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By Norm Phelps

Safeguard refractory installation

Take these 12 vital steps to ensure a successful refractory installation and a flawless dry out

Installing new refractory materials is a necessary part of periodic furnace maintenance. But extended downtime and installation errors can be a major financial and operational headache.

Furnace refractory basics

During initial dry out, the powerful effects of superheated steam can cause explosive, devastating consequences to freshly cured refractory material. Removing moisture from castables and precast shapes is a critical part of the installation. Pressures on the production department to minimize downtime can lead to rushed dry-out procedures. Usually, these ill-advised shortcuts have the opposite effect and quickly compound delays by causing thermal damage to refractory linings, sometimes leading to injuries.

Dry outs fail due to imprecise management of water extraction from refractory linings. At the boiling point of water, the pressure of steam is less than 1 psi. However, at 700 F, saturated steam reaches 3,000 psi, and possesses enough energy to destroy the most resilient refractories (see Figure 1). Too much heat, rapid ramp-ups, vapor lock, poor curing and surplus water can contribute to potentially hazardous situations. Here are 12 preventive factors to manage for dry-out safety and success:



Figure 1: At 700 F, steam can exert 3,000 psi pressure. All images courtesy: Plibrico Company

1. Hot spots and flame impingement

Ensure that your burner flame is centered accurately. The direction of flame in the vessel must promote equal heating of all the refractory surfaces. A flame that impinges on a single area of surface will quickly create a hot spot forcing an accelerated expansion of water vapor in that area, resulting in thermal spalling.

2. Temperature spikes are destructive

Insulation of the hot face is ill-advised. Attempting to cover green castable with an insulating blanket can lead to temperature spiking when the blanket is removed, breaks or falls off. At a hot face, temperature of only 550 F, insulation removal exposes the lining surface to an extreme temperature increase that will result in dangerous steam pressure.

3. Thermocouple placement and monitoring

Pay attention to the locations and readings of your thermocouples. Watching only the coldest location will allow the hottest area of your vessel to heat too quickly in the dry-out schedule. Conversely, monitoring only the hottest area will allow the colder area to retain too much water (see Figure 2).

4. Air temperature versus surface temperature

Thermocouples should report surface temperature. Air temperatures typically are 50 F to 100 F hotter,



Figure 2: Thermocouples need to be monitored at both hot and cold areas to measure temperature consistency.

and are not appropriate for guiding a dry-out schedule. The initial hold period typically is designed to allow burnout fibers to melt and create the necessary permeability. If the actual surface temperature is lower than specified during the initial hold, permeability is not created, leading to increased steam pressure in the next ramp-up period.

5. Field versus precast dry-out schedule

A field dry-out schedule is normally specified for single-sided heating. This type of dry-out leads to water migration that takes place in two stages. In stage one, most of the water in the lining moves toward the heat, since this is the path of least resistance. During stage two, most of the water moves away from the heat, and toward the furnace shell. Field dry outs are faster schedules than precast dry outs, where the pieces are heated from all sides simultaneously. During precast dry outs, water migrates to the center of the piece and takes longer to escape. Field dry-out schedules should never be used for drying precast shapes, since this can lead to spalling, even at temperatures of 550 F or less.



6. Venting and air circulation

Proper venting is required to allow the escape of water vapor from the furnace during dry out. Without vents, and free air circulation, humidity inside the furnace rapidly reaches 100%, making it difficult to remove additional water from the lining at the expected rate. As temperatures continue to rise and excess water remains in the lining, steam spalling becomes increasingly likely.

7. Avoid surface coating

An impermeable coating on the refractory surface will prevent the stage one escape of water from the lining, and pressure will increase as superheated steam builds up behind the impermeable layer. Often the net result is a surface spall that damages or destroys the hot face layer.

8. Weep holes

As stage two water migration occurs, weep holes are necessary to allow the water to pass through the furnace shell. It is critical to check that all weep holes are cleared of obstructions to allow clear paths for the water to exit the furnace and provide a release valve for buildup of steam pressure.

9. Cold weather curing is risky

During the room-temperature curing process, simple hydrates form a needle-like morphology. These structures promote permeability, allowing water and steam to more easily migrate through the refractory to escape (see Figure 4). Curing in low temperatures (below 59 F) allows the formation of hydrates, which are not needle-like. Instead, these low temperature hydrates are more like a low-permeability gel, which tends to prevent water from passing through (see Figure 5). Without the ability to move through the material as expected, water vapor can quickly build up and create localized areas of dangerous pressure, even when carefully following a recommended dry out schedule.

Figure 3: Precast refractory requires longer bake-out schedules to release all water vapor.

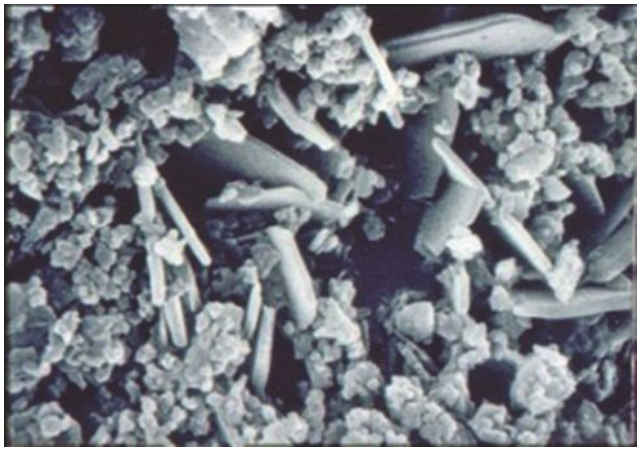


Figure 4: Normal hydrate structures create permeability.

furnace dry out. Nobody likes nonproductive downtime, but close adherence to installation instructions, cure times and dry-out schedules is the best way to avoid multiplying downtimes with an explosion during dry out. PE

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10. Cure time is critical

Every dry out is a battle between the steam pressure produced within the lining and the strength of the lining to resist that pressure. If the pressure within the lining exceeds the strength of the lining, an explosive spall will result. Recommended dry-out schedules assume a 24-hour equivalent curing time at room temperature. If cure time is reduced, expect strength to be reduced, and explosive spalling to become more likely.

11. Water removal is time and material dependent

An important goal during stage one of the dry out is to create permeability in the refractory at lower temperatures to enable water to escape. By quickly ramping up dry-out temperatures in an attempt to save downtime, permeability is diminished, and at higher temperatures, (more than 500 F), steam pressure rises more quickly (see Figure 6). Again, refractory composition drives curing and dry-out schedules, and as a rule, the faster temperatures rise beyond specification, the higher the risk of failure.

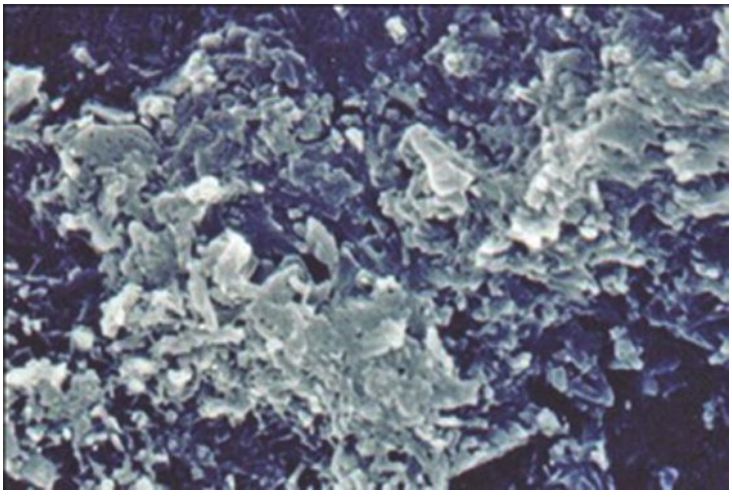


Figure 5: Cold weather curing distorts hydrates, preventing permeability.

12. Refractory strength is a function of water addition

A simple 1% excess of water beyond the recommended water addition will reduce refractory strength by as much as 20%. Exceeding the recommended water addition by 1.5% cuts strength 25% to 40%. This drastically reduces the ability of the refractory to withstand the steam pressures generated during dry out.

Looking ahead

Careful attention to detail during refractory installation is the key to a successful



Figure 6: Precast shapes spall at 550 F.