Insulating Refractory Bricks for Glass Industry, Possibilities of Production and Testing of Their Properties

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Production of insulating refractory bricks was completely changed in *P-D Refractories CZ* over the last 30 years. The main changes relate to decreased bulk density and increased classification temperature. Another important aspect is shorter and shorter required delivery term, which changed the classic production way of extruding the plastic mixtures. The main application is the glass industry (mainly for fireclay, mullite and silica insulating bricks). This range of insulating bricks includes also large blocks for glass tank bottom. Properties of bricks made by a new production technique not only for the basic tests required by the customer had to be set up, but also for the additional tests that include for example refractoriness under load and creep.

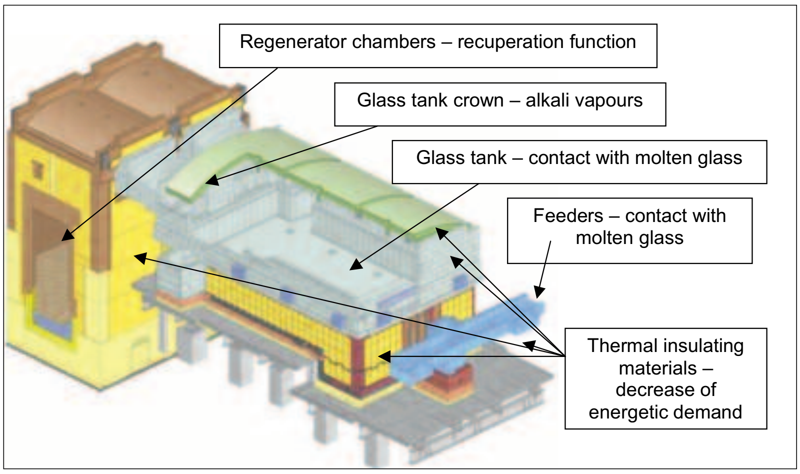

Fig. 1 Construction of a glass furnace

1 Introduction

Refractory materials used in the construction of glass furnaces must secure the construction itself and also ensure a safe operation, i.e. molten glass casting. These refractory materials may be produced by a variety of production technologies.

The working lining of the glass tank and feeders must be resistant to the effects of molten glass. The tank is most often bricked with electro-fused materials based on corundum and zircon. Feeders – lining of channels, spouts, tubes, plungers and orifice rings must be due to their complicated shapes produced by a technology of casting of materials with higher content of ZrO_2 – PD brands A65MZ11F and A55ZM25F. The second layer of construction and insulating lining of glass tanks is performed with large bottom blocks made of dense fireclay which may be produced by a technology of high-pressure machine pressing – PD brand AS-VK or by a technology of casting – PD brands A45F and A45FB. The next layer is made of large insulating bottom blocks – PD brands SL10C140, SL12C140 and SL11C150.

The construction stability of the crown is ensured mainly by silica lining – PD brands DSS and DOX. The silica lining is resistant to alkali vapours and temperatures up to 1650 °C. The other service the refractory materials provide to the glass tanks is the accumulation brickwork of regenerators made of e.g. high alumina or magnesia materials.

Important role play thermal insulating refractory materials, which decrease energetic demands of the furnace. According to raw material composition may the linings be divided to alumino-silicate materials (bottom insulation of tanks, feeders and regenerator chambers), alumino-silicate thermal insulating large blocks (third insulation layer of glass tanks) and silica materials with a high content of SiO_2 (insulation of glass tank crown).

Also specific materials with special characteristics are used within the construction of glass furnace. Such materials are on basis of fused silica and excel in minimal thermal expansion. These materials may be produced by a variety of production technologies: high-pressure pressing – PD brands KS99

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Keywords: insulating refractory bricks, glass furnace, silica bricks, insulating bottom blocks

Tab. 1 Insulating refractory materials

Product Group OPATERM		SL5-90	SL6P-130	SL6F-125	SL8P-140	SL8F-140	SL10P-150
Bulk density [kg·m^{-3}]		540	600	600	800	800	1000
Cold crushing strength [MPa]		2	3	1,5	8	4	6
Chemical composition [%]	SiO_2	64	57	37	39	36	29
	Al_2O_3	25	33	58	55	60	67
	Fe_2O_3	2,5	2,0	0,9	1,2	0,9	0,7
Thermal conductivity [W·m^{-1} K^{-1}] at	200 °C	0,13	0,22	0,21	0,34	0,35	0,37
	400 °C	0,14	0,23	0,23	0,35	0,35	0,38
	600 °C	0,17	0,26	0,26	0,36	0,36	0,40
	800 °C	0,20	0,30	0,29	0,39	0,38	0,43
	1000 °C	–	0,35	0,34	0,43	0,42	0,46
	1200 °C	–	0,40	0,40	0,47	0,46	0,50
Classification per ČSN EN 1094-2		85-0,55-L	130-0,6-L	125-0,6-L	140-0,8-L	140-0,8-L	150-1,0
Testing temperature [°C/h]		900 / 12	1300 / 12	1250 / 12	1400 / 12	1400 / 12	1500 / 12
Permanent linear changes [%]		–0,7	–0,6	–0,7	–0,8	–0,2	–0,6
Classification per ASTM C155-8		16	23	23	26	26	28
Testing temperature [°C/h]		900 / 24	1300 / 24	1250 / 24	1400 / 24	1400 / 24	1510 / 24
Permanent linear changes [%]		–1,0	–0,8	–1,0	–1,0	–0,4	–0,9

Tab. 2 Characteristics of insulating silica produced without "burn-out" substances

Product Group DITERM		LS8-155	LS10-160	LS12-160
Bulk density [kg·m^{-3}]		850	1000	1200
Cold crushing strength [MPa]		2	3	10
Chemical Composition [%]	SiO_2	92	93	94
	Al_2O_3	2,3	1,9	0,9
	CaO	3,3	3,3	3,3
	Fe_2O_3	0,9	0,9	0,9
Thermal conductivity [W·m^{-1} K^{-1}] at	400 °C	0,38	0,50	0,60
	600 °C	0,43	0,58	0,70
	800 °C	0,53	0,69	0,83
	1000 °C	0,68	0,86	1,03
	1200 °C	0,89	1,10	1,29
Classification per ČSN EN 1094-2		155-0,8-L	160-1,0-L	160-1,2
Testing temperature [°C/h]		1550 / 12	1600 / 12	1600 / 12
Permanent linear changes [%]		–0,23	0,09	0,38

and KS96 and casting – PD brands KS99F and KS96F. These materials are used for hot repairs and for a construction of glass batch entrance. Unshaped materials based on fused silica may be used also for sealing the joints within the crown (MKS99) which are also performed by masses on zircon sand basis (MZ64) which do not react in heat with the silica lining. So called painting mass (MS90LS) protects the upper insulation layer from dust originating in glass batch. This material has good insulation characteristics due to its low bulk density.

2 Insulating alumino-silicate refractory materials

Production technology of insulating refractory materials has changed a lot over the recent years within *P-D Refractories CZ a.s.* Due to still shorter requirements on delivery terms the plastic technology based on "burn-out" substances was abandoned and newly the semi-dry working mass is pressed on hydraulic press machines. The new technology allows us to shorten a period of drying and firing to ca. 5 days and to produce up to 10 000 pieces per day. There is no need to finalize the bricks after firing as the dimensional accuracy reached is ±0,75 %. A big advantage is the same shrinkage of material as by dense fireclay bricks resulting in possibility to use already existing moulds. From the quantity point of view is this production segment only a complementary one for us but we are decided to pay a close attention to it.

The basic characteristics of insulating refractory materials are bulk density and classification temperature set up either per European standard SN EN 1094-2 or per American ASTM C155-88. Both temperatures are conditioned by permanent linear changes of the material by ±2 %. Difference is made by the required temperature endurance. EN requires 12 h, ASTM 24 h. Values up to 1 % (reached due to modification of mixtures and technology of their preparation) had to be determined and thus declared per ASTM classification, which is often a condition of the customers. The aim was also to perform some savings when modifying the mixtures. The share of synthetic light grogs was decreased. This was enabled by the brand new prepar-ation line equipped with fully automatic mixer *EIRICH* where the choice of suitable mixing regime and input of additives result in lower density of working masses.

Glass industry uses insulating materials as per ASTM26 (PD brand SL8P-140) and ASTM23 (PD brand SL6P-130) for insulation of regenerator chambers and top lining of glass furnace. Material with higher classification temperature as per ASTM 28 is used for feeders (PD brand SL10P-150).

Usually 3 layers of insulating silica are used in crown of glass tank. Another already tested solution uses in the second layer material SL8P-140 and the last layer material SL5-90. For insulation of areas over molten glass materials with low content of Fe_2O_3 must be used (e.g. suspended roof over tin bath, materials SL6F-125 and SL8F-140).

3 Insulating silica refractory materials

Insulating silica materials form an integral part of glass tank crown. The main feature of silica materials is their dimensional stability up to temperatures around 1700 °C. The material starts to melt at these temperatures. The working lining of the crown is usually lined with silica which is insulated by insulation silica with the same thermal expansion. The main features of these materials are content of SiO_2, bulk density and classification temperature.

Insulating silica has been produced together with dense silica in Svitavy since 1986. Burn-out materials (mainly milled coke) are used there to create the porous structure.

As the insulating silica could be fired only on the tops of the loads (the same problem with uncontrolled burning out as in case of alumino-silicates) the technology of working mass preparation needed to be modified.

The new production technology without the use of burn-out substances enabled us to form full loads and shorten the firing time to half of that when fired on top of dense silica loads. The shorter firing time was achieved also due to the usage of fine sand with addition of mineralization agents processed on speed mixer. The desired porous structure can be achieved by a modified working mass preparation (using additives). Small components such as light-weight grogs on bubble alumina, diatomite and expanded natural raw materials are also used. Their use is limited by the content of Al_2O_3 which is present also in the incombustible coke particles.

For purpose of bricks comparison made by these 2 technologies (with and without burn-out substances) tests of refractoriness under load of 0,05 MPa and 0,1 MPa were performed. Results (more or less the same) may be seen in the Fig. 2.

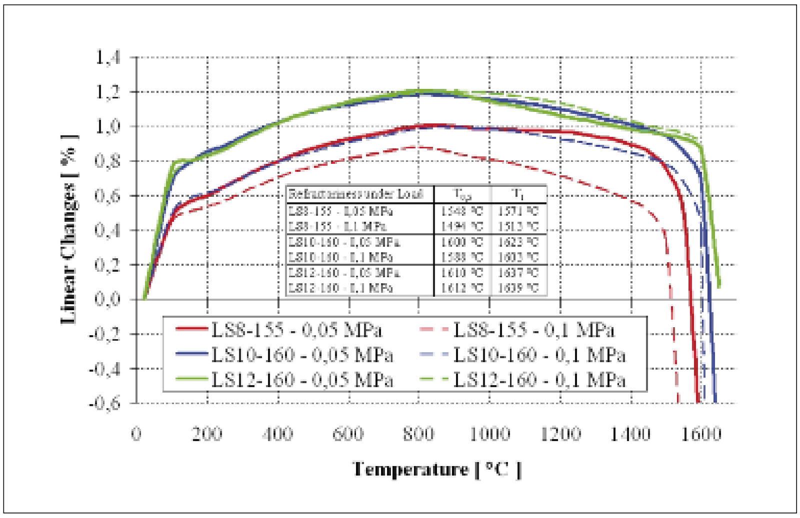

Fig. 2 Refractoriness under load as per SN EN 993-8

4 Large insulating bottom blocks

Large bottom blocks used in the construction of glass tank have construction and insulation function (usually 3rd layer of insulation). As the construction of glass tank bottom must be stable also the low layers of insulation must have high strength characteristics.

Material SL12C-140 has an average CCS of 20 MPa with BD of 1200 kg·m^{-3}. Also other parameters must ensure a flatness of bottom during the operation of the furnace.

This assortment is required mainly in dimensions 600 mm × 600 mm × 200 mm and 1000 mm × 500 mm × 200 mm. Critical points are manipulation with the block after pressing on *HORN* press machine and tuning of the firing regime. Dimensional allowances for delivery are ±1 mm (block are calibrated). Sometimes also pre-assemblies are required.

Insulation of palisades is not that demanding on CCS values and thus material with lower thermal conductivities – such as SL6P-130, SL8P-135 and SL10C-150 – may be used.

5 Discussion and testing

An integral part of research and development is verification of parameters. Not only the required parameters were varified but also parameters which allow us to get deeper information about the material and performed technological changes.

The operation program "Enterprise and Innovation" was used as a part of program "Potential" registered under no.

Tab. 3 Characteristics of large insulating bottom blocks

Product Group OPATERM		SL6C-130	SL8C-135	SL10C-140	SL12C-140	SL10C-150	SL11C-150
Bulk density [kg·m^{-3}] Cold crushing strength [MPa]		600 3	800 8	1000 10	1200 20	1000 5	1150 12
Chemical composition [%]	SiO_2 Al_2O_3 Fe_2O_3	57 33 2,0	55 40 1,7	55 38 2,4	55 38 2,8	29 67 0,7	29 67 1,0
Thermal conductivity [W·m^{-1} K^{-1}] at	200 °C 400 °C 600 °C 800 °C 1000 °C 1200 °C	0,22 0,23 0,26 0,30 0,35 0,40	0,39 0,41 0,44 0,48 0,53 0,58	0,48 0,51 0,55 0,59 0,64 0,69	0,57 0,60 0,64 0,68 0,73 0,78	0,37 0,38 0,40 0,43 0,46 0,50	0,53 0,54 0,56 0,62 0,68 0,75
Classification as per ČSN EN 1094-2 Testing temperature [°C/h] Permanent linear changes [%]		130-0,6-L 1300 / 12 –0,6	135-0,8-L 1350 / 12 –0,8	140-1,0 1400 / 12 –1,8	140-1,2 1400 / 12 –1,8	150-1,0 1500 / 12 –0,6	150-1,1 1500 / 12 –0,7
Classification per ASTM C155-8 Testing temperature [°C/h] Permanent linear changes [%]		23 1300 / 24 –0,8				28 1510 / 24 –0,9	28 1510 / 24 –1,2

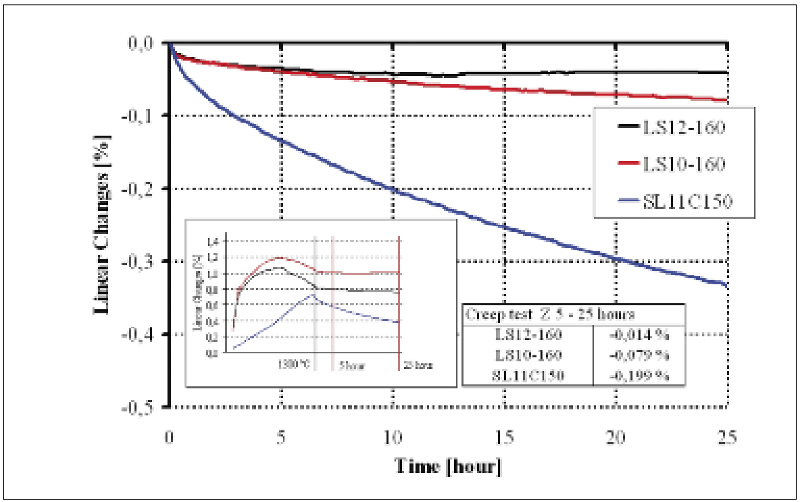

Fig. 3 Creep test as per SN EN 993-9 (load at 0,1 MPa)

4.2.PT02/062 in order to improve and increase the capacity of our laboratories for microstructural (RTG diffraction) and heating tests (thermal expansion, refractoriness under load and creep).

The test, which determines stability of refractory material in heat is (beside classification temperature) creep. Material SL11C-150 is tested at 1300 °C (200 °C below classification temperature) and load of 0,1 MPa (Fig. 3).

Important information provides a test of thermal expansion compared with the curve of refractoriness under load as can be seen in Fig. 4.

Besides standard rectangular shapes also complicated shapes are required. These cannot be pressed and must be produced by a technology of vibro-casting. This technology is used also for small series. High alumina insulating material A90FLK may be taken as an example. This vibro-casted material has already been successfully installed. Materials with bulk densities of 800–1400 kg·m^{-3} and classification temperature around 1400 °C are being developed right now. We are about to start a development of silica insulating materials produced by the technology of casting.

6 Conclusion

Standard insulating materials are used in the construction of glass furnace. Silica insulation materials are used in the crown. Special area of insulation present fireclay and high alumina large bottom blocks with classification temperature above 1350 °C and high strength characteristics. From the dense materials producer's point of view was the inclusion of insulating materials in the production program an important step which allowed us to complete the range materials and occupy free production capacities.

The focus was put on use of the current production equipment (high pressure hydraulic press machines) which is used for effective production of dense materials. The classic plastic production technology using burn-out substances for production of insulating materials is being removed due to their higher demands on time and workload. An important step presented a launch of production of large insulation bottom blocks. Besides the technology itself, laboratory tests on characteristics which are usually not required by refractory materials are monitored more and more closely as they also determine the behaviour of material in heat and are very much helpful in the innovation process.

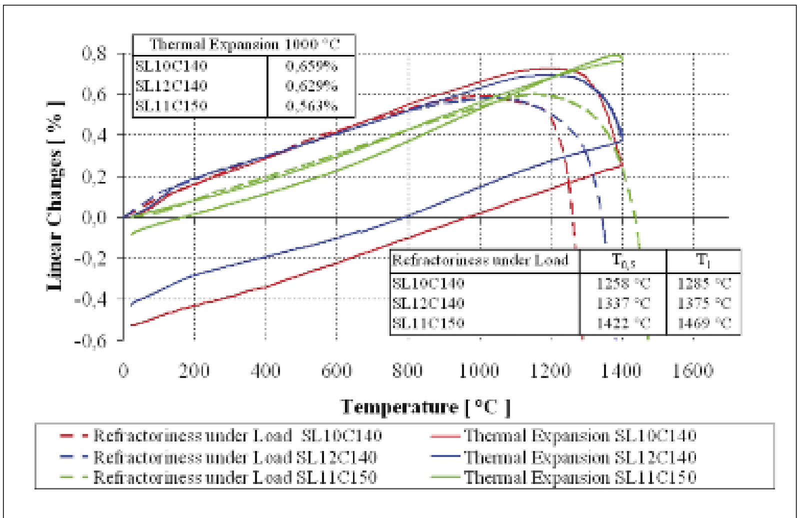

Fig. 4 Refractoriness under load (0,05 MPa) and dilatation curves of insulating bottom blocks

Acknowledgements

This paper has been prepared with the financial support of the project „SUPMAT – Promotion of further education of research workers from advanced building material centre"; registration number CZ.1.07/2.3.00/20.0111. The project is co-funded by the *European Social Fund* and the state budget of the Czech Republic.

References

[1] Schacht, C.: Refractories handbook. New York 2004

[2] Kutzendörfer, J.; Máša, Z.: Žárovzdorné tepeln izola ní materiály. Informatorium, Praha 1991

[3] Staro, J.; Tomš, F.: Žiaruvzdorné materiály. Bratislava 1992, 437–439

[4] Strouhal, T.; Lang, K.; Mareček, P.: Koroze žárovzdorných materiál ve sklářských agregátech. 14th Conf. on Electric and Other Highly Efficient Methods of Glass Melting, 10.–12.8.2007, Ceské Budjovice

[5] Ková, P.; Lang, K.; Kotouček, M.: Izola ní dinas – možnosti výroby a sledování užitných vlastností, příspěvek na konferenci „Hutní keramika 2011", Rožnov pod Radhošt m 2011

[6] Ková, P.; Lang, K.: Nevivová, L.: Vlastnosti isolaních žáromateriál používaných pro stavby sklá ských pecí, příspěvek na konferenci Zborník referátov z medzinárodnej vedeckej konferencie Žiaromateriály, pece a tepelné izolácie. Vysoké Tatry (2010)