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Improving Asset Utilization with the Right Coating

By Ed Curran, CEO, Curran International

Corrosion, fouling and leakage can adversely affect the performance of your heat exchanger equipment. Inefficient heat transfer in heat exchangers is a common bottleneck that plagues refineries and energy operations around the world, requiring no small amount of attention and, at times, greater-than-anticipated expense.

Applying polymer coatings to the inner diameters (ID) of heat-transfer equipment used in petrochemical refineries can provide significant benefits that last throughout the lifetime of the machinery. Applying the right type of coatings to the metal tubes in heat exchangers not only protects the tube IDs, but also results in reduced plant and equipment downtime, slower depreciation on capital assets, efficient energy usage, and fewer stoppages for routine repairs. This all adds up to higher maintenance standards, improved reliability, greater operational efficiencies, increased production capacity and - ultimately - higher margins for your business.

The return on investment in cost savings for a "penny" toward protection is worth millions of dollars per year. One US Gulf Coast refinery estimated it saved $30,000 per day in reliable production, reduced downtime and lower energy costs, amounting to nearly $11 million per year after coating the tubular systems in their heat exchangers. Additionally, the costs they saved in not retubing each exchanger increases that amount by an additional $3 million per year compared to historical retubing cycles. Bare steel or costly alloy tubes need to be cleaned and replaced much more frequently than tubes with protective coating treatment.

Tubes take the Heat

Heat exchangers play a mission-critical role in the daily operations of petrochemical refineries. Water is corrosive to metallic tubes, and is also susceptible to fouling and bacterial contamination that eats away at the exchanger tubes' inner and sometimes outer surfaces. Leaks and damage, pitting and obstructive buildup all point to routine maintenance and regular stoppages for cleaning – about five times more often, on average, if your tubes remain bare, or uncoated.

In refineries, heat exchangers are typically used for cooling the feedstock during processing. It is of vital importance to preserve these systems' efficient operation, and to prolong their working lives through best maintenance practices. The cost of entirely retubing a large piece of heat-transfer equipment climbs well into the tens or hundreds of thousands. Therefore, it is usually preferable to extend the life of the tubes through coating their inner diameters with phenolic or epoxy materials that are especially suited to protect the base metal of the tube bundles in the heat exchanger.

One Gulf Coast refinery tracked its heat exchanger costs over a 12-year period. Measuring leaks per month at six-month intervals from January 1993 through January 2005, the company saw a dramatic improvement in reduced heat exchanger outages, which averaged nearly 20 per month before coatings. After completing a significant amount of coating the heat exchanger tubes in 2000, the refinery put the equipment back in action. By the following year, unplanned cleanings had dropped to an average of fewer than two per month and remained so through the rest of the tracking period.

The number of service years between leaks also increased significantly during this time, particularly from January 2002 to March 2004 and beyond. The number of years between service maintenance for leaks was trending toward 20, compared to before the coating program started, when the number of service stoppages was as frequent as fifteen times per month. Outages per month decreased to a mean of less than five *after* coatings, from a mean of nearly 15 per month before coatings.

This represents a trend of 120 fewer service outages and 72 fewer repairs per year. With the cost of an outage at approximately $5,000 per heat exchanger, the savings in outages amounts to $600,000 per year. In addition, repair and replacement costs run as high as ~$50,000 per tube bundle (in each heat exchanger). Total savings including retubing (replacement) costs and fewer outages on a single heat exchanger amount to 800,000 or more. If the tubes had remained uncoated, the operator experienced retubing approximately every three to five years.

The cost of coatings runs normally between 25% and 50% of the cost of retubing, so the savings in coating versus retubing are attractive for many refiners. The coating normally lasts between eight to 20 years in normal cooling water service. Coatings can be inspected during routine maintenance cycles to insure the durability of the coating to protect the exchanger tubes until the next turnaround. If the coating is showing signs of breakdown, the heat exchanger coating can be removed and replaced to original condition providing perpetual equipment life with minimum maintenance. Over a 12-year period, the costs saved by coating the tubes runs into the millions of dollars.

With coatings and proper maintenance procedures now in place, this refinery is actually saving close to $1.4 million per year. Combined, the outage and repair savings are approximately $2 million per year.

Alkylation Unit Success Story

Challenge: A California refinery was constantly suffering bottleneck problems in their alkylation unit. Exchanger ID fouling significantly reduced unit throughput by 33%. A 6,000 HP compressor was constantly recycling 2,000 HP of the unit's gas. Historically, these exchangers would typically drop from 5,000 GPM when new or "just cleaned," to 700 GPM in six months. Expensive and time-consuming high-pressure water cleaning cycles were needed constantly to maintain the exchangers in minimal operating condition.

Solution: Curran International was contracted to coat the ID of two effluent refrigerant condensing exchangers that cooled butane in the unit. The equipment required full-length tube ID coating -- including the entire exchanger bundle (**see photo**), which was coated with <.010" film of coating. A polymerized, homogenous thin film applied down full-length tube IDs eliminates corrosion reduces friction and drag at the substrate. Tube ID coating sustains flow of cooling water through tubes.

Results: By coating the ID of two effluent refrigerant-condensing exchangers that cooled butane in the unit, the refinery was able to resolve the issues. After 30 months of service, flow rates have remained a constant 5,000 GPM and the unit had not been stopped for cleaning. All compressor gas recycling was eliminated, which boosted the unit output from 13,000 B/D to 16,500 B/D even on the hottest days of August. As an added benefit, the compressor backpressure dropped 5 psi, saving substantially on energy costs to power the compressor. ***By reducing fouling and "backpressure," the long-term performance of the carbon steel exchanger became a***

lasting reality. The requirements for normal bundle maintenance, including hydroblasting, are reduced or entirely eliminated.

[Insert photo sent via email]

Improved Asset Utilization

At a different refinery, several heat exchangers in the catalytic cracker recovery unit's refrigeration section also required maintenance. They were operating inefficiently, and upon examination, the diagnosis was severe tube corrosion and pitting. Two of the six exchangers required complete retubings due to age and damage over time. The four remaining exchangers had only been operating for three years, but still had telltale wear and tear, corrosion and pitting.

The refinery management opted to apply coatings to all six exchangers to prevent further damage and to decrease fouling from sulfate-reducing bacteria. By coating all the equipment, preventive maintenance in future would suffice to reduce stoppages, repairs, replacements and the need for any retubings – and the unit would see better performance from the equipment in the refrigeration area.

Since corrosion causes leaks and fouling reduces pressure generated by the systems in which the exchangers operate, the tube bundles in the exchangers were given three coats of polymer each, after being pre-treated with grit blasting to ensure their inner surfaces were prepared per NACE-1 standards for white metal cleanliness. Grit blasting also creates a more surface area so the coatings can achieve a better bond to the carbon-steel tubes when applied.

In the past, coating inner diameter piping had to be done in special shops, and could not be done onsite. That meant each heat exchanger had to be completely disassembled, shipped and then reassembled. This inconvenience and expense usually precluded the largest units from being transported or treated at all. However, techniques have progressed, enabling *in situ* application to take place under most circumstances. Coatings are applied with special equipment adapted to operate in tight areas, using a type of spray nozzle that can reach into the deepest, longest tubing from almost any narrow angle.

[Sidebar:] **The "Skinny" on Heat Transfer & Coatings**

Tube coatings usually consist of polyamides, fluorinated products, phenolics and novolacs, depending on the base material to which they are applied. Polymer tube linings have always suffered from the perception of heat-transfer penalties due to lower thermal conductivities. Although the coating's thermal conductivity is less than the parent tube, several factors offset these effects.

The first factor covers normal design considerations. Generally, heat exchangers are designed with a certain fouling factor (0.001-0.002 btu/hr). Coating to the tube ID lowers the thermal duty by 0.0006-0.0008 btu/hr, which is well below the precalculated design. Applying the coating either totally eliminates the subsequent fouling or greatly reduces the accumulation of typical micro- and macro-fouling, mitigating the initial design consideration.

The second major factor is the boundary-layer drag reduction. About 70% of total heat transfer resistance across a heat exchanger tube is the slow-moving fluid coming into contact with the tube wall. Friction at the tube wall reduces this flow and creates an insulating barrier of low-velocity fluid.

Polymer coatings reduce the surface tension at the tube wall substantially—by a factor of 30-40 dynes/sq cm vs. bare steel or metal alloy in a non-oxidized or new condition. Reducing friction reduces the boundary-layer drag and substantially opens up the flow profile.

Before coatings, the only way to extend bare-tube performance life involved regular chemical cleaning and mechanical cleaning. The chemical cleaning actually produces toxic H_2S gas and hazardous waste, and removing oxides also causes further corrosion due to structural degradation rendered to the tubes in the process.

The results the refinery realized in taking the preventive measure of coating the tubes in six of their heat exchangers included improved pressure, measured in PPI (pounds per inch). The two older heat exchangers ran at more than 230 PPI before retubing and coating. Afterwards, the pressure drop remained steady within a range of 190 to 200 PPI, a desirable metric in its consistency. During their first three years of "bare" pipe service, the four younger exchangers experienced an increase of pressure drop by 15 PPI per year. Once the tubes were coated, the pressure performance stabilized.

The refinery expects a ten-year coating life for the exchangers, barring some minor tube-sheet touchups during maintenance periods. After a decade, the tube bundles will need to be inspected, but the life expectancy of the heat-transfer equipment is expected to exceed to be 10-20 years, and the maintenance required is extremely minimal compared to the bare pipe alternative.

A History of Coatings

Fluids that come into contact with tubular surfaces have always plagued heat-exchanger equipment. Historically, water treatment and periodic cleaning by hydroblasting managed this process, but the results were not always optimal. Now, users are applying polymer coatings to the tubular inner and outer diameters (ID and OD) of the heat-transfer apparatus. Over the years, this practice has evolved and matured into a cost-effective remedy to reduce typical fouling and corrosion problems intrinsic to heat-exchange equipment. Improvements in materials, surface preparation, application and thermal conductivity, plus owner-operator data collection and analysis, have established tubular coatings as viable heat-transfer equipment (HTE) problem solvers.

A German Chemical Company first developed phenolic materials for tube ID coatings in the 1940s. Applied by a fill, drain and rotate method in a specialized shop, it was the industry's best option until the mid-1980s. By that time, companies in Italy began experimenting with air-atomized spray applications of epoxy phenolic developed by their engineers. By coating the tube ID with the epoxy phenolic compound, the Italians achieved excellent results and improved fouling and corrosion resistance to the main condensers, which actually restored the generating units to normal operating capacity.

Today, ID coatings are considered the most cost effective practice for extending the performance and lifecycle of a heat-transfer system. It took decades of trial and error in upstream, midstream and downstream applications to find the right solutions for each ID, bare metal, and chemical coating compound to optimize the practice for each and every condition and situation.

Bottom-Line Benefits

Applying polymer coatings to the ID of tubes in heat transfer equipment operating in refineries provides lasting benefits. Besides increasing heat transfer duty, eliminating corrosion, reducing micro and macro fouling, and improving cleaning cycles, tube recoating also provides perpetual equipment life. There are now more cost-efficient approaches to reduce loss incurred through inefficient heat transfer in petrochemical refining, saving refinery operators a bundle in opportunity costs.

By taking care of these little details – paying attention to the small tubes in heat transfer equipment – you can save big on unnecessary maintenance, lower energy costs and enhanced operational efficiency over the lifetime of your equipment. One small step in tube coatings is a giant step for improved asset utilization in the petrochemicals industry.

For more information about best practices or project references, contact www.curranintl.com.

Curran International specializes in advising on and applying the correct ID and OD coatings for smaller diameter tubular systems such as those found in the heat transfer equipment operating at petrochemical refineries, in the oilfield and in pipeline recompression stations.