Hotwork
COMBUSTION SERVICES

REFRACTORY DRYOUT

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ABSTRACT

As monolithic refractory products have become more technically sophisticated and their usage increased, the end user/consumer is more often requiring a turnkey project that includes the supply of materials, installation and dryout in one package. It is therefore imperative that all parties work closely together to ensure a proper dryout, which ultimately maximizes the performance of the refractory lining in the application for which it was designed.

THE INDUSTRY HAS COME A LONG WAY SINCE HOTWORK INTRODUCED CONTRACT DRYOUTS AND FOR THAT MATTER, HIGH VELOCITY BURNERS, TO THE WESTERN HEMISPHERE OVER 35 YEARS AGO. QUITE A NUMBER OF CHANGES HAVE OCCURRED IN THE REFRACTORY COMMUNITY OVER THOSE YEARS:

1. There has been significant improvements in castable and plastic refractories through the selection of better raw materials, improved particle sizing, additives, improved bonding materials and improved manufacturing processes and placement methods. Of note in particular are the advances in low, ultra low and no cement castables.

2. There is indeed more awareness by vendors and owners alike of the importance of proper dryouts or heatups, especially with the new breed of castables.

3. We are proud to have kept up with these technologies. Externally by communicating well with the refractory companies and in participating in society committee activities and other communications, internally through training, innovation, and continual safety and equipment upgrading.

FIRST, WE WOULD LIKE TO SQUARE AWAY A FEW DEFINITIONS AND MISCONCEPTIONS AS TO THE USE OF TERMS AND CONCEPTS WITHIN THE INDUSTRY:

1. **CURING** - This is the period following placement of the material. Upon placement of a conventional castable a hydraulic bond is formed, usually taking 24 hours or less. At this point we cannot help but to add that the environment, in particular temperatures during installation and curing, have a profound influence on the ability to drive off the chemically combined water.

2. **CERAMIC BOND** - As of late comments are being made that it is desirous to go to 850 - 1000 ° C to form a ceramic bond.

   By definition: "a ceramic bond is the mechanical strength developed by a heat treatment which causes the cohesion of adjacent particles", usually meaning fusion. Some MOR curves have exhibited minor increases in this range due to some phase formations, probably feldspatic. Is it a ceramic bond? You also need to consider the actual temperatures achieved for the bulk of the lining. While you have reached these temperatures at the hot face the internal temperatures are not anywhere near that required to form a ceramic bond.

3. **DRYOUT** - The removal of sufficient quantities of moisture from the hot face to warrant it safe to either start the main burners or the process at a later date. It is a dryout, pure and simple! The term "Heat Cure" is being used, but nothing we do not believe we are curing anything.

4. **BAKEOUT** - We feel it is the elevation of temperature in a refractory lining to cause, in particularly plastics, a chemical bond to be formed. This word crept into our vocabulary a few years ago and we accept it as valid.

5. **HEATUP** - To have either of the above initial phases continue so that the unit can be put into operation.

Frankly, the latter mode should be encouraged whenever possible. From a purely ceramic or engineering standpoint a cooldown can be more detrimental to the lining than the heatup. One can clearly demonstrate that all ceramic materials fail under tension only. So, to cool a furnace or anything else down to see if there are any cracks is ludicrous. Of course, you will see cracks after the lining is expanded and then cooled back down again! We were instrumental in changing the practice of cooling aluminum furnaces down for inspection after heatup in the United States market years ago and are now seeing success in other areas of the world in this regard.

A CONTRACT DRYOUT SHOULD BE CONSIDERED IF:

1. The permanent burners do not have the turndown ratio, i.e. the maximum to minimum input fuel rates for a given amount of air, for low temperature control and uniformity.

2. The process itself or heat from another process cannot be controlled at low temperatures. In that regard, we are also being used by companies with processes that have unacceptable emissions during the dryout process at low temperatures.

3. The installed life of uncured plastics, particularly phosbonded plastics is running out and the permanent burners or process is not ready to provide heat.

FOLLOWING ARE ITEMS TO BE CONSIDERED IN PREPARATION FOR A DRYOUT. THEY HAVE NOTHING TO DO WITH THE ACTUAL DRYOUT BUT CAN IMPROVE THE OUTCOME OF THE DRYOUT PROCESS:

1. **TEMPERATURE** - The temperature at which the material is placed is of utmost importance. Observe the refractory supplier's recommended procedure.

2. **BURNER ACCESS** – Plan adequate access that permits proper placement of the temporary dryout burners into the unit so that a proper dryout or heatup can be accomplished. Too often no consideration is given in this regard and we have to compromise by placing burners in locations that do not permit good circulation of the heated media we are supplying and therefore sacrificing uniformity of temperature across the entire surface of the refractory lining.

3. **FORMS** - Forms and particularly wooden forms, must be removed before dryout. The thought process is to leave forms installed to hold the refractory in place until an elevated temperature is reached. Most forms are tightly spaced and tend to cover or insulate the hotface during the initial critical stage of the dryout at low temperatures. The wood or tube material will typically ignite around 230°C creating high, uncontrolled temperatures occasionally in excess of 500° C and which results in spalling of castables and/or the collapsing of plastic linings.

4. **WEEPHOLES** - Although a considerable amount of water is evaporated through the hotface, most will be driven to the cold face and condense at some point near the shell. It will usually collect at the bottom of the furnace or vessel wall. Where possible, drain holes should be provided at the lowest points of the vessel or furnace. After many years of monitoring weep holes placed above these low points, we feel that they are relatively ineffective and we are not therefore proponents of drilling holes all over a furnace or vessel. On many occasions we have performed dryouts on extremely thick refractory linings in pressure vessels where cutting holes in the steelwork was not permitted. The steam always found its way out and the dryouts were completed without any detrimental effect to the refractory lining.

5. **THERMOCOUPLES** - During the refractory installation is the best time to install imbedded thermocouples when interface temperatures of multiple linings need to be known to study profiles in order to gain a better understanding of refractory deterioration, or to get accurate cold face temperatures on refractory covered water tubes in boilers.

FOLLOWING ARE ITEMS ONE NEEDS TO KNOW AS EARLY AS POSSIBLE IN ORDER TO PROPERLY PREPARE FOR A CONTRACT DRYOUT:

1. The physical size of the unit. Drawings are very helpful during the quoting process and for project engineering to minimize setup time and the customers downtime.

2. The physical configuration or shape of the furnace or process unit and in particular any ancillary portions such as incoming feed lines or exhaust gas ducts.

3. Access points or openings. Anything over 6" is of interest to us. In conjunction, we need to take stock of the areas and accessibility outside the man way for the burner, combustion air fan and gas train. Arriving at a job site and having to install a burner in a man way 15' up without a platform or scaffolding becomes difficult and unsafe without proper planning and coordination.

4. Exhaust considerations are quite often overlooked.

    a. Of preference is the highest elevation.

    b. At times it might be necessary to control the exhaust with a temporary damper plate. In the case of a stack, the damper should be operable. Do we need to bring a burner to activate the stack draft as an option? It is occasionally required.

    c. Are exhaust points removed from areas where personnel may have to perform other duties or are they a potential safety hazard?

5. Fuel sources need to be considered. A multitude of fuels can be burned but there is nothing more convenient, safer, and economical than natural gas! It is usually less expensive in comparison to alternative fuels. If fuels, such as propane are contracted, we need to understand that these items must again receive the proper pre-site planning as generally they pose additional safety considerations and extra manning may be required to ensure safe and efficient operation.

6. Is cooling air or water available for protection of unlined areas during the dryout?

7. Are temporary bulkheads required to isolate unlined areas from the rest of the unit or to divert heat to areas inaccessible for burner placement?

REGARDING THE DRYOUT ITSELF AND WHEN ENGINEERING THE NUMBER AND PLACEMENT OF BURNERS, THE BOTTOM LINE IS "MASS FLOW" BECAUSE WITH MASS FLOW COMES:

1. Controllability,

2. Comes temperature uniformity

3. Improved film coefficient of heat transfer, which improves the rate at which heat is transmitted into the lining. Reynolds Law deals with the fluid friction between boundary layers and how they affect each other. All heat exchangers work with this principle. It also works with refractories.

Consideration also needs to be given to putting the bottom of the vessel or furnace under positive pressure or at least neutral to flood this area with hot air as well as preventing the ingress of cold air.

Thermocouples should be placed in the expected hottest areas near the burners and at the coldest exhaust points. If we have done our homework correctly, the temperature differential across the lining will be at a minimum.

Thermocouples placement has been debated over the years. We are in full accord with virtually all of the refractory manufacturers, or they are in accord with us when we introduce the concept, that the temperatures referred to in dryout schedules should be the temperatures of the hot gases in contact with the hotface and not the refractory itself.

There are several reasons why:

1. The air is the media providing the heat and subsequently should be the item to be controlled and measured.

2. The installation method of a thermocouple onto or into the refractory can introduce as much as a 50 °C error.

3. We must recognize material's conductivity. 25 mm of dense, high conductive material, such as used extensively in the petrochemical industry, will produce considerably different results versus a thick, lightweight castable.

If specific temperatures are to be achieved at an interface, or at the shell, or any other area, a thermocouple can and should be located there.

WHAT DRYOUT SCHEDULE SHOULD BE USED?

Certainly the best source to start with is the manufacturer of the refractory material. They have done considerable research on their products as well as drawing on their experiences in the field. Considerations for various schedules are or were primarily from the differences in permeability, density, as well as thickness.

There is little doubt that it is not the free water which causes problems during dryout and it has been shown in research several years ago that higher water to cement ratio facilitates drying and heatup. Of course it also increases porosity and decreases strength.

It is the chemically combined water that comes off en-mass between the 200 to 320 °C range that creates problems during dryout.

A lot of discussion tends to take place about visible steam and the interpretation of pressure steam. After many years of observing steaming of refractories during dryout, we are becoming more and more convinced that it is not the steam one sees that creates the problem as it has made it to the surface and is relatively free to escape but rather, it is the invisible steam that ultimately leads to problems in way of explosive spalling as the result of being entrapped within the refractory lining.

Steam should not however be ignored and one needs to be keenly aware of pressure steam which can lead to problems although we very seldom have observed it. We define pressure steam when you cannot hold your hand in its stream at a distance of about 4 inches for more than 10 seconds. Do not be concerned about the whisks of some steam as it is evidence that the dryout is achieving the desired results of driving the moisture out of the refractory lining.

For dryout purposes, the optimum lowest top temperature should be sought to accomplish the task of sufficiently setting the plastic, or with castables, removing the moisture from the hotface to a safe level. Taking the unit to quote "operating temperature" may not only be costly from a time, fuel or preparation standpoint, but not having cooling air or water in specific areas or some air on the permanent burners can be disastrous. It may be here, that when an installed threshold thermocouple reaches equilibrium after a few hours hold, that the unit is considered sufficiently dry to safely proceed into operation utilizing the permanent combustion equipment or process heat.

Finally, very little research has been done in the field of refractory dryout. We have conducted our own internal studies and have learned over the years through practical experience in the field having completed in excess of 15,000 dryout projects. We have also participated in some studies conducted by API and others. In the total scheme of things, we believe the refractory manufacturers have done an excellent job in developing new products with the necessary quality control in place. Where they dealt with pounds of additives / ton, manufacturers are now having to deal with ounces / ton. There is also of course the refractory installers who have had to deal with refractory products that are more sensitive to proper water content, mix time and placement methods and who have done an excellent job of adapting to such requirements. In addition, there is more awareness of the importance of a proper dryout.

In the final analysis, it is a combination of the efforts of all parties, the manufacturer, the installer and the dryout contractor that will result in a final product that will perform to its design capability and meet or exceed the expectations of the end consumer.
