THE EVOLUTION OF INDUSTRIAL GAS AND OIL BURNER SYSTEMS FOR BOILERS: THE LAST 50 YEARS

This article covers a theoretical discussion between NTFB Combustion Equipment USA's CEO, Edison Guerra, and its Director of Engineering, John DeLacy. Edison quizzes John about the evolution of the industrial burner industry.

Edison: How long have you been involved in the industrial gas and oil burner industry?

John: My grandchildren say it's been since dirt was invented, but it's actually a bit shorter timeframe than that. I started out as a junior engineer in the 1960s for Coen Company while still going to college. I soon managed several engineering groups and through the years climbed Coen's corporate ladder as Vice President of Engineering and eventually V.P. / Division Manager, both executive positions with their Steam Generation Systems Division.

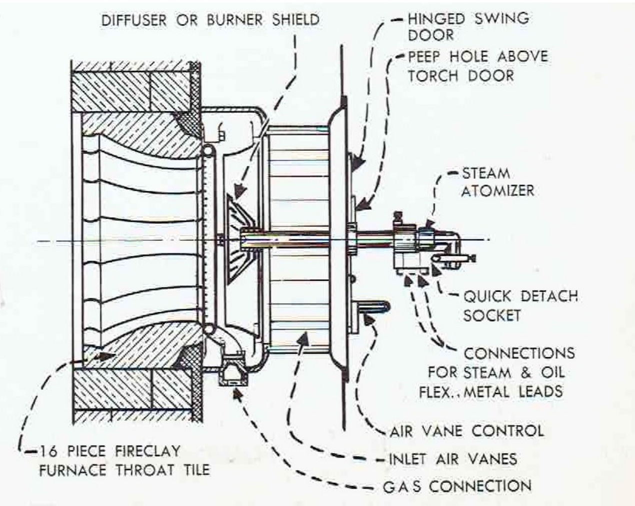

FIGURE 1: CONVENTIONAL GAS & OIL REGISTER TYPE BURNER

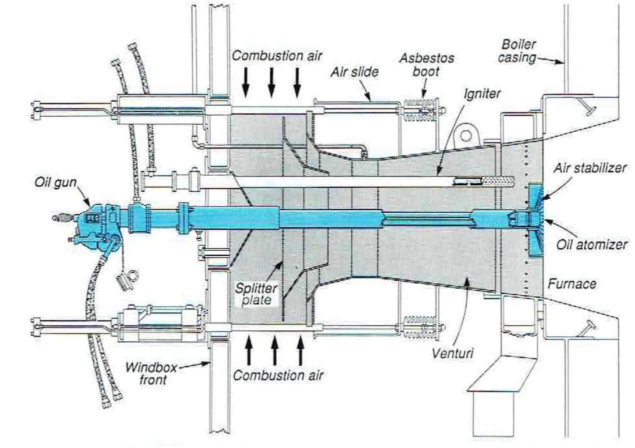

FIGURE 2: VENTURI TYPE INDUSTRIAL BURNER

Edison: So what's changed over the years in the burner industry? And what about stack emissions and the effect on burner designs for boilers since the dark ages of the 1960s and '70s?

John: While industrial gas and oil burner designs were pretty basic in the dark ages, as you put it, they were designed to be efficient with a high regard for safety first. Figure 1 shows a basic register burner design used in the '60s. Registers were equipped with one or two sets of adjustable register louvers (sometimes called vanes) to optimize the spin of combustion air before it was mixed with fuel. They were also a tool for factory service engineers to adjust the flame width. Similar register burner designs were used for many years. More sophisticated register burner designs are still used by some burner companies.

Edison: It's getting interesting. Tell me more.

John: Register burners were commonly used for gas and oil fuels. For fuel gas, they were equipped with multiple spud elements (lances), or perhaps a center fire gun, or a gas ring burner element (Figure 1). For fuel oil, a gun-type burner (atomizer) would be inserted down the center of the register burner.

In later years, other types of burners were developed that did not employ register louvers, such as the Venturi type burner shown in Figure 2 (gas burner elements aren't shown in this drawing). Whether a register type burner, a Venturi burner, or other type of burner, most all required a flame-stabilizing device, such as a burner diffuser or spinner.

In the early 1980s, when nominal NO_X emission reductions became a necessity, minor burner design changes were made, such as special gas element drill patterns to slightly influence thermal NO_X levels.

Edison: How did this all evolve to the other types of NOx control used on boiler burners and specifically the use of FGR (flue gas recirculation)?

John: In the mid to late '80s, ~80 PPM NO_X was achievable on industrial gas burners without the need for FGR. In a few short years this changed in S. California. There, the South Coast Air Quality Control Management District mandated NO_X emissions for natural gas fired industrial boilers at <30 PPM NO_X. This was achieved with either forced or induced FGR. In the years that followed, some burner suppliers were able to achieve <30 PPM NO_X without FGR,

See Figure 3 for an example of a gas flame from an industrial low NOx burner on a large watertube boiler operating at <15 PPM with induced FGR. Quite a few burner companies have designs to achieve this or even lower NOx levels.

John: One of the ironies when stringent low NOx requirements

FIGURE 3: LOW NOX GAS BURNER W/ INDUCED FGR FOR <15 PPM NO_X

became the norm in the U.S. was the apparent lost focus on burner designs that might have otherwise minimized excess air in the combustion process or other design improvements to increase system efficiencies.

Edison: So there are problems in simply increasing induced flue gas recirculation (FGR) to drastically reduce NO_X emissions in tandem with Ultra-low NO_X burners everywhere in the U.S.?

John: First of all, as you increase FGR rates, this increased mass flow is literally starving the burner of the oxygen in the mix needed for stable combustion. While this may vary by burner type and design, this limit of flammability is typically approached at around 35 to 40% FGR. These are the levels needed for many single-digit Ultra-low NO_X burner designs. As these high FGR levels are approached, gas burner flames can become unstable, depending on the design, and can result in extreme pulsations and possible burner flameout. This is particularly troublesome with rapidly swinging boiler loads. Controls suppliers have developed complex and costly control systems to cope with high flue gas rates. But they, coupled with the associated burner, can be difficult and costly to both start up and maintain.

Edison: Okay. But low-NO_X gas burner systems are now available to achieve single-digit NO_X levels, correct?

John: The use of large amounts of FGR on conventional register burners isn't achievable for single-digit NO_X levels. Even if it were, extreme NO_X reductions aren't (yet) required in most areas of the U.S. An exception is much of California, where single-digit NO_X levels have been mandated for years.

One of the problems faced in the combustion process is yet another form of NOx called Prompt NO_X. It forms in the fuel-rich zones common to virtually all conventional burners. On natural gas, it can be as high as ~25 PPM NO_X. Because it's instantaneously formed, the use of FGR will NOT reduce Prompt NO_X.

Edison: So that's where the use of Ultra-low NO_X burners using high levels of FGR came in to play to address both Thermal NOx and Prompt NO_X?

John: Yes, but with a penalty due to high initial capital costs, significantly higher power costs, high startup costs, and higher maintenance costs. Such burners have been available for quite some time, initially developed for gas fired industrial watertube (and now smaller commercial type) boilers supplied in many populated areas of California such as the Los Angeles Basin and the Central Valley, where air pollution is a major issue.

Edison: Okay, what exactly is an Ultra-low NO_X burner?

John: There are quite a few Ultra-low NOx burner designs available in the U.S., both for large industrial watertube boilers as well as for smaller commercial boilers, such as firetube boilers. These burners attack BOTH Prompt NOx and Thermal NOx formation.

The challenge for Ultra-low NOx burners is to significantly inhibit Prompt NO_X formation by thoroughly premixing fuel and air prior to combustion, thereby eliminating most fuel rich zones that can lead to Prompt NOx. They do this while also reducing Thermal NO_X, usually with high levels of induced FGR (sometimes approaching 35% or higher). As previously noted, this can lead to major operational problems.

Some Ultra-low NO_X gas burner designs use simulated premix designs that uniformly inject fuel gas into the combustion air stream. This inhibits Prompt NOx formation. Adding lots of FGR reduces Thermal NO_X. Add the complex combustion controls required along with a much larger combustion air fan to induce large amounts of FGR. Add the needed FGR lines, dampers, etc., between the boiler or economizer outlet and the fan inlet. You now have a system that can attain single-digit NO_X levels.

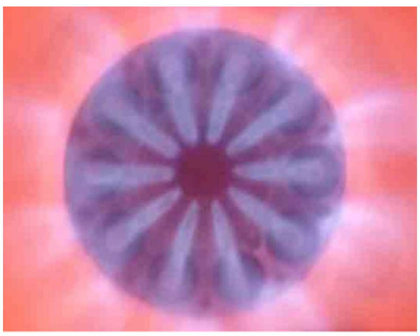

FIGURE 4 – TYPICAL ULTRA LOW NO_X BURNER FLAME USING FGR

Figure 4 shows what the gas flame looks like from one such ultra-low NO_X burner. It shows a well contained, uniform flame body. Flame appearance from other Ultra-low NOx burner designs may look radically different.

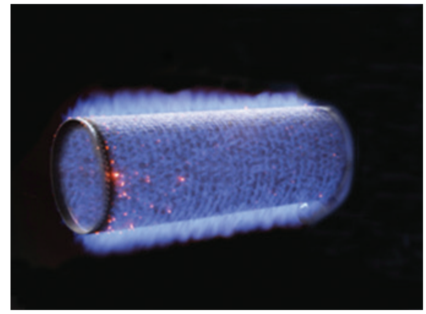

FIGURE 5: MESH TYPE ULTRA LOW NO_X COMMERCIAL GAS BURNER FLAME USING HIGH EXCESS AIR

Edison: Anything you can tell me about smaller commercial Ultra Low-NO_X burners?

John: Large or small Ultra-low NO_X burners must attack both Prompt and Thermal NO_X. Some commercial burner designs are nearly identical to larger industrial "big brother" Ultra-low NO_X burners. Another type of burner uses a true premix of fuel gas and combustion air to eliminate fuel rich zones.

See Figure 5. This commercial burner extends several feet or more into the boiler furnace. The use of mesh material in this manner with many small openings along the entire surface of the cylindrical barrel provides a large uniform surface with resulting relatively low temperature gas flames. This large surface area also eliminates the fuel rich zones associated with Prompt NO_X formation.

Note the uniform short 'blue' flame around the surface of the round extended mesh tube. This signifies a large amount of excess air used to also reduce Thermal NO_X. Typical excess air levels are ~50 to 60% excess air. The associated fans and motors are smaller and the impact to annual operating costs is more tolerable compared with larger industrial Ultra-low NO_X burners.

Now see Figure 6. While not yet common in the U.S., induced FGR can be used in lieu of high levels of excess air on mesh type Ultra-low NOx gas burners if the flue gas is thoroughly treated (filtered) to capture particulate matter, etc. from spent flue gases. This burner also employs an extended mesh tube. The flame appearance (photo taken from furnace rear wall) is quite different due to the use of FGR for thermal NO_X reduction instead of high levels of excess air.

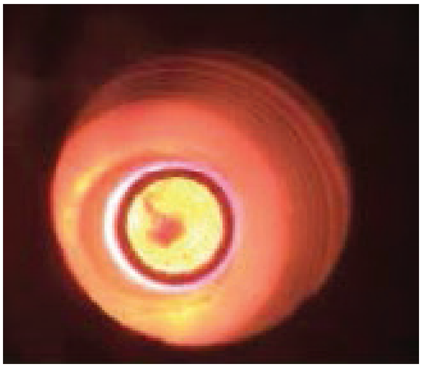

FIGURE 6: MESH TYPE ULTRA LOW NO_X COMMERCIAL BURNER FLAME USING INDUCED FGR (END VIEW)

Most mesh type burner designs also employ combustion air filters to help keep air-borne particles from clogging the burner tube's mesh screen material.

Edison: What about the future? And what about fuel oil?

John: Burner companies are not standing still. Their R&D departments are forever busy with combustion concepts to significantly and efficiently reduce NO_X. Expect this to go on for as long as gas burners are powering boilers and furnaces of all types.
Reducing NOx levels when using heavy oil or diesel fuel (light oil) is more of a challenge. High levels of bound nitrogen in heavy fuel oils makes it not viable for significant NO_X reduction in today's typical packaged boiler. Low bound nitrogen light oils, however, can be burned as a standby fuel, usually with reduced levels of FGR for "reasonable" NO_X reductions, though no way near as low as when using natural gas. Enough said about oil.

John: Our discussion has focused on the burner industry and improvements the last 50 years, particularly to reduce NO_X. However, we have ignored strides made in back-end cleanup of stack gasses to significantly reduce NOx emissions.

Much progress has been made with SCR (selective catalytic reduction) designs to efficiently tackle single-digit NO_X levels in stack gases from large gas fired industrial boilers without the need for Ultra-low NO_X burners and controls. By comparison, installed costs for packaged SCRs, service life for catalyst materials, and maintenance costs have become more tolerable for large boiler users. NO_X reduction using SCRs can be as high as ~95%. The State of California, in particular, is paying close attention to the high power costs associated with Ultra-low NOx burner systems vs SCR operating costs. We might return someday to simpler controls without the need for high levels of FGR and/or high amounts of excess air often associated with Ultra-low NO_X gas burner systems.

Let's hope that with improved technologies, burner and boiler companies alike won't fear the threat of heavy back-charges from frustrated endusers due to long drawn out startup times and operational problems. Likewise, the hope that endusers might not have regulators routinely threatening heavy fines and/or power plant shutdown for boiler emissions violations. If these coming combustion technologies had occurred ~25 years ago, I surely would have much less gray hair today. TB

Edison Guerra serves as NTFB's Chief Operations Officer. He earned a B.S. degree in biology and M.S. in project management, in addition to an MBA specializing in marketing. Edison also holds the distinction of serving in the United States military and is an Iraqi war veteran. Edison has had extensive experience in project management and materials control, plus more than four years directly in the laboratory environment.

John DeLacy, an award winning, published combustion engineer with more than 40 years of experience. He serves as NTFB's Director of Engineering/Chief Engineer. His career focused on both new boiler applications and boiler retrofit conversions to optimize performance and meet demanding environmental requirements. He has also served as Chair of the Burner Group for the American Boiler Manufacturers Association, and on NFPA's Technical Committee for Single Burner Boilers for the prevention of boiler furnace explosions. John's undergraduate degree is from St. Mary's College with an MBA from Golden Gate University.