COST / BENEFIT CONSIDERATIONS IN COKE PLANT REHABILITATION [(1)]

Helmut SCHULTE [(2)]
Werner HIPPE [(2)]

Summary
Aging coke batteries can extend their useful life cost-effectively by undergoing a major rehabilitation program. The program includes the end flue and / or through wall repair using modern coke oven repair technology. Major aspects of the rehabilitation are addressed. Cost comparison of different methods of rehabilitation is provided.

Keywords:
Coke Oven Rehabilitation, Battery Inspection, Repair Concept

---

(1) This paper is to be presented at 1st International Meeting on Ironmaking, September 24th to 26th, Belo Horizonte, MG, Brasil
(2) System Technology, Coke Oven Plants, ThyssenKrupp EnCoke GmbH, Germany

AGE STRUCTURE OF SOUTH AMERICAN COKE OVEN BATTERIES

The existing cokemaking facilities in South America continue to age. 50 % of the coke oven batteries in South America are older than 20 years, and 15 % of the batteries are more than 30 years old.

Although alternative ironmaking processes have made some inroads, the traditional blast furnace will remain the major source of economical iron supply at least for the near future. With the present stage of reduction of coke rates in the blast furnace, now more than ever the steel industry needs high quality blast furnace coke from reliable sources. Therefore it makes sense to maximize the longevity of existing coke plants by thorough measures aimed at ensuring several years of continued production.

In the some countries the Clean Air Act anticipates a further tightening of emission limits in the following years. This suggests that a "window of opportunity" now exists to perform a thorough rehabilitation of aging existing batteries which could then operate at maximum coke production in the years also in the future.

PLANT ASSESSMENT IN LIGHT OF OPERATIONAL AND ENVIRONMENTAL ASPECTS

Operational and Environmental Aspects

The aging and the progress of deterioration of a coke oven battery varies significantly depending on the operating practices and the operating conditions, such as coking rates, the quality of the coal blend as well as on the specific maintenance program.

The obvious signs of aging of the coke oven batteries usually start at the heating wall ends and at the battery top. The refractory brickwork and steel and cast parts installed in coke oven batteries are subjected to extreme thermal and mechanical loads. The oven quoins are exposed to 10,000 – 15,000 temperature changes during a service life of 25 years when the doors are opened and the coke is pushed out.

The deterioration of the refractory block is frequently a result of damage to the mechanical parts, above all when the oven bracing system loses its strength and is no longer capable to transfer the forces to keep the brickwork under the necessary restraint. In such case the swelling pressure of the coal may lead to cracks in the walls particularly in the end heating flues. Stack emissions are a result of the cracks and open joints in the walls.

Over the years of service life the thermal loads also lead to permanent deflection of the cast parts at oven quoins, which can no longer be compensated by adjustments. Leakage from the jambs and the doors is the result.

The well known post-expansion of the battery has the consequence, that the charging holes drift out of line, standpipes are moved or out of plumb and the charging car rails may leave their original location. This has a negative influence on the performance of the charging car and leads to operational problems and finally to unacceptable emissions.

Maintenance Aspects

The aging and deterioration process begins with the start-up of the battery. In the beginning of the service life of a battery minimal routine maintenance only such as gunniting, dusting, and the adjustment of the bracing system and doors is sufficient.
The required activities for routine maintenance increase with the service life of a battery and - as a consequence - the maintenance-related production losses grow, too. If routine maintenance is no longer sufficient for solving the operational problems, major revamping or rehabilitation of the battery may be more economical.

Revamping / rehabilitation might be seen as expensive at first sight but it can reduce routine / daily maintenance and so-called spot repairs which in the end are more costly than rehabilitation.

Generally 3 scenarios can be defined when the usual proper maintenance is no longer sufficient for maintaining the service life of a battery:

1 The basic condition of the refractory structure becomes so deteriorated that the routine maintenance becomes daily maintenance for the same damage, which consequently provides production loss in addition to the costs.
2 Environmental considerations may provide the impetus for the rehabilitation of a coke oven battery.
3 The operation of the service machines is obstructed by the post-expansion of the battery.

Detailed Battery Inspection

When the condition is reached, that only revamping / rehabilitation maintain the service life of a battery, a plant assessment shall provide the basis for the extent of rehabilitation. This assessment must consider the elimination or minimization of the causes of the deterioration, or - at least - reach the best compromise between the available improvements as a result of the rehabilitation and the resulting economic benefit.

It is a precondition that the assessment is a matter of confidence between the operator and the coke oven engineering company.

Plant operators know the condition of the battery from their operational difficulties and from the extraordinary efforts needed to meet the emission control regulations.
The coke oven engineering company has the experience to evaluate the causes for the deterioration and damage and to propose the best available improvements in order to eliminate or, at least to minimize the deterioration after the rehabilitation.

The first step is the inspection of the physical condition of the facility. It is necessary to know the exact, present condition of the battery including the refractory part, steel and cast parts as well as of the oven machinery.

The inspection covers the physical damage to the facility, as well as the areas of non-compliance of environmental regulations. Additionally the battery heating status has to be precisely considered.

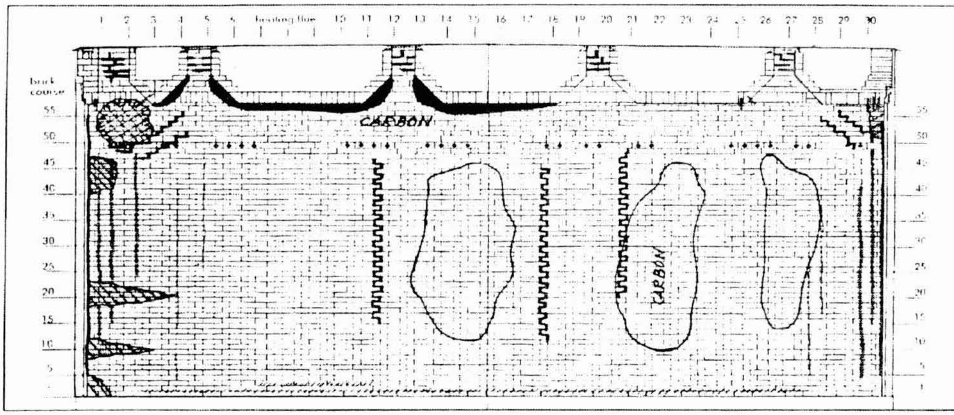
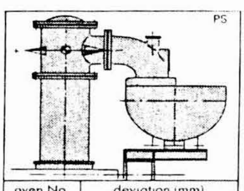


Fig. 1 Inspection sheet for heating wall damage

The inspection of the refractory is usually recorded on a wall inspection sheet for each oven representing all different types of prevailing damage in the heating wall. Similar inspection data are prepared for the status of the standpipes, buckstays, tie rods, springs, etc.



oven No	deviation (mm)	
	+	
01	25	
02	32	
03	30	

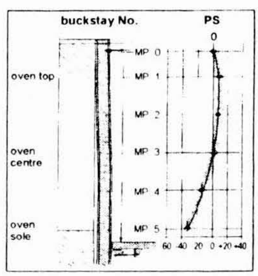


Fig. 2 Survey of Standpipes Fig. 3 Survey of Buckstays

Furthermore, the location of the individual face of each oven and the individual level of each oven sole have to be verified by topographical survey

In addition, process data such as temperature distribution are collected for evaluating the operating condition of the battery.

Considerations for determining the rehabilitation scope

As the second step of the assessment the results of the inspection have to be evaluated, compiled and provided in a report. On the basis of the inspection report and the analysis of the operating condition, a rehabilitation plan is developed outlining the extent of the repairs to refractory and steelwork necessary to bring the battery back into good condition as well as the procedures and the methods for the rehabilitation. Of course, the procedures and the methods depend on the age and on the overall condition of the individual battery.

On the other hand every rehabilitation opens the chance to equip the existing battery design with the latest technology such as an improved bracing system, new door design, latest design of the ascension pipe area etc.. These design changes shall be proposed considering the elimination and / or minimization of the causes of the deterioration as found during the inspection.

As a result of the assessment the rehabilitation may be determined as

- Replacement of the steel and cast parts of the oven ends
- End flue repairs
- Through wall repair
- Oven roof repair
- Pad-up rebuild of the battery

In case of extraordinary loads on the steel and cast parts of the oven ends (Wall protection plates, jambs, doors) it might be necessary only to replace the steel and cast parts whereas the refractory part may be in good condition and need not be repaired. If this extraordinary replacement happens within less than 15 years of service life normally no or only little refractory repair work is necessary.

As the thermal stresses on the end flues are higher than on the flues further inside of the oven, and the swelling pressure during carbonization acts mainly on the end flues it is in most cases sufficient to replace only the end flues, usually up to 4 flues deep. The replacement of end flues is in such cases the appropriate repair method. It is not unusual that the entire battery on the coke side or pusher side needs this repair, in some cases even on both sides.

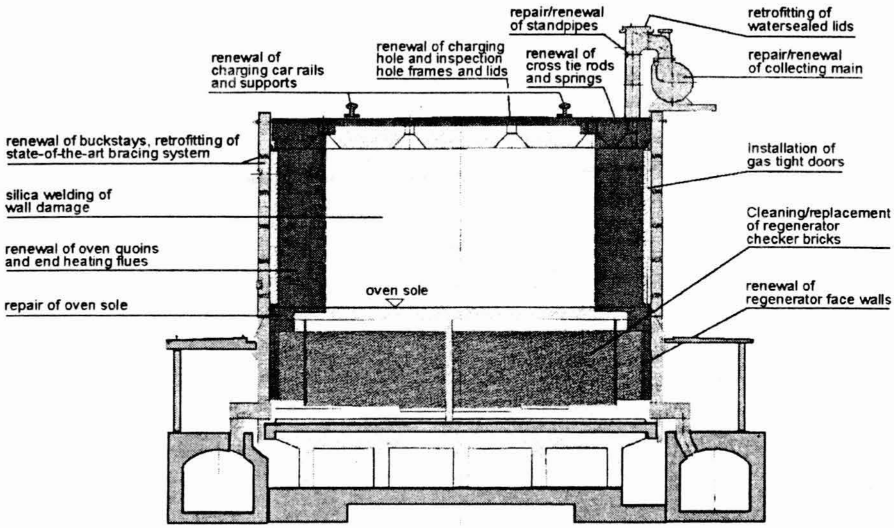


Fig. 4 Typical rehabilitation of a coke oven battery after 15 years of operation.

After several years of service life following an end flue repair it is possible to extend the service life further by a second program of end flue repair, however this time considering that the connection between the remaining and new flues must be 1 to 2 flues deeper inside the oven chamber.

Depending on the scope of damage it may become more cost effective to replace the wall entirely.

The battery roof can have a slow but continuous expansion over the years. This may be caused by ingress of carbon, delayed crystal modification of residual quartz. Other causes for roof deterioration may be shortcomings in the design of the charging car rail supports, improper decarbonization of the gas collecting space, and poor operating practice. In most cases the scope comprises to replace at least the upper 300 mm of the battery roof.

If the deterioration has spread to such an extent that more than half of the refractory has to be replaced or if the assessment indicates that also the regenerator brickwork is deteriorated, most probably due to combustion problems, then a pad-up rebuild should to be considered. The scope of rehabilitation then comprises the demolition of the entire battery down to the nozzle deck (underjet ovens) or to the pad (gun flue ovens) and the reconstruction of the refractory structures including new buckstays down to the bottom.

Repair Concepts and Procedures

General Considerations

It is important to plan the implementation of the rehabilitation work, especially on an operating battery, in order to minimize production losses and to safeguard the integrity of the battery structure. Except when the entire battery has to be reconstructed (pad-up rebuild), the rehabilitation of a coke oven battery should be performed as a hot repair, i.e. the remaining brickwork will be kept hot.

The actual repair schedule is determined based on the local labor conditions, production requirements, etc..
Usually the rehabilitation of the battery will be divided into a certain number of repair blocks depending on the number of ovens in the battery. In case of repair of 5 heating walls in one repair block for example, the 6 adjacent ovens plus 2 buffer ovens will be out of production. The 2 ovens adjacent to the buffer ovens can only be operated with reduced production because of the reduced heating flue temperatures of approx. 1050 °C in the heating wall adjacent to the buffer oven.

An important consideration is the method of heating the battery during the repair. At least the ovens belonging to one repair area must be heated by coke oven gas because of safety reasons and more flexible temperature adjustments.

End Flue Repair

Essential for the success of end flue repair is the correct temperature control in both, the old and new brickwork before, during and after completion of the repair. The temperature in the heating flues of the remaining part of the heating wall will be kept as high as required for safe ignition of the coke oven gas.

After having pushed the relevant ovens empty they have to be isolated from the collecting main. Bulk heads are installed inside the empty ovens and heat shields replace the oven doors. Suitable thermal insulation avoids the cooling down of adjacent heating walls.

The heating flues scheduled for repair are now demolished course by course, always insulating the front of the tie-in flue. Furthermore struts between the remaining brickwork and the buckstays secure the stability of the tie-in flue.

A vertical sliding joint between the tie-in flue and the new heating flue as well as a horizontal sliding joint at the oven sole level allows the proper expansion of the new cold refractory bricks along / over the hot remaining bricks.

After bricking-up, the new flues are heated-up to a temperature of approx. 850 °C (approx. 1550 °F). Finally the ovens are sealed by means of dusting (also called dry-sealing).

Through wall repair

In a through wall repair the entire wall surface of the neighboring walls is covered by insulating panels. Then the heating wall to be repaired is demolished down to the oven sole level. Subsequently a proper horizontal sliding joint must be provided to allow the new wall to expand over the remaining refractories. The new heating wall will be bricked-up only up to the chamber cover

Oven roof repair

In most cases the replacement of at least the upper 300 mm is sufficient to realign or replace the charging holes and realign the standpipes. Usually some or all of the cross tie rods are replaced in combination with the oven roof repair.
After the execution of a proper revamping the battery roof will be tight and even, and the charging holes, charging car rails and standpipes will be correctly aligned. The ovens can be charged again with a proper fit of the charging car telescopes which is a precondition for smokeless charging.

Fig. 5 Oven Roof after Rehabilitation

Pad-up rebuild

For the pad-up rebuild the entire battery is cooled down and all refractories are demolished down to the nozzle deck (underjet ovens) or to the pad (gun flue ovens) respectively, as well as dismantling all steel and cast parts. Before reconstruction the pinion walls and the nozzle deck / pad will be refurbished in order to provide a smooth surface for the new brickwork. After reconstruction a careful heating-up of the entire battery follows in the same way as for new batteries.

PRACTICAL EXPERIENCE

Major battery rehabilitation projects recently carried out by TKEC are:

Pad-up Rebuilds

- 4.4 m CEC batteries in Italy (1992 and 2000)
- 4.2 m Heinrich Koppers battery in UK (2000)
- 4.2 m Dr. C. Otto battery in UK 1999
- 6.2 m Koppers Becker battery in USA (1995)

Battery rehabilitation comprising end flue repairs, throughwall repairs and oven roof repair

- 6,2 m Dr. C. Otto battery in Argentina (1995)
- 6,5 m CEC batteries in Spain (1996)
- 5.0 m Heinrich Koppers batteries in Mexico (1996)
- 7.0 m Giprokoks battery in Finland (1997)
- 4.5 m Koppers Becker battery in Turkey (1997)
- 5.0 m Dr. C. Otto battery in Canada (1998)
- 6.0 m Carl Still batteries in Taiwan (1999)
- 4.5 m CEC battery in Italy (2000)

Most of these batteries are in operation at full capacity after the rehabilitation.
Presently in progress are similar repairs on 6,5 m batteries in Italy and 4.5 m batteries in Turkey.

Experience from the above mentioned batteries shows that a major rehabilitation program with end flue replacement, bracing and buckstay replacement and appropriate repairs in the oven roof area can extend the service life of a battery for 10 - 15 years. Crucial for the success of further battery operation is a strict monitoring and maintenance program.

Cost / Benefit Considerations

As mentioned before the following options are available:

- Build New Battery
- Rebuild Existing Facility (Pad-up rebuild)
- Perform Major Rehabilitation Such as End Flue Repair or Through Wall Repair

As with any major projects of this nature economic evaluation dictates the final decision. In addition to results of the plant assessment, the cost of each option dictates the selection of the option.

	new battery	pad-up rebuild	rehabilitation
	%	%	%
Engineering	6	6	7
Supplies	45	45	32
Civil work	10	2	0
Demolition & erection	39	47	61
Total for each case	100	100	100
Comparison of total costs	**100**	**85**	**45**

Table I -Cost Comparison-

Table I gives an indication of the cost relation among the three options. The cost for each option was calculated for a battery with a coke capacity of 850,000 mt/year and the cost for the option of the new battery is set at 100 %.

It is obvious that if the condition of the battery permits, the major rehabilitation will be the most cost-effective way to extend the service life of a battery.

The comparison becomes even more favorable for the rehabilitation option, if the loss of coke production is also evaluated. A new battery starts coke production only after more than 24 months after effective date of contract. The manufacturing time for the refractory material is the time leading factor.
In case of rebuild of an existing battery the battery will continue producing coke until the refractory material and the steel and cast parts are available at site. Thus the production loss from start of demolition until end of heating-up can be reduced to approx. 14 – 15 months.
In case of major rehabilitation only the 6 – 7 ovens in the repair area will not produce coke during the revamping of this section. Considering 1 month for the revamping of

each section the production loss can be reduced to totally 1 month plus the production loss by the buffer ovens and reduced production of the adjacent ovens (another 0,5 – 1 month production loss).

Looking to the feasibility of a rehabilitation from another point of view, and that is the comparison with the standard maintenance practice, the following experience received from European coke plants has come out over the years:
The maintenance costs necessary to maintain the production level can be taken as 0,50 – 1,00 € / mt of produced coke during the first years of operation, increasing slowly to 2,50 .- € /mt coke. After ten years they start sky-rocketing, arriving at up to 10 € / mt coke after approx. 15 – 20 years of operation.

That moment can be considered as the break even point because the rehabilitation would cost approx. 5 - 6 .- € / mt coke. This amount considers the depreciation within ten years and a rate of interest of 7 %.

As a result of the rehabilitation the maintenance costs will decrease to approx. 2,50 € /mt coke.

Of course, the decision process is more involved and the above is intended only to be a guide for investment considerations.

SUMMARY

The wear of coke oven batteries during their service life, which can no longer be compensated by routine maintenance does not automatically require the pad-up rebuild of the battery.

Advanced battery repair and battery rehabilitation techniques have been developed and have proven their reliability in a number of applications. The service life of batteries can be extended by 10 - 15 years if proven methods are applied by competent contractors.

To ensure the success of the rehabilitation it is absolutely necessary to provide an accurate assessment of the plant condition and a concept for eliminating the causes for the different deficiencies before execution of the rehabilitation.

The rehabilitation allows for the implementation of new facilities, for adoption of the state-of-the-art design and for fulfilling the environmental requirements.

However, when appreciating the lower costs and the lower coke production loss by the rehabilitation compared to a pad-up rebuild it must be considered that the rehabilitated battery will not be a new battery.

Experience demonstrates that the capital spent for the rehabilitation has been in all cases a good investment. The repair or rehabilitation of a battery is economically often a more attractive solution than a pad-up rebuild or a newly built battery.