

Improving Ladle Stir Reliability and Service Life Using new Design Purge Plug

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The Evolution of Steel Ladle Stir Plugs

✦ Refractory Materials:

- ✦ Magnesia
- ✦ High Alumina
- ✦ Alumina-Magnesia
- ✦ Alumina-Chrome
- ✦ Alumina-Spinel

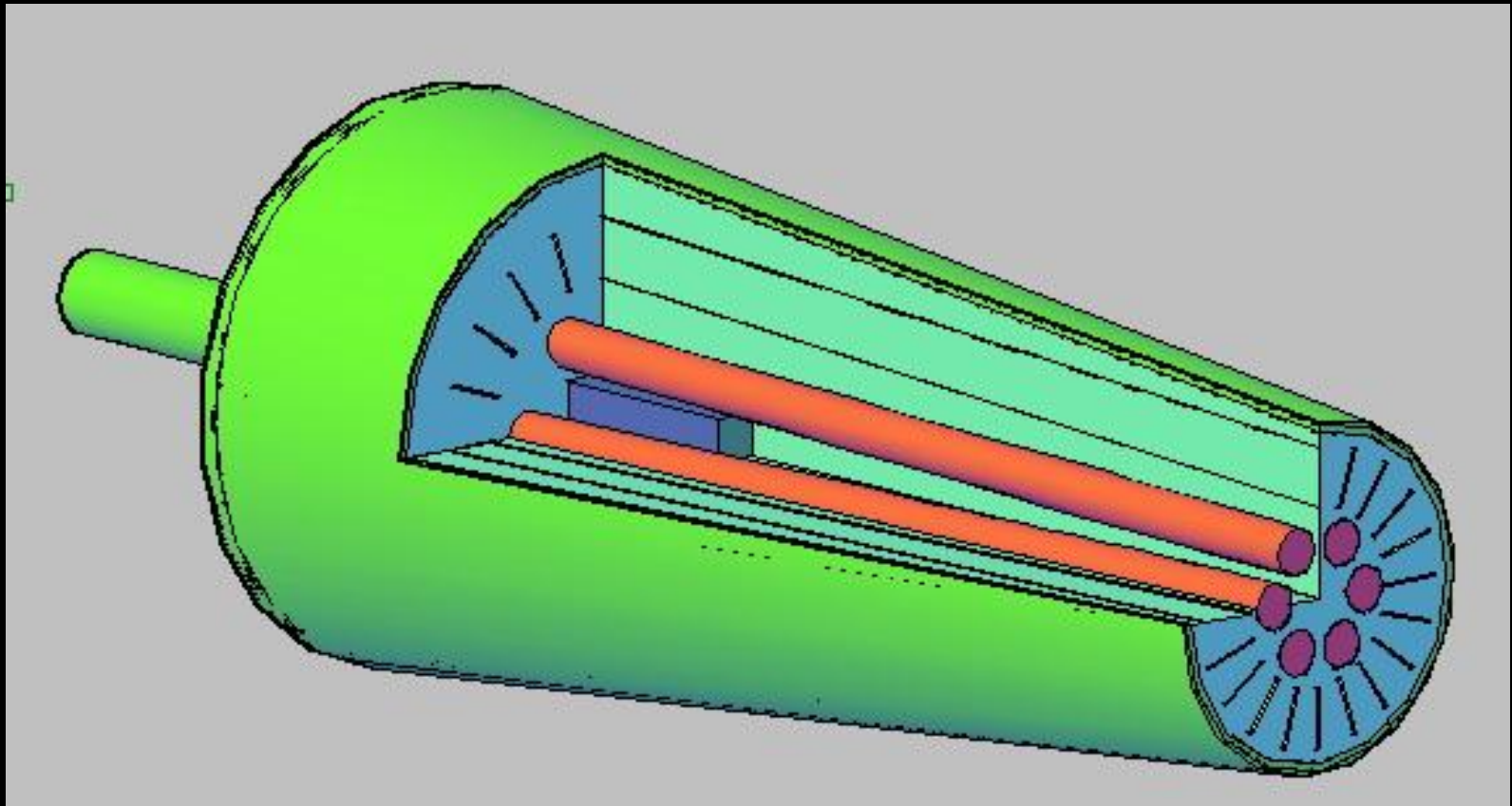
✦ Plug Design:

- ✦ Porous
- ✦ Interconnected net
- ✦ Segmented
- ✦ Slotted

Evolving Steel Making Operating Objectives

- ✦ Reduced usage of argon injection lance as backup to plug is both a steel quality and a cost concern.
- ✦ Improved productivity reduces the window of time available for refining at treatment at the LMF. Operators must be able to complete refining steps, such as desulphurization in quicker time.
- ✦ Faster turnaround time is required for ladles.
- ✦ Improved service life of ladle refractories, including plugs and ladle slagline, is necessary to meet CPT objectives.

Stir Plug with Ceramic Rods and Slots



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	ZrO ₂ +HfO ₂	Al ₂ O ₃	MgO	CaO	LOI	Sizing
Sintered Alumina	-	99.77	-	0.06	0.14	325
Ceramic Alumina	-	99.25	-	0.08	1.31	325
Ceramic Alumina	-	99.48	-	-	-	6
Tabular Alumina	-	99.56	-	0.09	-	325
Fused Alumina Spinel	-	74.20	-	0.74	-	325
Monoclinic Zirconia	99.09	0.15	-	0.09	-	1000
Zircon	66.01	-	0.26	0.11	-	320
Burned Magnesia	-	0.30	87.93	1.04	8.59	180

Chemistry and Physical Properties of Ceramic Rod

	DKG11	CTB36	CTB39	CTB48
Al ₂ O ₃ , %	84.67	93.86	94.48	98.71
ZrO ₂ + HfO ₂ , %	-	-	4.02	
MgO, %	12.56	5.37	-	0.22
Modulus of Rupture, Mpa	84.9	128.3	116.0	134.5
Bulk Density, g/cm ³	3.06	3.60	3.62	3.71
Apparent Porosity, %	13.1	6.1	0.9	0.6
Reheat Linear Change, % 1600 C x 8h	0.15	0.01	0.02	0.01
Thermal Expansion, % Ambient to 1300 C	1.07	1.00	0.95	1.00

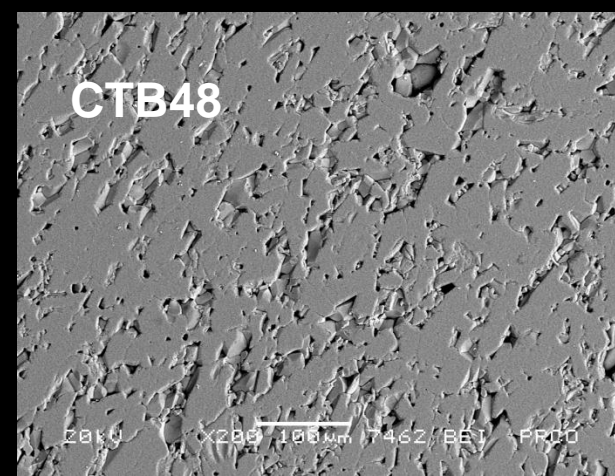
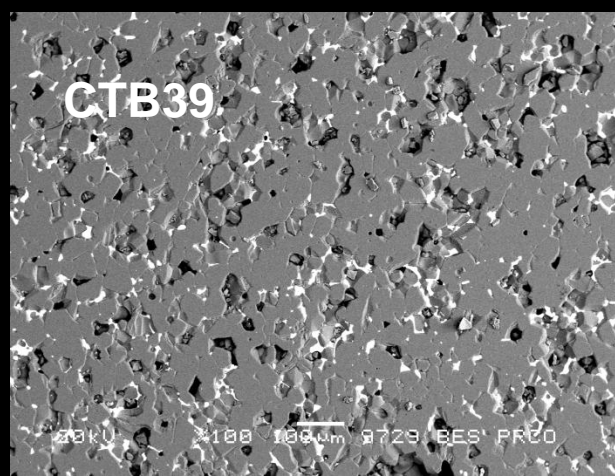
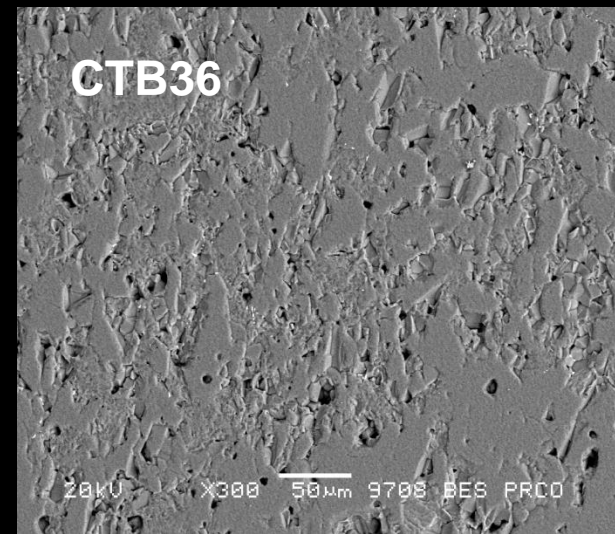
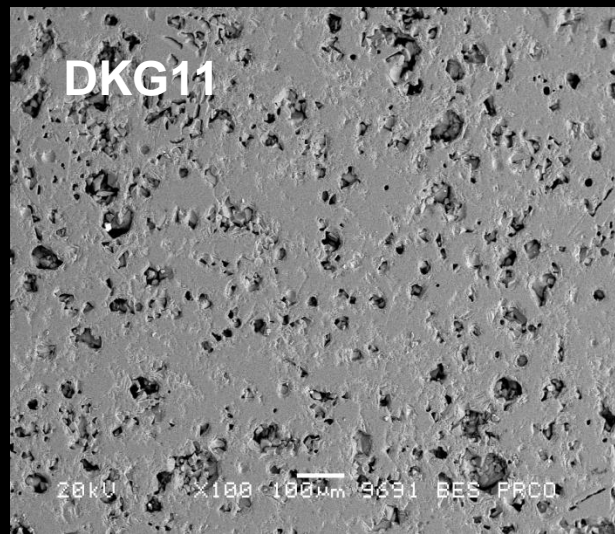


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SEM Photos of Structure of Ceramic Rods



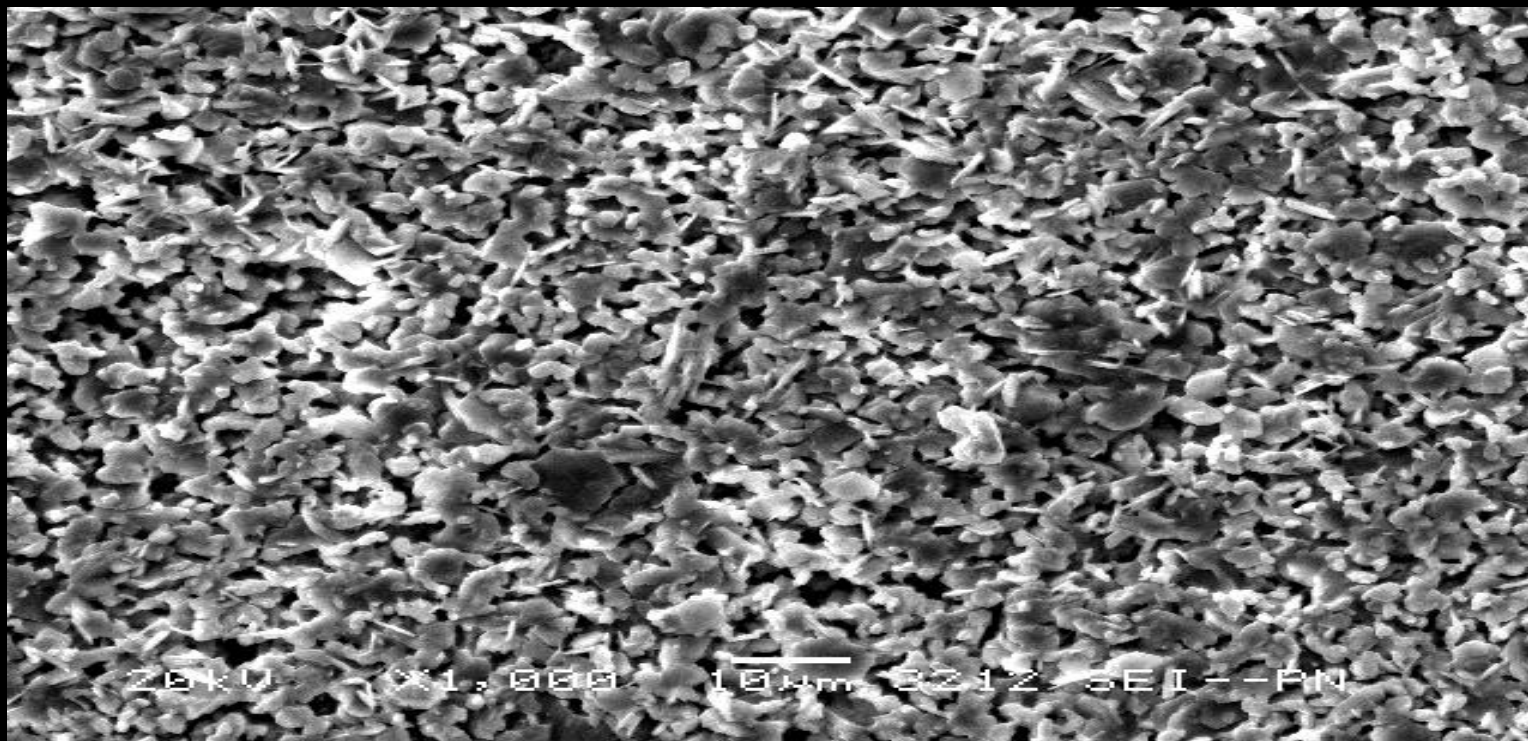
Spinel Castable Raw Materials

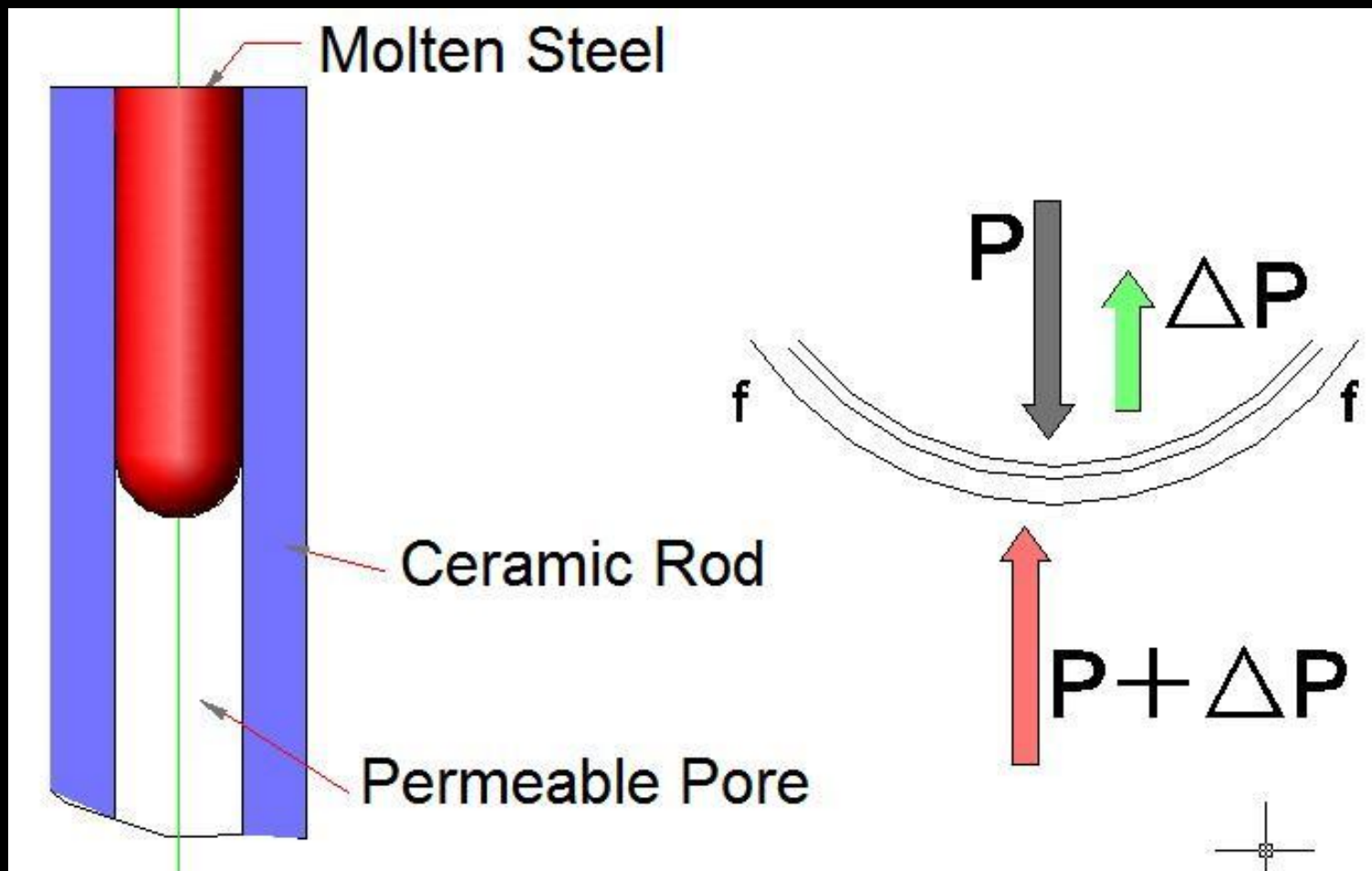
	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	CaO	MgO	Alkalai
Tabular Alumina	0.03	99.63	0.01	0.03	0.09	0.00	0.21
Alumina Powder	0.03	99.76	0.02	0.02	0.05	0.00	0.09
Alumina Cement	0.29	69.02	0.03	0.12	25.6	0.43	0.38
Spinel	0.23	73.86	0.00	0.21	0.05	25.23	0.22

Spinel Castable Physical Properties

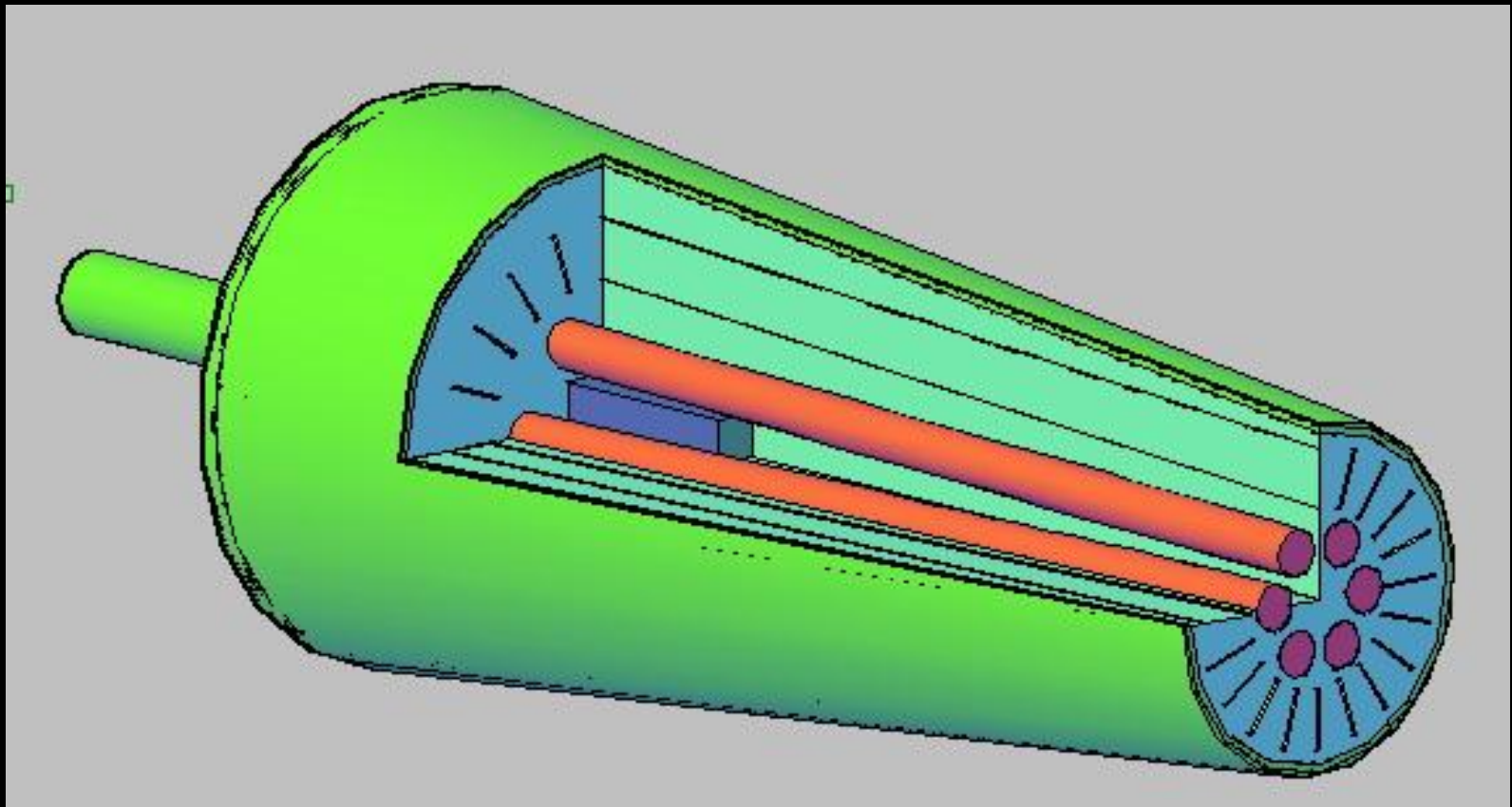
	PROPERTY
110 Cx24h Bulk Density, g/cm ³	≥3.10
110 C x24h Linear Change, %	±0.1
110 Cx24h Modulus of Rupture, Mpa	≥6
110 Cx24h CCS, Mpa	≥40
1500 Cx3h Bulk Density, g/cm ³	≥3.05
1500 Cx3h MOR, Mpa	≥20
1500 Cx3h CCS, Mpa	≥100
1500 Cx1h HMOR, Mpa	≥15

SEM Photo of Spinel Castable





Stir Plug with Ceramic Rods and Slots



CASE HISTORY of PERFORMANCE

	Shop A		Shop B		Shop C		Shop D	
Ladle, MT	180		110		120		100	
Plug design	A	B	A	B	A	B	A	B
Erosion rate, mm/heat	.32	.24	.16	.10	.16	.12	.60	.50
Service Life Improvement	33%		60%		33%		20%	
Depth of metal penetration	20	0	10	0	20	0	20	0

Plug A = Regular Slotted Design

Plug B = New Compound Ceramic Rods with Slot Design

CONCLUSIONS

- ✦ Newly developed ceramic materials provide higher density and lower porosity versus regular castable for improved resistance to chemical and mechanical erosion.
- ✦ The use of permeable ceramic rods reduce the obstruction of the stir plug.
- ✦ The need for oxygen washing is reduced.
- ✦ Service life is improved.
- ✦ More reliable and consistent stirring is achieved..
- ✦ The addition of slots provides sufficient volume for rapid desulphurization.
- ✦ Bubble size is reduced and quantity of bubbles is increased for improved steel quality.

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