WHITEPAPER

5 Common Causes of Refractory Failure and How to Fix Them

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Introduction

All process heaters operate at high temperatures and are constructed with process tubes inside a refractory-lined enclosure, which is heated by radiant heat from gas-firing or, less commonly, oil-firing.

Refractory linings are insulating and minimize heat loss, making them essential to retaining the high-temperature environment. However, when subjected to high temperatures, refractory can deteriorate and potentially lead to failure if remedial work is not carried out.

Types of refractory lining include refractory ceramic fiber, brick, and castable or concrete. If refractory failure results in an unplanned shutdown, it can cost plants more than $1m/day in lost production.

In this whitepaper, we will discuss the most common causes of refractory failure, how to inspect fired heaters or furnaces for damage, and the methods of repairing refractories online without the need to disrupt normal operation.

5 Common Causes of Refractory Failure

1. Deterioration Due to Length of Service

As refractory linings age, their physical properties change. The high-temperature environment causes microstructural changes to the binders within the materials, leading to a loss of surface or internal strength. If the refractory material carries a compressive load, such as bricks, or castable linings, this can lead to local, or widespread failure.

If the refractory is subject to flame impingement, which is common in many radiant wall applications, the useful life will be shorter.

In oil-fired heaters, refractory deterioration is accelerated by corrosive agents in the combustion products. Fortunately, there are few cases where oil-firing is used now.

2. Incompatible Refractory Materials

A combination of refractory materials is a common feature in fired heaters. Openings such as doors often use fiber and brick material, and peep sights may use IFB, castable, or fiber modules.

A standardized design using different materials can be challenging as each material has varying properties at high temperatures. Therefore, refractory linings can become damaged, leaving the shell exposed to hot flue gases and causing hot spots.

To lower the risk of mismatched refractory materials, it is a good idea to work closely with the refractory supplier to ensure comparable materials are used around openings.

3. Loss of Support

All types of refractory linings are attached to and supported by the external steel shell of the fired heater. The conventional support is provided by an anchoring system, which is welded to the shell.

Frequently, the welded joint between the shell and the anchor is compromised by corrosion and support is lost. The corrosion is caused by hot flue gases penetrating through the refractory lining and condensing upon reaching the cooler shell. The local environment is ideal for rapid oxidation, or corrosion of the weakest point; the weld.

Once support is lost, individual bricks, modules, etc. can fall away, leaving the metal shell exposed, which creates a domino effect and the failure of adjacent refractory lining.

At a plant in Europe, a hot spot was discovered on the transition shell ducting between the radiant and convection sections of a CCR Platformer. In this case, the failure of the ceramic fiber blanket in the roof left the shell exposed to hot flue gas. This caused the external shell temperature to exceed 560°C/ 1040°F.

To prevent overheating the shell until failure, the production rate on the CCR Platformer had to be decreased, resulting in a loss of production of more than $400,000 per day. The plant used Hot-tek's hot refractory repair service to fix the issue until the next planned turnaround. This service is discussed in more detail later in this whitepaper.

4. Mechanical Stress

There are several factors that can cause mechanical stress to lead to refractory failure.
This includes:

- **Vibrations** - Vibration or interference from other equipment can cause refractory to become displaced and break down over time.
- **Thermal expansion/ spalling** - This occurs when refractory linings expand and contract at different rates due to thermal conditions. This often leads to cracking and spalling which can cause failure if not repaired.
- **Impact** - Mechanical impact from falling objects/components can also damage refractory.

5. Poor Installation or Maintenance

Improper installation or maintenance is a common cause of refractory failure. Factors such as installation techniques, curing time, inadequate support, or poor-quality materials can all weaken the refractory and contribute to its failure.

Refractory installation begins at the manufacturing stage. Good communication between the manufacturer and the plant is critical to ensure that the refractory is fit for purpose. It should be resistant to thermal stresses and other processes caused by the operating environment. Parameters such as temperatures, start-ups and shutdowns, flue gas temperature and chemical components, and required heat loss should all be evaluated.

Once manufactured, the refractory should be stored in a dry, well-ventilated space and installed within three months for high-temperature or high-abrasion operating environments. If installed and maintained correctly, refractory linings should last 20 years or more.

However, several characteristics could suggest issues at the installation stage. For example, if you notice fiber modules have fallen from the roof or gaps have appeared, it could be due to an issue such as insufficient stud welding. It could also be a sign of shell corrosion, which is more common if a protective alloy cladding, such as IGS' High Velocity Thermal Spray (HVTS) has not been applied to the shell before installation.

Whilst there is a range of potential installation issues that can lead to refractory failure, regular and diligent inspections can help to identify damage early to allow remedial work to be carried out.

How to Inspect Furnaces for Damage

Often the first sign of refractory failure is a hot spot on the external steel shell since direct observation of the problem area is not possible. IGS has designed and developed Cetek's Lancescope™ fired heater inspection tool. It allows the undertaking of a high-temperature furnace inspection to determine the scope of the problem, often avoiding an expensive shutdown of the heater.

The hot inspection system uses a state-of-the-art digital camera system, which provides clear, detailed images of problem areas up to 3000°F (1650°C). The furnace inspection system can be inserted into openings as small as 2.75" (7cm) and reach up to 30ft (10m). In applications below 1000°F (540°C), the heater inspection system provides illumination via a high-temperature light source for optimum clarity.

The benefit of performing a hot inspection includes:

- Performed while the unit is in operation
- Provides insight into production availability
- Identifies damage in early stages
- Reduces maintenance costs
- Minimizes repair downtime
- Maximizes production

Methods to Repair Refractory

Once the damage has been identified, there are usually options to fix the issue. Production can be interrupted to take the asset offline and carry out conventional repairs, or the furnace can continue to run at reduced performance until the next planned turnaround. However, this could exacerbate any existing damage.

Alternatively, an online refractory repair service is offered by Hot-tek™, where there is no need to bring the heater off-line and production will not be interrupted or capacity limited. This is a good option to temporarily fix damage until the next planned turnaround.

A team of refractory technicians can be mobilized at short notice and the repair involves creating minimal access point openings to insert specially designed components and repair material, delivering a semi-permanent repair lasting at least until the next turnaround.

Case Study:
Fired Heater Shutdown Prevented with Hot Refractory Repair

A refinery in the U.S. discovered serious refractory integrity concerns on its catalytic reformer (CCR) heater unit. The refractory ceramic fiber was missing in a furnace. As a result, the outer steel shell was damaged due to exposure to high temperatures in multiple areas of the roof and sidewall.

Refinery Furnace Infrared Images Reveal Problem Areas

This refinery is a downstream energy company with assets in petroleum refining, logistics, convenience stores, asphalt, and renewables with a capacity of fewer than 150,000 barrels per day. The refinery produces types of gasoline, distillates, and propane products.

The plant invited Hot-Tek to inspect the unit and carry out hot refractory repairs. The team took infrared images of the hot spots on the CCR fired heater roof during the pre-project meeting.

Temperatures of more than 1500°F/815°C were being reached at the bridge wall, relatively high for a CCR fired heater. Material selection utilized in the previous repairs was not sufficient for these elevated bridge wall temperatures.

Hot-Tek #1 & #2 Repair Area. Repaired using Hot-Tek Module Style on the ceiling of the installed dog boxes.

Hot-Tek #3 Repair Area. Repair performed utilizing the Hot-Tek Basket Style Repair on the existing ceiling.

Hot-Tek #4 Repair Area. Repair performed utilizing Hot Tek Basket Style Repair on the side of the Dog Box and existing ceiling.

Hot-Tek Hot Refractory Repair Solution

The damaged areas were repaired using two techniques; Hot-Tek's unique basket-style repair and the larger module repair. The larger damaged furnace roof areas were cut into sections and removed one at a time. Then, prefabricated modules consisting of higher alloy plates and hardware along with high-temperature ceramic fiber created a long-term repair solution for the refinery. The basket-style repair method was used to seal around the perimeter of the modules.

Step-by-Step Hot-Tek Repair Solution

Hot-Tek furnace repair using the module style on the ceiling of the installed dog boxes:

Cutting theTiles and Leaving an Area for Support

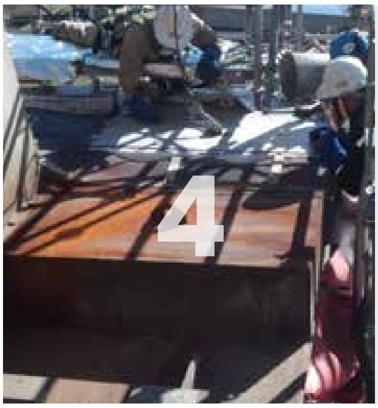
The first tile was cut using a plasma cutter and removed from the furnace ceiling. Approximately 1”-2” area of the original furnace shell was left for support for the new Hot-Tek Module. After installing the module temporarily, the team then moved to the next tile.

Installing Prefabricated Hot-Tek Module

The team installed a prefabricated Hot-Tek module and tack-welded it into the place.

Large Module Installed in Another Section

The installation of the large module was completed in the next roof section. The module and technician were tethered for safety.



Module Fitted and Welded in Place

The module was fitted and fully welded in place with an alloy rod for dissimilar metal welding.

Hot-Tek Basket Solution

The large, damaged roof area was repaired with 16” square alloy Hot-Tek baskets. The baskets were welded together to form the new “ceiling” of the roof.

Pouring New Refractory

Pourable/pumpable refractory was laid into the large opening. After curing, the surface becomes cool to the touch. Once cool, an alloy plate was welded over the refractory.

The Result – Hot-Tek Hot Refractory Repair Solution

The Hot-Tek project was completed within the agreed schedule of eight days. The refinery continued operations at full capacity, completely unaffected by the repairs taking place. A shutdown would have cost the refinery millions in lost production.

Conclusion

There are numerous causes of refractory failure, but shutting down the furnace should always be a last resort as this has a huge impact on production and revenue. The operating environment is responsible for most refractory failures and a common oversight is to increase the furnace temperature without assessing the impact that this will have on the design parameters of the refractory. Planning for over-capacity can help to mitigate the risk of refractory failure if specifications change after installation.

Understanding and preventing refractory damage is key to the overall furnace performance. IGS recognizes the effects of asset failure and works in partnership with plants worldwide to optimize equipment reliability and performance. Identifying refractory damage early and understanding the reasons behind it will help operators increase furnace up-time and maximize overall performance which could save millions in otherwise lost revenue.

If unexpected performance losses are impacting your operations, IGS can mobilize quickly to help you identify, fix, and prevent future damage.

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