COMBUSTION

BOILER ROOM DESIGN AND ENGINEERING TODAY

BOILER SYSTEMS AND COMPONENTS

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This paper presents an overview on a variety of considerations that relate to the application and operation of commercial and industrial gas and oil burners in hot water and steam boilers.

The function of the burner is to completely burn liquid or gaseous hydrocarbon fuel at a specified BTU input, in a safe, clean and efficient manner within the confines of the boiler combustion chamber.

1.0 The Combustion Process

Combustion, or burning, is a rapid combination of oxygen with a fuel, resulting in a release of heat and light.

The oxygen comes from the combustion air, which is approximately 21% oxygen ($O_2$) and 79% Nitrogen ($N_2$).

Hydrocarbon fuels contain carbon, hydrogen and in some cases, sulfur and nitrogen. Natural and LP gas contain no fuel bound nitrogen. Nos. 2 through 6 fuel oil contain high levels of fuel bound nitrogen.

The combustion process will combine the carbon and the oxygen to produce carbon dioxide, heat and light. It will combine the hydrogen and the oxygen to produce water vapor, heat and light. Sulfur, when present, will combine with oxygen to produce sulfur dioxide, heat and light. It is preferable to burn fuels with little or no sulfur content. Some fuel bound nitrogen will combine with oxygen to form NOx (oxides of nitrogen) the control of which is now a timely subject (more will be said about NOx later in this paper).

Stoichiometric combustion would be attained by mixing and burning exact portions of fuel and oxygen required - in order to completely consume both. In reality, to make certain that all fuel is burned an extra quantity of air is required. This is referred to as "excess air". Modern commercial and industrial standard burners typically operate between 5% and 20% excess air, most at 20%. Many older units will run as high as 50% or more excess air - due to poor fuel/air mixing. If there is a deficiency of air in the combustion process, carbon monoxide (CO) and/or smoke will be generated, representing a safety hazard and reduced efficiencies.

High levels of excess air also mean high levels of nitrogen (79% approx. of the combustion air) in the flue gases. Nitrogen does not take part in the combustion process. It is a negative constituent, as it absorbs heat from the combustion process, raising stack temperatures (excess $O_2$ also absorbs heat from the combustion process). Both high CO and excess air result in reduced combustion efficiencies. In addition, the nitrogen content in the high excess combustion air is subject to ultimately forming NOx.
A simple method to determine burner/boiler system efficiencies measures the percentage of carbon dioxide ($CO_2$) or the oxygen ($O_2$) in the flue gases. These values are then correlated to flue gas temperature, the combination of values providing the efficiency percentage. (Note that "dirty" water side or fire side surfaces would reduce heat transfer capability which would raise flue gas temperatures resulting in lowered "system" efficiencies).

2.0 Combustion Air - General Ventilation Requirement

Fresh air required to support combustion, as well as to provide adequate boiler room ventilation, must be supplied. All types of fuel require approximately 10 cubic feet of standard air (sea level @ 60 F) per 1000 BTUs firing rate for theoretical 0% excess air (stoichiometric) combustion. As noted prior, in actual practice, a certain amount of excess air is required to ensure complete combustion, but this can vary substantially with specific job conditions and type of burner. Additional air is lost from the boiler room through barometric dampers, draft diverters and venting devices. It is generally accepted that 1/2 square inch of free air opening per 1000 BTU/hr. firing rate will be adequate. Under no circumstances should a boiler room be under negative pressure. Jurisdictional authority relating to combustion air and boiler room ventilation requirements vary widely. To assure compliance, local codes and building officials should be consulted.

Often automatic outside combustion air dampers are employed. The sequence of operation provides that on a call for burner operation the fresh air damper motor will be driven open. At the open position, an end switch contact is made and the combustion system is energized.

In freezing climates, the potential for "freeze-up" exists, were the burner to fail to fire with the fresh air dampers open. Alarm circuitry should be employed to warn of the condition. One method would be to provide alarm circuitry that would be energized if the main burner automatic fuel valves were not opened within five (5) minutes of fresh air damper energization. Additional logic choices might be to close the fresh air dampers in the event of burner failure.

It is also necessary, in freezing climates, to protect boiler room equipment from "freeze-up" due to low temperature combustion air during burner operation - as well as when the burner is off. Some installations will require extra insulation, heaters, etc..
3.0 Fuel Delivery Considerations

3.1 Natural Gas - Gas supply piping should be sized to provide the required pressure at the burner gas train inlet manual shutoff cock, when operating at the maximum specified input. This pressure will be specified by the burner manufacturer. Gas flow piping tables are part of the information provided in all burner manufacturers installation manuals. This information notwithstanding, a frequent cause for a burner not being able to achieve its' full input, relates to undersized gas supply piping.

Gas piping must be in accordance with NFPA 54, the National Fuel Gas Code, state and local codes.

On occasion supply pressure from the gas meter will be raised to compensate for under sized lines. Under these conditions the static gas pressure must be measured at the burner train inlet, to make certain it does not exceed the pressure rating of the gas train components. The latter condition can sometimes be remedied by installing a "lock up type" gas pressure regulator in the burner gas train. Its design function will prevent downstream pressure from exceeding a preset regulated pressure under dynamic and static conditions.

Before pressure testing gas supply lines, blank off, or otherwise isolate them from burner gas train components. Gas supply line test pressures often exceed the rated pressure limit for gas train components.

When pressure testing gas train components, ensure that the test pressure does not exceed the rated pressure limit for gas train components. Burners with inputs of 8,000 MBH or less often use gas train components rated for 14" w.c. (0.5 psig).

Good piping practice includes the installation of a dirt pocket or trap immediately up stream of the burner gas train manual shutoff cock.

3.2 Fuel Oil - On single burner single pump installations it is recommended that a two pipe oil system be used - employing separate suction and return lines between the tank and the pump. In using a 2 pipe system any air which might be entrained in the oil will be returned to the tank without effecting flame conditions.

Suction lines should be sized to ensure that no greater than 10" to 15" H.G. vacuum will be developed. If the suction vacuum is excessive the oil will begin to emulsify causing oil supply problems resulting in flame instability. High suction vacuum also increases the possibilities of developing suction line air leaks causing cavitation in the pump, with resulting oil supply problems and flame instability.
On multi burner systems where pressurized oil supply loops are being supplied by a remote pump feeding pressure pumps at the burners, the same system pressure guidelines apply. Additionally, pressure regulating valves, if used, should be set to limit the supply pressure to the burner pumps to 3 psig in order to comply with NFPA regulations.

Other considerations depending upon job conditions, relate to the use of fusible link and/or anti-syphon valves. All applicable codes should be carefully considered prior to installation to make certain of compliance.

Oil piping and burner installation must be in accordance with NFPA 31, state and local codes.

4.0 Stack Outlets

The flame retention burner design used by most burner manufacturers can operate satisfactorily in negative or positive combustion chamber environments. These pressures are dictated, for the most part, by the boiler design but in some cases draft conditions resulting from stack design will have an effect on the combustion chamber pressure.

When structures are one or two stories, the stack serves as a vent only and combustion chamber pressures are easily adjusted by the positioning of a manual damper provided by the boiler manufacturer in the smoke box outlet.

When multi story stacks are used in new high rise structures or where new burners or boiler/burner packages are being connected to existing tall stacks, natural draft variations, depending on weather conditions, can be extreme. The result of these variations and their potential negative effect on boiler efficiencies as well as possible light off and flame stabilization problems warrant the use of automatic overfire draft controls.

These systems automatically reposition a stack outlet damper in accordance with combustion chamber pressure conditions, to maintain a preset draft value determined as optimum for that boiler/burner application. The overfire draft logic is tied into the flame safeguard programming control to provide safe and logical sequencing of all related burner functions.
5.0 **Burner Firing Modes of Operation**

Dictated in part by the BTU input of the burner - there are four (4) basic modes of operation.

5.1 **On/Off** - The combustion air dampers and fuel flow are set to the optimum combustion conditions. The burner lights off at a given input and remains at that input until the system load demand is satisfied, at which time the automatic fuel valves are closed. While the use of this system will vary by the manufacturer involved, it is typically limited to about 1,500 MBH.

5.2 **Low/High/Off** - This system is selected when it is desirable to light off at a reduced air/fuel input rate. It allows a brief time period to stabilize the firing conditions before moving to the high fire input position.

The system lights off at the reduced air/fuel position and then gradually increases the air and fuel input automatically. The unit runs at the high fire position until the system load demand is satisfied, at which time the automatic fuel valves are closed and the air dampers return to their light off position in preparation for the next operation.

These systems are typically used on fuel inputs up to 6,300 MBH.

5.3 **Low/High/Low** - The Low/High/Low system is identical to the Low/High/Off system except that the fuel valves have a Low Fire Operating Position and High Fire Operating Position. This system lights off at the Low Fire Operating Position.

An additional high-low temperature or pressure controller is used with this system, to electrically switch the fuel valves and air dampers to either the low fire or the high fire position, as the system load demand requires. The burner can alternate indefinitely between the low and the high fire positions without shutting down, depending on system load conditions. When the system demand cutoff point is reached, the automatic fuel valves are closed and the air inlet damper will go to the low fire light-off position in preparation for the next firing cycle.

5.4 **Modulation** - A modulating system can fire at any BTU input from low to high fire, to match load demand.

A modulating temperature or pressure controller senses load demand and positions a modulating motor to control burner BTU input. The controller and modulating motor can either be the Series 90 (135 ohm potentiometer) electric type; or 4 to 20 MA electronic type.

The modulating motor, with fuel-air linkage, positions gas and/or oil modulating fuel flow valves and dampers to provide burner input appropriate for load demand, while maintaining fuel-air ratio.
The burner lights off at the low fire input rate. After a short period of time, the burner flame safeguard system releases the modulating control system for automatic modulating operation. The system modulates to provide burner input in accordance with load demand.

When the system demand cutoff point is reached, the automatic fuel valves are closed and the air inlet damper will go to the low fire light-off position in preparation for the next firing cycle.

6.0 Flame Safeguard and Component Sequencing

U.L. and other approval agencies have certain sequential and timing functions with which burner manufacturers must comply. The following is a brief explanation of each as relates to a modulating burner being fired above 2,500 MBH (There are several other sequences available depending upon burner input, fuel used and flame safeguard control selected).

6.1 Prepurge period

Commences at the beginning of the burner cycle. To meet current U.L. requirements - prior to ignition, the combustion air blower must operate for a period of time that will equate to a minimum of four (4) volume air changes of the heat exchanger. The number of air changes and the method by which this is achieved may vary among approval agencies. The purpose is to vent any accumulated combustibles prior to introducing an ignition source.

Gas units firing over 5,000 MBH, - U.L. requires that one of two automatic shutoff valves include a "valve seal overtravel interlock switch" (proof of closure switch). This switch is electrically interlocked with the burner control system to prevent the burner from going into the prepurge cycle if the valve seat is not proven fully closed.

Oil burners with remote pump sets or firing with inputs of 20 GPH and above have the same 4 air change U.L. purge requirements as prior mentioned.

6.2 Trial for pilot ignition period

Once the prepurge has been completed - on gas pilot ignition systems, the ignition transformer and pilot gas valve are energized for a minimum of 10 seconds. If the presence of a gas pilot flame is not detected in this time period the system will shutdown and will require manual reset to restart.

6.3 Trial for main flame ignition period

With the ignition pilot proven the main fuel valves will open at the 10 second point. The pilot will remain on for another 10 seconds allowing the ignition of the main flame on gas and light oil systems. Another 5 seconds will be allowed beyond that for heavy oil systems. If the main flame is not ignited and detected at the end of the trial period, the system will shutdown and lock out requiring manual reset to start.
With the system running normally - After the pilot is extinguished and the main low fire flame proven, the system will be allowed to increase the firing rate to full high fire. The timing sequence for this activity is dependant on type of Flame Safeguard programmer used.

6.4 Main Flame run period

The main flame will remain on until the system demand is met. If a flame out occurs during the main flame run; the main fuel valves will be de-energized within 2-4 seconds, resulting in burner shutdown. Manual reset will be required to restart the system. Other interlock devices such as gas pressure switches, air flow switches, low and high oil pressure switches can also create non recycling safety shutdown of the system.

On gas inputs of 2,500 MBH and below, U.L. will allow, on the loss of main flame, one attempt to relight. The relight attempt can be made only after a mandatory prepurge. If the burner fails to relight, the system will go into a safety lockout mode, requiring manual reset to restart the burner.

6.5 Post Purge Period

Commences at the end of the burner firing cycle. Its purpose is to run the burner blower in order to ensure that all residual combustion gases remaining in the combustion chamber are purged from the system.

7.0 Flame Detection Methods

For Oil and Gas burners - All optical sensors detect flame by various measurable frequencies generated by the flame. They are generally categorized as white light (or visual), ultraviolet, or infrared (lead sulfide) sensors.

Each has selection guidelines, which have to do with the specific application. In general, UV is the preferred choice on gas and pressure atomized oil systems - Infrared (lead sulfide) is the preferred choice for oil systems, which use air or steam atomizing nozzles.

Gas burners not exceeding 2,500 MBH, - Rectifying flame rods can be used. Oil burners firing 20 GPH or less - Cesium Oxide and Cadmium Sulfide photocells can be used. Each represents an economical and safe method of detection in these size ranges.

8.0 Control Safety Regulating Bodies

Underwriters Laboratory (U.L.) standards represent the basic criteria for burner operating design, for forced draft burners operating in the range of 400 to approximately 25,000 MBH.
Prior to being accepted for U.L. listing, burner products are thoroughly inspected and tested to assure compliance with U.L. standards. Following the granting of U.L. listing status, U.L. assures continued compliance and enforces standards by reinspection and periodic unannounced visits to burner manufacturing plants. The U.L. label on the burner is the purchasers evidence of compliance.

Effective April 1, 1994, U.L. standards in our industry became more stringent. Changes involved pre and post purge timing and control sequencing, the quantity and types of gas and oil valves required and additional non recycling type devices.

The Factory Mutual Insurance group have made requirement changes over the past year. Their requirements do not exceed those of U.L. in gas inputs to 2,500 MBH and oil to 2,800 MBH. From these inputs through 12,500 MBH, there is some minor variance between U.L. and FM, part of which is the FM requirement that certain components must carry the FM label.

The Improved Risk Insurors (IRI) group have maintained their requirements without change, over the last several years. We understand they are considering some changes in the future - but to our knowledge a specific time frame has yet to be determined.

It is important to note that local insurance inspectors are usually empowered to either impose more stringent burner requirements or to waive requirements, depending on the nature of the project (risk) being considered.

ASME CSD-1 code requirements - The most currently promulgated U.L. requirements dated April 1, 1994, now closely resemble CSD-1. Compliance to this code format is proliferating. At this writing 31 jurisdictional areas (plus the U.S. Postal Service and Coast Guard - CFE subpart 63.15) have adopted this standard. Seven (7) provinces in Canada have also made CSD-1 mandatory.

NFPA 85 codes apply to burners having inputs exceeding 12,500 MBH. Their current requirements have been in place since August 1992.

There are a variety of other code writing bodies that exercise area jurisdictional or insurance group authority, however, the above requirements are most frequently encountered.

9.0 Flame Safeguard Controls

State of the art FSG controls have developed significantly expanded capabilities over the past few years. In addition to providing appropriate sequencing for the burner system components, i.e., motors, valves, interlocks, etc., and providing pilot and main flame monitoring - micro processor based units now offer such features as:
• Operational sequence status in English text readout.
• Flame signal values.
• Hours and cycle of operation - by fuel type.
• Self diagnostics for trouble shooting.
• Fault history.
• Multi point first out annunciation.
• Communication interface for local or remote monitoring, reporting and trouble shooting.
• Compatibility with commonly used PC models.

These capabilities allow their integration into overall building management computer control systems.

10.0 **Dual Fuel**

Burner sales remain active for those looking to take advantage of reduced natural gas rates based on automatic changeover to oil or LP gas when outdoor temperatures reach a predetermined level.

The switching action is usually achieved automatically - but can also be done manually. Under both arrangements the burner goes through its normal post and prepurge sequences before initial lighting off the alternate fuel.

An additional advantage of dual fuel burners is, of course, the ability to burn an alternate fuel in the event of non-availability of the primary fuel.

11.0 **Controls to Improve Efficiency**

There are a variety of techniques offered by burner manufacturers that relate to improved fuel efficiency.

Some of the more common methods are:

11.1 **Lead/lag Control** - where 2 or more boilers provide steam or hot water to a common building heating system. The object of the L/L system is to maintain building water temperature or steam pressure at burner BTU firing rates that will identically match the heat requirement load condition. This is achieved by automatically bringing on line additional boilers as soon as load conditions exceed the capabilities of the primary firing unit. The "shut down" sequence is reversed as the boiler’s output reach the load demand. A properly operating L/L system can represent significant fuel savings.
Microprocessor based L/L systems offer a wide variety of selectable system sequencing and options.

11.2 **Sequenced Overfire Draft Control** - saves energy by closing (or nearly closing) the boiler breeching damper during burner off periods, reducing the loss of boiler surface heat up the stack. The overfire draft control system also maintains precise system draft required to optimize combustion product flow rates over the boiler heat exchanger surfaces, providing the highest boiler efficiencies.

11.3 **Preheated Combustion Air** is another fuel saving technique employed in larger boiler systems. It does, however, usually require burners of a special design capable of handling elevated air temperatures of 250°F and above.

11.4 **Characterized Fuel Metering** devices, on modulating burners, will significantly assist in providing efficient fuel/air ratios throughout the firing range.

11.5 **O₂ Trim systems** are typically used on systems in excess of 500 BHP. These devices go a step beyond the characterized fuel metering system by providing a yet higher level of control over fuel/air ratios by monitoring and controlling the excess air used throughout the full range of the combustion process.

11.6 **Low Excess Air Burner** designs provide increased efficiencies by precisely controlling and monitoring the minimum amount of air required for good clean efficient combustion. This is typically in the area of 1% O₂ or 5% excess air. This compares to traditional burner designs at 3.5% O₂ or 20% excess air, which is generally acceptable in today’s market place. Low excess air designs are generally more expensive and are more common in size ranges beginning at 500 boiler horsepower.

An inherent advantage of the low excess air burner is in the fact that approximately 79% of the "air" that is used in the combustion process is actually Nitrogen. The Nitrogen in the combustion process can develop into "thermal NOx" (Oxides of Nitrogen). By virtue of the significant reduction in the excess air used in this type of burner - the generation of thermal NOx is proportionately reduced.

12.0 **Current Low NOx Control Technologies**

Oxides of Nitrogen (NOx) is the collective term used in referring to Nitric Oxide (NO) and Nitrogen Dioxide (NO₂), the latter being formed when the NO is subjected to atmospheric oxygen. NOx is formed in all combustion processes.
12.1 Environmental and Health Concerns Related to NOx

- Smog - Photochemical smog, the largest fraction of which is ozone, results from the reaction of NOx, hydrocarbons and oxygen in the presence of sunlight.

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\text{NOx} + \text{HC} + \text{OX} + \text{Sunlight} = \text{Smog}
\]

- Ozone - In the stratosphere, ozone filters out harmful ultraviolet rays and is helpful to living things on earth. At ground level, ozone when inhaled causes health problems.

Many major industrial areas in the United States have been targeted by the Environmental Protection Agency as violating the National Ambient Air Quality Standards for ozone.

- PM-10 - NOx contributes to the formation of PM-10, suspended particulate matter smaller than 10 microns in size - known to effect the human respiratory system.

- Acidic Deposition including Acid Rain and Fog.

12.2 How is NOx Formed in Combustion?

NOx is produced from the nitrogen present in the combustion air and in the fuel being burned. The generation of NOx results from high flame temperatures in the presence of oxygen, over a period of time.

12.3 There are three main areas of NOx formation.

- **Prompt NOx** - The start of combustion. That moment at the base of the flame when the process of combustion starts is the area of prompt NOx. This is one of the most difficult areas of NOx formation to control because there are minimum temperatures required to maintain stable combustion.

- **Thermal NOx** - Results when nitrogen and oxygen in the air combine at the elevated temperatures of the combustion process.

- **Fuel Bound NOx** - Is the result of nitrogen organically bound in the fuel hydrocarbon chain combining with air at the elevated temperature present in the combustion process. Fuel bound nitrogen has a high propensity to form NOx and is difficult to eliminate from the fuel.
12.4 **Combustion Chamber Design** - The generation of NOx relates directly to peak flame temperature, heat release volume per cubic foot of the combustion chamber as well as the heat absorbing (and reflecting) characteristics of the chamber surfaces. The larger the combustion chamber volume (for a given BTU input), the lower the NOx emission rate. By derating a boiler firing rate, the NOx formed will be lower than at full design input capacity. A chamber with a floor and sidewalls of refractory materials will, due to re-radiation of heat back into the flame, generate a higher level of NOx than a chamber formed by heat absorbing water legs, a wet base or water tube design.

13.0 **Current NOx Reduction Methods**

In general the reduction of NOx in the process of combustion involves two methods. The reduction of excess air and therefore excess oxygen to react with the nitrogen atoms freed in the combustion zone and the reduction of the peak flame temperature to reduce the tendency to form free nitrogen atoms and NOx.

13.1 **Low Excess Air Operation** - Generally results in a higher flame temperature, but does reduce the amount of oxygen available for the formation of NOx. For every percentage point of reduction of the flue gas oxygen level, the NOx level is generally reduced by 2 to 8 ppm of NOx.

13.2 **Staged Air Burners** - This design allows enough air at the burner nozzle to maintain a stable flame and channels the remaining air into the flame zone down stream of the main flame. This staging leaves a small reducing zone at the burner nozzle and causes the flame core to increase in size with reduced intensity. Staged Air burners reduce NOx approximately 30 to 35%.

13.3 **Staged Fuel Burners** - The Power Flame NOVA® low NOx burner uses staging of the fuel rather than the air. This method provides for a lean first stage (or primary zone) combustion, maintaining lower flame temperatures and retarding the formation of thermal NOx temperatures. Fuel concentration in the primary zone is reduced to within the limits of flammability and flame stability, whereby the secondary fuel and available excess air react downstream to complete the combustion process. This results in NOx emissions reduction on the order of 40 to 60%, depending on application. Combined with FGR, this technique can be very effective in reducing the formation of nitrogen oxides.

Staged fuel combustion offers the added feature of simplicity of operation. The burner is essentially setup and operated in a similar manner as any standard burner. This allows the installation and operation of the burner without any special controls or operator training.
13.4 Flue Gas Recirculation - This well-known method uses cooled flue gases from the boiler stack as a source of dilution gas. They are very low in oxygen content and are composed of inert compounds like nitrogen, water vapor and carbon dioxide, which are excellent heat sinks. These inerts reduce the peak flame temperature in the combustion chamber and reduce NOx formation. This method has been used successfully in large boilers for many years and has been adapted for use on Power Flame burners. Originally FGR was forced into the NOVA low NOx head and used in conjunction with staged fuel firing. The forced FGR approach required a separate blower to deliver the FGR to the firing head. A much simpler approach was devised using a special adapter mounted on the combustion air blower to induce a flow of FGR, which is mixed with the combustion air in the burner. Induced flue gas recirculation (IFGR) has been used on hundreds of burners (Model J, C, AC and Vector) in a wide variety of applications. On gas firing, the use of recirculated flue gases can reduce NOx formation by 75 to 80%.

Due to the inherent design characteristics of the HP burner, forced FGR injected into the flame through the NOVA low NOx head is still the primary method for reducing NOx emissions.

13.5 Steam Injection - The injection of steam is used to lower the flame temperature in the same manner as recirculated flue gas. The introduction of water into the flue gas makes the results slightly less dramatic due to the dry basis reporting methods. Other potential drawbacks to steam are its negative impact on the refractory, unavailability with hot water boilers and cost.

13.6 Premix Surface Burners - These burners incorporate surface burning, radiant technology to spread the flame out into a thin film and reduce peak flame temperatures. Fully premixed air and gas are diffused through a matrix-style combustion head, usually constructed of metal, ceramic or fibrous materials. In our industry, these combustion heads are now constructed predominantly of special alloyed metals for durability and long life.

The Power Flame NOVA® Plus surface stabilized combustion burners can reduce NOx emissions to sub 9 to sub 12 ppm meeting the most stringent requirements in the country. CO emissions are extremely low and these burners provide for reliable, smooth operation. Besides the ultra-low NOx and CO emissions throughout the firing range that these burners exhibit, FGR and associated flue gas piping are not required, therefore providing lower cost and easy installation. Premix Surface burners generally require a combustion air intake filter to prevent particulate from clogging the surface burn element.
13.7 **Premix Non-Surface Burners** - Conceptually similar to the Premix Surface Burners in that the fuel and air are fully pre-mixed, ultra-low NOx and CO emissions can be achieved. The primary difference between the Premix Non-surface and Premix Surface burners is that the flame of the Premix Non-surface burner produces a more traditional, nozzle mix burner type flame in appearance. Combustion air intake filters are generally not required since a more traditional-style diffuser or perforated screen with larger gas pathways is used which allow for easy passage of typical air-borne particulate. However, burner size (input rating) is generally limited with this technique for NOx reduction due to the relatively larger size of these passageways.

Similar to the J series burner in both size and capacity, the Power Flame NOVA® Premix burner is a non-FGR, low cost solution to achieve sub 30 and sub 20 ppm NOx applications in a wide range of boilers and heat exchangers.

13.8 **Selective Catalytic Reduction (SCR)** - This is a very expensive add-on post combustion system, which uses a catalytic bed to cause the NOx to react back to nitrogen and water. These systems also require the injection of ammonia or synthetic urea in a tightly controlled temperature zone. These systems are most often used on very large systems requiring major NOx reductions. Low NOx burners are usually applied to fire boilers equipped with SCR to optimize NOx reduction. Reduction levels of up to 90% can be achieved with SCR.

13.9 **Low Temperature Oxidation (LTO)** - This extremely expensive post combustion NOx reduction technology has begun to be applied to boilers. In this system, ozone is generated on site and injected into combustion gases at relatively low temperatures (around 300°F), reacting to reduce NOx to elemental nitrogen and water. A Low NOx burner used in conjunction with this post combustion technology will optimize NOx reduction. NOx reduction is reportedly in excess of 90%.

14.0 **NOx Compliance Requirements**
Under the Federal Clean Air Act Amendments of 1990 (CAA), states have been required to submit to the EPA for approval, then enforce, State Implementation Plans (SIP's) to attain and maintain National Ambient Air Quality Standards (NAAQS). NOx emissions regulation can be required in geographical areas that are in non compliance with applicable NAAQS standards.

14.1 In addition, CAAA Title V requires a Federal EPA permit to be administered by the individual state air pollution control agencies, for major facilities having the potential to emit NOx and other air pollutants. The NOx threshold, per facility, varies from 10 tons per year in an extreme ozone nonattainment area, like Los Angeles, to 25 tons per year in a severe nonattainment area like Philadelphia, to 100 tons per year in areas meeting NAAQS standards for ozone.
Your local or state Air Quality Regulatory Agency can provide information on any specific NOx regulations impacting your area. NOx regulations in some jurisdictions have been changing rapidly. If you are in doubt as to which Air Quality Agency has jurisdiction you can contact the Federal Environmental Protection Agency (EPA).

15.0 Power Flame and the NOx Issue

Power Flame combustion engineers are constantly working to push the lower threshold of NOx formation. The NOVA® low NOx Burner systems offer a wide range of solutions to NOx reduction. Our Research & Development group continues to develop combustion technology to meet and exceed the emissions standards throughout the U.S.

Our latest developments include the NOVA Premix (NPM) gas burner for sub-30 and sub-20 ppm NOx emissions up to 2,200 MBH, and the NOVA Plus (NVC) gas burners capable of sub-9 ppm or sub-12 ppm NOx emissions from 2,000 to 63,000 MBH natural gas input. Both burner series are fully pre-mixed systems requiring no FGR and associated piping. The NOVA Premix gas burners have been Pre-Certified on a number of boilers and hot water heaters by the Southern California Air Quality Management District (SCAQMD).