LONG-TERM PERSPECTIVES

FOR THE COKE MARKET AND

COKEMAKING TECHNOLOGIES

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Introduction

Some introductory findings:

- Steel products will remain the basis of economic progress worldwide for many years to come
- The metallurgical process on the basis of the blast furnace technology will remain the basis for it as it has been the decades before, with a HM/CS ratio of 0.7
- Blast furnace coke will thus continue to be far into the future the most important raw material for steel production and steel-derived products which are so important to assure economic progress worldwide.

Is it a challenge to international cokemaking industry or can we fulfill this task without any efforts as comparably done in the past 20 years? As usual? That would be too simple and would overlook or ignore those problems which have been predicted for a long time.

A sober analysis of the present situation indicates that the international cokemaking industry faces a dilemma. The causes for it are summarized below.

- **1.** As a consequence of the more stringent requirements imposed on environmental protection/industrial hygiene on coke plants the capital investment costs increased overproportionally and due to the losses made with coal by-products - raw tar, raw benzole, and ammonia - the net coking costs for coke have multiplied (Fig. 1, Lit. 1). The consequences are:

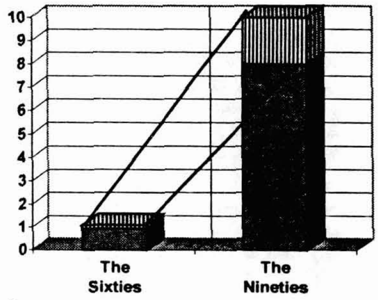

Figure 1. Development of relative net coking cost

The consequences are:

- Efforts geared to drastically reduce specific coke consumption in blast furnaces by way of technical measures and by injection of other low-cost reduction agents were intensified. In 1975, the average specific coke consumption rate worldwide amounted to approx. 590 kg/tHM, including 60 kg for sinter plants. In 2000, this rate still amounted to approx. 500 kg/tHM incl. 40 kg for sinter plants. It means that the coke demand for a HM production of 490 million tons amounted to approx. 290 million tons in the year 1975 and in the year 2000, with a HM production of 576 million tons it also amounted to approx. 290 million tons. Thus it becomes evident that despite a doubling in HM production, the coke consumption for steel production has not changed. (Fig. 2).

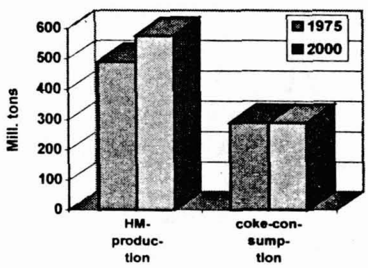

Figure 2. Hot metal production and BF-coke consumption

- Since the 40s, there have always been certain visions and all the technical efforts to substitute the metallurgical process on the basis of coke-dependent blast furnaces by coke-independent processes, for example direct reduction and melting reduction processes. The fact is that despite all these efforts the HM/CS ratio of approx. 0.7 has not varied in the past 60 years. (Fig. 3).

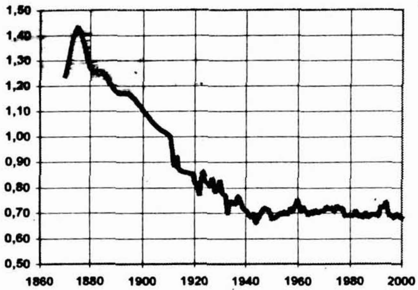

Figure 3. Ratio hot metal to crude steel production, wordwide

- Add to this the consequences of the oil crises in 73/74 (Yom Kippur War) and 79/80 (Chomeini effect), the COMECON abolishment in 89/90, and the crisis in Asia in 97/98 which involved setbacks in the development of steel demand and thus for the realization of projects geared to expand steel production worldwide. (Fig. 4).

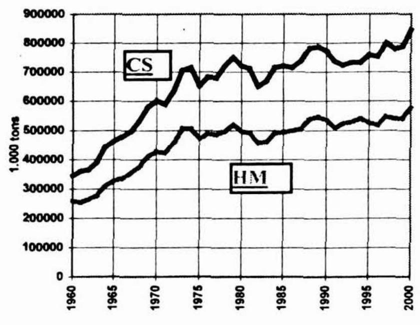

Figure 4. Crude steel- and hot metal production worlwide

- As a consequence of the general development on the market and of competing materials, the international steelmaking industry was forced to invest more downstream so that there was no money left for those areas upstream, which primarily affected the meanwhile unpopular coke plant. Instead of restructuring and reorganizing obsolete plants, the technology of maintenance and up-keep has been made more and more perfect since the 80s in order to gain time for new chances and to save investment capital. The expectation was that the world trade for coke would be able to supply sufficient quantities in more critical times.

- **2.** As a consequence of these developments as outlined above and due to the stagnation associated therewith on the market for cokemaking technology, the originally existing engineering capacities shrunk back to approx. 15 %, and the even more important know-how potential was cut back to approx. 7 %. Even the highly qualified, efficient management especially responsible for the cokemaking industry which had still been available in various states worldwide as well as the organizational structures needed therefor could not be maintained any longer. Hence, despite the availability of some innovative, improved and new cokemaking technologies, it was only possible in part to utilize this potential which could ensure better prerequisites for a low-cost coke production in terms of economics and ecology. Even the formerly close cooperation between large-scale coke plant owners and coke plant building industry needed to realize such projects does not exist any longer. Today, the shaken plant engineering industry for cokemaking technology alone cannot bear the responsibility for it and this industry cannot be the initiator and responsible for the further development in cokemaking technology any longer.

A dilemma has always two sides. The causes for one side, the negative one, were briefly outlined under subsections 1 and 2. Now let us turn to the positive side.

- **1.** Despite the difficult times which the cokemaking industry has had to cope with in the past decades, there was a great number of developments which set new perspectives for a long-term assurance of the required coke supplies under more economic and ecologically more acceptable conditions. This potential could be activated very quickly through a fair split of responsibility between plant operator and client as well as the plant engineering industry.

- **2.** The fact is: in the next decades to come, the blast furnace process will remain the basis for steel production, and the basis for the blast furnace process is blast furnace coke with rising requirements for quality and more favorable cost of production. Coke plants and blast furnaces depend on each other. It is a community of fate which should be strong and powerful enough to secure its own future. (Lit. 3)

Which conclusions can be drawn hereof to solve this dilemma?

- A first step: the "Seminar on Coke" organized by IISI -Brussels, Belgium, and VDEH - Düsseldorf, Germany, held on September 04/5, 2001 in Brussels on the topic:

  - Perspectives for coke demand and supply as well as
  - Which realistic perspectives do exist for cokemaking Technologie to solve pending problems in a more economic and ecological way?

Target:

- Perspectives for a long-term assurance of coke supply

International experts are called on to participate. It should crucially matter to address the decisive figures and facts in a detailed manner both in the speeches and extensive discussions in order to come to a lasting realistic perspective for coke market and cokemaking technology in future.

- A second step: it will be of fundamental importance for the management having responsibility in blast furnace operation and blast furnace technology, plant operators and plant engineering companies to look after the cokemaking sector in a common intensified effort. The capability of survival of the "community of fate" is at stake, unless this process linkage is considered to have no future in the long-term view. But this would entail an absolute standstill.

- Last but not least: after the decision-making structures for the cokemaking industry which were in fact independent had been dissolved or got lost, respectively, in the past 3 decades, it must now be the primary target to establish two international groups of experts, if possible, beyond the frontiers of individual countries, one for the international market/merchant coke plants and the other one for cokemaking technology/coke plant operation. These expert groups should concentrate their activities on clear-cut tasks within the scope of studies and expertise dealing with these topics so as to be able to initiate a development to secure coke supply optimally in a long-term approach.

Perspectives for the Future Coke Demand and Supply - Risks and Chances

The potential development in coke demand till the year 2010.

Coke demand worldwide is by approx. 80 % influenced and determined by the development in the steelmaking industry.

- The development in steel consumption is expected to rise by 2 %/year. Accordingly, crude steel production is predicted to grow from 844 million tons in the year 2000 to approx. 930 million tons in the year 2005 and to 1030 million tons in the year 2010. (Fig. 5, Lit. 4).

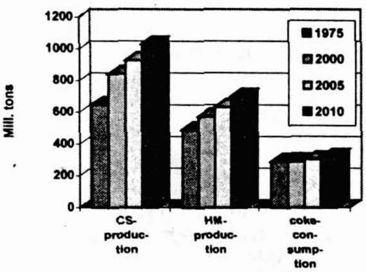

Figure 5. Worldwide crude steel-and hot metal production, coke consumption

- The corresponding figures for hot metal production, while maintaining the current HM/CS ratio, amount to approx. 635 million tons for the year 2005 and to approx. 700 million tons for the year 2010.

The specific coke consumption rate will be further decreased as long as it is not accomplished to reduce the coke/coal price relation down to a magnitude of approx. 1.4. Considering a decrease of the average specific consumption from 460 kg/tHM in the year 2000 to 420 kg/tHM in the year 2010, the expectable coke demand by steel industry for the year 2005 will amount to approx. 280 million tons and/or approx. 305 million tons, including coke breeze for sinter plants. For the year 2010 it is predicted to account for approx. 295 million tons and/or approx. 320 million tons. (Fig. 6).

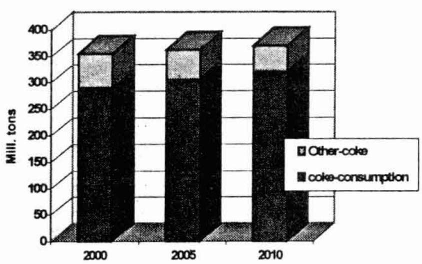

Figure 6. Total coke consumption

- Predictions for the remainder of the market are that demand will decline from presently approx. 65 million t/y to approx. 50 million tons in the year 2010.

- On condition of a stable development on the steel market, it will result in a total coke demand of approx. 360 million tons in the year 2005 and approx. 370 million tons in the year 2010.

The present structure of the cokemaking industry worldwide cannot satisfy this possible development in coke demand. Instead one will have to reckon with a cutback on technically available cokemaking capacities to well under 300 million tons/year, unless obsolete capacities are drastically restructured and new cokemaking capacities built. It means a gap of approx. 60 million tons of coke and even more cannot be ruled out. (Fig. 7,Lit. 5,6,7).

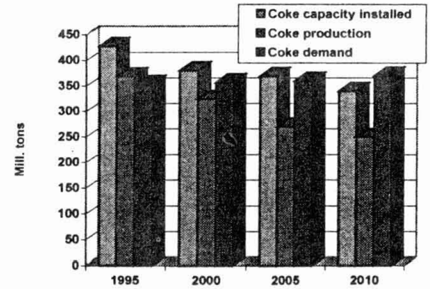

Figure 7. Medium term development of coke capacity, coke production and coke demand

Assessment of available cokemaking capacities worldwide and their possible development - risks and chances

The development of cokemaking capacities worldwide and the effective, technical availability of these capacities are difficult to assess. On the one hand, the available data are incomplete relative to the technical availability of reported capacities and on the other hand, those projects currently under discussion for expansion of capacities are not realistic. A huge factor of uncertainty in this statistics is the PR China in particular. Still in the year 1997 the perspective was that the available capacities in the PR China would rise to 190 million tons/year till the year 2005. (Lit. 8). The basis for this prediction was the quick availability of "simple and primitive cokemaking capacities". In the year 1997, a production of 139 million tons was achieved on that basis. Meanwhile, these figures have been revised. For reasons of environmental protection, the Chinese government decided to shut-down these capacities and to reduce production till the year 2005 down to 90 or 100 million tons which should by then exclusively work on the basis of the conventional cokemaking technology. It means the cokemaking capacities still reported for the year 1997, not considering further shutdowns in other countries, would shrink to 360 or 370 million tons. Judged by initial experience made in the year 2000, their technical availability would just account for approx. 325 million tons with a further recessive development. (Lit. 6,7).

In those years marked by a very good cycle of economic business in the international steelmaking industry, i.e. in 1999 and especially in 2000, coke production reached approx. 325 million tons, with the contribution from the PR China still accounting for approx. 120 million tons. Based on information received from all over the world, the available cokemaking capacities were fully exploited within that period of time. Another reduction in coke production as planned from 120 million tons to 100 or 95 million tons would just enable a max. coke production of approx. 300 million tons. Coke demand of the steelmaking industry in the year 2000, including coke breeze, amounted to approx. 285 million tons. Considering the other coke demand of approx. 65 million tons, the total demand accounted for approx. 350 million tons, i.e. approx. 25 million tons more than what would match the available production. Hence it can be concluded that either the figures submitted are incorrect or the difference could be fully offset by taking coke from the stock. Experts worldwide guess that further cokemaking capacities will be shutdown in the next years and, respectively, that their technical availability will decline even further. Realistic projects for new coke plants geared to ensure a lasting expansion of available capacities are hardly known. But at the same time, the obsolescence of available capacities grows rapidly. Consequently one has to rule out that there will be any security in coke supplies covering the demand in the medium or long-term view. Based upon the latest surveys, approx. 55 % of these capacities in the year 1999 were older than 21 years and even approx. 25 % thereof were older than 30 years (Fig. 8). The assumption voiced in the paper titled "Outlook of the World Coke Market and Chinese Coke Export" (Lit. 6,7) is that the gap in the coverage of demand is expected to be 66 million

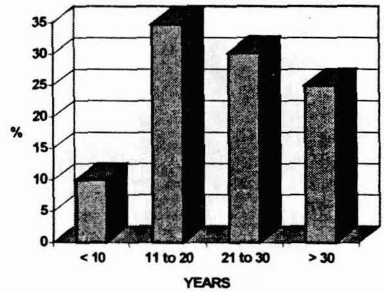

Figure 8. Age distribution cokemaking capacity world

tons coke for the year 2005, considering a total demand of 336 million tons, and assuming that the available capacities will only account for approx. 270 million tons. This will be valid on condition that the PR China will just produce 95 to 100 million tons of coke per year.

Chances and Risks of the World Coke Market

In the past, the world market for coke fluctuated by 15 to 25 million tons, depending on business cycle. These figures are valid even today, but there are strong changes on the market. The main exporters in the year 2000 were China with approx. 15 million tons, Poland with approx. 3 million tons, though with a declining trend, Japan with approx. 3 million tons, also with a recessive trend. Fig. 9. The main importers are the European Community with approx. 10 million tons, the USA with approx. 3.5 million t, India with approx. 2 million t, and Japan with 1.5 million t (Fig. 10). Judging this situation soberly, one has to assume that coke imports in the near future will only depend on China's willingness to create the necessary prerequisites.

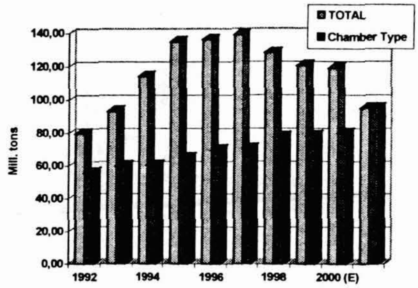

Figure 9. Coke production China

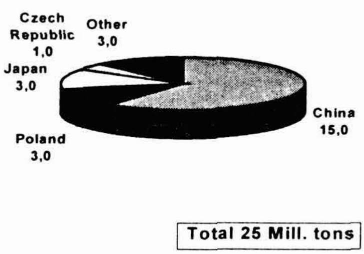

Figure 10. Coke trade volume world 2000

Quote:

"Indeed, to maintain long-term reliability and stability of supply, it is important to make Chinese coke production and operation calculable. Keeping Chinese coke price at a reasonable level and maintaining the market stable will benefit not only the suppliers, but also importers and traders. And it is also good for the smooth running of the global iron and steel industry."

Unquote:

Is it a realistic offer satisfying coke demand in future, accompanied by ever greater national gaps in the coverage of demand, in the EC, USA, India, and possibly Japan, too? Can China offset the gap in demand coverage as predicted for the year 2005 in the paper published in CMI 1/2001? Will the PR China thus hold the "trump card" in its hands as the dominant supplier in world trade by then?

For over 30 years there have always been discussions about a co-operative construction of merchant coke plants in Australia, India, Canada, and in other countries. It has never been possible to come to a final decision. But the international steelmaking industry would like to dispense with capital investment in the upstream area, if possible, which means particularly the field of coke plants, because they deem it more important to invest downstream with the aim to secure the market for themselves. Hence it seems as if only a future-oriented co-operation between coal industry, international trade, and steelmaking industry could be a significant step on the way to set new ways for the assurance of coke supply. It is a great challenge, but also an indispensable prerequisite. **Which perspectives can be offered to this effect by a modern, future-oriented cokemaking technology?**

Requirements for a future-oriented cokemaking technology

Prerequisites for compliance with requirements in terms of blast furnace coke quality

The most important requirements posed to blast furnace coke are listed below:

◊ formation of support structures with large clear cross-sections to secure a proper sequence of the metallurgical process in blast furnace:

This results in these most significant requirements for coke quality (Lit. 3):

◊ high cold strength ISO 20 > 80% and/or ISO 10 < 20%
◊ low reactivity CRI <25, tendency < 20, and
◊ high hot strength CSR > 65%, tendency > 70%
◊ ash content, ash composition

The quality features of blast furnace coke can mainly be influenced by:

◊ coking properties of charging coal and/or coal blend,

◊ ash composition of coal, particularly low alkali and iron oxide contents,
◊ coking conditions
  -bulk density
  -coking temperature/coking rate
  -final coke temperature
  -deposits of cracked carbon on coke pore surfaces

And last but not least: low production costs and environment-friendly.

Cokemaking processes for the future will have to take account of these requirements.

After formed coke turned out to be inadequate for being used in the blast furnace process, it became necessary to lay the focus again on realizing advanced cokemaking processes, making it possible to produce a blast furnace coke characterized by a conventional grain size structure and a porosity of approx. 50% while considering rising requirements for coke quality. This goal must be reached by enhancing the flexibility in the coal basis and by securing low production costs.

Perspectives of different cokemaking technologies

The realistic cokemaking processes available within a foreseeable time are focused on

◊ Conventional Multi-Chamber System (MCS) and the techniques based on the modular technology, such as on the
◊ Single-Chamber System (SCS), using the more than 130 years of experience of the MCS and making it perfect to obtain an independent process-controlled modular technology, and the
◊ Heat-Recovery System (HRS) which represents the advanced development of the Non-Recovery System (NRS), an independent modular technology, too.

As far as known, there are no other realistic cokemaking processes which could become available within in the next decade.

The Multi-Chamber System (MCS)

With the construction of the coke plant Kaiserstuhl, Germany, having a capacity of 2 million tons/year, comprised of 2 batteries with 120 chambers each, sized 7.80 m by 18 m by 610 mm, yielding a productivity of 16,700 t of coke per chamber and year and operating at a machine cycle of 115 pushes per day, the development potential of the MCS was in fact fully exploited. The coke plant Schwelgern, Germany, currently under construction, which is designed to have a capacity of approx. 2.6 million tons per year, comprised of 2 batteries with 70 chambers each, sized 8.43 m by 20.80 m by 590 mm, run at 135 pushes per day, yielding a productivity of approx. 19,000 tons of coke per chamber and year which will go into operation in the year 2003, will still have to prove its efficiency, particularly its comparable independence from the mixture of charging coal **after its commissioning in the year 2003**.

Coking chamber widening and technical optimization represented a significant and right step on the way towards reducing operation cost and improving environmental protection and industrial hygiene. But a great number of problems we are facing with today's cokemaking technology, both economically and ecologically speaking, could not be solved satisfactorily by the MCS technology, even if supposing the "latest state of the art", e.g.

- extended flexibility in the coal basis, particularly by utilizing low volatile coal,
- general use of preheated coal and thus utilization of the achievable over-proportional productivity advantage by about 70% and more (Fig. 11)

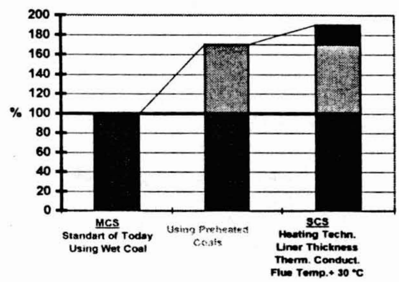

Figure 11. Influence of coal preheating and Single Chamber System on specific throughout (kg/m³ x h)

- improvement of the thermal efficiency by rational utilization of energy by

-use of preheated coal and application of program-controlled heating - CODECO - and
-linkage between coke dry quenching and coal preheating

- cost-neutral solutions to ecological problems by utilization of synergy effects as well as
- comprehensive production and process control by application of the modular technology

Primarily, the cause is the battery-wise arrangement of coking chambers alternating with heating walls and its comparably very small limit load (80 to 100 mbar) which is mainly reached only by way of roof load and lateral anchor restraint (PS to CS). This is an absolutely insufficient stability which is reduced substantially along with further rising chamber heights, causing a substantial risk considering that coking pressures of up to 300 mbar, and sometimes even a manifold of this value, were measured in coke oven charges today!

The Single-Chamber System (SCS)

Considering all the experience made with the further increase in productivity and efficiency of the MCS, possibilities for an advanced development of the conventional MCS into an independent Single Chamber System (SCS) were contemplated at the end of the 70s. (Lit. 9,2). At the initiative of Ruhrkohle AG, the order for two extensive engineering studies was placed by Bergbauforschung GmbH with the four German coke plant builders in the 80s, i.e. Didier Engineering GmbH, Dr.C. Otto & Co. GmbH, Krupp Koppers GmbH, and Carl Still GmbH & Co. KG. These studies were elaborated under the managerial leadership of Ruhrkohle AG, Germany.

The study had the task

- to evaluate the still possible development potential of the MCS
- to determine the potential of improvements in process technology, economy and ecology achievable by splitting the MCS into an independent SCS (modular technique), and
- to clarify whether it would be possible to achieve a production of 2 million tpy in **2-shift operation**, 24 hrs. coking time, 55 machines cycles/day, by way of an appropriate design of the coking chamber. Independently from the political requirement imposed at that time - i.e. to dispense with night shift working - the chamber width to be applied for the SCS, i.e. the smaller the width, the higher the specific performance rate will be, thus demanding less capital investment cost, it is naturally possible to apply traditional chamber width as done in the past or even smaller chamber widths because of the extremely high load-bearing capability of these chamber walls.

Advantages of the new process technology

Engineering

◊ The modular construction concept requires engineering work for one single chamber only.
◊ Engineering is to a high extent independent from the geometrical layout and consequently of the desired specific throughput or productivity (45 to 90 kg/m³ per hour or 40,000 to 100,000 t/chamber per year - Fig. 12).

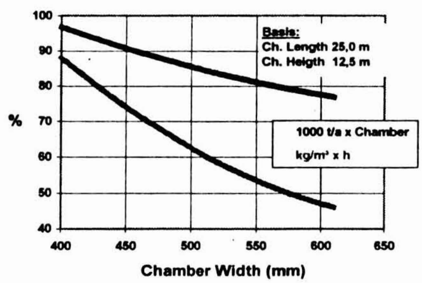

Figure 12. **Productivity and specific output Single Chamber System (coke dry)**

Construction

◊ The number of different bricks is reduced by little less than 50% independently from the geometrical layout of the chamber.
◊ Refractory brick production is facilitated due to lesser mould provision.
◊ For instance, refractory bricks could be produced in advance and delivered just in time.
◊ Lesser transportation activity during refractory brick production and coke battery construction on site.
◊ Significantly lesser space requirement for the coke plant – up to 40% and more.

Operation

◊ Modular process control.
◊ Short-term production adjustment of the modules: 100% - 0%.
◊ Individual repair works and – if required – partial commissioning.
◊ Reduced thermal stress of the chamber walls.
◊ No permanent deformation of coke oven walls.
◊ Reduced damage and reduced expenditure for repair work.
◊ Homogeneous carbonization progress as a consequence of preheated coal charging.
◊ Due to the application of programmed heating the carbonization process and the final coke temperature can be predetermined.
◊ Energy savings of approx. 8 – 10% by coal preheating and programmed heating (CODECO) and additionally approx. 20% by combining coal preheating and coke dry quenching (Fig. 13).
◊ Reduction of the pushing cycle by up to 50% and more.
◊ As a result: a significant reduction of costs for maintenance, energy and environmental protection and safety and health at the work place.

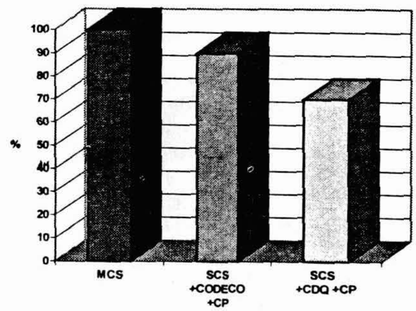

Figure 13. Specific heat consumption MCS –> SCS

Raw material coal

◊ Significantly widened coal basis and therefore increased flexibility in the coking coal blend or with regard to the aim of achieving higher coke qualities.
◊ Negative influence due to the use of a higher proportion of highly swelling coals in the blend is nearly excluded.

Product blast furnace coke

◊ Improved coke quality by coal preheating (CSR up to 10%) and/or higher-rank charging coal with a higher coke yield (Fig. 14).

Figure 14. CSR/CRI values of different cokes (The values R and L are not comparable)

Environmental protection and safety and health at the work place

◊ up to 80% fewer chambers
◊ closed charging system
◊ reduced pushing cycles
◊ reduced energy consumption by up to 30%
◊ in total a reduced emission potential of more than 50% (Fig. 15)

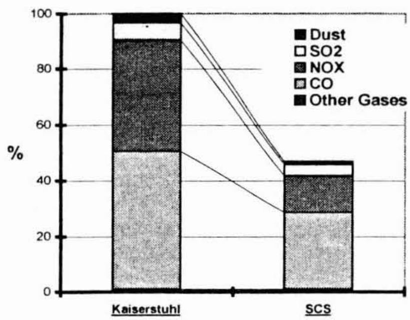

Figure 15. **Emission reduction MCS --> SCS**

The engineering studies submitted in 1988 and 1989 when evaluated brought the result that

◊ the development potential of the MCS was in fact exploited with the design of the coke plant Kaiserstuhl
◊ a high potential in technical, economic, and ecological development was to be expected for the SCS.

These results established the basis for the decision of founding the "European Development Center for Cokemaking Technology" which tested the efficiency of the SCS on an industrial scale during a 4 years' long experimental operation from 1992 till 1996.

The results demonstrated that the expected results were not only reached but partly even exceeded.

In summary, it can be concluded that the SCS cannot only be applied for the new construction of coke plants because of the geometrical design of cokemaking chambers, but also for a restructurization of obsolete batteries, considering local conditions. Moreover, the SCS offers ideal prerequisites for the construction of "lean coke plants" linked to mini steel mills.

What is the difference between Single-Chamber System and Multi-Chamber System? (Fig. 16)

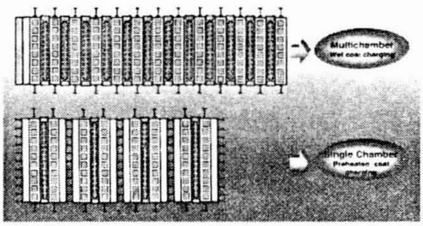

Figure 16. **From multi-chamber to Single Chamber System**

In contrast with the MCS, every coke chamber of the SCS disposes of its own heating system which can be heated and controlled individually and independently from neighboring coke chambers. Owing to the special design marked by a stable lateral anchoring based upon steel girders which can also be utilized in linkage with several coke chambers, the static load-bearing capability of chamber walls is many times higher than that of the MCS. The individual chambers can be operated independently from the neighboring chamber as an independent modular unit. The capital investment costs for a coking chamber as compared with the MCS, due to the greater demand for material, refractory insulation, and steel parts/castings per chamber, are by up to 4 times higher, depending on design figures. However, as compared with the MCS, the SCS achieves a productivity measured in tons of coke per chamber and year which is up to 5 times higher. This is mainly made possible through a general application of the coal preheating technique and by the chamber volume which is by a factor of up to 2 higher than that of the MCS. Example: capacity 2 million tpy - MCS coke plant Kaiserstuhl 120 chambers - SCS only 22 chambers.

Economic perspectives SCS vs. MCS: investment and production costs

The economy is governed by:

- ◊ investment costs
- ◊ raw material costs
- ◊ expenditure on environmental protection and safety and health at the work place and
- ◊ production costs (staff, energy, maintenance).

Investment costs

Specific investment costs of coke ovens depend on their geometrical layout. Higher and longer chambers reduce the investment costs, wider chambers lead to an increase (Fig. 17).

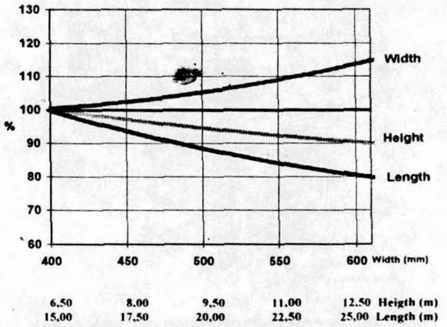

Figure 17. Capital cost depending on coke oven design (Basis: 2mty coke)

SCS really has an extremely high stability due to its construction features. Therefore, this system can be applied also in case of chamber widths of less than 600 mm and also for heights of up to 12.5 m and chamber lengths of up to 25 m – as has been envisaged time and again in the past. (For the MCS chamber height and length are restricted because of the high roof load and for static reasons).

The mandatory preheated coal charging and the SCS increases the spec. throughput by up to 70%. That means the coal preheating plant can be relied on to be an independent separate economic unit.

In comparison with the MCS, basis coke plant Kaiserstuhl – Germany – (chamber width 610 mm) the specific investment costs for the coke plant SCS without coal preheating amount to 90% (H 12.5 m, W 610 mm) and taking into account the residual rationalization potential (statement of an engineering company) the specific investment costs drop to 80%. With a chamber width of 450 mm – no problem with the SCS – the comparable figures drop to 75% and to less than 70% respectively. (We have to note, as a consequence of the negative operational experience with 6.5 m high and 450 mm wide MCS ovens in the past, that the chamber width had been increased to about 600 mm in order to improve the heating wall stability and to achieve a higher shrinkage during the coking process.) A further reduction of chamber widths of less than 400 mm should be possible from the technical point of view. Herewith, investment costs could be reduced effectively. In particular, coke supply to minimills on the basis of blast furnace and SCS even with less than 400 mm wide chambers could be very advantageous. Overall specific investment costs are increased by 20% abs. because the economically independent coal preheating plant is added (Fig. 18).

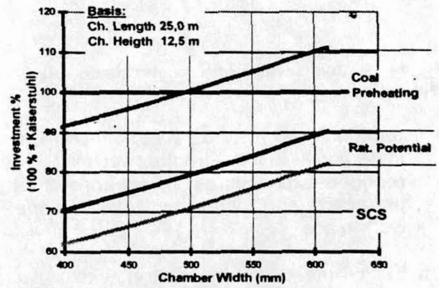

Figure 18. Investment cost Single Chamber System and coal preheating (function of chamber width)

Production costs

Production costs for blast furnace coke can be reduced significantly by the SCS. A final economic evaluation must be carried out in case of restructuring old coke oven batteries considering local conditions.

In the following, some examples are given for the potential for savings, and perspectives are shown supposing European conditions. The computer model can be made available at any time.

Application of the SCS in comparison with MCS (Fig. 19)

- The utilization of cheaper coking coal blends implies a potential for savings in the magnitude of 5.00 $/t blast furnace coke,
- reduced manpower expenditure,

energy savings of approx. 8 – 10% and in case of combining preheating with coke dry quenching system of up to 30%,

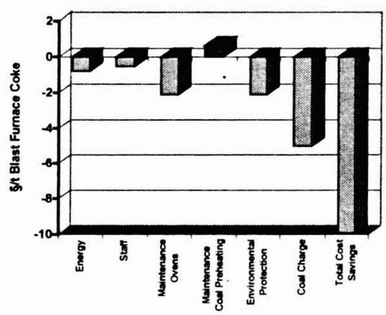

Figure 19. Cost savings with Single Chamber System

- reduced expenditures for maintenance, in particular in the refractory section,
- reduced expenditures for environmental protection and safety and health at the work place.

On the whole one may reckon with a reduction in cost of production by approx. 10 $/t coke when applying the SCS. The figures comprise savings by coal preheating of approx. 5$/h. Considering the coal preheating plant as an independent economic unit, return on the corresponding investment would take less than 4 years.

Within the scope of the European Cokemaking Technology Development Center, the SCS was tried out on an industrial scale during a 4 years' long trial operation. The results expected within the scope of the engineering studies were fully achieved and partly even exceeded. The SCS is available for industrial application and utilization. (Lit. 15,16)

Heat Recovery System (HRS)

The HRS is based on the modular technology, too, and has already been developed in the middle of the 19th century on the basis of the Non-Recovery System (NRS). These ovens were built-up of silica bricks. In the meantime, the 2nd generation of beehive ovens with a modified flue gas and air supply were designed and built in various locations. As compared with their predecessors, they were run at negative pressure. The NRS was further developed to HRS the most modern example of which is the plant variant of Sun Coal of Indiana Harbor Coke Comp. which is contemplated here. (Fig. 20, Lit. 10,11).

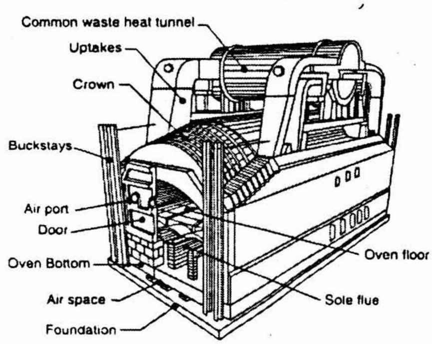

Figure 20. Jewell-Thompson non recovery coke oven

Coal is carbonized

- in chambers being around 14 m long and 4.6 m wide, the charge reaching a layer height of around 1 to 1.2 m, coking time being 48 h,
- "raw gas" is burnt in the ovens, and
- hot flue gas attaining a temperature range of 1100 to 1250°C (crown temperature) is to be utilized for steam and electric power generation, respectively
- the productivity of the HRS oven amounts to approx. 4500 t of coke/chamber and year.

Though its technology has been improved throughout the years, some well-known problems still exist, e.g.:

- very low productivity (t of coke/chamber and year)
- a certain "coke burn-off" during carbonization leads to a reduced coke yield,
- much higher space demand for the battery area compared with the MCS and in particular with the SCS,
- comparably higher investment costs and possibly higher production costs, if the proceeds of the steam/electricity production are insufficient,
- HRS will hardly be able to meet demands and requirements for cokemaking technology, especially for an integrated steel mill coke plant and
- substantially less operational availability than MCS or SCS, respectively.

These problems may possibly lead to higher costs for coke.

The benefits for this process are, e.g.

- simple coke oven design and construction
- simplification in oven service machines and
- shorter construction time in comparison with MCS and SCS.

The new HSR is characterized by a coke production in a quaternary number of coking units with low productivity and long coking times, a direct heat generation via by-product utilization for steam/electricity production. The produced coke meets the quality demands set by modern huge blast furnaces.

Considering the huge space demand required by the HRS as compared with the MCS and especially with the SCS, this technology will attain importance in those countries which dispose of the required space and in particular where a favorable marketing for electric power obtained bas a by-product is feasible. Another reason could be the need to cover a short-term demand for coke.
(Fig. 21).

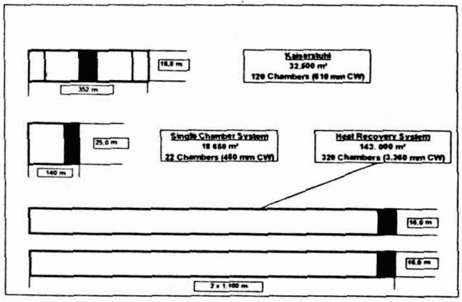

Figure 21. Space demand of various cokemaking systems incl. mechanical equipment (capacity 2 mty coke)

The capital investment costs for the HRS with steam and electric power generation are comparable to those of a conventional coke plant with a comparable capacity of 1.2 million tons of coke per year. For larger coke plants, the corresponding capital investment costs for the HRS will be higher.

A final evaluation of the production costs for blast furnace coke by using the HRS is not possible today because there is no detailed information available.

By-products of cokemaking: problems and new perspectives - The way to the 2-products cokemaking technology -

The by-products of the standard cokemaking process debit the investment costs, yield negative coverage proceeds for coke

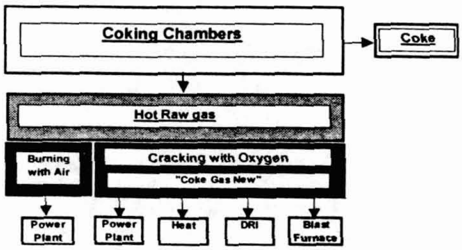

Figure 22. Process alternatives of a 2-product coke plant

production and in result increase the production costs for blast furnace coke. In future, it should be possible to choose among four possibilities for recovery and exploitation of by-products (Fig. 22, Lit. 12):

- conventional crude gas processing with recovery of traditional by-products – application possible with MCS and SCS only,
- crude gas cracking with oxygen to obtain "coke gas new" (CGN) (> 60% H_2 and > 30% CO) and using the CGN either with the traditional energy compound in an integrated steel mill or for iron ore reduction – application possible with MCS and SCS only,
- crude gas combustion and exploitation of heat for steam and electric power generation – applied with HRS, but also possible with MCS and SCS.

The final decision on crude gas exploitation if MCS or SCS are applied will have to be taken within the framework of a study, considering local infrastructures and their development trends.

Application of the 2-Product Cokemaking Technology (2-PCT) - Based on Oxygen Cracking - and its Economic Perspectives

Examples for using the CGN

Cracking of coke oven raw gas with oxygen results in CGN with more >60 % hydrogen, > 30 % carbon monoxide, a residue of methane and a calorific value of > 11,000 kJ/m³, comparable with the cracking of natural gas. This CGN is primarily used within the energy framework and - if desired, also used as chemical feedstock with a significant reduction potential for the iron ore reduction within a temperature range below 1,000 °C (Table 1).

Cracking of coke oven raw gas leads to gas temperatures of 900 - 1,000 °C, depending on the route : cracking with oxygen with or without catalyst. Downstream utilization of CGN requires gas cooling, e.g. for steam production or any other use of the exchanged heat, desulfurization, and finally compression to the required process pressure.

As an example: the utilization of the CGN is described in case of a directly reduced iron production, whereby primarily the combination with a submerged arc furnace (SAF) or electric arc furnace (EAF) should be envisaged in order to produce hot metal (HM) or crude steel, respectively. As a consequence, the sensible heat of the product DRI can be utilized, and the briquetting process can be omitted. The production of hot briquetted iron (HB) as a sales product should be envisaged only under restricted circumstances. The utilization in the blast furnace should not be envisaged either because of the high expenditure on compression and heating of this gas. An economic success cannot be expected.

The DRI plant works on the basis of a partial reaction of the gas with oxygen at high pressure (5 bar) due to the "self-reforming scheme". Secondary oxygen serves to regulate the gas temperature and the residual methane content to carborize the product. Gas utilization efficiency reaches 40 % in one reaction period. Residual gas will be used via the works gas grid for underfiring. Approximately 10 to 15 % of the gas will remain in the gas network. Based on this process layout, approx. 0.5 million t DRI/year can be produced, supposing a coke production of 1 million tons per year. In case of a complete gas utilization and an additional CO_2 scrubber, 1.0 to 1.3 million tons of DRI/year can be achieved. The advantage of this process layout compared with natural gas based plants is substantiated by the use of sensible heat from the coke oven gas and the CNG which amounts to approx. 25 % of the energy demand for the DRI process (Fig. 23, Lit. 12,13).

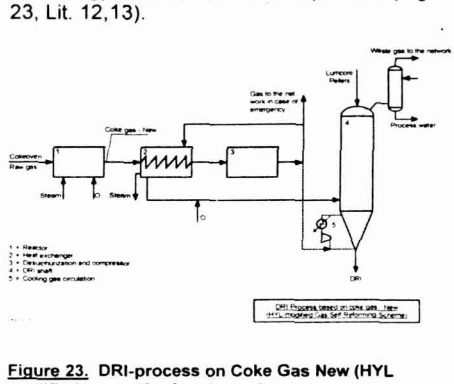

Figure 23. DRI-process on Coke Gas New (HYL modified gas self-reforming scheme

On this route the CGN can be used for the reduction of iron ore apart from the conventional utilization even if surplus energy will increase in future. Consequently, the capacity of a steel mill could be extended or, as an alternative, the demand for hot metal and coke could be reduced.

Economic perspectives

The application of the 2-PCT leads to increased flexibility in the use of the by-product CGN. A preliminary estimation of the required investment costs including desulfurization leads to an investment cost reduction by approx. 15% compared with the conventional coke oven raw gas processing. Normally, the CGN will be used and evaluated in case of the traditional energy compound. Utilization of the CGN for iron ore reduction will be envisaged only if a higher increase in value can be achieved.

Based on preliminary calculations carried out for a steel mill, the reduction of the production costs of blast furnace coke can be expected in the magnitude of approx. 5.00 \$/t blast furnace coke supposing a conventional utilization of the hot CGN and an oxygen price of 0.04 \$/m³. When using the gas for the production of DRI the increase of the value can be higher, supposing some favorable pre-conditions (Fig. 24, 25, Lit. 15).

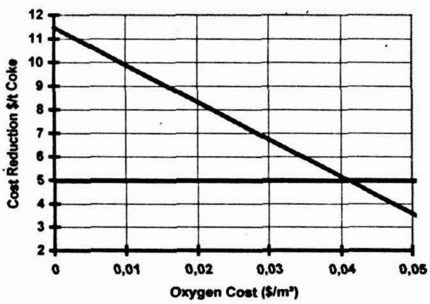

Figure 24. **Influence of oxygen cost on coke price, Modell: raw gas cracking, steam production and generation of energy**

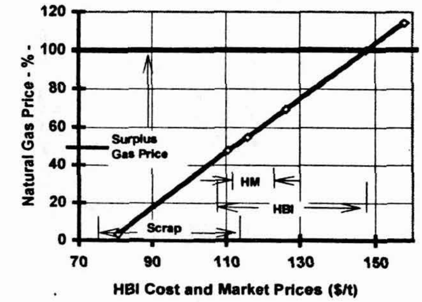

Figure 25. **Receipts for Coke Gas New as a function of applyable price for HBI**

The utilization of the coke oven raw gas cracking and process optimization between coking chambers and cracking systems must be developed to full scale maturity. Due to published R & D projects, the necessary period of time is estimated to be 3 years, provided that the funds needed can be furnished and made available. What matters is to optimize the linkage of coke chambers with the cracking reactor for hot raw gas - approx. 800 °C - at low-pressure mode.

Economic perspectives combining SCS with 2-PCT in comparison with MCS and conventional by-product technology

The modern technologies – SCS and 2-PCT – in total promise a decrease in production costs for blast furnace coke by approx. 15.00 \$/t of blast furnace coke and more. The benefit - related to local conditions an specific pre-conditions – must be determined on the basis of a locally-oriented economical analysis. (Fig. 26, Lit. 15, 16)

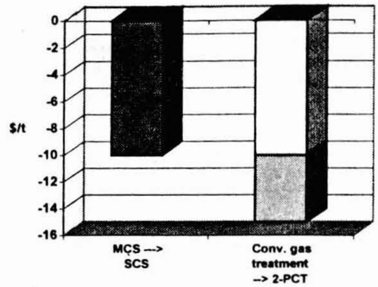

Figure 26. Cost savings MCS ---> SCS and SCS with 2-PCT

The technical layout of a coke plant has to be decided by taking into account local conditions, required production capacity, pushing cycle, requirements on environmental protection and safety and health at workplace. In the final instance, the layout is determined by the optimization of the economic unit, ultimately resulting in the specific investment and production costs.

The final decision on crude gas exploitation, if MCS or SCS are applied, will have to be taken within the framework of a study, considering local infrastructures and their development trends.

Conclusion

Steel will remain the basis for world-wide industrial and economic progress, and steel consumption will continue to rise along with growing gross national product in the world. For a long time reaching far into the future, hot metal produced in the blast-furnace line will remain the basis for growing steel production. Only, cokemaking industry in the world is in a deadlock. Decisions have to be made in a short time! But indeed, to play an active role in shaping the metallurgical process in future, cokemaking technology today also offers advanced process techniques and concepts that take account of future demands. The combined SCS process with 2-PCT will give major advantages for future applications. The community of fate between the coke plant and the blast furnace will live on far into the future. Cokemaking technology will regain a new confidence potential. As outlined above, the coking plant of the future will be available on a "call-off" basis and bought tailor-made "off the peg".

It cannot be the task of engineering companies alone to bear responsibility for it, at least not after in fact 25 years of a dormant market and after a shrinkage process which is dangerous for the cokemaking industry. Coke consumers, mainly the steelmaking industry, must be willing to throw the crucial switches for the future. The **"Community of Fate"** must tackle the pending problem of securing coke supply in future jointly. By as much as 80 to 90 %, it will in future matter to have a flexible coke plant available which will also be able to contribute to varying process structures within steel mills. The present status of discussion on the further configuration of the cokemaking technology offers all the prerequisites needed to this effect. The time left has become tight, as demonstrated on the coke market. It leaves no further scope. Action must be taken now!

Literature

1. Nashan, G.: Future Development in Cokemaking Technology – An European View, 2nd International Cokemaking Congress, 28 – 30 September, 1992, London.
2. Nashan, G., European Development Center: Tasks and Targets. February 1990.
3. Beppler, E. K. H. Großpietsch, K. Louis, L. Nelles: Impact of the Coke Quality on the Operating Performance of the Blast Furnace. Cokemaking International (CMI 2/1999).
4. Christmas, Jan: Presentation to the Annual Conference of the International Iron and Steel Institute, Melbourne, Australia, October 3, 2000 (IISI-34: Annual Meeting and Conference).
5. Wessiepe, K. E. Karsten: Recent Developments in the World Coke Industry – Coke Demand/Coke Production, Cokemaking International 1/2000.
6. Liu, H., CH. Cai and W. Zheng: China's Coking Industry Stepping in the New Century, Coke Making International 1/2000.
7. Hua Zugui and Wu Lan: Outlook of the World Coke Market and Chinese Coke Export, Coke Making International 1/2001.
8. IISI: Coke and its Alternatives, Committee on Raw Materials, Brussels 1997.
9. Nashan, G.: Eine Konzeption für die Kokerei der Zukunft, Conference: Cokemaking Technology, 14/15 May 1981, Essen, Germany.
10. Walker D. N.: Sun Coke Heat Recovery, Coke Technology at Indiana Harbor, IISI Technology Meeting, Washington DC, USA, April 1998.
11. Ellis, A. R., K. J. Schuett, Th. Thorley, H. S. Valia: Heat Recovery Coke Making at Indiana Harbor Coke Company, Ironmaking Conference Proceedings, 1999.
12. Nashan, G., W. Rohde, K. Wessiepe, G. Winzer: Modular and 2-Product Technology – The Cokemaking Process for the Future. 4th European Coke and Ironmaking Congress, June 2000, Paris, France.
13. Nashan, G., W. Rohde, K. Wessiepe: Some Figures and Facts on the Present Status and New Proposals for a Future-oriented Cokemaking Technology. Cokemaking International 2/2000.
14. Nashan, G., K. Wessiepe, G. Winzer: Evaluation of Coking Systems under Technical and Economic Aspects. Cokemaking International 2/1998.
15. Baer, H., H. Bertling, W. Rohde: Cokemaking with SCS Module Technology ready for Industrial Implementation. 2nd International Congress on Science and Technology of Ironmaking, Toronto, Canada 1998.
16. Ameling, D., H. Baer, H. Bertling, H. B. Lüngen: Cokemaking Technology 2000 – State of the Art and New Structures, CMI 1/1999.