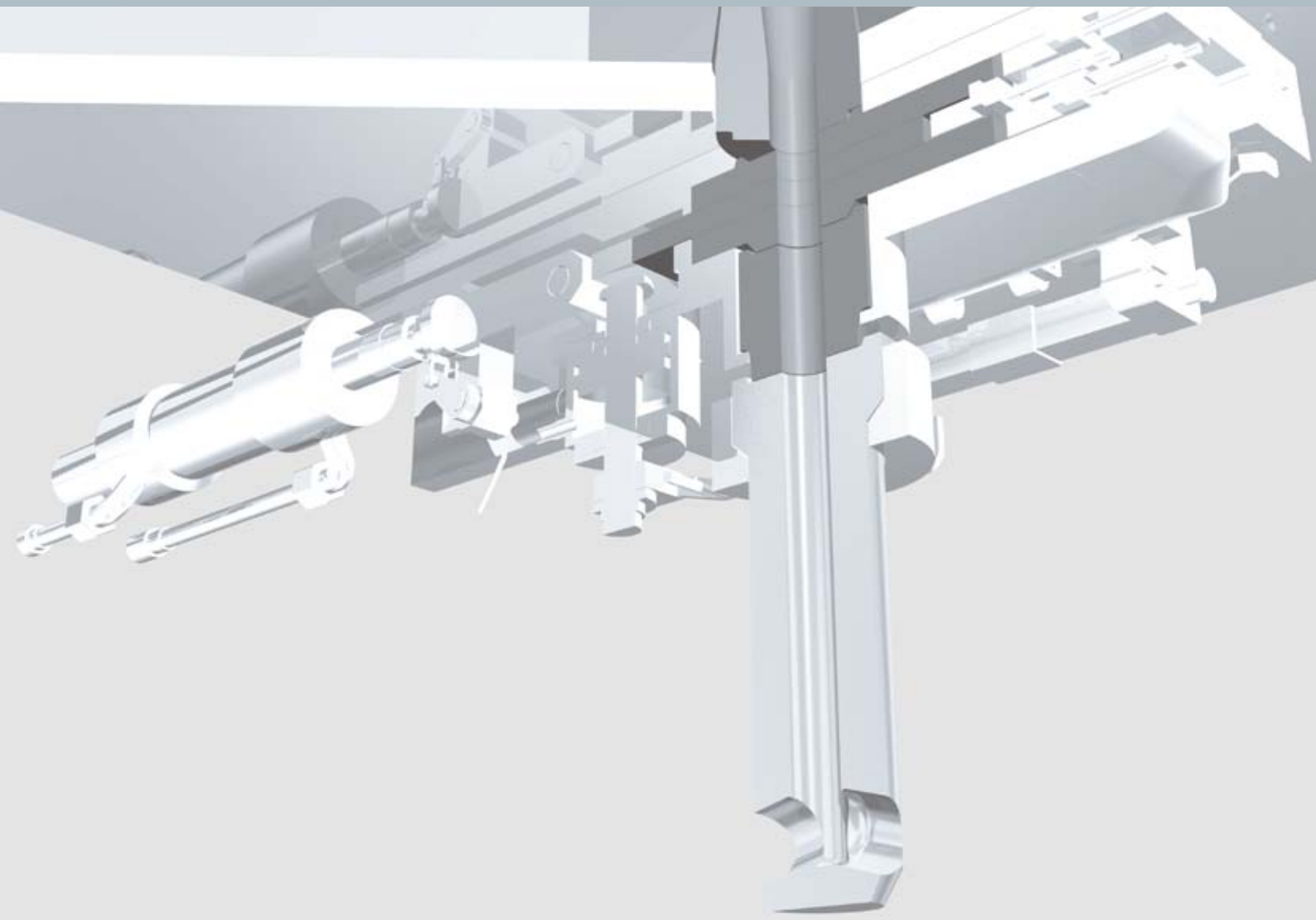

Shinagawa's Refractory Solution for High Quality Steel

SHINAGAWA

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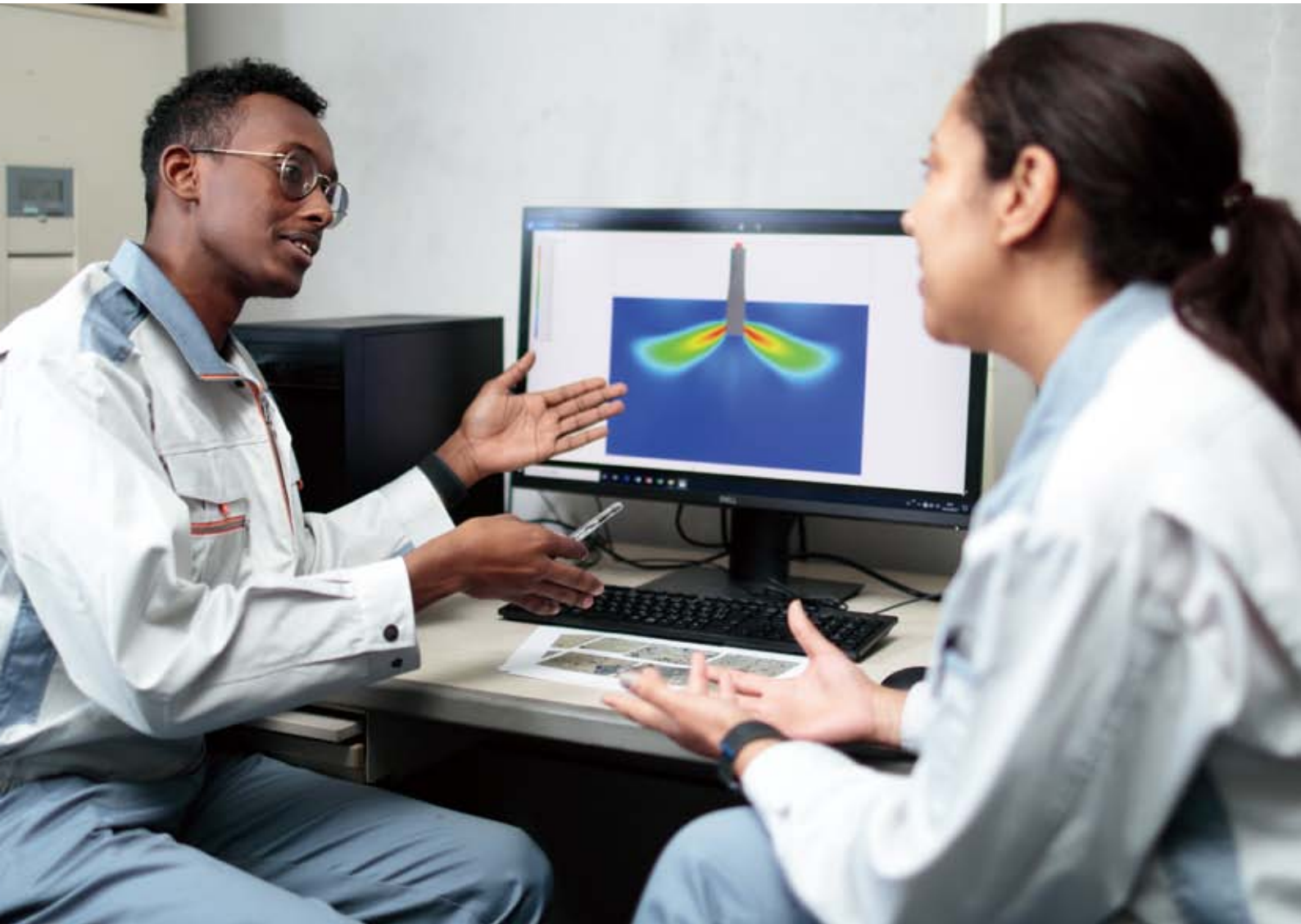
Shinagawa's Refractory Solution for High Quality Steel

Continuous casting technology has prevailed in Japan since the 1950s, and Shinagawa Refractories has developed specific refractory products and associated equipment to support the steel industry.
Our expertise includes slide gate valve systems, submerged entry nozzles, tundish linings and mold powders, and we continue to break new ground every day with technological advancements.
With over 145 years of refractory experience, Shinagawa's dedicated engineers stand at the forefront of innovation for the future of steelmaking.



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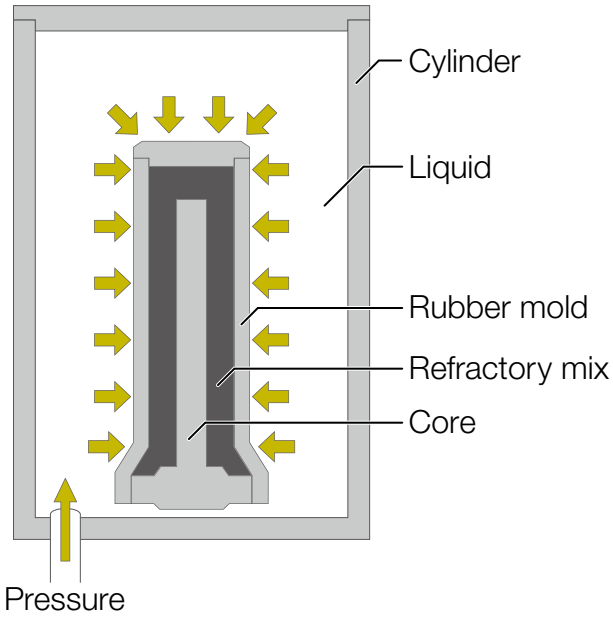
Refractories for Continuous Casting

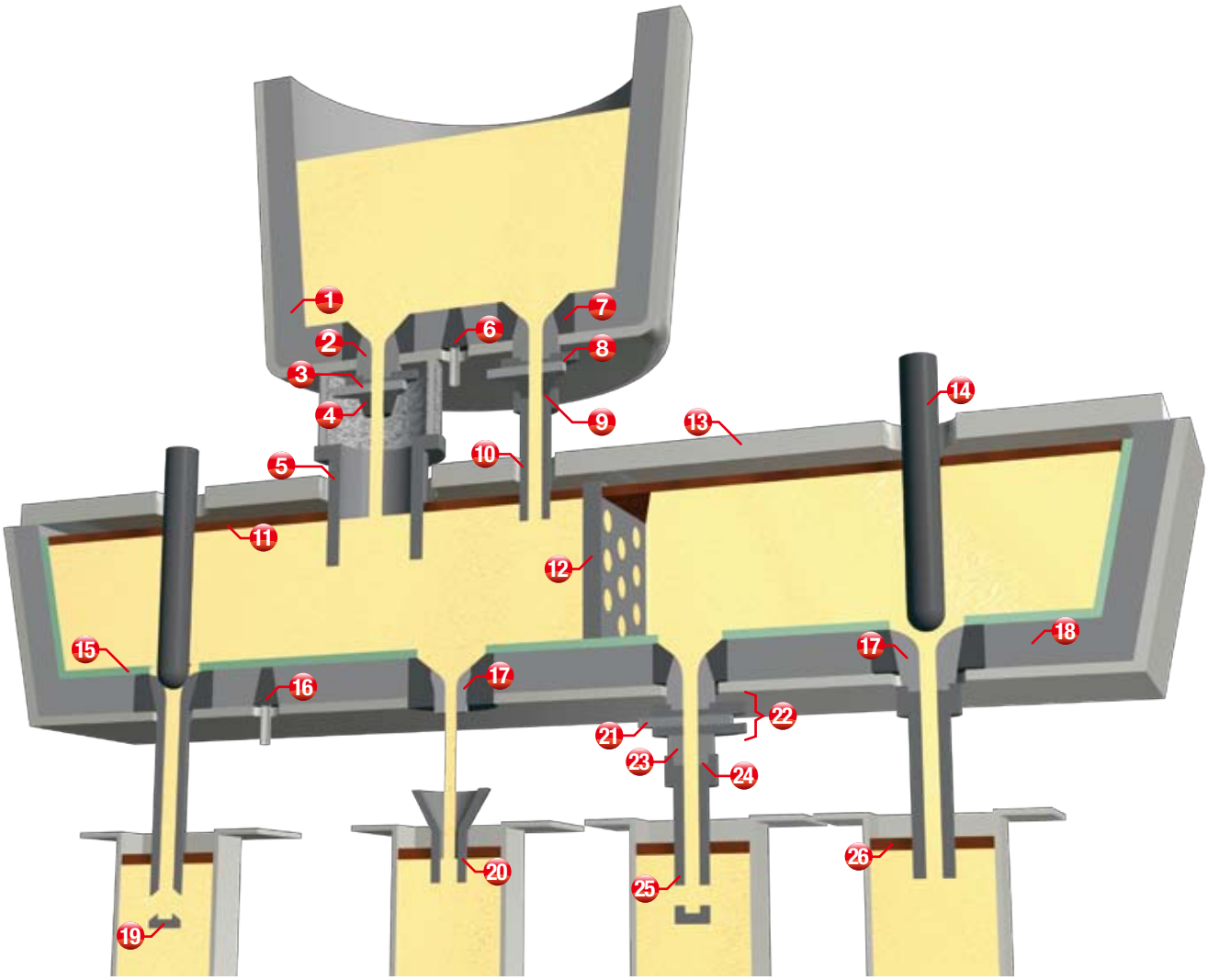
Most steel today is manufactured by the continuous casting process. This technology benefits from further advancements and developments such as high-speed casting, multi-sequence casting and the improvement of steel quality.
Shinagawa Refractories has over 145 years of experience in thermal solutions, and for over 50 years, since 1968, the company has developed optimal design and formulas for continuous casting applications. From the ladle to the caster mold, slide gate valve flow rate control systems, tundish refractories, ladle shrouds and submerged entry nozzles, Shinagawa covers the whole range of refractory needs.
The company's rich experience and advanced techniques are much in demand for various casting operations: for casting of billets, blooms, slabs and thin slabs. Shinagawa values close relationships with every customer and will always find the ultimate solution best suited for the unique conditions and parameters found at each caster.

Cold Isostatic Press for Ladle Shrouds and SEN Production

Among all the refractories necessary for casting, ladle shrouds and submerged entry nozzles (SENs), are critical in the final stages of process. In order to achieve a stable operation while maintaining the highest steel quality, these refractories play extremely important roles.
At Shinagawa, these refractory products are manufactured using a Cold Isostatic Press (CIP), which employs uniform pressure and allows high compaction rates and uniform density of the refractory material.



Refractory Products for Continuous Casting of Steelmaking



< For Ladle and Tundish >

1. Ladle
2. Upper nozzle
3. Plate bricks
4. Lower nozzle
5. Tundish pipe
6. Porous plug
7. Well block
8. Slide gate valve
9. Ceramic gasket
10. Ladle shroud
11. Tundish powder
12. Weir block
13. Tundish cover
14. Monoblock stopper
15. Surface coating material
16. Porous plug
17. Tundish nozzle
18. Tundish lining

< For Casting >

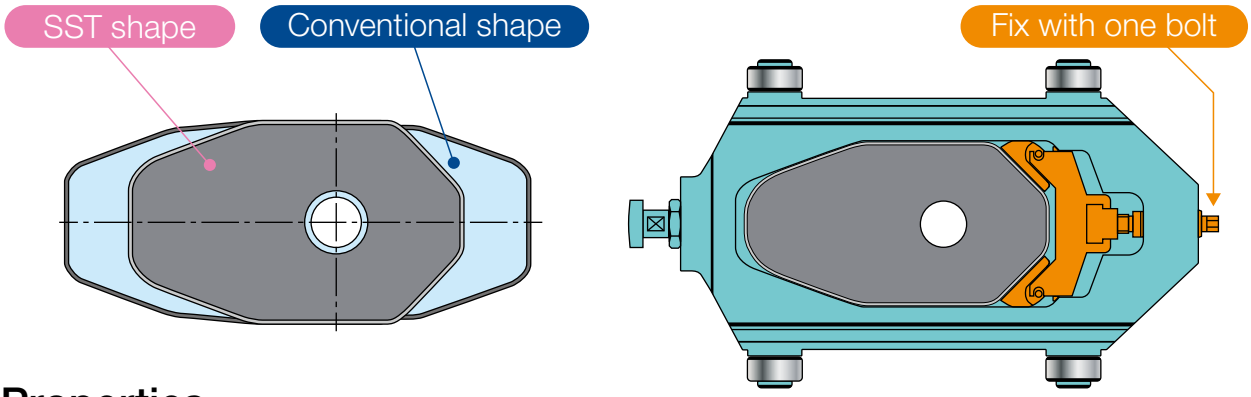
19. Inner-set SEN
20. Semi-immersion nozzle
21. Plate bricks
22. Slide gate valve
23. Lower nozzle
24. Ceramic gasket
25. Outer-set SEN
26. Mold powder

Ladle and Tundish Applications

Slide Gate Valves

Plate Bricks

The Shinagawa engineering team conducted an experiment to discover how to reduce the cracking of slide gate valve plates.
As a result of stress simulation tests, a new shape for plates was developed which is smaller in size and well suited for “SST,” Shinagawa’s slide gate valve control system. The design of four faces fixed with one bolt secures the plate uniformly and prevents longitudinal cracking. Additionally, the weight of a typical sized plate is 20% less than conventional shapes. This is one less burden for casting process operators.



Properties

Brand		SVR-FK3	SVR-PK73	SVR-PK87	SVR-PR57	SVR-PL1	SVR-PB50	SVR-PM5	SVR-PZ32
Quality		Al_2O_3-C	Al_2O_3-C	Al_2O_3-C	Al_2O_3-C	Al_2O_3-C	MgO-C	MgO-Spinel	ZrO_2
Apparent porosity (%)		9.0	8.0	8.8	11.6	9.0	10.0	14.2	15.6
Bulk density		3.30	3.27	3.35	3.23	3.21	3.00	3.07	4.53
Crushing strength (MPa)		165	150	185	110	130	80	100	150
Thermal expansion at 1000°C (%)		0.7	0.7	0.7	0.7	0.7	1.2	1.2	0.7
Chemical composition (%)	Al_2O_3	77	83	75	80	84	—	6	—
	SiO_2	1	1.5	3	4	—	—	—	—
	MgO	—	—	—	—	—	92	90	—
	ZrO_2	10	6	10	9	3	—	—	94
	C	6	6	5	5	5	4	—	—
Application		Ladle & TD	Ladle & TD	Ladle & TD	Ladle & TD	Ladle & TD	Ladle & TD	TD	TD
		Regular steel	Regular steel	Regular steel	Regular steel	Regular steel	Special steel	Special steel	Special steel

Nozzle Bricks

Shinagawa provides two types of nozzles for slide gate valves: upper nozzles (insert nozzles) and lower nozzles (chute nozzles). Nozzles are required to resist various erosion, corrosion, spalling and abrasion problems. For example, lower nozzles are usually exposed to severe heat cycles, so spalling resistance is the first priority in this application. However, upper nozzles are subjected to more corrosion, so they are designed to meet this challenge by being more corrosion resistant. Shinagawa provides a variety of refractory nozzles to meet the needs of each customer.

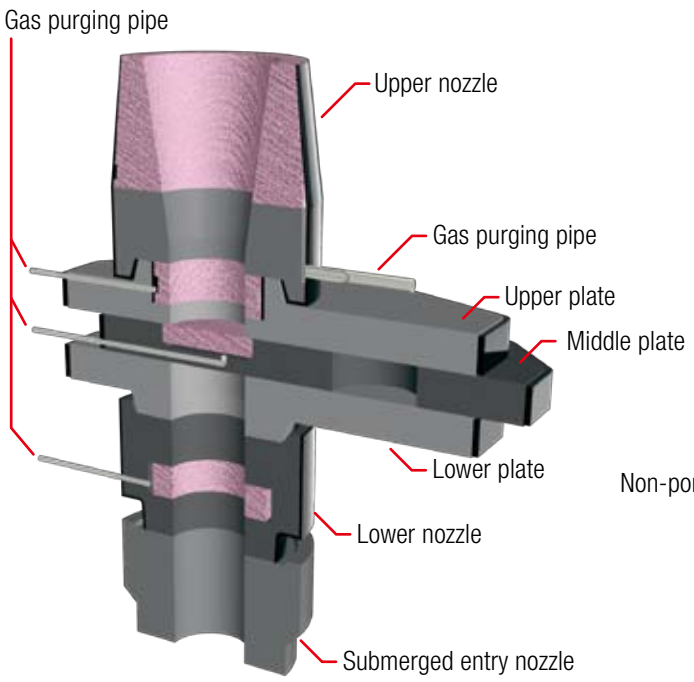
Properties

Brand		SVR-NU40	SVR-NU60	SVR-NA5	SVR-NU28	SVR-NU30	SVR-NZ7	ZCN-N-1	ZCN-ZR90
Quality		Al_2O_3-C	Al_2O_3-C	Al_2O_3	Al_2O_3-C	Al_2O_3-C	Zircon-FS	ZrO_2	ZrO_2
Apparent porosity (%)		8.0	9.0	17.0	11.0	7.5	15.0	14.0	13.1
Bulk density		3.20	3.22	3.05	2.75	2.93	3.02	4.83	4.88
Crushing strength (MPa)		100	100	85	80	110	70	195	115
Thermal expansion at 1000°C (%)		0.7	0.7	0.7	0.5	0.5	0.3	0.8	0.8
Chemical composition (%)	Al_2O_3	92	92	92	73	66	—	—	—
	SiO_2	—	—	7	18	17	50	—	—
	ZrO_2	—	—	—	—	8	44	95	95
	C	5	3	—	6	6	—	—	—
Application		Upper Nozzle	Upper Nozzle	Upper Nozzlel	Lower Nozzle	Lower Nozzle	Lower Nozzle	TD Nozzle	TD Nozzle

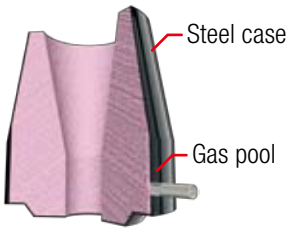
Configuration of Slide Gate Valves with Gas Blowing

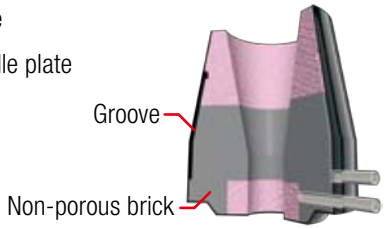
Shinagawa can provide various methods of gas blowing from upper / lower nozzles and plates : porous type or direct pore type, and configuration can be selected for any purpose or usage conditions.

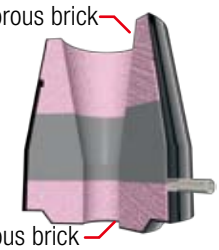
‹Slide Gate Valve›



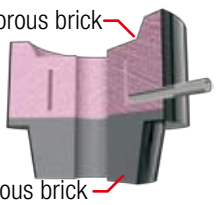
‹Upper nozzle›

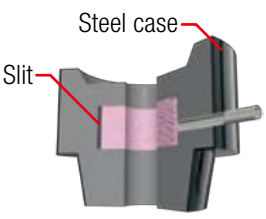






‹Lower nozzle›

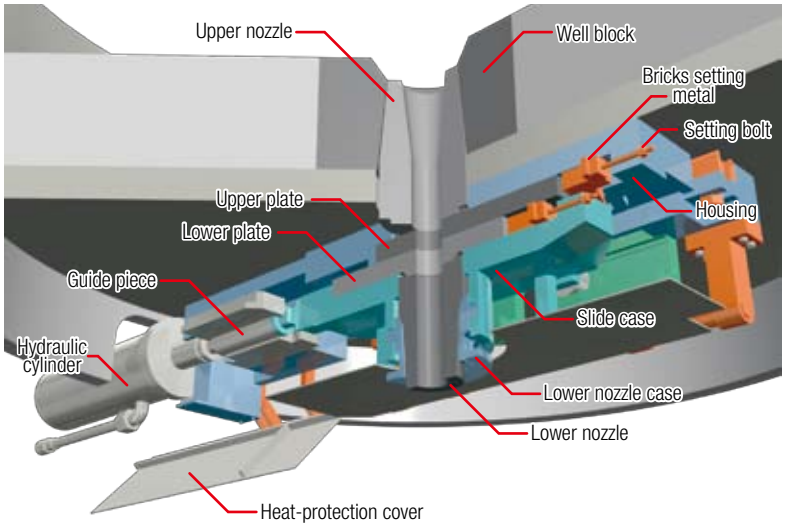


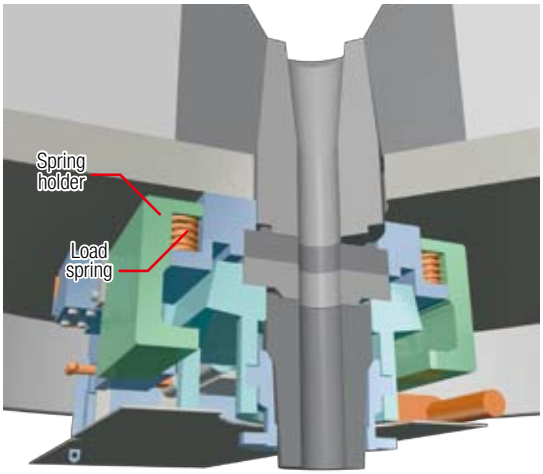


Slide Gate Valve Control Systems

Slide Gate Valve Equipment for Ladle (SST)

Configuration





Features

1. Refractories cost saving and increased performance

- Optimized shapes reduce the weight of each refractory plate. Shinagawa's unique plate fixation structure gives extended plate life with a significant reduction in cracking problems.

2. Maintenance cost saving

- The total number of components is reduced by 50% from the conventional design, and consumable parts can easily be replaced.
- Extension of spring life using a unique cooling system for the load spring.
- Simple, convenient and stable contact pressure application structure and high rigidity of the equipment.

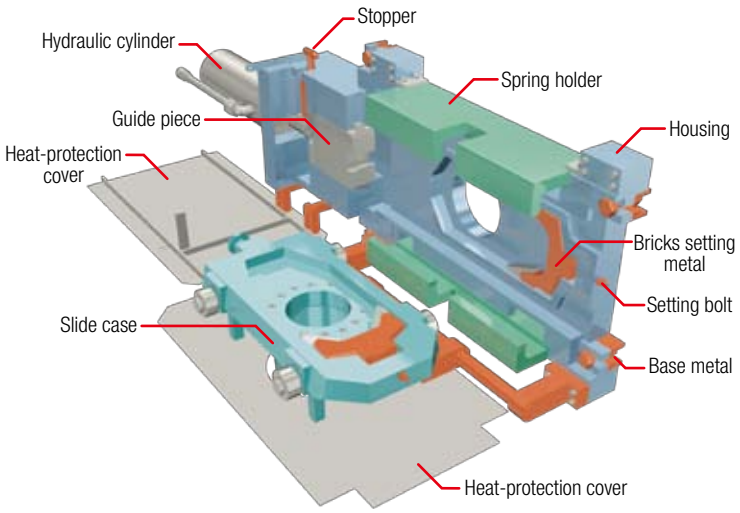
3. Excellent working efficiency

- The time for refractory maintenance can be minimized through our simple, quick change system.

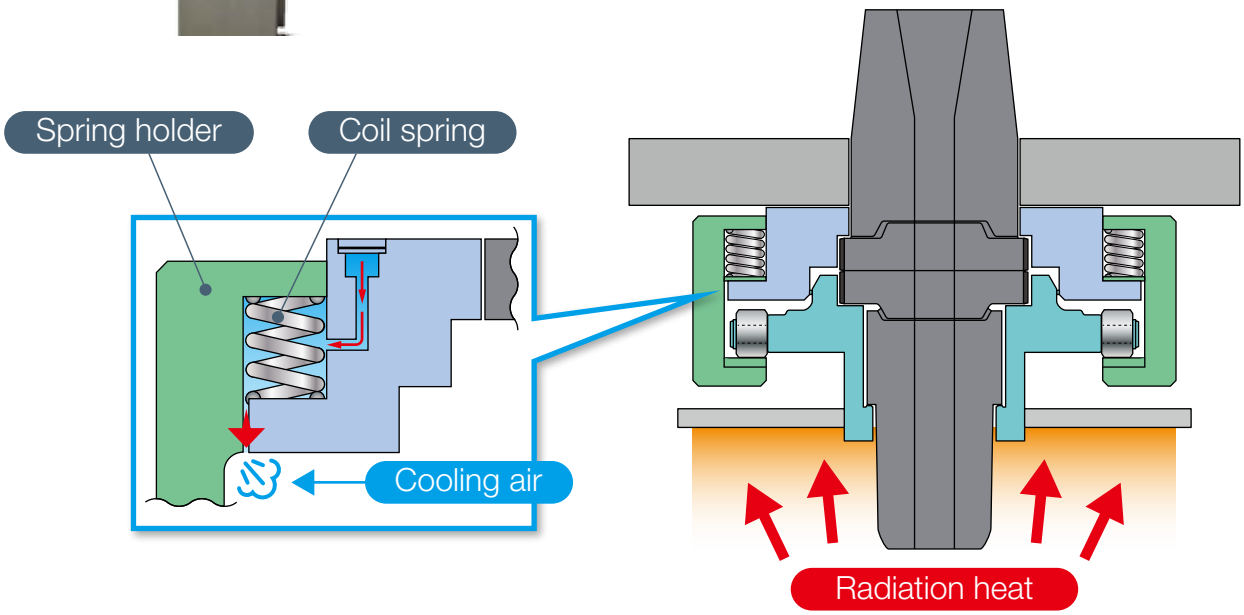
Standard specification

Model name / Item	SST		
	50	70	80
Plate brick composition	2 or 3-plate pattern		
Standard nozzle diameter (mm)	50	70	80
Sliding stroke (mm)	150	175	210
Loading Mechanism	Automatic Loading Mechanism		
Weight (kg) (including cylinder)	600	800	1000

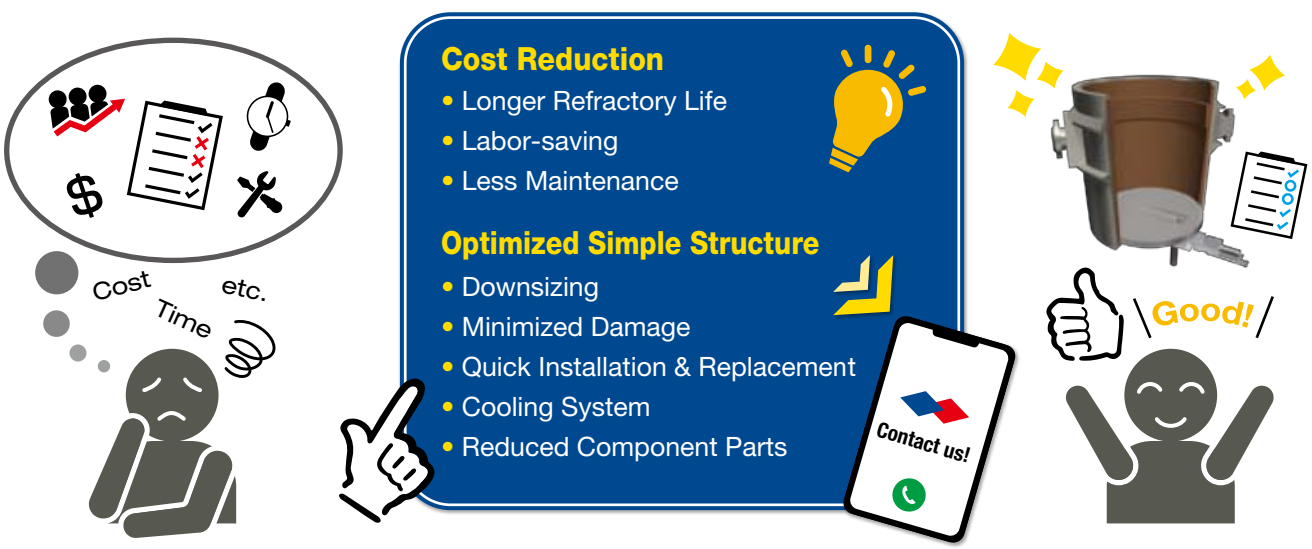
Automatic loading mechanism



The slide gate valve system controls the flow of molten steel into the tundish. Refractory plates are face pressure loaded and adjusted either by a hydraulic or an electric cylinder.
“SST,” Shinagawa’s slide gate valve control system, is equipped with a cooling function for the coil springs, and this increases the life of springs and hence the whole system. Whereas Shinagawa’s conventional system typically lasted less than 500 heats, SST has achieved a typical life of more than 2,000 heats. Furthermore, the SST structure is simply designed and mechanical component parts are reduced by half, compared to a conventional system.



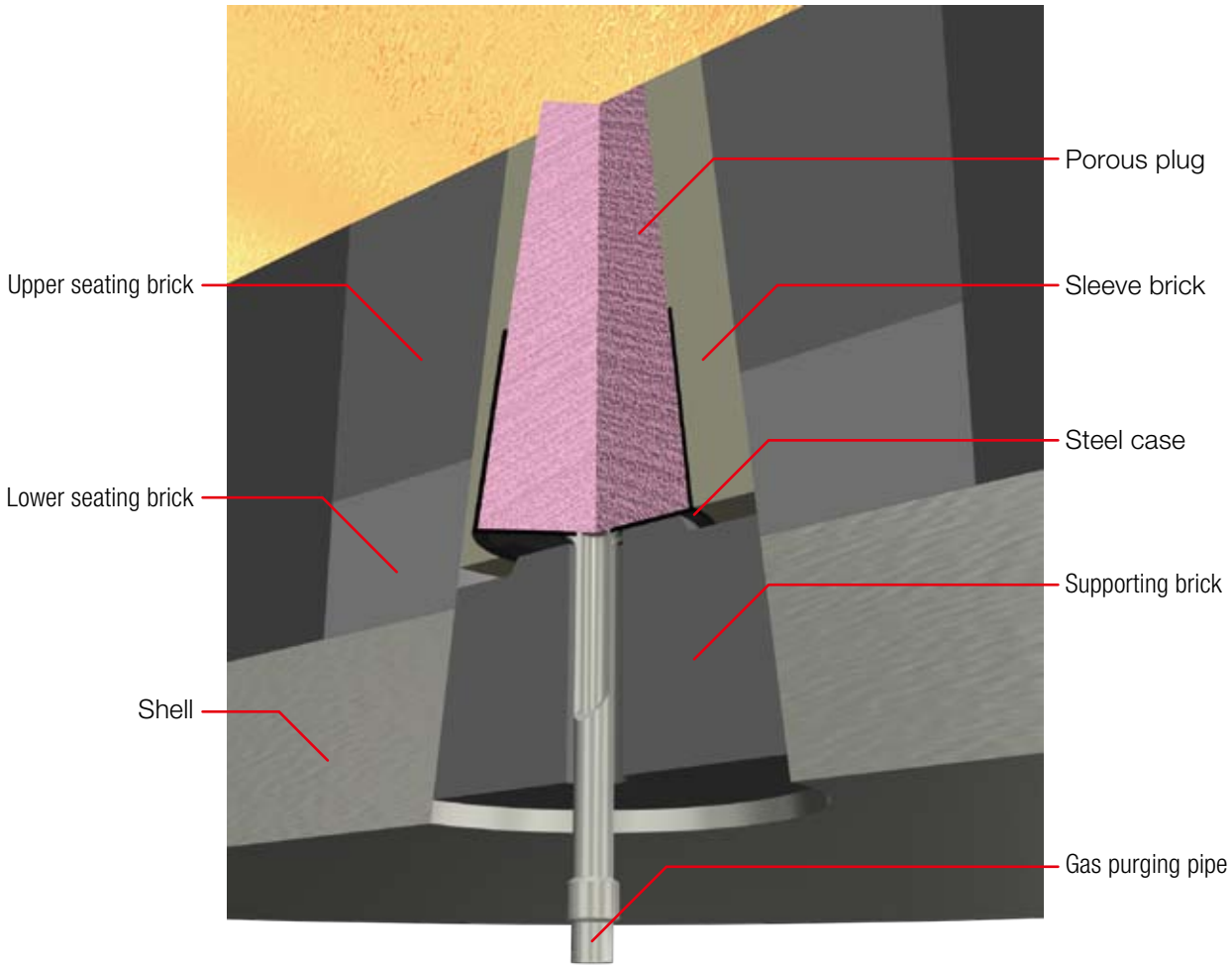
SST Consultation and suggestions



Purging Plugs

Purging plugs are used to stir molten steel while it is in the ladle. Shinagawa has developed various gas blowing methods, materials and configurations for any purpose and requirement.

Configuration

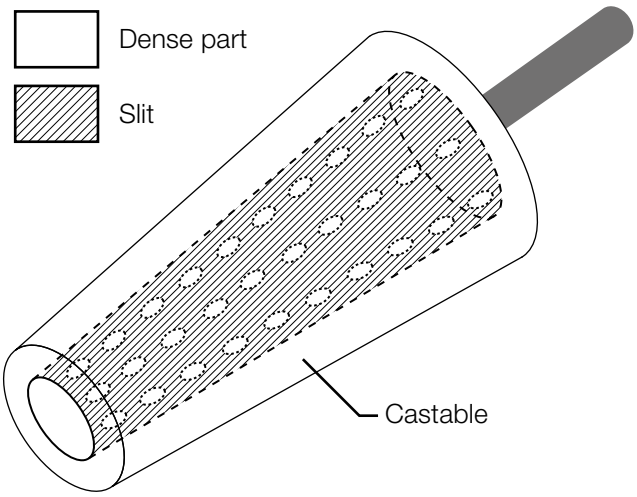


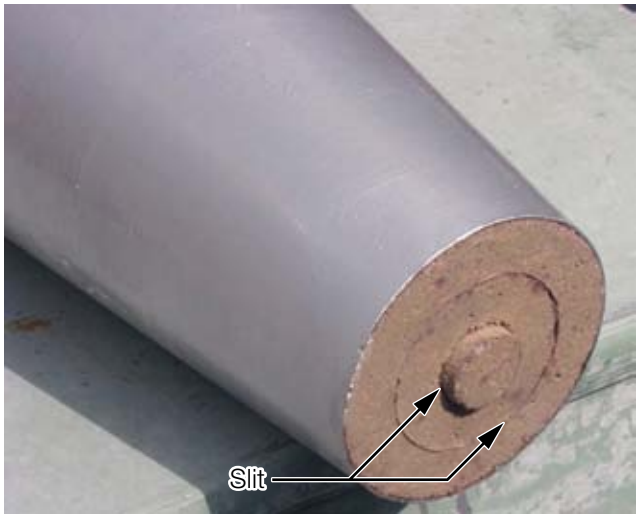
Gas blowing methods

- **Porous brick method**
  Different gas flow rates can be achieved by defining the pore size and controlling the porosity levels.

- **Slit method**
  Anti-corrosive performance and gas flow rate can be controlled by selecting materials and slit width. This method generates bigger bubbles.

Slit Plugs





Properties

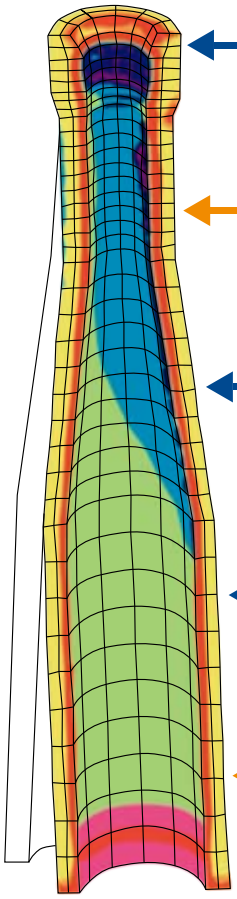
Properties \ Brand		ALP-A14	ALP-A21	HSP20	HSP203	HSP209
Apparent porosity (%)		26.3	27.4	24.0	23.4	22.5
Bulk density		2.47	2.56	2.80	2.83	2.89
Cold crushing strength (MPa)		36	48	54	86	89
Medium pore diameter (μm)		104	102	120	149	113
Chemical composition (%)	Al_2O_3	79	80	89	86	86
	SiO_2	19	15	7	7	6
	ZrO_2	—	3	—	3	3
	Cr_2O_3	1	1	2	2	4
Remarks		—	—	Normal	High flow rate	High durability

Ladle and Tundish Applications

Ladle Shrouds

Ladle Shrouds

Ladle shrouds are installed between the ladle and the tundish to prevent aspiration and increase slag removal from the molten steel.
Shinagawa has developed a series of techniques to resolve typical problems with this refractory application.



Nitrogen pick up → Airtight and non-stick ceramic gasket

Thermal and mechanical stress → High strength alumina graphite materials
Heat insulating carbon free inner lining

Erosion by molten steel → Corrosion resistant inner lining

Corrosion by tundish slag → Corrosion resistant slag line materials
(Spinel-C, ZrO_2-C)

Thermal stress → Spalling resistant alumina graphite materials
Low expansion carbon free liner

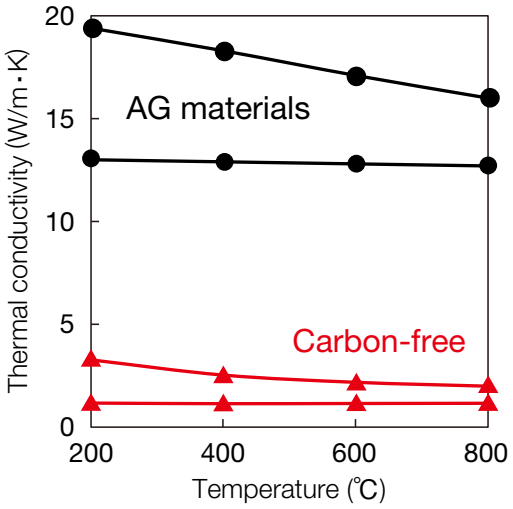
Properties

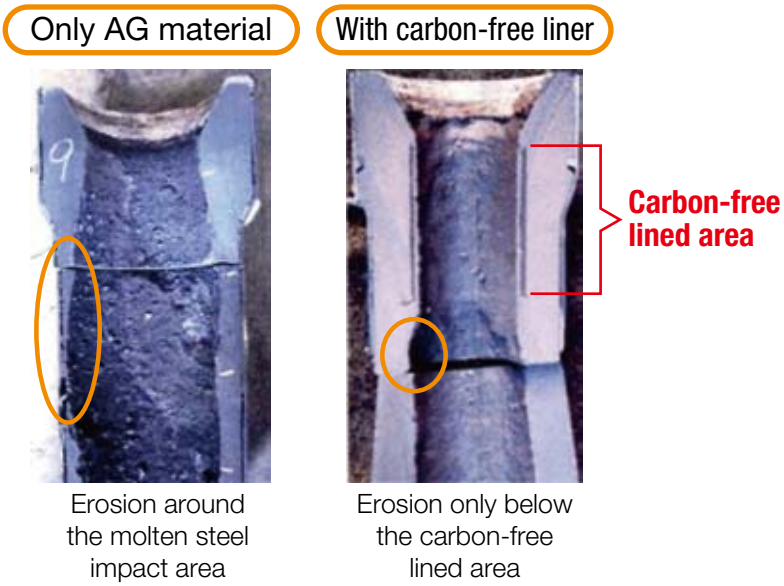
Area of application		Seat		Main body				Submerged body		
Purpose		All purposes	Oxidation resistance	Cold start	All purpose	High durability	High strength	All purposes	High durability	Corrosion resistance
Brand		G21B Series	G15B Series	G32D Series	G25A Series	G23A Series	G27A Series	G30C Series	G34H Series	G3Z Series
Apparent porosity (%)		13.5	12.0	14.0	14.5	14.0	13.0	14.0	13.5	14.5
Bulk density		2.45	2.45	2.35	2.45	2.35	2.40	2.55	2.55	3.60
Modulus of rupture (MPa)		11.0	13.0	8.0	9.5	10.0	11.0	9.5	10.0	9.5
Thermal expansion at 1000°C (%)		0.32	0.35	0.32	0.33	0.28	0.30	0.42	0.42	0.45
Chemical composition (%)	Al_2O_3	50	46	52	58	54	47	60	63	—
	SiO_2	18	19	14	14	23	20	3	—	—
	ZrO_2	—	—	—	—	—	—	—	—	70
	C+SiC	24+4	23+9	33	27	22	30+2	30+5	34+2	23
Remarks		—	High strength	—	—	—	—	SiO_2 less	Non SiO_2	ZrO_2-C

Ladle Shrouds with carbon-free inner lining

Features

- **Reduced thermal shock to prevent cracking.**
- **Improved erosion resistance at molten steel impact area.**





Ceramic Gasket for Nozzles

High sealing properties are necessary for any joints with nozzles because it affects the quality of steel and refractory damage. Shinagawa provides ceramic gaskets based on each unique ceramic material.

Features

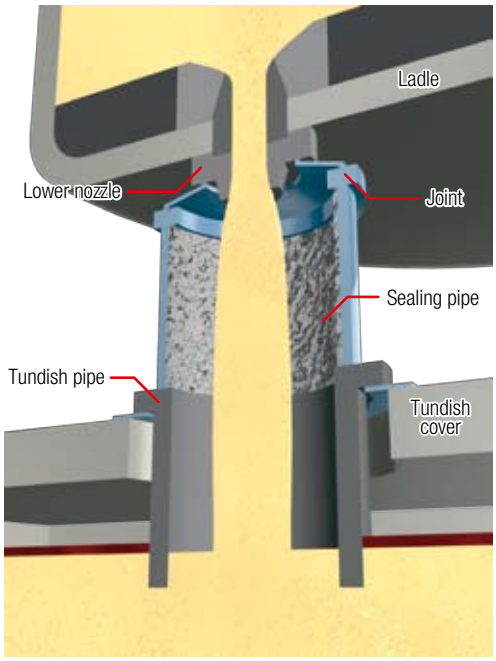
- **Hard at room temperature but becomes flexible when heated.**
- **Deforms under loading pressure to improve air tightness.**
- **Coated with carbon, which allows for easy removal after use and gives a clean joint surface, preventing aspiration.**

Ladle and Tundish Applications

Tundish Pipes & Monoblock Stoppers

Tundish Pipes

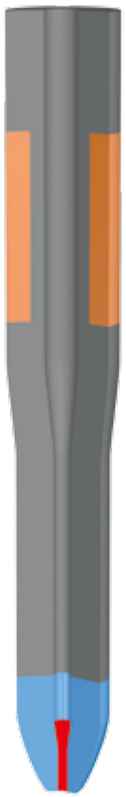
As with ladle shrouds, tundish pipes are placed between the ladle and the tundish to prevent air aspiration.



Properties

Area of application		Main body Submerged region	Submerged region
Brand		G32U series	G3MU series
Apparent porosity (%)		10.0	9.0
Bulk density		2.35	2.60
Modulus of rupture (MPa)		11.0	11.0
Thermal expansion at 1000°C (%)		0.26	0.30
Chemical composition (%)	Al_2O_3	48	—
	SiO_2	18	—
	MgO	—	63
	C+SiC	32	32
Remarks		Al_2O_3-C	MgO-C

Monoblock Stoppers



The stopper head requires high resistance to abrasion and corrosion because it directly affects flow control from the tundish and the mold. Shinagawa has developed various materials to provide the best specification for different operating conditions.

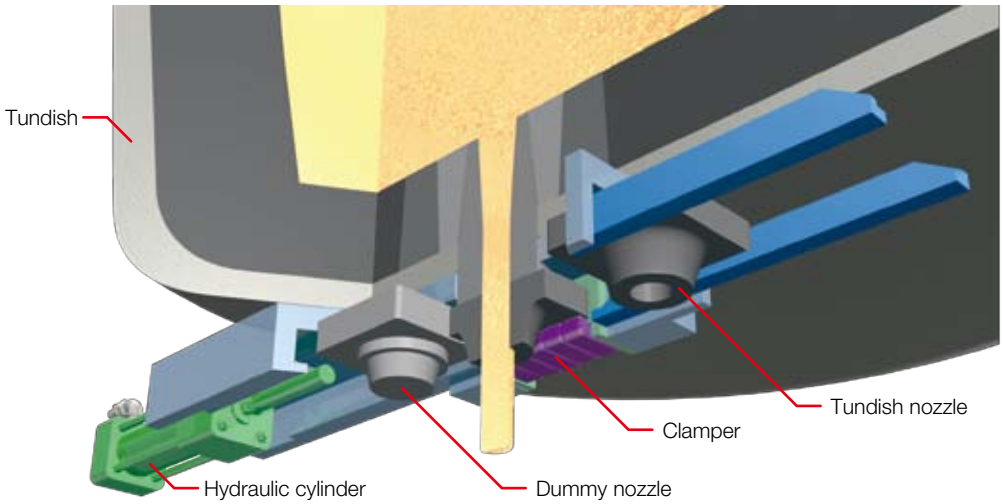
Properties

Area of application		Main body	Head		
Brand		G23H series	G20H series	G1M series	G3M series
Apparent porosity (%)		14.5	15.5	15.5	16.5
Bulk density		2.75	2.75	2.60	2.55
Modulus of rupture (MPa)		21.5	15.0	15.0	7.5
Thermal expansion at 1000°C (%)		0.42	0.42	0.50	0.63
Chemical composition (%)	Al_2O_3	73	74	58	7
	MgO	—	—	18	64
	C+SiC	21+4	19+4	16+4	23+3
Remarks		Al_2O_3-C	Al_2O_3-C	Spinel-C	MgO-C

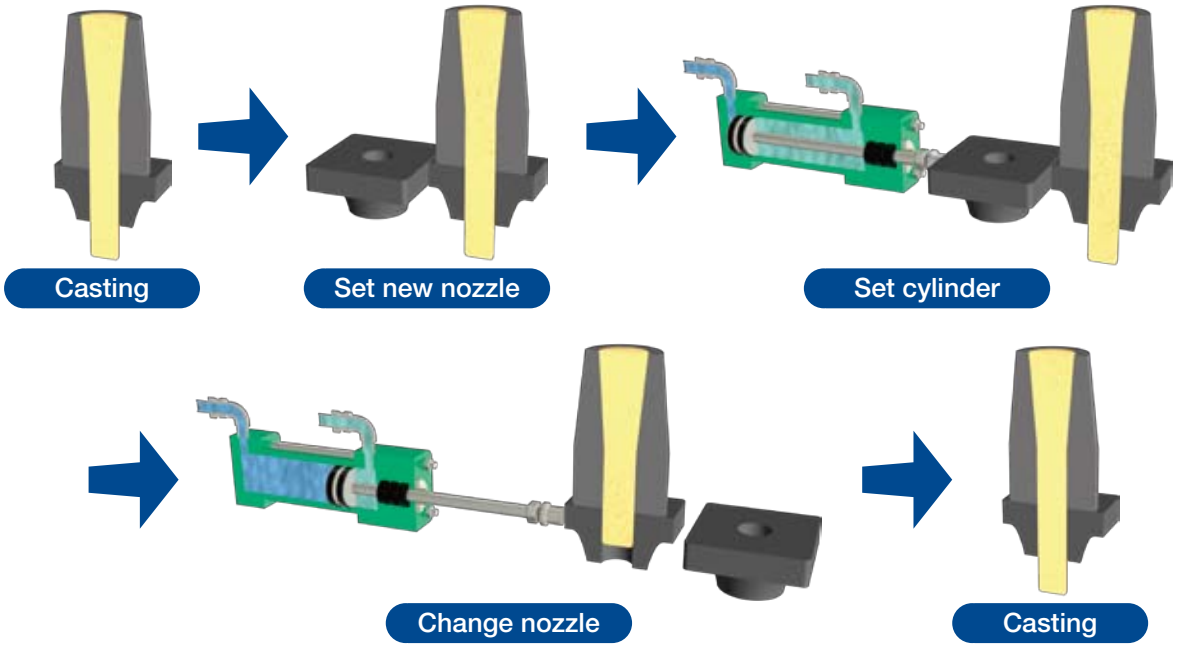
Tundish Nozzle Control Systems

Tundish Nozzle Quick Change Systems (NQC)

Configuration



Flow of change



Features

1. Productivity enhancement
- Tundish nozzles can be replaced without stopping casting.

2. Cost-saving
- Reducing refractory costs by increasing life.

3. Enhancement of stability and safety
- High risk operations, such as plugging after casting stop, are no longer necessary.

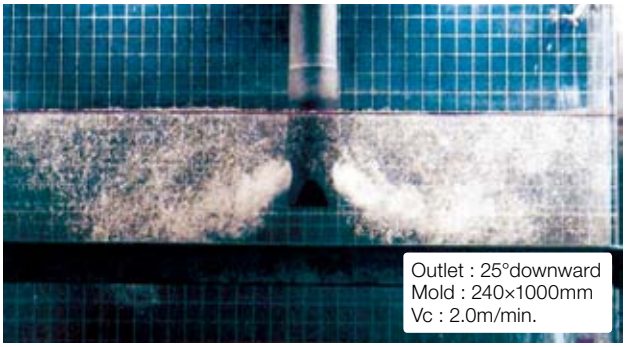
Casting Applications

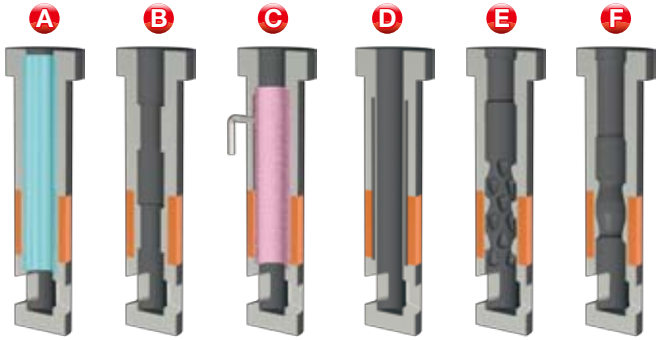
Submerged Entry Nozzles

Submerged Entry Nozzles (SENs)

Submerged entry nozzles, SENs, are vital refractories for stable continuous casting and consistent steel quality. They control the flow rate of molten steel between the tundish and the mold, while also preventing air suction into the molten steel.

Shinagawa has developed a number of different SEN shapes to provide the best performance under various casting conditions. Each SEN design is unique, specifically made and examined by water modelling and CFD (Computational Fluid Dynamics).





A : Anti-clogging material B : Step type C : Gas blowing structure
D : Heat insulating slit E : Mogul F : Slope annular step

Examples of clogging prevention by special materials

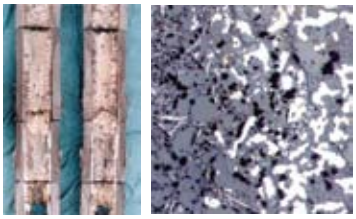
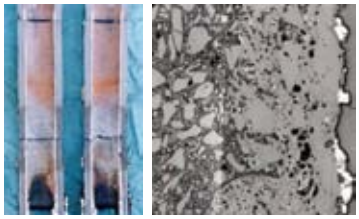
Conventional — Anti-clogging (CZ-C)

Conventional — Low thermal conductivity

Properties

Items		Main body			Slag line		
Purpose		All purpose	Stainless steel	High oxygen steel	All purpose	High density type	High ZrO_2 type
Brand		G31D Series	G30H Series	G1M Series	G6Z Series	G7Z Series	G8Z Series
Apparent porosity (%)		15.0	16.5	16.5	15.0	14.5	12.5
Bulk density		2.25	2.55	2.50	3.70	3.85	4.10
Modulus of rupture (MPa)		7.5	9.0	6.5	8.5	8.5	10.5
Thermal expansion at 1000°C (%)		0.26	0.44	0.52	0.48	0.49	0.51
Chemical composition (%)	Al_2O_3	38	64	52	—	—	—
	SiO_2	27	—	—	—	—	—
	MgO	—	—	23	—	—	—
	ZrO_2	—	—	—	77	81	84
	C+SiC	31	30+5	25	19	15	12
Remarks		—	Non-SiO_2	Spinel-C	—	High corrosion resistance	High corrosion resistance

Carbon-free inside liner for SENs

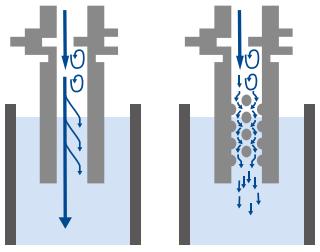
Conventional AG material	Carbon-free inside liner
 Alumina build-up was developed on the decarbonized AG hot face.	 The sintered carbon-free material prevented alumina build-up.

Properties

Area of application		Inner		
Brand		0X series		
Type		Al_2O_3	Al_2O_3-SiO_2	Spinel
Apparent porosity (%)		23.0	22.5	21.5
Bulk density		2.90	2.40	2.70
Modulus of rupture (MPa)		1.5	2.0	3.0
Thermal expansion at 1000°C (%)		0.80	0.48	0.65
Chemical composition (%)	Al_2O_3	96	66	70
	SiO_2	—	27	—
	MgO	—	—	26

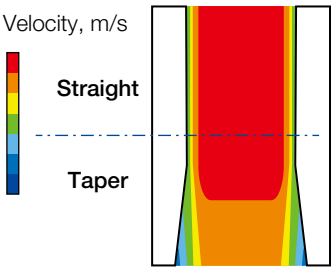
Trumpet SENs (Single port with Mogul and reverse-taper)

In actual casting, the direction of the outlet flow from a single port does not become perpendicular.
Biased and deeply penetrating flow can cause uneven shell solidification and prevent inclusions floatation.



Standard SEN
Biased outlet flow

Mogul SEN
Even outlet flow



"Trumpet" SEN can generate straight and shallow flow.

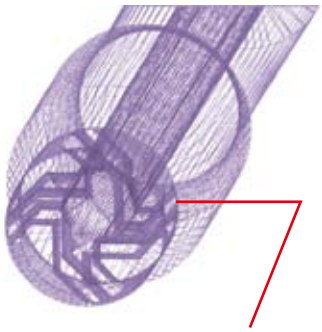
Standard SEN

Trumpet SEN

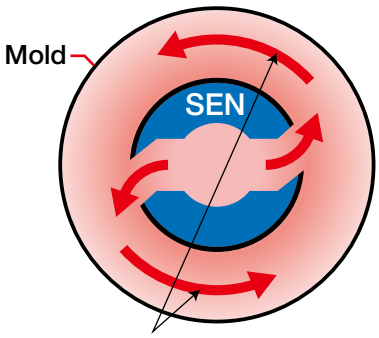
"Trumpet" SEN produces ideal flow pattern in bloom and billet caster. ➡ Decreasing defects

Naruto (Lateral bend ports) SENs

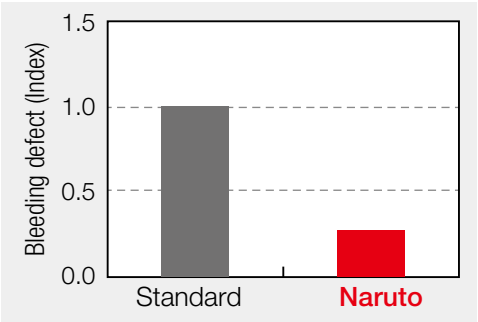
"Naruto" SEN



The feature of "Naruto" is "bend ports".



The outlet flow has turning movement.

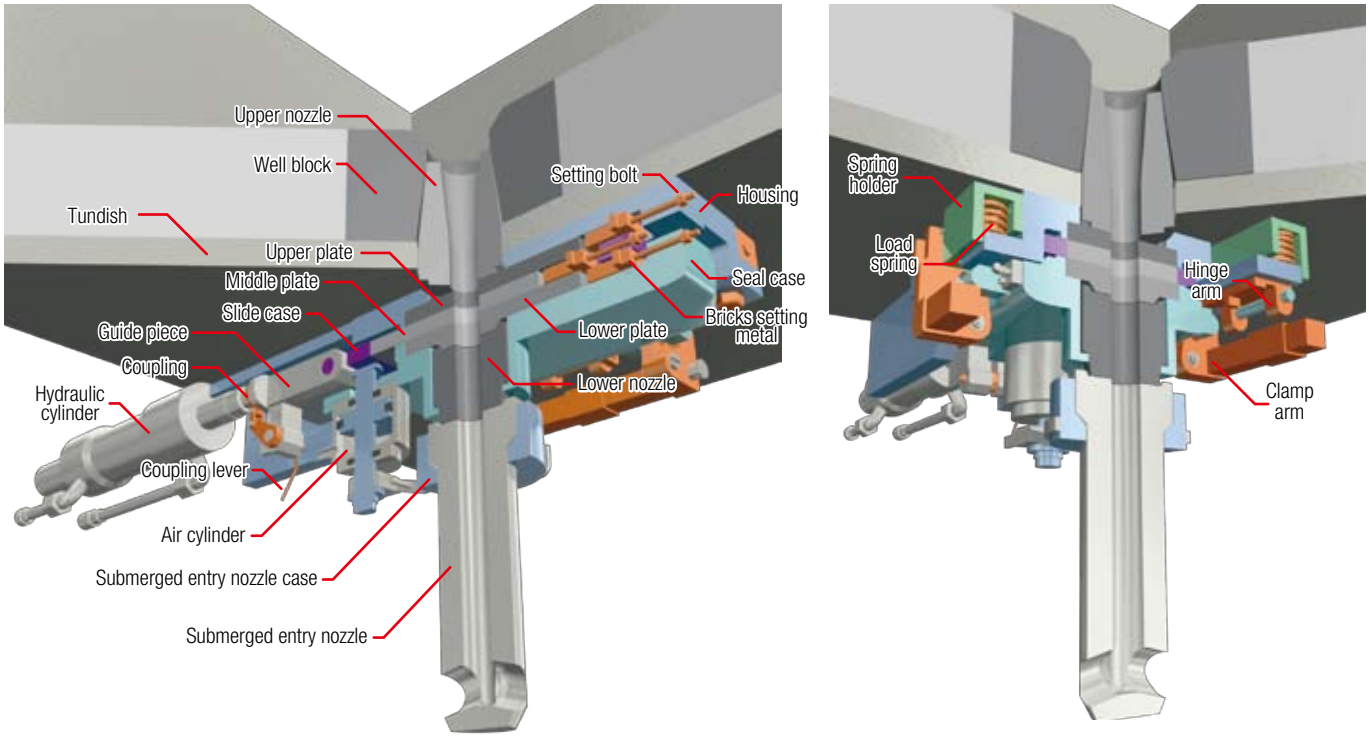


The ratio of bleeding defects decreased to 1/3 by using "Naruto" SEN

Submerged Entry Nozzle Control Systems

Slide Gate Valve Equipment for Tundish

Configuration



Features

1. SEN with an excellent air-sealing performance

- Shinagawa's SEN mounting device is equipped with an air cylinder, which improves the sealing performance of the engagement parts. At the same time, this simplifies the process for replacing submerged entry nozzles.

2. Clogging preventive configuration

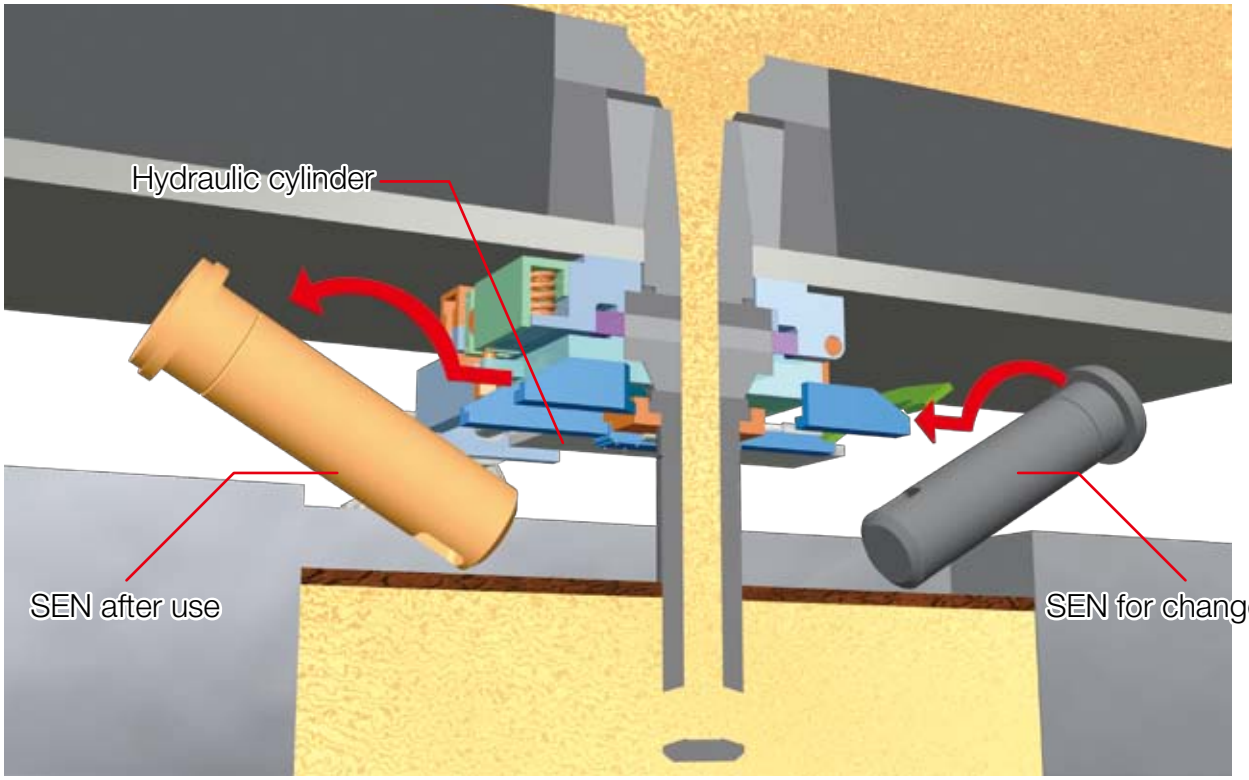
- This configuration includes a function to inject inert gasses into the upper nozzles, lower plates, lower nozzles and SENs. This prevents the formation of alumina deposits which causes clogging.

3. Enhancement of stability and safety

- This configuration injects inert gas into the area around the joint and prevents the aspiration of air.

Submerged Entry Nozzle Quick Change Systems (QTC)

Configuration



Features

1. Productivity enhancement
- SENs can be replaced without stopping casting.
- Minimized downtime required for SEN exchange.

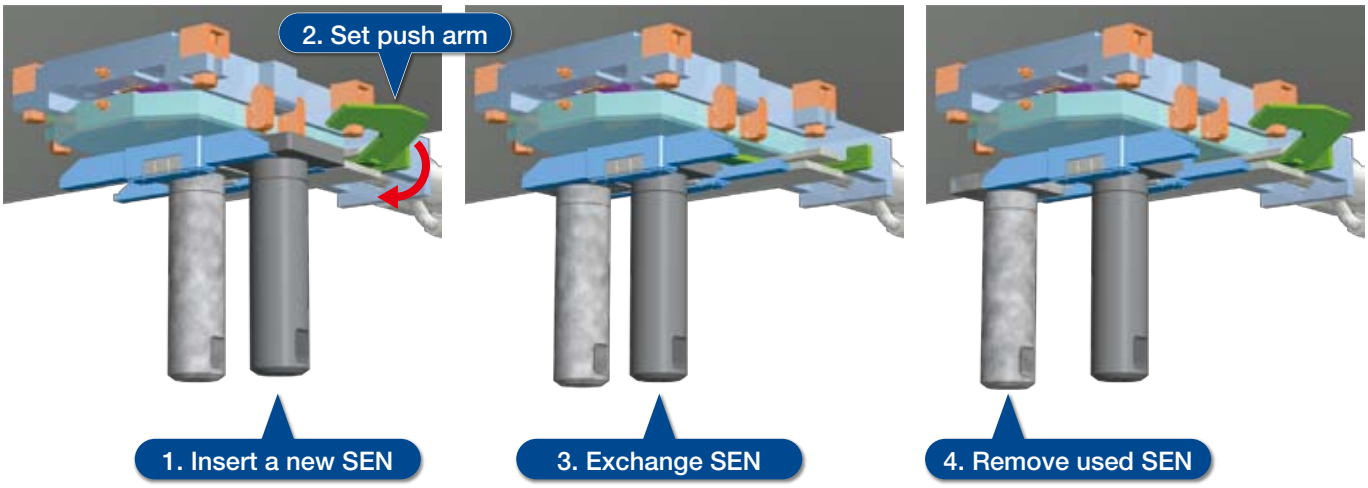
2. Cost-saving
- Resolving the problem of scrap slab joints.
- Reducing refractory costs by increasing life.

3. Enhancement of stability and safety
- New sealing material is available for better sealing performance between each engaged part.

Submerged Entry Nozzle Control Systems

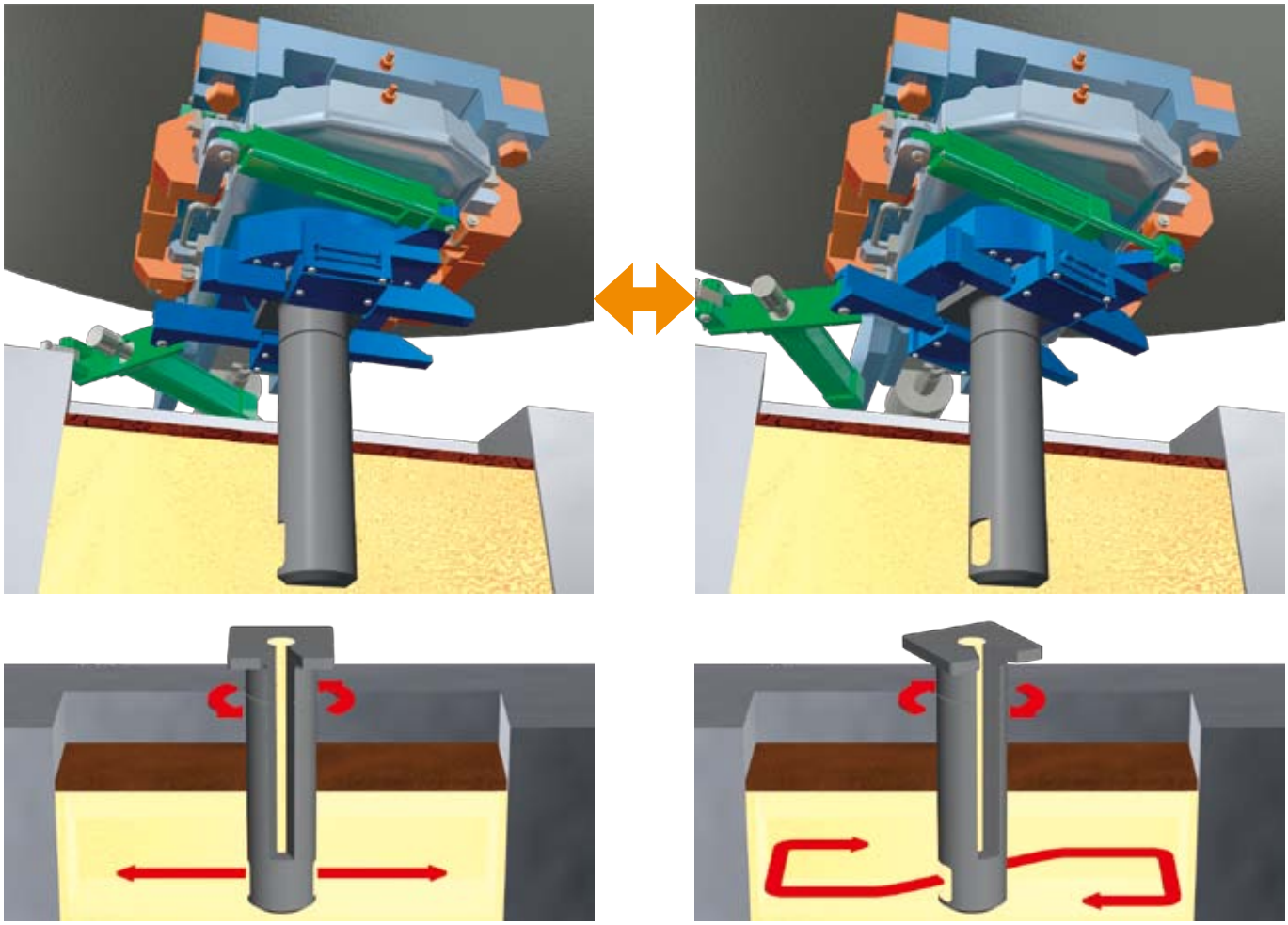
To improve the quality of steel, electromagnetic stirring is sometimes used to create a mixing action in the molten steel in the mold. However, this equipment requires a considerable amount of capital expenditure and is not ideal for some customers.
For this issue, Shinagawa has developed a new tundish gate system called “SGT.” This system is designed to control molten steel flow, change SENs quickly, rotate the set SEN and change the outlet direction of the casting steel.

The SGT system can achieve reduced downtime for SEN replacement and can exchange the used SEN for a new one without stopping casting. SGT has a pair of guide rails at the bottom, and SENs move parallel to the mold.



Advanced SEN Quick Change Systems (SGT)

Configuration



Features

1. Improvement of steel quality
- Improvement of steel quality by generating swirling flow in the mold without an Electro Magnetic Stirrer.

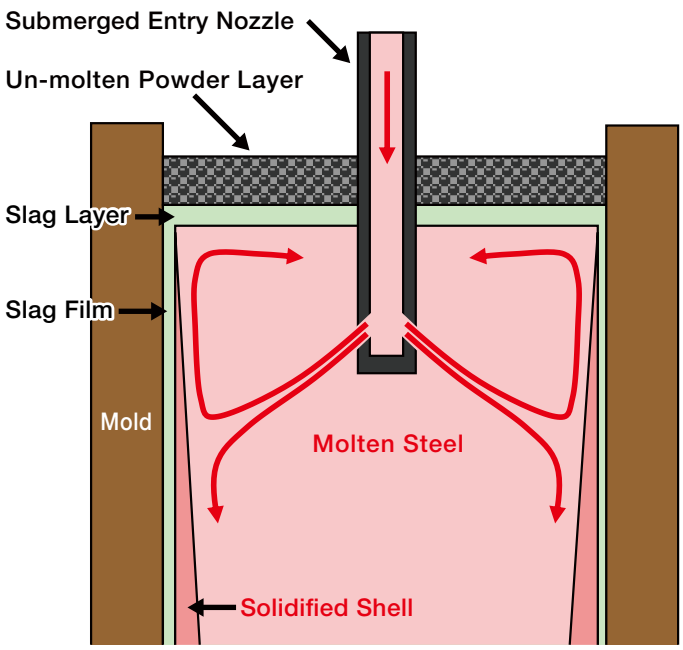
2. Cost-saving
- Resolving the problem of scrap slab joints.
- Reducing refractory costs by increasing life.

3. Productivity enhancement
- SENs can be replaced without stopping the casting operation.
- Minimized downtime required for SENs exchange.

Mold Powder

Mold powders play a vitally important role in the continuous casting process of steelmaking because it directly affects the final quality of the steel. Shinagawa has been supplying high quality mold powders to global steel industries for over 50 years, since 1971, supporting the production of advanced steel products in the most effective and efficient manner.
We are proud to remain the leader in contributing to the global steel industry by maintaining a strong focus on research and development activities for mold powder applications.

Roles of Mold Powder



Insulation
Un-melted mold powder layer and molten powder slag provide thermal insulation on the meniscus surface to contain the heat of molten steel and to stimulate inclusion floatation.

Prevention of Re-oxidation
Powder slag layer prevents re-oxidation of molten steel by sealing the surface from the air.

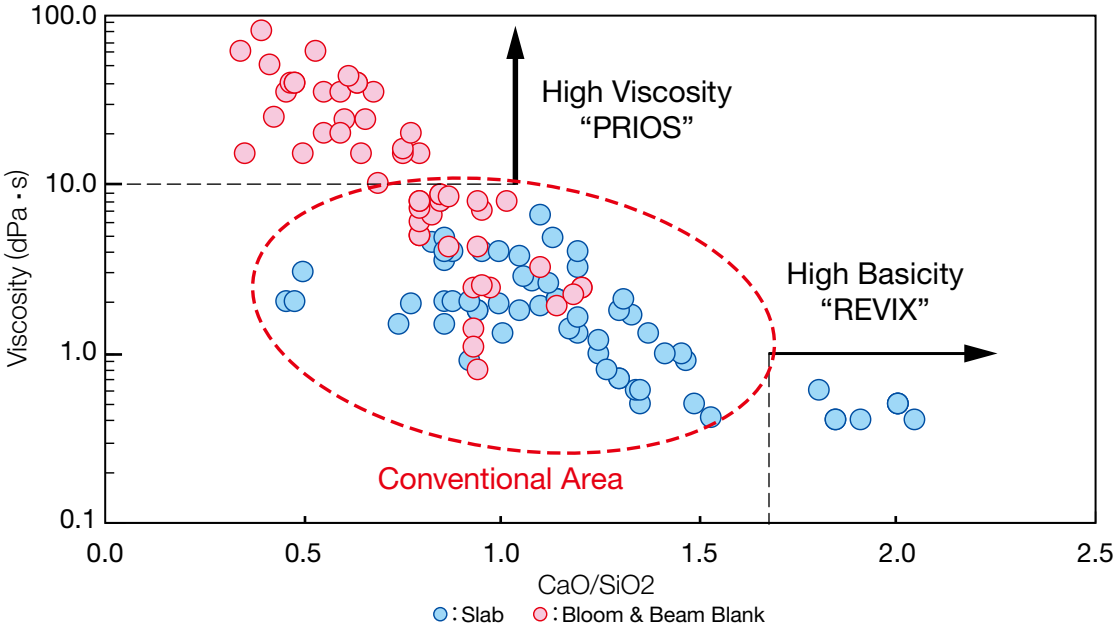
Absorption of Impurities
Powder slag absorbs and removes non-metallic impurities and gas bubbles from molten steel to prevent defects.

Lubrication
Powder slag flows into gaps between mold wall and solidified steel shell, and provides lubrication.

Heat Removal Control
The powder slag film reduces heat removal between the mold and the solidified steel shell and prevents strand surface cracking.

Chemistry	%
SiO_2	28-40
Al_2O_3	2-10
CaO	28-44
R_2O (Na_2O+Li_2O+K_2O)	0-20
F	2-12
T.C	2-15
CaO/SiO_2	0.7-1.5

Mold Powders Matrix

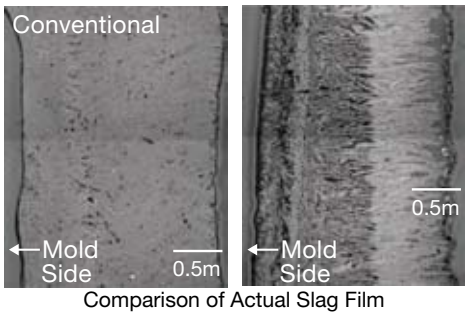


Features

“REVIX” with High Basicity

Application: Peritectic & Medium Carbon Grades

- High crystallization speed in the slag film
- Providing softer heat removal from initial solidified stage in the mold
- Prevention of strand surface cracking

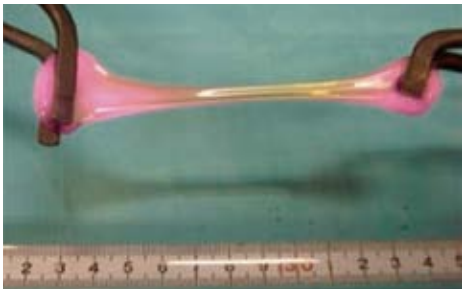


Comparison of Actual Slag Film

“PRIOS” with High Viscosity

Application: Billet, Bloom and Beam Blank casting

- Reduced powder consumption rate
- Improved surface quality
- No sticking
- Reduction of casting machine corrosion
- Low erosion rate and extended SEN life

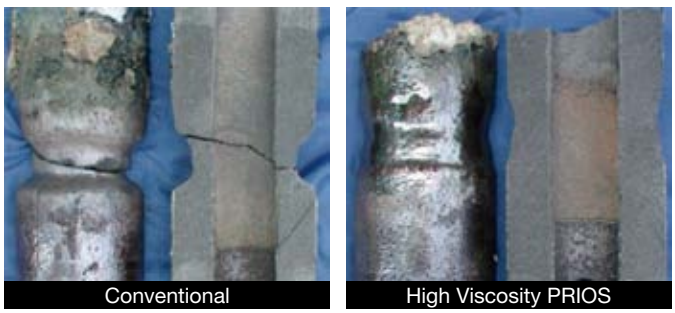


High Viscosity Slag

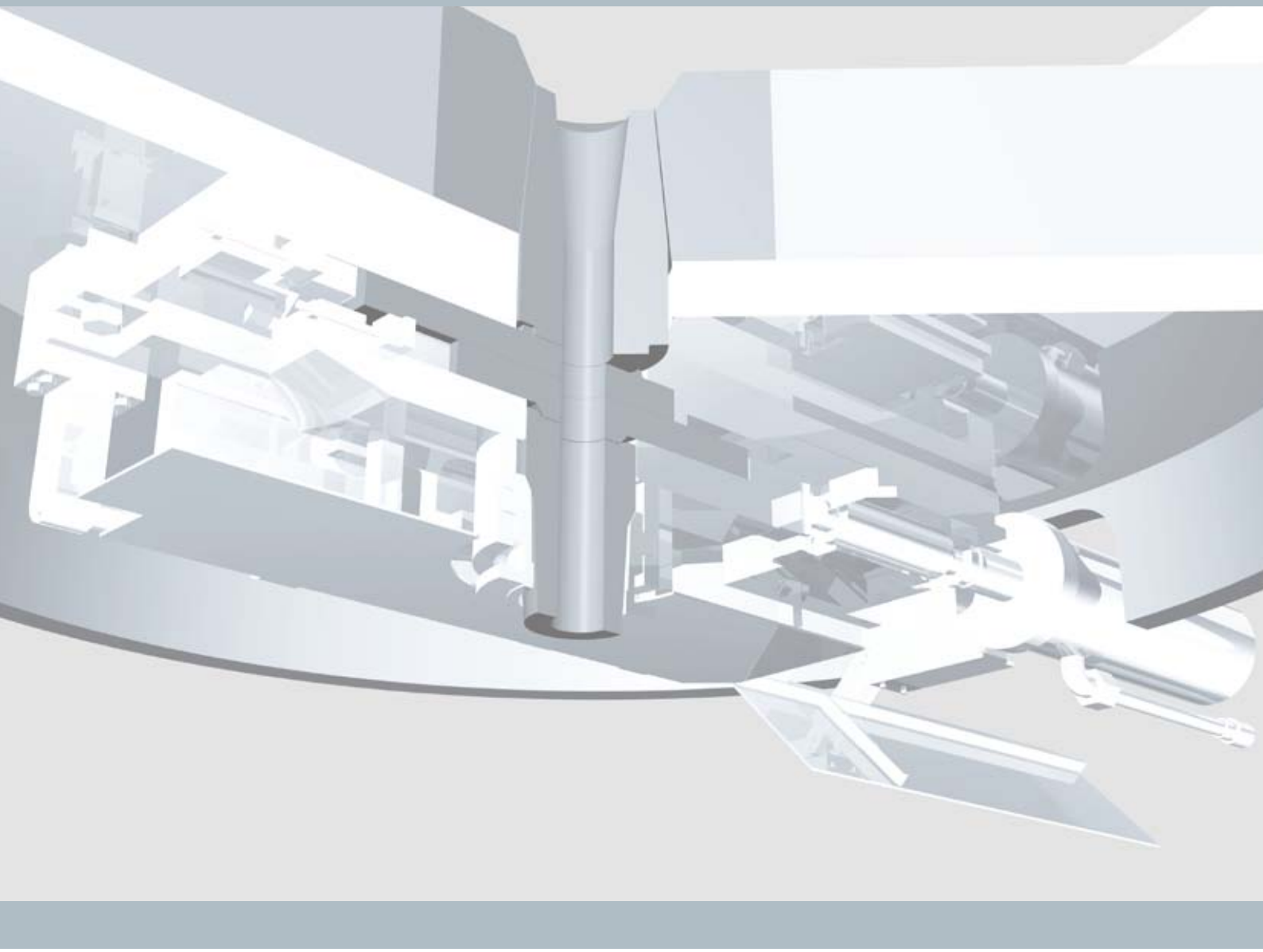
Exothermic Type

Application: Starter and Running Powder

- Exothermicity through metal oxidation in the mold powder
- Reduction of gas and inclusion defects
- Stable operation at casting start
- Reduction of oscillation mark depth
- Less carbon content to prevent carbon pick-up



Comparison of SEN Erosion



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