Enhanced combustion

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Alternative fuel substitution can provide an effective means to significantly reduce plant operating costs but often at the expense of production. The use of oxygen to improve the combustion of alternative fuels has been shown to reduce or eliminate emission concerns and increase flame temperature. The resulting improved burning zone control enables operators to maintain feed and burn at a more consistent rate. Over time, improved kiln stability translates into more production, increased fuel substitution rates, and lower operating costs. Actual operating results and data from several cement plants are presented in this article.

Figure 1: Air Products makes a delivery to Buzzi Unicem

The use of alternative fuels is beneficial to the cement industry as well as to our environment. Firing alternative fuels reduces primary fuel consumption, typically coal, and lowers operating costs for the cement plant. From an environmental standpoint, the reduction of the primary fuel decreases the use of non-renewable fossil fuel and the associated environmental impacts. Waste products fired in cement kilns are a viable fuel source, which would otherwise be subject to incineration or landfill.

European cement producers have been leaders in the utilisation of alternative fuels as they can significantly reduce their demand for expensive coal. High landfill and disposal costs in Europe further enhance the overall economics of fuel substitution. As a result, a wide variety of wastes, such as tyres, animal meal, waste oil, plastics, waste wood, and waste paper products or 'fluff', etc, are routinely fired in cement kilns. In the United States, tyres and petcoke are more commonly employed with many of the older, less efficient wet kilns firing hazardous waste fuels (waste derived fuel).

Since landfill costs are less expensive in the United States, the economics of using these wastes depends heavily on transportation costs.

Another key difference between the United States and Europe has been vastly different market conditions. While there has been an excess of cement capacity in Europe, US cement producers have experienced very high demand levels since the mid 1990's. Until the recent housing slump in the United States, many of the US cement producers were operating at extremely high capacity levels to keep up with demand. Most could not afford to implement changes in their processes that would negatively impact production. Therefore, substitution of their primary fuel with lower heating value waste products has not been an economically viable option.

Kiln operation

Utilisation of alternative fuels can range from five to 100 per cent, depending on the fuel 'quality' and production demands of the kiln. The fuel 'quality' or heating value determines the potential substitution rate. Low quality fuels possess a lower heating value either due to higher moisture content, lower carbon content, or lower volatility of the fuel component. When firing alternative fuels, generating sufficient heat in the kiln can be difficult. The flame temperature of alternative fuels is routinely below the primary fuel flame temperature. This 'colder' flame necessitates a reduction in feed rate to maintain burning zone temperature and clinker quality.

Additionally, variations in the composition (chemical and physical) of alternative fuels make it difficult to maintain stable operating conditions. Variations in the fuel quality and composition lead to incomplete combustion and fluctuations in kiln emissions, specifically carbon monoxide (CO) and total hydrocarbons (THC). Stringent emission regulations for kilns burning certain alternative fuels exist to ensure complete combustion and destruction of the wastes. Sufficient 'excess air' is often required to ensure complete combustion. In some cases, too much air through the kiln becomes detrimental as it will change the kiln temperature profile and possibly impact combustion efficiency due to the higher kiln velocities. In order to operate within regulated emission limits, plants must carefully monitor emissions and make necessary adjustments to fuel substitution and production rates.

Oxygen impact

Oxygen is required for any combustion process. Although air is the most common source of oxygen, it is not the most effective, since it also contains about 79 per cent nitrogen. Nitrogen in air takes up volume, absorbs heat, and lowers flame temperature. Adding pure oxygen (oxygen enrichment) improves the overall combustion process by increasing the flame temperature and the amount of available

Figure 2: oxygen supply system at Buzzi's Chattanooga plant

Table 1: oxygen injection into wet kiln firing waste derived fuels (solvents, chemicals, solids)

Case study A	*Base operation*	*Operation with oxygen*	*% change*
Clinker (tpd)	1000	1080	+8%
Waste Derived Fuel (kg/min)	100	148	+48%
Coal Replacement	38.5%	58%	+51%
Waste Fuel Cut-Offs (per day)	3.4	1.8	-47%

All data is normalised

Table 2: modified oxygen injection into wet kiln firing waste derived fuels and using oxygen

Case study B	*Original oxygen*	*Operation with injection*	*% change*
Clinker (tpd)	1000	1050	+5%
Waste Derived Fuel (kg/min)	100	138	+38%
Coal Replacement	37%	51%	+38%
Oxygen Flow Rate (Nm^3/hr)	1200	800	-33%

All data is normalised

heat. In the kiln, oxygen enhances burning zone control and improves kiln stability.

The use of oxygen to improve the combustion of alternative fuels has been shown to reduce or eliminate emission excursions and increase flame temperature. The resulting improved burning zone control enables operators to maintain feed and burn at a more consistent rate. Over time, improved kiln stability translates into more production, increased fuel substitution rates, and lower operating costs. Depending on the value of the alternative fuels, increased substitution can lead to a net negative fuel cost (including the cost of oxygen).

Initial use of oxygen to increase alternative fuels

Oxygen was implemented at a customer's wet kiln to increase the rate of waste derived fuel (WDF) consisting of non-disposable chemicals, solvents, etc. The kiln was experiencing THC concentration spikes, which in turn would require the cessation of firing with waste derived fuel. To optimise kiln operation, constant fuel firing needed to be achieved. Air Products' kiln combustion specialists devised a solution employing oxygen injection. The positive results were immediate – a reduced level of THC emissions was achieved, enabling the plant to significantly increase their fuel substitution rate while gaining a slight production increase. This plant has been using oxygen effectively since 2000, often achieving net operating costs similar to a modern precalciner due to the increased revenue from the waste fuels processed and reduced coal costs. Normalised data from the first few months of operation is presented in Table 1.

Air Products then installed a similar injection technique at a second plant that was already using oxygen and firing waste derived fuels (see Table 2). Not only were increases in fuel substitution made possible, but an overall reduction in total oxygen consumption was also achieved.

Common to both of these locations were fuel substitution rate increases with slight increases in production. Prior to implementing oxygen, this combination of benefits had not been possible.

Recent experiences at Buzzi Unicem

During the past two years, Buzzi Unicem USA has implemented oxygen at three locations (see Table 3). The first of these was a precalciner that did not fire alternative fuels. Oxygen was implemented for the sole purpose of gaining an incremental production increase. After observing the positive impact of oxygen on kiln performance and burning zone control, Buzzi sought to use oxygen at one of their locations that fired a combination of alternative fuels.

Chattanooga, TN

Buzzi Unicem's Chattanooga facility is a modern five-stage precalciner dry process with a 2475tpd baseline clinker capacity burning petcoke as the primary fuel. The plant also burns oil for heat up of a cold kiln. Air Products and Buzzi Unicem implemented oxygen enrichment in July 2005 primarily for clinker production increase. The oxygen enabled Buzzi Unicem

Table 3: oxygen enrichment results at Buzzi's facilities

		Base operation	*Operation with oxygen*	*% change*
Chattanooga	Clinker (tpd)	2475	2796	+13%
	Fuel (% petcoke)	100%	100%	–
Cape Girardeau	Clinker (tpd)	3787	4014	+6%
	WDF (kg/min)	152	164	+8%
Greencastle	Clinker (tpd)	3719	3904	+5%
	SNHW (tph)	1.36	1.36	–
	WDF (kg/min)	272	272	–

SNHW – Shredded Non-Hazardous Waste
WDF – Waste Derived Fuel

to fire additional fuel and increase plant production over 13 per cent during the trial, while maintaining 100 per cent petcoke firing. Further, during kiln heat up, the oil flame was unstable, typically requiring another fuel source to stabilise the heat up flame. Oxygen was implemented to stabilise the oil flame resulting in much shorter kiln heat up times and eliminating the need for the secondary fuel.

Cape Girardeau, MO

Based on the positive results at Chattanooga, Buzzi Unicem implemented oxygen at its Cape Girardeau, MO plant. This facility has a four-stage precalciner dry kiln process with a 3787tpd baseline clinker capacity. The kiln burns liquid waste derived fuels (solvents, chemicals, etc) and coal. Air Products and Buzzi Unicem implemented oxygen in April 2006 primarily to increase clinker production, while increasing the burning of liquid waste derived fuels. With oxygen, the kiln's clinker production increased about six per cent with an increase in liquid waste derived fuels of eight per cent.

Greencastle, IN

Following the success of oxygen enrichment at the Chattanooga and Cape Girardeau locations, Air Products and Buzzi Unicem implemented an oxygen trial at Greencastle, IN during December 2006.

The Greencastle plant is a single-stage precalciner semi-dry kiln with a 3719tpd baseline clinker capacity. The plant burns coal, shredded non-hazardous solids and a very high rate of liquid waste derived fuels in both the kiln and precalciner. Oxygen was implemented primarily to increase clinker production and potentially to increase the burning of liquid waste derived fuels and solid waste. Clinker production increased five per cent while maintaining the maximum firing rate of liquid waste derived fuels. More testing is planned to determine the impact of oxygen on the firing of additional shredded non-hazardous solids.

Summary

Recent implementation of oxygen enrichment at several Buzzi Unicem USA locations raised clinker production while maintaining or increasing WDF rates. In total for these three plants, over 700tpd of incremental clinker capacity has been added through the use of oxygen. Other plants have substantially increased their utilisation of alternative fuels especially where emission limits (CO, THC) have been the rate limiting factor.

Employing oxygen injection to enhance the combustion of alternative fuels is technically and economically viable. With minimal capital investment, plants can implement oxygen enrichment to increase fuel substitution rates and increase clinker production. Oxygen also enables the use of lower quality (or higher value) waste fuels, further enhancing economics. Each cement plant must evaluate their specific economics and operating requirements to determine the optimal utilisation of oxygen enrichment.

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