



**Oxygen-enhanced
cement and lime production
that can help improve your
kiln operations . . .
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Inject a breath of fresh oxygen into your kiln, and watch it perform like never before.

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Whether you are trying to increase alternative fuel utilization, boost production, reduce emissions, or all of the above, our industry specialists and proprietary oxygen injection technologies can help deliver improved kiln performance.



Proven technology

Oxygen enrichment is a flexible, efficient, cost-effective technology that can help improve your kiln operations. Since 1997, Air Products' proprietary enrichment systems have been installed and demonstrated on over 30 kilns around the world. With minimal capital investment, you can increase alternative fuel utilization, increase production, decrease emissions, and improve kilns performance. The technology is applicable to all types of kilns and its low installation costs make it an attractive alternative to expensive equipment modifications.

Benefits of improved combustion

Adding oxygen enhances combustion, no matter what type of fuel you burn. By installing an oxygen enrichment system, you have the potential to realize a wide variety of benefits:

Increased alternative fuel utilization

Reduced fossil fuel consumption

Reduced CO₂ emissions

Improved kiln stability

Better burning zone control

More consistent product quality and production rates

All of these add up to improved performance that can help lower your overall costs.

How oxygen enrichment works

Oxygen is required for any combustion process. Although air is the most common source of oxygen, it is not the most efficient, since it also contains about 78% nitrogen. Nitrogen is relatively inert and does not contribute to the combustion reaction. The nitrogen contained in air actually inhibits fuel from reacting with oxygen and absorbs heat from the combustion reaction. This results in a flame temperature below that attainable with pure oxygen.

The basic principle behind oxygen enrichment is straightforward. Oxygen is added to combustion air or is injected to react directly with the fuel. Adding pure oxygen (oxygen enrichment) improves the overall combustion process and the resulting heat transfer by increasing flame temperature. In a cement or lime kiln, this translates into improved kiln stability and provides operators with greater control and flexibility in dealing with challenging conditions.

The result—more consistent kiln operation and product quality, increased alternative fuel utilization, and increased production when needed. Additionally, by substituting pure oxygen for a portion of the combustion air, overall gas flow rates are reduced and thermal efficiency increases.

Increased use of alternative fuels

While economically attractive, the use of alternative fuels presents a major challenge to the kiln operator. Many alternative fuels are available, and their chemical and physical properties vary significantly. Due to this wide range in properties, there is often a practical limit to substitution levels. In the kiln, maintaining sufficient front-end temperature is paramount to consistent kiln operation. If the optimal temperature cannot be maintained due to the low heating values of the fuels employed, production levels must be curtailed. As a result, overall fuel substitution and the economic benefits are often limited. Oxygen enrichment improves the combustion of these fuels, increases flame temperature,



and thereby raises the level of possible alternative fuel substitution. The resulting improved kiln control and stability with oxygen enable operators to maintain feed rates and burn more consistently than with air alone.

The nitrogen component of combustion air is particularly problematic for kilns firing alternative fuels, since these fuels generally produce more exhaust gases per thermal input. This is due to their composition and higher moisture content relative to conventional fuels. Excess air requirements increase with alternative fuels, adding even more air and nitrogen, to the system. As substitution levels increase, it is common for the induced draft (ID) fan to reach its operating limit, preventing additional thermal input. Once fan-limited, oxygen enrichment enables increased alternative fuel substitution without a further reduction in kiln throughput.

Through the use of oxygen, cement and lime plants are able to increase alternative fuel utilization and lower operating costs while maintaining or improving production and quality. The savings for our customers has been substantial, with most achieving a net payback of less than six months.

Oxygen enrichment increases alternative fuel utilization

	Plant							
	A	B	C	D	E	F	G	H
% alternative fuel usage without oxygen	45.4	31.1	45.9	44.3	42.8	43.9	60.5	27.0
% alternative fuel usage with oxygen	72.9	52.4	69.3	65.6	77.3	58.3	67.0	40.7
% reduction in fossil fuel	-50.0	-25.9	-40.0	-36.0	-57.5	-25.0	-10.8	-22.0
CO ₂ e savings (tons per year)	13,500	8,100	10,800	9,720	34,500	10,800	3,780	11,880

Notes:

1. Production rates were held constant except for Plant G where there was a 4% production increase with oxygen.
2. Carbon dioxide equivalent (CO₂e) savings at Plant E were greater due to the substitution of biomass fuels for fossil fuel.
3. Results are from recent installations (since 2009).



Steetley Dolomite's lime plant faced challenges in burning solvent-derived fuel (SDF) prior to oxygen enrichment.



Air Products' engineers designed the oxygen system as an easy retrofit.

Alternative fuels case study

When UK lime manufacturer Steetley Dolomite started burning a combination of waste solvents and low calorific value coal in its three rotary kilns, product quality did not suffer, but throughput fell. By using Air Products' proprietary oxygen injection technology, Steetley Dolomite's production increased about 10%, restoring the performance they had before using alternative fuel. John Carlill, Managing Director, says, **"We believe Air Products is leading the way in oxygen enrichment technology through their knowledge, expertise and professional approach. From installing the equipment, operating the plant, training and providing continued support, Air Products has exceeded all expectations, and continues to impress."**

Increased production rates

Most cement and lime plants that are fan-limited implement oxygen enrichment to increase production. The added oxygen enables the combustion of additional fuel, allowing operators to increase feed rates. Enhanced kiln stability and quick recoveries from “pushes” also translate into increased production. We have helped customers routinely increase kiln throughput by 5 to 30 percent. The capital cost to install an oxygen system is typically very low compared to other equipment or system upgrades and is not a significant factor in considering oxygen. In most instances, simple payback on total capital is on the order of two to three months.

Typical production gains using Air Products' oxygen injection technology

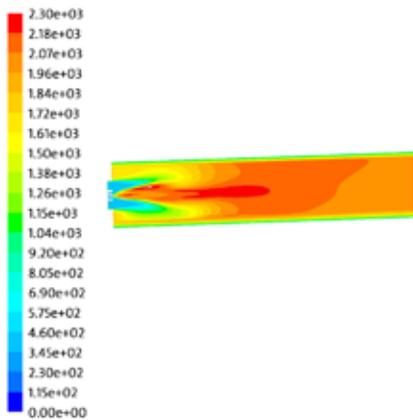
Company	Base Production (tons per day)	New Production (tons per day)	% Increase
A	1,300	1,490	15
B	4,000	4,360	9
C	3,800	5,000	32
D	2,000	2,140	7



Oxygen is either produced at large cryogenic air separation plants and then transported by tank truck to a customer's site or, in some cases, it can be generated directly on location.



Air Products' advanced Clean Energy Laboratory enables development and full-scale testing of new oxygen-enriched combustion technologies.



Advanced computational fluid dynamic modeling of kiln combustion helps in developing new technologies and visualizing your oxy-fuel enrichment application.

Benefit from our expertise

For over 15 years, Air Products has been helping customers with all types of kilns improve their operation. Specific plant design, burner configuration, and types of fuels employed will often dictate the most appropriate location for oxygen injection. Our technology specialists will work closely with your process engineers and operators to select the best injection technique for your unique operating conditions. To get your system up and running, we will work with you on-site. We also provide ongoing technical support after installation. In addition, you will benefit from Air Products' research into new methods for enhancing oxygen enrichment with our goal of optimizing kiln performance with the lowest possible consumption of oxygen.

Your success is our success

We understand oxygen enrichment and know that it can make a difference for you, whether you need to increase production, maximize the use of alternative fuels, reduce emissions, or achieve other competitive advantages. Our unique approach to customer relationships is based on understanding your needs first so that we can offer the right gases, technologies, and services to help you be more successful. When you work with us, you deal with people whose understanding, integrity, and passion have been valued by our customers for years.

Our emphasis on safety and sustainability

At Air Products, nothing is more important than safety—not sales, not production, not profits. We have one of the best safety records in the industrial gas and chemical manufacturing industries, and our oxygen injection systems meet the highest safety standards. We are equally diligent about sustainability. Often, our offerings and applications expertise help our customers' sustainability by reducing energy use, increasing productivity and product quality, and lowering emissions and waste. For cement and lime producers, carbon dioxide emissions are a key concern. Oxygen enrichment increases energy efficiency and enables increased use of alternative fuels, resulting in significant CO₂e savings.

About Air Products

Air Products serves customers in many markets worldwide with a unique portfolio of atmospheric, process, and specialty gases as well as performance materials, equipment, and technology. For over 70 years, the company has developed innovative solutions that help customers become more productive, energy-efficient and sustainable.

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