Important Considerations for Refractory Dryouts, Startups & Shutdowns

By

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Abstract

Significant changes in temperature can have catastrophic effects on refractory systems. The term “significant”, however, is highly dependent upon the particulars of the lining system and the materials utilized.

In today’s business climate with the strong push to get units back into service as a result of budget constraints and economic drivers, oftentimes little consideration is given to furnace heat up rates that will prevent damage to the refractory linings. This has sometimes led to refractory failure before reaching normal operating conditions or premature deterioration of lining systems leading to unexpected, time consuming repairs required before or during scheduled outages. One cannot fault a calculated risk, for business reasons, to get a unit back into production, but many times these decisions are made by those not even aware they are exposing a piece of equipment to any abnormal risk.

In the first part of this paper we will present information to better explain when there is a need for a refractory dryout and the critical aspects that affect and determine the dryout schedule; we will discuss the differences between two common types of dryout schedules; and we will review the thermal and mechanical issues involved in a normal startup/shutdown outside of any dryout needs.

In the second part of the paper we will address some of the real world issues or problems involved in executing the required dryout/startup/shutdown schedules with different equipment configurations. After a discussion of the various concerns and equipment restrictions, we will consider some techniques that have been utilized in operating plants to allow for better dryout/startup/shutdown temperature control in order to reduce damage to the refractory lining system.

Refractory Discussion

Refractory dryout is the controlled process of applying heat to a refractory lining to remove water from the lining system without causing damage to the refractory materials. Whenever linings are heated up from ambient temperatures, whether it be the initial heatup after a new lining installation or a subsequent heatup of an existing lining after an outage, heatup procedures, ramp rates and hold points should always be thoroughly discussed and agreed upon by the owner, lining designer, lining installer, refractory manufacturer and dryout subcontractor.

This paper is intended to present general information to help industry operation personnel better understand the critical points and concerns of a typical dryout without delving into all of the possible bond phases and chemical water release points that can be identified by refractory ceramic engineers. We will focus on the conventional, cement based castables as their use is most common in sulfur recovery units. Conventional castable materials cover a very wide range of products; from very lightweight (25 lb/ft^3) to very dense (170 lb/ft^3), with numerous possibilities for the cement binders and product mixes.

Please note that many of the figures stated in this paper represent only average or order of magnitude numbers in order to not get bogged down in countless options and variables that would be of more importance to specific materials and installation parameters associated with an actual project.

Definitions

To clarify some misused or misunderstood terminology in the industry, let us start with some definitions:

- Curing – The cement bonding process that takes place within the castable material (cement + aggregate) after the dry components are mixed with water and either poured or gunited into place. The water and cement then react to form a strong bond with the aggregate at ambient temperatures, normally occurring in the first 24-48 hours after placement.
- Dryout - The initial application of heat under controlled rates to safely remove retained free and chemically combined water from the refractory lining after completion of the curing process.
- Free or Physical Water – Excess water remaining in the castable material pores after installation. This is the portion of the water that does not react with the cement and will boil off at normal temperatures as free water.
- Chemically Combined Water – Water that is tied up in the cement hydrate phases (bond structure). This water does not boil off at 212ºF as does free water, but is released in stages at elevated temperatures.

Water Ratios (Free vs. Chemical)

Let us begin by better understanding free/chemical water ratios in castables. On average, conventional castable products require about 25% of the total water added to the dry castable mixture to hydrate the cement in order to form the expected bond structure. As already noted, this is defined as the chemically combined water. The other 75% of the water added is required to facilitate material placement (flowability, compaction and de-airing). The type of product, type of cement and other additives in a castable mix can affect these percentages. One significant factor, often overlooked, that can impact the amount of chemically combined water contained within the castable is the ambient temperature at which the curing process takes place. Low curing temperatures (below manufacturer's suggested guidelines) can result in the formation of certain gel (bond) phases that can complicate a normal dryout schedule. To further explain: In a typical castable dryout, the free water first boils off when temperatures reach 212°F. The boiling off of this free water creates porosity within the matrix. The more free water, the higher the porosity of the castable material. It is this porosity which facilitates the removal of the chemically combined water that is released at higher temperatures. Some gel phases result in a higher percentage of water than normal being tied up in the cement (chemically combined water). The net effect is that more water has to be driven off at higher temperatures and this water also has to be forced thru a bond matrix that is less permeable than normal for the same product. The bottom line then is that linings cured at less than ideal temperatures will require a longer than normal dryout schedule with reduced ramp rates and additional or longer hold points. This can actually be a significant increase in total dryout schedule time.

The refractory manufacturer should therefore always be consulted as to the proper refractory placement and curing temperatures in advance of the lining installation so that environmental controls can be initiated if necessary. If linings are installed or cured at lower than the recommended limits, this information should also be relayed to the material manufacturer when requesting the dryout schedule recommendation.

Importance of Permeability

	Type of Refractory Castable				
Type Materal	Low Cement	Dense Conventional	Medium Weight	Insulating	Ultra-light Insulating
Density (lb/ft^3)	140-180	130-170	100-130	30-100	20-30
Water Content %	4-8	8-12	15-18	20-40	40+
Permeability (after air cure)	Least	→	→	→	Most
Water release issues	More difficult	→	→	→	Less difficult

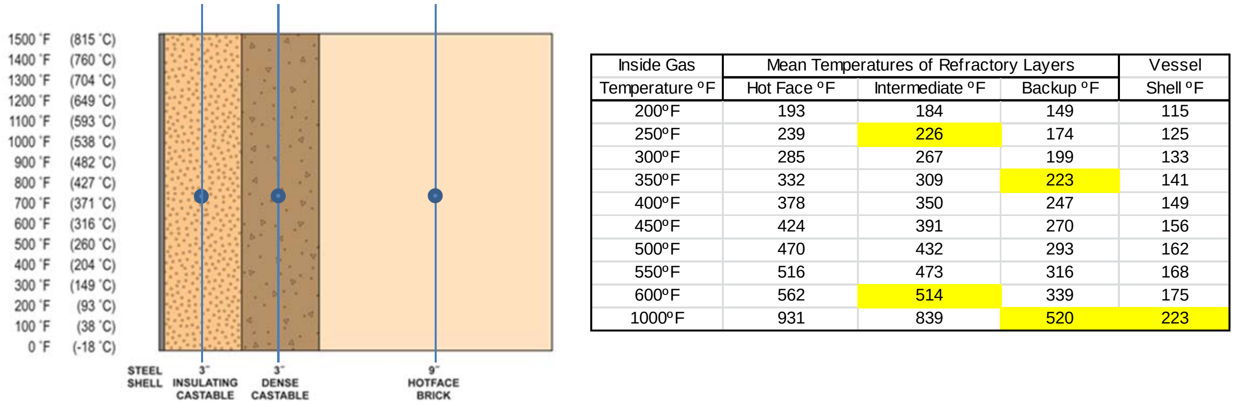
The simple table above helps to illustrate the importance of permeability in refractory dryouts. In general, decreasing density relates to increased water content and therefore typically higher permeability. Realizing that the volume difference from water to steam is 1600X, any restriction of the water/steam removal from the lining will build pressure within the lining system.

To consider the extremes, a completely permeable lining will prevent (steam) pressure buildup with the result that there would be no dryout concerns, as steam spalling cannot occur without the formation of steam pressure regardless of the amount of water. At the opposite extreme, a completely impermeable material will not allow any steam to pass thru; the integrity of the lining being limited by its ability to contain the buildup of steam pressure within. In an actual lining, even a little water highly restricted can develop pressures that exceed the strength of the refractory material resulting in significant damage from explosive spalling. Permeability of the lining is therefore a significant key to the criticality of the dryout.

Understanding Thermal Profiles

Everyone realizes that water boils at 212°F. Chemically combined water is released at various elevated temperatures, sometimes as high as 900°F, depending on the types of cement phases formed during the curing process. For many castable materials, a common critical water release point (due to the volume of chemical water being released) occurs within a range of 400 -600°F. By thinking through the entire process, one begins to realize the complexity of the problem. Most thermal measurements are taken at the hot face of the refractory. The chemical water is released at progressively greater depths within the lining as the lining is heated up. When castable materials are used as backup linings in thermal reactors, the water commonly extends very deep in the lining going all the way to the steel shell and has to be driven not only through castable but also the hot face brick lining. The bricks utilized in reaction furnaces typically have very low permeability. Dryout schedules must account for the constantly changing thermal profile thru the lining to assure temperatures do not ramp too fast through a critical temperature range deep inside the lining and that proper time is allowed for the steam to work its way through and out of the lining without increasing steam pressure greater than the lining can contain. Further complicating these calculations is that the free water still in the pores of the unfired material affects it's thermal conductivity.

To illustrate some of the dynamics, one of the projects we are currently involved in is utilizing a three component lining. The specified lining includes 9" 90% brick on the hotface; a 3" intermediate layer of of a high temperature, dense castable; and 3" of insulating castable against the shell. This is a fairly large reaction furnace in which this design results in a total of 2500 gallons of water added to the two layers of castable behind the dense, low porosity hotface brick. The graphic and table below illustrate the effect of the thermal profile through this lining as various water release points are obtained at different points inside the lining. The following calculations are for illustration only, are based upon steady state and utilize thermal conductivity factors of fired samples. An initial dryout is much more dynamic with changing K-factors and transient heat flow as water is driven off and temperatures are increased. For discussion purposes, we are assuming 212ºF for free water release and an average of 500ºF for chemical water release.



Inside Gas	Mean Temperatures of Refractory Layers			Vessel
Temperature ºF	Hot Face ºF	Intermediate ºF	Backup ºF	Shell ºF
200ºF	193	184	149	115
250ºF	239	226	174	125
300ºF	285	267	199	133
350ºF	332	309	223	141
400ºF	378	350	247	149
450ºF	424	391	270	156
500ºF	470	432	293	162
550ºF	516	473	316	168
600ºF	562	514	339	175
1000ºF	931	839	520	223

Thermal Profile Charts

As one can see in the Thermal Profile Chart above, this lining will have both free and chemically combined water being released at the same time at different depths within the lining. Critical dryouts such as these may use external and/or buried thermocouples to evaluate and better understand what is going on within the lining. As mentioned earlier, as water is removed from the lining during the dryout the insulating properties of the material changes. This can be monitored by tracking changes in shell temperature particularly during an internal hold period.

Complex Linings

Complex linings include different lining configurations within the same unit. This can mean a change in material quality and/or thicknesses. Thickness changes can be as important as material changes due to the changes in water volume and the thermal profile through the different lining thicknesses resulting in different water release points at the different measured hotface temperatures. All of these scenarios need to be considered in determining a final dryout schedule that accounts for all critical points in the entire lining system to be fired.

Essential Parties

Projects are structured differently from job to job. From major new construction to minor repairs; from the design, supply and installation of the lining split between 2 or three different companies or all combined into a single contract. Assuming a new construction project with newly designed linings, we would recommend the following structure in regard to the dryout plan and responsibility.

1. Refractory Designer – Must provide the refractory material manufacturer with essential information such as various lining compositions, material thicknesses and maximum dryout temperature for the lining.
2. Refractory Material Manufacturer – Responsible for determining the appropriate dryout schedule based on information provided by the Refractory Designer and adjusted based upon information provided by the Refractory Installer for installations outside the manufacturer's guidelines (water content/quality, ambient cure conditions, etc.).
3. Refractory Installer or Designer – Originates the dryout plan and secures owner's approval of same. Communicates with owner or equipment designer regarding heating temperatures, exhaust points, protection of equipment internals from excessive heat, etc. If the refractory installer is responsible for the dryout, they assist the dryout subcontractor with equipment setup and installation of any thermal bulkheads.
4. Dryout Subcontractor – Executes the dryout plan. Records the thermocouple readings.

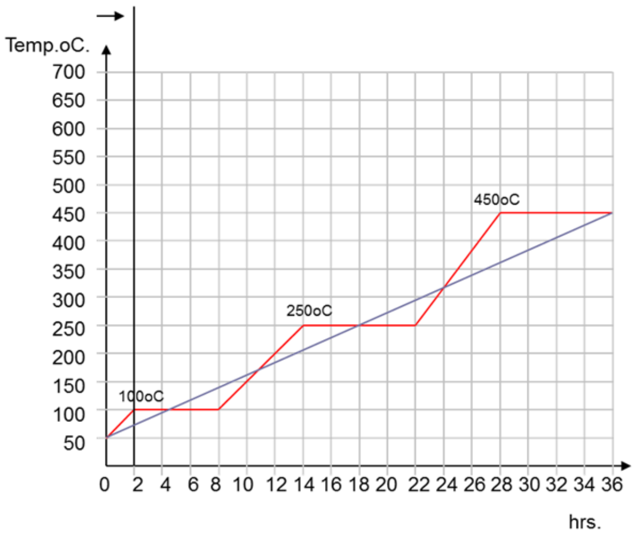
Subsequent startups/shutdowns

While technically not considered a dryout (assuming no new moisture has been added to the existing lining), subsequent startups/shutdowns can still have a significant impact on the refractory and its performance. The majority of units are constructed with brick hotface linings that have high reversible thermal expansion rates at normal operating temperatures. The steel vessel shells operate at a much lower temperature, with a resulting lower overall expansion than the brick lining. As a result, there is an "interference fit" between the lining and shell that is created during heatup and normal operation of the unit. This interference fit is desirable in preserving the integrity and stability of the lining that needs to be in compression against the steel shell. In steady state conditions, the thermal expansion of the steel shell helps to compensate for the greater expansion of the lining. However, heatups from ambient result in a transient condition as it takes some time for the lining temperature gradient to reach equilibrium. Too rapid a heatup can result in full brick expansion before the heat soaks thru to the shell to offset the generated hoop stresses. This can result in internal stresses within the brick exceeding the compressive strength of the brick (at temperature) and cause brick to crack or spall; the beginnings of brick failure. Conversely, a forced or too rapid a cooldown can cause the hotface of the brick to contract too quickly, before the shell cools off. This can also result in thermal spalling of the brick hotface as well as loose brick rings and some bricks (or larger sections of brick) slipping down out of position. It is Thorpe's general recommendation that in order to maximize lining life, disregarding the consequence of any refractory repairs or the introduction of water from any source (repairs, rain water, tube leak, etc.), ramp rates of 100°F – 125°F per hour should not be exceeded for startups and shutdowns that take place after the initial dryout.

Dryout Curves

First of all, there does not exist a “Holy Grail” (one schedule fits all) of dryout schedules… at least not one that people would want to use. All schedules should be developed for the specific lining/unit to be dried out. For castable linings, the refractory industry has historically utilized what is characterized as a ramp and hold regimen. Temperatures are ramped up at not to exceed rates (say 25°F - 75°F/hour) and then held at various hold points for specific periods of time.

One major dryout company, Hotwork Combustion Services, promotes a slow, continuous ramp-rate dryout schedule. While Thorpe does not have the in-depth knowledge or testing equipment to verify their arguments, there is a logic to what they say that is interesting. It is well known that as heat is driven into a lining that steam formation builds pressure within the lining. The slower the ramp rate the more time steam is allowed to move out of the lining, decreasing the pressure inside the lining. This is the goal of a dryout, to remove the water without creating excessive steam pressure buildup. In simple terms, Hotwork’s philosophy can be demonstrated by considering a conventional type ramp and hold schedule as shown in the Thermal Dryout Graph below. The idea is to draw a straight line between the starting and end points of the schedule. Note that this does not result in a shortening of the overall dryout duration, but it does eliminate the fast ramp rates that would tend to drive heat faster into the lining. The time vs temperature dryout chart to the right shows the two sample schedules overlaid on top of each other. The ramp and hold schedule is showing ramp rates of 25°F/hr. where the straight line curve calculates to a continuous 12.5°F/hr. Hotwork’s full presentation illustrates the changes in internal steam pressure at various points throughout these overlaid dryout schedules which shows reduced peak steam pressure at all points for the straight line dryout schedule. While we can understand there could be specific instances where one approach may be needed over the other, this would be an interesting topic for those with the full knowledge and equipment capabilities to expound on.



Thermal Dryout Graph
Ramp and Hold vs. Straight Line

REAL WORLD SCENARIOS

Refractory Dryout Challenges

Plant owner/operators face numerous challenges with respect to performing a proper refractory dryout during unit commissioning and after maintenance activities. Unit configuration and environmental considerations do play an important part in planning for a proper dryout, however, these hurdles are often overcome (sometimes easily and sometimes not so easily) with careful planning. Perhaps the biggest challenges facing plant owner/operators when considering refractory dryouts are time and budgetary constraints. For new unit commissioning, or for complete refractory system replacement of an SRU Reaction Furnace, advanced planning for proper time and budgetary allowances is essential. However, due to inexperience and manpower level constraints facing the Engineering and Construction companies and the owner/operator companies, these critical items may be missed in the project planning until very close to the intended startup date. Here we will review some recent examples of refractory dryout plans that went very well, and others that perhaps did not give the intended results.

New SRU Reaction Furnace Commissioning

A new SRU reaction furnace (RF) and waste heat boiler (WHB) was commissioned at a gulf Coast refinery in the last half of 2003. The Engineering and Construction Company (E&C), refractory installer, refractory material supplier and the owner/operator developed a very well thought out and detailed dryout plan for the RF and WHB. Please see **Table 1**. The dryout procedure was considered a critical portion of the commissioning of this unit since the RF refractory design was comprised of a two layer back-up castable with a hot face brick configuration. Review of the high performance burner early in the engineering process gave the impression that the main burner could be used for the dryout and there was no plan in the commissioning to use a third party burner/contactor to aide in the work.

TABLE 1
Refractory Dryout Plan As Planned By Project Group

Temperature	Duration
250°F – Hold	12 Hours
Increase to 500°F at 50°F/Hr	5 Hours
500°F – Hold	12 Hours
Increase to 1000°F at 50°F/Hr	10 Hours
1000°F – Hold	12 Hours or Until Complete
Increase to 1500°F at 50°F/Hr	10 Hours
1500°F – Hold	12 Hours
Increase to 2400°F at 50°F/Hr	18 Hours
2400°F – Hold	12 Hours

Just prior to the commencement of commissioning activities, it was discovered that the main burner was not able to accomplish the dryout as planned. Investigation showed that 30% excess air was the maximum amount that could be added to maintain stable flame. Tempering steam and nitrogen addition at maximum rates were also discovered to be inadequate to achieve the desired dryout procedure. Finally, it was discovered that the burner turndown on Natural Gas was only about 50% versus the 10% that was assumed during the development of the dryout procedure. Therefore, the E&C and owner/operator personnel onsite had to quickly devise a modified dryout plan that would fit within the limitations of the installed equipment. Please see **Table 2**.

TABLE 2
Refractory Dryout Plan As Modified By Project Group During Commissioning

Temperature	Duration
500°F - Hold	12 Hours (Pilot)
700°F – Hold	12 Hours (Pilot)
1400°F - Hold	24 Hours (Main Burner)

A comparison of the initial dryout plan versus the modified plan shows that this was a less than ideal situation, based on the complex RF refractory design in a newly commissioned unit. Please see **Figure 1**. The unit did make a three year run before being brought down for scheduled maintenance and inspection. During the 2006 inspection, sagging and spalling of the brick at the burner throat was discovered; only minor repairs were made due to time constraints. These repairs, made in 2006, failed in the spring of 2009 resulting in a burn-through of the RF shell. The failure investigation determined that the refractory design was the main cause. It was noted that the 2003 dryout did not meet the original recommendations identified. After these major refractory repairs were completed, the unit was then restarted *after* completing a proper dryout using a third party burner/contactor. Please see **Figure 2**. A follow-up inspection was completed in summer 2011 and the refractory repair was found to be in excellent condition.

FIGURE 1
Planned Versus Modified Dryout
Due To Equipment Limitations

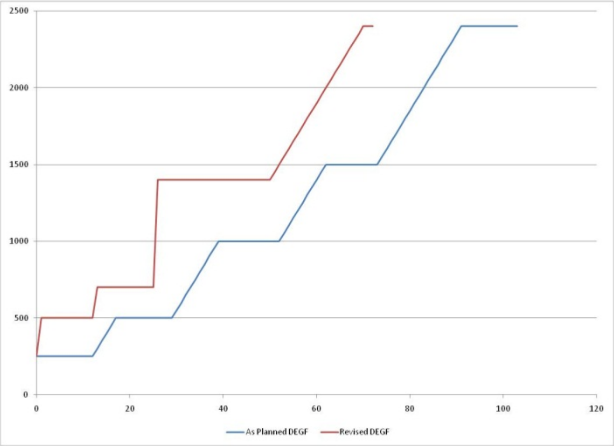
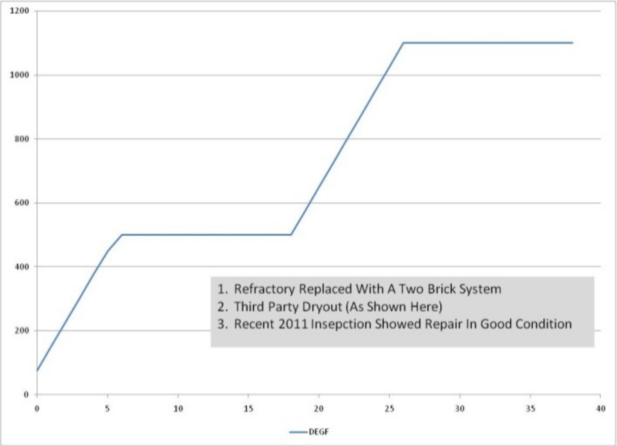


FIGURE 2
Subsequent Dryout With
Third Party Burner



1. Refractory Replaced With A Two Brick System
2. Third Party Dryout (As Shown Here)
3. Recent 2011 Insepction Showed Repair In Good Condition

New SRU WHB Tube-Sheet Protection System Commissioning

A new WHB Tube-Sheet protection system was installed at a Gulf Cast refinery during a scheduled unit shut-down for routine maintenance and inspection. This unit is of an older vintage without a high performance main burner and with only a medium pressure WHB. The existing Tube-Sheet (TS) protection system comprised of non-headed ferrules surrounded with castable material. Modern headed ceramic ferrule protection systems are not applicable to this TS protection system due to the pitch and layout of the tubes. After the installation of the new TS protection system, the plan was to start the unit up using the main burner to dry out the castable of the TS protection system. The burner had limited turndown capability and the results of the dryout procedure may be found in **Figure 3** below.

Figure 3 shows that after lighting and during the period of stabilizing the main burner operation, the rate of temperature rise as measured in the RF was approximately 1140°F/hr. **Figure 3** also shows that during the attempted dryout procedure that the overall temperature rate rise was approximately 300°F. The unit began normal operation with the introduction of feed shortly after the dryout and other start-up procedures were completed.

Approximately two months after this start-up, the unit was brought down to repair some items unrelated to the RF and the TS protection system. Due to issues encountered when shutting the unit down, a decision was made to inspect the main burner and RF. During that inspection a water line (or unexpected "staining") was noted on the TS protection system and the RF was entered for inspection. Inspection of the TS protection system revealed that the castable had separated from the tube-sheet by one to two inches in most places; the ferrules were cracked and could be spun and removed freely by hand. The TS protection system was replaced in the same manner as two months prior with the exception that the TS protection system dryout would be done using a third party burner/contractor. **Figure 4** shows the measured results during the third party dryout. This unit was recently inspected after three years in operation and while the TS protection system did not look perfect, it was intact, protecting the equipment as intended.

FIGURE 3
Dryout Using Main
Burner

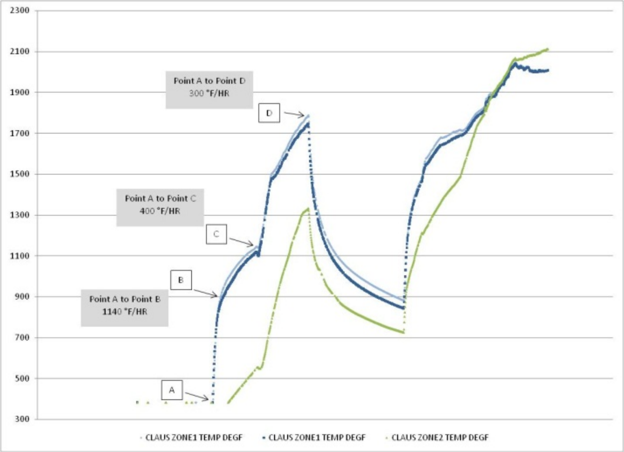
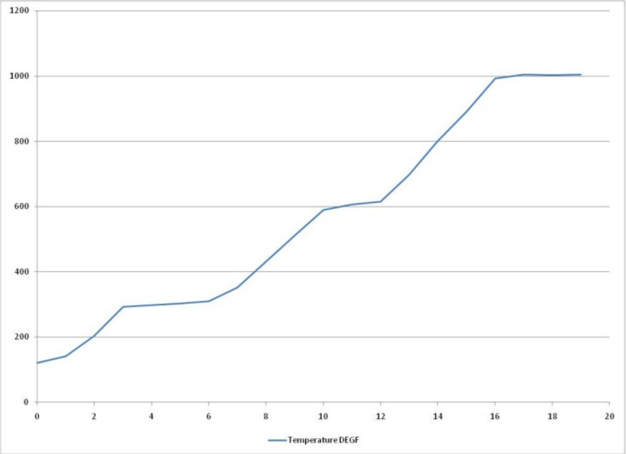


FIGURE 4
Dryout Using Third Party
Burner/Contactor



SRU Start-Up After Refractory Repairs During Routine Maintenance

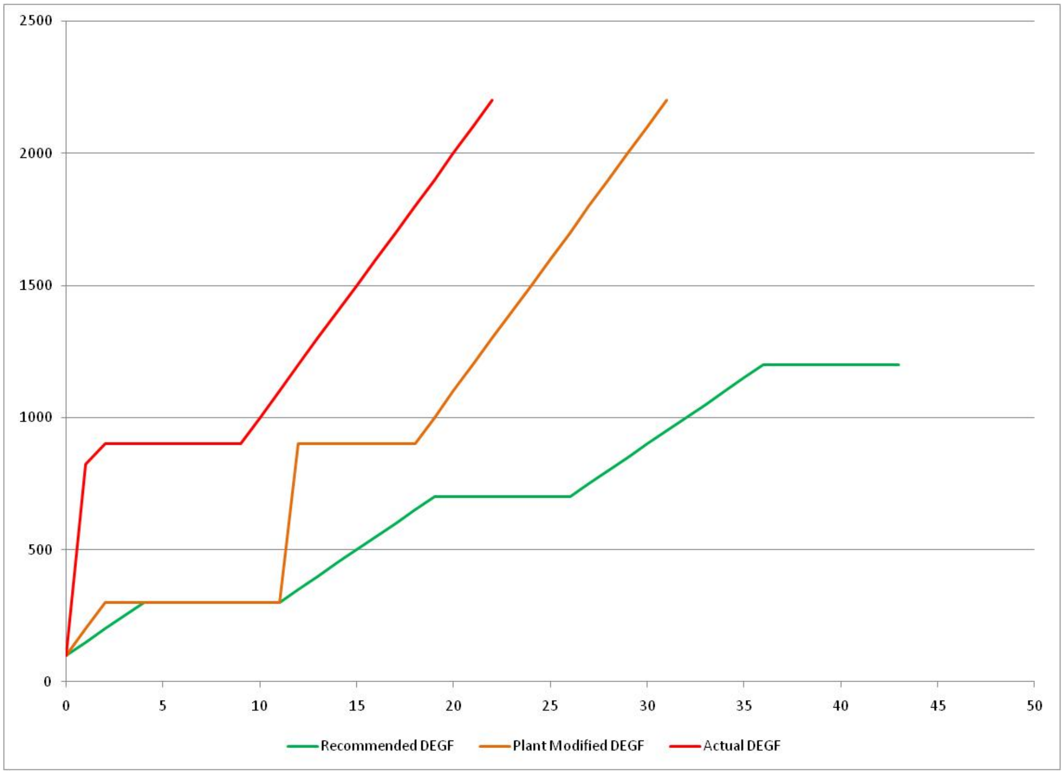
Earlier this year a unit was brought down for scheduled maintenance activities during which time repairs were made to the refractory system in the RF. These repairs were planned and encompassed known trouble areas as well as areas where nozzle modifications were performed for temperature indication reliability. This particular refractory protection system consisted of seven inches of castable behind the hot face brick.

Based on manufacturers and installers recommendations a dry out schedule was then created for the start-up. See **Figure 5** below. Due to the limited nature of the repairs, the owner/operator equipment integrity personnel decided to develop an alternate dryout schedule that was not as comprehensive, also shown in **Figure 5**. The actual dryout was performed using the main burner and the equipment was not able to deliver the intended results of the modified dryout schedule. Again, please see **Figure 5**.

Since the unit was started up, it has been noticed that the E^2T temperature indication has been steadily decreasing. This has led to continuous temperature monitoring for fear that refractory lining damage may have resulted from not following a proper dryout schedule.

FIGURE 5

Dryout Schedule Recommended/Modified/Actual



Practical Refractory Dryout Strategies

As illustrated in the three examples above, refractory dryouts using the main burner have not been able to deliver the required results of a proper dryout schedule. The results of an improper dryout have led to refractory failures, equipment damage and increased monitoring requirements.

In order to contrast the effects of a controlled vs. non-controlled dryout, **Figure 6** shows Reaction Furnace temperatures during a proper refractory dryout and subsequent controlled start-up using the main burner at burner minimums until about 1000°F.

Other than schedule and cost considerations, owner/operators often cite the routing of the exhaust gas as another hurdle in utilizing a third party contractor for dryouts . This hurdle is a function of equipment limitations and local HSSE and regulatory considerations. With careful planning however, dryout burner exhaust gas may be safely routed to an appropriate location such as the tail gas incinerator, dedicated vent stack connection downstream of the WHB or through a stack connection on the outlet of the first pass of a two pass WHB.

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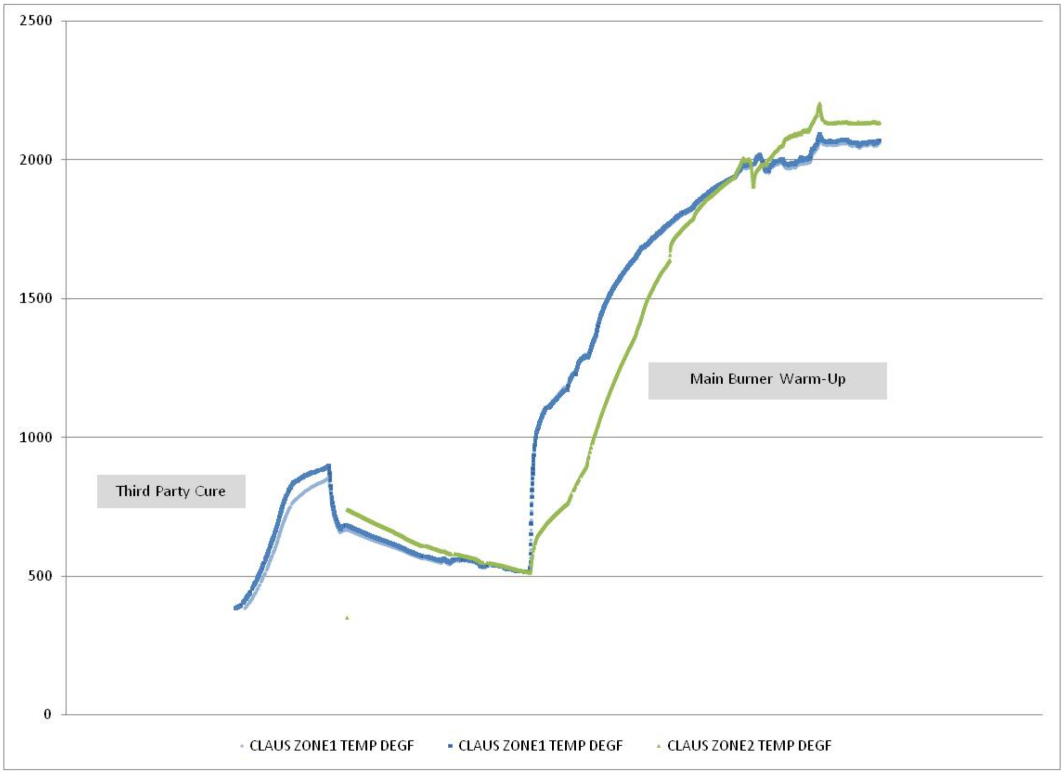
FIGURE 6

Dryout Schedule Followed And Main Burner Warm-Up



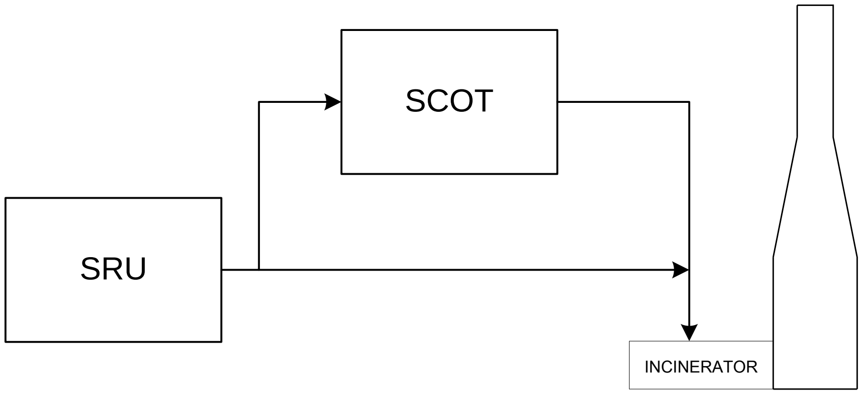
Dryout Exhaust Routed To Incinerator

In some locations, environmental regulations dictate that the exhaust from the dryout procedure be routed to the incinerator. Please see **Figure 7**. From an HSSE standpoint this is a preferred option. A typical line-up or procedure would be as follows;

1. Main Burner is already installed on the RF and the dryout burner is mounted on the manway of the RF. (Normally, the dryout burner is inserted thru the mainburner opening and gases are exhausted thru the WHB tubesheet. This results in uniform heating of the entire thermal reactor which is essential in the case of a total reline.)
2. Blinds are pulled and the Claus plant is lined up directly to the incinerator, bypassing the SCOT or Tail Gas Treating Unit.
3. Nitrogen is added to the main burner for protection.
4. The WHB has boiler feed water routed as normal on Level Control.
5. Nitrogen is available for introduction at the inlet of each converter.
6. Free oxygen will always exist with third party dryout contractors, since the burners need to burn large amounts of excess air in order to achieve the required temperature uniformity. When temperatures exceed 250°F in the process piping elemental sulfur may begin to melt, contributing to incinerator SO_2 emissions. Nitrogen addition upstream of temperature increases in the process reduces emissions and protects the equipment.

FIGURE 7

General Schematic



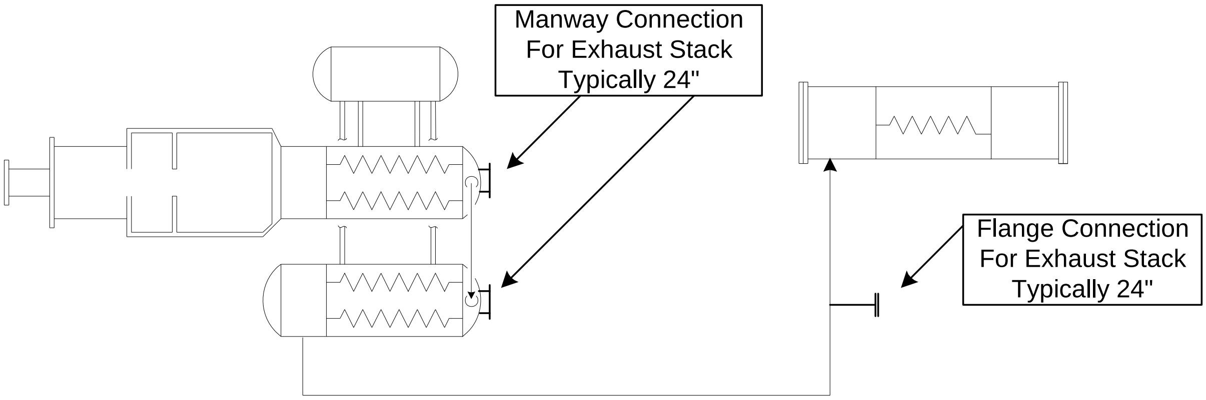
Dryout Exhaust Routed To A Temporary Stack

When local regulations allow for it, an acceptable location to route dryout exhaust gas from an HSSE standpoint is somewhere down stream of the WHB or between the two passes of the WHB. This will ensure that the exhaust gas is as cool as possible prior to venting and unit monitoring may be avoided as referenced above when routing to the incinerator. Common locations to attach the temporary stack to the SRU are the following;

1. Downstream of the WHB and upstream of the first sulfur condenser.
    a. In some new unit designs, a flanged connection is located in the process piping to allow for connection to a temporary stack. This connection is often 24 inches which is a typical manway dimension for convenience of temporary stack utilization for multiple units. This connection is rather convenient with thought given to placement of the flange to account for ongoing maintenance activities. Please see **Figure 8**.
2. Manway connection at the outlet of the WHB.
    a. This would be most common for single pass, or two pass – two shell design WHBs. This connection is often 24 inches and consideration will have to be given for ongoing maintenance activities.
3. Manway connection at the outlet of the first pass of the WHB.
    a. This would of course be most common for two pass – single shell WHB design.

FIGURE 8

Dryout Exhaust Stack Typical Locations



Dryout Using Third Party – NO BURNER

From a logistics and HSSE standpoint, there is always the desire to minimize the use of fired equipment for non-routine items. As a result, alternatives to using a temporary, third party burner for proper refractory dryout are always being sought out. Along with the required safety checks needed for a temporary burner, the desire to minimize schedule and cost impacts (planned or unplanned) is a strong motivator. Two recent alternatives to using a temporary burner have been used for minor and major repairs to refractory protection systems. One owner/operator has had significant issues with RF refractory lining reliability using the main burner for dryout. They now do the majority or entire dryout using ceramic heaters, and well positioned thermocouples. This does take them much more time during scheduled maintenance outages; however, the reliability has been much better. For minor repairs, the following scheme has been recently applied:

1. Tube Sheet Protection System Replacement
   An owner/operator has an SRU with a non-headed ferrule and castable tube sheet protection system for the WHB. This protection system has been considered reliable in the past, *provided* that dryout is performed by a third party burner/contractor. In an effort to reduce the time associated with start-up activities following a scheduled repair/inspection window, alternatives to the previous design and procedure were sought. (Please see **Figure 9**.) Following are highlights of the modifications:
   a. Non-headed ferruless were replaced by square head type ferrules.
   b. Stress relieving heat coil blankets were used to cure the tube sheet protection system
   c. There was a forty (40) hour reduction in the normal start-up planning for this unit (when compared to previous start-ups.
   d. No follow-up inspection has been completed; however plant operation monitoring shows no areas of concern.

FIGURE 9

Dryout – Alternate Methods

Original Tube Sheet Protection System

Stress Relieving Heat Coil Blanket

New Tube Sheet Protection System

Start-Up and Shut- Down Considerations

Start-Up and Shut-Down heating and cooling rates are also a critical item in the protection of the refractory lining system for the SRU. In general, heatup and cool down rates are specified as 100°F/hr. so that thermal stresses are reduced. Due to the fact that it is often difficult to control to these rates utilizing the main burner, certain steps may be taken to control process close to the specified schedule.

1. Tempering Steam – One method used to control heatup and cool down rates is the introduction of steam.
2. Nitrogen – Perhaps the most essential item used to control heat up and cool down rates. Nitrogen from the main plant supply is adequate as long as the logistics are in place to ensure that the supply will meet the demand. Nitrogen from trucks is most often the preferred method due to the ability to control the nitrogen supply temperature as well as the fact that the unit operations directly control the logistics and supply of the trucks.

Conclusions

Today's operating environment exerts tremendous stress onto plant decision makers to reduce costs, minimize downtime and to get units back into operation. Many times these decision makers do not have as much unit specific history or experienced advisors as in the past and therefore may not be aware of the critical issues involved in removing water from refractories nor the limitations of their equipment to perform these functions. Additional challenges are imposed by different equipment configurations and environmental restrictions. And let's not forget that SRUs are not the high visibility, profit deriving units as other higher profile equipment in a refinery. All of these reasons and more often lead to decisions made with incomplete information, or unknown risk taking, resulting in further disruptions in unit startups from refractory failures. Too often this affects those "profit deriving units" with reduced production and severe cost impacts while these "unexpected" repairs are performed a second time. We hope this paper provides these decision makers, and advisors, insight into these challenges to assist them or to aleast make them aware of the pitfalls and the risks in overlooking these complex issues. Following a proper refractory dryout schedule is critical to the reliability of the refractory lining system and ultimately the overall reliability of the SRU and therefore, other associated equipment throughout a refinery.

References

1. "Dryout of Refractory Castables" by Jeffrey E. Bogan, ANH Refractories Company, West Mifflin, Pennsylvania, USA. Presented at the American Ceramic Society St. Louis section meeting.

2. "Hotwork Services for the Hydrocarbon Processing Industry" Power Point Presentation (2008) by Hotwork Combustion Services in Lexington, Kentucky (www.Hotwork.com).