# REFRACTORIES IN HEATING UNITS

## REFRACTORY MATERIALS AND METHODS FOR INCREASING THE LIFE OF CONVERTER LININGS FROM EXPERIENCE OF OOO GRUPPA MAGNEZIT

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Experience of using OOO Gruppa Magnezit refractory materials in the lining of acid converters in Russia and the Ukraine is summarized briefly. Information is provided on the basis of results obtained in different metallurgical enterprises about the practice of using a set of measures promoting an increase in the operating life of converter linings.

Steel production in converters using oxygen combined with ladle finishing and pouring into a CBCM is developing effectively in the direction of energy and resource saving technology [1]. The requirement for reducing specific expenditure with an increase in the volume of production of converter steel gives rise to a constant trend towards increasing converter lining life. For Russia and the Ukraine the importance of this problem emerges from the fact that the proportion of steel produced in converters will increase within the foreseeable future (Table 1).

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OOO Gruppa Magnezit currently supplies refractories for all converter production in Russia and the Ukraine (with the exception of OAO MM Kim. Il'icha, Ukraine). Here the maximum life is achieved for the lining of converters in OAO MMK, OAO NLMK, OAO DMKD, OAO Alchevsk Metallurgical Combine, OAO Enakievsk Metallurgical Plant, OAO Mittal – Krivoi Rog, OAO MK im. Petrovskogo, OAO ChMK; good results have also been obtained in both workshops of OAO ZSMK, and in OAO NTMK.

The reason for the success of OOO Gruppa Magnezit is in the combined approach to solving the problem of increasing the life of converter linings, starting with qualified engineering: development of a lining plan taking account of the

**TABLE 1.** Production of Steel and the Proportion of Converter Steel of Steel Produced in Russia and the Ukraine*

| Volume of steel production | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|
| **in Russia** | | | | | | | | | |
| Overall, million tons | 65.7 | 66.2 | 70.8 | 74.0 | 73.8 | 74.8 | 77.1 | 77.5 | 78.0 |
| Including converter steel: | | | | | | | | | |
| million tons | 39.4 | 39.2 | 41.7 | 42.7 | 43.2 | 43.5 | 45.8 | 46.3 | 46.5 |
| % | 60.0 | 59.2 | 58.9 | 57.8 | 58.5 | 58.2 | 59.4 | 59.7 | 59.6 |
| **in the Ukraine** | | | | | | | | | |
| Overall, million tons | 39.3 | 38.6 | 40.2 | 40.7 | 43.5 | 44.8 | 45.0 | 45.0 | 45.0 |
| Including converter steel: | | | | | | | | | |
| million tons | 20.0 | 19.8 | 21.2 | 21.4 | 30.4 | 34.2 | 35.6 | 36.8 | 39.3 |
| % | 50.9 | 51.3 | 52.7 | 52.8 | 69.9 | 76.3 | 79.1 | 81.8 | 87.3 |

* Data for 2004 – 2006 is actual, for 2007 – 2012 is predicted.



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**TABLE 2.** Characteristics of Periclase-Carbon Refractory Objects for Lining Converters (Examples)

| Index | DALCAR P9 | DALCAR P10Cb | DALCAR P10 | DALCAR P14 |
|---|---|---|---|---|
| Weight fraction, %: | | | | |
| MgO* | > 80 | > 81 | > 79 | > 76 |
| C | > 14 | 10–14 | 10–13 | 14–16 |
| Open porosity, % | 5.5 | ≤ 5.5 | ≤ 4 | ≤ 4 |
| Ultimate strength in compression, MPa | > 30 | ≥ 35 | ≥ 35 | ≥ 35 |
| Raw materials | Fuzed periclase (> 97% MgO), antioxidant Al, Al + $B_4C$, combined organic binder | Fuzed periclase, high quality graphite, antioxidant using pitch coke binder Carbores-P | Fuzed coarse-crystal periclase (97 – 98% MgO), high quality graphite, various functional additions, antioxidants, combined binder | Fuzed coarse-crystal periclase (97 – 98.5% MgO), antioxidants Al, Al/Mg, Al + $B_4C$, high quality graphite various functional additions, combined binder |
| Recommended application zones | Universal refractory, specific zone determined during planning | | Loading and pouring | Trunnion |

* In calcined substance.

features of specific converter operation; supply of refractories from OOO Gruppa Magnezit certified according to ISO 9001; participation of specialists of the holding in performing lining work; monitoring operating conditions and the quality of performing hot lining repair, presence of specialists in dismantling a lining at the end of service life; an important factor is also the marked volume of holding production: the possibility of preparing periclase-carbon (PC) refractories of different quality and format in OAO Kombinat Magnezit and SP Yangkoy Dalmond (China), and also various materials required for high quality maintenance of the lining during operation in enterprises of the holding in Russia, China and Germany.

A significant role in improving converter lining life has been played by the improvement in PC refractories and the manufacture of differential lining schemes for zones using refractories of different quality, including separation of zones of intense lining wear; loading, metal pouring, cradles, and over trunnions below the bath (the last two zones have little access during certain operations of hot repair) [2]. The most typical grades of periclase-carbon refractories, used by OOO Gruppa Magnezit in the proposed projects and brief characteristics of these refractories are given in Table 2. One of the designs with layout of PC refractories with respect to zones is given in Fig. 1.

Converter lining breakdown is normally described by the following scheme:

- decarburization of the layer at the PC refractory – oxidizing agent boundary (oxidizing component of the molten bath, atomic oxygen, to some extent sulphur, FeO from the slag, oxygen entering through the lance during blasting, and atmospheric oxygen during the remaining periods);
- impregnation with slag of the high porosity decarburized layer followed by washing out as a result of circulation of the molten bath and the mechanical action of lumps of loaded charge;
- mechanical failure under the action of impact of descending metal scrap and poured metal.

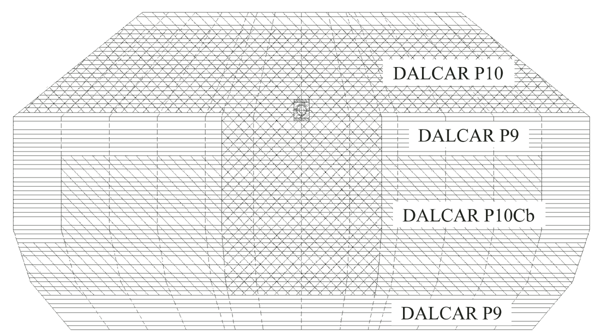


**Fig. 1.** Design of differential converter lining made from periclase-carbon refractories (see Table 2).

Naturally these factors operate continuously and in parallel, mutually accelerating the lining breakdown. The task of the lining developer, as a result of selecting the quality of optimum differential converter lining scheme, is to slow down its breakdown and create conditions for its regeneration directly during converter operation.

As a result of operation of the research and engineering center of OOO Gruppa Magnezit, including full-scale tests, the following ways of increasing PC object service life have been determined:

- use of magnesium fuzed clinker with a crystal size of more than 300 mm, and for individual lining zones of 800 – 1000 mm (coarse-crystalline periclase), containing MgO in the clinker from 96 to 98% depending on the zone of PC refractory application; here the impure part of the periclase, presence and distribution in the intercrystalline space of monticellite, merwinite, larnite, etc., are also considered. Sources of fuzed periclase are: a Chinese producer for SP Yangkoy Dalmond, and for OOO Gruppa Magnezit it is internal production of fuzed periclase in Satka in the Urals and in the Krasnoyarsk region (OOO SAGMK), based on pure magnesite local deposits belonging to OOO Gruppa

**TABLE 3.** Flux Characteristics

| Flux | Content, % | | | | | | Dissolution rate, g/min |
|---|---|---|---|---|---|---|---|
| | MgO | CaO | $Fe_2O_3$ | $SiO_2$ | C | $\Delta m_{pre}$ | |
| IMF-30* | 30 – 35 | 48 – 52 | 7 – 11 | 2 – 5 | – | – | 3.0 – 3.3 |
| Iron dolomite* | 31 – 32 | 57 – 60 | 3 – 4 | 3.5 – 4.5 | – | – | No data |
| FOM* | > 70 | 1.5 – 3.0 | 6 – 12 | < 5 | – | – | 1.0 – 1.1 |
| FMBUZh* | > 70 | 5 | 4 – 8 | 4 – 8 | – | – | 3.3 – 3.5 |
| SMG-10S | > 47 | – | – | 3 | > 8 | 47 | 5.5 – 5.7 |
| SMG-10 | > 55 | – | > 7.5 | 3 | – | 25 | 3.9 – 4.1 |
| FOMI* | > 66 | 12 – 22 | 4 – 8 | 5 | – | – | No data |

* For calcined substance.

Magnezit (MgO content in calcined substance up to 98.5%), and imported periclase, primarily from China;

● use of high quality graphite with an ash content of not more than 4%, and for critical parts of the lining of not more than 2%;

● use of efficient antioxidants preventing oxidation of refractory carbon. There is most widespread use in Russian and Chinese enterprises of aluminum metal, aluminum alloy with magnesium and boron carbide, and also combinations of them;

● use in the production cycle of high-speed mixers, hydraulic and impact presses that make it possible to obtain a pressure up to 160 MPa.

A differential converter lining scheme for zones suggests use of more resistant objects (normally with 97 – 98% MgO) in the pouring side, and in cradles and trunnions. Objects with a lower MgO content (95.5 – 97.5%), but providing the same lining element life, are laid in the region of the bottom of the converter (removable or stationary) in the cylinder from the direction of loading. In fact, this scheme (see Fig. 1) makes it possible to obtain in OOO MMK a lining life of more than 5354 melts.

In the majority of Russian enterprises the number of converter relinings per year was reduced by 25 – 30% from 2003. However, this result has been achieved not only as a result of using a differential lining scheme. Use of a laser system for measuring liner profile, for example the LR-2000 system, makes it possible with a high degree of reliability to determine the most worn parts of the lining and repair them as necessary.

One of the repair technologies for zones of intense lining wear is repair using a periclase-carbon briquette based on a phenol and pitch binder: the latter is more effective as it provides a lining layer life up to 20 melts without additional repair. Another effective method for increasing converter lining life is semidry torcrete mixes with a basic composition using phosphate and organic binders, both of Chinese and Russian production. It should be noted that an important element of this technology is use of a torcrete-machine providing application of concrete mixes. A torcrete-mix for hot repair of converters is prepared both in the Chinese enterprise and also in OAO Kombinat Magnezit, and as required it is developed for a specific user taking account of existing equipment for torcrete application and converter operating technology. These mixes are manufactured using fuzed periclase.

Already for many years an increase in converter lining life has been achieved as a result of correcting slag composition in different stages of the steel smelting process [3 – 5]. The technology developed includes correction of slag composition with different fluxes in two stages. In the first stage the slag corrosive effect is reduced with respect to the periclase-carbon lining, and in the second stage a slag is formed providing formation of a covering layer at the surface of the lining during blowing the slag with high-pressure nitrogen. This layer is retained in a satisfactory state over the whole lining surface after blowing the next melt and pouring metal from the converter.

Slag quality (basicity, FeO and $SiO_2$ content, viscosity) is mainly determined by the quality of the raw material used (cast iron, deoxidizer, lime). In practice the content of MgO within it, resulting with correct adjustment of slag composition in increasing lining life, is normally introduced as a result of external sources. These materials operate as loose cooling agents, and their use requires additional energy consumption. Experience of using fluxes enriched with magnesium oxide (Table 3) compared with weakly-burned dolomite, dolomitized lime, and iron dolomite, points to a marked advantage of the first. Use of magnesium fluxes also requires less energy consumption for correction of slag composition. According to the experience of one of the enterprises, equipped with a 160-ton converter, in order to obtain the same effect with an increase in viscosity and slag refractoriness for one melt 3.3 tons of iron-dolomite and 1.2 tons of FMBUZh flux are required.

Carrying out direct studies of the slag phase composition during introduction of fluxes is difficult for known reasons, although simulation of dissolution of fluxes in slag or another composition (carried out in OAO Ural Institute of Metals by an original procedure) has shown an almost linear dependence of the effect of FeO content, basicity and slag temperature on viscosity: with an increase in these indices slag viscosity is reduced and in contrast it increases with an increase of the amount of $SiO_2$ in the slag under stable uniform conditions.

With supply of flux in the first melting period there is enrichment of slag in MgO up to its concentration approaching the solubility limit in the slag; in this case mass transfer of MgO from the refractory into the slag during the whole melting period is markedly slowed down. A study of the kinetics of impregnation of slag with magnesium oxide during simulation of the interaction of PC refractory with magnesium flux has shown a marked slowdown in the rate of entry of MgO from the refractory into the slag, i.e. by a factor of 2.0 – 2.5.

Blowing slag with nitrogen, enriched in magnesium oxide, and formation of a surface covering on the lining prevents direct contact of oxidizing agent during metal with oxygen, particularly in the first period of this process (as is well known in fact in this period the slag is more aggressive). At the same time, at the end of melting assimilation of calcium and magnesium oxides by slag, including from entrained slag-forming materials, is completed; here a continuous series of solid solutions in the system MgO–FeO with refractoriness above 1700°C is synthesized, and addition of a known amount of rapidly assimilated magnesium product makes it possible to maintain the required slag viscosity ahead of blowing. Thus, consideration of the FeO and MgO ratio in the slag is the main factor for correcting conditions of slag lining formation at the surface of a lining during slag blowing.

A study of slag, that forms the lining covering, has shown complete assimilation of MgO from the flux in 2 – 3 min of performing the operation of flux supply (0.02 – 0.04 tons/ton of slag), i.e. blowing of slag for slagging the lining. An increase in lining resistance of a 385-ton converter with use of solely flux grade SMT-10S in order to correct slag composition is 400 – 600 melts. Use in the initial and final periods of converter melting of high-magnesium fluxes makes it possible to reduce lining corrosion, to improve (control) slag formation by converter melting, which is important in evaluating dephosphorization and desulfurization of metal.

In OAO Kombinat Magnezit production has been assimilated for a broad range of fluxes, i.e. material of basic composition (see Table 3) with a high MgO content in order to create the slag composition with respect to this oxide. Available at the disposal of OOO Gruppa Magnezit in one production area are raw materials with a different CaO:MgO ratio, i.e. from pure magnesite to pure dolomite, and also many years of experience of cooperation with users makes it possible to correct the flux composition for a specific user taking account of features of their production technology. In addition, the possibility has developed of precisely affecting the slag quality, to use an individual approach, both from the point of view of increasing life and from the point of view of the refining capacity of slag due to varying the flux composition and time of its supply to the melt.

Today the volume of production of magnesium fluxes using raw materials from the Satkinsk magnesite deposit is several hundreds of thousands of tons a year. The process of expanding the assortment of grades of magnesium fluxes is continuously connected with steel production technology (slag chemical composition and oxidizing capacity, rate of flux dissolution, time of supply to the converter, etc.) with an attempt to optimize flux composition in order to achieve the best adhesion capacity during forming the slag covering on the lining.

As is well known, the frequency of replacing units affects converter life. OOO Gruppa Magnezit proposes two main versions: individual objects produces by OOO Gruppa Magnezit and SP Yangkoy Dalmond or periclase-carbon integral tapping units of isostatic formation with a length up to 1600 mm. The life of integral units, according to the experience of a number of metallurgical enterprises, reaches 150 melts. Within the set there are mixes for installing these objects in nesting blocks, for example mix grade PPF, manufactured on the basis of sintered and fuzed periclase and phosphate binder. In order to prepare tapping zones during operation there is effective use of a mix based on phosphate binder of Russian and Chinese enterprises OOO Gruppa Magnezit.

The high resistance of a converter lining and the inter-repair cycle are determined by economic desirability. On one hand, reliable accounting of the expenditure for performing lining work, accounting for possible losses of production in the case of taking units out of operation, and on the other hand consideration of expenditure in maintaining a lining in a working condition, loss of production in performing repair work (since the frequency of these increases with time), make it possible to predict the efficiency of some adopted economic solutions. OOO Gruppa Magnezit has considerable potential for realizing any innovations in the field of increasing converter lining life and using their potential successfully.

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