JNFL May 21, 2012

Causes of and Countermeasures against Degradation of Discharge Flow during Operation Confirmation of System B of the Glass Melter

1. Past status

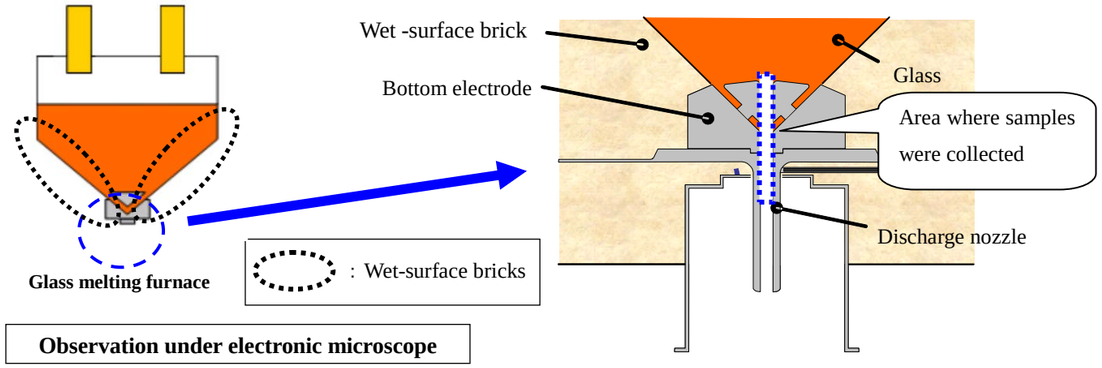
- January 24～ Started operation confirmation test in preparation for preliminary verification tests of system B of the glass melter towards to resume Active test (final commissioning test).
  ⇒Degradation of the discharge flow was found in the first batch. Restoration efforts were subsequently carried out using mixing rods, but did not lead to full recovery.
- February 3～ Stopped glass melter operation
- February 13～15 Inside of discharge nozzle flow duct was checked and cleaned using foreign materials removal apparatus
- March 4 Restarted heating of the furnace
- March 21～25 Carried out glass removal work
  ※ At the start of discharge, small particles which is believed to be from bricks were found, but after initial discharge and onward, hardly any such particles were observed inside the furnace.
- April 6～9 Observation of inside of the furnace

2. Cause analysis and investigation

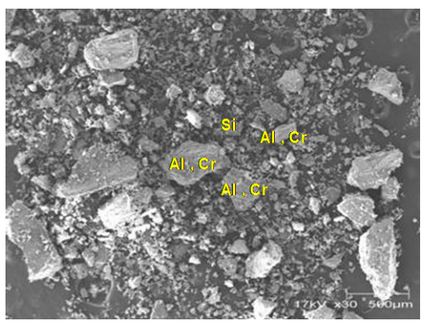
- Samples collected from the foreign materials removal process were analyzed, the causing factors were analyzed by;
  1. Examining the discharge status
  2. Observations of inside of the furnace
  3. Analysis of glass melter operation history
- Discussions were carried out based on the opinions of experts from within and outside Japan.

(1) Analysis of the samples collected from the foreign materials removal process

- The samples which were collected from the discharge nozzle, **major substances of the bricks (wet-surface bricks) that came into contact with the glass inside the furnace were found**, in addition to glass substance..
- Representative substances of ceiling bricks and glass ceramics were not found.

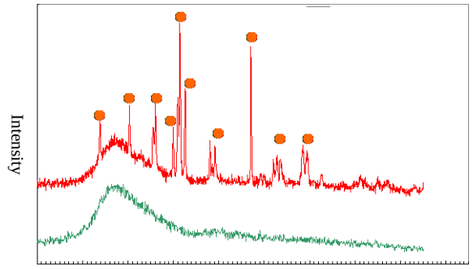


Observation under electronic microscope



Si (silica)
⇒Glass substance
Al (aluminum), Cr (chromium)
⇒Representative substances of wet-surface bricks

X-ray examination result



: Simulated glass beads
: Collected sample
: Places where high-intensity of wet-surface brick materials were found

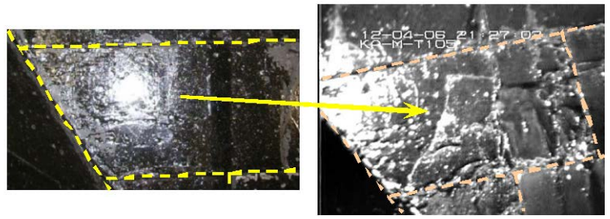
⇒ Places where high-intensity were found closely matches places where wet-surface brick substances were found

(2) Results and evaluation of observations of furnace

a. Results of inside of furnace observations

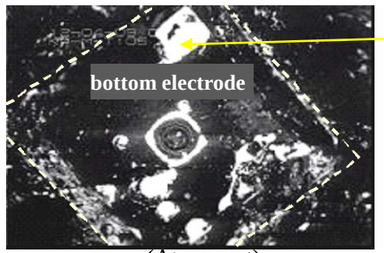
- **Some cracks and chips were found, but there was no major damage that would affect operation, and it was confirmed that there were no problems with the integrity of the furnace.**
- Hardly any residual materials were found, and it was determined that residual material removal work was not needed.

Condition of wet-surface brick on bottom electrode



(Before Active test) (At present)

State of residual material



(At present)

b. Evaluation based on observation of furnace (evaluation of cracks and chips in bricks)

- **Nearly all of the cracks inside system B of the furnace occurred before the active test.**
  ⇒**Due to the cracks that formed before the active test, new cracks do not easily form. (System A has the same tendency)**

・ The terminology related to the Startup and Shutdown of the glass melter are hereafter defined as follows.

【Furnace startup】
○ Heating : Startup without any glass inside the furnace
○ Startup : Startup with glass inside the furnace
【Furnace shutdown】
○ Drain-out : Shutdown with all glass removed from inside the furnace
○ Shutdown : Shutdown with glass still inside the furnace

(3) Volume of foreign material from past operations

・Investigated the volume of foreign material at the time of discharge in past operations and confirmed that **large volume of foreign material at the time of discharge after Startup/Shutdown of system B was identified**.

(4) Evaluation of impact on bricks at furnace Startup /Shutdown

・Investigated the temperature trends at the base of the furnace at the time of the glass melter Startedup/Shutdown, and reviewed the impact on the bricks by means of stress analysis.

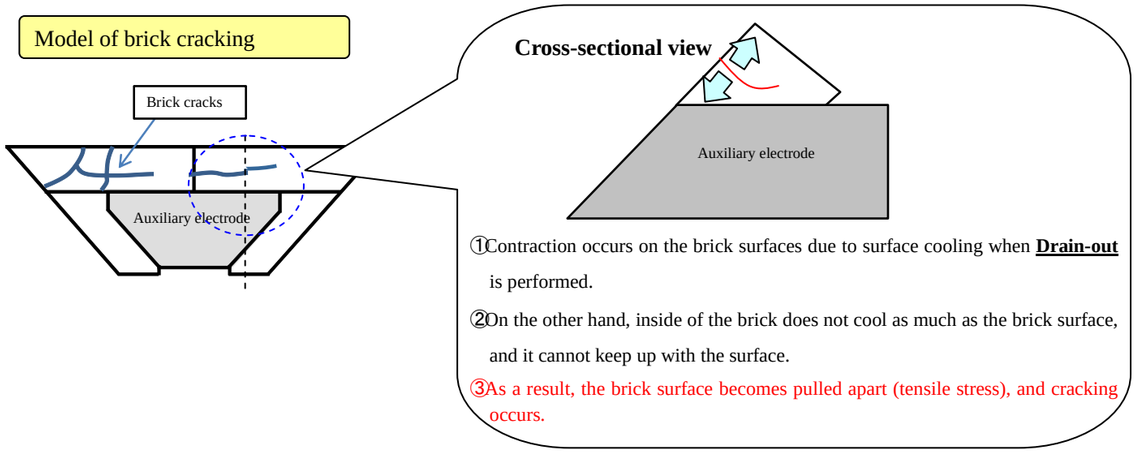
・ As a result, **bricks were found to be susceptible to ;**

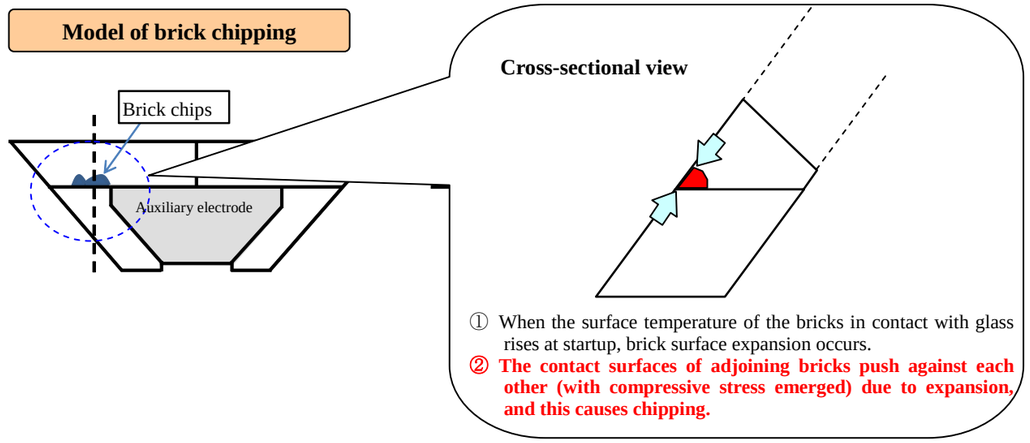
1. **Cracking at the time of drain-out due to surface tensile stress of the wet-surface bricks**

※When drain-out is performed after the glass has been removed from inside the furnace, the interior cools more rapidly than in the case of shutdown, due to the air flow in the furnace, the stress of the bricks will be much greater.

2. **Chipping at Startup operation, as a result of compressive stress due to expansion of the bricks.**

※The bricks are subjected to greater stress at the time of Startup operation compare to the Heating operation which is when the furnace is gradually started up while placing glass inside the furnace.





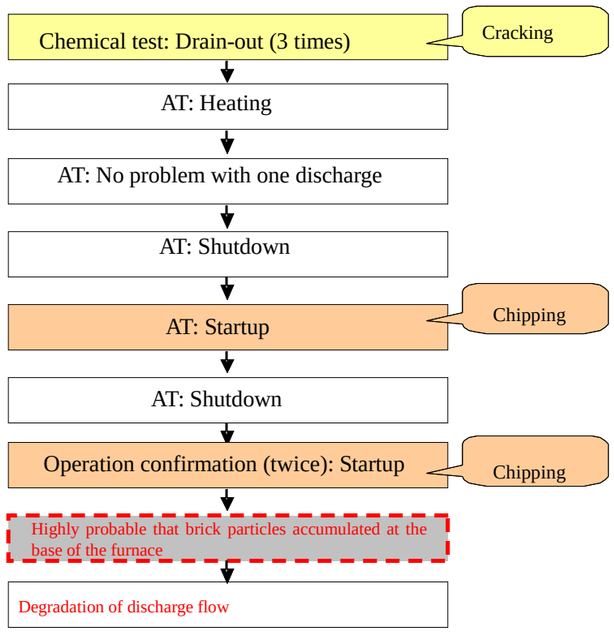
⇒ **Once cracking and chipping occurs, the stress is alleviated, thus new cracks and chips are unlikely to occur.**

3. Presumed cause of discharge flow degradation

・From the above mentioned examinations, it has been concluded that the following results were identified as highly probable causes.

◆**Cracking occurred at the time of Drain-out（Chemical test）, and chipping occurred at the time of Startup（Active test）, creating brick particles.**

◆ **Since discharge was carried out only once in the two Shutdowns and Startups during the long term standby of 3.5 months, this has resulted in brick particles accumulation.**



AT: Active test (final commissioning test)

4. Countermeasures

【① Curtail the generation of brick particles】

- Perform the glass melter Startup and Shutdown operations with gradual temperature changes.
- In principle, drain-out should be performed so as to avoid startup where there is a high probability of chipping which leads to degradation of discharge flow.

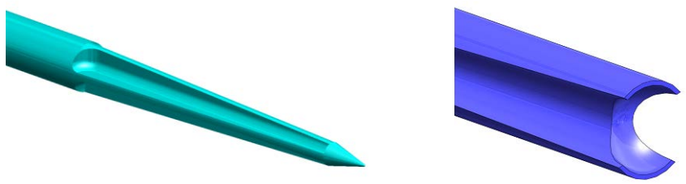
【②Inhibit accumulation of brick particles】

- When Shutdown is performed as a trouble prevention measure or when unscheduled Shutdown occurs due to power failures, purge the furnace of brick particles.

【③ Countermeasures for discharge flow degradation】

- In the unlikely event of discharge flow degradation, implement recovery operations similar to the current Drain-out using improved mixing rods.

Improved structure of mixing rod tip



Cross-shaped needle

Double edged type

- **The analysis of data and soliciting opinions of experts shall be continuously performed and reflect these knowledge into operations appropriately.**

【Monitoring brick condition】

- Monitor the inside of the furnace whenever Drain-out is performed and check the advancement of cracking and chipping of wet-surface bricks.
- Check the status of discharge status of the first and second batch after startup in order to grasp an understanding of the occurrence of chipping.

5. Procedures for Startup

- After the heating is completed, test discharge operation will be performed using simulated glass beads before the preliminary verification test, in order to be fully prepared for the preliminary verification tests. This will be followed by operation confirmation of verification equipment, and then the preliminary verification test will begin. For future vitrification tests, the measures summarized in this report shall be carefully heeded, and carry out each work with caution and greatest priority given to safety.

(Reference) Integrity assessment of glass melter

- From the results of observations of the inside of the furnace, it is judged that there is no problem or serious damage that could impact operation or integrity of the glass melter. In addition, because further formation of cracks and chips are unlikely and measures to mitigate them have been implemented, the furnace is evaluated as operable hereafter even with cracks and chips existing on wet-surface bricks.

- The assessment of cracks and chips on the wet-surface bricks from the standpoint of safety of the furnace is as follows.

【Confinement function】

- It was confirmed through the assessment that even if the molten glass seeps into joints and cracks, the temperature of the glass goes down, and the liquidity of the glass slows down and stops, as it escapes toward the outside.
- The atmosphere of negative pressure is maintained inside the furnace by means of the vitrification waste gas processing unit.

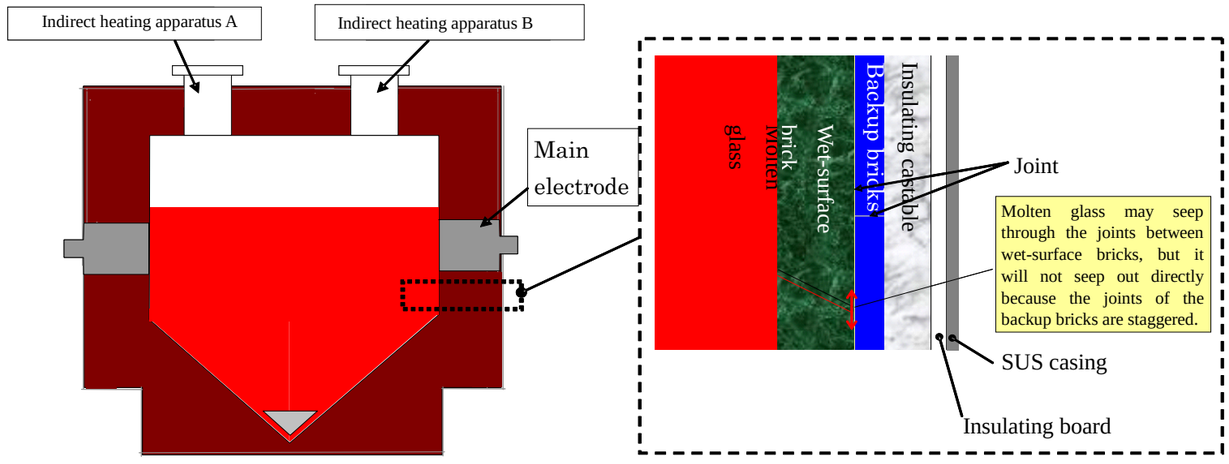
【Earthquake resistance】

- Earthquake resistance of the glass melter is evaluated on the basis of the strength of the casing.

※ The maximum temperature at which the casing can be used is calculated as part of the evaluation of seismic resistance, but, it was confirmed through the assessment that the maximum casing temperature is not reached even in the situation when there are no wet-surface bricks.

【Functionality of the shield】

- In the evaluation of the shield for the solidification cell where the glass melter is installed, the wall thickness of the solidification cell was checked.



[Wet-surface bricks]: Fireproof bricks that have superior anti-corrosion properties against molten glass.
[Backup bricks]: Fireproof bricks with appropriate temperature keeping properties and anti-corrosion properties.
[Insulating castable]: Fireproof material for insulation and temperature keeping of the furnace. It is hardened mold of fireproof materials poured in like cement.
[Insulating board]: Insulating materials that enhance the heat-keeping insulating properties of the furnace while also absorbing the thermal expansion of the bricks.
[Casing]: Container for the above furnace structure.