Preface

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2007 was a record year in terms of world steel output. A total of 1.351 bn tonnes of crude steel were produced during that year, thereof 422 million tonnes via the electric steelmaking route. This represents a share of 31.2 %. However, the share of electric steelmaking varies markedly in the regions of the world. The share is biggest in the Middle East, accounting for 85.9 %. In total figures this, however, amounts to only 13.8 million tonnes. In the United States of America, 58.9 % (57.8 million tonnes) of the steel is produced via the electric steelmaking route. The highest output, namely 84 million tonnes, is achieved in the 27 member states of the European Union, accounting for 40.2 %. These figures illustrate the importance of electric steelmaking in the various regions of the world.

A total of 530 million tonnes of scrap were used to produce the 2007 crude steel output, making a major contribution to environmental protection and efficiency in resource and energy use. I estimate the scrap input to produce the world electric steelmaking output at about 415 million tonnes. The recycling rate of the total steel output is 34.5 %. The electric arc furnace improves resource efficiency. By the way, the recycling of steel is higher than that of any other metal.

Scrap is a secondary raw material. Almost 90 % of scrap is metallic iron. Steel scrap has already undergone the process of iron ore reduction which in blast furnace/BOF steelmaking is almost completely (more than 90 %) effected by carbon. Accordingly, scrap-based steelmaking produces much lower CO_2 emissions. Whereas high-efficiency BF/BOF steelmaking generates about 1.85 tonnes of CO_2, including cokemaking and sinter plants, the equivalent figure for an EAF is only about 400 kg CO_2 per tonne of crude steel, assuming a CO_2 freight of 570 g per kWh of supplied electrical energy. This is a significant advantage with a view to the objective of reducing CO_2 emissions.

Scrap will certainly remain the most important input material in electric steelmaking. Nevertheless primary raw materials from direct reduction of iron ore have been playing a gradually increasing role recently. Direct reduced iron can be produced, for example, by the Midrex process, which was developed at the end of the 1960s and during the 1970s. The most commonly used reductant is natural gas converted to CO and H_2. In 2007, the record year of steel production, approximately 65 million t of DRI were produced, with India accounting for the biggest share, namely 18 million tonnes.

High or ultra-high power electric arc furnaces with specific transformer ratings of 1,000 kVA per tapped tonne achieve tap-to-tap times of some 40 minutes today. A modern ultra-high chemical power electric arc furnace (UHCP), which can be operated in a burner mode using eight 8 MW natural gas-O_2 burners, achieves production rates of 320 tonnes per hour. The trend towards ever higher output rates started in the late 1960s when it became clear that it was not a technologically reasonable option to retrofit the existing open hearth furnaces, which were major consumers of scrap, with dust removal equipment. This trend gained additional momentum in the 1970s when electric furnaces with water-cooled walls were developed. However, the fact that the secondary voltage was initially limited to 1,000 V brought the continuing capacity growth to a temporary halt. When this limit was overcome, high-capacity furnaces for 100 to 150 tonnes charge weight could be built. Higher secondary voltage resulted in increased radiation from the electric arc on the furnace walls. When foaming slag practice was introduced, the electric arc could be covered during flat bath operation, shielding the furnace walls against excessive radiation. The dramatic improvement in efficiency, from tap-to-tap times of about three hours in the 1960s down to approximately

40 minutes, was accompanied by a corresponding decrease in energy consumption. Electric energy consumption was brought from 630 kWh per tonne down to 345 kWh per tonne, or -45 %; electrode consumption was cut by 83 %, from 6.5 kg per tonne to 1.1 kg. Although the dramatic reduction in tap-to-tap times was the main driver of this positive development in consumption figures, it must not be left unmentioned that the low rate of electrode consumption was also enabled by the simple, though ingenious practice of spray cooling the graphite electrodes.

We certainly also owe this impressive efficiency improvement to a great deal to the cooperation work between the Electric Arc Furnace Committee of the Steel Institute VDEh, the USA and Japan. The momentum triggered by exchange of ideas and experience is not to be underestimated. Since 1982 the Electric Arc Furnace Committee of VDEh has organized seminars with a special focus on electrical engineering aspects of the electric arc furnace. Under the expertise of Prof. Dr. Klaus Timm, Professor Emeritus at the University of the Federal Armed Forces Hamburg (nowadays Helmut-Schmidt-University) and, since the mid-1990s, co-organized by Prof. Dr. Klaus Krüger, University of the Federal Armed Forces Hamburg, these seminars are intended to provide metallurgists important knowledge about electrotechnical aspects of electric arc furnaces. The German-speaking seminar was last held in May 2009, for the 30th time. Since 2000 there is also an English equivalent. The most recent one in a line of eight was held in May 2008.

The initiative to publish this book came from Dr. Ben Bowman, when he retired as consultant to GrafTech.

Dr. Ben Bowman, born in 1939, studied physics at the University of Liverpool where he was awarded a B.Sc. in 1961, followed by a Ph.D. in electrical engineering in 1965 based on research into electric arcs under the guidance of Professor Harry Edels. He commenced his involvement with arc furnaces in 1965 at the Arc Furnace Research Laboratory in Sheffield, England, of the United Steel Companies (later British Steel Corporation), at that time the operator of the largest electric steelshop in the world (6 furnaces, 7.3 m dia., 40 MVA). It is now a museum!

He joined UCAR Carbon Company Inc.(Now GrafTech International) in 1971 at the European Headquarters in Geneva, Switzerland, as a customer technical service manager for arc furnace technology.

Dr. Bowman has authored more than 40 publications and seminars in the field of furnace arcs, AC and DC furnaces, electrode and refractory consumptions. In 1981 he suggested the addition of a reactor on the primary of arc furnaces in order to stabilize the long arcs being sought by steelmakers after the successful introduction of water-cooled panels. This idea was taken up in South Africa in 1983 and has since developed into the now standard High Reactance Arc Furnace. That same year Dr. Bowman created an entertaining and instructive arc furnace computer game for steelmakers (at the 1st European Arc Furnace Conference in Aachen).

In 1993, Dr. Bowman became a Senior Corporate Fellow and accepted a position at GrafTech's Parma Technical Center in Parma, Ohio, where he added electrode development to his continuing studies of arc furnaces.

In 2003 he retired but has kept an active interest in arc furnaces. He has acted as consultant to GrafTech while writing the book on Arc Furnace Physics with Prof. Klaus Krüger.

Klaus Krüger, born in 1967, took up a career as an officer of the Federal Armed Forces after his graduation from secondary school. Doing so, he studied mechanical engineering at the University of the Federal Armed Forces in Hamburg. On completion of his studies at the end of 1992 he was honoured with the Böttcher award for his results. After 1½ years in the army, Klaus Krüger accepted to return to the university in order to conduct research for a doctoral thesis. Being a scientific assistant to Prof. Klaus Timm from 1994 to 1998 he acquired profound knowledge about the electric arc furnace. In November 1997 Klaus Krüger finished his dissertation about the development of a closed-loop power control for AC arc furnaces. Leaving the army Klaus Krüger joined to the Robert Bosch GmbH, where he was in charge of the production of microhybrid automotive Circuit Units from 1998 to 2003. In 2003 the chair of Process Data Processing and System Analysis at the University of the Federal Armed Forces Hamburg was offered to him. Assuming this professorship, he reconnected to his roots of electric arc steelmaking, which now presents an important field in his research activities.

Ben Bowman and I first met in 1971, the year when I started my industrial career as an electric steelmaker, and I have held him in high esteem ever since. I first met Klaus Krüger when he was working on his doctoral thesis under Professor Timm. With great pleasure have I been following his great achievements in not only continuing but greatly advancing the research issues commenced by Professor Timm.

I am glad that I have been able to bring together two authors from two generations and living some 8,000 km apart – in Ohio/USA and in Hamburg/Germany – to join forces for this work. Since the middle of 2008, they have had a one to two hour telephone conference every Wednesday afternoon to exchange and coordinate their ideas. The result is a highly comprehensive, excellent encyclopedia of the physics and electrics of the electric arc furnace, a technology which still holds much development potential to be tapped. Congratulations for both authors on this remarkable work.

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Chairman of Electric Arc Furnace Committee of VDEh from 1981 to 1986
Chairman Steel Institute VDEh from 1998 to 2008
President German Steel Federation from 2000 to 2008