Process Burner Tiles

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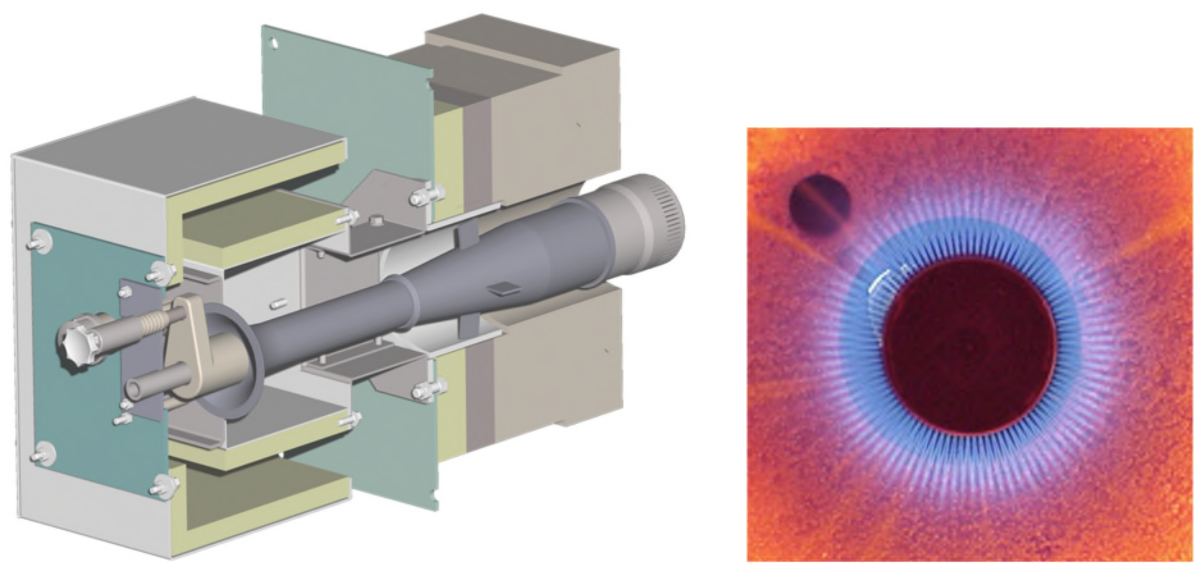
Introduction

Many people think that the burner tile is simply a piece of refractory or firebrick. Nothing could be further from the truth! The burner tile is the “heart” of the burner. Tile that has not been poured correctly, installed correctly, or that has not been properly maintained can have a serious impact on burner performance.

Burner tiles, sometimes called quarls, are an important component in burners (Baukal, 2003). Tiles are typically made out of some type of ceramic and may serve many different purposes. One common purpose is to protect the metal components inside the burner from the heat in the combustion chamber. Another is to shape the flame. Another purpose for some tiles is to radiate heat; these burners are commonly called radiant wall burners (see Figure 1) as they are normally mounted on the side wall of a heater (Venizelos et al., 2003).



(a) (b)

Figure 1 Radiant wall burner: (a) cutaway, (b) photo of burner radiating in a furnace.

There are many potential issues related to the tile. For example, if the ceramic used to make the tile is not properly cured, the tile may be damaged during start-up. If the burner tile is not properly installed, this can adversely affect the operation and performance of the burner including the emissions. If a burner tile is damaged, burner performance may suffer. The furnace temperature and composition of the combustion products can affect the materials used in the tile. Burners fired downwardly (see Figure 2), for example in a down-fired reformer, require special mounting considerations. If the tile is oversized, the burner may not operate correctly because the air-fuel mixing and flame shaping may be adversely affected. If the tile is undersized, the pressure drop may be too high and the firing capacity reduced.

Figure 2 Downfired burners in a reformer furnace.

This paper will discuss these elements in detail including photos of both good and bad applications of each of the six Ms of process burner design as applied to tiles. It will also discuss general fabrication, installation, and troubleshooting issues related to burner tiles.

6 Ms

There are six Ms used to describe general burner design principles (Waibel et al, 2013) which can be applied specifically to the tile. These are discussed next.

Meter the Fuel and Air

The tile helps meter the air flow. The tile throat is sized to allow a certain amount of air into the combustion reaction at a given pressure drop (see Figure 3). If the throat is too small or too large, the burner will not operate with the required amount of excess air. If the tile is too small, then not enough air can be pulled through a natural draft burner or the pressure drop and power requirements will increase in a forced draft burner.

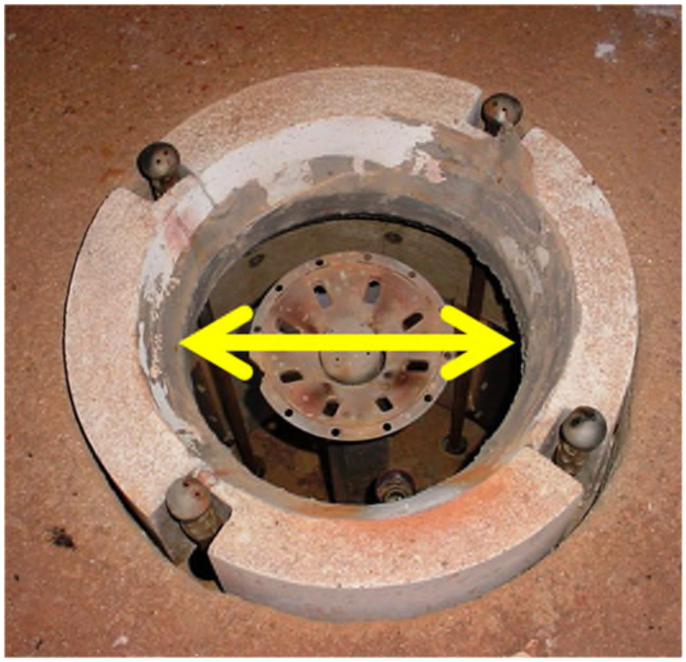


Figure 3 Burner tile throat which creates an orifice to meter the combustion air flow.

It may be tempting to oversize the tile throat in case the burner firing rate needs to be increased at some point in the future. However, an oversized tile reduces the turndown in a natural draft burner. For example, if the tile is sized for 10 MMBtu/hr burner capacity and has a 5:1 turndown, then its lowest design firing rate would be 2 MMBtu/hr. If the actual operating conditions today require only 5 MMBtu/hr, then the effective turndown is 5:2 or 2.5:1. Oversizing the tile for a possible firing rate of 10 MMBtu/hr is also detrimental to burner performance because the burner is designed to work optimally at 10 MMBtu/hr. If it is fired at half rate, it may not for example, get as low emissions as it would have at the full design rate.

Mix the Fuel and Air

Proper mixing of the fuel and air is critical to process burner operation. Burner tiles are often used to help mix the fuel and air using a variety of techniques. One is to have ledges inside and/or at the top of the tile (see Figure 4). These ledges are bluff bodies that promote mixing. For example, a ledge at the top of a tile can be used to cause the combustion air inside the tile and the fuel on the outside (from secondary or staged fuel injectors) to form vortices on the ledge to promote mixing. This may be desirable to delay mixing until the end of the burner to prevent flashback. It may also be desirable to reduce NOx emissions because of the delayed combustion which minimizes hot spots in the flame.

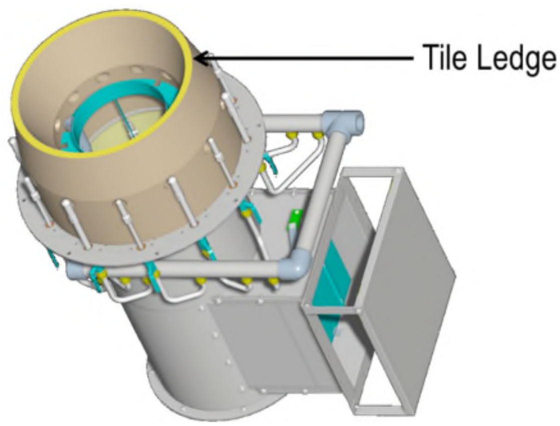


Figure 4 Burner tile with a ledge at the outlet.

The holes through the side of some tiles help mix fuel and air. Some burner designs have fuel injectors or tips outside the tile. Those tips may inject fuel up along the outside of the tile to delay mixing for NOx reduction (Baukal and Bussman, 2013). Those tips may also inject some fuel through holes in the side of the tile into the main or primary flame zone. Those holes may be straight through the tile or they may be at an angle to impart some swirl (see Figure 5) to the flame. In either case, they are used to help mix the fuel and air.

Figure 5 Burner tile with angled holes to produce swirl.

Figure 6 shows a burner tile with four secondary air outlets built into the tile. The primary air comes through the middle of the burner throat. The purpose of the secondary air is for staging to reduce NOx emissions.

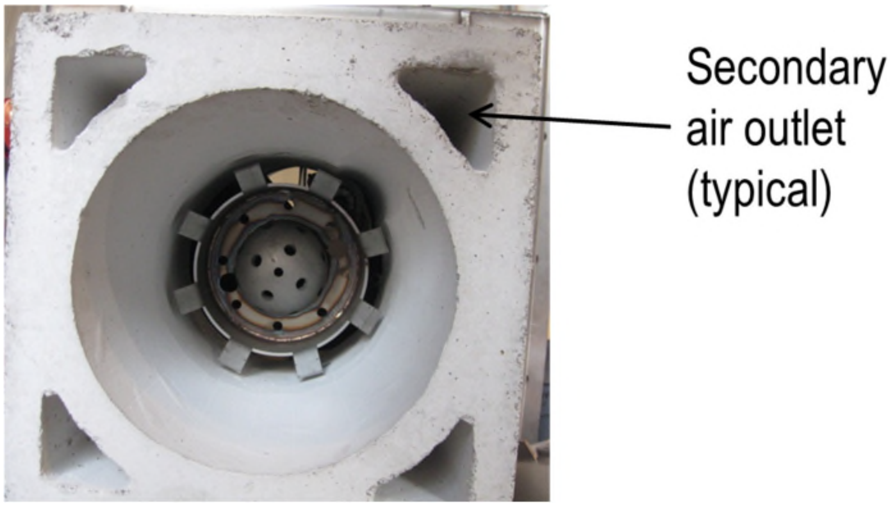


Figure 6 Burner tile with 4 secondary air outlets.

Maintain Ignition

An important safety consideration in any combustion system is to maintain ignition when fuel is flowing. Otherwise, that fuel may ignite somewhere else that could prove to be dangerous.

The tile ledges may be designed to help anchor the flame and sustain combustion as previously described for mixing. Many process burners are diffusion or raw gas (also known as nozzle-mix) burners which means the fuel and air are mixed at the burner outlet. This is in contrast to premix burners which mix some or all of the fuel and air inside the metal parts of the burner. While there are some advantages of premix burners, a significant disadvantage is the possibility of flashback. The tile used in raw gas burners is specifically designed to mix the fuel and air at the outlet to anchor the flame throughout the design firing rate range.

The visible flame may start a short distance away from the tile, but it should not be a very long distance, regardless of the firing rate. If the gap between the end of the tile and the start of the visible flame is too long, then the condition is referred to as a *lifted flame*. Lifted flames are not desirable as they are much more susceptible to lifting off completely, causing the flame to be extinguished. If fuel continues to flow to that burner and components in the heater, such as the burner tile or heater walls, are above the autoignition temperature for the fuel/air mixture, then there is likely to be re-ignition of the mixture which can lead to an explosion. An obvious sign of an unstable flame is pulsing or huffing where the flame is bouncing up and down. This is a very dangerous condition that must be corrected immediately.

Figure 7 shows an example of a burner tile with a specially-designed edge, that has the appearance of teeth, for flame stabilization.

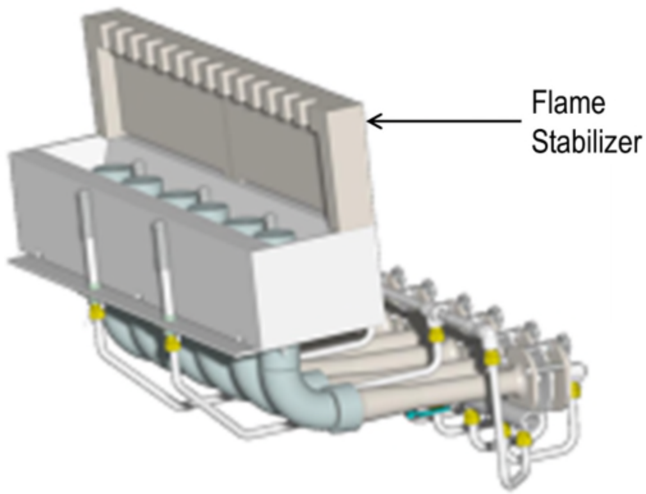


Figure 7 Burner tile with a “teeth” for flame stabilization.

Another important function of the tile when firing liquid fuels is to produce a hot chamber where the liquid fuel is atomized. The higher temperatures help promote and maintain liquid vaporization. Some burners are designed to recirculate hot combustion products inside the tile to aid in the vaporization. These tiles are sometimes called *regen tiles* which is short for *regenerative tiles* (see Figure 8).

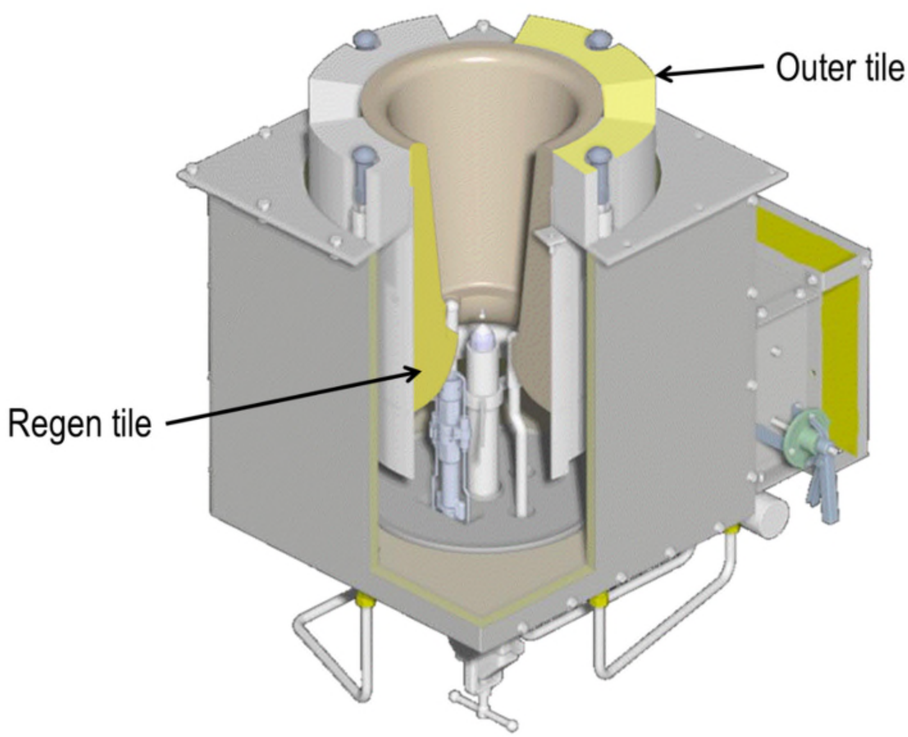


Figure 8 Example of an inner regen tile for a combination burner capable of firing on gas or liquid fuel.

Mold the Flame

The shape of the tile outlet helps determine the cross-section of the flame: round tiles make round flames (see Figure 9) and rectangular tiles make rectangular flames (see Figure 10). These are by far the two most popular tile cross-sections for process burners (Baukal et al, 2003).

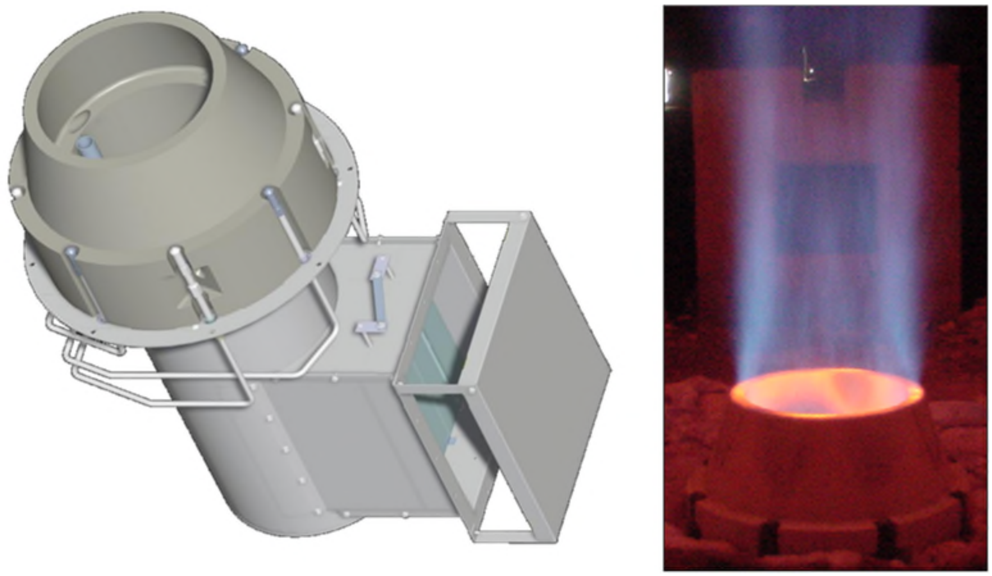


Figure 9 Burner with a round tile.

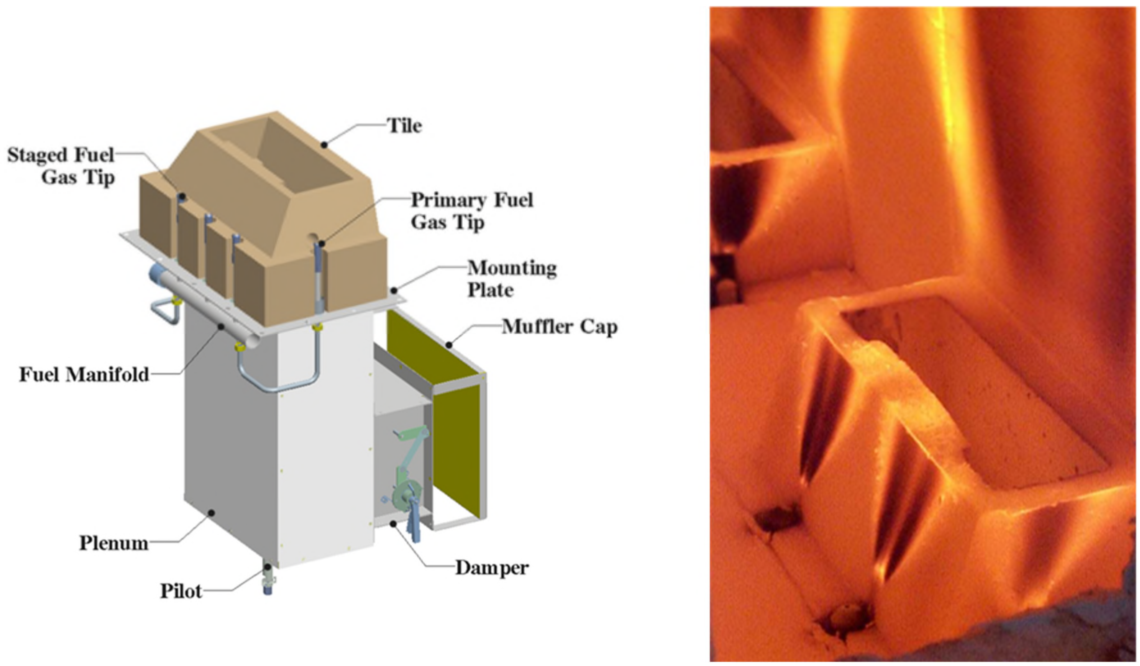


Figure 10 Burner with a rectangular tile.

Minimize Emissions

In some burner designs, the tile helps reduce NOx. Figure 11 shows a burner tile where secondary fuel tips are in the tile wall. The purpose is to stage the secondary fuel into the flame to reduce hot spots which reduces NOx emissions.

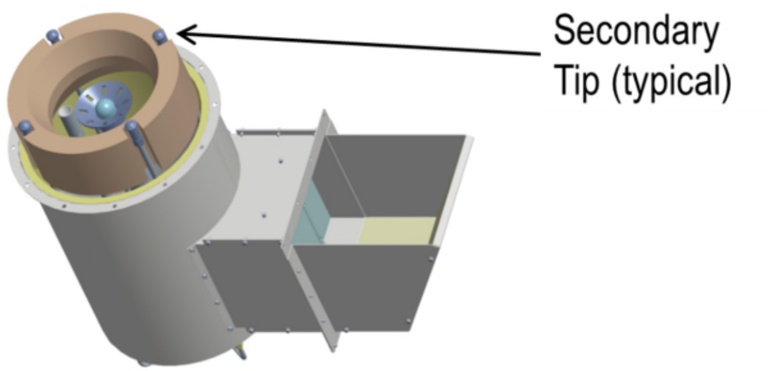


Figure 11 Burner tile with secondary fuel tips in the tile.

Figure 12 shows an advanced burner tile designed to help minimize NOx formation. The tile has two different alternating slopes with dividers in between. Primary tips inject some fuel through the tile into the primary flame zone inside the tile. Those primary tips also inject some fuel up along the outside of the tile. The staged tips only inject fuel up along the outside of the tile. The overall purpose of the design is to minimize the amount of fuel in the primary zone and maximize the amount of fuel in the secondary flame zone. This fuel staging reduces hot spots in the flame which minimizes NOx formation.

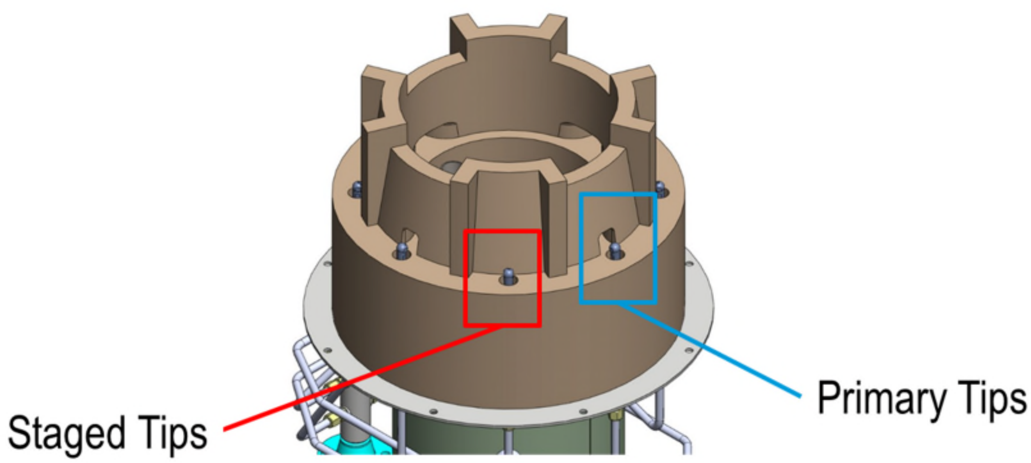


Figure 12 Advanced burner tile design to help minimize NOx formation.

Another important aspect of this tile design is the holes going through the side of the tile. In addition to the high speed fuel from the primary tips flowing through those holes, furnace gases are also entrained by the fuel and flow into the primary flame zone as well. That entrainment of furnace gases helps to homogenize the flame temperature and reduce flame hot spots which helps minimize NOx. The size of those holes is important. If the holes are too small, less furnace gas is entrained and more NOx is produced. If the holes are too big, too much furnace gas could be entrained which could cause flame instability.

Minimize Costs

While lots of tile shapes could be made, round and rectangular are by far the most common shapes for process burners. They are typically the cheapest to make because the tile molds are simpler to build. Those tile shapes are also usually stronger because they have fewer sharp changes in direction that produce corners which are more likely to crack.

Tile Fabrication

Proper tile fabrication is critical to burner performance. Obviously the shape must be correct (see Figure 13) but the actual fabrication process is important as well. For example, if the ceramic is made from a water-based slurry, it must be slowly dried to prevent steam from rapidly forming inside the mold which could cause the ceramic to spall apart. If the tile is not properly dried prior to installation in a heater, a rapid start-up could also cause steam formation in the tile to spall the refractory. There are chemically-base ceramic materials such as Thermbond which do not need to be slowly dried because of the lack of water in the ceramic.

(a) (b)

Figure 13 New burner tiles: (a) rectangular, (b) round

Tile Installation

Burner tiles will not operate properly if they are not installed correctly (Johnson et al., 2013). Figure 14 shows a burner tile consisting of four segments or sections. The segments make it easier to lift the tile into position without the use of a forklift. It is important that enough, but not too much, mortar is applied between the segments. The burner drawings and manual should be followed to make sure the proper tile throat area is maintained.

Figure 14 New burner tile with four segments.

Figure 15 shows a tile that was not properly aligned where the top tile segment needs to be moved upward to achieve the proper tile opening. That tile will not allow the design combustion air flow rate because of the tighter flow area. Also, the metal diffuser for that burner is not centered in the tile.

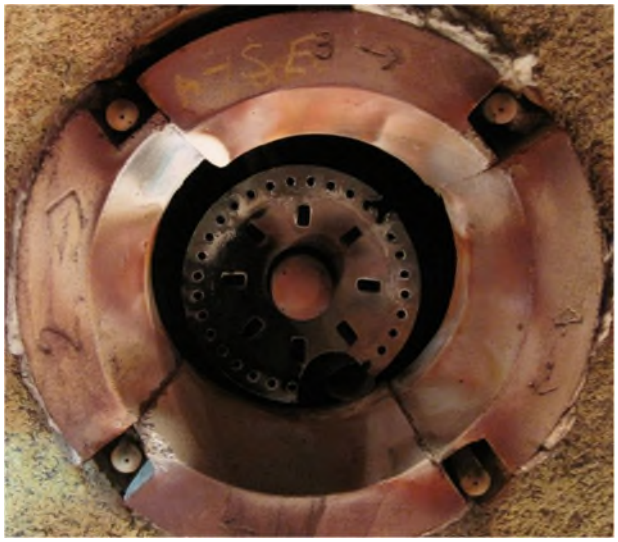


Figure 15 Burner tile segments improperly aligned.

Figure 16 shows a burner tile that was installed upside down. Burner performance suffered as a result.

Figure 16 Burner tile installed upside down.

Tile Maintenance

Tile maintenance is relatively simple – make sure any damaged tiles are repaired or replaced. Figure 17 shows a cracked burner tile that is possibly reparable but probably should be replaced. Figure 18 shows some tiles that have been damaged beyond repair.

Figure 17 Cracked burner tile.

(a) (b)

Figure 18 Damaged (a) regen tile, (b) burner tiles.

Figure 19 shows a tile that has been damaged by vanadium attack where the source of the vanadium was the liquid oil fuel.

Figure 19 Vanadium attack on a tile.

Figure 20 shows a tile that has been coated with catalyst. That coating reduces the burner outlet which reduces the air flow through the tile for a given draft level. Some cracks in the tile are evident as well.

Figure 20 Catalyst build-up on a regen tile.

Troubleshooting

Burner tiles usually degrade over a period of time, although they can become damaged suddenly as well. For example, refractory falling out of the roof onto a tile can cause damage. Operators should examine the burner tiles on a regular basis during heater operation. Burners can be operated with damaged tiles, as long as the damage is not too severe. A much closer inspection should be made during maintenance turnarounds. Typically, turnarounds are far apart so any damaged tiles should be repaired or replaced during turnarounds as there may not be another chance to do so for some time.

Conclusions

The burner tile is an important and integral part of a process burner. It may impact the fuel/air mixing, burner stability, flame shape, and pollution emissions. It must be properly manufactured, installed, and maintained for optimum performance. There are a variety of possible tile problems such as cracking, buildup, chemical attack, and improper installation. Most of these are easy to detect and should be corrected as appropriate.

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