FIRED HEATER HEALTH MONITORING AND RELIABILITY MANAGEMENT IN CHALLENGING TIMES

TIM HILL, Principal Consulting Engineer at Quest Integrity Group
FIRED HEATER HEALTH MONITORING AND RELIABILITY MANAGEMENT IN CHALLENGING TIMES

BY: TIM HILL, Principal Consulting Engineer at Quest Integrity Group

INTRODUCTION
The reliable operation of fired heaters is critical to the successful performance of any petroleum refinery. Because they operate under such extreme conditions, the life of furnace tubes is often limited by creep, corrosion, and oxidation. This article covers many essential elements for optimizing the performance and reliability of fired heaters. Refining facilities benefit from having a strategic optimization plan, both short-term and long-term, through improved reliability and performance of fired heater assets, resulting in cost reduction and a decreased risk of unplanned asset failures.

The standards for successfully managing assets have changed with the expectations of refinery leadership in the current industry climate. Historically, refineries were satisfied with programs that repaired equipment as quickly as possible, using a reactive approach. However, today’s leaders demand more from their managers. With refineries being pinched by low crude oil prices, demands for cost effective unit reliability and performance continue to rise. Operations managers now have to meet and exceed the challenges from these high expectations, in order to ensure and maintain longstanding fired heater health and reliability.

Due to the high demand for continuous reliability and productivity of fired heater assets, it is important to develop a systematic strategy based on best practices. It should identify and address all essential elements for achieving optimum performance and reliability for each fired heater asset.

THE IMPORTANCE OF PERFORMANCE
Achieving fired heater reliability in conjunction with meeting performance standards can be a challenging feat. Performance is a measure of the degree to which the fired heater is in an operable condition at any given time. The difficult factor of meeting performance standards is that the required fired heater operation (mission) is ever changing, at random frequencies.

Measures of asset performance are shown in Figure 1. These measures define what operators want a fired heater to accomplish at any given time. For example, if the heater was designed for a 30,000 bpd (barrels per day) feed rate, the charge heater must be able to process this charge capacity; otherwise the mission has failed.

The fired heater asset manager’s main goal is to achieve a balance between reliability and demand/performance. The manager can achieve this goal provided the reliability (what the fired heater can do) exceeds or is equal to the performance demand. However, if the reverse situation occurs (performance demand

Figure 1. Fired Heater Performance Standards.

Figure 2. Impact of Failure to Manage Risks.*

*Figure 2 tube failure: This coil was designed for dry feed only. However, wet feed was going into the coil. Internal tube fouling occurred as liquid vaporized within the coil. Fouling was not detected, leading to localized corrosion damage in the fouled areas. Improper burner operation led to flame impingement on the fouled tube areas. Due to this damage, the tube overheated and ruptured. The cost to the refinery was an 8-week outage to re-build the asset.
exceeds inherent reliability of individual components), asset failure is certain to happen at some point in the future. Regardless of what is done to maintain the asset, eventually demanding more from the fired heater than it is capable of delivering will result in asset failure. In addition to the failure occurring randomly, the results are often catastrophic.

For example, internal fouling of process fired heater tubes leads to higher tube metal temperatures, eventually affecting the reliability of the heater. Failure to detect this reduction in reliability could lead to damage negatively affecting the performance and desired reliability of the asset. The first indication of this imbalance could be a disastrous tube failure (Figure 2).

**KEY ELEMENTS TO HEALTH MONITORING AND RELIABILITY MANAGEMENT**

Essential elements provide the refinery’s fired heater manager the necessary knowledge to achieve the optimum balance between reliability and performance. These elements (Figure 3) include:

- Reliability and performance optimization accomplished through on-line and off-line monitoring of the fired heater's health
- Fitness-for-service and remaining life assessment of the detected damage mechanisms
- Risk assessment of the fired heater process and steam tubes and auxiliary components
- Failure analysis of components that suffer premature failures

In this management program, the performance data is fully integrated with the reliability data to provide managers with the knowledge to manage the reliability of key components and identify opportunities to improve heater operation to meet performance goals.

**HEATER HEALTH MONITORING**

The first steps of an effective health monitoring program define what is happening inside the process heater while in operation. This involves monitoring critical operating parameters that define the reliability and performance capability of the heater, such as tube metal temperature. Key monitoring tools utilized include infrared thermography, flue gas conditions analyzer, combustion emissions, and isothermal and heat flux profiles (Figure 4). Reliability limits (i.e. integrity operating windows (IOWs)), for the key components are established and the performance measurements are compared to these limits to identify potential failures and operating risk.

Infrared (IR) thermometry is an excellent diagnostic tool for detecting tube hot spots from internal fouling or non-uniform heat distribution in fired heaters. However, to ensure the full capability of IR thermometry, operators should employ the right instruments for the job and implement a proven methodology to measure accurate temperatures in a repeatable process. Today, infrared programs that correct for common environmental and instrumental errors are available to operators that are looking to optimize their use of this technology.

Ultimately, health monitoring requires data collection. The collected data must be analyzed and addressed to optimize the reliability and performance of the fired heater asset. Effective health monitoring programs include the following key attributes:

1. Reliability and tube integrity limits are clearly defined.
2. The fired heater, through consistent principled execution, is operated within predefined limits.

3. The components of the fired heater, including small things such as air registers, sight doors, and burner gas tips are maintained in peak condition.

4. Lessons learned from mistakes are captured and corrected by applying effective root cause failure analysis techniques.

5. Best practices are codified and followed to achieve peak performance.

FIRED HEATER INSPECTIONS

After assessing the on-line factors affecting the performance and reliability of fired heater assets, the next step is off-line health monitoring. Every 4 to 7 years, the fired heater is shut down for a short period during which the condition of components must be quickly assessed and action taken to repair or replace damaged components. Shutdown plans based on the major tube damage mechanisms and major reliability and performance concerns must be prepared and executed.

Effective offline health monitoring programs have employed advanced condition assessment tools to identify, map, and quantify the rate of deterioration and future impact of flaws present in the material condition of the refinery’s fired heater tubes. Whether the primary concern has been bulging, creep strain, isolated corrosion, or other material defects in tube wall thickness, an optimum program must start with inspection and
detection of these flaws during shutdown. Ultrasonic-based smart pig inspection technology can be used to provide quick and comprehensive inspection to both convection and radiant sections in serpentine fired heater coils. The smart pig is propelled with water throughout the length of a heater coil. The use of custom ultrasonic sensor technologies combined with a powerful graphical data analysis package has resulted in high resolution, digital, and quantitative inspection data for the entire piping coil (Figure 5). Data is obtained in a matter of minutes after being collected without removing return bends or entering the furnace firebox. Today’s designs are capable of inspecting coils with nominal diameter dimensions of 3–8 inches and schedule 10-120.

FITNESS FOR SERVICE AND REMAINING LIFE ASSESSMENT

There are several standards to assist the fired heater manager in assessing the fitness for service of heater components: API 530 Annex A, API 573 and API 579-1. Each of these documents provides the necessary knowledge to accomplish the assessment tasks. The reliability and performance data collected during heater health monitoring is used to calculate the fitness-for-service and remaining life.

Annex A of API 530, Calculation of Heater-tube Thickness for Petroleum Refineries, has recently been updated to include important methodologies for establishing operating tube metal temperature limits and tube retirement wall thicknesses. The operating limits may be used to prevent catastrophic tube failures, as well as manage the balance between tube reliability and performance demands. The retirement wall thicknesses are used to quickly assess a particular tube’s fitness-for-service, and is a pass or fail assessment. If the tube failed the Annex A assessment, the more rigorous API 579-1 assessment steps should be performed, or a tube replacement should be considered.

RISK BASED INSPECTION AND ASSESSMENT

After accomplishing heater health monitoring of the performance and condition of the fired heater, a risk assessment can be conducted. Risk assessment methodologies in API 580 and 581 may be followed to obtain a more detailed understanding of how a component is likely to fail and what shortfalls currently exist that can lead to an unexpected on-line failure event.

Risk is conventionally described, as shown below, as a function of likelihood of failure (LoF) and consequences of failure (CoF):

\[
\text{RISK} = \text{LOF} \times \text{COF}
\]

The risk assessment method employed may be qualitative, quantitative, or semi quantitative. For each piece of equipment, the risk is determined by assigning scores to a series of questions concerning the design, operation, and history of each component. The LoF and CoF are further subdivided to enable a paired type analysis of the various factors, which comprise the risk of failure (RoF). These scores are then used to establish numerical values for the LoF and CoF. These factors are qualitatively graded allowing a risk value to be determined and compared to the refinery and industry benchmarks (Figure 6).
FAILURE ANALYSIS
Failures, and even near-misses, should be investigated and corrective action should be taken to prevent re-occurrence. There are numerous methodologies available to asset managers to accomplish these investigations, as well as API 585, Pressure Equipment Integrity Incident Investigation. Whatever investigation technique is utilized, it must be well-understood by the investigation team and lead to identification of the root cause(s). An example of a root cause investigation for the catastrophic tube failure of Figure 2 is shown in Figure 7. The chain of events identified in Figure 7 indicates the logical conclusions regarding the root causes of the tube failure. The asset manager is now able to identify corrective actions to prevent the re-occurrence of the event. It is worth noting that corrective actions should be specific to the action taken, measurable, acted upon, relevant and achievable, and time based.

DEVELOPING A STRATEGIC ACTION PLAN
Finally, a strategic action plan that is customized to each fired heater must be prepared. The essential elements of the described reliability management program provide valuable information to enable a refinery to determine where the management shortfalls lie with each fired heater, and what corrective actions must be taken. A reliability strategy should be developed that addresses the major concerns and potential risks identified in the assessment (Figure 8). The strategy for each fired heater will include policy and procedure changes, capital improvements, inspection and test plans, performance monitoring and maintenance plans, and tube replacement plans. As the action plan is executed, the strategy should be updated and plans adjusted to manage the balance between reliability and performance demand.

CONCLUSION
Achieving proper balance between reliability and performance of a refinery’s fired heaters can be challenging. The health monitoring and reliability management program for fired heaters outlined in this article can help refinery management achieve their long-term goals. It is important to develop a strategy that identifies the essential elements for achieving optimum performance and reliability for each fired heater. The strategy should identify the major potential tube damage mechanisms and any significant issues observed for the fired heater. These damage mechanisms and issues, as well as other industry best practices should be addressed by a strategic action plan. Principled execution towards accomplishing these strategic actions will lead to a higher level of performance and reliability with respect to each individual fired heater. This documented strategy should be periodically reviewed, updated, and changed to ensure fired heaters remain at optimum production. Establishing a fired heater health monitoring and reliability management program will significantly improve fired heater performance and safety by ensuring all risks are understood and accounted for, helping operators reduce the risk while extending run times, and optimizing tube replacements.

For more information on this subject or the author, please email us at inquiries@inspectioneering.com.
Manage the risk of unplanned downtime, loss of production or a catastrophic failure in your fired heaters.

Quest Integrity’s Furnace Tube Inspection System (FTIS™) is a globally proven technology providing 100% inspection coverage of your serpentine coils, compliant with the API-573 Fired Heater Inspection guidelines. The FTIS inspection results are processed with our LifeQuest™ Heater engineering software, providing a comprehensive fitness-for-service and remaining life assessment compliant with the API-579 Standard. Quest Integrity delivers a complete solution that helps transfer your integrity and maintenance risk into reliability.

- Pitting (interior or exterior of pipe)
- Corrosion (interior or exterior of pipe)
- Erosion and flow assisted wear
- Denting and ovality
- Bulging and swelling
- Coke and scale build-up

Get the information you need to confidently make decisions on your fired heaters with plug headers.

To learn more about FTIS, visit us at the link below.
TIM HILL
Tim Hill, P.E., is a Mechanical Engineer and Principal Consulting Engineer for Quest Integrity Group with 30-plus years of experience, including the evaluation of thermal processes, fired heater operations and maintenance, risk assessment, root cause failure analysis and life assessment for fired heater equipment in the petrochemical, refining and power generation sectors. For 10 years, Tim was responsible for the operation and reliability of all furnaces in a major refinery in the USA. During this period, he developed and implemented effective integrity management tools (including infrared inspection) covering operation, maintenance and risk assessment.