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Technical Report

Observation and Repair of Hot-blast Stove at High Temperature

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Abstract

Observation of high temperature refractories inside huge vessels like hot-blast stoves became possible with CCD cameras in water-cooled jackets and external lights. It leads to the determination of damaged area and the estimation of remaining life of refractories. Reliable repair of hot-blast outlet pipe comes out true by using the hot observation equipment.

1. Introduction

The life of hot-blast stoves has been prolonged remarkably thanks to improvements in refractory design and operation method.[1, 2] Although various measures have been taken to protect hot-blast stoves from typical damage, some wear and tear to their parts during their long life is unavoidable. Most recently, the types of damage that afflict hot-blast stoves differ according to the stove type, age, operation mode, and refractory quality, etc. Thus, it has become difficult to prevent damage to hot-blast stoves simply by taking care of specific parts.

In addition to that, since the hot-blast stove is a closed type of equipment whose interior is exposed to high temperatures, it is difficult to assess any damage to its refractory lining even during shutdown. If the condition of the interior of the stove is left unobserved for a prolonged period, it is possible that any damage to the stove may not be detected until some operational problem occurs. In this case, the stove has to be shut down at the time the damage is found. Thus, a failure to check the stove interior periodically may affect stove operation significantly.

In order to manage hot-blast stoves properly, it is important to implement periodic checks of the stove interior and proper repair of any damaged parts. Checking and repairing hot-blast stoves requires methods that vary according to the stove type and damaged part. In this paper, we describe the methods for hot observation and repair of internal combustion type hot-blast stoves at Nippon Steel's Nagoya Works.

2. Hot-Blast Stove Parts that are Susceptible to Damage

The development of damage to various parts of a hot-blast stove during its long service life is unavoidable. The parts that are especially susceptible to damage are shown in **Fig. 1**, and the types of damage are shown in **Table 1**.

3. Off-Line Hot Observation Test

Prior to hot observation of the interior of an actual hot-blast stove, we carried out an off-line verification test. The test furnace used is shown in **Fig. 2**. With the furnace temperature raised to 1,000℃, we observed the furnace interior using a CCD camera. A sample brick on which the letters "H" and "S" were written was placed inside the furnace. The burner was stopped when the furnace interior reached the prescribed temperature, and then the visibility of the letters under radiant light only was compared with that under radiant light

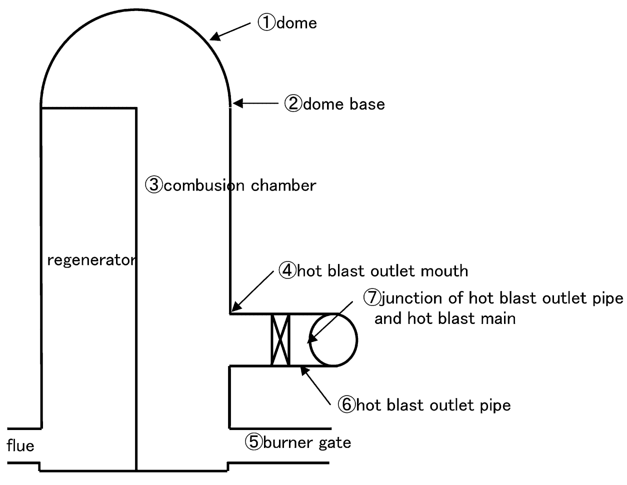

Fig. 1 Damages in hot-blast stove refractories

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Table 1 Damage of hot-blast stove refractories

No.	Area	Type of damage
①	Dome	Subsidence of dome, vertical cracking and dropout of bricks
②	Dome base	Cracking and rupture of bricks with load from the dome
③	Combustion chamber	Lighetning-shaped cracking on side and partition wall
④	Hot blast outlet mouth	Dropout of mouth bricks because of their complicated structure
⑤	Burner gate	Spalling and cracking with rapid temperature change and load form wall bricks
⑥	Hot blast outlet pipe	Cracking with steel shell movement around the expansion
⑦	Junction of hot blast outlet pipe and hot blast main	Loose and dropout of bricks with thermal expansion of hot blast outlet pipe and hot blast main refractories

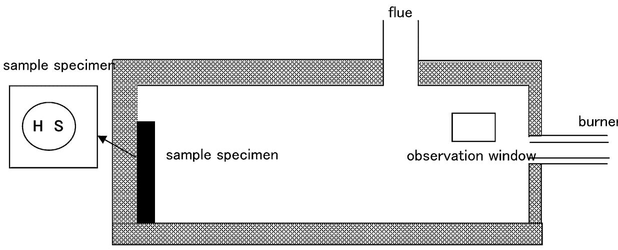


Fig. 2 Test furnace for hot observation

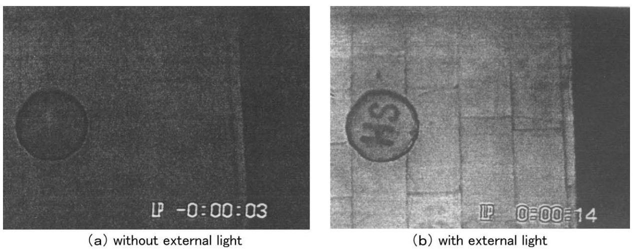


Fig. 3 Hot observation

plus external light. The results are shown in **Fig. 3** (a) and (b). Under radiant light only, the letters written on the sample brick were invisible, whereas under radiant light and external light, they became visible.

4. Hot Observation of Stove Interior

4.1 Observation of the dome interior

4.1.1 Position of observation

The existing openings in the dome of a hot-blast stove are shown in **Fig. 4**. There are holes in the dome's top and base for temperature measurement. In view of the scope and ease of observation of the stove interior, we decided to conduct observations from the dome base. The parts of the stove observed were the dome top, dome base, and checker bricks, etc. In order to observe those parts, we designed an observation device.

4.1.2 Outline of observation device

In order to observe the dome interior, a device equipped with an external light source was used. An outline of the observation device is shown in **Fig. 5**.

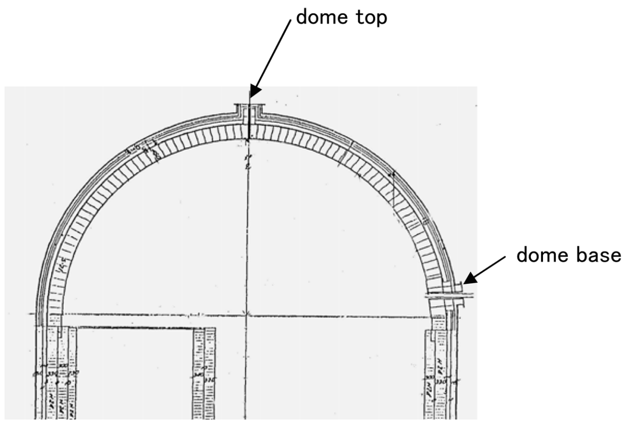


Fig. 4 Observation holes on the dome

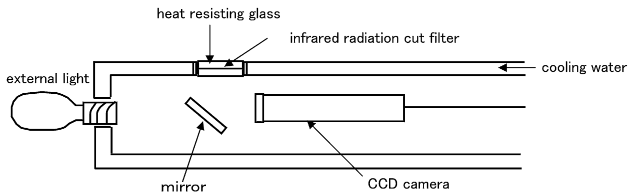


Fig. 5 Hot observation equipment with external light

4.1.3 Results from observation of dome interior

Examples of the observation results of the dome interior are shown in **Fig. 6**. The temperature inside the stove during the observation was 1,000°C. Fig. 6 (a) shows the condition of the dome brick. The brick is sound, being free of broken joints and chips, etc. Fig. 6 (b) shows the dome base brick. Broken pieces of brick have fallen on the sidewall top and checker brick. Fig. 6 (c) shows the brick at the sidewall top and the top of the checker brick. The holes in the checker brick can clearly be seen and the dust on the top of the checker brick is visible.

4.2 Observation of the combustion chamber

4.2.1 Combustion chamber parts observed

The combustion chamber was observed by inserting the observation device into the chamber through the manhole provided in the chamber bottom. From the combustion chamber, the sidewalls, par-

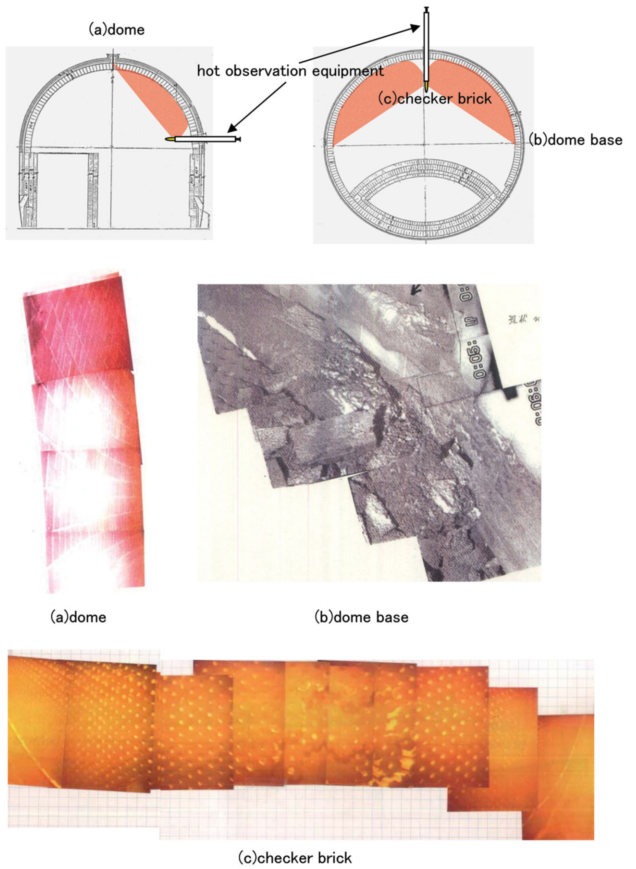


Fig. 6 Obtained images from hot observation inside dome

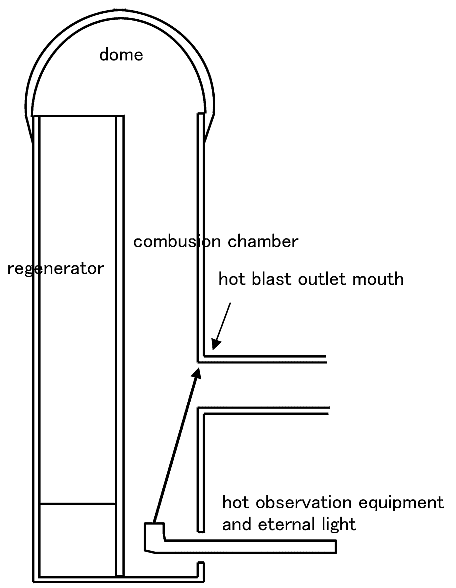


Fig. 7 Observation inside combustion chamber

tition wall, hot-blast outlet mouth brick, and burner nozzle, etc. can be observed. The method of observing the combustion chamber is shown in **Fig. 7**.

4.2.2 Observation device

Since the objects under observation in the combustion chamber were some distance from the position of observation, we used a camera with a zoom lens. As the external light source, two 5-kW lamps were used. An outline of the observation device is shown in **Fig. 8**.

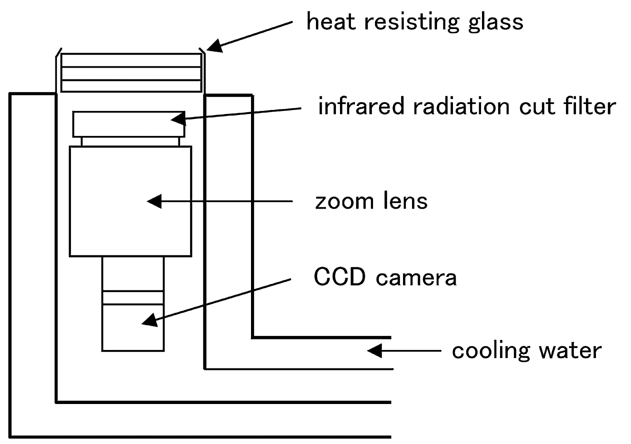


Fig. 8 Hot observation equipment without external light

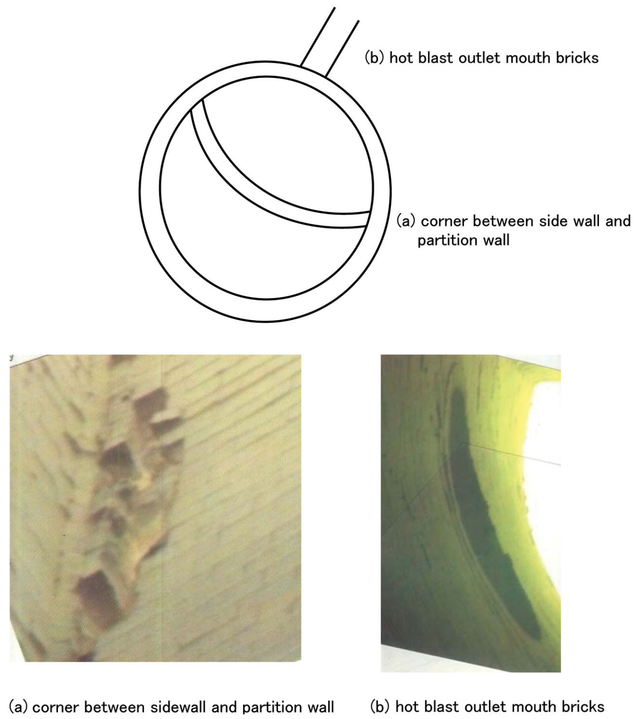


Fig. 9 Obtained images inside combustion chamber

4.2.3 Results from observation of combustion chamber

Fig. 9 shows the condition of the combustion chamber interior. Fig. 9 (a) shows the corner at which the partition wall and the sidewall meet. This part was some 20 m from the position of observation. Protruding and broken bricks can be seen. Fig. 9 (b) shows the condition of the hot-blast outlet lining brick. No damage to the brick is observed.

5. Examples of Hot Observation and Repair Methods

5.1 Observation of hot-blast outlet pipe

The interior of the hot-blast outlet pipe can be observed using an observation device equipped with an illumination lamp. **Fig. 10** shows the condition of the outlet pipe interior. Damage to the brick in the expanded part can be seen.

5.2 Combination of hot observation and flame gunning repairs

In order to repair the hot-blast outlet pipe by flame gunning, a manhole is installed in the hot-blast main pipe and a long nozzle is used. The part to be repaired was some distance from the hot-blast main pipe and could barely be seen. Besides, it was partly obscured. By using the flame-gunning repair method and the hot observation device, the damaged part could be repaired completely. **Fig. 11** shows an outline of the flame gunning equipment, and **Fig. 12** shows the condition of the flame-gunning repair seen by the hot observation device. The properties of the flame-gunning materials are shown in **Table 2**.

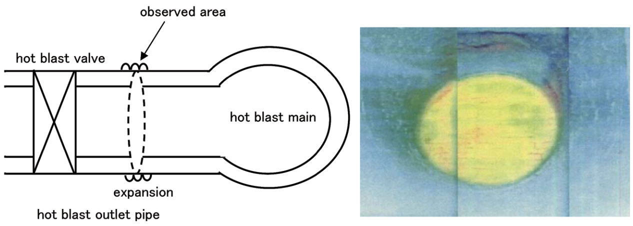


Fig. 10 Observation inside hot blast outlet pipe

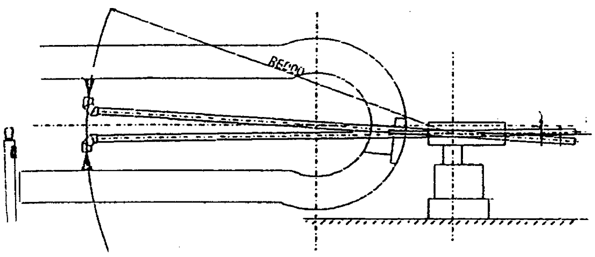
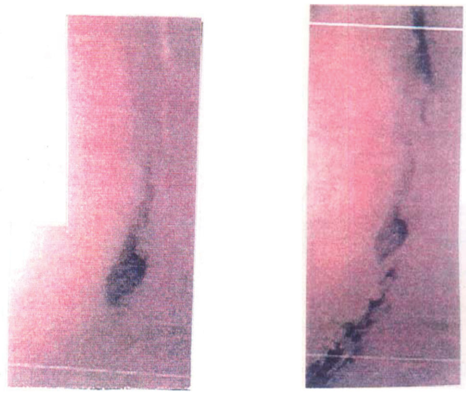


Fig. 11 Schematic drawing of flame gunning equipment

Fig. 12 Sidewall under repair with flame gunning

Table 2 Properties of flame gunning materials

Chemical composition (mass%)	Al_2O_3	62
	SiO_2	33
Hot bend strength (MPa) at 1,000℃		25
Bulk density (g/cm^3)		2.6



(a) after first injection (b) after second injection

Fig. 13 mortar injection repair of hot blast outlet pipe refractories

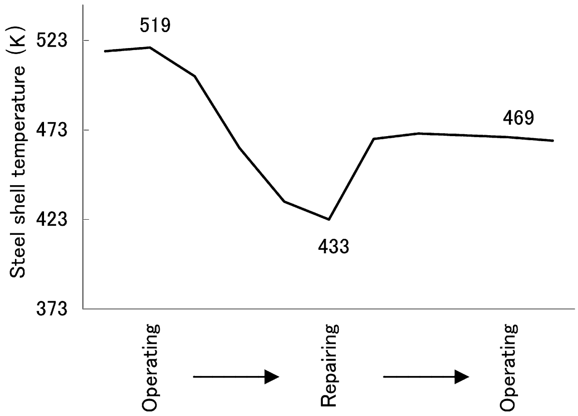


Fig. 14 Temperature of steel shell before and after repair

Table 3 Properties of injection mortar

Chemical composition (mass%)	Al_2O_3	43
	SiO_2	50
Bulk density (g/cm^3)		0.49

5.3 Combination of hot observation and mortar injection repair

The rise in the steel shell temperature of the hot-blast outlet pipe is considered to be due to the formation of a passage leaking hot gas caused by a crack in the steel shell. Therefore, mortar is used to block the gas's passage. **Fig. 13** shows images of the behavior of injected mortar obtained by the hot observation device. Fig. 13 (a) shows an image obtained when the injected mortar began entering the stove, and Fig. 13 (b) shows an image obtained when the mortar injection was resumed after interruption. It can be seen that the injected mortar is forming from another part.

Fig. 14 shows the change of temperature in steel shell before and after the mortar injection repair. Following the mortar injection, the temperature in steel shell declines, indicating that the mortar was injected into the right part. **Table 3** shows the properties of the mortar used for the repair.

6. Conclusion

(1) In order to estimate the life expectancy of large closed-type fur-

nace equipment, such as the hot-blast stove, we have established and put to practical use hot observation technology.

(2) It was found that when an external light was used in hot observation, the object under observation could be seen clearly.

(3) Our hot observation device applying the above technology has made it possible to observe various parts of the interior of a hot-blast stove.

(4) In addition, by using the hot observation device and a suitable repair method in combination, it has become possible to repair a damaged hot-blast outlet pipe efficiently.

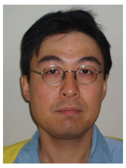
Our technology has been used in equipment analysis at the following steelworks: Nagoya Works, Muroran Works and Oita Works of Nippon Steel, Kokura Works and Wakayama Works of Sumitomo Metal Industries, Ltd., Kure Works of Japan Steel Works, Ltd., Nakayama Steel Works, Ltd.

Acknowledgment

We wish to express our heartfelt thanks to the people at the Nagoya Branch of Krosaki Harima Corporation for their generous cooperation in the development of the hot observation device described in this paper, improvements to the device handling method, and the implementation of equipment diagnosis applying the hot observation technology described in this paper.

References

1) Sugita, K.: Refractories for Ironmaking/Steelmaking Equipment. 1995, 167-183
2) The Technical Association of Refractories, Japan: Taikabutsu Notebook '97. 1997, p.310-315



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