Overview

> Combustion with oxygen enhancement
> Applications in cutting, brazing, heating, and welding
> Applications in metals processing
Combustion with Oxygen Enhancement

What is Oxygen?

A gas which is:
> Colorless
  - (Liquid oxygen is pale blue)
> Odorless
> Necessary to support life
> Necessary for combustion
What is Oxygen-Enhanced Combustion?

> Air is the oxidant for most combustion processes
> Air contains roughly four parts nitrogen and one part oxygen
> As the concentration of oxygen increases:
  – Flame temperature increases
  – Available heat increases
  – Heat transfer rates increase
  – Combustion efficiency increases
**Oxygen vs. Air**

**Natural Gas Combustion**

<table>
<thead>
<tr>
<th></th>
<th>Oxygen</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adiabatic Flame Temperature (°F)</td>
<td>~ 5,000°F</td>
<td>~ 3,500°F</td>
</tr>
<tr>
<td>Available Heat (2500°F exhaust)</td>
<td>70%</td>
<td>33%</td>
</tr>
<tr>
<td>Exhaust Gases CF / MMBtu</td>
<td>3,000</td>
<td>11,000</td>
</tr>
</tbody>
</table>

**Useful Heat**

> A high temperature process
> Exhaust gases will leave at or above process temperature
> Combustion must be well above process temperature to provide useful heating
Oxygen Enhanced Combustion

Value of High Temp Combustion on a High Temperature Load

Benefits of Oxygen-Enhanced Combustion

- Increased productivity
- Fuel savings
- Reduced emissions
Benefits of Oxygen-Enhanced Combustion

> Fuel savings
  - 15% to 70% fuel savings depending on load temperature
    • Economics dependent on fuel cost, oxygen cost, and load temperature
  - In air/gas combustion
    • Sensible heat is lost through the exhaust gases which contain mostly nitrogen
  - Oxygen-enhanced combustion reduces exhaust gas losses and increases heat transfer rates

Benefits of Oxygen Enhanced Combustion

> Reduced emissions
  - Oxy/fuel eliminates the primary nitrogen source
    • Lowers NOx formation within the combustion process
  - Low NOx oxy-fuel burners using staged combustion
    • “Staged” – burners or systems that split one of the reactants (fuel or oxidant) into two streams
    • The first stream supports combustion under design conditions in the “primary zone”
    • The second stream is mixed with the products of the primary zone and the furnace gases to complete combustion
Oxygen Production

>Cryogenic distillation
  — Plants produce most of the commercially used gaseous and liquid oxygen
  — For requirements greater than 100,000 scfh with constant use patterns

>Bulk liquid supply systems
  — For smaller requirements and intermittent use
  — Delivered and stored at users’ sites in special tanks designed for cryogenic liquids

>Adsorption Systems
  — Pressure Swing Adsorption (PSA) or Vacuum Swing Adsorption (VSA)
  — Nitrogen from the air is preferentially adsorbed
  — Purity ranges from 80 to 95%, up to 120,000 scfh

>Membrane System
  — Air is passed through a membrane which oxygen permeates faster than nitrogen
  — Low purity, 28 to 35%
  — For requirements in the 1,000 to 15,000 scfh
Methods for Using Oxygen to Enhance Combustion

- Air enrichment
- Oxygen lancing
- Air-oxy/fuel
- Oxy/fuel

Air Enrichment

- Oxygen concentration is above that of normal air
- Oxygen is blended with the blower air to raise the oxygen content to 22% to 25%
- Enriched air is sent directly through burner
- Moderate temperature elevation applications
Oxygen Lancing

- Improved combustion characteristics by injecting oxygen near an air-fuel flame
  - Can target portion of flame to enrich
- No concerns with burner compatibility
- Go to higher oxygen level than enrichment
- Can lower NOx due to “staged combustion”
- Move to higher enrichment and temperature requirements
**Air-Oxy/Fuel**

- Effective oxygen enrichment up to 40%
- Burner is designed with integral oxygen passageways

**Oxy/Fuel**

- No blower air is used
- Fuel is combusted with ~ 100% oxygen
  - High flame temp ideal for melting applications
  - Good for high temp processes because of available heat (Ladle Preheating)
  - Good for applications where high heat transfer rates are required (Rapidfire)
# Oxygen Enhanced Combustion

## The Hazards of Oxygen

- Pressure
- Supports and accelerates combustion
- Oxygen enrichment
- Reactivity

## Reactivity

- Increases with concentration and pressure
- Combustible contamination in system may ignite
  - Heat generated from this reaction may spread
  - Systems must be cleaned for O₂ service
Fuels

> Common fuels in an atmosphere of air
  - Wood
  - Coal
  - Gas
  - Oil

>Fuels in enriched oxygen atmospheres
  - Aluminum
  - Stainless steel
  - Steel

Non-typical Ignition Sources for Oxidizers

> Velocity
  - Particle impingement

> Friction
  - Opening valve

> Adiabatic heat of compression
  - Pressure Slig can start a fire
  - Open valves slowly

> Contamination
  - Hydrocarbon oils can spontaneously combust in an oxygen atmosphere
General Precautions - Oxygen

> Open and close valves slowly
> No smoking or open flames in storage areas or near piping
> Never consider oxygen as a direct substitute for compressed air
> Avoid skin contact with frosted piping
> If clothing becomes saturated with oxygen or you suspect you have been exposed to oxygen, fully aerate clothing and avoid all sources of ignition for at least 30 minutes.
  — Clothing soaked with oxygen can explode in flames if an ignition source is present

Material Compatibility - Oxygen

> Select materials adequate for pressure conditions
> Select materials adequate for temperature conditions
> Copper and copper-based alloys
> Monel
> Teflon TFE - DuPont, Viton
> Halocarbon Grease (halogenated chlorotrifluorethylene)
> NOTE: Carbon steel and stainless steel may be used for piping if sized and cleaned according to CGA guidelines
Special Precautions

> All piping and flow control components must be specially cleaned and suitable for oxygen service
  — Oxygen cleaning procedure called Pamphlet G-4.1.1 - Compressed Gas Association (703) 412-0900
> Keep all piping and controls free of oils and greases
> Never use liquid pipe dope or any material not specifically designated as suitable for oxygen service

Applications in Cutting, Brazing, Heating, and Welding
Overview

> Natural gas can be used as an industrial gas for many applications, replacing acetylene or propane
  — Is natural gas a good industrial fuel gas?
  — What equipment is needed to use natural gas and what does it do?
  — Review example applications

Customer Questions

> How does natural gas compare to acetylene and propane? Is natural gas hot enough?
> Does natural gas provide enough BTUs?
> Can I save money with natural gas?
> Is natural gas safe or safer?
> Can natural gas do the job?
Is Natural Gas Hot Enough?

- Natural gas burns at 5,100°F
- Propane burns at 5,200°F
- Acetylene burns at 6,000°F

- Mild steel combusts at 1,600°F
- Most braze alloys melt between 1,100 - 1,800°F
- Pre/post weld heating requires 350 - 400°F

Does Gas Provide Enough Heat?

- Natural gas 1,000 BTUs/cf
- Propane 2,560 BTUs/cf
- Acetylene 1,470 BTUs/cf

- Torch equipment must be adapted to provide greater gas flow with natural gas
Can I Save Money With Natural Gas?

- Natural Gas: $0.75 per 100,000 BTUs
- Acetylene: $10.08 per 100,000 BTUs
- Propane: $2.56 per 100,000 BTUs
- Per 100,000 BTUs, no fuel gas costs less than natural gas

Natural Gas Users Also Save Because...

- There are no cylinder rental charges
- No residual fuel is returned in “empty” cylinders
- No extra cash tied up in fuel gas inventory
- You pay for natural gas AFTER it is used, not when it is delivered – improved cash flow
**Why is Natural Gas Safer Than Acetylene, Propane, etc.?**

- Gas is lighter than air; leaks rise and dissipate
- Natural gas has a narrow combustibility band
- Removing/reducing on-site storage improves safety

Acetylene cylinders in a Columbus, OH Midas Muffler shop explode and burn three customer vehicles.

**Best Applications**

- Torch cutting
- Brazing
- Heating

"Natural gas is an excellent fuel for braze welding, flame cutting, heating and soldering."
- Edison Welding Institute
Applications

>Torch cutting – gas with 100% oxygen
>Brazing – generally gas with air
>Heating – generally gas with air

Superior Cutting Performance in Some Common Materials

>1/8” to 84” thick plate
>Cleaner cuts with less slag
>Squarer corners
>Less heat damage to top
>Similar pierce times

Natural Gas - 2” Mild Steel
Acetylene - 2” Mild Steel

Source: G-TEC Natural Gas Systems
Natural Gas Cut Speed Is Only Slightly Slower than Acetylene...

Get Superior Brazing Performance

> Wrap around flame yields more uniform heat-through
> Rod flows more smoothly
> Less porous braze
> Little carbon means fewer fisheyes
Get Superior Heating Performance

> The high heat content of the natural gas secondary flame enables a wider area to be heated more evenly, more quickly

> Users notice that an area can be heated and kept hot more easily with natural gas than with acetylene

Source: G-TEC Natural Gas Systems

Natural Gas is...

> Readily available – easily piped into most buildings
> Low cost - no fuel gas costs less per BTU
> Safe - natural gas is the safest gas
> Can produce cleaner cuts, better quality brazes and even heating
> The question is whether the customer can get natural gas at the pressure he needs for his application
What Equipment is Needed?

- Gas is rarely available at sufficient pressure
- Torches need 45+ psig
- Often involves adding a compressor or “booster”

Torch Booster

- Elevate low pressure utility gas service to ~45 psig to supply torches directly
- 60 - 500 cf/hr
- However, high usage over limited periods may require excessive booster capacity
**Refueler**

- Boost pressure up to 275 psi at 60 cf/hr
- Allow customers to fill tanks to serve high intermittent loads
- Cylinders available to 130 cf (adsorption)
- Also allow customers to fill their own cylinders for portable applications

Source: G-TEC Natural Gas Systems

**Refueler/Storage System...**

- Storage system that uses refueler with NG cylinders to create a system that never runs out of gas
- Refills cylinders when they reach 175 psi
- Regulator connects to burning table or other “peak-demand” torch application

Source: G-TEC Natural Gas Systems
Oxy / Gas and Air Gas Systems

> Torches may use oxygen, air, or enriched air for combustion

Oxy/Gas Supply for Cutting Metal
Oxygen in Stainless Containers

Blue Flame Gas Air Torch in Food Processing

Applications

Torch Cutting

Ham Glazing

Shrink Wrapping

Brazing

Jewelry Manufacturing

Auto Repair

Glass Lampworking

Source: G-TEC Natural Gas Systems
Individual Torch Systems

UA Local 501 - Chicago

One Booster for Multiple Torches

Sheridan College - Toronto

Source: G-TEC Natural Gas Systems
Tank Refueler System
Assink Brothers - Toronto

Food Processing
Heavenly Ham-Buffalo

Source: G-TEC Natural Gas Systems
Certifications

> Compression systems are certified by CSA-IAS; Fire Marshal or building inspector approval is not a problem

> System should automatically shut itself off if:
  ─ An output hose is cut
  ─ Building gas pressure drops below 2”WC
  ─ Internal pressure limits are reached

Source: G-TEC Natural Gas Systems

Applications in Metals Processing
Common Large Industrial Applications of Oxygen Enhanced Combustion

> Steel
  − Blast furnace oxygen enrichment
  − EAF
    • Oxy/fuel assisted melting
    • Post combustion
  − Rolling mill
    • Reheat furnace enrichment
    • Rapidfire technology

EAF Oxy/Fuel-Assisted Melting Benefits

> Increased production (10-25%)
> Reduced electrical power (30-80 kwh/ton)
> Electrode savings (10-15%)
> Lower unit production costs
Oxy/Fuel Ladle Preheating

Benefits

> Reduce molten steel temperature loss
  > 40% faster heat-up
  > Hotter ladle bottoms

> Reduce/eliminate metal skulling on ladle lining

> Increase ladle refractory life
  > Improved temperature control
  > Less spalling

> 70% fuel savings

> 90% reduction of exhaust gases
**Rapidfire**

> Heat metal via direct flame impingement  
> Very high heat transfer rates/efficiencies  
  > High combustion temperature produces high heat transfer rate  
> Easily retrofitted to existing lines  
> Compact

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**Rapidfire Applications**

> Rolling mill heating  
  > Edge  
  > Head/tail  
> Billet/slab preheating/post heating  
> Strip heating  
  > Continuous annealing

Source: Rapidfire
**Rapidfire Edge Heating Benefits**

- Improved edge quality
- Less roll wear
- Reduced ripped tails
- Increased productivity
- Lower furnace temperature
  - Fuel savings
  - Increased yield

**Rapidfire Continuous Annealing**

- Copper producer
  - Older continuous annealing furnace was bottleneck in the plant on higher gauge strip
- Applied Rapidfire to pre-heat strip entering continuous annealing furnace
- Achieved 40% production increase with less than 1MMBtu/hr firing rate
- No degradation of surface quality
Common Applications of Oxygen Enhanced Combustion (cont’d)

> Iron
  ─ Cupola enrichment
  ─ Cupola oxy/fuel

> Aluminum
  ─ Rotary
  ─ Reverb furnace

Summary

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Questions?