THE PROBLEM WITH TRAMP AIR

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Process heaters are typically designed to operate with a negative pressure (draft). Most process heaters are natural draft, which means there are no fans or blowers because the air for combustion is pulled in by the negative pressure inside the heater. The draft in a heater is directly related to the difference in pressure between the inside and outside of the heater. Under normal operating conditions, the pressure inside the heater is significantly lower than outside the heater due to the hot combustion products which are very low density and buoyant. As they rise in the firebox, they create a negative pressure or draft. The draft in a heater is a function of the firebox temperature, the height of the stack, and the location in the firebox. Since the firebox is less than atmospheric pressure, the combustion air is pulled into the heater through the burners. The draft is the highest (most negative) at the floor, which is typically where the burners are located. This maximises the amount of air that can be pulled into natural draft burners.

Not only will air be pulled through open burner air registers, but it will also enter the firebox at any location that is not adequately sealed. This includes, for example, open air registers on burners that are out-of-service, tube penetrations, open sight ports, leaky explosion doors, and cracks in the heater shell. Most heaters have been in service for many years, which means that it can often be very challenging to seal up unwanted air leaks. It is not unusual to find that levels of excess O_2 anywhere from 1 to 3% or higher enter the heater through leaks in the convection section. Air that enters the heater at locations other than the operating burners is often called 'tramp' air. Too much tramp air leakage can be very detrimental to process heater operation and potentially dangerous.

Effects on operations

Tramp air can impact the heater operation in many ways, each of which is briefly considered below, including how they impact the operation of the heater.

Reduced heater efficiency

Air that leaks into a heater is cooler than the flue gas. Any air above that needed for combustion is absorbing energy, some of which is in the flue gas leaving the radiant firebox. The higher the flue gas temperature, the higher the sensible energy loss due to the tramp air leakage. This means a portion of the fired duty is being used to heat this tramp air instead of heating the process. This reduces the energy efficiency of the process. It also indirectly increases pollution emissions because the heater consumes more energy than needed when the thermal efficiency is reduced due to tramp air.

Figure 1. Air leaking around a process tube and header box.

Figure 2. Sealed sight port design.

Increased NO_X levels

Tramp air leakage may increase NO_X levels. Since air is cooler and heavier than the flue gas, some of the tramp air will actually fall to the floor of the heater. This can increase the local concentration of oxygen near the burner gas tips. This can result in higher amounts of NO_X formation because NO_X increases with excess O_2 during typical operating conditions. If a very large amount of excess air is used, NO_X levels on a concentration basis actually decline because of dilution and lower flame temperatures. However, the thermal efficiency also declines with higher levels of excess air, which again indirectly increases NO_X as more energy is needed per unit of production.

High carbon monoxide and combustibles

Tramp air may produce high levels of carbon monoxide (CO) and possibly even combustibles. Depending on where the tramp air is coming into the heater, the measured excess O_2 levels, which should be measured at the top of the radiant section (also known as the arch), may be within target levels and yet the burner flames may be starved for air. Another possibility is that tramp air infiltration near the excess O_2 sampling location can produce a false high O_2 reading. This means there is actually less excess O_2 in the heater than is measured. Either of these conditions can result in the burners being operated with a reduced amount of air, which can lead to increased levels of CO. If the flames are very starved for air, combustibles may also be high, which should not happen under proper operating conditions. While some of the CO and combustibles may be consumed as tramp air leaks into a heater at higher elevations, they are not nearly as efficiently consumed as in the flame due to much lower temperatures in the firebox compared to the flames.

Afterburning in the convection section

Possible afterburning in the convection section is related to high levels of CO and combustibles. Because tramp air can result from the burners being starved for air, the flue gas entering the convection section may contain high amounts of CO and combustibles. The convection section is normally where much of the tramp air enters a heater. This is due to the many tube presentations and the presence of header boxes. The oxygen in the tramp air results in oxidation of the CO and combustibles, which increases the temperature in this part of the heater. Combustion in the convection section can damage the finned tubes, tube supports, and tube sheets. It will also likely reduce the thermal efficiency as there may not be enough residence time in the convection section to transfer as much of the heat before the combustion products exit the stack. This can result in high flue gas temperatures, which is an indicator of reduced thermal efficiency.

Flame impingement on the process tubes

If the burners are short of air, then the flames tend to get soft and lazy. Flames that have lost some of their mixing energy are influenced more by the flue gas currents in the furnace. This condition can lead to the flames impinging on the process tubes. Additionally, flames that are starved for air tend to get longer due to the lack of air needed to complete combustion. Those longer flames may impinge on the convection section tubes. Prolonged flame impingement can lead to process tube damage ranging from coking inside the tubes, to tube leaks, and to the worst-case condition of a tube rupture.

Unstable flames

A final detrimental effect of significant tramp air leakage is also potentially the most dangerous, which is unstable flames. If the process burner flames are lacking enough combustion air, the flames could be operating near the upper flammability or fuel rich limit. Operation near that flammability limit is dangerous because if the flames get close enough or go above that limit, they could become unstable and even flame out if there is not enough oxygen for combustion. Unstable flames may bounce or pulse ('huff'). If a flame goes out in a heater that is above the ignition temperature of the fuel, the flame could be reignited when sufficient air is found such as by tramp air leakage. This re-ignition could lead to equipment damage and personnel injuries.

Figure 3. Engineered tube seals (image courtesy of Thorpe Corp., Houston, Texas, US).

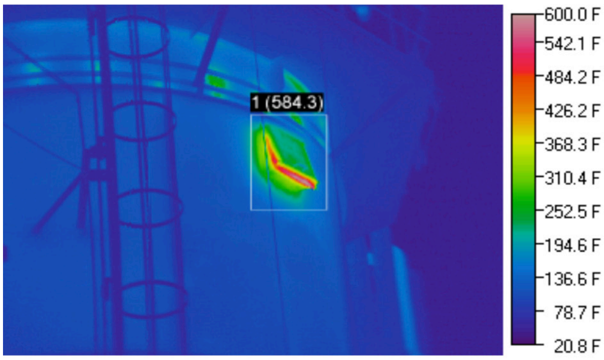

Figure 4. Thermal image of a partially open explosion door.

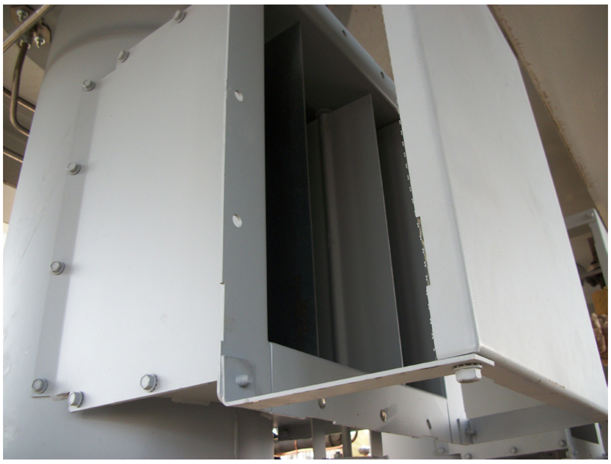

Figure 5. Burner out-of-service with an open air damper.

Corrective/preventive actions

The first step in reducing the amount of tramp air is to locate areas where air is undesirably entering the heater. The most common places for air to leak into a heater are: the convection section; header boxes; process tube penetrations (Figure 1); partially or fully open sight, access, or explosion doors; and burners out-of-service with the air registers open.

Performing a visual inspection around the heater will normally show many areas that need attention. Some of the common materials used to seal around tubes and sight doors are ceramic blanket, engineered tube seals, braided rope gasket, and high temperature (500°F) silicone sealant. If the heater casing has developed cracks, these should be welded closed to prevent air infiltration.

Sight doors and inspection ports should be closed when they are not being used. The heater should never be operated with the sight doors open to get enough air for combustion. There are some sight port designs (Figure 2) that are sealed with a shutter that opens inside the heater which dramatically reduce tramp air leakage.

When a heater is down for maintenance, smoke testing is a common way to determine where air is leaking into a heater. This can be done with smoke bombs placed inside the heater or with smoke cartridges placed in a blower inlet. The stack damper should be closed so that a slight positive pressure is created inside the firebox to force smoke out of the heater at the leak locations.

Tube penetrations can be a large source of tramp air. Engineered tube seals (see Figure 3) eliminate tramp air from getting into the heater around the tubes while also allowing the tubes to grow as the temperature increases.

Explosion doors should be sealed to eliminate tramp air. Figure 4 shows a thermal image of an explosion door that was not well sealed. This can allow a significant amount of tramp air leakage.

It is not uncommon to find burner air registers open on burners that are not in operation (see Figure 5). This may be an oversight or for convenience when the burner is brought back into service. However, open air registers on burners that are out-of-service can be a very large source of tramp air leakage because the burners are often located where the draft is the highest. Note that there will still be some air leakage through closed air registers as the seal is not designed to be air tight.

The effort and labour put into eliminating tramp air from the heater can result in better efficiency, higher yields, improved flame quality, lower NO_x and CO levels, lower tube temperatures, and improved safety. As far as possible, tramp air leaks should be minimised or eliminated. The reduction in fuel costs alone will normally far offset the cost of the inspection and repairs.