Establishing the Optimum Composition of Superaluminous Refractory Products, Used for Steel Ladle Bubbling

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It is widely acknowledged by all specialists in the field of ferrous metallurgy that the porous peg of the kit for injecting inert gases into the steel casting ladle is the weakness of the entire assembly. This is the most prompted piece due to the thermal shocks that occur when injecting cold gas and the wear and tear and corrosion caused by disturbances in the steel during the injection process. The porous structure of the peg considerably weakens the physical properties and widens the surface of metal - refractory material contact thus enabling the destructive chemical action. In addition, the process of injecting oxygen for cleaning the metal peg also contributes to the destructive action and the substantial decline in its endurance. All these considered, it has been decided that the material for producing these items should contain at least 95% Al_2O_3 which means using only tabular alumina. As far as the binder is concerned, it has been established that a liquid chemical binder made of colloidal alumina should be used since this does not considerably diminish the Al_2O_3 content of the end product. It is the aim of this paper to bring forward the author's research regarding the production of the porous plug using high-alumina refractory materials.

Keywords: ferrous metallurgy; steel ladle; porous plug; injecting inert gases; tabular alumina

Increasing requirements more stringent quality steel and need for further clues as large eject led to the expansion of continuous casting technology which, in turn, resulted in an increase in the role and importance of gas blowing into the pot. [1, 2]. Instilling and gas bubbling into molten steel pot has the following essential functions that have changed the role of simple pot of transport equipment into a true metallurgical complex aggregate:- Homogenizing the molten metal and the steel bath temperature equalization over the entire height of the pot, especially the high-capacity pots;

- Uniform and speedy dissolution of alloying elements in steel table;
- Mixing with fillers steel desulfurization and dephosphorisation;
- Purification by improving settlement steel non-metallic inclusions;
- Decarburization and dezoxidation more advanced [3].

With the use of a reduced energy equation and the Green–Naghdi dissipation inequality, the entropy function is determined in terms of the Helmholtz free energy and other functions that are known or can be determined for certain classes of materials with temperature-rate and strain-rate dependent thermomechanical constitutive response functions [4]. The bubbling of gas in the ladle of steel is practiced using the system lance or permeable refractory stopper mounted in the lining of the pot. Regardless of the injection system used, the inert gases used are argon, nitrogen and to a lesser extent. The blowing lance the advantage possibility of directing the gas jet in less sensitive areas of the bottom of the pot or sparing zone enclosures drawer and the possibility of alloying elements, desulfurization and / or dephosphorisation mass metal bath, but has the great disadvantage that advanced local causes wear liner pot in the impact zone of gas or dust that require restoration of the

lining dense, sometimes leading even to its perforation [5, 6] .

For this reason, in the case of a stream of inert gas is preferred refractory stopper system is mounted in the bottom of the tundish or, more frequently at the bottom of the side wall [7].

The main part of the ensemble is, of course, plug porous, permeable through which the dissemination of the bubble blowing and causing bubbling bath of liquid steel from the ladle. Porous plug - may have different shapes, the most common being frusta-conical shape and the rectangular shape of the last with the same size of the refractory bricks constituting the lining of the ladle to be easily classified into the masonry. Passing the gas through the permeable plug is made by several different ways, namely: - Uncontrolled high porosity but refractor; - Porosity directed (oriented) take the form of channels arranged in different ways, made by special technology; - Practiced full height slots stopper; - Gaps between the refractory stopper and the surrounding wall.

The choice depends on the purpose of the system, the volume of gas that is injected, the injection, the desired form of gas bubbles, their size and their desired movement of the print. Thus, the use of porous plugs uncontrolled gas bubble diameter is smaller and the porous structure of the material, in all its mass, leading to a sharp decline in mechanical strength, advanced corrosion due to a large contact surface steel / refractory slag- and the increased possibilities of infiltration of steel shutter stopper gas access routes. The use of plugs with directed porosity allows to obtain high speeds of injection of the beneficial effects of bubbling or by homogenization, especially in the case of casting ladles of large capacity. It also plugs with directed porosity have a better behavior peeling, corrosion and penetration of liquid steel in the pores. A model explaining non-monotonic behavior of the overall thermal conductivity (TC) and monotonic behavior of the thermal expansion coefficient (CTE) at high volume fraction of diamond particles [8]. To ensure adequate quality, blasting caps are manufactured from raw materials of high purity

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oxide refractory. The most used plugs are manufactured from aluminum trioxide (Al_2O_3), magnesium oxide (MgO) or chromium trioxide (Cr_2O_3) with hydraulic or chemical bond. Shaping apply to their special technology for achieving channels.

The corrosion resistance to the penetration of the steel as the injection of the gas is adjustable pore size. The diameter of the channels typically directed to porous plugs is 0.3-1.0 mm, these dimensions to avoid infiltration of steel surface tension thereof. It should be noted that a *support* best refractory material and a reduction in the tendency to cracking due to thermal shock to which they are subjected permeable plugs are caught in a steel shell which allows attaching the nozzle to jet gas. This guarantee both full gas passing through the porous plug into the mass of liquid steel.

Manufacturing assembly for injecting inert gas into the steel ladle began with the expansion of continuous steel casting technology which imposed severe conditions refractory material used. And whilst the injection method with refractory plug leaky has expanded and has accumulated experience in this field were many new variants of the plug instilling in particular with a view to improving its quality in order to achieve sustainability bigger operation. Meanwhile disappeared parts of protective cap (bushing and plate sealing) today assemblies modern consisting only of two parts: plug porous and support him, remained necessary for the embedding of masonry bottom of the pot and to protect his safety. It is interesting that during appearance a new type of plugs was not limited to older versions, which are today used in parallel depending on the objective of the insufflations gases and the working conditions existing steelworks. Factors determining the choice of permeable plug are multiples depending on the effect desired bubbling but especially in the technical conditions for the production and treatment of steel. It may include many factors that influences the choice of more or less permeable plug that:

- Aggressiveness (composition) of steel and slag;
- The temperature of the casting or steel processing;
- Residence time of the steel ladle, ladle factor directly related to the volume;
- The primary effect desired to obtain (mixing, dissolution of the alloying elements in the steel inclusions is decanted, the temperature equalization, etc);
- Nature of the gas used (argon, nitrogen, oxygen);
- During the injection of the gas;
- Ladle capacity, etc.

Given the multitude of factors that influences both user and sustainability stopper insufflations gas ladle steel factors which differ (sometimes essential) from a steel producer to another, it can be seen from the start that worldwide manufacturers of refractory materials is that they have focused on the preferences of their intended beneficiaries in finding solutions to technical and constructive optimal, whether occurring in parallel a wider range of parts that we recommend to use depending on specific conditions in the steel mill beneficiary. Plugs with directed porosity (channels, segments, etc.) have a superior behavior peeling, corrosion and penetration steel (followed by finishing) against uncontrolled porous plugs [9, 10]. Although demonstrated superior strength plugs porosity directed the plug porous steered not disappeared it is preferred steelworks conditions staple work (one batch per day or to interrupt work on weekend) because it presents a greater capacity insufflation and has a small cost [11]. Regarding refractories used for manufacturing stoppers for blowing gas permeable ladle, I can make the following findings:

-having the multitude of factors influencing both the use and sustainability injection assembly

- bubbling factor which sometimes differ significantly from a steel producer to another, it can be seen from the start that worldwide manufacturer of refractory materials whether they turned on preference main beneficiaries, either in parallel to produce a wider range of parts that we recommend to use depending on the specific beneficiary steelworks.

Thus, every company that offers products for all blowing gas into the steel ladle recommends that its products are based on different raw materials from sint alumina, tabular alumina, corundum, magnesite, chromite, etc. In recent years, with the assimilation of a new technology for manufacturing refractory cast with a chemical binder was passed to a new stage in the manufacturing of products for assembly injection of inert gases in the ladle treatment of steel [12].

New technology has enabled first assembly manufacturing parts in one piece eliminating the disadvantage posed by joining multiple joints. At the same time it successfully is achieving superior characteristics compared to the normal baseline. It is considered that an improvement in physical and mechanical characteristics of these products will obtain higher reliability of gas injection assembly approaching it sensitive to sustainability which currently presents products manufactured by renowned European companies.

Experimental part

a)- Raw material

To obtain products that contain over 85% Al_2O_3, it has been established to use high purity alumina raw material that can be purchased from our country. Therefore, the chosen feedstock is the high-alumina burned fire-clay SA68 A) made by S.C CCPPR S.A from Alba Iulia and (N.T.I. 278/82) tabular alumina produced by S.C 'Cemtrade S.A from Oradea. The characteristics of the raw materials are presented in table 1.

As far as the granulation is concerned, the following granulations were used in the form offered by the producers:

-For fire clay SA 68A - the granulation is < 3.2 mm and for fine fire clay granulation is < 0.06 mm

-For tabular alumina: fraction between 3.36 and 1.19 mm, fraction < 1.19 mm and a fine < 0.06 mm.

-The materials purchased this way were subjected to a granulometric analysis on site and as a result the following data was obtained.

Table 1
PHYSICO-CHEMICAL CARACTERISTICS OF THE FEEDSTOCK

Characteristics	Burned fire clay SA 68 A	Tabular alumina
Al_2O_3, [%]	min 68	99
Fe_2O_3, [%]	max 1.5	0.15
Na_2O, [%]		0.11
Water absorption, [%]	max 5.0	-
I.P refractoriness	185	K (^{0}C) 2073.15(1800)

Characteristic	Al_2O_3, [%]	Fe_2O_3, [%]	CaO, [%]	SiO_2, [%]	Waste on 0.06 mm bolter
Value	Min. 70	Max. 0.5	Max. 26	Max. 0.3	10

Table 2
CARACTERISTICS OF ALICEM 2 ALUMINA CEMENT

When establishing the gratings, we took into account the chemical composition in order to produce items with a minimum of 85% Al_2O_3 as well as the grading in order to obtain maximum output of the end product. Besides this main feedstock, chemical and hydraulic binders were used having in view that the method of moulding was employed. Alumina cement type ALICEM 2 – produced by SC 'CCPPR' SA from Alba Iulia was used as hydraulic binder as well as a chemical binder made of colloidal alumina produced by SC 'CCPPR' SA from Alba Iulia. The main characteristics of alumina cement which was used are mentioned in table 2.

b)-Method of preparing the casting paste

The casting pastes were prepared in the laboratory in a propeller agitator having the following characteristics: the recipient volume -10 L, agitating engine - 220 V; 1000 W, number of rotations 950 rot/min, two - pedal agitator. The order in which the materials were introduced into the agitator was as it follows: globular grease remover, fine grease remover, hydraulic binder (alumina binder). Water was added after a 2-3 minute - mixture and it was stirred for 5 more minutes. As far as the formula with chemical binder is concerned, the order in which the materials were introduced was the following: globular grease remover, fine grease remover; they were mixed for 2-3 min, water was added, then the chemical binder and after mixing for 2-3 min the intensifier was added. After one minute's stirring it was cast in moulds. When the cycle of homogenization was over the past was cast in cubic moulds of 80 mm each side, by filling. A batch containing 5 kg of material was made for each formula. This was necessary for obtaining 3-4 samples (cubes) whose main characteristics were then determined.

c)- Molding, drying and burning the samples

Molding the cubic samples was made by casting the paste prepared as previously described. After the samples became stiff, they were taken out and allowed to dry for 48 hours in open air. Then they were introduced in a drying room and kept for 24 h at a temperature of 393.15 - 413.15K (120-140^{0}C). After drying, the samples were subjected to a process of burning in a continuous furnace at 1773.15 - 1823.15K (1500-1550^{0}C) for 16-20 h at burning point.
After burning, the cubes were subjected to physical and chemical testing in order to characterize the corresponding formulas.

d)- Establishing the testing to describe the formulas

As previously shown, this is the treatment to which the products that make up the assembly for injecting inert gas into the steel casting ladle were subjected: Cold or hot pressure resistance; Resistance to steel and scum corrosion; Resistance to shocks caused by melted steel and cold gas injection; Resistance to wear; Refractoriness or the temperature that guarantees the usage of the refractory material under the working conditions of the steel foundry (casting temperature and residence time of the liquid steel in the casting ladle). Although there are standardized assessment methods for this stress, these take too long, involve high costs or require a high number of samples. Under these circumstances, it has been established that it is sufficient to undertake simpler and faster means to assess the samples to ensure a comparative description. As a result, it has been decided to use only the following laboratory means of assessment to define the samples: -Establishing cold pressure resistance; -Establishing the porosity of the samples and determining the characteristics that are related to this (water absorption and apparent density). These characteristics are sufficient to appreciate the comparative quality of the products obtained when the chemical composition is similar.

The main technical characteristics recommended by the producer consist just in indicating the values of these simple assessments, as shown in table 3.

To obtain optimum values of these important characteristics, special attention has been paid to realizing the proper granulometric composition because this represents, along with the chemical composition, the essential factor in realizing high quality final products.

e)- Realizing products that contain over 95% Al_2O_3

As far as the granulation of the of the grease remover is concerned, having in view that the pegs will have guided porosity (gas injection canal), one should use a granulation that allows a compact structure of the material, like the grids which have reached optimum results in the attempts made to obtain products that contain 85% Al_2O_3. The experience gained in the first part of the laboratory research was used in this way and therefore, only few attempts were necessary. Thus, many 5 gratings were realized in the laboratory under similar technological conditions to those in which the first series of attempts were realized: The same paste preparation equipment was used; The casting was made using the same method (by filling); 3-4

Characteristic	Values which are required in the country	Values which are recommended by foreign companies
Chemical composition: Al_2O_3, [%] Fe_2O_3, [%] CaO, [%]	 85-92 Max. 1.0 -	 82-94 0.6-1.5 1.5-2.0
Apparent density, [g/cm^3]	2.70-2.80	2.60-2.80
Apparent porosity, [%]	20-25	17-22
Pressure resistance, [N/mm^2]	25-40	55-80
I.P refractoriness	188-192	-
Working temperature K (^{0}C)	-	2023.15 – 2073.15 (1750-1800)

Table 3
THE MAIN TECHNICAL CHARACTERISTICS REQUIRED FOR REFRACTORY PRODUCTS WHICH MAKE UP THE KIT FOR INJECTING INERT GASES INTO STEEL CASTING LADLE

cubes were obtained in order to make the established laboratory determinations; -After the 2-3-h hardening time, the cubes were left for 48 h in the air after which they were dried for 24 h in a dryer at a temperature of 393.15 – 413.15K (120-140^{0}C); Their burning was made in the continuous furnace for 16-20 h at 1773.15 – 1823.15K (1500-1550^{0}C);

As mentioned before, a chemical binder was used. This contained a self-intensifier composed of:

- Alcohol solution prepared by using chlorine hydride and aluminum powder. The solution had a density of 1.240 (recorded with the immersion densimeter) which was diluted to a density of approximately 1.040 - 13.5% of this binder was added to each formula (reported to dry material). The solid magnesia intensifier was added in proportion of 0.15%. Under these conditions and using the fabrication order described in point 1.3, the hardening time of the paste in moulds was of approximately 2 h (with slight variations according to the granulometric formula that was employed), after which the cubes were taken out of the moulds and subjected to drying and burning processes. Table 3 includes the 5 formulas that were realized and the chemical and physical mechanical characteristics established on the cubes that resulted from each formula.

An analysis of the data that resulted at laboratory stage for obtaining products that contain over 95% Al_2O_3, necessary for making the porous peg for injecting inert gas in the casting ladle, points out the following important aspects:

- Apart from grid no. 1 and 3, the other laboratory trials meet the conditions required by internal regulations and offered by foreign companies;
- It is mentioned that, as far as pressure resistance and apparent porosity are concerned, the parameters mentioned in the offers made by foreign companies are higher although the apparent density of the products included in the research meet the bounds in the offers.

This can be explained by the fact that the raw material that was used was different and by a weaker compaction of the products included in the research. Of all 5 formulas used in the trials, formula no 4 is the one with the best results, respectively: apparent density- 2.79g/cm^3, water absorption - 8.10%, apparent porosity -23.0%. Having in view the results that were obtained during the laboratory trials, it is recommended that the products should have lower porosity and higher-pressure resistance, corresponding to the values in the foreign companies offers.

Results and discussions

a) -Establishing optimum granulation for realizing products that contain more than 85% Al_2O_3

It is known that in a monodispersed system of spherical particles the porosity does not depend on the diameter of the spheres but on the way, they are arranged. To a great extent, the rule also applies in the case of nonshperical granules, the way they appear in industrial practice. In this case, the realized porosity is approximately 40%. In the case of a mixture of two different granulometric fractions (a coarse one and a fine one), the fine fraction takes up the empty spaces between the big granules and therefore a porosity of 16% in volume can be obtained. A minimum porosity is obtained in a ratio of fractions when all the spaces between the granules of the fraction are occupied by fine fraction. This can be realized at approximately 30% fine fraction and 70% coarse fraction. In a binary system of two grain size fractions, a porosity of min 25 % can be obtained. To obtain lower porosity, it is necessary to use more granulometric fractions. Thus, in a ternary system (coarse fraction-medium fraction-fine fraction) porosity can be as low as 22%.

Theoretically, the porosity can be even more reduced by using four or more fractions, but this cannot be taken into account in practice. In practice, however, the problem is much more complicated since the grain size fractions obtained by the process of size reduction are continuous (even within certain bounds) and on the other hand the shape of the granules obtained in different size reduction equipment is different and it influences their arrangement, respectively the tightness of the obtained product and therefore its porosity. For this reason, there are authors who have suggested introducing two distinct notions to characterize the granules of a mixture granulometry, the notion related to the size of the granules and which can be expresses either as the medium diameter of the granules or as the fraction percentage that remains or passes through a bolter with a particular mesh [14, 15]. Granularity, notion related to the shape of the granules and which can be expressed as a factor that is in the different granulation calculation formulas and which mirrors the shape deviation compared to the ideal spherical one. Besides these, it must be mentioned that the determinations made in order to shape these systems were realized on dry mixtures or semidry systems with a reduced binder quantity and a proper humidity for the spinning technology which is generally used when producing refractory items.

Table 4

EXPERIMENTAL FORMULAS FOR PRODUCTS THAT CONTAIN OVER 95% Al_2O_3 AND THE RESULTS OF THE DETERMINATIONS

No.	Tabular alumina formula [%]			Formula Granulation [%]			Chemical and physical mechanical characteristics					
	Fraction: between 3.36 - 1.19 mm	Fraction: < 1.19	Fine fraction	3.2-1.25 mm	1.25-0.5 mm	< 0.5 mm	Al_2O_3 [%]	Absorption [%]	Apparent density [g/cm^3]	Apparent porosity [%]	Pressure resistance [N/mm^2]	Contraction [%]
1	35	10	55	36	5	59	98.2	12.0	2.73	33.0	31.2	1.8
2	45	17	38	47	7	46	98.8	8.2	2.85	23.4	36.5	1.2
3	37	36	27	45	15	40	98.7	8.3	2.89	24.0	31.2	1.3
4	37	23	40	40	10	50	98.0	8.1	2.79	23.0	37.0	1.6
5	28	36	36	37	15	48	98.5	8.2	2.81	23.1	38.0	1.3

*The values represent the average of three determinations

Table 5

EXPERIMENTAL FORMULAS FOR PRODUCTS WITH 85% Al_2O_3 AND THE RESULTS OF LABORATORY DETERMINATIONS

Nr.	Formula in [%]								Granulation [%]			Physical chemical characteristics					
	Fire clay SA68A			Tabular alumina				Cement (binder)									
	Granules	Fine	Total	3.36 – 1.19	1.19 – 0.0	Fine	Total		3.2-1.25 mm	1.25-0.5 mm	< 0.5 mm	Al_2O_3 [%]	Absorption [%]	Apparent density [g/cm³]	Apparent porosity [%]	Pressure resistance [N/mm²]	Contraction [%]
1	-	20	20	50	10	10	70	10	70	5	25	87.72	8.93	2.73	24	71.5	1.5
2	23	-	23	32	-	35	67	10	47	3.5	49.5	88.12	10.2	2.57	26.4	61	1
3	30	13	43	30	-	17	47	10	50	4.5	45.5	82.75	10.4	2.56	26.2	52.2	1
4	12	23	35	5	-	5	55	10	56	2.5	41.5	85.25	10.4	2.56	26.7	48.5	1.5
5	10	10	20	50	10	10	70	10	57	7	36	87.52	9.3	2.71	25.3	42	1.2
6	-	25	25	45	15	5	65	10	47	7	46	87.35	7.6	2.85	17.5	58.5	1.1
7	20	-	20	35	30	5	70	10	60	15	25	88.21	8.65	2.62	22.7	46	1.1
8	20	5	25	25	30	10	65	10	45	15	40	88.10	7.9	2.65	20.9	56	1.3
9	15	15	30	10	50	-	60	10	37	23	40	81.82	8.1	2.48	20	48.5	1
10	15	20	35	20	30	5	55	10	37	15	48	85.68	7.9	2.56	20.2	55	1.2
11	7	13	20	10	60	-	70	10	30	25	45	86.58	8.3	2.78	23.1	49.5	1
12	10	15	25	15	35	15	65	10	30	15	55	87.85	8.1	2.81	22.8	52	1.3
13	10	15	25	5	45	15	65	10	22	20	58	88.21	9.5	2.85	27	58	1.2

*The value of chemical and physical mechanical characteristics representthe average of three determination

These conditions have decisively influenced the *gliding* of one granule over another, their mutual arrangement and therefore the shape of the obtained cubes but especially the value of the determined parameters. As far as the injection moulding technology is concerned, where the mobility of the granules in the fluid mixture is much higher, it is expected to obtain different values and even different shape of the curves, respectively of the optimum value zones. Having in view the reasons mentioned above and the fact that the raw materials which are used are of a different nature (alumina fire clay and tabular alumina), it has been established to use a series of formulas with various granulations which can comprise a larger area of a coarse-medium-fine ternary system, provided that the realization of the set chemical composition for the end product allows it.

The determinations made on these mixtures will indicate the optimum granulometric composition for realizing a proper quality product or will at least mark off the zone within the ternary granulometric system in which will be placed the formulas for producing the products which are necessary for the assembly for injecting inert gases into the steel casting ladle. In all the cases we found granulometric compositions within the bounds indicated below, according to the size of the granules being considered coarse, medium and fine and according to their shape: - coarse granules 30-50% ;- medium granules 15-25% ;- fine granules 35-55%. Since, as it has been shown, casting provides special conditions for the arrangement of the granules, it has been decided that the trial area in the ternary system should be extended to the following ratios: coarse granules 30-50%; medium granules 5-25%; fine granules 25-60 %. It has been decided to take into account the following granulometric fractions according to the indicated granulations and the raw materials that were used: Coarse fraction: between 3.2-1.25 mm; Medium fraction: between 1.25-0.5 mm; Fine fraction: less than 0.5 mm. According to this division, the raw materials that were used have the grain-size distribution presented in table 4.

In order to obtain a chemical composition of approximately 85-90% Al_2O_3 which is necessary to inject the inert gases and realize the protection bushings from the injection assembly, it has been concluded that the following composition is necessary: 35% fire clay SA 68A × 68% Al_2O_3 = 23.8% Al_2O_3, 65% tabular alumina × 99% Al_2O_3 = 64.4% Al_2O_3. 10% alumina cement was added in all cases as binder with fine fraction (<0.06 mm). Using the technology previously described 13 different granulometric formulas were realized, 3-4 cubic samples being cast and on which the established determinations were made after the drying and burning processes. In all cases the pastes were prepared with 11-13% mixing water (reportable to the weight of the solid material) to present proper casting characteristics. The formulas that were used, as well as the results of the laboratory determinations are presented in table 5.

Conclusions

Refractory porous plug in running must match the reliability, steel ladle liner and must have a durability in service at least equal to the entire refractory linings durability. A premature deterioration of the support necessity of a change in the ladle during use, causing an interruption of casting steel for a period of time to rebuild the entire assembly bubbling refractory linings. Therefore, besides the use of high quality refractory materials requires respect of fabrication technologies to ensure superior product quality characteristics.

By analyzing the data obtained during the laboratory work, the following can be concluded:

The formulas used during the trial (apart from formulas 2-5,7,9,10 and 13) meet and sometimes exceed the requirements for the chemical and physical mechanical characteristics (apparent density, apparent porosity, pressure resistance). The calculated CaO content exceeds the recommended limit and the one offered by foreign companies, which might lead to a slight decrease in the refractoriness characteristic (usage temperature) and respectively in the corrosion resistance of the products to the steel and scum action. Of all the trials, formulas no. 6 and 8 have shown the best values of the characteristics, respectively: apparent density – 2.65-2.85 g/cm^3, apparent porosity - 17.5-20.9%, pressure resistance -56.0-58.5 N/mm^2. These characteristics are better than those imposed by internal standards and meet the requirements of import products.

Considering these results, it is recommended that, for the production of the batches which will be tried at the beneficiary, a formula similar to no 6 or 8, respectively containing 25% fire clay AS 68 A and 65% tabular alumina (with 10% additional alumina cement ALICEM 2), with granulations comprised between: 45-47% large granules between 3.2-1.25 mm, 7-15% medium granules between 1.25-0.5 mm, 40-46 % fine material < 0.06mm.

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