

F.I.R.E. Compendium Series

Refractory Castable Engineering

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F.I.R.E. – Federation
for International Refractory
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This book is dedicated to
Prof. Michel Rigaud, the heart, soul and spirit of F.I.R.E.

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F.I.R.E.

The Federation for International Refractory Research and Education, F.I.R.E., (www.fire.research.mcgill.ca) is a non-profit organization established to promote refractory related research and education on a global basis.

F.I.R.E. aims to stimulate and reinforce international education and research programmes for the refractory industry. Its strength is a unique group of members whose expertise is drawn from all sectors of refractory industries (production, supply and consumption), as well as the world's leading academic institutions involved in refractory research.

F.I.R.E. is committed to assisting the education of young professionals by financially supporting student exchanges among the network of members. There is also a series of research programmes which are, by definition, pre-competitive and are aimed at leveraging the research network capability of F.I.R.E. with contributions from both industrial and academic partners. They are designed to promote refractory science and provide a basis for education through academic research.

In order to fulfill this mission, F.I.R.E. has also initiated a compendium series and is delighted to partner them with Göller-Verlag publishers to make refractory science and technology available to academia, students, refractory raw material suppliers, producers, users and others interested in the refractory industry.

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Foreword

It is essential to outline the clear vision of the members from the Federation for International Refractory Research and Education to support the publication of books on refractory materials, so that basic principles may be disseminated, manufacturing can be understood, as well as selecting appropriate products for specific uses.

As with all the other books to follow in the F.I.R.E. Compendium Series, “*Refractory Castable Engineering*” aimed to serve not only as a reference, but also for educational purposes. For this reason, this book has been peer-reviewed by members of the Editorial Board Committee, listed hereafter. It has been written to provide the fundamentals to design and manufacture castables with the required structures, from the microstructural to the macro- and textural levels, presenting the features and properties to meet the expected requirements of many of the users.

The book is divided into ten chapters and its content is focused more on concepts rather than on descriptions. It provides insights into processing castables at different stages: dispersing, mixing, placing, curing, drying and firing. The three themes of the book cover: i) the formulation design, linked to dispersion, particle size distribution, packing and binder additives, ii) the installation and drying steps and iii) the properties and optimization of traditional, as well as novel monolithic formulations, containing alumina, magnesia, spinel and carbon. In the last chapter, there is a review on castables comprising nano-scale admixtures, the potential of mimicking natural composite materials, as well as bio-inspired and transient liquid containing castable formulations.

The authors are to be commended for their contribution, as they present the subjects with ample references, facilitating tasks for readers (faculty members, students, researchers, manufacturers and users in general) to determine what to know, to know how and to know why. This has demanded considerable effort to complete the manuscript in the time frame allocated to them. To find answers to specific questions, readers are invited to look at the table of contents at the beginning of the volume or at the subject index at the end. The latter has been compiled to cover the most “burning” questions one may have about castables. It is not a word index.

Foreword

This work would not have been possible without the keen interest and financial support of the F.I.R.E. industrial and academic members and the technical support of Göller Verlag GmbH, acting as co-editors.

Montréal, January, 2015

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Preface

Refractories have shaped the way we live. Without them, many of the scientific and technological inventions, as well as advancements over the past 100 years would not have taken place. Although for a layperson, refractories could be considered as a commodity or the result of trial and error procedures, they constitute one of the most complex products developed so far, where an advanced ceramic can be only one of their microstructural components. The progress of refractories and their industry started well before understanding that modern science and novel materials are based on the convergence of different areas of knowledge. Before becoming aware of that, the icons from the field of refractories had already anticipated what are called complex engineering systems today.

Refractory castables comprise a large group of materials that have grown significantly over the past 30 years. Evolving from rather simple mixes, products nowadays are based on complex and advanced formulations, and are used in a variety of very demanding applications. Considering these aspects and the distinct chemical and physical (specific surface area, densities, etc.) features of the many raw materials commonly found in the compositions, it is easy to realize that designing a castable is not an empirical and straightforward task, as it requires a wide knowledge of particle size distribution, particle dispersion, phase transformations at low (curing stage) and high temperatures (drying/firing and service conditions), chemical compatibility/equilibrium of solid/liquid/gas components (microstructure development and chemical corrosion stability), etc. Taking this into account, this book covers the major concepts related to the main steps involved in the composition development (dispersion and particle packing), processing (mixing, curing, drying) and applications, including some specific castable systems (containing MgO, spinel, carbon sources, and advanced and/or nano-materials).

This is a reference and educational book, therefore you should not expect to find everything about a particular topic in a single chapter. The same subject considering different perspectives, potential applications and respective properties can only be better assimilated when the knowledge provided by the various chapters is combined. Based on practical examples and theory, it is hoped that the complexity, evolution stages and advances of different refractory compositions and processing techniques can be identified and understood. Furthermore, by applying the presented fundamentals, high-performance castables can be designed, aiming to extend the equipment's working life and withstand harsh operational conditions.

Preface

A large number of the references quoted in this book involve the authors, as well as other current and previous members of our research group GEMM (Materials Microstructural Engineering Group). Owing to the fact that refractories have a strong technological component, most of the papers were published in proceedings and headed by industrial authors, where the general idea is usually well presented, but the whole information is not clearly disclosed, for understandable reasons. Therefore, when compiling the available data to result in a “self-flow” text, it is difficult to insert such information due to the lack of important details concerning the composition and/or packing design, dispersion, drying procedures, testing and its working conditions. Considering these aspects, you may not find a particular paper quoted as it might be part of this context.

What you are about to read stems from team work, not only involving the authors, the members of our research group, the anonymous referees who, based on their expertise, revised and suggested grammar and technical corrections (please read the Foreword), but also the whole refractory community that with determination, outstanding quality and endurance, helped to write a history that partially changed the way we live. Over time we have worked with hundreds of collaborators and it would not be possible to thank all of them. Nevertheless, more than having their names mentioned in the preface, we think that the frequency of their respective work being quoted in the text will express the due relevance and share of our gratitude. However, various others, people and institutions, might not be so often referred to in a technical text, but their importance to make things happen is remarkable. Based on that, we are deeply grateful to ALCOA for 25 years of continuous partnership, represented here by O. Carneiro, J. Carvalho, F. Feder, J. Gallo, L. Maso and E. Schiavotelo (listed in alphabetical order) and MAGNESITA, which with the technical and administrative leadership of L.R. Bittencourt and the company’s team (P. Bonadia, P. O. Brant, M. Brito and C. Pagliosa) have provided insights and brought life to most of the laboratory results carried out at GEMM. Our deep gratitude is also extended to PETROBRAS, F.I.R.E. industrial and university partners, to the staff of the Materials Engineering Department at the Federal University of São Carlos, especially to J.A. Rodrigues, FAPESP, CNPq, M. Rigaud, C. Parr, J.G. Coury and to all the researchers and professionals of the refractory area that inspired us to carry on.

S. Carlos, January 2015

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