Lance Zier and Jerry McBride, Industrial Specialists LLC, a BrandSafway company, explore ways of reducing FCC refractory lining inspection, installation and repair time.

MUSIC TO YOUR EARS

Like a symphony conductor, a contractor that specialises in refractory installation knows how to coordinate the elements to create music to the refinery operator's ears: reducing the turnaround schedule and completing the work without recordable incidents.

The need for maintenance on fluid catalytic cracker (FCC) reactor and regenerator components often begins when thermography reveals hot spots, created by spalling, erosion and coke build-up between the shell of the vessel and the refractory lining. Another cause of hot spots is catalyst carryover, which is caused by catalyst abrasion creating a hole in the refractory – often in the cyclones.

To evaluate the scope of work, a refractory installer works with the refinery design, process and liability engineering personnel, as well as mechanical crews, to review the infrared scans, FCC unit (FCCU) history, as-built drawings and isometric drawings from previous repairs. Knowing the FCCU's history helps identify recurring trouble spots and issues with previous repairs. For example, if a section of refractory wears prematurely time and again, it may signal the need for a mechanical design change, but it might also signal the need to use a different refractory material or installation technique.

To minimise shutdown time, refinery managers can work with an experienced refractory installation and repair contractor. This article highlights some of the best practices contractors use, provides guidance on selecting a good contractor, discusses a highly productive process for welding refractory anchors, and reinforces the importance of the API Standard 936 for refractory installation quality.

Enter the matrix

Based on the initial evaluation, the refractory installer will prepare isometric drawings and create a refractory matrix that addresses the work description, repair procedure, base material, surface preparation, anchor details (type, size and alloy), welding details (welding process and, if applicable, filler metal type, pre-heat temperature and post-weld heat treatment), refractory type, lining thickness and estimated square feet of area to repair.

Knowing the intended service life of the refractory may also guide decisions. If a repair needs to last one year before a major turnaround, the scope of work and specifications may differ from a lining that is expected to perform for four or five years.

After shutdown, the installation contractor's team will visually inspect and hammer test the reactor, regenerator and associated components. A hammer test is a subjective test of green or fired refractories, where the operator impacts the lining with a hammer to evaluate soundness and uniformity via audible resonance. Because intact refractory lining creates a monolithic barrier, any imperfections create a resonance difference. The refinery operator will typically allocate seven days of around-the-clock work for refractory inspection.

Figure 1. Failed refractory lining.

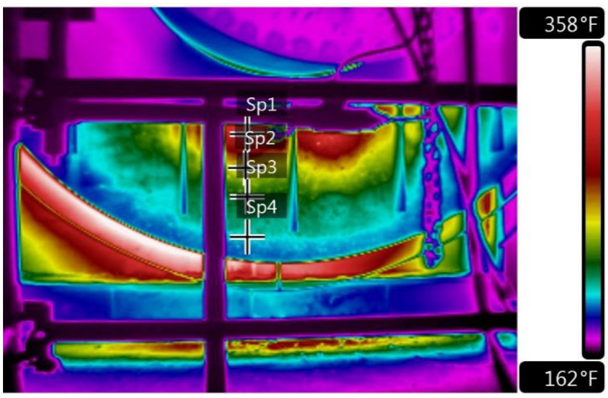

Figure 2. Thermal imaging shows the location of hot spots, which identify potential repair areas.

Make or break access

The ability to provide inspectors with access to all areas of the FCCU can make or break a turnaround schedule. Scaffold requires a deck every 6 ft, 6 in., and comes in standard dimensions. However, the irregular shape of an FCCU often requires customised access solutions and equipment. Furthermore, complete access requires organising, transporting and installing tens of thousands of individual components in a specific order so that inspectors have access when and where they need it. At this point, there is no substitute for experience, which will be indicated by the speed of scaffold erection, the efficiency by which access is provided, the skill of the inspection team and the safety record of the contractor. A safety-oriented contractor should demonstrate a near-zero or zero total recordable incident rate (TRIR), as well as have an experience modification rate (EMR or E-Mod) of below 1 as the considered industry average. EMR is a numeric representation of a company's claims history and safety record compared to other businesses in the same industry.

In addition to inspection personnel, the access plan also needs to consider where, when, how and in what order the various crafts require access, including crafts associated with refractory demolition and removal, welding and related mechanical trades, refractory installation and final inspection. Safely managing access as well as the flow of people, materials and equipment requires extensive planning and constant communication.

For example, consider that welding stainless steel may require protecting workers from exposure to the hexavalent chromium present in the welding fumes, typically through use of a powered air purifying respirator (PAPR). Only good communication and planning will determine whether it is more efficient to schedule a dedicated welding time, have all trades working inside the FCCU wear a PAPR, or some combination thereof.

To further evaluate an access provider, they should be asked if they have documented procedures, routinely review the procedures and continuously train/re-train personnel as needed. Access providers should be asked if they have safety training. When the access team understands the hazards around them, acts based on safety training, and knows how to communicate with other craftsmen, they stay more focused and can operate at a higher level of efficiency. When a refinery has routine safety meetings, consider including not just supervisors, but also representatives from the ranks of the crew. When craftspeople attend a meeting and then go out to the field and converse with their peers, it reinforces the fact that they are all responsible for safety at an individual, equal level.

Welding advances

Anchors secure the refractory to the base metal, with the type of anchor varying by application. A job might require several thousands to hundreds of thousands of anchors. Using traditional shielded metal arc welding (SMAW) or gas tungsten arc welding (GTAW) processes, a welder can install 250 – 350 anchors in a 12 hr period. These welding processes are inherently slow, and each anchor requires 100% welding around its base. Furthermore, failure to find enough qualified welders has seriously derailed more than one turnaround schedule.

Standard stud welding processes address speed and labour shortages, but quality was inconsistent. There are industry stories about stud-welded anchors falling off when hit with a hammer. Fortunately, a newer technology called rapid fusion welding (RFW) delivers consistently good fusion between the anchor and base material while enabling an operator to install 1000 – 1500 anchors in a 12 hr period.

RFW features a digitally-controlled system that enables the installer to program, store, recall and adjust parameters to match the application and type of anchor being used. With RFW, the operator places one end of the anchor in the socket of a hand-held gun (connected to the power source), while the other end of the anchor terminates in a flux ball. The operator places the gun in position, depresses the trigger and a plunger pushes the anchor toward the plate.

The welding sequence consists of the ferrule approaching and touching the plate so that the system can measure electrical resistance, a process that determines if the plate has excess contaminates (rust, old refractory, etc.). The power source then creates a pilot arc and moves the anchor to a pre-set height above the plate. After proper pre-positioning, the power source ramps up the welding current and holds the anchor at the correct height for a programmed amount of time (measured in seconds or fractions of seconds). After forming a molten pool inside of the ferrule, the plunger moves the anchor into final position inside the pool while ramping down current and terminating the weld.

Because the RFW system automatically controls the position and weld sequence, each anchor is rapidly welded with a reliable degree of fusion. In addition to high productivity and quality, other benefits include:

- The ability to reach into tight areas.
- Welding around and behind tubes without risking fusion on the tubes.
- The ability to weld on thin plate without burn-through.
- Dramatically reduced fume generation and risk of exposure to hexavalent chromium.
- Reduced risk of arc flash (heavily shaded lenses are not required).
- Reduced inspection time.

Setting the standards

Installing refractory directly depends on the skill of the crew involved. To bring order to art, the industry sought to define the minimum requirements for the installation of monolithic refractory linings and to provide guidance for the establishment of quality control elements necessary to achieve the defined requirements. The result was API Standard 936, Refractory Installation Quality Control Guidelines – Inspection and Testing Monolithic Refractory Linings and Materials.

Originally produced in October 1996, the standard has been updated three times, most recently in June 2014. Although not mandatory, quality-conscious contractors have adopted the standard, and a majority of their personnel at the foreman level and above will have passed the API Standard 936 certification test. The quality control elements of the standard include: documentation of the execution plan, material qualification, applicator qualification, installation monitoring, as-installed testing, pre-dryout inspection, dryout monitoring and post-dryout inspection.

Figure 3. This scaffold provides access to a repaired FCCU regenerator where the dry gunning technique was used to install refractory.

Figure 4. Erecting a scaffold in an efficient and timely manner requires coordinating thousands or tens of thousands of pieces of material and associated skilled labour.

Figure 5. A field installed vibe cast of the air pre-heater.

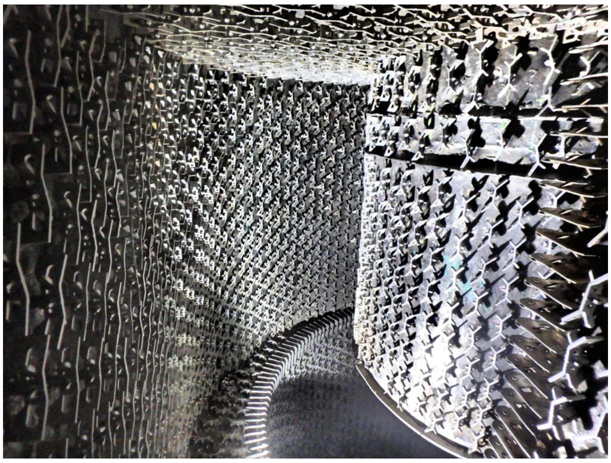

Figure 6. When installing thousands of anchors, the rapid fusion welding process can shave shifts off repair time compared to traditional stick welding.

One of the most critical sections is 8.3 'Qualification of Installation Procedure and Crew/Installers'. This section states that "prior to installation, the contractor shall demonstrate that the specified quality standards will be met using the material qualified for the job, including metal and organic fibres as applicable, and the installation method, equipment, and personnel to be utilised for the installation work. This shall be done by simulating the installation and sampling and testing the applied materials."

What follows are guidelines for preparing test samples for common refractory installation techniques, including dry/wet gunning, casting and ramming. These guidelines, coupled with the installation/execution techniques detailed in section 9, help ensure that the as-installed refractory has the required physical properties.

To further appreciate the importance of the standard, consider that dry gunning requires controlling about 18 – 20 variables. The operator, or 'nozzleman', must properly direct material while controlling air pressure, material feed and water flow rates, which in turn affect the homogeneity, strength and density of the final lining. If the air pressure is too low, the refractory will have insufficient density, which must be within +/- 5 lb/ft^3 of specifications. Insufficient water affects density, but also homogeneity, arguably the most important characteristic of gunited linings.

To ensure homogeneity, API Standard 936 directs the operator to "begin gunning at the lowest elevation, building up the lining thickness gradually over an area of not more than 10 ft^2 to full thickness." If a work stoppage exceeds 20 min. or if an inspector determines that the lining has initially set, only sections that have their full thickness should be retained. These practices eliminate 'cold joints' and the creation of layers. A good lining possesses a monolithic structure that better withstands thermal cycling. Conversely, sections of a poorly consolidated lining will heat and expand at different rates, leading to spalling that could allow gases and foreign objects to work their way between the lining and the base metal.

Good vibrations

Then there is vibration casting, which became popular in the 1980s. The process appears simple: create a form, mount two or more external vibrators, mix and pour the refractory, vibrate, cure and strip the form. However, vibration casting is more complex and requires more expertise than other methods. Previously, there was not enough working time to mix the refractory and pump it into the forms without risking homogeneity in field applications. As a result, vibration casting was used in shop settings for new installations (and especially because removing or repairing a poorly installed lining in the field is prohibitively expensive).

More recently, refractory materials have been developed specifically for vibration casting. Along with pumping and vibration equipment advancements, these materials have been successfully cast in the field. Some cast-in-place work may take up to 48 hrs to perform, but that is not an issue. Crews rotate so that pumping continues uninterrupted, ensuring homogeneity on large forms. Target applications include dense castables with thicknesses of 4 in. and greater to provide insulation and abrasion resistance in riser lines, vapour lines and spent catalyst/regenerated catalyst standpipes. With this application, operators get improved shop quality installation in the field, which greatly increases the life of linings in critical areas of units.

Safely getting back online sooner

Erecting scaffolding and inspecting and repairing refractory lining might seem like routine, standard service. However, a well-designed and flawlessly executed plan for the inspection, installation and repair of refractory linings can reduce shifts during turnaround time. It can bring millions of dollars' worth of daily capacity back online sooner, ensures the refractory linings perform as intended, and provides the comfort of knowing that all workers remain safe every day.