NEW REFRACTORY CONCRETES AND BINDING SYSTEMS: BASIC TRENDS OF DEVELOPMENT, PRODUCTION, AND USE OF REFRACTORIES IN THE XXIst CENTURY.
PART I. TRENDS OF DEVELOPMENT, BINDING SYSTEMS

Yu. E. Pivinskii

Translated from Ogneupory i Tekhnicheskaya Keramika, No. 2, pp. 4 - 13, February, 1998.

Original article submitted October 20, 1997.

General trends in the development, production, and service of refractories are considered. The share of refractories used in ferrous metallurgy amounts to 60 - 70%, which means that the predominant trend is determined by the requirements imposed on the refractories used in the steel industry. The proportion of unshaped refractories in the total production will inevitably grow. The basic problem in this field is the improvement of their matrix (disperse) phase, i.e., the binding system. The main types of refractory binders, of which highly concentrated ceramic binding suspensions (HCBS) are the most interesting, are considered. In contrast to natural ceramic binders (clays) HCBS are artificial systems that can be obtained on the basis of many refractory materials. The priority aspect in the creation of new refractory concretes (castables) and binders is described. The first artificial ceramic binders and cement-free refractory concretes based on them were created and installed by the author at the end of the 60s, and in the 70s he suggested many types of ceramic castables, including superlow-cement ones.

1. MODERN TRENDS

Analyzing the specific volume of world consumption of refractories [1 - 7], we will see that in recent decades about 60 - 70% of refractories have been used in ferrous metallurgy. This is a fact that requires attention because the intense development of out-of-furnace treatment has turned the ladle into the main manufacturing device. It is used for a large number of metallurgical operations over a considerable time and with intense mixing of the metal. For this reason, the requirements on the quality and reliability of ladle linings are very strict; they should provide high endurance and minimum wear. The greatest successes of the leading metallurgical firms in Japan have been achieved in the development and use of new castables [9 - 11]. Substantial progress in the use of new refractory materials has been achieved in the field of monolithic linings of intermediate ladles. These trends are important from the standpoint of predicting advances in the production of refractories because the proportion of refractories used in linings of steel-teeming and intermediate ladles is about 40 - 60% of their total consumption in converter production of steel. At the present time all ladles (including intermediate ones) in Japanese plants have a monolithic lining of the side walls. In Europe (and especially Russia) brick linings still predominate although transition to
40 Yu. E. Pivinskii

Fig. 1. Dynamics of the change in the annual volume $A_t$ of the production of unshaped (1) and shaped (2) refractories in Japan and in the relative fraction of the class of unshaped refractories $Unsh$ in their general balance (3).

Fig. 2. Dynamics of the change in the relative fraction $F$ of the production of the most important types in the class of unshaped refractories in Japan: 1) castable refractory concretes; 2) mixtures for guniting; 3) ramming mixtures; 4) plastic mixtures.

Monolithic linings is inevitable because of their exceptional efficiency.

Figure 1 presents the dynamics of the change in the annual volume of production of refractories, and Fig. 2 shows the dynamics of the change in the relative fraction of production of the most important types of unshaped refractories in Japan. It can be seen that production of shaped refractories has fallen quite markedly (curve 1 in Fig. 1), whereas the volume of production of unshaped refractories has remained relatively stable (for the last twenty years). From 1980 to 1994 the fraction of unshaped refractories in the general balance has grown from 35 to 55% (see curve 3 in Fig. 1). Proceeding from the rate of growth of the proportion of unshaped refractories in the 90s (over 2% per year), we can assume that as early as 1998 Japan will surpass the 60% level in the production of unshaped refractories. This places Japan much ahead of the U.S. (44%), the FRG (35%), and Russia (33%).

Castable refractory concretes constitute the greatest part of unshaped refractories (curve 2 in Fig. 2). The rate of growth of their production is also maximum. This is a result of the development and wide use of new castables in Japan not only for monolithic linings of steel-teeming or intermediate ladles but also for steel degassers, blast furnaces, open-type ladles, oxygen converters, arc furnaces, etc. In addition, these castables turned out to be effective in monolithic linings of heating units in the nonferrous industry (aluminum), the cement industry, power engineering, garbage furnaces, etc.

Advances in the field of refractories are connected with the development and use, in foreign countries, of refractory concretes known as castable thixotropic refractory mixtures [5, 7 – 18]. In addition to their use in the form of monolithic linings these refractories are used successfully in many critical large-size shaped parts such as socket blocks of steel-teeming and intermediate ladles, blocks for bottom blowing and for immersion tuyeres for top blowing of steel in the ladle, blocks for the tuyere layer of blast furnaces, protective plates for converters, arch blocks for arc furnaces, protective plates for the zones of incidence of the stream in casting and intermediate ladles, etc.

It should be noted that the classification of unshaped refractories is somewhat arbitrary. We classify them here in accordance with the method of use rather than the composition. All mixtures (ramming, plastic, guniting) are castables that differ substantially in their consistency and rheological properties. Upon correcting the moisture content and introducing liquefying and other additives that make it possible to control the rheological properties, many refractory mixtures with similar chemical and grain compositions can be used for different purposes, namely, as self-flowing (without vibration), vibration-cast, vibration-pressed, pressed, rammed, and guniting mixtures. Refractory solutions (mortars) are also a kind of special-purpose fine-grain castable. A common problem of all these kinds of castable materials is that of their matrix (finely dispersed) phase, represented by a binding system. Therefore, progress in the field of unshaped refractories is connected predominantly with improvement of existing binding systems and creation of new ones.

2. BINDING SYSTEMS: GENERAL INFORMATION AND CLASSIFICATION

A weak point of conventional refractory concretes fabricated with the use of a binder based on liquid glass, phosphates, and alumina or high-alumina cement [1, 2, 19 – 23] consists in their diminished mechanical and thermomechanical properties. In the last 10 – 20 years at least two new trends have appeared in the development and use of effective castables. One trend involves hydration-hardening castables and provides a substantial decrease in the content of high-alumina cement mostly due to the development of composite binders where a major portion of the cement is replaced by a highly