





**Fernando Hernández Polanco**

**Refining of industrial metals,  
ferronickel refining process.  
“Secondary metallurgy”**

**Bogotá - 2018**

Original title: Refining of industrial metals, ferronickel refining process.

Illustrations: Fernando Hernandez P.

Copyright © F. Hernández P. 2018

All rights reserved. No part of publication  
may be reproduced, distributed, or transmitted  
in any manner whatsoever without the written  
permission of the author.

Revised by: Daniel Fernando Hernandez Rodríguez.  
and Peter Bergsneider Serrano

2018 Autoreseditoers.com

ISBN: 978-958-48-5388-2

Edition: Expotech & S.- Bogotá.

ferherpol@gmail.co

First published in Bogotá Diciembre 2018

*This book is dedicated  
To my wife Judith,  
to my son Daniel,  
and my daughter Laura.*

*"I am the master of my fate.  
I am the captain of my soul"*

*William Ernest Henley*



## Acknowledgments

Thank God for giving me the opportunity to develop my professional life in the world of metallurgy and especially in the area of refining industrial alloys.

I'm eternally grateful to Dr. Rodrigo Palma V. (RIP.), who in a disinterested way contributed to my instruction as a metallurgical engineer.

I have a very special acknowledgment to engineer Peter Bergsneider for the valuable help in reviewing the entire text.

I want to sincerely thank the managers of Cerro Matoso S.A., for allowing me to develop my profession in this prestigious company. To the operators, the maintainers and the technicians of the laboratory, to the supervisors and to my colleagues in the refinery area, especially engineers Héctor Bello U, Manuel Torres, Julio Sáenz Q, Clímaco Caraballo, Arturo Escobar and Jorge Díaz, who contributed to make the CMSA ferronickel refinery one of the most efficient processes in the world.

I also want to thank Rafael Ataide, president of Platinum Group Metals Corporation, and his collaborators, Kelly Ventanilla, Merceditas Nejar-da, and Rex Escuadra; for hosting me at the Iligan Philippines plant as a metallurgical process consultant.

Thanks to my friends from Brazil, Simão Pedro Oliveira and Eliseu Gimenez Fenelon from Magnesita S. A., To engineer Flavio Lemus for allowing me to contribute with my experience in starting the refinery in Onça Puma and also to Camilo Romanha. To company Vale S. A., for accepting me as a process consultant and to all the operators, supervisors and engineers, especially José Henrique Moreira, José Antonio Rodríguez Jr, Chris Doyle, and Roberto Damasceno.

A very special recognition to the consultants from HATCH and in particular to Egil Jahansen, the Vendors like ASEA-SKF, RIMAX S.A, INTECO GROUP, UCAR Co and RHI, with whom I had the opportunity to discuss and exchange knowledge.

Finally, I want to thank my wife Judith, my daughter Laura and my son Daniel, who encouraged me to write this book.



## Preface

This text describes in chronology the evolution of the refining processes of metals from the elaboration of arsenical bronze, the obtaining of iron, the refining of steel in converters and the refining of ferronickel in furnace crucible.

This work is not a scientific text or the product of an isolated research. In the first part, I present to the reader how the technique of purifying copper and iron is developed up to refining steel on an industrial scale. In the second part, I refer to the metallurgical processes that were developed to refine the crude ferronickel produced in electric reduction furnaces from nickel ore (laterites).

In relation to the practical process of refining ferronickel, the work is based on a series of experiences during my professional performance at Cerro Matoso SA of the BHP-Billiton group in Colombia, at Maria Cristina Corporation Industries Co in Iligan, Philippines and on Onça Puma of the group VALE / SA in Ourilândia do Norte, Brazil.

I have observed that, during the start-up and stabilization of commercial production, a series of accidents have occurred, attributed to design errors and ignorance of the operation, which have caused a series of problems that have forced the suspension of the operations with the economic consequences translated into losses for shareholders.

On the other hand, I wanted to record in this book these lived experiences not with the intention of questioning the designers or the suppliers of the technology to refine ferronickel, but rather with the main purpose of providing tools to improve the refining process. In this work, I do not refer to capital investments, operational costs or the profitability of the processes.

On the other hand, by not having valid and pertinent information on the incidence of ferronickel refining processes carried out in the current Russian Federation, in China, and in India; I not refer, will to them without ignoring its technological development and its great importance and the development of ferronickel refining in the world.

The preparation of this text is supported by bibliographical references that have been obtained from the literature, technical publications and electronic documents Taken from the Internet. The text was divided into 10 chapters as follows:

In chapter 1, I mention the history of the origin of metals, how they are in a pure state in nature and in minerals forming compounds.

In chapter 2. I refer to the procedures that man found the technology to obtain pure metals from minerals, then bronze and iron to the development of good quality steel (*Wootz steel*).

In Chapter 3, I give a description of the chemical and technological properties of metals and how other elements influence the crystal-line structure responsible for the mechanical properties.

In chapter 4, I present the theory of the refining of metals and alloys, the processes to eliminate impurities by pyro-metallurgy (in liquid and solid state) or by hydro-metallurgy with chemical or electrolytic methods.

In Chapter 5, I refer to the procedure developed since 1780 to refining pig iron in a reverberatory furnace. In 1850 H. Bessemer developed a method to blow air through pig iron in order to oxidize impurities. In 1865 C. Siemens designed an open hearth furnace to refine pig iron. After the Second World War, Linz-Donawitz-steelmaking develops a process to refining steel with oxygen blow to reduce using a refrigerated lance (LD). After 1960, the refining of steel in the crucible was implemented.

In Chapter 6, I present the production process of several alloys developed to refine steel and produce other ferroalloys.

In Chapter 7, I refer to the main ferronickel producing plants that have a refining station to supply a high-quality product to the world market.

In Chapter 8, I make a description of the theory of each stage of the refining process of ferronickel, taking into account the role of synthetic slag and aggregate ferroalloys to deoxidize molten metal and achieve the technical specifications.

In Chapter 9, I refer to a detail operation of each refining stage of the ferronickel in a crucible furnace.