Premix Burners and Applications

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Pre-mixed surface stabilized

Applications
## Sample Btu conversion factors

<table>
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<tr>
<th>Energy source/fuel</th>
<th>Physical units and Btu (averages,(^1) 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>1 kilowatt-hour = 3,412 Btu</td>
</tr>
<tr>
<td>Natural gas</td>
<td>1 cubic foot = 1,037 Btu</td>
</tr>
<tr>
<td></td>
<td>1 therm = 100,000 Btu</td>
</tr>
<tr>
<td>Motor gasoline</td>
<td>1 gallon = 120,476 Btu(^2)</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>1 gallon = 137,452 Btu</td>
</tr>
<tr>
<td>Heating oil</td>
<td>1 gallon = 138,500 Btu</td>
</tr>
<tr>
<td>Propane</td>
<td>1 gallon = 91,333 Btu</td>
</tr>
<tr>
<td>Wood</td>
<td>1 cord = 20,000,000 Btu(^3)</td>
</tr>
</tbody>
</table>

\(^1\) Weighted averages for energy sources/fuels as consumed by end-use sectors.

\(^2\) Gasoline sold at retail in the United States, with about 10% ethanol content by volume.

\(^3\) This conversion is an estimate. A cord of wood is a volume unit and does not take wood density or moisture content into account. Wood heat content varies significantly with moisture content.

The Btu conversion factors above are approximations. EIA provides more heat contents for fuels and electricity.
Gas Combustion

\[ \text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O} + \text{energy} \]

• CH4 is methane, most common component of natural gas
• O2 is oxygen, in the air that surrounds us (app. 20 %)
• CO2 is carbon dioxide, no smell or colour, non-toxic
• H2O is water in gas (vapour) or fluid form
• Energy is heat
• By products
  • Complete combustion requires excess air, the ratio of air excess is given by \( \lambda \) (if there is 10% excess air \( \lambda = 1.1 \))
Gas combustion

By products of combustion

CO: carbon monoxide
Caused by a lack of oxygen, inefficient mixing or (rapid) cooling of the flame

This can be caused by too much air or by flame quenching
Gas combustion

Relationship between excess air and CO2%
Natural gas

![Graph showing the relationship between excess air ratio and CO2% for natural gas. The graph indicates that CO2% increases with an increase in excess air ratio, reaching a peak at around 1.1 and then decreases as the excess air ratio increases further.]
By products of combustion

NOx: nitrogen oxides
(NO and NO2)
Caused by high flame temperatures and long residence at high temperatures
By products of combustion

The three primary sources of NO\textsubscript{x} from combustion

1. Thermal NO\textsubscript{x}
   Thermal NO\textsubscript{x} refers to NO\textsubscript{x} formed through high temperature oxidation of the nitrogen found in combustion air. The formation is primarily a function of temperature and residence time of nitrogen at that temperature. Usually above 2900 deg F.

2. Fuel NO\textsubscript{x}
   Fuel NO\textsubscript{x} refers to NO\textsubscript{x} from fuels with nitrogen in them where the nitrogen bond is released during combustion. Primarily from fuels like coal and oil.

3. Prompt NO\textsubscript{x}
   When atmospheric nitrogen bonds during the combustion process. Usually with an element that is not oxygen in the beginning but later oxidizes to NO\textsubscript{x}
Gas Combustion

- Non-Premixed – Diffusion – Air and fuel meet during ignition
- Partial Premixed – Non-uniform mix of air and fuel before ignition
- Premixed – Uniform mix of air and fuel before ignition
Pre-mixed surface stabilized combustion
Gas combustion

What effect does air have on combustion?

Natural gas

<table>
<thead>
<tr>
<th>CO2</th>
<th>6.5</th>
<th>7.8</th>
<th>9.0</th>
<th>11.0</th>
<th>11.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>1.8</td>
<td>1.5</td>
<td>1.3</td>
<td>1.06</td>
<td>1</td>
</tr>
</tbody>
</table>

Flame lift

Normal operation

Incomplete combustion
Pre-mixed surface stabilized

Pre-mixed:

The gas and air are completely mixed before combustion starts. This means that as soon as the combustion process starts it can continue until completion.

Surface stabilized:

The position of the combustion process is defined by the burner surface.
Pre-mixed surface stabilized burners

Advantages
- Lower emissions on CO and especially NOx.
- Shape of burner and flame can be manipulated
- Can be made to have very compact flames
- Freedom of mounting orientation
- Large modulation range
- Ability to monitor combustion at burner/flame (Gas Adaptive)

Disadvantages
- Chances for Thermo-acoustic
Pre-mixed surface stabilized burners

Thermoacoustics is the interaction between temperature, density and pressure variations of acoustic waves.

Easiest way to demonstrate is a Rijke Tube.

Rijke's tube turns heat into sound.
Examples of different surface stabilized burner shapes

Radially fired only
Radially and tip fired
Flat
Dome
Three dimensional surfaces
Custom shapes and applications
Pre-mixed surface stabilized burners

- **Surface loading:** Pre-mixed surface stabilized burners operate over a wide range of surface loading. They easily operate below 50 (kbtu/hr)/ft², and beyond 1000 (kbtu/hr)/ft². The maximum is defined by the flame lift behavior which itself is related to the excess air level and burner designs.

- **Excess air:** Pre-mixed surface stabilized burners operate with an excess level from 1 to 1.8. When high surface loads are applied the maximum excess air level will decrease.

- **Surface temperatures.** Pre-mixed surface stabilized burners operate with high burner surface temperatures, especially on lower loads because the flame is close to the surface. Higher loads will cool the burner medium. The Nit Fabric surface temperature can be over 1800 deg F.
Flame images

Increasing excess air level, same load
Increasing load, same excess air level
Flame images

Not enough air shows itself by long, wavy flames: the flame are looking for oxygen. Enough air is a stable, short flame on the surface.
Applications

Residential

Water heating

Boiler - Hydronic Furnace

Up to 96% Efficient

1. The quiet, brushless DC blower prepurges the submerged combustion chamber for 8 seconds and turns off.
2. The hot surface igniter is energized and glows red hot.
3. The blower turns on, precisely mixing air and gas for combustion. The mixture is forced through the metal fiber burner and is ignited by the hot surface igniter. A blue flame is evenly distributed across the entire burner, resulting in clean combustion with low nitrous oxide emissions.
4. The combustion chamber wall efficiently transfers high temperature heat from the flame to the water.
5. The blower pushes hot combustion gases through the spiral coil, which scrubs the remaining heat from the hot gases.
6. As combustion gas exits the bottom of the spiral coil, it is barely warm to the touch. Up to 96% of the heat from the flame is transferred to the water.
7. Combustion gases are vented through PVC, CPVC or ABS plastic pipe.
8. Condensation formed by cooled combustion air is captured by a condensate trap and drained through a drain line.
Applications

Commercial

Water heating

Boiler – Hydronic and Steam

Furnace

Cooking
Industrial

Flare