

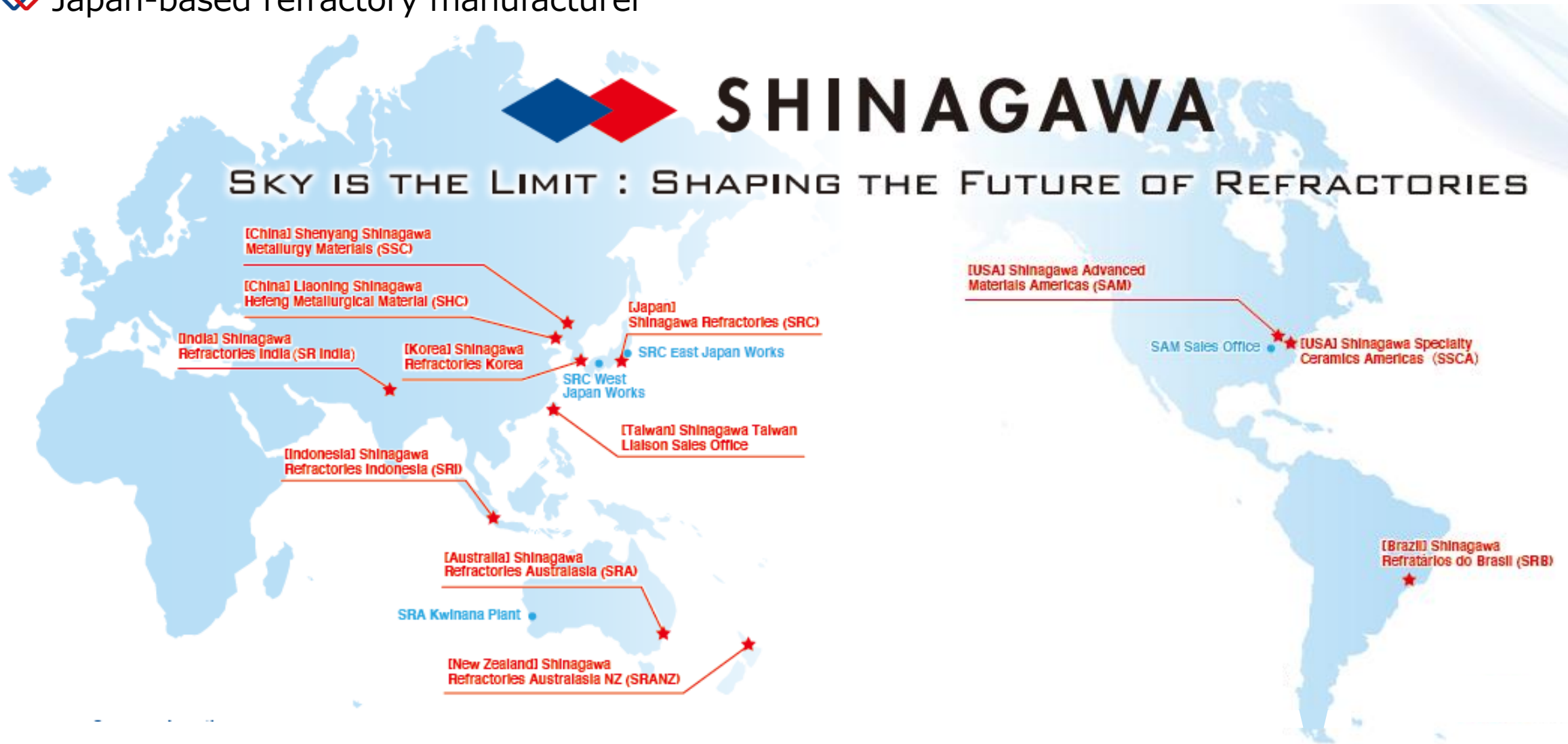
Recent Activities of Spent Refractory Recycling of SHINAGAWA Refractories in Collaboration with JFE Steel

Masakazu Iida

Apr. 24th, 2024

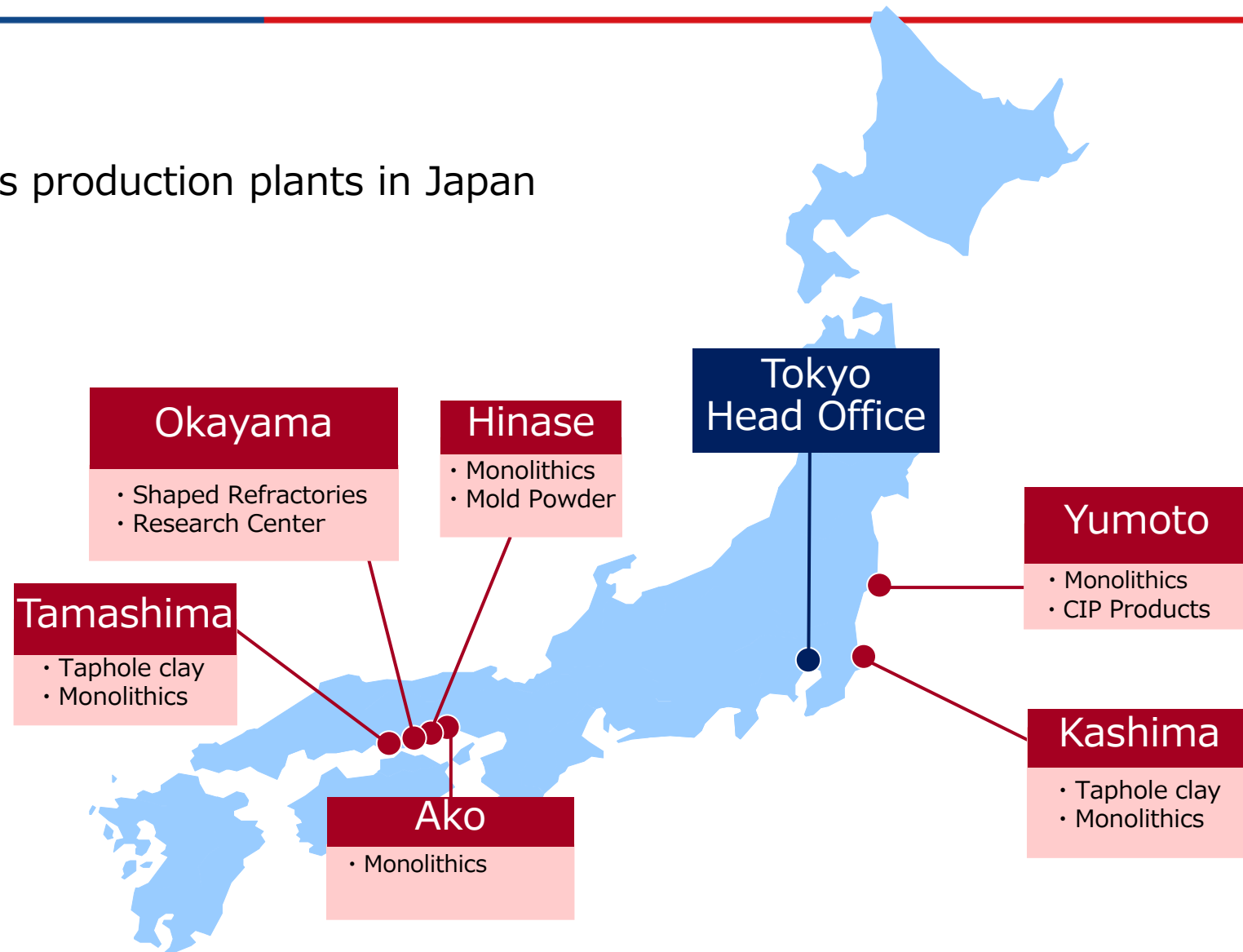
SHINAGAWA Refractories ... Who we are

 Japan-based refractory manufacturer



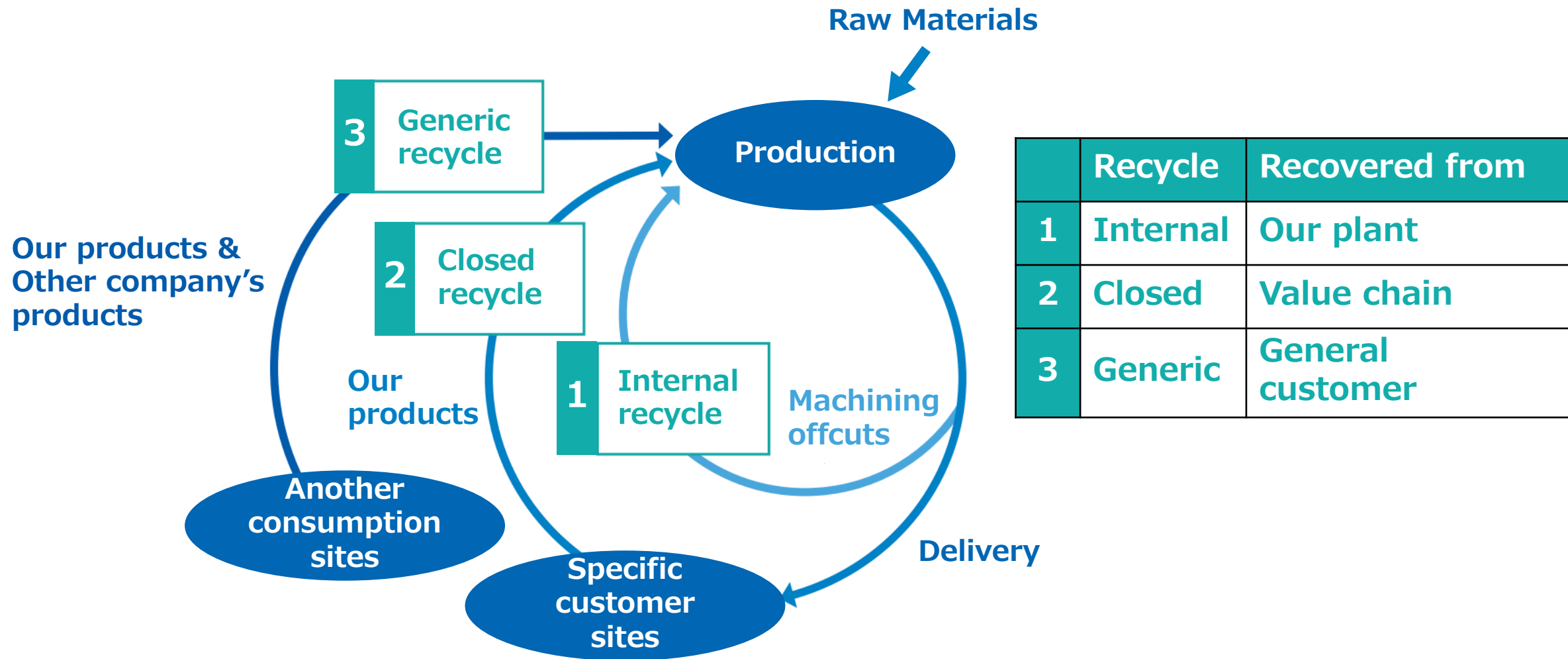
SHINAGAWA Refractories ... Who we are

 6 Major Refractories production plants in Japan



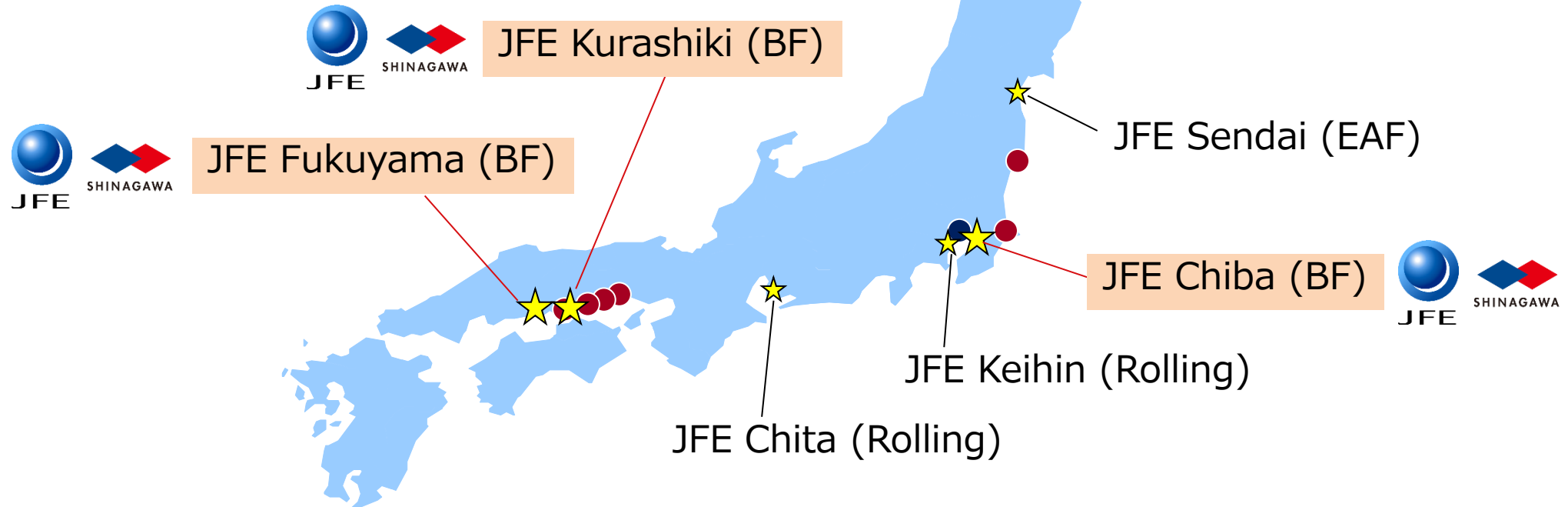
Pursuing the Circular Economy

SHINAGAWA Refractories is pursuing the circular economy by promoting recycling.



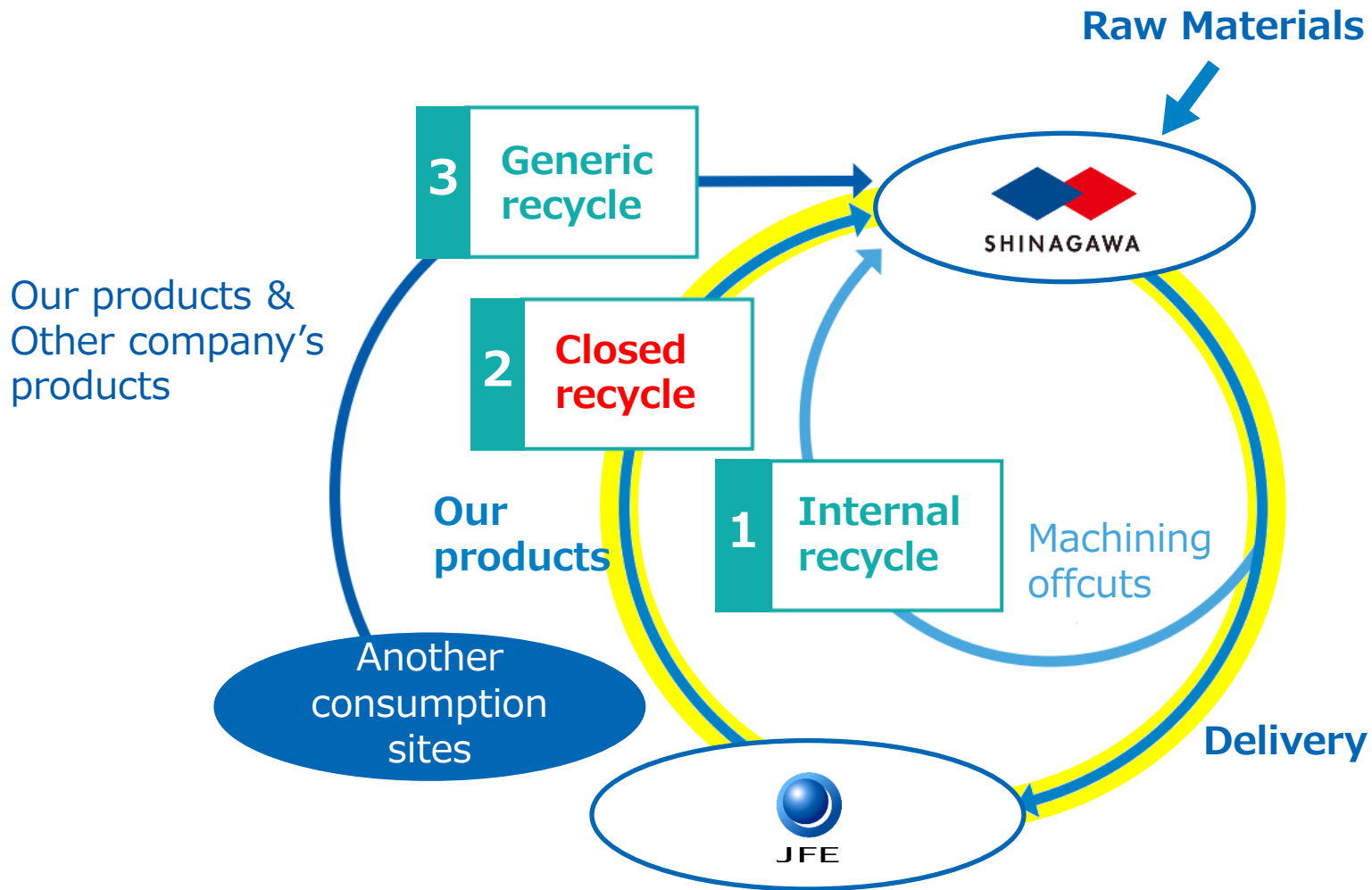
Partnership with JFE Steel

- SHINAGAWA Refractories is responsible for refractory construction, maintenance and management in three major integrated steel mills of JFE steel.



Creating Closed Recycle System with JFE Steel

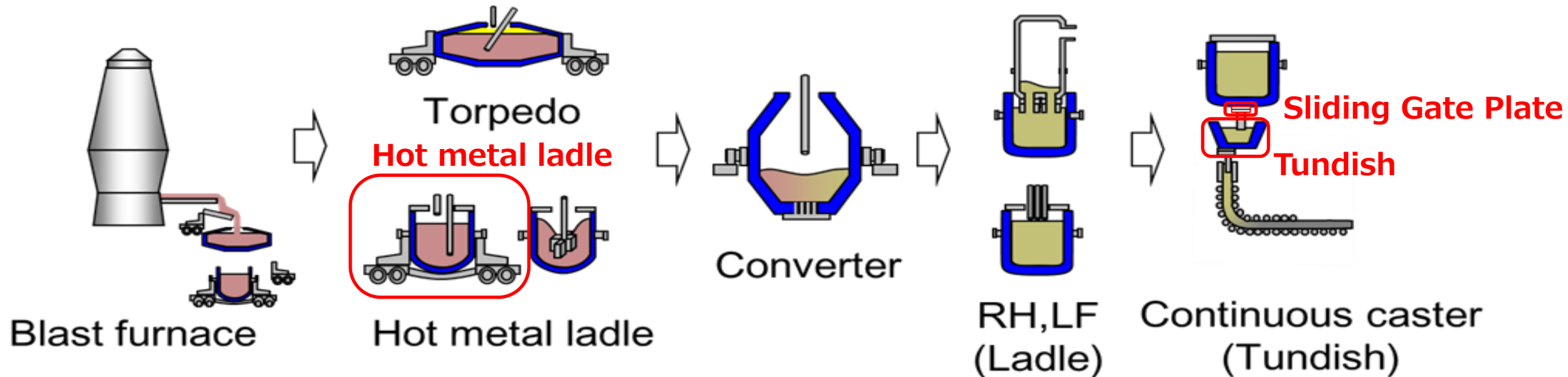
Refractory recycling based on close partnership with JFE steel is being promoted strategically.



	Recycle	Recovered from
1	Internal	Our plant
2	Closed	JFE Steel
3	Generic	General customer

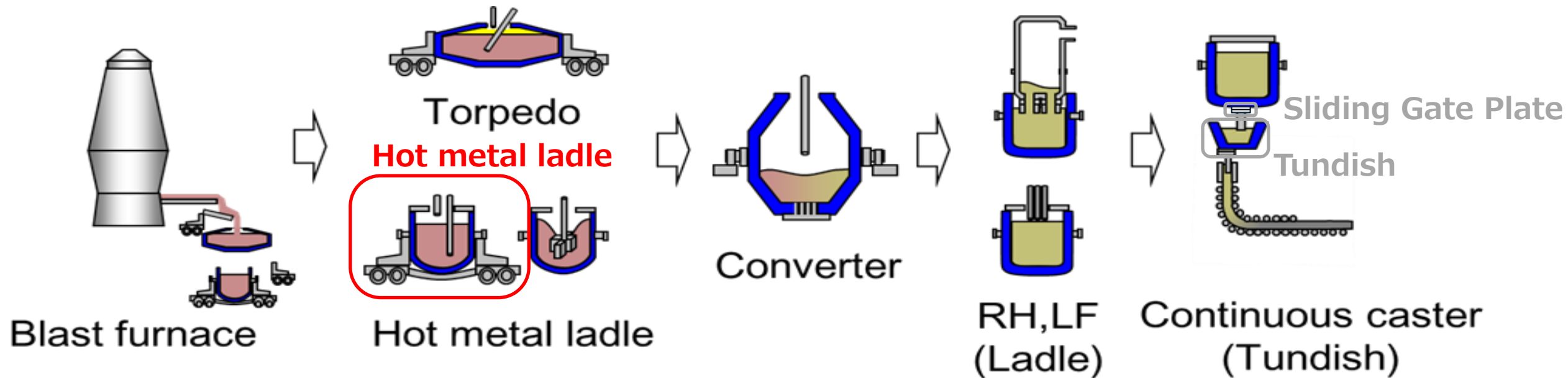
Topics

- Hot metal ladle Managed dismantling & Quality control based on chemical analysis
- Tundish Color sorting for crushed grain of monolithic refractories
- Sliding gate plate Reuse by partial replacement



Topics

- Hot metal ladle Managed dismantling & Quality control based on chemical analysis
- Tundish Color sorting for crushed grain of monolithic refractories
- Sliding gate plate Partial replaceable design (Eco plate)



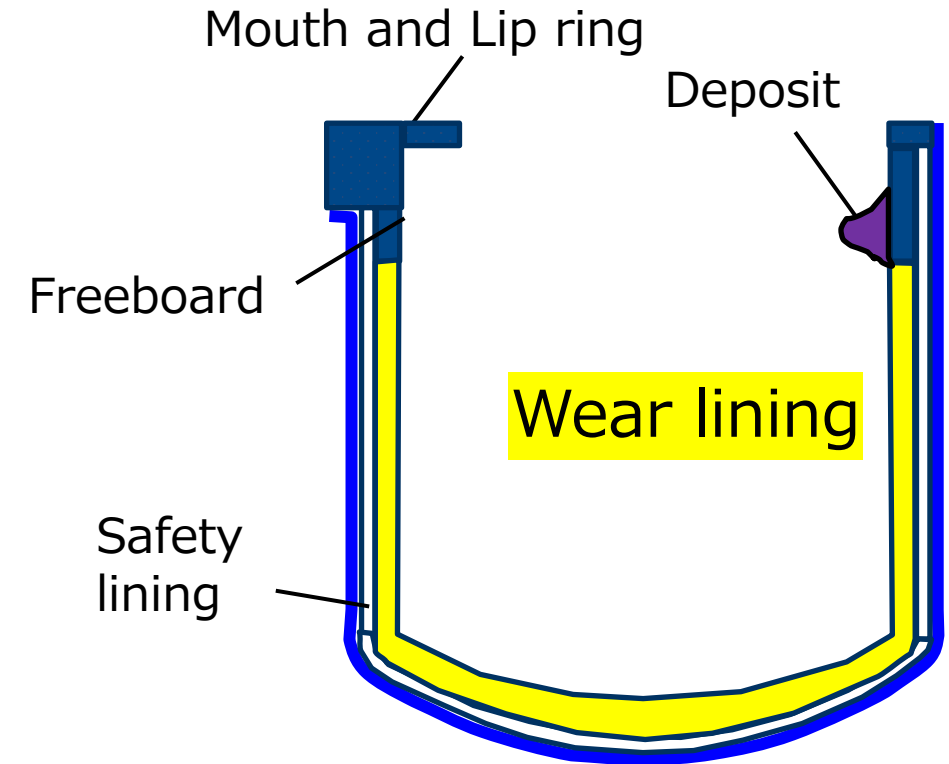
Materials to Be Demolished in Hot Metal Ladle

- There are several materials to be demolished
- Wear and safety linings are targeted for recycling

Component	Material
Deposit	Skull, Slag
Lip ring	Alumina based monolithics
Mouth	Alumina based monolithics
Freeboard	Alumina based brick
Wear lining	Al ₂ O ₃ -Pyrophyllite-SiC-C brick
Safety lining	Pyrophyllite brick



Target of Recycling

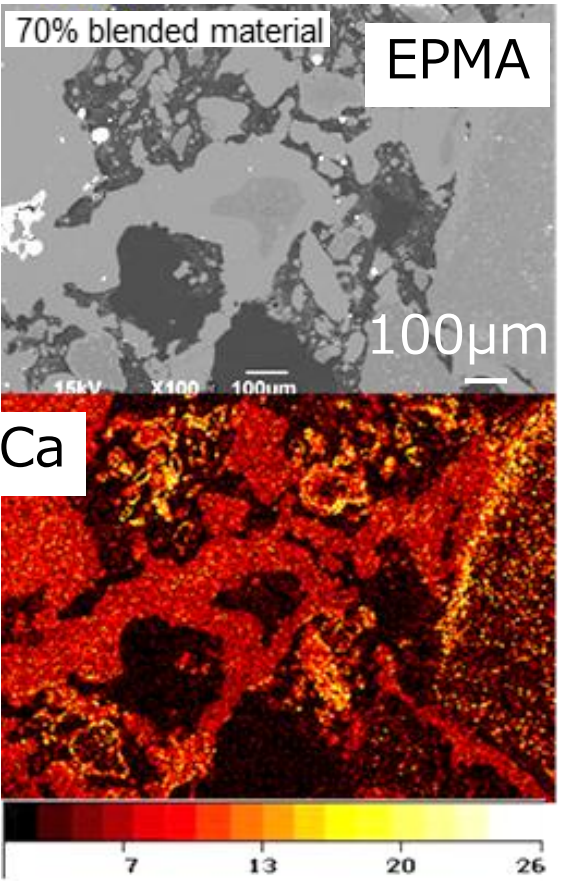
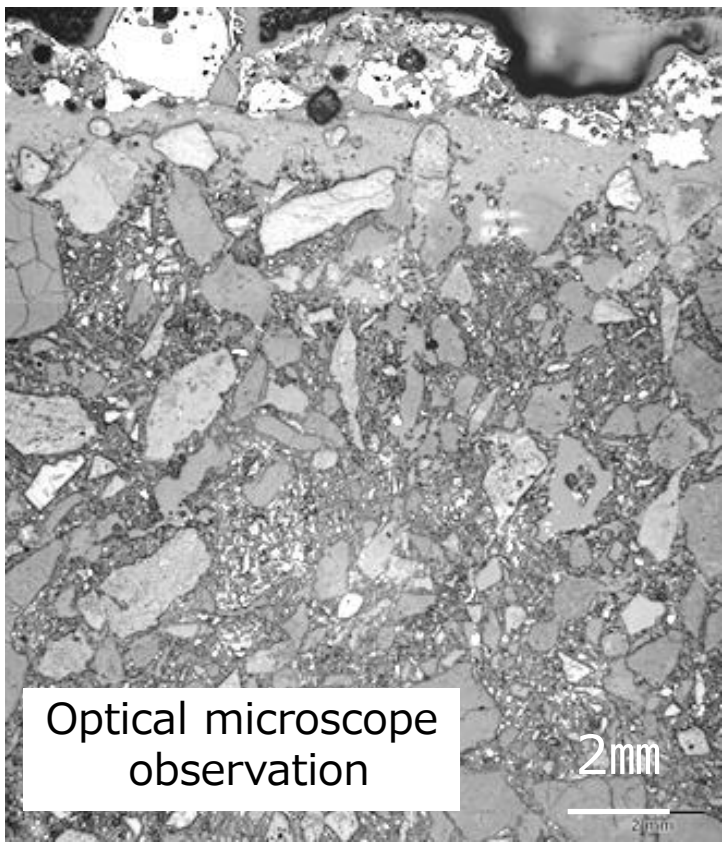
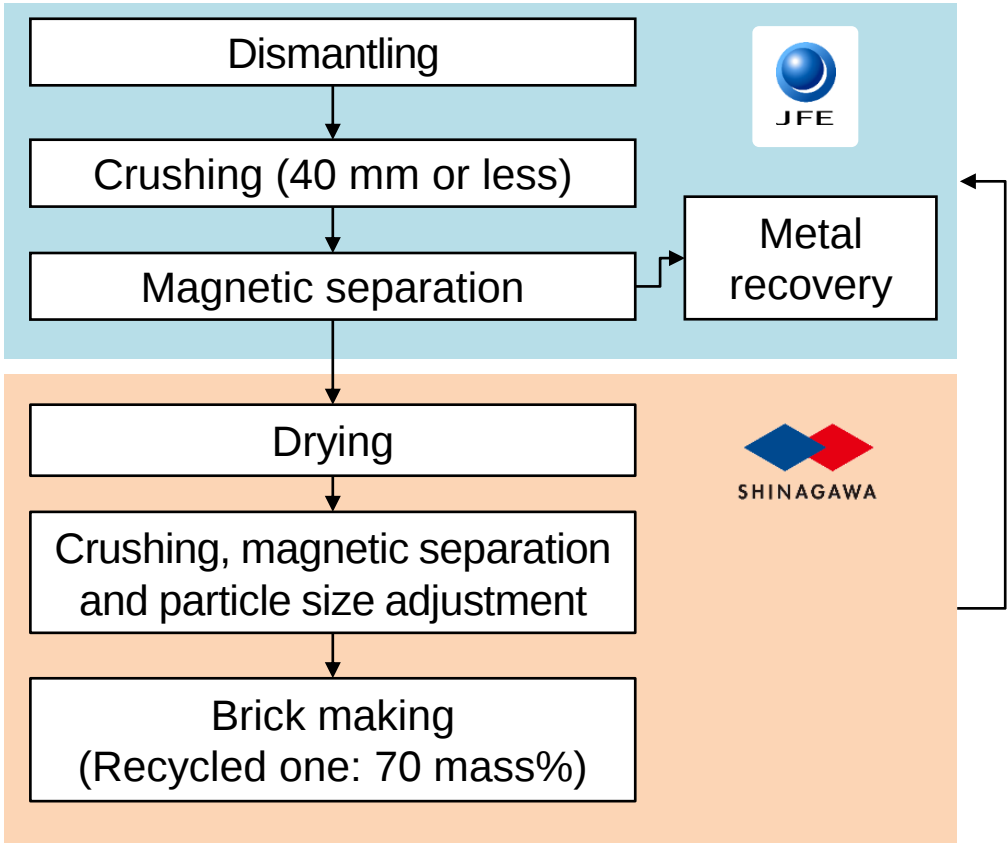


2 Heats/day
400 Heats/service life

Result of the First Trial

- Recycled material-including brick was produced through simple process.
- Impurities were contaminated and promoted matrix melting.

Brick Preparation



Corrosion Experiment

- ❖ Excessive amounts of impurities deteriorates corrosion resistance of brick.
- ❖ Less than 2.5 mass% of CaO+MgO in recycled material is necessary to ensure the equivalent performance if the brick includes 70 mass% of recycled material.

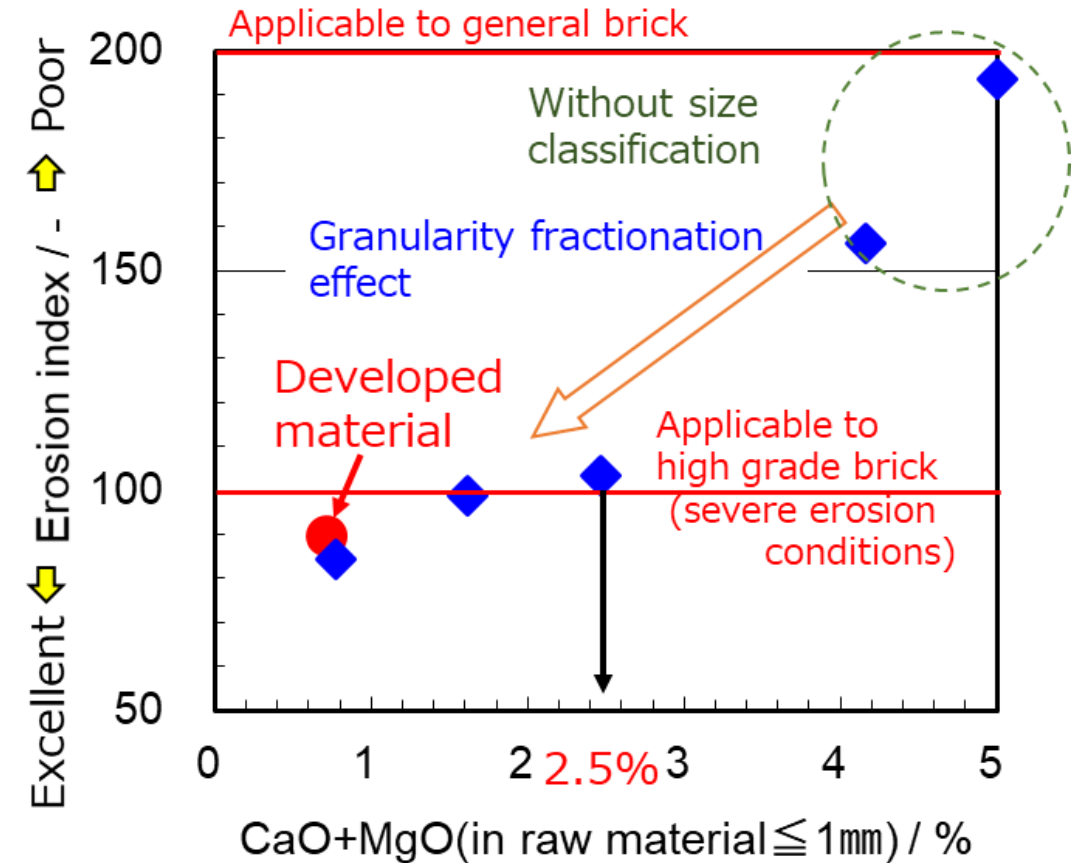
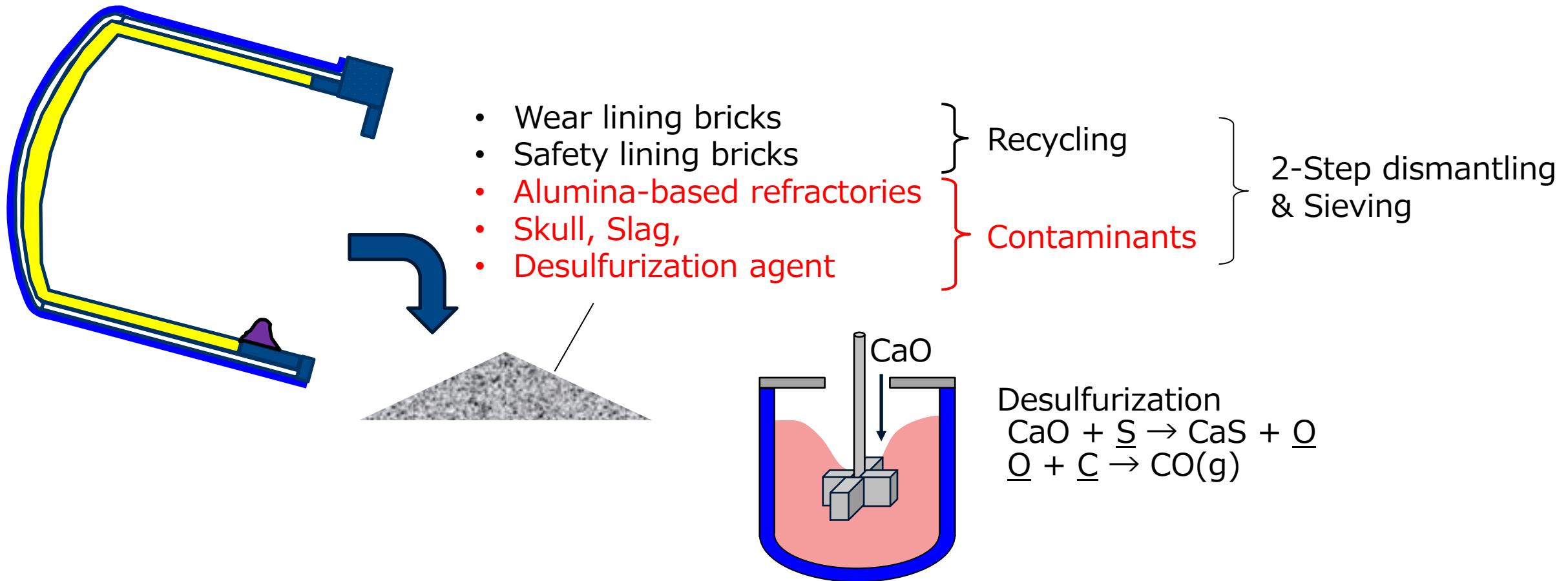


Fig. Relationship of impurity content and erosion resistance (70 % recycled raw material content)

Route of Contamination and Countermeasures

- It was assumed that impurities were contaminated during dismantling process.
- Dismantling process management was intensified.

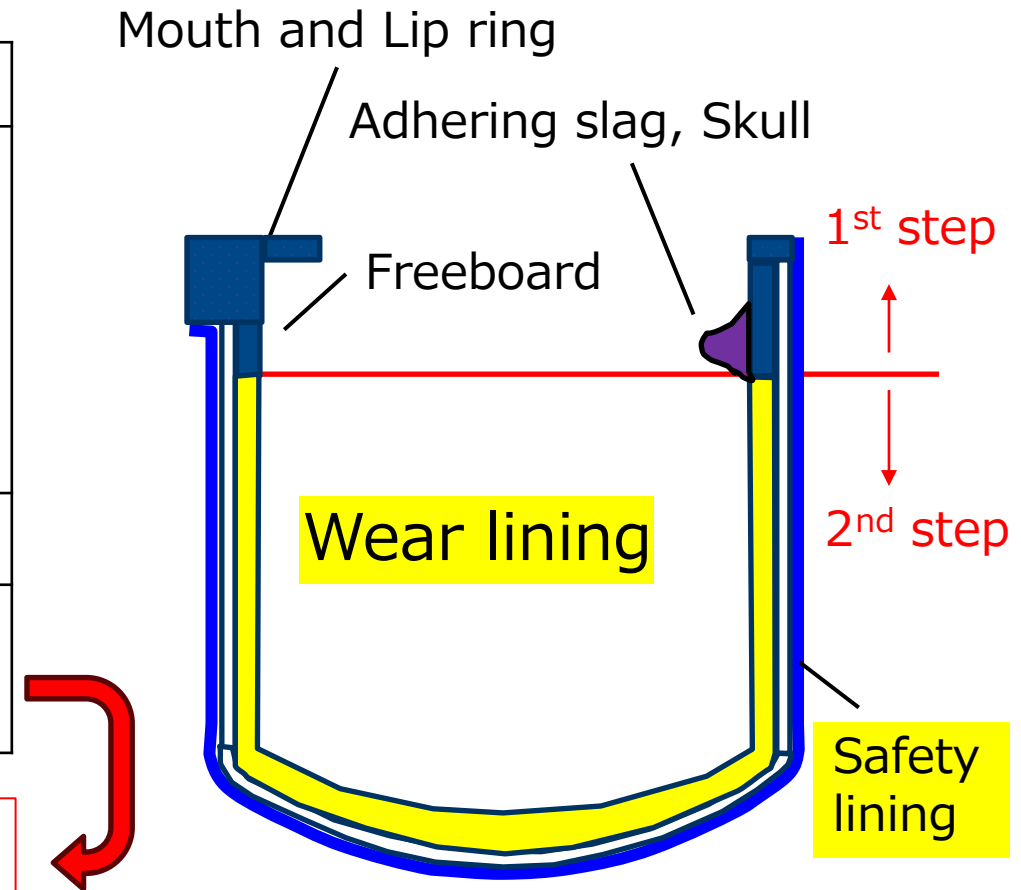


2-Step Dismantling & Sieving

2-Step dismantling & sieving are implementable.

Component	Material	Steps
Deposit	Skull, Slag	1. Waste demolishing
Lip ring	Alumina based monolithics	
Mouth	Alumina based monolithics	
Freeboard	Alumina based brick	
Discharging demolished waste		
Wear lining	Al ₂ O ₃ -Pyrophyllite-SiC-C brick	2. Demolishing for recover
Safety lining	Pyrophyllite brick	

Sieving to reject fine powder which includes contaminants



Modification was necessary to maintain equivalent performance.

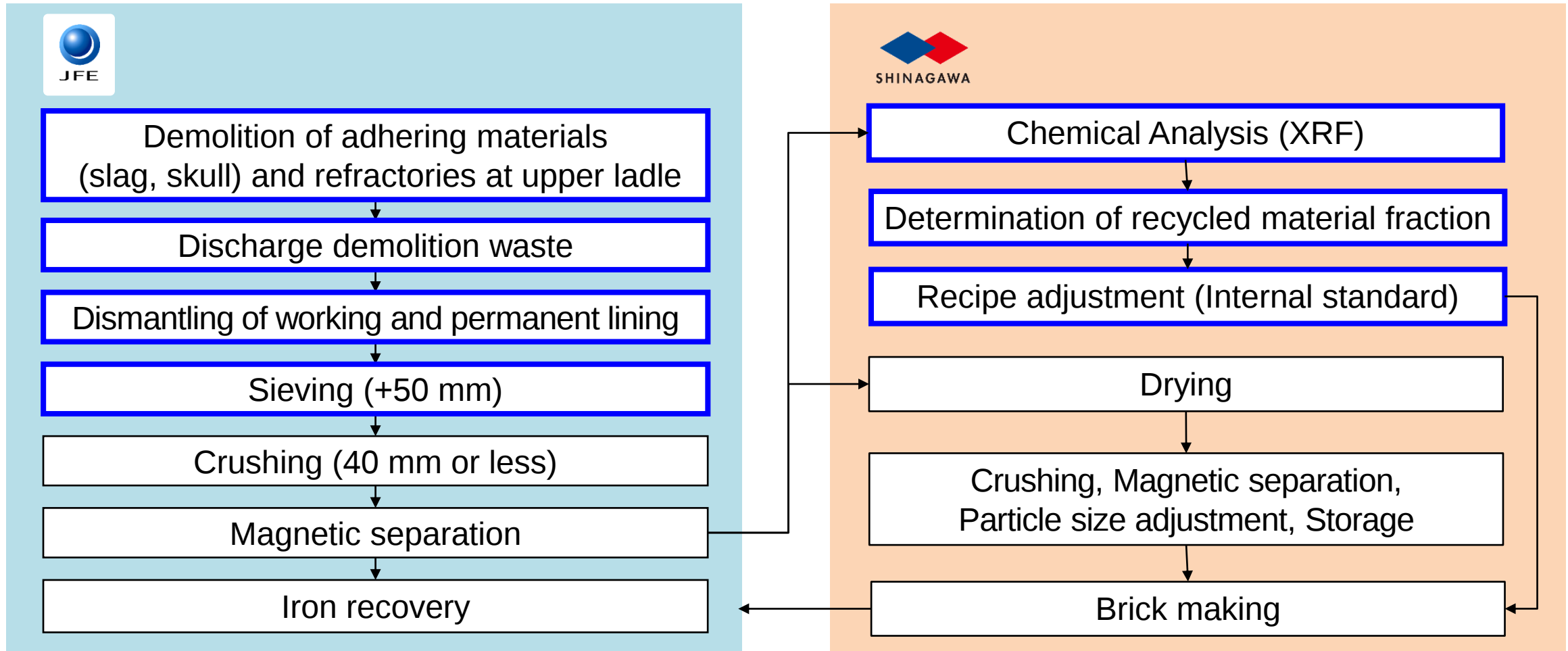
	Conventional	Recycled material-containing
Chemistry / mass%		
Al ₂ O ₃	64	55
SiO ₂	16	25
SiC	5	7
C	10	10
AP / %	5.0	6.5
BD / kg · m ⁻³	2920	2800
CCS / MPa	53	56

← Adjustment of PLC

← Improving corrosion resistance

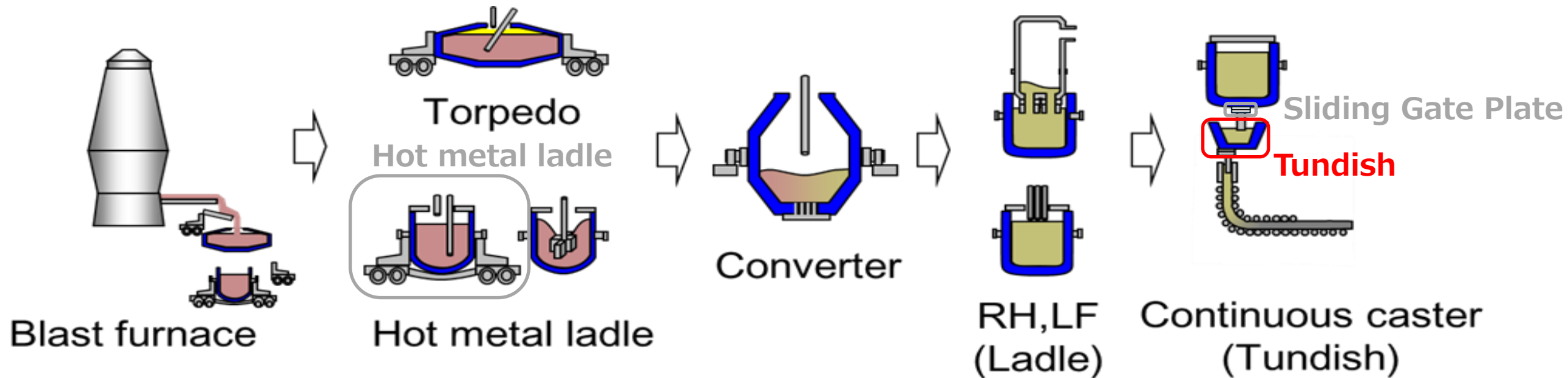
Recycling Process Ensuring Performance Stability

- Recipe adjustment according to the chemical analysis is being implemented to secure the performance stability.



Topics

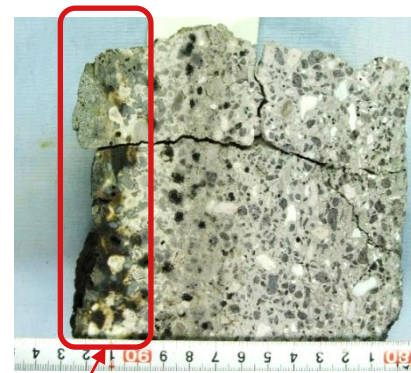
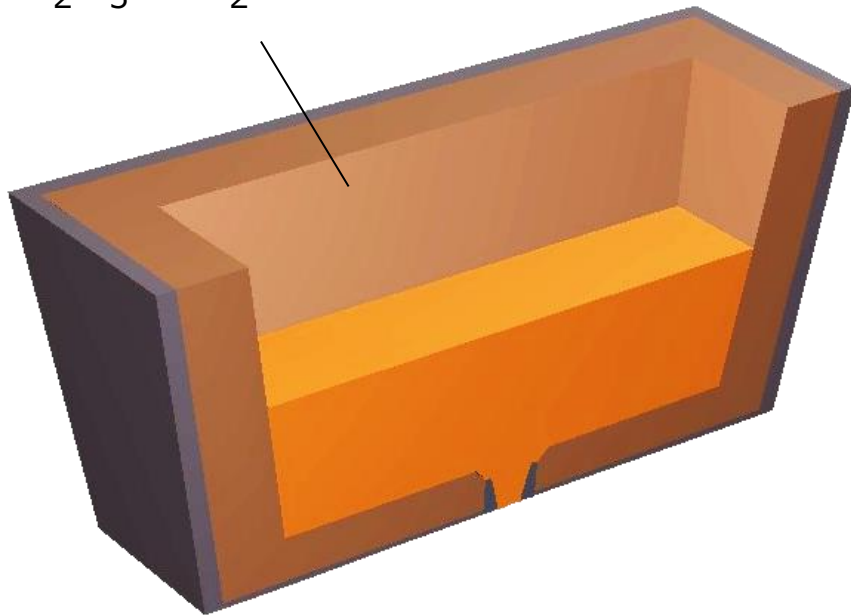
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Altered Layer Removal of Monolithic Tundish

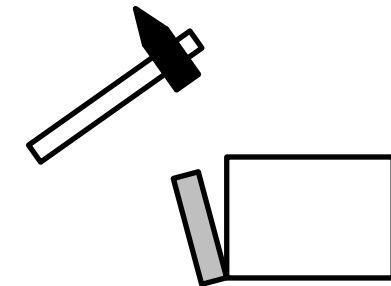
- ❖ Tundish wear lining refractories includes colored altered layer.
- ❖ It is difficult to remove the altered layer by manual chipping if the monolithic is installed.
- ❖ Sorting after crushing was assumed to be convenient.

$\text{Al}_2\text{O}_3\text{-SiO}_2$ Monolithic

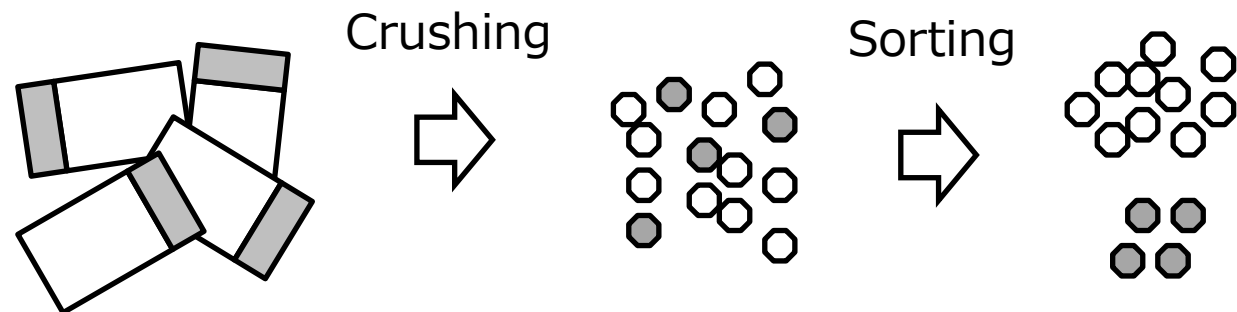


Altered layer...Colored

Chipping

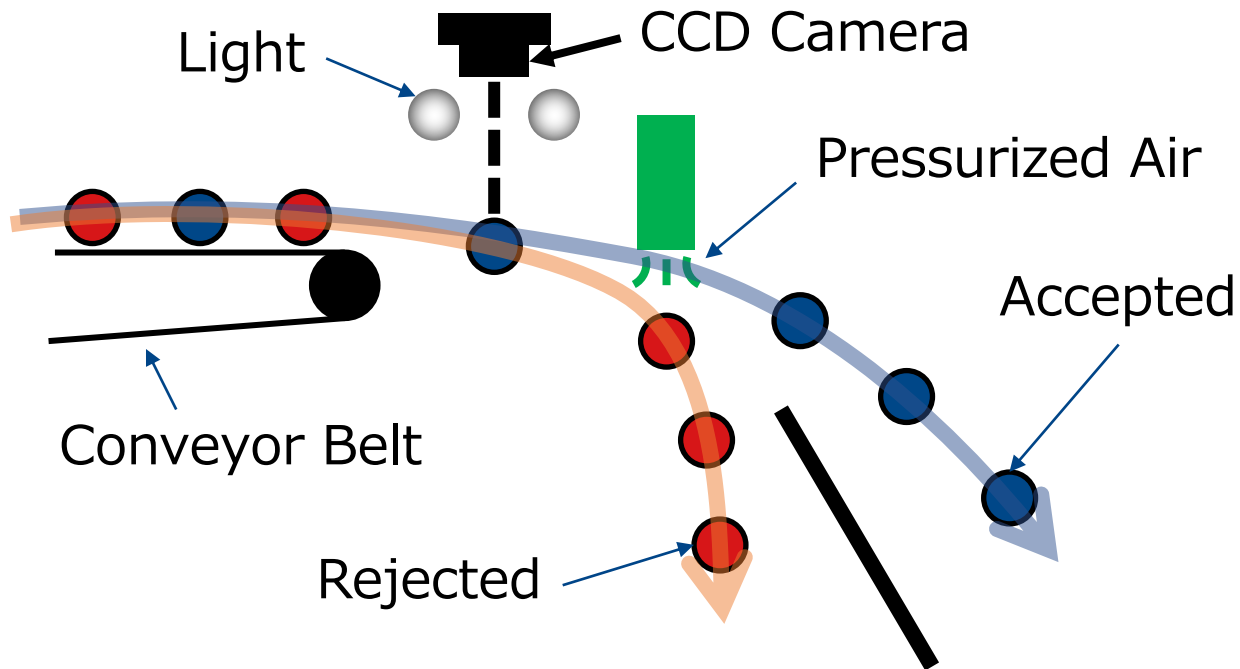


Crushing & Sorting



Color Sorting

- ❖ Color sorting technologies for particle had been already available.
- ❖ Operating parameters were specified for tundish refractory sorting.

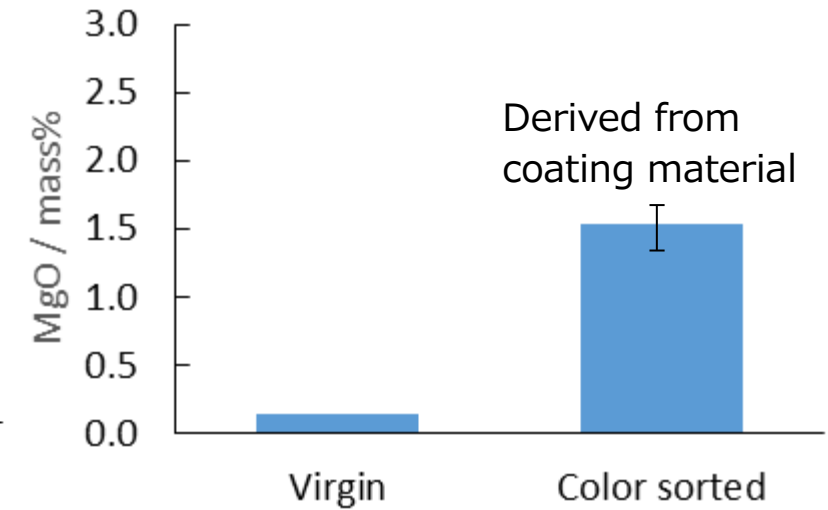
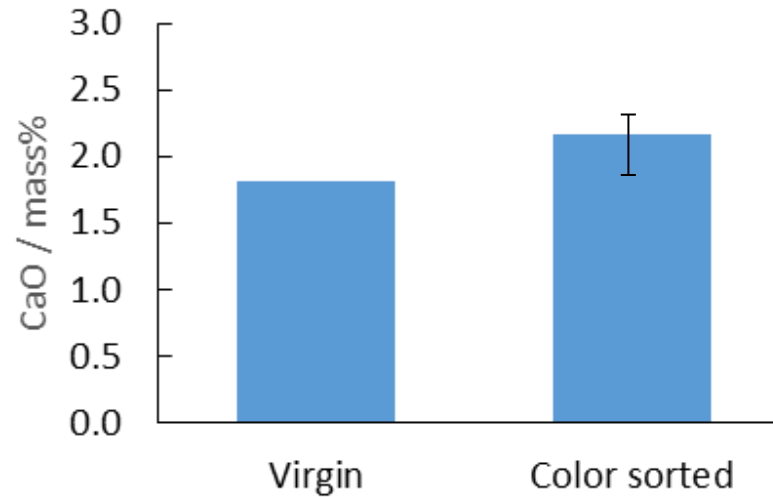
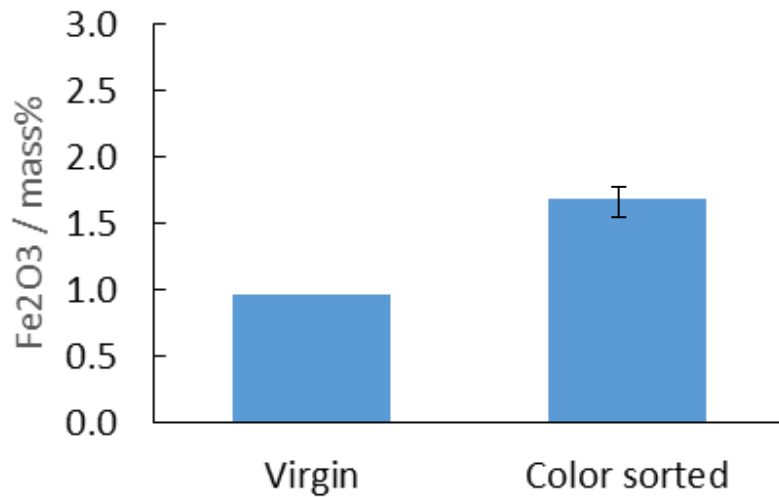


Applicable Size : 10 – 30 mm
Capability : 1.5 ton/hour
Regular application has just begun

[クボタ色彩選別機 選別王シリーズ - YouTube](#)

Impurities Included in Recycled Material

- From industrial point of view, maintaining sufficient yield rate is necessary.
- Maintaining 60 % of yield rate, a slight decrease in purity is recognized.

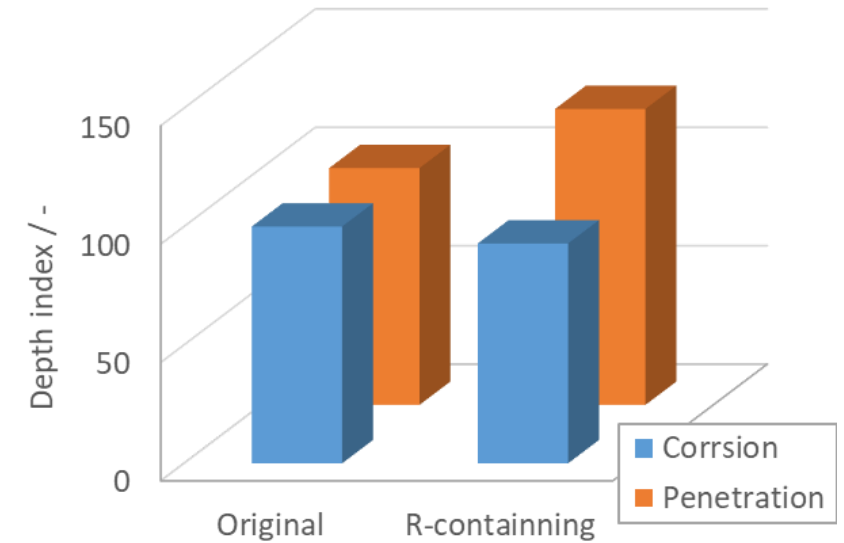
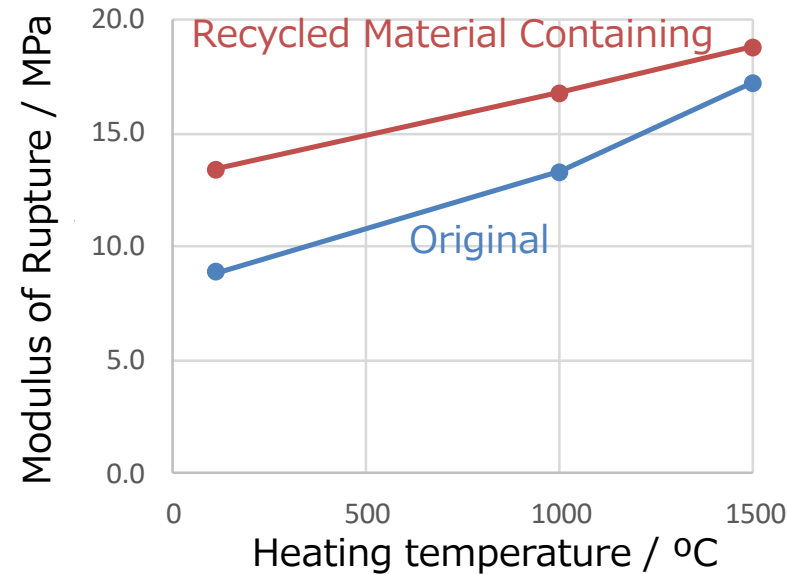
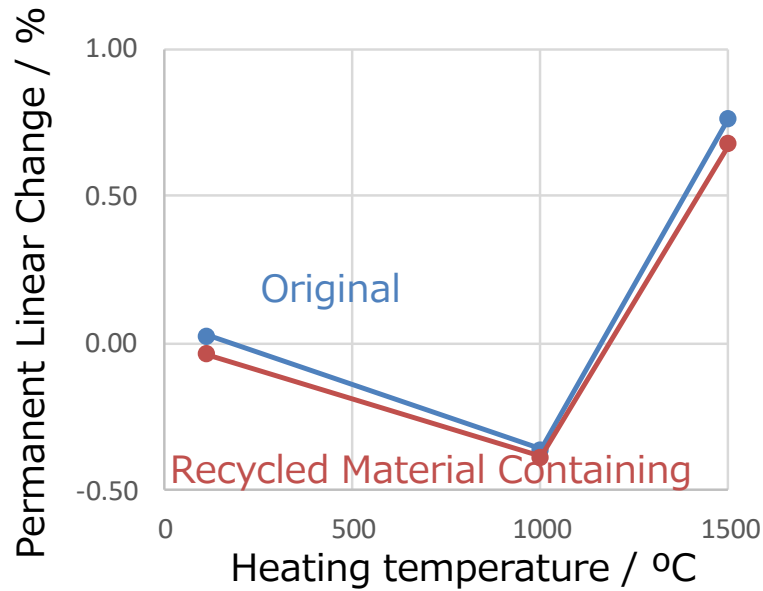


Yield rate : Approximately 60%

Further purification : Reducing yield rate

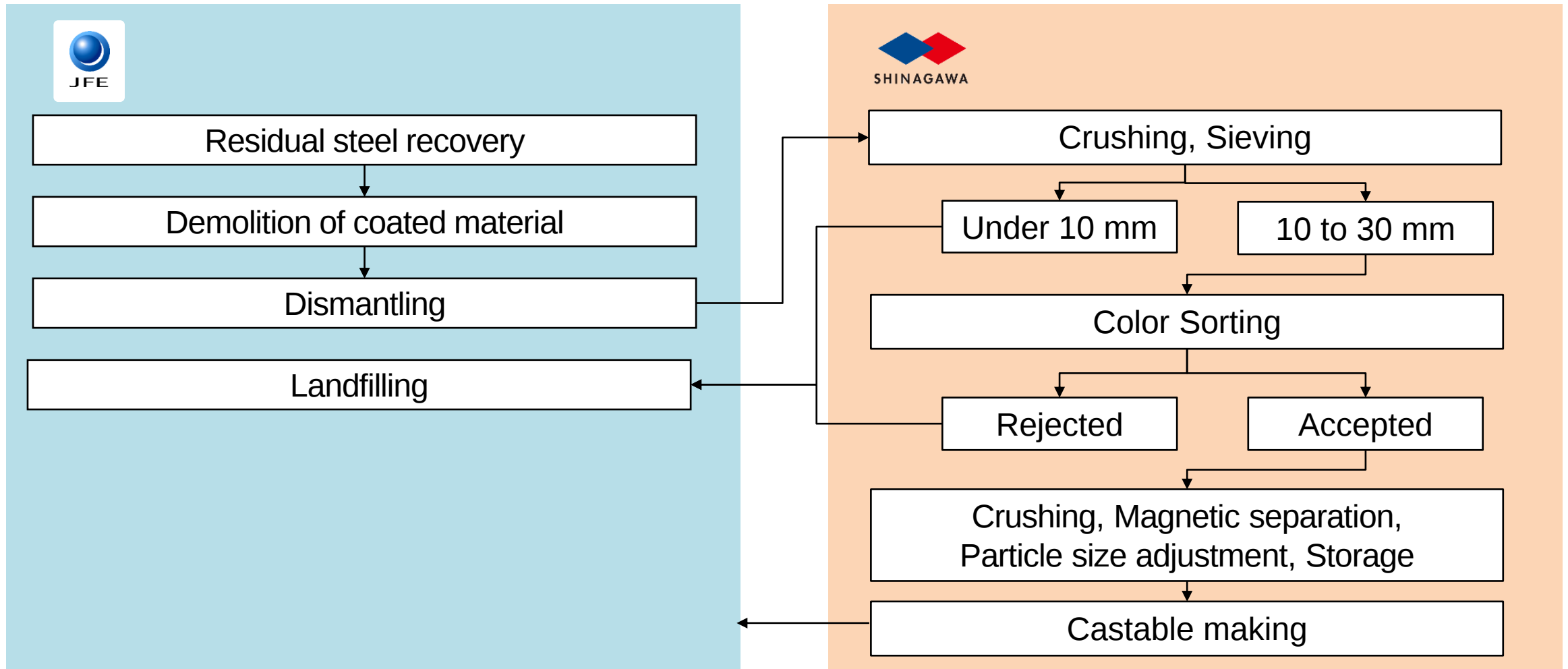
Castable Properties

Castable containing recycled material (more than 20%) showed acceptable properties.



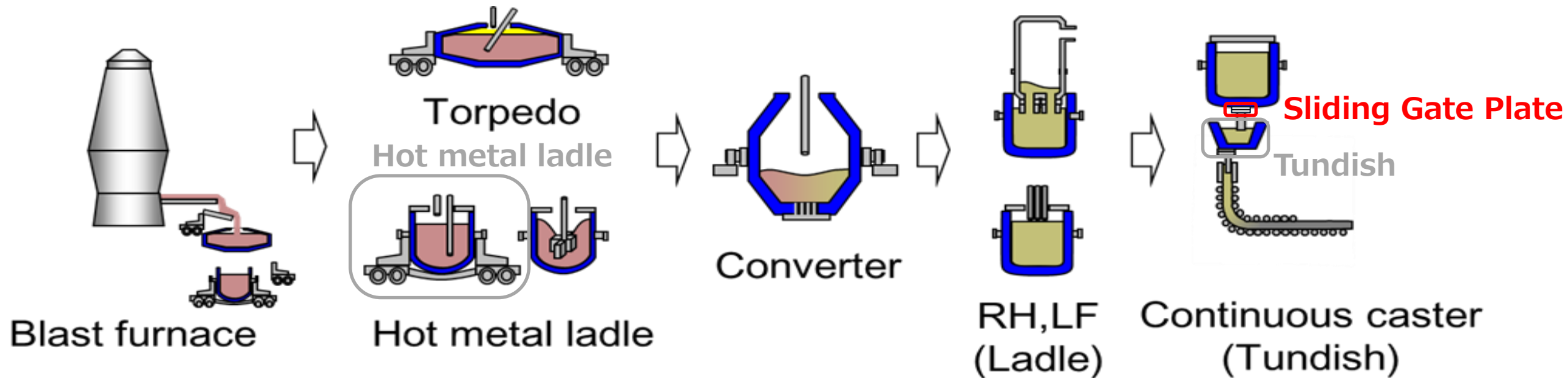
Recycling process

Reduction in landfilling amount is expected for JFE steel.



Topics

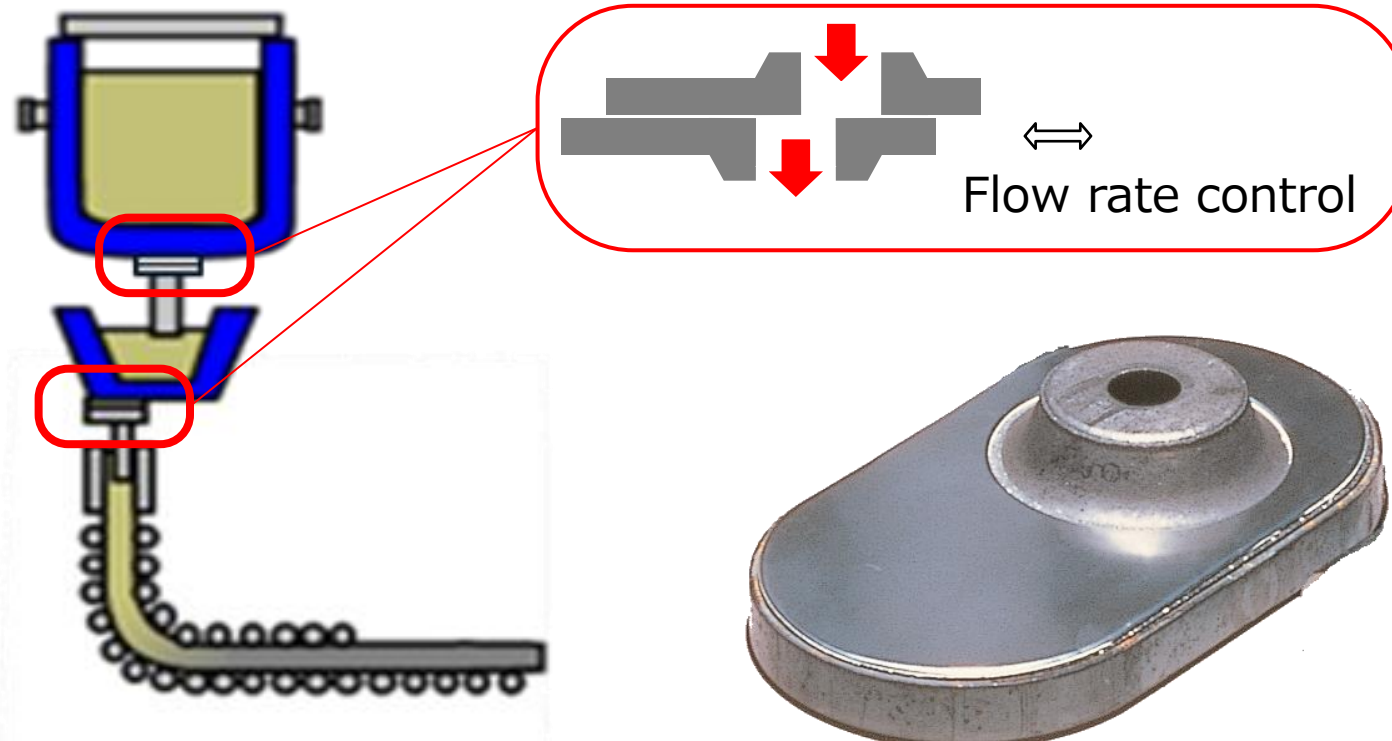
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Function of Sliding Gate

❖ Sliding gate regulates steel flow rate for proper casting.

Sliding Gate

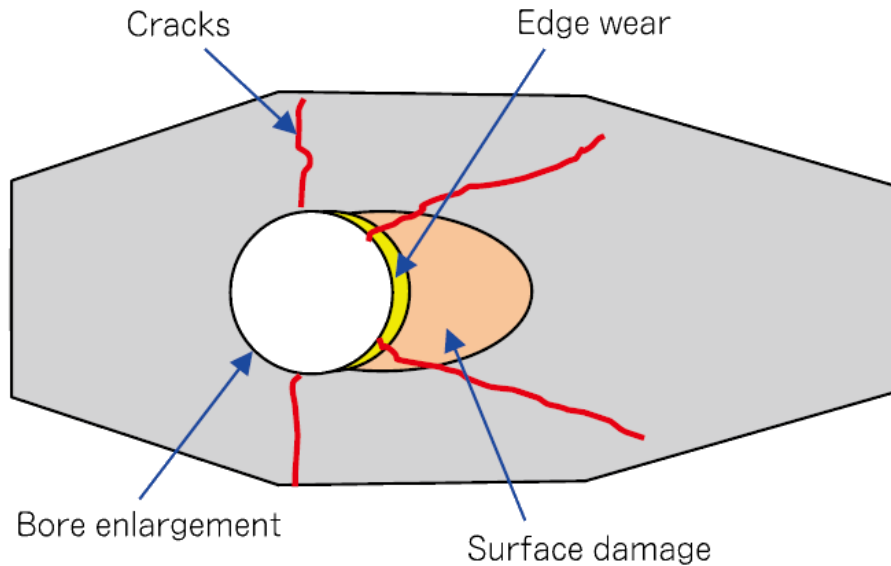


Typical Properties

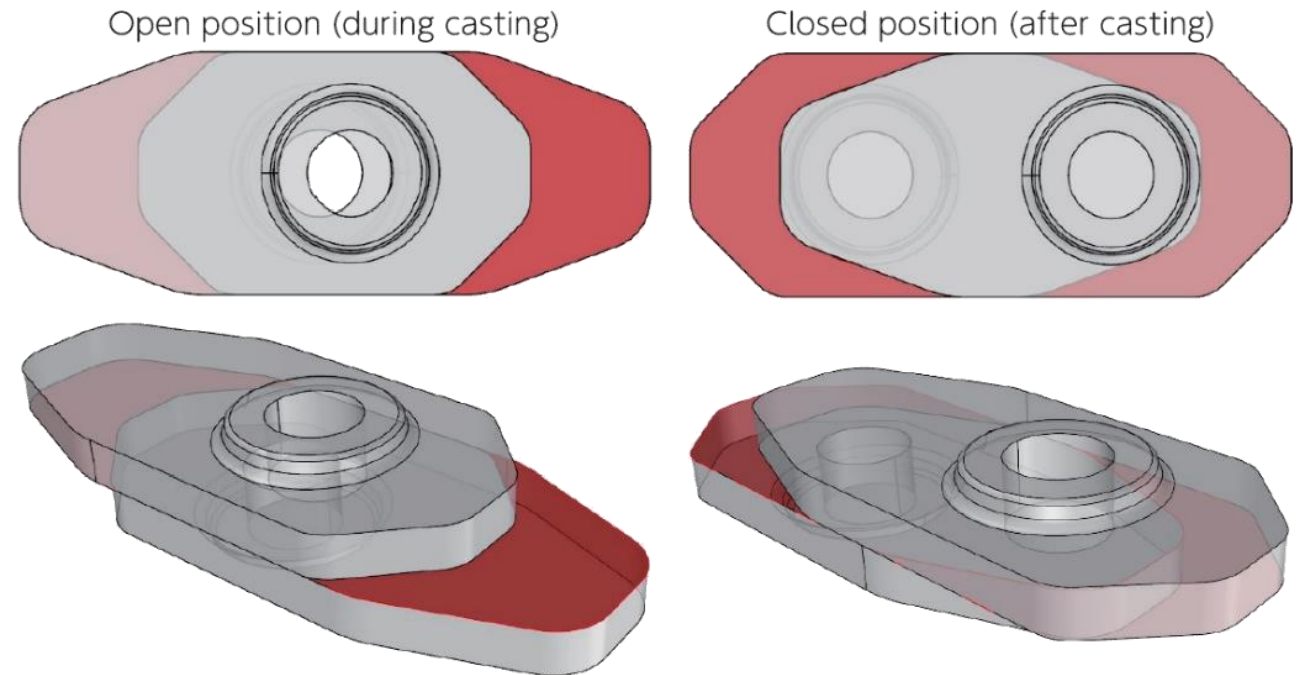
Chemistry / mass%	
Al ₂ O ₃	84
SiO ₂	1
ZrO ₂	5
C	6
AP / %	4.3
BD / kg·m ⁻³	3320
CCS / MPa	230

Localized Damage of Sliding Gate

- Only the area around bore suffers sever damages.
- Multiple use of rest of the part was attempted.

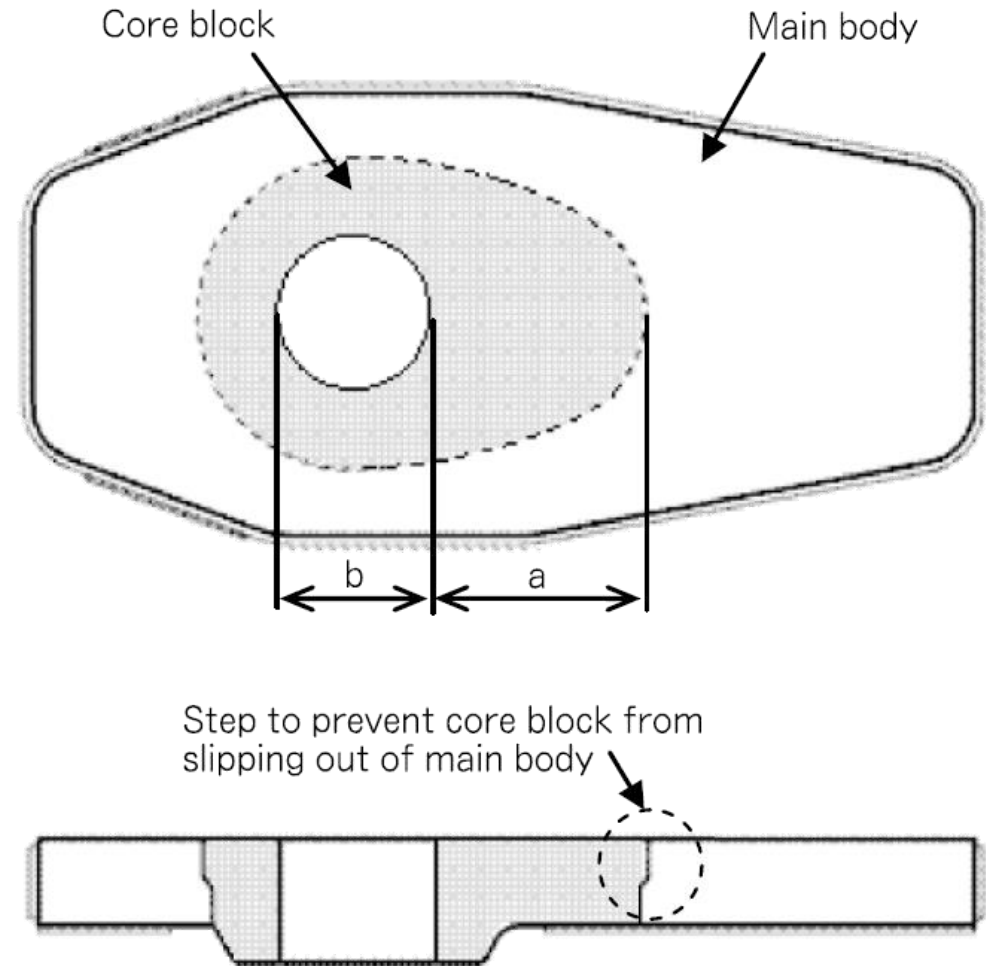
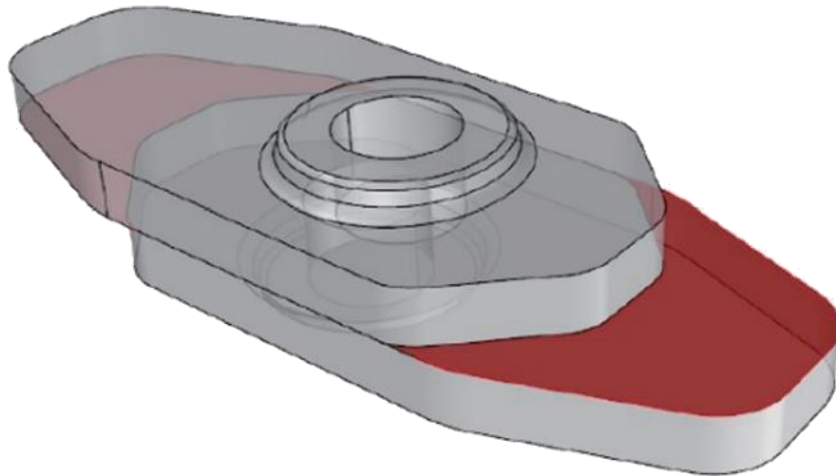


Limits the service life



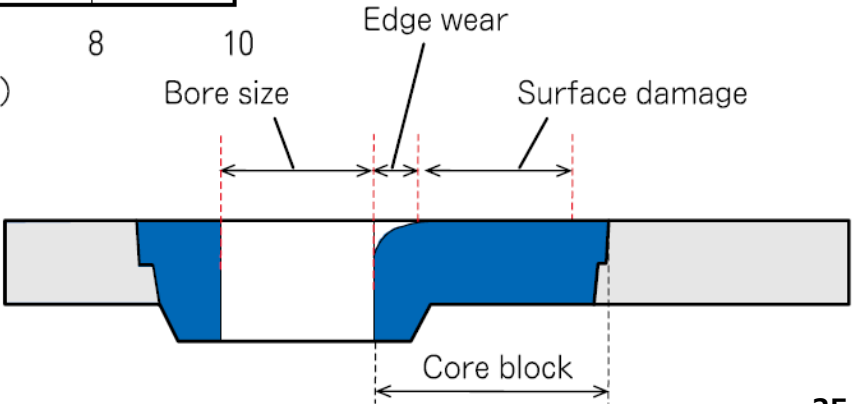
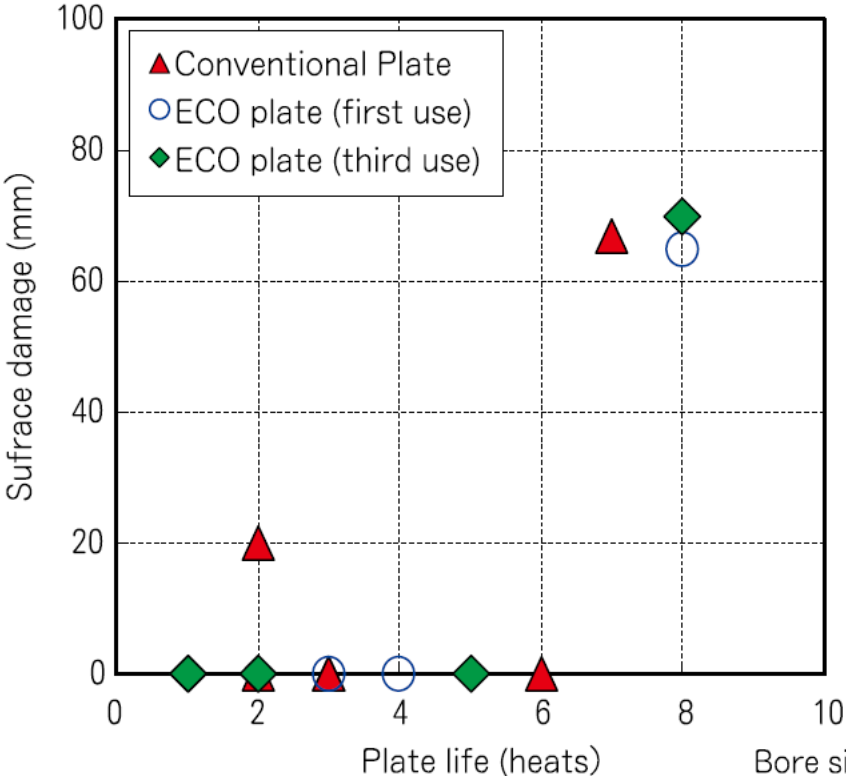
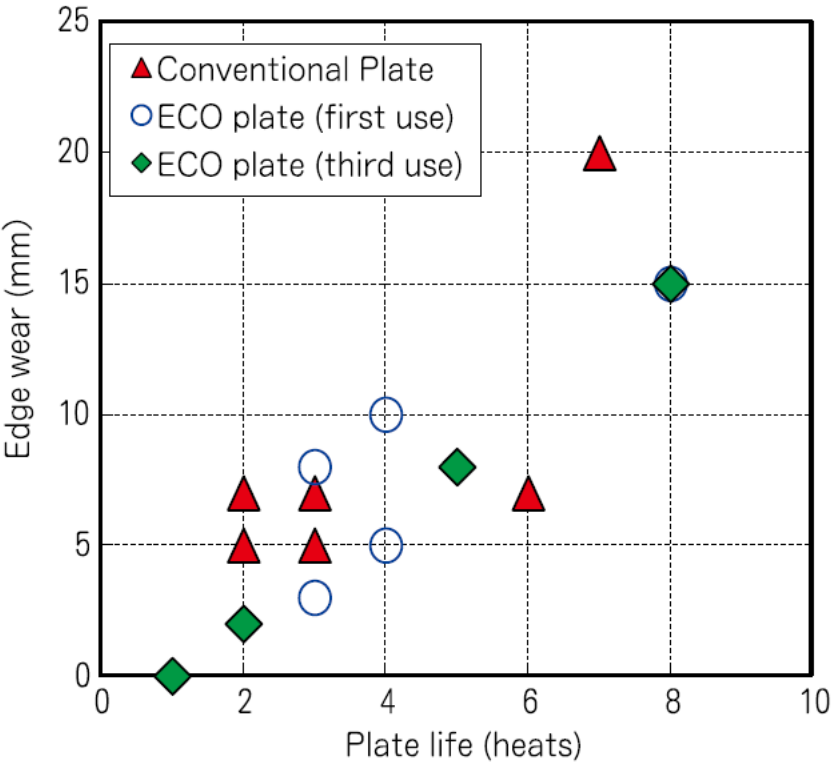
Eco Plate; Partial Replaceable Design

- Surface damaged area is replaced.
- Main body is used for multiple time.



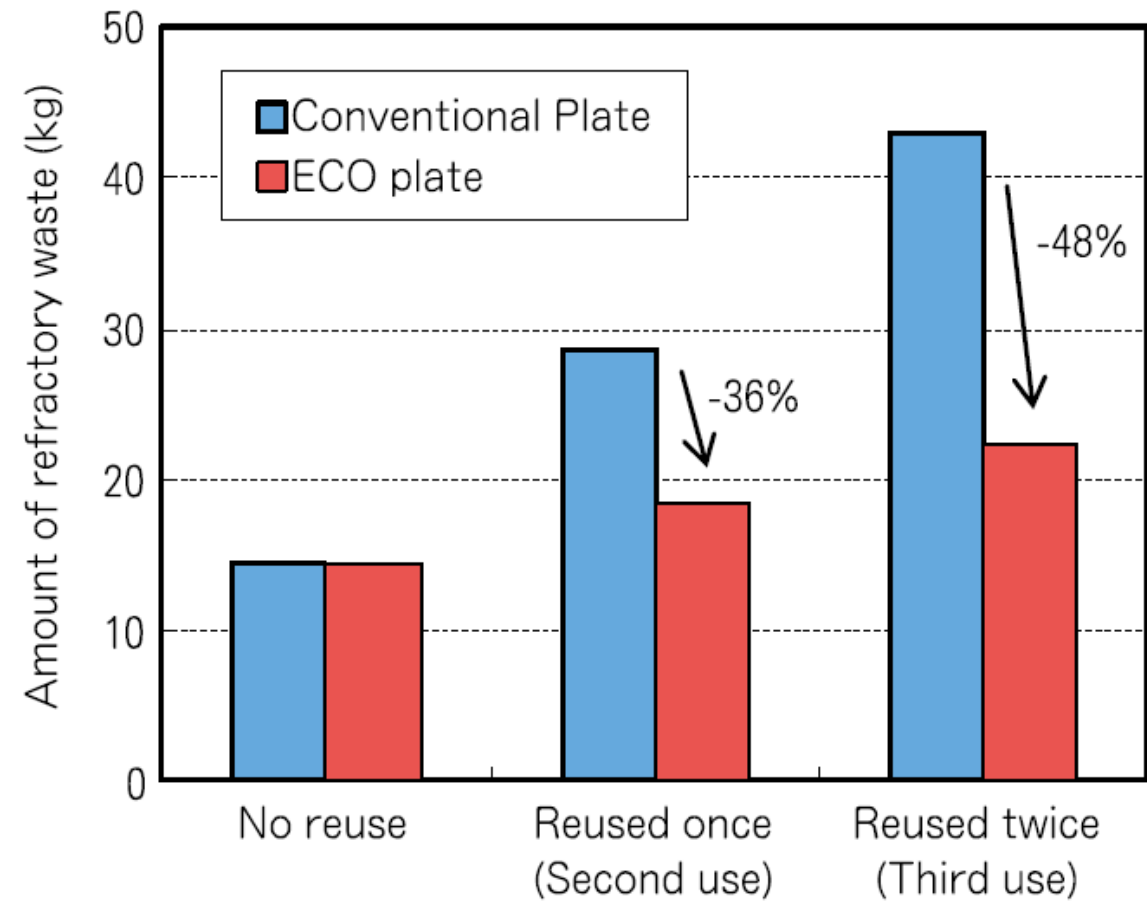
Commercial Application

Equivalent damage rates were observed for multiple use.



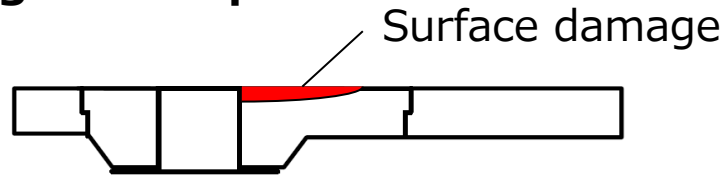
Reduction in Waste Rate

By using 3 times, 48 % reduction in refractory waste is expected.

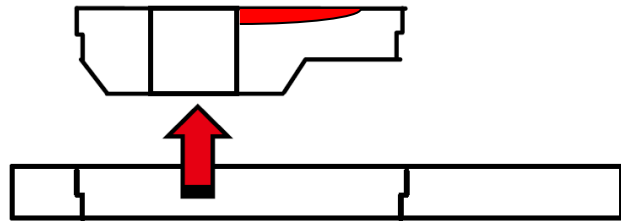


Reuse Process of Eco Plate

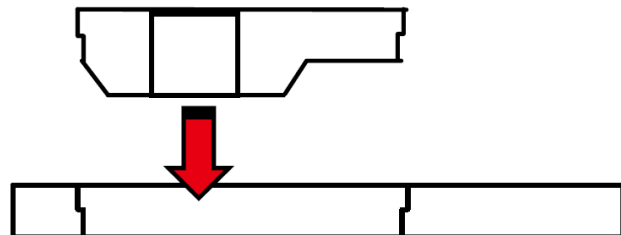
1. Getting a used plate



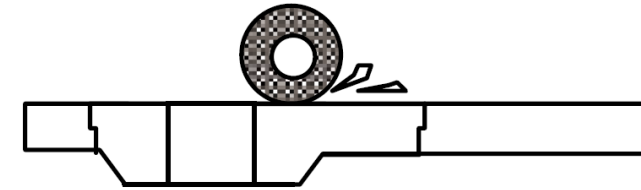
2. Core brick removal



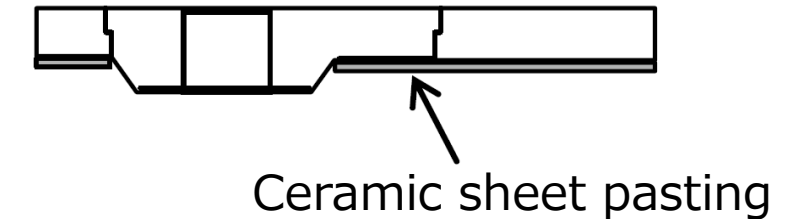
3. Core brick installation



4. Sliding surface grinding

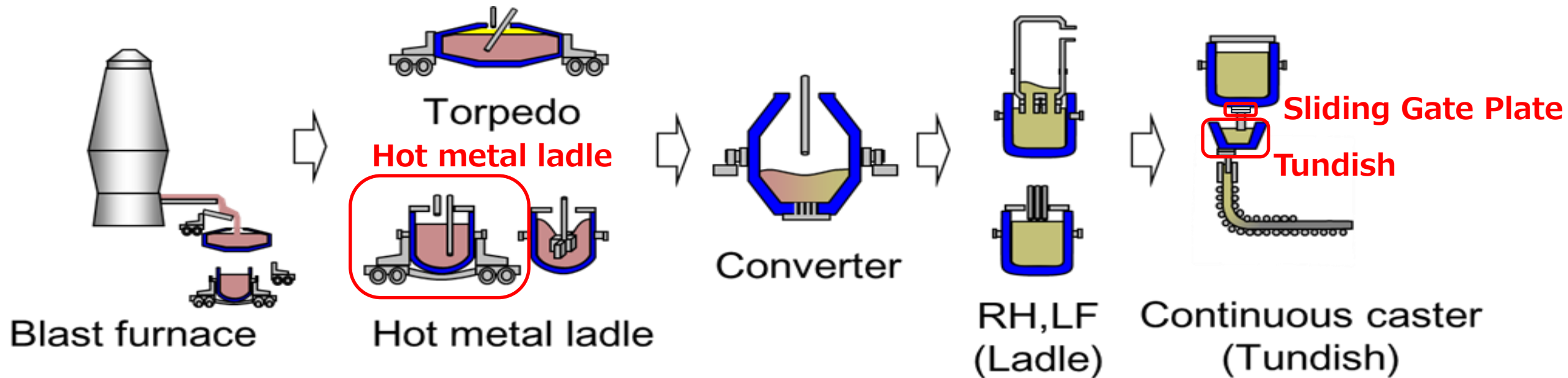


5. Thickness recovering



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- Sliding gate plate Reuse by partial replacement



Conclusion

- ❖ SHINAGAWA refractories and JFE steel are promoting spent refractory recycling strategically with close partnership.
- ❖ Recycling activities of three items, i.e., hot metal ladle, tundish and sliding gate plate, were exemplified.
- ❖ Concerning the hot metal ladle, strictly managed dismantling & chemical analysis-based quality control achieve the stable operation of recycled material-containing brick.
- ❖ For monolithic refractory installed tundish, industrial application of color sorting for crushed particle to remove colored altered layer has started.
- ❖ With respect to the sliding gate plate, partial replacement of critical zone allows multiple use of main body.

Thank you!



SHINAGAWA

SKY IS THE LIMIT :
SHAPING THE FUTURE OF REFRACTORIES



SHINAGAWA REFRACTORIES CO.,LTD.