

Chapter 7

Pre-Treatment of Hot Metal

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7.1 Introduction

Pre-treatment of hot metal is the adjustment of the composition and temperature of blast furnace produced hot metal for optimal operation of the oxygen converter process; as such, it is one of the interdependent chain of processes that constitute modern steelmaking¹, Fig. 7.1. When taken to the extreme case, the converter process function is reduced to scrap melting and carbon reduction subsequent to the prior removal of silicon, phosphorus and sulfur in preparatory steps under thermodynamically favorable conditions. An important benefit of removing phosphorus and sulfur from the hot metal prior to the oxygen converter process is the ability to produce steels with phosphorus and sulfur contents lower than otherwise achievable without severe penalty to the converter process. Silicon removal is beneficial to the converter to reduce the chemical attack on the basic refractory lining and to allow the use of only minimal amounts of slag-making fluxes, thereby maximizing process yield.

Hot metal pre-treatment by North American and European steel producers presently is focused on desulfurization due to the common use of relatively low phosphorus containing iron ores.

In a unique approach to pre-treatment, ISCOR, in South Africa, installed a hot metal mixer equipped with channel inductors to provide electrical energy to heat the liquid, and thereby raise the scrap melting capability of the steel plant.

Details of the process steps introduced above are provided in the following sections.

7.2 Desiliconization and Dephosphorization Technologies

The introduction of oxygen converter technology in Japan occurred at a time of limited availability of high quality scrap, and, as a result, the desire was to minimize the use of this expensive resource. Steel production was focused on the use of controlled, prepared raw materials. The technologies developed for the efficient removal of silicon and phosphorus from the hot metal, both fundamentally endothermic when carried out using the customary oxide reagents, provided an economic benefit by consuming chemical energy otherwise available for melting scrap in the converter. By 1983, a large number of pre-treatment facilities were in use, Table 7.1.^{2,3}

Initially, these pre-treatment processes were performed by adding iron ores or sinter to the hot metal⁴ during its flow in the blast furnace runner. Further improvements and control over chemical

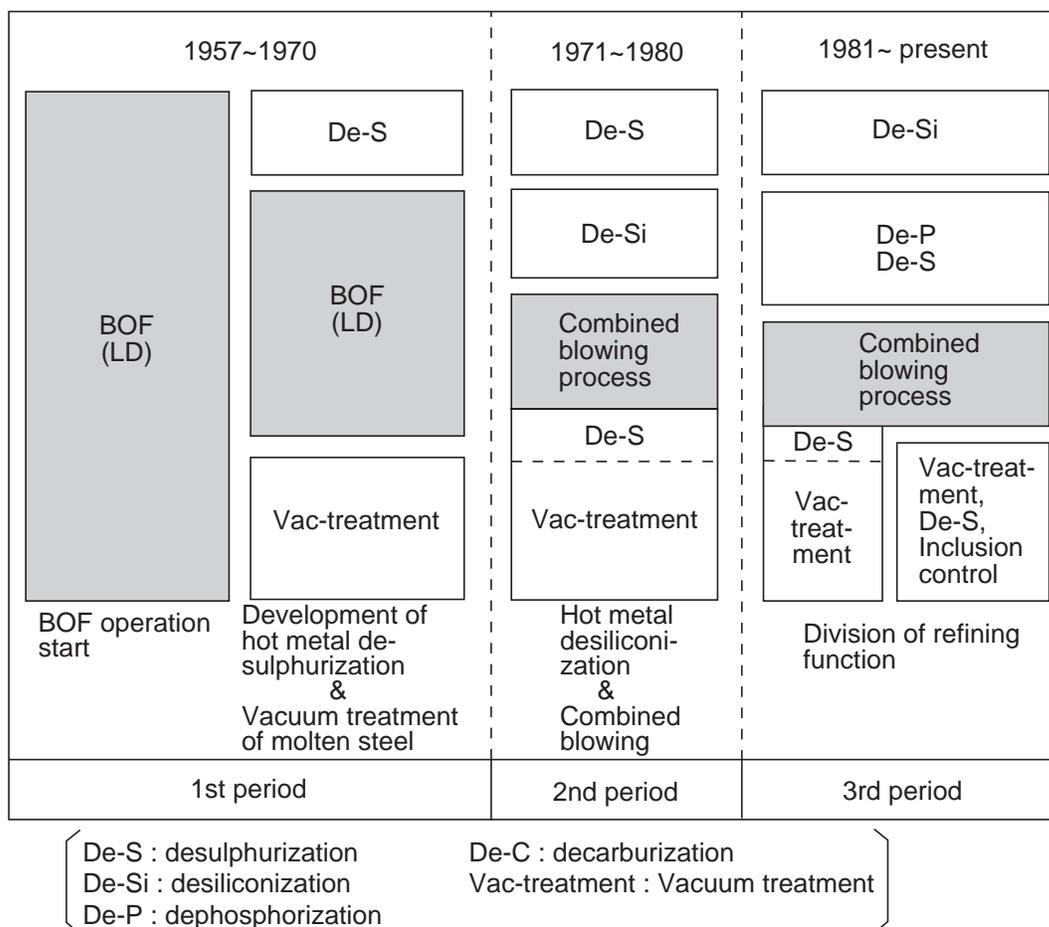


Fig. 7.1 Changes in refining functions in the Japanese steel industry. From Ref. 2.

results were attained⁴⁻⁸ by the addition via subsurface injection of the reagents in dedicated vessels, such as oversized torpedo or submarine cars. This brought on the use of a variety of chemical reagents, including soda ash (sodium carbonate), which also provides for significant removal of sulfur. When using iron oxides for desiliconization, it is essential to separate, i.e., remove, the process slag before the hot metal is desulfurized as this operation requires low oxygen potential for efficient performance. It is important to recognize that phosphorous removal occurs only in hot metal containing less than 0.15% Si, additionally, phosphorus held in the slag could be subject to reduction, i.e., reversal, into the hot metal if it were present during desulfurization. An interesting technical development was the combination of dephosphorization and desulfurization in a single vessel whereby⁵ phosphorous is reacted with the oxidizing reagents as they rise in the liquid and sulfur is removed by the top slag in the vessel, Fig. 7.2.

Desiliconization and dephosphorization are accompanied by losses of carbon from the hot metal and evolution of CO₂ from carbonate reagents.⁴ Thus, control strategies such as addition of coke breeze⁹ or equipment accommodations must be made in the reaction vessel and gas capture systems to contain foaming and flame evolution. In the recent timeframe, environmental considerations over disposal of sodium-containing slags has forced the use of limestone based reagents, often mixed with iron ore or sinter fines and delivered with oxygen, the latter used to diminish the thermal penalty from the pre-treatment process. Oxygen consumption in these process steps is illustrated in Fig. 7.3.

Table 7.1 Hot Metal Pre-treatment Facilities in Japan (1983). From Ref. 3.

	Desiliconization equipment				Dephosphorization equipment					
	Desiliconization in blast furnace runner		Desiliconization transport vessel		Dephosphorization in transport vessel (soda ash)		Dephosphorization in transport vessel (lime-based flux)		Dephosphorization in furnace for exclusive use (converter)	
In operation	NSC	Kimitsu (No.2, 4 BF) Yawata (No. 4 BF)	NSC	Muroran Yawata Sakai Nagoya (No. 1 LD plant)	NSC	Yawata (No. 1 LD plant)	NSC	Kimitsu Nagoya (No. 1 LD plant)	KSC	Chiba (No. 2 LD plant)
	NKK	Fukuyama (No. 4 BF)	NKK	Fukuyama	NKK	Fukuyama		Muroran Yawata		Mizushima
	KSC	Chiba (No. 6 BF)	SMI	Kashima	SMI	Kashima		Chiba (No. 1 LD plant)	KSL	Kobe
	SMI	Kashima (No. 3 BF) Wakayama (No. 4 BF)								
	KSL	Kobe (No. 3 BF)								
Planned or under construction	NSC	Oita (No. 2 BF)	NSC	Nagoya (No. 2 LD plant)	NISSHIN	Kure	NSC	Oita Nagoya (No.2 LD plant)		
	NKK	Fukuyama (No.2 BF) Keihin (No. 1 BF)	NKK	Keihin			NKK	Keihin		
			SMI	Wakayama			KSC	Chiba (No. 3 LD plant)		
	SMI	Kokura (No. 2 BF)	KSL	Kakogawa			SMI	Wakayama Kokura		
	NISSHIN	Kure (No. 2 BF)					KSL	Kakogawa		

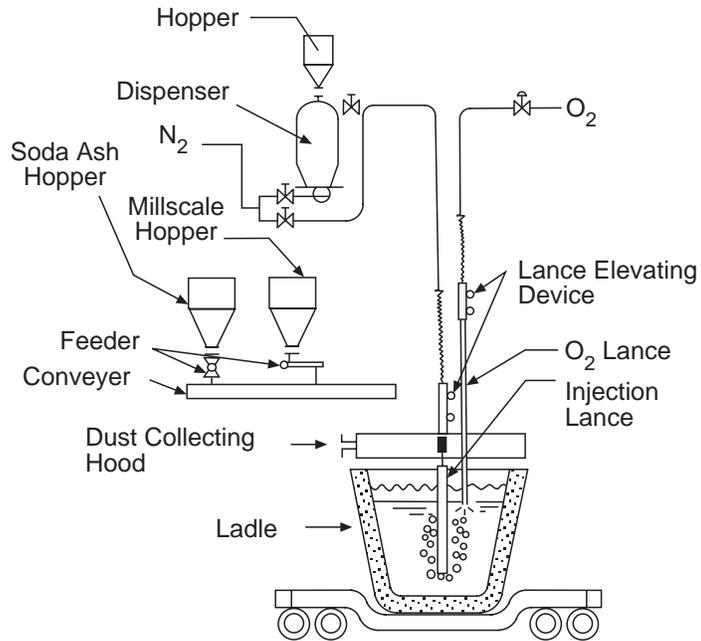


Fig. 7.2 Equipment for concurrent dephosphorization and desulfurization. From Ref. 7.

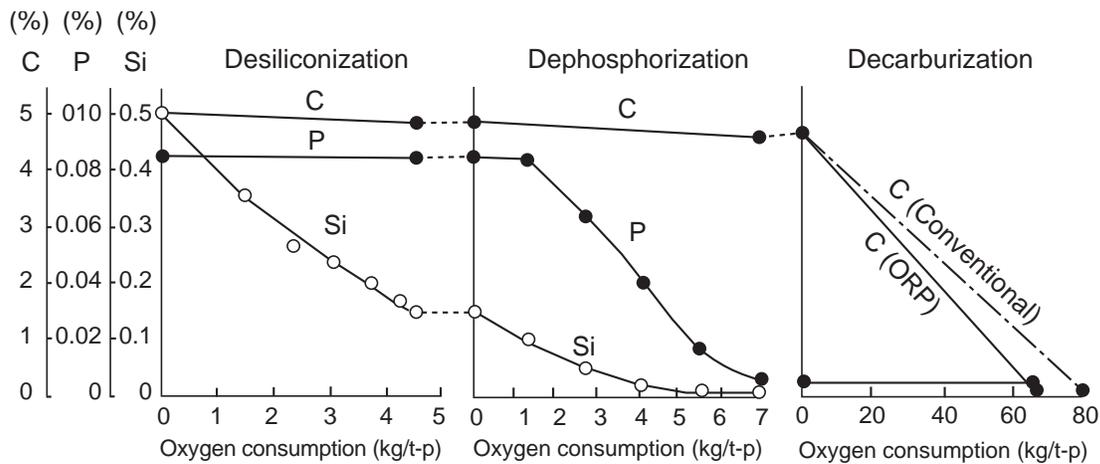


Fig. 7.3 Changes in silicon, phosphorus and carbon contents of iron in each stage of steelmaking. From Ref. 4.

In some plants, the silicon and phosphorus removal steps occur in full size oxygen converter vessels and the resulting carbon containing liquid is transferred, after separation of the low basicity primary process slag, into a second converter, Fig. 7.4, for carbon removal by oxygen top blowing.^{4,7} In this sequence, the slag from the second vessel is used as a starter slag for the first step. In a way, this is today's equivalent of the former open hearth process, which provided for flushing of the initial silica and phosphorus rich slag and thus allowed the use of hot metal made from phosphorus bearing ores for production of what was then considered low phosphorus steels.

7.3 Desulfurization Technology

7.3.1 Introduction

"...sulfur is frequently found in metallic ores, and, generally speaking, is more harmful to the metals, except gold, than other things. It is most harmful of all to iron..." so wrote Agricola four and one half centuries ago.¹⁰ From ancient times, through puddling furnaces and into blast furnaces,