

Performance audits for burners and flares

Performance audits and pre-retrofit checks identify issues and help specify the correct equipment for process heater and flare revamps

JESSE CHAMBERS, JIM SMITH and KEITH WADE
Zeeco, Inc

A refinery that experiences an unplanned outage due to equipment failure counts the cost per hour until it is back to full production. Proper performance audits and necessary flare and burner pre-turnaround inspections help prevent unplanned plant downtime and enable combustion equipment to operate most efficiently. Energy costs represent a significant portion of the cost of running a chemical/petrochemical/refining complex. Furnace and heater fuel is a significant component of this cost. When most refinery operations include multiple process heaters with multi-burner configurations, small gains in efficiency can result in noticeable improvements to the bottom line. In addition to low-Btu gases, flaring waste gases at less than optimum operating efficiencies results in higher costs for the fuel gases used to boost the lower heating value (LHV) to achieve necessary destruction removal efficiencies.

In this article, we will discuss proper performance audits or pre-retrofit checks to identify the issues and specify the

correct equipment for both process heater and flare revamps, plus take a look at some of the common field challenges operators encounter.

Process heater inspection

Refineries and gas processing plants depend on one or more process heaters for their operations. A process heater is defined as an enclosed device using a controlled flame, with the unit's primary purpose being to transfer heat indirectly to a process material (liquid, gas or solid) or to a heat transfer material for use in a process unit. The combustion gases do not come into direct contact with process materials. Refinery operations require at least one process heater such as a crude oil heater, start-up heater, vacuum heater, reformer furnace and/or others. Each heater can vary in process design and burner operational characteristics as well as performance requirements. Heater designs are typically cabin, box or vertical cylindrical and consist of a convection and radiant section. Hot combustion gases are used by

heaters to raise the temperature of a feed flowing through aligned coils of tubing. A convection section preheats the contents of the heat transfer tubes using the heat from the flue gas, reducing the amount of heating that must happen in the radiant section where combustion occurs. The radiant section must provide the remaining heat required to meet the necessary coil outlet temperature of the process material being heated.

The main performance objective of a process heater is to safely maximise heat transfer while achieving minimal stack emissions, structural wear and fuel consumption. In order to meet these objectives, proper maintenance, monitoring and control are the keys to avoiding potential problems with heater efficiency, safety, burner operation and excessive NO_x production.

Most refineries utilise refinery fuel gas, which largely consists of methane. However, various processes require the use of hydrogen and hydrogen-rich off-gases, and these gases are needed to meet process

<p>Register/Damper If the register/damper does not operate properly, the burner may operate with insufficient or too much air depending on damper position. This can lead to inefficient combustion, incomplete combustion, poor flame patterns, etc. registers/dampers need to be in good operating condition as these are what control combustion air into the burners.</p>	<p>Secondary Gas Tip(s) If the secondary tips/staged gas tips become plugged or damaged, it will affect burner stability and could cause the burner flame to go out.</p>	<p>Gas Manifold The gas manifold supplies the fuel gas riser with fuel. Therefore, if it leaks or is plugged, it will reduce the amount of fuel the burner will receive for combustion. If leaking occurs, the leaking fuel gas can catch fire, creating a serious safety concern.</p>
<p>Burner Tile If the burner tile is not in good condition, the combustion air pressure drop, flame shape and stability may be affected.</p>	<p>Diffuser/Cone The diffuser/cone is the primary stability source for the flame as well as the combustion air pressure drop source. If it is damaged or missing, the burner can become unstable and combustion air control becomes virtually impossible.</p>	<p>Pilot Tip If the pilot tip is damaged or missing it should be replaced immediately. The pilot is the ignition source of the burner. Therefore it needs to be kept in proper working order. If not, the burner will have difficulty lighting.</p>
<p>Regen Tile If the burner is an oil-fired burner and the regen tile is damaged or plugged, it can affect the flame pattern and stability, and cause severe oil leaking within the burner housing, which can lead to fires, oil pooling underneath the burners, etc.</p>	<p>Oil Tip/Atomiser/Spud If these items become plugged or damaged, the burner may not be able to fire oil or will be very unstable. Most likely, the oil will not light and therefore oil could pool inside the burner housing or underneath the burner, causing safety issues.</p>	<p>Pilot Mixer The pilot mixer is the "combustion air source" for the pilot. The pilot is a pre-mix burner. If the mixer is damaged or plugged, the pilot may not light, therefore preventing the burner from lighting.</p>
<p>Primary Gas Tip(s) If the primary gas tip is plugged or damaged, it can affect the entire burner operation. Typically, the primary gas tip is the initial combustion source of the fuel gas and if damaged it can cause the burner to become unstable and or even go out.</p>	<p>Oil Gun Similar issues and concerns as burner oil tips.</p>	<p>Light/Sight Ports These are used for inspections and/or lighting the pilot. If missing, they will allow excess oxygen into the burner, making it difficult to control the proper amount of combustion air.</p>
	<p>Venturi A venturi is used with pre-mix burners and, if it is damaged or plugged, it will limit the amount of combustion air the burner can inspire, therefore causing inefficiency and reduced firing rates. The venturi must be kept clean in order for the burner to work properly.</p>	

Figure 1 Typical performance audit burner checklist

demands instead of being utilised as heater fuel, as was often the case in refineries in the past. Other gases with a varying calorific content are widely used as process fuels. However, using varying calorific gas feeds can vary the heat generated in the radiant section and may lead to greater demands on the process control of combustion to maintain the product or feed temperature. Coking and accompanying capacity drop can result from localised heating, so the process tube temperatures and furnace operating temperatures must be monitored. When process heaters operate with

too much or too little air, poor flame geometry or unstable combustion, equipment life can be shortened, fuel costs rise and emissions may increase.

Performance audits

A thorough performance audit by qualified combustion experts can identify burner and/or heater issues and help plant managers quickly and accurately determine if a revamp is in order or if the only way to achieve the desired operational goals is a retrofit. Performance audits are often performed by physically walking the refinery, checking operational parameters and controls, evaluating

heater operational and performance data, and visually inspecting the heater, burners, burner components (tile, gas/oil tips, pilots) and other components such as draft gauges and emissions monitoring equipment as completely as possible (see Figure 1).

If conditions indicate more efficient operation is possible through replacing parts and optimising controls, the combustion expert will indicate the recommendation to revamp in a report to the customer. In cases where the existing equipment is simply not sufficient to achieve necessary emissions or efficiencies, the report may

recommend a retrofit instead. Plant operators benefit when the person evaluating the heaters thoroughly understands combustion as well as the combustion equipment and can suggest corrections based on visual inspection, current operation, overall condition, flame geometry and heater performance data, if available.

Another common type of inspection is a pre-turnaround inspection. In this case, the combustion expert will evaluate the heaters and burners in a refinery or petrochemical plant prior to a scheduled turnaround. By identifying the parts a customer will likely need at turnaround time, the expert can look at current inventory statuses and advise components that need to be ordered before a plant goes into a scheduled shutdown. This inspection eliminates expensive expediting fees and extended plant downtime by making sure the necessary parts are on hand when required.

During one recent performance audit inspection at an oil refinery in the US, a Zeeco combustion expert noted problems that a trained service technician might not have noticed. For instance, the burner exhibited tips with incorrect drill sizes for specific burners, incorrect gas tip orientation and incorrect riser lengths. Also noted was the need for new pilot tips, mixer assemblies and gas riser mounting plates. The project would require more than simply cleaning burners, as the plant operator had originally indicated, and each burner would need to be refurbished in order to restore them to original

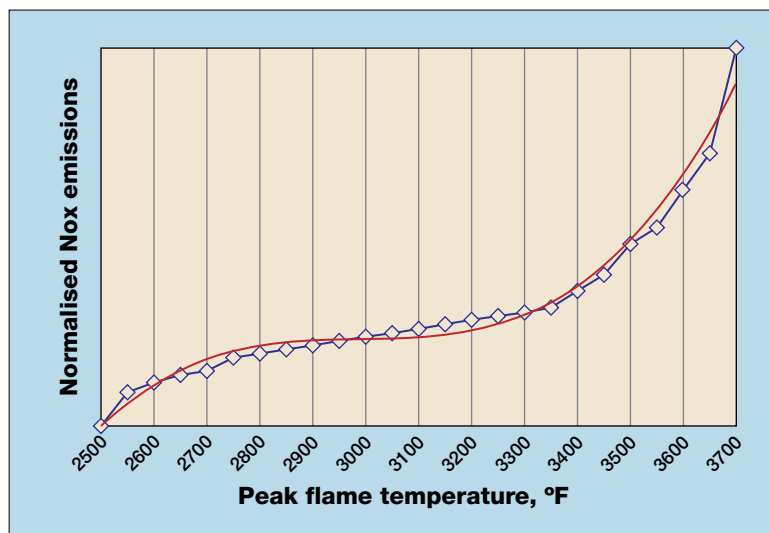


Figure 2 Calculated peak flame temperature versus thermal NO_x production

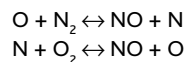
operating condition. The expert recommended replacing all fuel gas risers, gas tips (primary and staged), pilot tips and mixer assemblies.

In another North American refinery, experts discovered major plugging within the primary burner tips and risers. This blockage was solid and could not be cleaned. Approximately 15% of the mounting plates for the staged and primary tip riser assemblies needed to be replaced due to risers breaking off at the threads. Even after refurbishment, the team had to go back and clean many of the burners due to re-plugging of the gas tips and risers due to liquids/solids in the fuel gas lines. Inspections and evaluations should take into account parameters such as heater geometry, overall flame conditions, designed furnace operating temperature, emission requirements and fuel ranges. To correctly evaluate how a heater is performing before any adjustments are made, original equipment

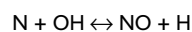
drawings plus designed operational parameters should be reviewed.

When emissions regulations drive a burner retrofit

When refineries use gaseous fuels without fuel-bound nitrogen, the primary contributor to overall NO_x production is the formation of thermal NO_x. Thermal NO_x is produced when flame temperatures reach a high enough level to “break” the covalent N₂ bond apart, allowing the “free” nitrogen atoms to bond with oxygen to form NO_x. A simplified reaction mechanism for thermal NO_x formation is the chain reaction:



with the additional reaction



Most of the nitrous oxide (NO) formed by the chain reaction above is oxidised to nitrogen dioxide (NO₂) in the

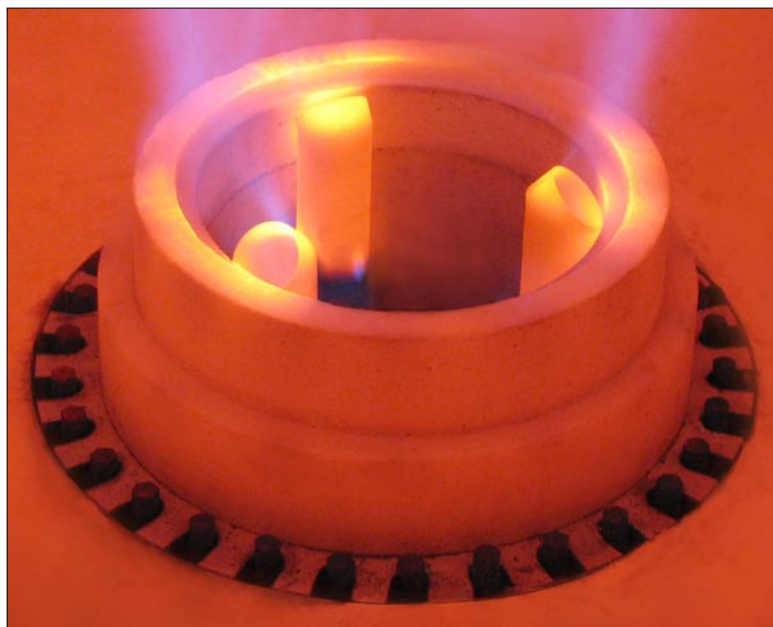


Figure 3 Zeeco's GLSF Free-Jet Burner in operation

atmosphere. The first reaction in the chain above possesses high activation energy and is strongly temperature dependent. Therefore, thermal NO_x generation increases radically at higher flame temperatures. Figure 2 illustrates how the slowing of the combustion reaction reduces the flame temperature, which results in lower thermal NO_x emissions. The challenge in retrofitting is not achieving lower thermal NO_x emissions; it is retrofitting the latest burner technologies into existing process heaters without adding expensive external components or processes.

It is to the plant operator's advantage to choose a burner for a retrofit that achieves the required emissions without major heater modifications in order to fit the burner into the box.

One method proven successful in process heaters for achieving ultra-low NO_x

emissions is to use a burner that induces flue gas into the burner fuel gas stream before the flame stabilisation point, thereby decreasing the combustion reaction rate. By placing the fuel gas tips outside the burner tile, as shown in Figure 3, the jet of fuel gas induces a local internal flue gas recirculation, entraining flue gas into the fuel gas. Since the flue gas in this region of the process heater is normally only 2-4% oxygen, it is largely inert and diluting the fuel gas in this manner delays the combustion reaction. Combustion air is introduced inside the burner tile and reacts with the fuel gas at the top of the tile, forming the flame stabilisation point. However, since the fuel gas has already been diluted with entrained flue gas, the overall reaction rate is slowed and the overall peak flame temperature is reduced. This results in significantly less thermal NO_x production compared to a

conventional burner. One example of a proven implementation to reduce NO_x through this method is the Zeeco Free-Jet Ultra-Low NO_x Burner. Retrofitting burners of this type can make existing process heaters meet stringent emissions requirements, reducing capital outlays necessary for new equipment.

Another critical process every refinery, petrochemical or chemical plant needs to perform regularly is an inspection of any flare systems. Each of these facilities uses one or more flares to safely dispose of waste, off or upset condition gases. Smart, thorough inspection of each flare system is a critical component in the performance audit of a plant.

Flare stack visual inspections

In a refinery, the flare system serves as a safety release device, and is usually the last system available for maintenance and one of the first required back in service after a plant turnaround. Due to their high elevation and intense heat radiation, flare systems can be difficult to inspect while in operation. Visual inspections must be made in order to help quantify the flare's maintenance status and possible parts and/or services needed well in advance of a scheduled turnaround due to such a short maintenance window. It is important the flare operates as designed at all times to ensure the safety of the refinery's process equipment.

In-service flare inspection

In the past, a refinery's standard for flare system maintenance scheduling was

based upon time in service rather than detailed inspection and did not take into account the actual mechanical condition of the flare equipment at the minute level. If flare operational issues were visible from a ground level inspection, maintenance time would be built into an upcoming turnaround schedule. When plant operators would conduct the flare investigation during the outage, addressing the maintenance issues previously observed would typically reveal additional problems. Discovering maintenance issues in this manner usually leads to extended plant downtime. Facilities were essentially forced to have expensive various flare parts on hand, or plan for a replacement of their flare tip at every outage to avoid extended downtime during turnarounds.

A visual in-service inspection from the air is an alternative solution that can detect problems in the flare system that are not identifiable from ground level. Correctly and completely identifying any flare system issues helps to define the turnaround scope of the flare early enough to procure the necessary equipment and/or schedule the time needed for repairs during an outage. One main challenge during an in-service inspection is maintaining the correct vantage point to safely view the upper flare system components while the flare is in service.

One in-service inspection concept included the use of a professional photographer in a manned helicopter. This inspection can only be performed

when the flare unit is in stable operation and weather conditions are favourable. In case of an emergency situation, the manned helicopter is equipped with a direct radio link to the plant's operations control room to communicate any plant upsets, allowing the helicopter adequate time to evacuate the flare area. Depending on the flare system, an inspection of this type can take 30 minutes to two hours of helicopter airtime. It is important that the photographer is familiar with what areas of the flare need to be photographed for evaluation. After the photos have been taken, the owner would need to interpret the photos, usually in consultation with the original equipment manufacturer (OEM). The evaluation of all photos and videos while the helicopter remains on-site is

required to determine if further shooting is needed to look at issues identified in the first set of photos. A formal flare inspection report is available within weeks and provides enough time for the maintenance groups to prepare for any upcoming plant turnarounds.

A second type of in-service flare inspection is by remote-control helicopter. The remote-control helicopter inspection method uses real-time video to visually identify any issues within the flare system that may require maintenance. The main areas of focus for visual flare inspections are the flare tip and upper structure (see Figure 4).

These areas are impossible to observe properly and inspect from the ground. The upper structure includes the ladders, platforms, flare stack, supporting structure, guy wire lugs and connections, aviation lighting fixtures and cabling. Any ancillary flare components such as the exterior of the molecular seal, steam piping, pilot gas piping, ignition gas piping and any retractable systems like the pilots and thermocouples should also be inspected. The longest lead item is typically the flare tip itself and therefore the tip should be the primary focus of the in-service inspection. The flare tip inspection checks for any indication of material failures including welds on steam manifolds, welds on the flare tip body, the muffler, the pilots and, if applicable, the internal steam/air tubes. Visual indication of internal burning could indicate a steam/air tube internal weld failure, insufficient



Figure 4 Flare tip upper deck and structure as observed during visual inspection

centre steam or capping of the flare.

On flare tips with internal steam or air tubing, it is important to note any signs of steam capping. Steam capping is the result of a large amount of steam being supplied to the upper steam ring while not enough steam is provided to the lower steam ring. The visual indication will be evidenced by discolouration of the flare body and/or muffler area and can be seen as a hot spot in low lighting. Repeated operation of the flare with internal burning will severely damage the flare body and internal steam/air tubes.

In-service inspections should also include the pilot gas connection to the pilot gas manifold. This area is prone to piping failure if too much pipe stress is introduced onto the pilot mixer. Piping supports, guides and hangers need to be inspected for proper alignment and bolting. This is important on the pilot gas, ignition lines and the steam lines. In the steam piping, the heat-affected components of the flare tip can be prone to weld failure caused by a lack of cooling steam or water hammer from wet steam. A commonly overlooked area in inspections is steam piping insulation and should be considered when conducting any flare inspection.

It is important to note that if the flare system is designed with ladders and platforms these will need to be visually observed during the in-service inspection so that problems can be identified and corrected

before personnel are allowed access. If the system is a structure-supported flare, the structure itself should be inspected for damage or missing bolting. If the flare is a guy wire-supported system, the attachments to the flare stack and the lugs should be observed in the inspection. In a self-supported flare system, any flanged connections in the flare stack should be inspected. Visual inspection of the flare stack itself for indications of corrosion or internal burning will help determine the turnaround maintenance scope and ensure that parts and scheduling are accurate. A careful and complete in-service inspection reduces downtime during turnarounds by identifying long lead-time items and accurately forecasting the timeline necessary for flare system maintenance during the turnaround.

Out-of-service or turnaround inspection

Although most external components can be visually inspected, there are still several internal components that must be examined when the flare system is out of service. These components include the flare system knock-out drum, molecular seal and liquid seal drum. The OEM specifications require internal components inspections while the flare is out of service. The steam/air tubes, and the knock-out and liquid seal drums should be examined for any weld failures, fouling and internal corrosion issues. The results of each of these internal

inspections can significantly impact a flare system outage and could result in additional plant downtime. API standards 510 and 570 should be used as criteria in developing out-of-service inspection details.

For both flares and burners, performance audits should be performed on a regular basis by qualified combustion experts to ensure existing equipment is operating safely at peak efficiency. Inspections can, and should, take a variety of approaches including visual inspections, data evaluation, in-service and out-of-service review, in-depth component checks and operator/control systems reviews. Often, combustion engineering and technology companies, including Zeeco, will provide an on-site review of a facility's equipment at little to no cost so that operators can have third-party evaluations to consider when planning for turnarounds, retrofits or revamps.

Jim Smith is Manager of Aftermarket Operations with Zeeco, Inc. He holds a BS in petroleum engineering from Oklahoma State University. *Email: Jim_Smith@zeeco.com*

Jessie Chambers is the Senior Applications Engineer of Zeeco, Inc. He holds several co-invented patents, and has troubleshooted for the combustion industry worldwide for more than 20 years. *Email: Jessie_Chambers@zeeco.com*

Keith Wade is North American Ethylene Market Manager with Zeeco, Inc. He holds a BS in petroleum engineering from Texas Tech University. *Email: Keith_Wade@zeeco.com*