GMELIN-DURRER

Metallurgy of Iron

Fourth, Totally Revised Edition

CONTINUED BY H. Trenkler and W. Krieger

Volume 8

Practice of Steelmaking 2

Volume 8a: Text

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The Open Hearth Process. The Electric Arc Furnace Process. Induction Furnace Melting. New Electric Steelmaking Processes. Continuous Steelmaking

Volume 8a: Text

(Volume 8b: Illustrations
English and German Subject Index

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Preface to Volumes 7, 8 and 9

The previous volumes of this series treat the general physico-chemical principles of ironmaking (Volume 1), the thermal pretreatment of iron ores (Volume 1), the principles of ore reduction as well as the technical details of the ore reduction processes outside of the blast furnace (Volume 2), and the production of hot metal in the blast furnace (Volumes 3 and 4).

Steelmaking has today become an extremely broad area of empirical and theoretical endeavor. During the past decades the theory of the processes involved in the production, treatment, and solidification of steel has been intensively studied. Although experience is still very important, today's steelmaker can no longer perform efficiently without this theoretical knowledge. Two volumes (5 and 6) therefore were devoted to the theory of steelmaking.

The technology and metallurgy of steelmaking, which had been easy to survey prior to the Second World War when relatively simple air refining or hearth processes were in use, have been expanded and developed into a broad and multifaceted technical field. The progress in converter technology and secondary metallurgy has been especially impressive. But even in the field of electric furnace steel production alternative ideas have been developed in the last few years. It has always been a consideration in the concept of this series that the gap be bridged between technologies that are losing significance or are no longer used and the most recent developments. The purpose of this is to document the learning process through which the steelmaking industry has progressed in the last decades and to present this process didactically in these volumes.

To present the state of the art in such a way that the specialist can obtain a sufficiently good insight into the relationships between different aspects of the field it was necessary to divide the material on practical steelmaking into three volumes. Volume 7 gives a thorough review of the raw materials and additives important in steelmaking, such as scrap, alloying additions, and slag formers, especially lime. Furthermore it appeared important to us to discuss the sampling of hot metal and liquid steel and the measurement of temperature. In addition, the unfired processes of steelmaking are discussed in Volume 7, where the greatest emphasis is on the oxygen blowing processes.

Volume 8 treats fired steelmaking processes and continuous steelmaking with special reference to the modern electric arc furnace and its metallurgy. The newest developments, such as the plasma furnace or the direct-current arc furnace, are also discussed in all respects.

The first part of Volume 9 discusses secondary metallurgy. The casting of steel is treated in detail with greatest emphasis on continuous casting. Separate chapters are devoted to steelmaking using powder metallurgy and to the automation of steelmaking processes, thus completing the treatment of practical steelmaking.

Because of the variety of the material and the differences in the opinions of experts that sometimes occur in specialized areas, we found it necessary to cover the literature extensively to provide a comprehensive in-depth presentation of the subject. This effort has demanded a great deal of time. We sincerely thank the authors, all recognized experts in their fields, who were willing to prepare treatises on their specialized subject areas in addition to pursuing their usual professional work.

The current volumes devoted to steelmaking practices are directed to a diverse group of metallurgists, just as were Volumes 5 and 6 on the theory of steelmaking. Included are the scientists in research institutes as well as practicing metallurgists who wish to orient themselves quickly with the state of the art in specialized areas. These books should also be useful to the more advanced student since they have been given a definite didactic character.

With these goals in mind it is hoped that this work will be of service to all who are concerned with steelmaking.

Leoben, Linz
December 1983

H. Trenkler W. Krieger

Foreword to Volume 8

Following the description in Volume 7 of the unfired steelmaking processes, the fired processes are covered in Volume 8. An adequate amount of space is dedicated to the open hearth (Siemens-Martin) process despite the fact that its importance is steadily dropping. This is because the process is still extensively employed in various regions of the world and its share of the world raw steel production in 1982 still amounted to about 20%. The central theme of Volume 8 is electric steelmaking, whose importance for the future is unquestionable. In the treatment of this technical field we have attempted to display the current competition among the various approaches, for instance, electric arc furnaces vs. plasma furnaces, alternating current vs. direct current. A separate section is devoted to continuous steelmaking.

Leoben, Linz
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H. Trenkler W. Krieger

Published Volumes of Gmelin-Durrer "Metallurgy of Iron"

Volumes 1a and 1b

Historical. Definitions. General physico-chemical principles. Thermal pretreatment of iron ore – 1964

Volumes 2a and 2b

General requirements for the commercial reduction of iron ore. Raw materials. The technology of iron ore reduction processes outside of the blast furnace – 1968

Volumes 3a and 3b

Blast furnace, Part 1: Blast furnace plant. Blast furnace practice. Pig iron and b products. Iron production in the world – 1971

Volumes 4a and 4b

Blast furnace, Part 2: Blast furnace process. Relationship between operating conditions and results. Mathematical models and automation – 1972

Volumes 5a and 5b

Theory of steelmaking, Part 1: The term steel. Steelmaking methods. Theoretical principles: Constitution of steel melts. Constitution of steelmill slags. Use of theoretical principles [illegible] analyses of the processes occurring during refining and treatment of stee[illegible] [illegible]978

Volumes 6a and 6b

Theory of steelmaking, Part 2: Kinetic principles of steelmaking. Formation and behavior of nonmetallic phases in the iron bath. Principles of solidification of steel melts – 1978

Volumes 7a and 7b

Practice of steelmaking, Part 1: Charge materials and additives. Sampling and temperature measurement. Unfired processes – 1984

Volumes 8a and 8b

Practice of steelmaking, Part 2: The open hearth process. The electric arc furnace process. Induction furnace melting. New electric steelmaking processes: plasma melting, direct-current electric arc furnace. Continuous steelmaking – 1985 (present volumes)

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1 The Open Hearth Process (Siemens-Martin Process)

Günther Schober
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Introduction. The process is called "Siemens-Martin process" (SM process) in German speaking countries, "Martin process" in France and the USSR, and in England and the USA it is known as the "open hearth process" [5].

The open hearth process is a hearth refining process in which the impurities in the iron (C, Si, Mn, and others) are oxidized by the refining action of the oxygen contained in the furnace atmosphere and in the charge (ore, rollscale, oxide), and in which heat is supplied by fossil fuels. In recent years the injection of technically pure oxygen into the steel bath has been introduced for acceleration of the refining. To reach sufficiently high temperatures, the principle of regenerative heating is used for either both the fuel and air or only for air in the case of richer fuels.

In contrast to converter processes, the open hearth process does not operate without an external supply of heat because on the one hand, the oxidation of the impurities does not supply sufficient heat for the process and on the other hand, the aim is to use large proportions of solid charging materials. The composition of the burden can vary widely and in extreme cases can be almost 100% scrap or nearly 100% pig iron, either in liquid or solid form. The open hearth process is thus highly adaptable to using the charging material that is economically most favorable [4]. See "Gmelin-Durrer" Vol. 5a, Section 1.1.2.1

The open hearth process is suitable for melting carbon steels as well as alloyed steels.

In **Fig. 1**, p. 1b, the process is shown schematically.

Because of the versatility of its heating and charging, the open hearth process was for many decades the most important steel-producing method. Since the development of the more efficient LD process and high-power electric arc furnaces which assure the same steel quality, yet produce steel more cheaply, the open hearth process has lost more and more of its importance. The oxygen blowing process took over especially where charges consisted of large proportions of hot metal, while the electric arc furnace process became more widely used with charges that had large proportions of solid scrap. See "Gmelin-Durrer" Vol. 5a, Section 1.1.2

While open hearth furnaces produced 78.7% of the world's steel in 1950, in 1982 their percentage of production was only about 20% and it is still shrinking today [1, 2, 13, 23].

A review of the open hearth furnaces still operating in 1977 and their charge weights can be found in [3]. Most of the open hearth furnaces currently still in use are in the USSR and the USA [17].

Fig. 2, p. 2b, shows the world's open hearth crude steel production in the period between 1965 and 1982 [24 to 31, 37 to 39]. **Fig. 3**, p. 3b, and **Fig. 4**, p. 3b, show the open hearth steel production of Europe (without the COMECON states), of the USSR including the COMECON states, and of the USA and Japan during the period of 1960 to 1982, in other words of the countries which have the largest proportion of the world's crude steel production. While the production of open hearth steel in the USSR still continued to increase between 1965 and the end of the seventies [32], in the rest of Europe as well as in the USA it sharply decreased in spite of the increasing world-wide steel production, and in Japan it was completely eliminated.

1.1 Historical Review

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The patent for a gas generator by Wilhelm Siemens provided, together with the principle of regenerative heating developed by his brother Friedrich Siemens, the basis for the production of high flame temperatures. Based on these concepts, father and son Martin constructed a furnace in their small foundry in Sireuil, France, in which they were able to melt steel in an open hearth. Their melting furnace was lined with Dinas bricks. The acid open hearth furnace was thus created and its use spread rapidly. On April 8, 1864, the first useful steel was melted and processed at Sireuil. It was Martin's idea to charge scrap (Bessemer steel scrap) and he found that rust was highly desirable because it decarburized the hot metal that was part of the charge. It is thus proper that the process is named the Siemens-Martin (open hearth) process.

The open hearth process received its greatest impetus only in 1879 when dolomite was introduced as the refractory material in the basic converter process. From 1880 on, dolomite was used as material for the construction of the hearth and lime was used as the slag former. From that time on, the basic open hearth furnace started its path to steelmaking dominance across the world [6]. Actually during the first two thirds of its history, the basic concept of the open hearth furnace hardly changed except for its tendency to ever larger sizes (from 1.5 ton melt weight in Sireuil to the current 900 ton facilities in Russian steelmills) [3]. The development of its modern construction really only started during the nineteen-thirties with the development and introduction of temperature fluctuation-resistant magnesite and chrome-magnesite bricks for the construction of the upper furnace. The striking developments leading to today's modern, high-efficiency furnace were made in the last 40 years. The cold-gas fired furnace without gas-preheating chambers which was already developed prior to the Second World War, especially in Germany, used coke-oven gas which, due to its high calorific value, did not require preheating. At about the same time, oil and natural gas fired open hearth furnaces became operational in the USA and also in the USSR, mainly by simply modifying the old warm-gas furnaces. The dominance of the oil-fired furnace, however, only began after the end of the Second World War in Europe as well as in other regions. Natural gas, another high calorific gas, increasingly began to be used. Warm-gas heating (producer gas or mixtures of blast-furnace gas and coke-oven gas) has completely disappeared today except in a few old furnaces [33].

When after the Second World War, oxygen was introduced into the steel industry, it also affected the technology and metallurgy of the open hearth process (see also Section 1.3.2.9). The last stage in the development of the furnace is recognized by the building block concept of construction of the upper part of the furnace which is an assembly of individual prefabricated parts.

The open hearth furnace reached its highest stage of development and efficiency at the time when it already had started to decline because of technological and economic reasons.