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Refractory — Is it working for you?

Many types of process heat transfer static equipment require some form of refractory to isolate the metallic structural component from high heat. A typical installation would be a reactor with internal temperatures greater than 2,000 F. The metal temperature of the structural component might have a maximum design temperature of less than 650 F. A typical refractory installation will consist of three or more refractory layers. Heat transfer paste of heat transfer paper will be installed between the refractory and the wall of the vessel. Analysis of the heat transfer to obtain a real world solution can be challenging.

Typical calculations involve determination of the heat transfer coefficients on the refractory hot face and the environmental ambient conditions outside the pressure vessel. Most often the refractory companies can provide detailed material properties such as thermal conductivity to calculate the heat load through the refractory. One consideration is the gaps between the reactor and the wall. During the cyclic life of refractory it moves within the vessel. The heat transfer paste and/or paper might not always cover the full range of movement over time. The movement might be in a ratcheting manner that could cause overstress of the refractory in time or lead to local hot spots within the vessel. Sometimes the refractory might crack to relieve its overload and still have useful life.

Some of the challenges in the heat transfer calculations involve what is called "gap heat transfer." This is exactly what it sounds like — heat transfer through the gaps. Radiation, conduction and convection through these gaps transport heat. The finite element method can be employed to heat calculate the "real world picture" with refractory.

The finite element model incorporates the refractory, gaps, heat transfer paste and/or paper and the metal. A sensitivity study can be conducted on the gap elements to determine the operating range for the physical properties of the gap elements. Measurements taken in the field can be used to calibrate the physical properties of the "gap" interface elements. These gaps traditionally have always been the "fly in the ointment" when it comes to the development of a successful heat transfer model with refractory.

The other side of the coin is the structural analysis of the refractory. This too can be accomplished using the finite element method. The response of refractory is not the same as metal. It exhibits movement as a complete unit consisting of several types of refractory and "gaps" that can behave as anisotropicly. This simply means it will not necessarily spring back to where it came from when unloaded. Like many structures, thermal expansion will is a factor in refractory design. Typically it will not grow as much as metal and therefore the "gaps" get bigger. Sometimes expansion joints must be incorporated into the design to account for the differences between the growth of the metal structures and the refractory. It is sometimes a practice to use supports like a spring and expansion joint to ensure the refractory will not be overstressed.

A good refractory design incorporates the metal, supports, gaps, refractory materials and heat transfer interface material in the gaps.

A methodology for installation of refractory should include the following:

1. Make sure the refractory is designed for the process. Considerations include, but are not limited to, corrosion and hot erosion of the hot face. Make sure the fluid velocities are calculated. Testing in pilot units or actual production units would be advisable.
2. Perform a rough heat transfer analysis of the system.
3. Perform preliminary sizing of the heat transfer internals.
4. Make sure embedded anchors can "take the heat."
5. Perform a structural analysis to account for the expansion and heat transfer. Don't forget about seismic analysis, as you would not want the refractory to loosen up during a seismic event.
6. Perform a final detailed heat transfer analysis.
7. Perform a final structural analysis.

The analysis should be reviewed by a professional engineering competent in refractory systems.

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