go up to even 6~8%.

EMISSION CONTROL

- There are no hydrocarbons in the exhaust gases; all hydrocarbons are incinerated due to high operating temperature in the oven and also the flue gas passage.
- NO_x levels are controlled by control of oven temperature. (<75 mg/Nm^3)
- SO_x levels are controlled by in situ desulphurisation and this lowers the load on further desulphurisation. (<120 mg/Nm^3)
- Charging and pushing emission are minimized by coal cake compaction and precision in oven door openings.
- Controlled automated introduction of tertiary air in the common flues ensures conversion of CO to CO_2 and combustion of all combustible SPM in the common flue.

CONCLUSION

Nonrecovery cokemaking technology has staged a come back with the intrinsic capacity to meet emission control norms and recover waste heat to generate power. The Sesa