COKE OVEN LIFE PROLONGATION – A MULTIDISCIPLINARY APPROACH*

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Abstract
In this paper, the coke oven life prolongation technology is reviewed from different points of view: blend design; battery heating; operational control; refractory maintenance. A summary of major inspections in critical areas, for the evaluation of the battery conservation situation is presented. A discussion on tools for the diagnostics of the degree of damage is carried out.
Keywords: Coke oven life; Coke oven refractories; Battery heating; Wall pressure.

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1 INTRODUCTION

The replacement of aged batteries needs investment and will be submitted to growing environmental pressures. Hence, an important effort is carried out to make the battery last longer. In this paper, coke oven life prolongation technology is reviewed taken into account several points of view: blend design; battery heating; operational control; refractory maintenance. Also, a technique for the diagnostics of the degree of damage is presented, as a tool for follow-up, damage assessment and application of corrective actions (figure 1).

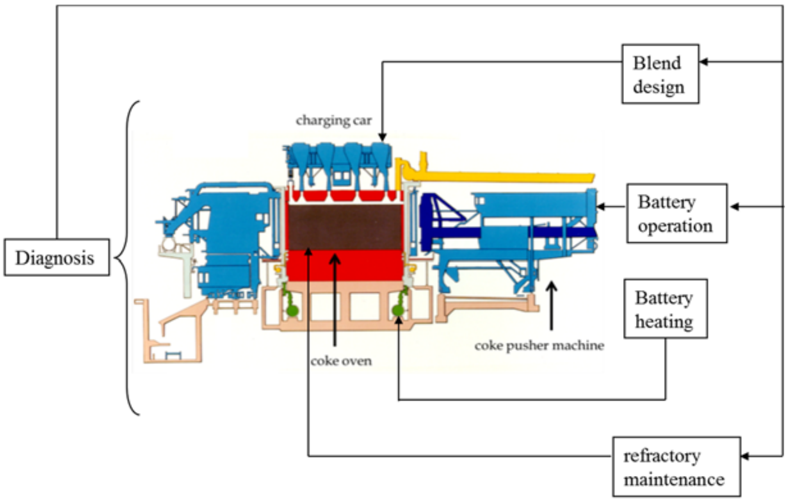

Figure 1. Factors involved in getting longer battery life

2 COKE BATTERY LIFE

Useful life of a coke battery has been estimated to be in between 12,000 and 15,000 pushings. For an oven of 450mm width and a gross coking time of 15 – 18 h, this would correspond to 20 to 30 years [1].Nevertheless, after each charge, the oven walls suffer a strong temperature drop, due to the cold charge, mainly in the end flues. This, together with other factors related with blend properties, heating, operation and refractories maintenance, may bring about a drop in thermal shock resistance, from 15 years of operation onwards [2], as shown in figure 2.

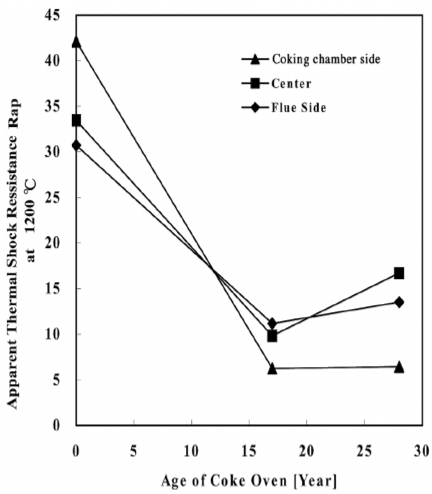

Figure 2. Relation between oven age and apparent thermal shock resistance [2]

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Good practices of blend design, heating and operation, as well as preventive refractory maintenance are keys to limit damage and to achieve long battery life (figure 3). This becomes more important as many batteries exceed 25 service years and the investment for new batteries becomes higher do to stringent environmental requirements.

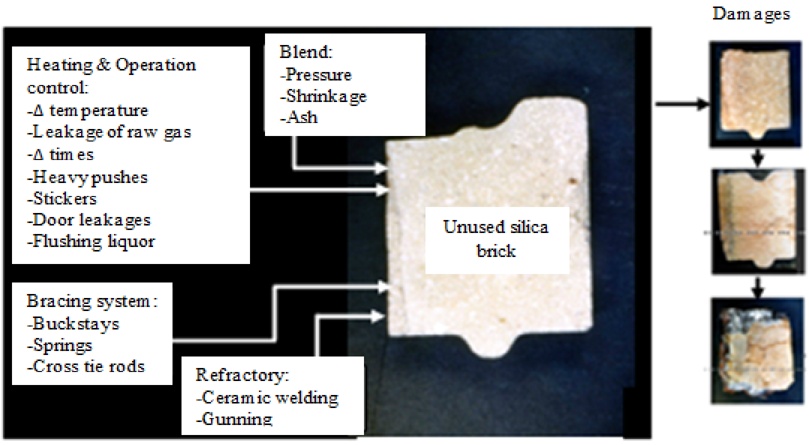

Figure 3. Mechanisms for oven damage [3]

3 BLEND DESIGN

Besides satisfying the coke quality constraints, the blend design has to take into account avoiding early wall damage by high pressure against the oven walls or reduced contraction, generating cracks, deformation and open joints.

3.1 Pressure on Walls

This pressure is originated in generated in the plastic layer, and transmitted to the walls through fissure in the coke closed to the wall. This variable is assessed in movable wall pilot coke oven. Maximum admissible value is 2 psi, while industrial values are usually between 0.5 and 1 psi.

3.2 Charge Shrinkage

The coke cake, before discharging, must have a certain contraction, for a normal push. If this does not happen, excessive force is needed, or even pushing is not possible; this means damage and deformation for the walls. According to ASTM D2014, the expansion / contraction of the blend is determined by the test of Sole-Heated Oven (SHO). Acceptable values fall between -7 and -15 %.

3.3 Ash Chemistry

Coal ash may penetrate and attack oven walls, causing spalling in some cases. Tests show that with a low content of basic oxides (Fe_2O_3+CaO+MgO) in the ash, penetration decreases [4].

3.4 Stamped Charging

This is an extreme case of very high charge density. Two world-class users of stamped charging: ZKS in Germany and Tata Steel in Jamshedpur. ZKS built

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batteries 1 and 2 by 1984. They were the first high stamp charged batteries in the world. Later on, battery 1 was demolished and replaced by a new one. Battery 2 was said to be shut down after start-up of new Battery 1. Then they were replaced with other stamped-charging batteries with some design changes for longer life. In the case of Tata Steel Jamshedpur, there are two stamped-charging batteries. The oldest stamp charged battery is #7, built in 1989. Failures were reported to start by 2005. One of the main causes was excessive pushing force. Six years of continuous improvement work with changing strategies were required to have all ovens of Unit 1 back on trail [5].

4 BATTERY HEATING

Important factors to take into account in battery heating, regarding longer life battery, are average battery temperature; crosswall temperature; raw gas leakage, vertical temperature and free space temperature. These factors are discussed below.

4.1 Average Battery Temperature

This temperature must be maintained with a safe range to avoid early damage. Recommended maximum value is in the order of 1300º C and minimum value 1100ºC [6], covering the range of stability of tridymite (1470ºC to 870º C).

4.2 Crosswall Temperature.

This is the temperature of the flues of a given wall, measure at the end of coking (net coking time). This temperature is useful to assess the thermal homogeneity along the oven. The temperature of the walls of one series should be measured daily, when coking ends. After charging the data, a data processing system may show the real temperature curve of each wall and the deviation in comparison with the standard. Then, taking into account the larger deviations detected, inspections and corrective actions must be prioritized (figure 4).
Then, the thermal map is automatically updated/. It shows normal, cool and hot flues in the battery. This is an important tool for management and control. Figure 5 shows decrease in deviation in measurements published by Ternium Siderar [7].

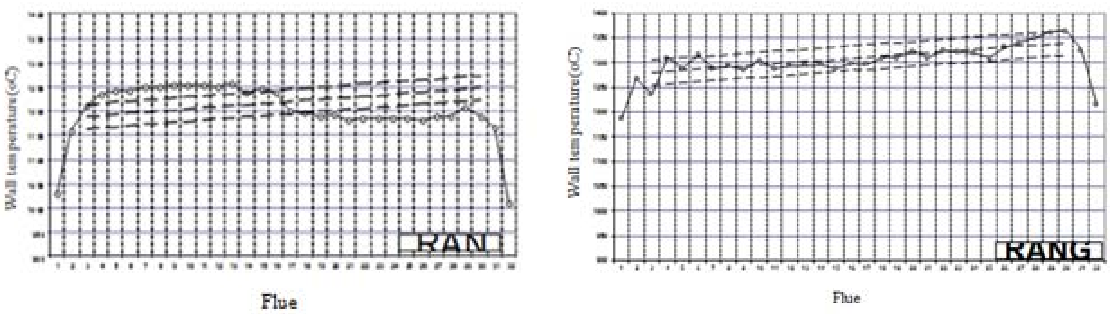

Figure 4. Left: crosswall temperature of a wall before correction. Deviation: 105 ºC. Right: crosswall temperature after correction. Deviation: 47ºC (standard ± 25ºC).

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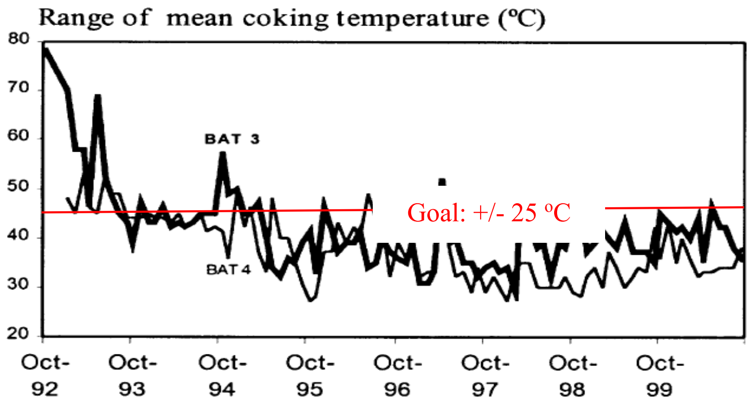

Figure 5. Crosswall temperature deviation in Ternium Siderar [7].

Other methods for this measurement are the use of fixed pyrometers located in three levels of the guiding car or the ram push.

4.3 Leakage of Raw Gas.

Filtration of raw gas from the oven to the flues needs to be controlled periodically, because it has implications like damage in the wall, less air/gas ratio in the flues, less temperature in the flue and increase black smoke emissions by the chimney.
A way to control leakage is the visual observation of the flues that are not burning, from the battery roof, during the first five minutes after oven charging (Figure 6).

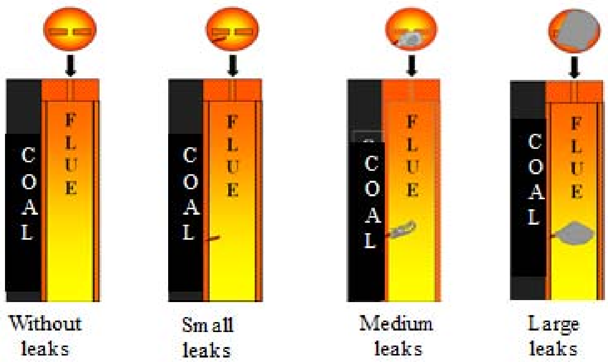

Figure 6. Inspection of raw gas leakage

According to the assessment defining S as small leakage, M as medium leakage and L as a large leakage an index is defined per wall, leakage index (LI) is.

$$LI = (\sum Sx1 + \sum Mx4 + \sum Lx10) \times 100) / \sum \text{inspected flues} \times 2)$$

Another way to have control of leakage is the use of an automatic monitoring system, measuring to the opacity of the waste gas exiting the stack, as proposed by Yokogawa [8].

4.4 Vertical Temperature

This is the difference between upper and lower zones of the charge. When lower temperature is too high there is excessive coking in this zone and this could bring about heavy pushing damaging walls, and reduced coking in the upper part, with excess of fines. With the opposite situation, there is high temperature in the free

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space above the charge, high deposition of graphite in wall and roof, increased pushing force and damage to the bricks.
Reference values are 60º C for coke oven gas operation and 35º C for mixed gas; the value is adjusted with corrections of O_2in the off-gas according to each battery and the type of gas in use. Some flue designs have several levels of air burning and in some cases recirculation of burnt gas to improve vertical distribution, mostly in tall batteries.
The measurement is carried out directly, with portable infrared pyrometers, or with pyrometers in three levels in the guide car or in the pusher ram.

4.5 Temperature in The Free Space

This is the temperature in between the coal line and the oven roof. It increases with the average battery temperature, lower oven charge and higher vertical temperature. It is usually in the order of 800ºC. If higher, excessive graphite is formed in the walls, thus generating heavy pushing with risk of wall damage. To have this temperature in range, the right charging height is relevant, in agreement with the design of the battery and the control of O_2 in off-gas.

5 OPERATING CONTROL

From the point of view of battery life, the operating control is responsible for thermal and operating uniformity, and for the control of the operating variables that influence the health of the battery.

5.1 Coking Machines

This equipment must be reliable; their availability to guarantee the objective in operating uniformity is important. It is necessary to have emergency equipment and installations; an effective preventive maintenance system and fluid communication with operations, to administrate and minimize production delays.

5.2 Delays

The programmed cycling time (time between two pushings) must be constant. An objective of admissible delay is recommended, as well as recording of these delays and their causes, to be able to reduce them along time. In figure 7, plant results of pushing regularity and delays are presented [7, 9].

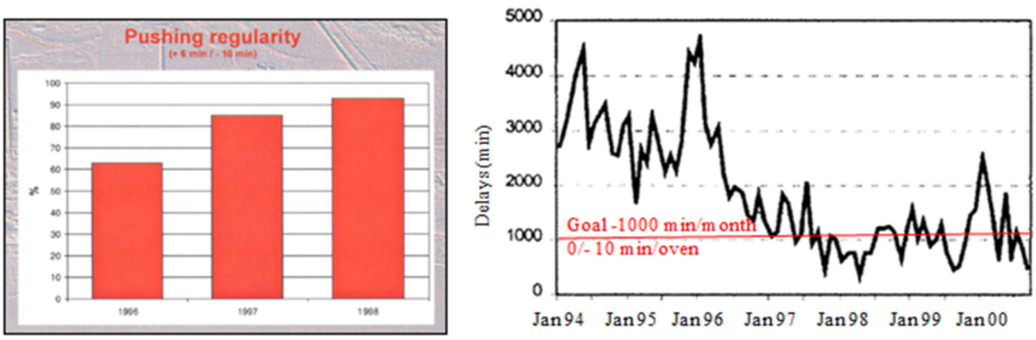

Figure 7. Left: Pushing regularity in Rautaruukki Raahe, Finland [9]. Right: Evolution of delays in Ternium Siderar, Argentina [7]

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5.3 Operating Uniformity

This is assessed taking into account the average daily gross coking time. Here the delays and advances in pushing, exceeding the aimed standard range, are detected and corrected. The statistical standard deviation and the average deviation in relation to the objective are used, too. In figure 8, the evolution of the range of gross coking time is presented [6].

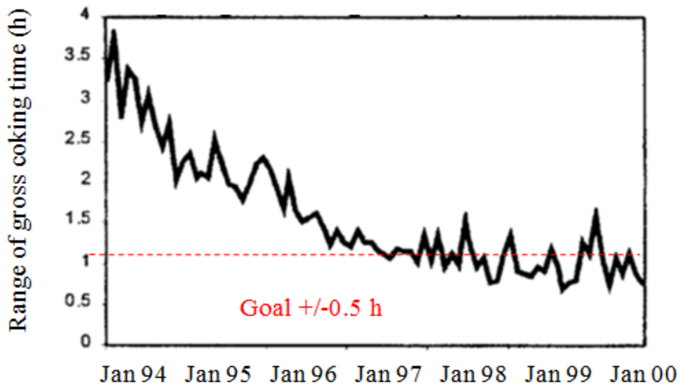

Figure 8. Evolution of the range of gross coking time [7]

When the production levels to be modified, it is recommendable to change 15 min/day or 5 % or working index each 5 to 7 days.

5.4 Thermal Uniformity

This parameter is assessed by means of the range of average daily net coking time, detecting and correcting the deviations larger than the goal. Possible causes for deviation are changes in: blend moisture, wall temperature, operating delays or advances, gas fuel. In figure 9 plant results are presented [10].

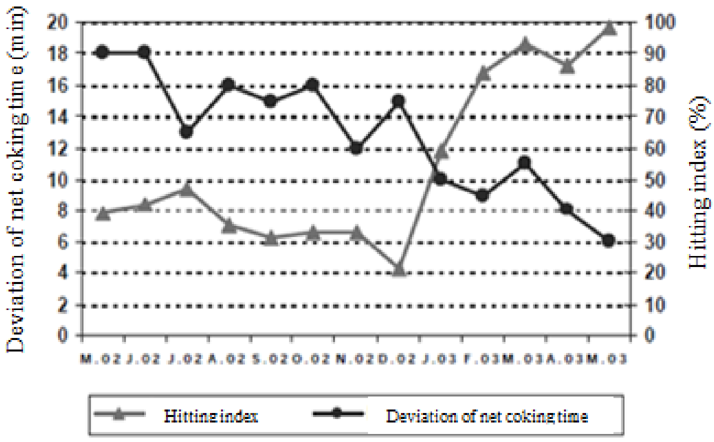

Figure 9. Deviation of net coking time [9]

The thermal uniformity may be achieved by means of manual or automatic corrections to the battery heating system using data of thermocouples in the stand pipe; semiautomatic adjustment including measurement of calorific power of gas; Wobbe index and utilization of complex control loops, including thermal balance of the battery.

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5.5 Control of Process Variables

Most important variables to control from this point of view are: Charge height, vertical contraction, pushing force and oven internal pressure. These controls allow to prevent damage to the oven walls.

6 REFRACTORY MAINTENANCE

Main activities are:

6.1 Ceramic Welding

Used for hot repairing of oven walls in the long range: cracks, joints, spalling, holes, patching, new-old wall joints and deformed walls. This technique contributes to minimize emission of black smokes in the stack.

6.2 Gunning

This repairing technique is complementary of ceramic welding, to keep sealed the oven walls and reduce emission of black smoke by the stack by repairing the open joints.

6.3 Dry Sealing

It is useful as a complement to ceramic welding and gunning, for sealing of very small cracks in the free space of the oven. It contributes in decreasing black smoke emission. Only is effective if applied after eliminating major leakages.

6.4 Sole Maintenance

Applied to level sole, recover worn profile and partial reconstruction with new bricks.

6.5 Luting

This technique is used to seal cracks in the silica ducts transporting coke oven gas to the flues.

6.6 Hot Repairing of Headers

The aim is to make battery life longer for 10 or 20 years more. For that purpose, too damaged walls are selected. The first 4 or 6 end flues are rebuilt, including roof and sole, forming repair group of one to four walls. Besides, tasks in regenerators, improvements in the roof and bracing system are included. As a result, there are heating improvements, less raw gas leakages, less heavy pushing and less emission of black smokes to the stack [11,12].
Other maintenance tasks are made in: heating system, oven doors, standpipes, flushing liquor nozzles and bracing system.

7 DIAGNOSTICS OF THE BATTERY STATE

The aim is to assess the state of conservation of the battery; give directions for servicing the heating system and the refractories, and evaluate the results of a hot repair. This diagnostics does not forecast the remaining life of a battery.

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This method developed by the then NSC takes into account five indexes: temperature deviation, leakage of raw gas through the oven walls, percent of bricks damages in all oven walls, percent of flues with cracks in all oven walls and percent of dilatation o refractory body [6, 13].
These indices are calculated with measurements and procedures of the method and then plotted on the curve pattern of evolution in each during the lifetime defined by NSC method.
The evolution of these indexes in a plant is shown in figure 10 [7], in comparison with the NSC pattern (straight lines).

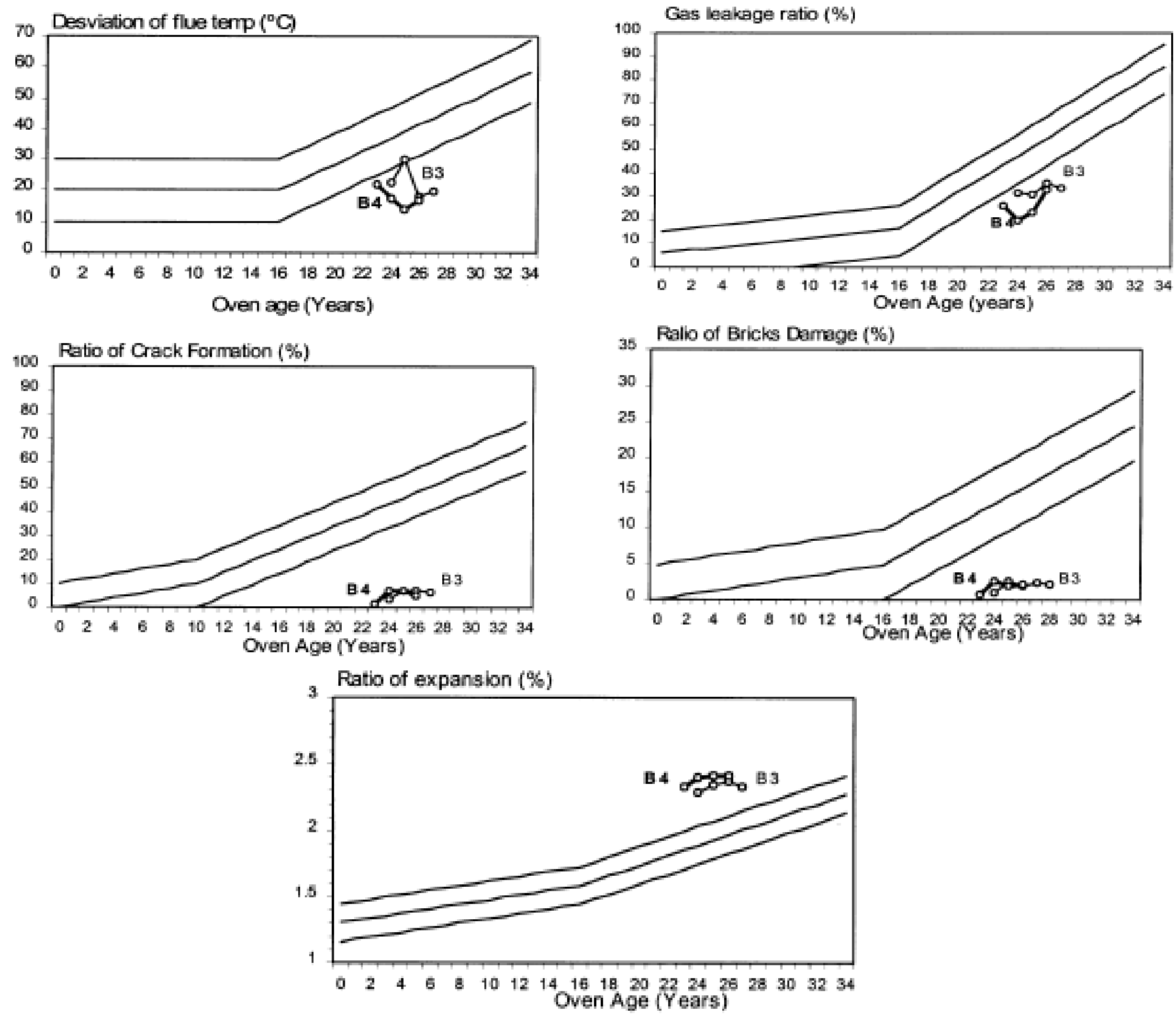

Figure 10. Results of diagnosis in terms of deviation of flue temperature, gas leakage ratio, ratio of crack formation, ratio of bricks damage and ratio of expansion [7]. Plant results in battery No. 3 (B3) and battery No. 4 (B4) compared with NSC pattern (straight lines)

Recently, a more sophisticated diagnosis system that is introduced in the oven has been deployed in several Japanese plants. It replaces the visual inspection of walls. The system consists of oven wall diagnostic equipment, which is provided with CCD cameras, and oven wall repair equipment, (figure 11).

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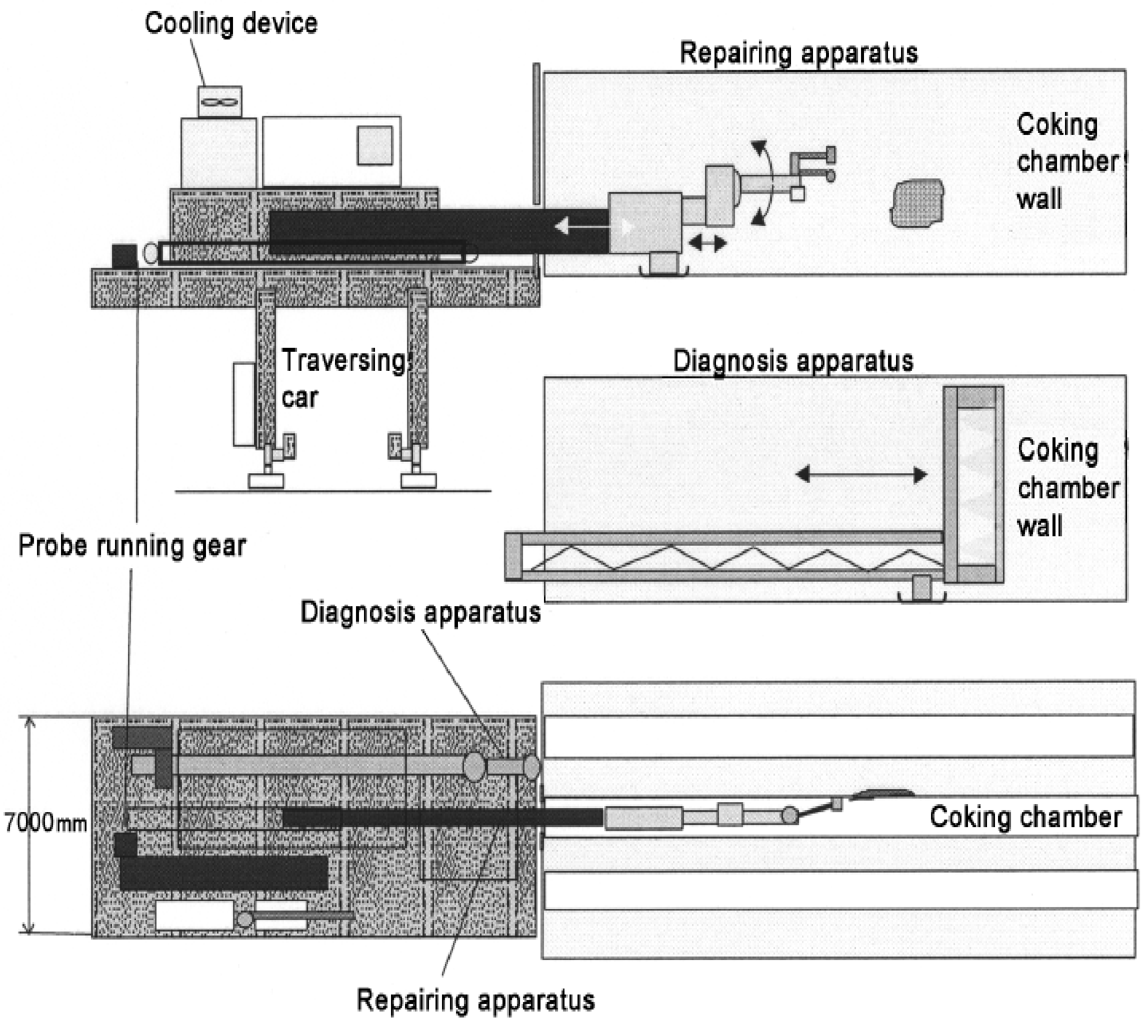

Figure 11. Schematic diagram of the coking-chamber wall diagnosis and repair equipment [14]

8 CONCLUSIONS

Right blend, heating practice, good operation and preventive refractory maintenance all along the life time of the battery, are the keys to a prolonged battery life.
The hot repair of headers and the diagnostics of damage are important to achieve this aim.

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