

REFRACTORY CORROSION – A RECURRENT TOPIC: ALWAYS TO BE CONSIDERED

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ABSTRACT

The goal of this presentation is to reveal the content of FIRE Compendium Series of books, number 2, on the theme of corrosion, to be covered in 3 volumes (or some one-thousand pages). Refractory materials are absolutely needed in various industrial sectors but they do corrode under harsh environment. Therefore, every effort to minimize corrosion are to be structured upon a good understanding of the processes involved. Corrosion resistance is not a well-defined inherent property of a given manufactured product; it is a characteristic which depends on a multitude of parameters, it is always essential to recall and to consider this aspect.

For the first volume, volume 2A, freshly printed, several authors have been called to provide a deeper understanding of the complexity of the interlinked phenomena. Hence a brief description of the content of this book is to be presented. Also, previews on the other two volumes to follow will be underlined: volume 2B: The Testing and Characterization Methods, to illustrate mainly the evolution in the tools nowadays available and to present innovative (in-situ) techniques of characterization; and volume 2C: The Impacts of Corrosion Wear, based upon selected case studies, to illustrate what can we learn from post-mortem analysis and what are the impacts on plant operation availability and products quality.

1 – INTRODUCTION

There are many words in use to talk about corrosion resistance of refractories, such as wear (continuous and/or discontinuous), degradation, dissolution, deterioration, erosion. To start, it must be emphasized that corrosion resistance is a characteristic rather than an intrinsic property of a given material. To understand what corrosion resistance means, one must consider a multitude of aspects, on top of the physical, thermal, mechanical, and chemical properties of a given piece of refractory material, such as its installation methods, selected shape, heating mode, environment fluctuations, etc.

It was here in Santiago that FIRE presented its first volume of the FIRE Compendium Series of books, on Castables Refractory Engineering (1). This series of books, number 2, in 3 volumes, on the theme of corrosion, has been undertaken with the ultimate aim to serve refractory engineers (including academics and students) and manufacturers of refractories as well as users of such materials, to optimize their useful life and so at first to help selecting the appropriate material to fit the widest intervals of conditions known to be encountered (including the cost issues).

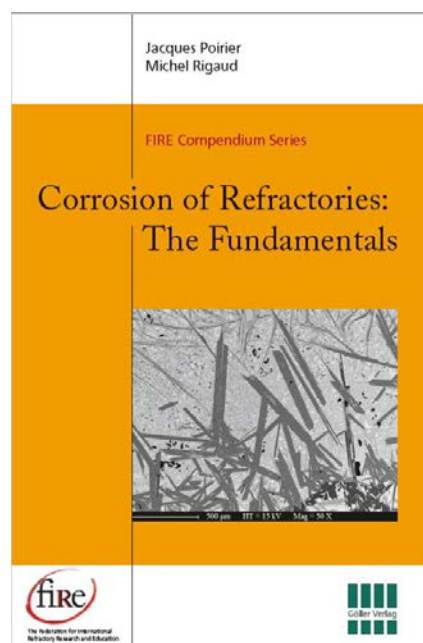
To reach such results, it is essential to acquire a thorough understanding of the complexity of any of the refractory materials available and the detailed knowledge of the global environment in which it is to be used. The first logical step is to start with the fundamentals (volume 2A), trying to make think as simple as possible but not simpler. To explain the complexity, it will be shown how to integrate simple considerations in a hierarchical order, step by step, revisiting the principles of thermodynamics and kinetics, the specificities of interfaces and wettability, coupling the thermal-mechanical-chemical processes with a well-defined global vision of the context and of the mechanisms. The second step is to realize how to measure, to characterize and to test refractory material to appreciate what is meant by corrosion resistance. This is treated in Volume 2B, in an echo to Lord Kelvin, who wrote: “When you cannot measure what you are speaking about or cannot express it in number,

your knowledge is of a meager or unsatisfactory kind”. The third step is to appreciate the impacts of corrosion of refractories on the quality of products, the wear management issues and the limitations imposed on the development of new processes. This is treated in Volume 2C, using case studies to illustrate what can be learned from post-mortem analysis in order help to find the best optimal way, to minimize the corrosion of refractories, a matter, which will be always to be considered

The detailed content of Volume 2A is now to be presented and previews on the other two volumes, 2B and 2C, to follow are to be underlined. FIRE is supporting the publication of the FIRE Compendium Series of books on refractories so that basic principles can be more widely disseminated, manufacturing can be better understood and selecting appropriate products for specific uses better achieved. What FIRE is and does is explained on its web-page www.fire-refractory.org/ and its influence and credit confirmed by M. Moreira et al. (2). Essentially FIRE funds international research projects, support academic education and pool the expertise, the experience and the willingness of the world wide most competent persons, institutions and companies in the field of refractories.

2– THE FUNDAMENTALS: WHAT TO FIND IN THE BOOK?

The book contains seven chapters, over 400 pages of texts. It has been written by seven authors, following a table of content drafted by the Technical Editors, for the whole series of books on Corrosion. Each chapter has been peer-reviewed by two members, selected among an Editorial Board Committee of 12 members. Each chapter is duly illustrated and provides a useful framework to educate new cohort of refractory engineers and consolidate the know-how of those concerned with such a matter.



After an introductory first chapter to illustrate the features, the series' main pillars to study corrosion: thermodynamics, kinetics and infiltration-wettability are treated each in one chapter. Then, in the last 3 chapters are described the reactions and mechanisms of corrosion, the T-M-C couplings, and the impacts of refractory lining corrosion on the operating conditions. Among the essential points mentioned in the table of content it

will be worthwhile to read how to use the main computational and thermodynamics data bases and programs to ascertain multi-components systems and the relationships between the corroded samples and the thermodynamics, in chapter 2. In chapter 3, one will find the formulation of the basic equations and the mathematical modeling to predict the dissolution kinetics rates. In chapter 4 the importance of the wetting, capillarity, and infiltration of refractories by liquid metals and liquid oxides, and the effects of interfacial reactions are comprehensively treated, with valuable examples and explanations. Then the reactions and mechanisms of corrosion, as they are influenced by the liquid phase characteristics and the gaseous environment are considered in chapter 5, stressing the key factors. The effects of the mechanical constraints when coupled to the thermal and the chemical ones are tackled in chapter 6. In chapter 7 the impacts of the operating conditions on refractory linings wear are underlined, as a preamble to volumes 2B and 2C, providing some immediate answers to the following questions: how to minimize corrosion? How to select the most appropriate refractories? The complete story will be tackled in the other two volumes.

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3 – THE HIGHLIGHTS

3.1 Assuming Equilibrium

The chapter on Thermodynamics after a brief review of the basic notions of stability, global and local equilibrium, phase rule and binary and ternary diagrams, the main focuses, which are among the original points covered in this book, not previously treated in other books on the corrosion of refractory ceramics, are on 1) the multicomponent systems calculation based upon the minimization of free enthalpy rule to predict the phases assemblages, assuming equilibrium, using different computer software's, 2) the interpretation of microstructures of corroded refractories explained by phase diagrams and predicted by the aforementioned thermodynamic calculations.

3.2 The Non-Equilibrium approach

In the next two chapters, 3 and 4, Kinetics and Wettability, the focus is on the multi-scale and physical approaches when non-equilibrium prevails. After a review on the main Kinetics principles and the various phenomenon caused by the wetting and infiltration of refractory material by liquid metals and/or oxides it becomes possible to appreciate the distances between equilibrium and non-equilibrium. It is again worthwhile to underline that such aspects are not frequently mentioned in previous books on Corrosion. It is then in Chapter 5, where the various reactions mechanisms of corrosion are exposed to obtain a global view in order to understand the immediate consequences on the refractory material behavior when in contact with specific reactive media, of different nature, be it liquid, gaseous or even solid, or all at once.

3.3 The T-C-M approach

This approach is described in chapter 6. The focus is on the treatment given to the thermo-chemical-mechanical coupling of constraints. Although the approach, the way it is being presented may seem impenetrable, because of its mathematical framework, it is possible to access to its essence, and to seize the concepts that will permit to become an informed user of the results of such models. It will also open doors to new researches.

3.4 How to minimize corrosion – First approach

Chapter 7 discusses the operating conditions and practical situations to minimize refractory corrosion. It is only the beginning since to better master the situation, it will be essential to consider the issues to be treated in Volumes 2B and 2C.

4 – CONCLUSION

At the end, it will be made clearer that the refractory corrosion will remain a recurrent topic, always to be considered. It is with this in mind that FIRE members have decided to contribute in order to facilitate the training of educated experts, still required and have agreed to disseminate these basic principles for the benefits of those belonging to the refractory constituency.

5 – REFERENCES

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- [2 Moreira M, Pelissari PIBGB, Parr C, Wohrmeyer C, Pandolfelli VC. Data mining on technical trends and international collaboration in the refractory ceramic area, Ceramics International to be published.

6– ACKNOWLEDGEMENTS

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