Suggested Actions

- Use current or projected energy costs with PHAST to estimate energy savings from oxygen-enriched combustion.
- Contact furnace or combustion system suppliers to calculate payback or return on investment.
- Include the cost of oxygen or of the vacuum pressure swing adsorption unit in the calculations.

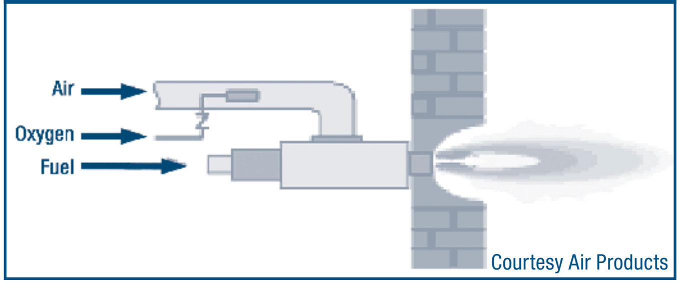
Resources

U.S. Department of Energy— For additional information on process heating system efficiency, to obtain DOE's publications and Process Heating Assessment and Survey Tool (PHAST) software, or learn more about training, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices.

Oxygen-Enriched Combustion

When a fuel is burned, oxygen in the combustion air chemically combines with the hydrogen and carbon in the fuel to form water and carbon dioxide, releasing heat in the process. Air is made up of 21% oxygen, 78% nitrogen, and 1% other gases. During air–fuel combustion, the chemically inert nitrogen in the air dilutes the reactive oxygen and carries away some of the energy in the hot combustion exhaust gas. An increase in oxygen in the combustion air can reduce the energy loss in the exhaust gases and increase heating system efficiency.

Figure 1. Oxygen-enriched burner



Courtesy Air Products

Most industrial furnaces that use oxygen or oxygen-enriched air use either liquid oxygen to increase the oxygen concentration in the combustion air or vacuum pressure swing adsorption units to remove some of the nitrogen and increase the oxygen content. Some systems use almost 100% oxygen in the main combustion header; others blend in oxygen to increase the oxygen in the incoming combustion air (see Figure 1). Some systems use auxiliary oxy-fuel burners in conjunction with standard burners. Other systems use staged combustion and vary the oxygen concentration during different stages of combustion. Still others "lance" oxygen by strategically injecting it beside, beneath, or through the air–fuel flame.

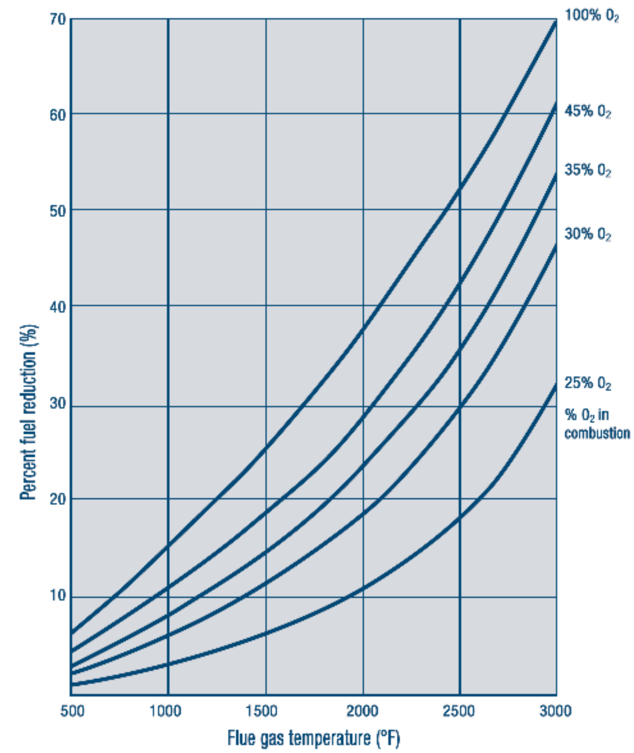
Benefits

Oxygen-enriched combustion can:

- **Increase efficiency.** The flue gas heat losses are reduced because the flue gas mass decreases as it leaves the furnace. There is less nitrogen to carry heat from the furnace.
- **Lower emissions.** Certain burners and oxy-fuel fired systems can achieve lower levels of nitrogen oxide, carbon monoxide, and hydrocarbons.
- **Improve temperature stability and heat transfer.** Increasing the oxygen content allows more stable combustion and higher combustion temperatures that can lead to better heat transfer.
- **Increase productivity.** When a furnace has been converted to be oxygen enriched, throughput can be increased for the same fuel input because of higher flame temperature, increased heat transfer to the load, and reduced flue gas.

Using oxygen-enriched combustion for specific applications may improve efficiency, depending on the exhaust gas temperature and percentage of oxygen in the combustion air. Figure 2 can be used to calculate energy savings for commonly used process heating applications. The Process Heating Assessment and Survey Tool (PHAST) can also be used to estimate the amount of energy that can be saved by switching to oxygen-enriched combustion.

Figure 2. Energy savings from oxygen injection



Conversion to oxygen-enriched combustion is followed by an increase in furnace temperature and a simultaneous decrease in furnace gas flow around the product. Unless there is a sufficient increase in the heat transfer to product, the flue gas temperature will rise above the pre-conversion level and little or no energy will be saved. In radiant heat-governed furnaces, the conversion could increase the radiant heat transfer substantially. Consequently, the flue gas temperature could drop to or below the pre-conversion level. In convective heat-governed furnaces, the furnace gas velocity may drop because the convective heat transfer coefficient may decrease in a larger proportion than the increase in gas temperature. If this happens, the conversion would do little to increase the overall heat transfer, so reducing flue gas temperature to pre-conversion level may not be possible.

Potential Applications

Oxygen-enhanced combustion is used primarily in the glass-melting industry, but other potential applications can be found in Table 1.

Table 1. Potential Applications for Oxygen-Enhanced Combustion

Industry	Applications
Steel	Reheat, soaking pits, ladles
Aluminum	Melting
Copper	Smelting and melting
Glass	Melting
Pulp and Paper	Lime kilns, black liquor boilers
Petroleum	Process heaters, crackers
Power Production	Coal-fired steam boilers
Chemical	Sulfur

Sample Applications

Theoretical — A a potential application is a PHAST analysis of a forging furnace where the flue gas temperature is 2,100°F and 95% of the combustion air is oxygen. This shows a 42% fuel saving over a conventional system.

Actual — The U.S. Department of Energy (DOE) sponsored a performance study (www.eere.energy.gov/industry/glass/pdfs/oxy_fuel.pdf) in which a glass melter was converted to 100% oxygen-enriched combustion. The plant was a 70 ton-per-day end-fired melter. Natural gas consumption was lowered by 10% to 20% and nitrogen oxide emissions were reduced by 90%.

Reference

Improving Process Heating System Performance: A Sourcebook for Industry. DOE and the Industrial Heating Equipment Association (IHEA) www.oit.doe.gov/bestpractices/library.shtml.

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

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