Chapter 4

Steelmaking Refractories

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4.1 Refractories for Oxygen Steelmaking Furnaces†

4.1.1 Introduction

The essential goal in the development of refractory practices for basic oxygen furnaces is to obtain a useful lining life that will provide maximum furnace availability for the operators to meet production requirements at the lowest possible refractories cost per ton of steel produced. To this end, the operators and refractories engineers seek to optimize their lining design, maintenance practices, and control of operating practices that are known to affect lining life. In most shops, longer lining life can result in lower refractories cost, but, in high production shops, longer life achieved with minimal downtime for maintenance will also enable increased productivity through increased furnace availability.

To optimize the lining design, most operators try to develop a balanced lining, that is, a lining in which different refractory qualities and thicknesses are assigned to various areas of the furnace lining on the basis of a careful study of the wear patterns. In a balanced lining, the refractories are zoned such that a given segment of lining known to receive less wear is assigned a lower quality or less thickness of refractory, whereas refractories of greater wear resistance and generally of higher costs are reserved for those segments of the furnace that will be subjected to the most severe wear.

The refractory qualities available to use in BOF linings range from pitch-bonded magnesia or dolomitic types to the advanced refractories that are made with resin bonds, metallics, graphites, and sintered and/or fused magnesia that can be 99% pure. Bricks are designed with a combination of critical physical properties to withstand the high temperatures and rapidly changing conditions/environment throughout the BOF heat cycle. A balance of properties such as hot strength, oxidation resistance, and slag resistance are necessary for good performance.

With the wide variety of available brick qualities, there is a wide range of prices; the more expensive brick can cost as much as six times that of a conventional pitch-bonded brick of the type used in many furnace bottoms. As lining designs are upgraded and more of the higher priced products

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are used in a lining, determining if the changes are cost-effective is important. For example, when the cost of a lining is increased by 25% in a shop that is averaging 2000 heats, the lining life will need to increase to 2500 heats for the refractories costs to be maintained. However, in shops where furnace availability is needed for productivity, a lesser increase in lining life and a higher refractory cost may be justified if the furnace availability is greater during periods of high production needs.

As lining designs are upgraded to optimize performance and costs, the effects of operating variables on lining wear are important to know. With this information, the possibility of controlling those parameters that affect lining wear adversely and the economic tradeoffs of increasing operating costs to extend lining life can be better evaluated. In general, the practices that improve process control, such as sub-lances, will benefit lining life. In addition, lining life is helped by charging dolomitic lime to provide slag MgO, minimizing the charge levels of fluorspar, controlling flux additions and blowing practices to yield low FeO levels in the slags. These practices need to be optimized to yield the most cost-effective lining performance.

Even when many operating conditions are improved, lining designs are optimized for balanced wear, and the best brick technology is used, wear does not occur uniformly, and, generally, maintenance practices that involve gunning of refractories and coating with slag are used to extend the life of a lining. See Section 4.2.

The above discussion illustrates some of the many factors that need to be considered in a strategy for BOF lining performance. Some details that are needed for developing the optimum refractories practices are provided in the following sections.

4.1.2 Balancing Lining Wear

4.1.2.1 General Considerations

In theory, linings for oxygen furnaces should be designed by refractory type and/or thickness so that no materials are wasted at the end of a furnace campaign; that is, so that all areas of the furnace are worn to a stopping point such as the safety lining at the same time. In the real case, however, some areas will show higher wear despite the latest brick technology and efforts to use internal maintenance techniques. A continuing and dynamic effort is always in progress in any shop to minimize wear and to provide longer life in these severe wear areas.

4.1.2.2 Areas of Severe Wear

The areas of severe wear are dictated to a large extent by the type of oxygen process involved (top-blown, bottom-blown, combination-blown, bottom-stirred, etc.). In all oxygen practices, the area where scrap and hot metal are charged into the furnace (charge pad) is subject to impact and abrasion. More uniform wear will occur during the oxygen blowing period on top-blown vessels, but bottom-blown vessels will be subject to accelerated bottom wear during the blowing period. On turndown for sampling and tapping, the furnaces (normally to opposite and generally horizontal positions), localized contact with slag will also produce localized wear. Accelerated wear is also experienced in the trunnion areas of any oxygen furnace, mainly because this area is the most difficult to protectively coat with slags or gunning. Other unusual wear areas may result from unique features of a particular oxygen process; for example, cone wear from post-combustion lances or the damage inflicted by deskulling.

Fig. 4.1 shows the different areas of a typical oxygen steelmaking vessel, where different types or thicknesses of refractory may be used to obtain balanced wear.

4.1.2.3 Wear-Rate Measurements

Consistent and predictable lining life is very important to avoid production delays in the steelmaking facility and related operations such as ironmaking, casting, or finishing; predictable life is

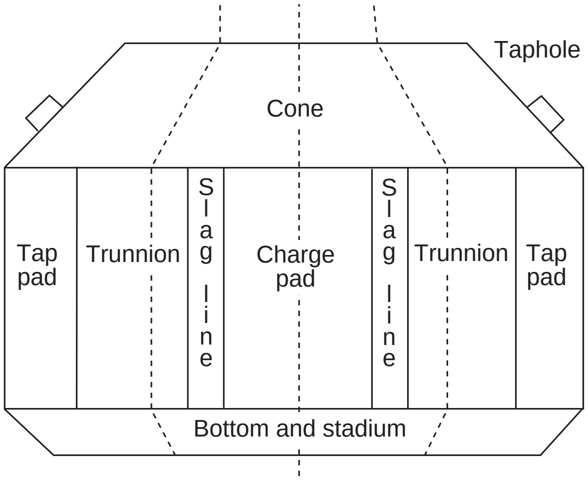


Fig. 4.1 Areas of a basic oxygen furnace.

also a vital part of a safe and stable operation. For these reasons, a variety of tools have been used to determine the condition of the lining at any time and to dictate the maintenance required to balance wear.

The most widely used method currently is a laser-measuring device as illustrated in Fig. 4.2. In this practice, a laser beam is rebounded off calibrated points on the furnace proper and compared to points in the worn lining. A computer analysis is then used to plot the remaining lining thickness. While this information is invaluable in comparing wear rates for different refractories and avoiding shell damage or breakouts, its primary usefulness is in determining and controlling furnace maintenance by gunning. Using the laser as a guide, the areas actually requiring gunning maintenance can be isolated, and the amount of gunning material required can be controlled. Fig. 4.3 illustrates one furnace campaign in which rapid trunnion wear was experienced in the first 500 heats.

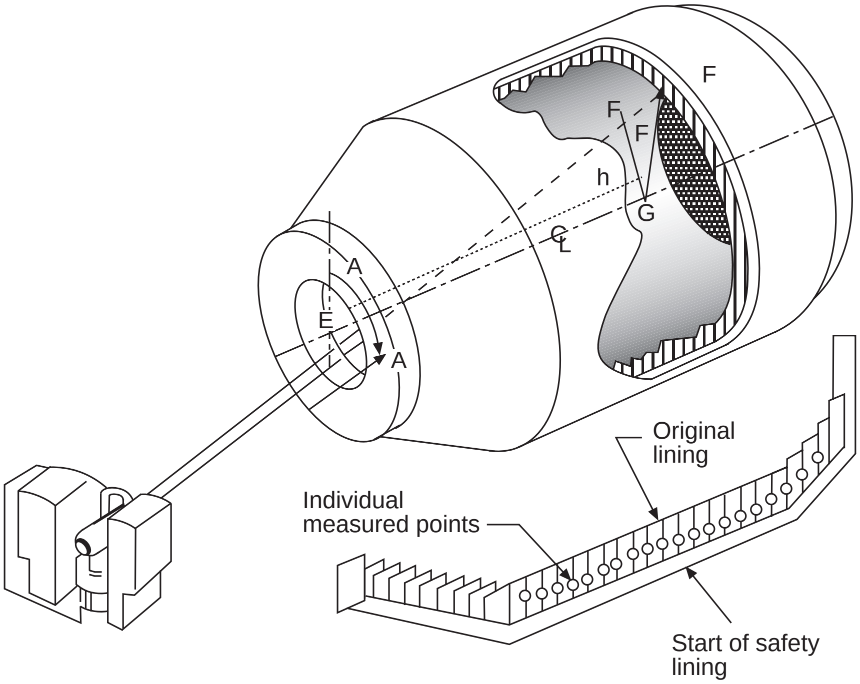
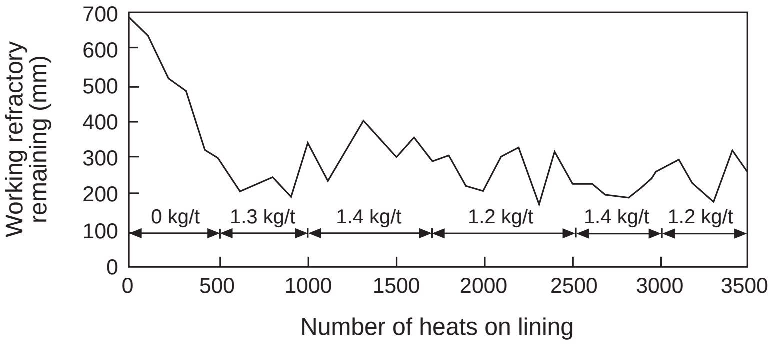


Fig. 4.2 Use of a laser to measure refractory wear.

Fig. 4.3 Wear and gunning rate in the trunnion area.



Gunning was initiated at the indicated approximate rate at that time and continued throughout the balance of the campaign.

4.1.3 Zoned Linings by Brick Type and Thickness

The previous chapter on refractories described the types of carbon-bearing basic brick available for use in modern oxygen steelmaking furnaces. The engineers who are responsible for designing todayís sophisticated vessel linings now may choose from greater than 30 proven compositions to construct a working lining to meet the service conditions found in a particular vessel. Normally, five to ten compositions have been found to cover most current operating practices and associated wear mechanisms.

Fig. 4.4 and Fig. 4.5 describe the zoning used in two types of operations to provide the optimum refractory behavior. The lining zones may also vary in working lining thickness from some 18 to 30 in. as an additional zoning method.

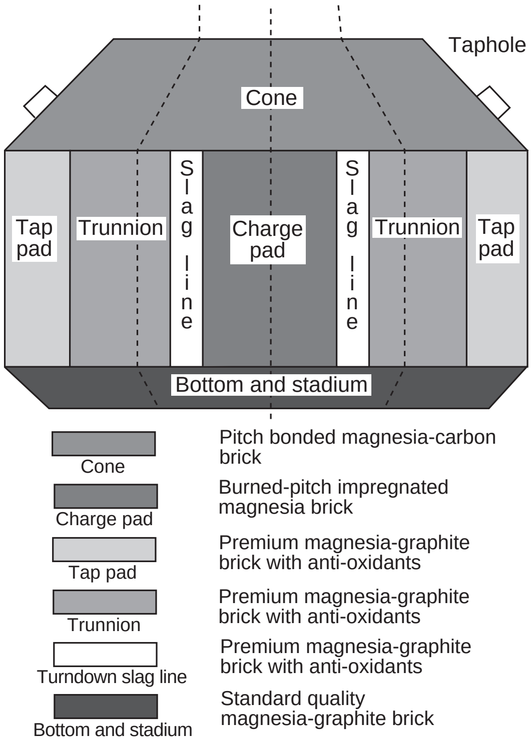


Fig. 4.4 Typical LD-BOF lining.