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Burner Operation and Maintenance

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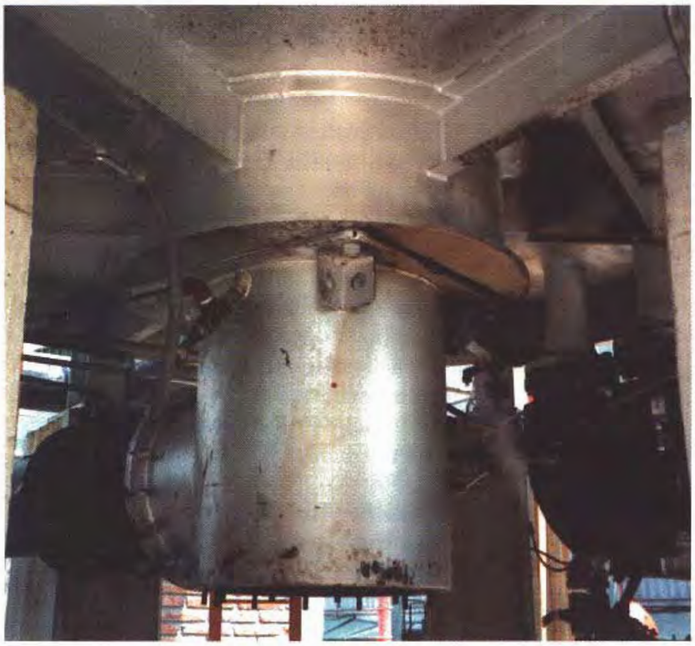
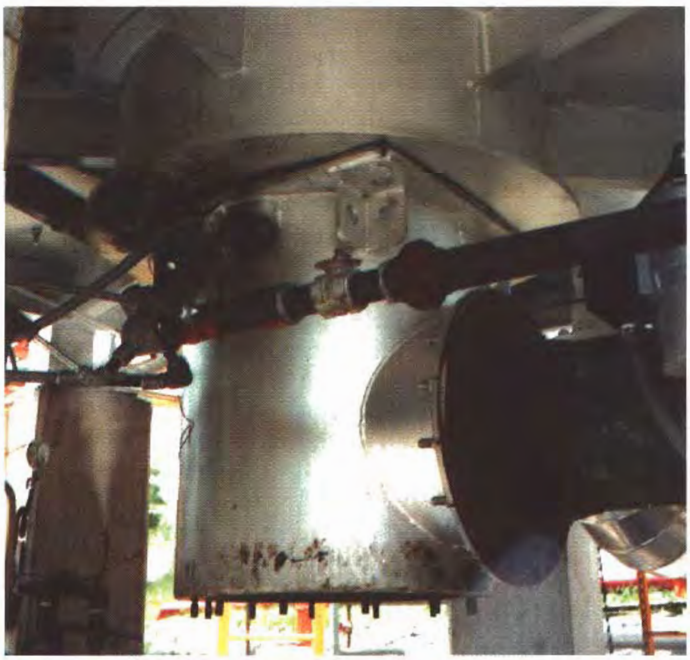
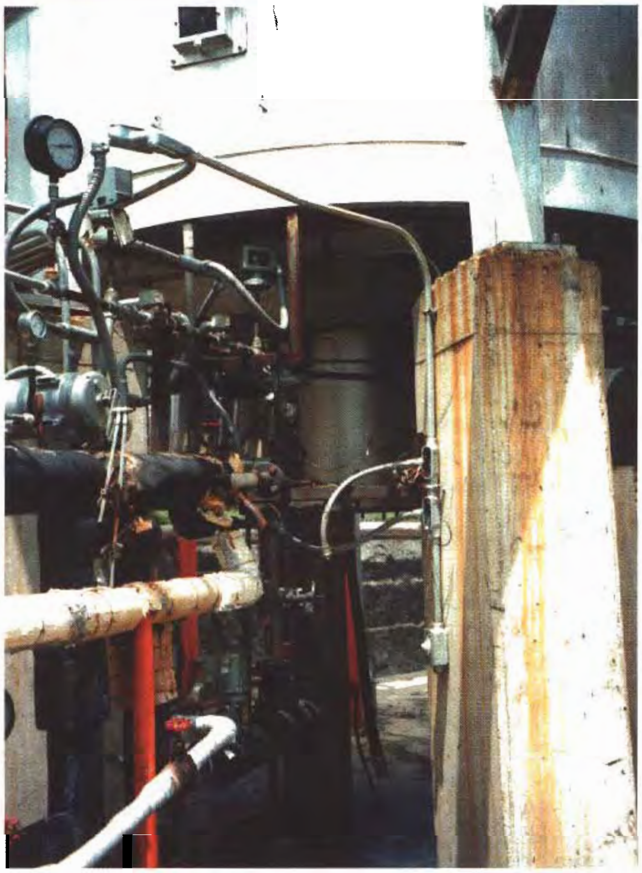
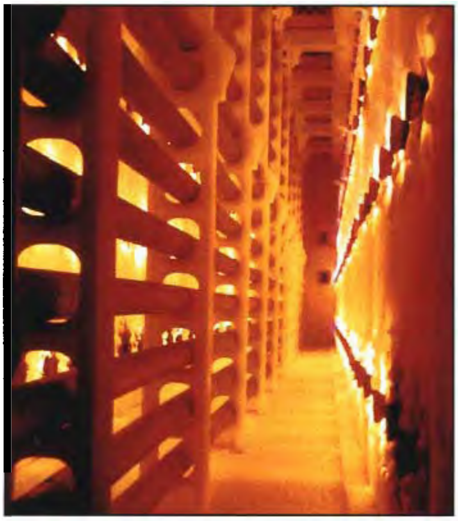






"Use this real-world advice to improve the reliability of burners ..."

Forced draft combination gas/oil burner in large chemical plant in Mexico



KEEPING BURNERS IN FIGHTING TRIM

Use this real-world advice to improve the reliability of burners in gas or oil combustion units

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A great number of reactions and unit operations in the chemical process industries (CPI) depend on a reliable source of heat. While the heat may be conveyed by heat exchangers and transfer fluids, air convection or radiation, the source of the heat is usually some type of boiler or furnace, burning a combustible fuel. The critical mechanical component in this combustion process is the burner. And while the technical discussion of burners in recent years has been dominated by air pollution control, the proper operation and maintenance of burners is vital to keeping CPI processes functioning.

A burner is a device that controls the mixing of air with a combustible fuel to produce a stable flame pattern in a boiler, furnace, heater, incinerator, process unit, flare or thermal oxidizer. A burner may be fired with a conventional fuel (gas, liquid or solid), gaseous or liquid waste, or any combination of combustibles. This report will be limited to burners fired with gas, oil or the combination.

Whatever the fuel may be, it is important to consider this fact: *Only the volatile vapors in any fuel are combustible.* And those combustible vapors must be freed from their liquid or solid source, vaporized and mixed with oxygen to support a flame.

Burner draft, indicated in inches (or millimeters) of water column, i.e., 0.2 in. w.c., is the difference in pressure between the inside of a heater and ambient air. There are three types of draft: *natural, induced* and *forced.*

Hot gases rising in a chimney or stack create a negative condition (natural draft), capable of pulling in the air required for combustion. Induced draft is created by using a fan on the exhaust side of a furnace to produce a negative pressure in a burner. Forced draft, created by using a fan on the fuel-inlet section of a burner to exert a positive pressure, is commonly used with heat-recovery systems.

Hybrid for critical applications

Special applications (i.e., thermal oxidizers or fume incinerators) may require a combination of forced and induced draft to overcome pressure losses in the quenching and scrubbing sections of these pollution control systems.

For other critical applications where process units cannot be shut down, forced-draft burners with natural-draft backup are required. The natural-draft backup is usually 50%–60% of the full capacity of forced draft operation. Draft values will vary depending upon the installation. Typical values are listed in the table on p. 68.

Combustion air: How much?

The combustion air required to burn a fuel completely without any excess (stoichiometric) air is based on the quantity of combustibles in the fuel. Approximate quantities of combustion air required for gas and fuel oils are:

10 ft^3 of air	1ft^3 of natural gas
1,300	1 gal of No. 2 fuel oil
1,450	1 gal of No. 5 fuel oil
1,500	1 gal of No. 6 fuel oil

There are three types of combustion air: *primary, secondary* and *tertiary.* Primary (inspirated) air is commonly used with small-capacity gas burners and pilots. The primary air is pulled in by fuel-gas pressure to provide a uniform and stable flame. Burners of this type tend to be naturally low in the emission of nitrogen oxides (NOx).

Secondary air for gas-oil burners is introduced through burner air registers by means of natural, induced or forced draft. When required, tertiary (third stage) air can be introduced downstream of the main burning process. Tertiary air is commonly used for air heaters, acid gas burners or for

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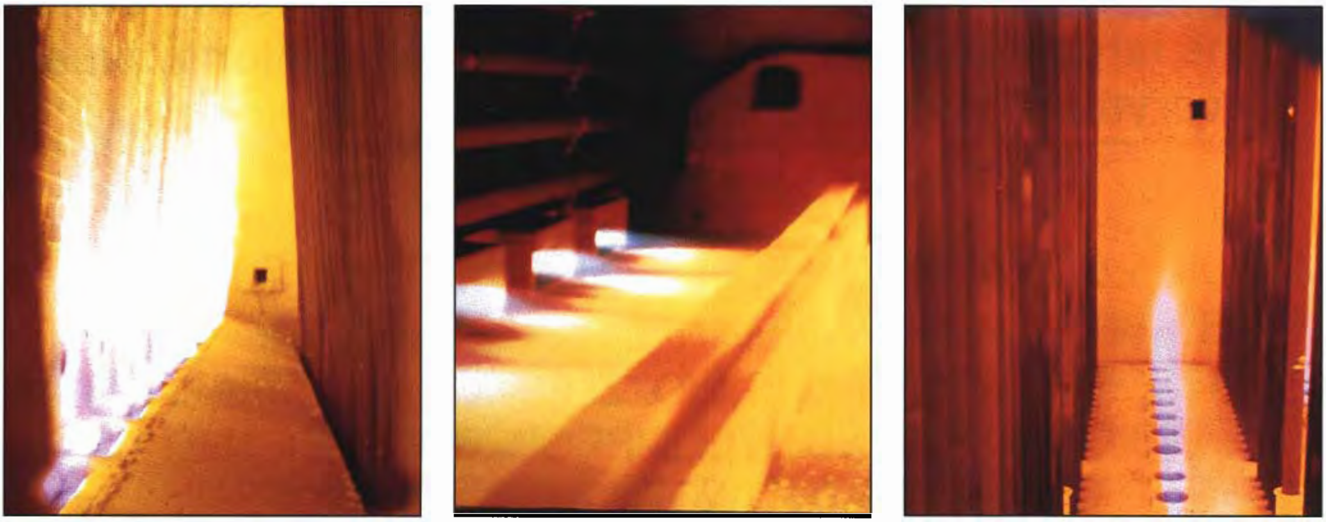

FIGURE 1. These burners—all combusting natural gas—are installed either vertically (for reformers) or horizontally (for cabin heaters)

staged air burners to reduce NOx and other harmful pollutants.

Fluegas analyzers are used to monitor oxygen (i.e., excess air) in the combustion products. One type of O_2 analyzer passes the gas through a magnetic field. Oxygen, being susceptible to magnetism, is affected by the field, while other constituents pass through unimpeded. The other type of fluegas analyzer consumes oxygen by burning a reference fuel (hydrogen) on a wire filament. The temperature rise of the core is proportional to the amount of O_2 in the sample.

One warning about fluegas sampling lines: All connections must be tight. Samples are drawn under a partial vacuum. If there is a leaking connection, even an oxygen-starved process unit could be misdiagnosed.

An insufficiency of oxygen is also a problem. It will result in incomplete combustion, excess fuel consumption and a lower heat release. It will also create carbon monoxide (CO); raise the temperature of the refractory; and eventually increase maintenance costs.

Too little air increases the possibility of smothering burner flames and releasing raw fuel into a hot firebox. If sufficient air is subsequently provided, the end result could be an explosion.

Too much air reduces efficiency because the extra air must be heated to the stack outlet temperature. With boilers, for example, less heat will then be available for transfer to the tubes. An increase in excess air from 20% to 50% will consume 4% of the total heat released to raise that surplus air to a stack temperature of 800°F. (Heat loss due to 20% excess air is 2.5%; the heat loss for 50% is 6.5%, giving a differential of 4 percentage points.)

Watch for plugged burners

Problems common to both gas and oil burners include: Coking or plugging of burner tips; misdirection of flames; and corrosion or erosion of burner tips. All three conditions are self-propagating. Conversely, a burner in good condition with no external influences (i.e., a catalyst-laden fuel) is remarkably indestructible. Many process heater burners and some boiler burners are over 50 years old.

Gas fuels, especially those with one (or few) carbons, are functionally non-coking. However, any entrained liquids are prone to coke inside the burner tips. Oil fuels, by contrast, are highly prone to coking or plugging of the nozzles and small ports.

Outside influences, typified by refractory falling on a burner, can do severe damage, including bouncing flames onto surfaces which are not intended to withstand flame impingement (a blowtorch effect).

Gas problems usually result from the following:

1. Tip plugging or coking by liquid hydrocarbons and sulfur or sulfides. Tips may be drilled clear, but the ultimate solution is to remove the liquid and heat-trace the gas supply lines
2. Changing from light to heavy gas fuels, without a change in burner tip configurations
3. Reduction of excess air below optimum level
4. Reduction of primary air in the case or pre- or bi-mix burners
5. Erosion of precisely drilled burner tips by entrained solids
6. Corrosion of burner tips by entrained liquids or wet hydrogen sulfide (H_2S)

Oil problems usually result from the following:

1. Inadequate viscosity (usually the oil is not hot enough to produce the needed 150 SSU *at the burner,* not just in the fuel-oil feed header)
2. Insufficient pressure differential with steam-atomized fuel-oil guns
3. Poor (wet) steam quality. Dry steam without superheat is best
4. Tip plugging
5. Tip corrosion or erosion from catalyst fines in fuel oil

Poor atomization of combustible vapors will allow oil to dribble over parts of a burner, thus diverting flames, blocking openings and accumulating mounds of slop or coke. In the plenum of a preheated air burner, coke deposits will eventually ignite and create an uncontrolled fire. Other frequently encountered ignition problems include:

No pilot spark. Moisture, corrosion or particulates from the pilot gas stream can collect between the spark gap or insulator to "short out" the electrode. If the spark gap is too wide, arcing will occur at points of least resistance, and the pilot gas may not be ignited. Another reason for no pilot spark: The ignition transformer may not be receiving power, or it may be burned out.

No pilot flame. The pilot jet orifice, which is of roughly 1/16 in. dia., may be blocked due to particulates from the gas or from corrosion. If the problem is persistent, consider installing pilot-gas filters. Low gas pressure creates a mixture with too much gas for ignition. If the air inspirator is open too far, the pilot jet will inspirate too much air and prevent the pilot from being lit.

High combustion air flow can blow out the pilot flame. For forced-draft and induced-draft units, air blowers should operate at low-fire settings for startup to avoid diluting the pilot gas mixture.

A pilot is normally monitored with a flame rod or ultraviolet (UV) scanner to ensure proper operation. These monitors, which are able to sense the presence of flame, must be installed correctly. A flame rod must be properly positioned and have sufficient contact surface with the pilot flame to sense the ionized particles in the flame.

If a UV scanner is aimed too low, it will detect a pilot spark and prematurely interrupt the ignition sequence. If the scanner is aimed at the top of a pilot nozzle instead of directly into the nozzle, false readings may result from adjacent burners.

Unstable pilots and short pilot flames can result from partially blocked pilot-jet orifices, plugged filters, wet pilot gas, too much or not enough air, high chamber draft and high or low gas pressure.

Gas burner will not light. Too much air will dilute a gas beyond its lower flammable limit. Check damper and fan settings. Not enough fuel in the air-gas mixture on forced-draft and induced-draft units can be caused by low gas pressure or by obstructions in the gas header. Low gas flow is frequently the result of low fuel pressure. Plugged gas strainers will block flow even when the supply pressure is adequate. Other ignition problems are caused by improperly set interlocking valves, which restruct fuel flow; strainers in the wrong positions or orientations; and the previously cited short pilot flames.

Oil burner will not light. Oil must be properly atomized for stable combustion without any flame quenching. Low air settings or restrictions in the air header will create a mixture that may be too rich to burn or that may ignite but will produce a smoky flame. Other problems include improperly positioned oil guns out of pilot range; improperly set interlocking valves which allow steam or inert gas to enter the fuel line; and small pilot flames that miss the air-oil mixture.

CHOOSING AMONG BURNER OPTIONS

Application	Burner Type
Cabin, box or cylindrical furnace without preheated air. Negative pressure: 2–3 in. w.c.	1. Natural draft, 2. Forced draft: 0.2 in.-0.3 in. w.c. 3. Forced draft with natural draft backup: 0.5–1 in. w.c.
Cabin, box or cylindrical furnace with preheated air. Negative pressure: 0.1–0.2 in. w.c.	1. Forced draft: 2–3 in. w.c. 2. High intensity vortex: 6–27 in. w.c. 3. Forced draft with natural draft backup: 0.5–1 in. w.c.
Water- or firetube boiler 0.1 in. w.c. (positive) to 0.3 in. (negative)	1. Forced draft: 6 in. w.c. 2. High intensity vortex: 6–27 in. w.c.
Incinerator or flare	Induced draft: 0.2–6 in. w.c. (negative)
Thermal oxidizer	Natural draft: 0.2–0.5 in. w.c. (negative)

Depending on the type of application, there are preferred configurations of burner types

When oil and steam connections are reversed, the result is always no atomization

Pressure gages must be installed at the pilot and burner. For oil-fired units, a thermometer (for oil temperature) and a least one pressure gage should be at the far end of the oil header.

Why flames become distorted

No. 5 and No. 6 fuel oil or heavier tar-laden oils must be preheated before they will flow through pipes and before they can be properly atomized with steam or high-pressure air. Common problems include low steam or low air flow, or low oil pressure caused by partially blocked valves or plugged strainers. Adequate pressures must be maintained for the effective atomization of heavy oils and tars. Reversed oil and steam connections always result in no atomization.

Incorrect burner positioning will result in distorted flame patterns. The refractory tiles of burners stabilize burner flames. If a burner is positioned incorrectly, it will be too close to some tiles and too far from others. The tiles close to the burners will absorb and radiate a disproportionate amount of heat, distorting burner flames. If tiles are broken, missing or out of position, they will not transfer heat properly, thus distorting the flame pattern.

Burners are designed to fire symmetrically. In some cases, burner tips are designed to fire at an angle to cause a swirling and turbulent cylindrical flame. In all cases, burner tips must be drilled for specific fuel compositions and pressures. Mismatching replacement tips will cause firing problems.

Tips may become plugged due to corrosion in header piping, or tip patterns may be worn away by particulates in a gas stream. If tip wear is persistent, replacement tips should be fabricated from abrasion-resistant, high-temperature alloys.

Other problems which may result from poor design, shortcuts in manufacturing, or improper operation and maintenance include:

- Undersized gas header piping, which creates a large pressure drop and reduces gas or air flow to a burner
- Improperly designed air boxes, which cause uneven air flow
- Heat damage, which warps the floors or walls of heaters and furnaces, shifting burner positions and firing patterns

Condensation of water in a gas header will be indicated by sparklers in the flame. Condensate in steam lines for atomizing oil burners will also cause small, bright sparks.

Too much air tends to blow out burner flames. Incorrect tip placement, due to improper burner mounting or warped floors or walls, will affect the ability of burner tiles to stabilize a flame. Slugs of liquid in a gas stream will bring too much fuel to a burner. If that liquid carryover burns on the tip, it will greatly accelerate burner corrosion and erosion.

Some burners use baffles to prevent air flow from blowing out a flame. Others employ an effective burner-block configuration that absorbs and radiates heat to stabilize the combustion flame. Raw gas burners have flame-retention (vortex spin) devices to prevent the flame from being blown off the burner tip. Metal-baffle flame retainers tend to corrode and break off, leading to unstable gas flames.

Oil burners are designed for specific conditions. If those conditions are not met, unstable combustion will result. Slugs of water will displace fuel oil and periodically snuff a flame. Overheated atomizer guns or pump cavitation will also cause pulsating flames.

Fan sizing is very important for forced-draft operation. Oversized air blowers will surge at low flow rates. Undersized blowers cannot provide adequate air at high fire rates.

Misalignment of an oil gun can cause the oil spray to touch the burner block. The block then prevents proper atomization of the fuel, allowing it to burn partially and form carbon buildup on the gun and block.

Countering corrosion

Vanadium, sulfur or sodium in oil will corrode metal burner tips, standpipes, housings, refractory linings and metal support structures. If the problem is persistent, exotic alloys should be specified to combat the corrosive effects of vanadium and sulfur.

The adverse effects of vanadium on furnace tubes can be partially counteracted by reducing tube-metal temperatures. Except for furnaces operating with exceptionally high-tube metal temperatures, a vanadium content of 20 ppmv or less is normally not of concern. Although sodium presents an equally serious problem with burner refractories, de-salting the crude oil will usually eliminate this concern.

Over time, burner tips can be worn away by sand and grit particles. This problem may be minimized by replacing strainers that are too coarse. Other problems are more difficult to solve unless they are considered at the design, fabrication and materials-selection phases. H_2S, for example, will react with carbon steel piping to form a yellow powder that can plug tips and other orifices.

Excessive furnace-air leaks must be corrected. Tramp air, the excess air that enters through leaks in furnace floors or walls, will cool the products of combustion and reduce their buoyancy. Natural draft caused by the chimney effect will then be reduced. Stack dampers or air registers that are stuck open, and improperly controlled blowers in forced-draft units can also cause excess draft.

Flashback and smoke

Low gas flow on a pre-mix burner will slow the velocity of the air-gas mixture through the burner nozzle. When the velocity drops below the flame speed, the flame can move backward into the mixture tube, and a harmful condition known as flashback occurs. Flashback can also occur with pockets of hydrogen in refinery gas because the flame speed of hydrogen is significantly greater than methane or propane, the primary constituents of refinery gas.

Excessive heat on the venturi or other piping of a pre-mix burner, due to damaged insulation or absence of air flow, may raise the gas-air mixture above its auto-ignition temperature. Again, the result will be flashback.

Smoke and CO formation often result from too little or too much air. Too much fuel or an inadequate fuel-oil temperature will also prevent complete combustion and cause smoke and CO formation.

The formation of NOx is primarily a function of the nitrogen content of a fuel and the combustion temperature. Oil produces more NOx than gas because of the presence of fuel-bound nitrogen. The higher the flame temperature, the higher the NOx. Firing a burner at low excess air eliminates most of the nitrogen that can form NOx; however, all fuel-bound nitrogen cannot be eliminated.

Burners designed for NOx reduction typically rely on staged-air or staged-fuel combustion and use low excess air or fluegas recirculation. The most effective low-NOx burners employ both flue gas inspiration and recirculation to reduce NOx, CO and other pollutants without sacrificing combustion efficiency or flame stability.

Dampening objectionable noise

Distorted and unstable flames generate low frequency noise that may be heard, and felt, over a wide distance. Pulsations from nozzle-mix burners or steam injection can also generate low frequency noise. Oversized air dampers that are almost completely closed may cause pulsation of air flow past the dampers.

Noise shrouds are only partially successful, unless the basic problem is addressed in burner design, manufacturing, operation and maintenance. Routine maintenance and professional onsite service are two keys to improved burner performance.

More-efficient burner operations, in turn, reduce maintenance costs, fuel costs, spare-part inventories and emissions. They also provide a better return on investment. But improper operation quickly negates all benefits. A final thought to keep in mind: The extra fuel consumed by an inefficient, poorly maintained or improperly operated burner can never be recovered! ■

Edited by Nicholas Basta

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