Combustion and Burner Systems Technology

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Section I – The Basic Science of Combustion

Fire Good
Combustion occurs when fuel and air are combined in proper proportions with an ignition source.

- Ignition Source
- Fuel *(Natural or LP Gas)*
- Air
IGNITION SOURCE

- Standing Pilot
- Spark to Pilot
- Hot Surface Ignition
- Spark Ignition
FUEL (Natural Gas)

Components of Natural Gas

CH$_4$ = H-C-H

- Methane (CH$_4$)
- Ethane (C$_2$H$_6$)
- Propane (C$_3$H$_8$)
Real World Application

From Gas Supply to Burner(s)
# Pipe Sizing Chart, Natural Gas

<table>
<thead>
<tr>
<th>Nominal Iron Pipe Size Inches</th>
<th>Length of Pipe in Straight Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>3/4</td>
<td>369</td>
</tr>
<tr>
<td>1</td>
<td>697</td>
</tr>
<tr>
<td>1 1/4</td>
<td>1,400</td>
</tr>
<tr>
<td>1 1/2</td>
<td>2,150</td>
</tr>
<tr>
<td>2</td>
<td>4,100</td>
</tr>
<tr>
<td>2 1/2</td>
<td>6,460</td>
</tr>
<tr>
<td>3</td>
<td>11,200</td>
</tr>
<tr>
<td>4</td>
<td>23,500</td>
</tr>
</tbody>
</table>

Base on ½ PSI
AIR

• Air or oxygen will mix with the fuel to create the flame.
• Additional air may appear in the combustion process depending on the combustion process and burner design.
  • Primary Air
  • Secondary Air
  • Excess Air
  • Dilution Air
• **Primary Air** - the air that is mixed with gas and consumed for combustion

• **Excess Air** – part of the primary air that is not consumed in combustion but is necessary to ensure complete combustion
  • Too much excess air will reduce the heat transfer efficiency
  • Excess Air influences CO & CO$_2$ levels in the flue products
AIR

- **Secondary Air** – air that passes through the combustion system that is not part of the combustion process
  - “Atmospheric” burners operate with large amounts of Secondary Air, limiting the heat transfer efficiency
- **Dilution Air** – air added to the flue products after combustion to facilitate proper operation of the vent system
Real World Application
COMBUSTION

Excess Air

100 ft³

Gas CH₄

+ 1000 ft³

AIR O₂ + N₂

455 ft³

Carbon Dioxide

100 ft³

CO₂

H₂O Vapor

200 ft³

Excess Air

Nitrogen

455 ft³

N₂

800 ft³

NOTE: LP Gas 2400 ft³ of air
COMBUSTION PROCESS
EMISSIONS

• The combustion process is not perfect. Manufacturers seek to limit the by-products through combustion system and burner design strategies

• $\text{NO}_x$ – Oxides of Nitrogen
• $\text{CO}$ – Carbon Monoxide
• $\text{CO}_2$ – Carbon Dioxide
COMBUSTION PROCESS EMISSIONS

- CO – Carbon Monoxide and CO$_2$ – Carbon Dioxide
  - Produced as a result of incomplete combustion
  - Less than 400 ppm of CO is the national standard
  - CO$_2$ products operate between 8% and 10%
COMBUSTION PROCESS EMISSIONS

• $NO_x$ – Oxides of Nitrogen
  • Fuel Bound $NO_x$ – Not in Natural Gas
  • Prompt $NO_x$ – Formed at burner ports
    • Premix systems limit this type
  • Thermal $NO_x$ – Formed from high temperature, lean combustion
    • Burner design is the primary approach for limiting this type
Hey, vent flue products OUTSIDE the building!

NOT the Real World Application
Real World Application
Section II – Burner and Combustion System Technology

My combustion system can beat up your combustion system
BASIC BURNER CONCEPTS

- ATMOSPHERIC
- POWER BURNER
- FAN ASSISTED
- FAN ASSISTED - PREMIX
“ATMOSPHERIC” BURNER SYSTEMS
“ATMOSPHERIC” BURNER SYSTEMS

- Typical to residential water heaters and residential and light commercial boilers.
- The burner or burner tray is open to the atmosphere. Air is drawn into the combustion process naturally with no combustion air blower.
- Products that utilize this technology have been around for generation but atmospheric combustion is on the decline in commercial installations.
- Operates in the high 70% to low 80% combustion efficiency range.
“ATMOSPHERIC” BURNER SYSTEMS

- The atmospheric burners are typically horizontal burners that are designed to operate at a specific Btu/hr input rate.
- The input rate is determined by a fixed gas orifice designed to control the volume delivered to the burner.
“ATMOSPHERIC” BURNER SYSTEMS

- Gas is injected into the burner and mixed with available primary air
- Secondary air enters the process at the burner ports and the open combustion chamber
- Dilution air enters after the combustion process and mixes with the flue products
COMBUSTION PROCESS

Combustion Air

Gas

Atmospheric
“ATMOSPHERIC” BURNER SYSTEMS

- There is limited control of the combustion process
- Lack of available air in the room will have a direct impact on the combustion process
- The venting system operates on a negative draft and is comparatively large in size for the total volume of flue products, secondary air and dilution air
- While perhaps the most forgiving and robust of all designs there are some inherent limitations that accompany atmospheric combustion.
  - Typically operate with higher levels of unwanted flue by-products such as NO$_x$
  - Secondary air limits heat transfer efficiency
“FAN-ASSISTED” BURNER SYSTEMS
COMBUSTION PROCESS

- Fan Assisted
- Dilution Air
- Secondary Air
“FAN-ASSISTED” BURNER SYSTEMS

- Typical to light and mid size commercial water heaters and boilers, particularly non-condensing, stage fired appliances
- This is a stable platform that has been available for more than 20 years
- The blower / burner combination provides more precise control of combustion to reduce flue by-products
- Efficiencies are typically in the mid-eighties due the elimination of secondary air in the process
“FAN-ASSISTED” BURNER SYSTEMS

- The blower forces air into the sealed air chamber and the combustion chamber.
- Gas is introduced via a manifold to the burner opening and mixes with the air in the burner.
- The Gas/Air mixture is forced through the precisely sized burner ports where it is ignited.
“FAN-ASSISTED” BURNER SYSTEMS

Pressurized Chambers
All air is primary; there is no secondary air.
The air / gas mixes in the burner before combustion.
“FAN-ASSISTED” BURNER SYSTEMS
“FAN-ASSISTED” BURNER SYSTEMS

- The removal of secondary air improves thermal transfer
- The sealed combustion chamber reduces heat loss
- The controlled process dissipates the pressure and maximizes the efficiency
- Air is minimized which allows the vent system to utilize smaller vent diameters
“POWER” BURNER SYSTEMS
Power Burner

- FLUE OUTLET
- FIBERGLAS INSULATION
- FLUE BAFFLE
- OUTER JACKET (22 GA. STEEL)
- FLUE PASSAGE
- PRECAST CERAMIC COMBUSTION CHAMBER
- AIR GAP
- TANK SKIRT
- COMBUSTION CHAMBER LINER (STEEL)
- 3 LEGS
- BURNER
- DRAIN VALVE FITTING
- GLASS LINED STEEL TANK
- WATER TEMP CONTROL FITTING
- MAGNESIUM ANODES
- T&P RELIEF VALVE FITTING
“POWER” BURNER SYSTEMS

- Typical to large commercial boilers
- There is increased control of the combustion process that results in decreases in the unwanted flue by-products, such as NO\(_x\)
- The power burner can operate across a broad input range, or modulation
“POWER” BURNER SYSTEMS

- The blower operates at high pressure to supply the necessary primary air for combustion
- Gas is injected into the high velocity air flow before ignition
- Combustion occurs under pressure and is controlled
- The burners need to set-up and tuned
“POWER” BURNER SYSTEMS

- The power burner is an established technology with controlled modulation of input rate.
- Works with gas and oil.
- The vent system is subject to positive pressure and therefore must be sealed accordingly.
“FAN-ASSISTED" PREMIX BURNER SYSTEMS
“FAN-ASSISTED” PREMIX BURNER SYSTEMS

- Also known as “Negative/Regulation” or “Zero Governor” systems.
- These products represent the primary growth segment of the small to mid size boiler industry
- Utilized in condensing and non-condensing products
- The blower / burner combination can operate across a broad input range, or modulation
- Efficiencies range from the mid-eighties to the upper nineties
“FAN-ASSISTED” PREMIX BURNER SYSTEMS
“FAN-ASSISTED” PREMIX BURNER SYSTEMS

- The blower delivers precise Gas/Air mixture to the burner for complete combustion.
- As the blower speed increases or decreases, the amount of air and gas remains precisely controlled and increases and decreases accordingly.
- The result is a wide range of firing rates through a single burner – most common is a 5:1 modulation ratio, which means the burner operates from 20% capacity all the way up to its full firing rate.
“FAN-ASSISTED” PREMIX BURNER SYSTEMS

**Burner Modulation**

The images above show a burner operating along its modulation range beginning at 20% of firing rate on the left and progressing up to full fire on the right.

**NOTE:** The orange color is not poor combustion. It is the metal fibers in the fiber mesh glowing from the heat.
“FAN-ASSISTED” PREMIX BURNER SYSTEMS

- The burners are specially designed employing different methodologies to protect the burner from damage at the lowest rates.

- Many burners are protected with a ceramic coating while others use a metallic fiber mesh sock, or jacket.
"FAN-ASSISTED" PREMIX BURNER SYSTEMS

Ceramic Fiber

Micro-Metal Fiber
“FAN-ASSISTED” PREMIX BURNER SYSTEMS

- The burner materials are selected based on the application.
- Ceramic is the more cost effective, but it is only used in non-condensing systems because the water vapor present in a condensing environment will deteriorate the ceramic material over time and degrade the burner’s performance.
- A metal fiber mesh is the choice with condensing products for the moister environment.
“FAN-ASSISTED” PREMIX BURNER SYSTEMS

- Modulation with precise combustion across the firing range
- Thermal efficiencies so great that the positive pressure vent material can be PVC, CPVC or Polypropylene
TAKE AWAY

- The installation will influence the combustion.
- Let your equipment breathe.
- Gas is more than a pipe to the equipment.
- Remove the flue products safely from the building.
Questions?
Extra Credit Item

A New Advancement in Burner Design
Advances in Turndown Ratio

- The turndown ratio of these systems has been limited in the past by the burner and blower system’s capability to operate across an extremely wide spectrum in an efficient manner.

- An innovation to increase total boiler turndown ratio is to utilize a burner with multiple chambers.
Advances in Turndown Ratio

- The turndown ratio of this system is 25:1 because of the separate 5:1 combustion systems.