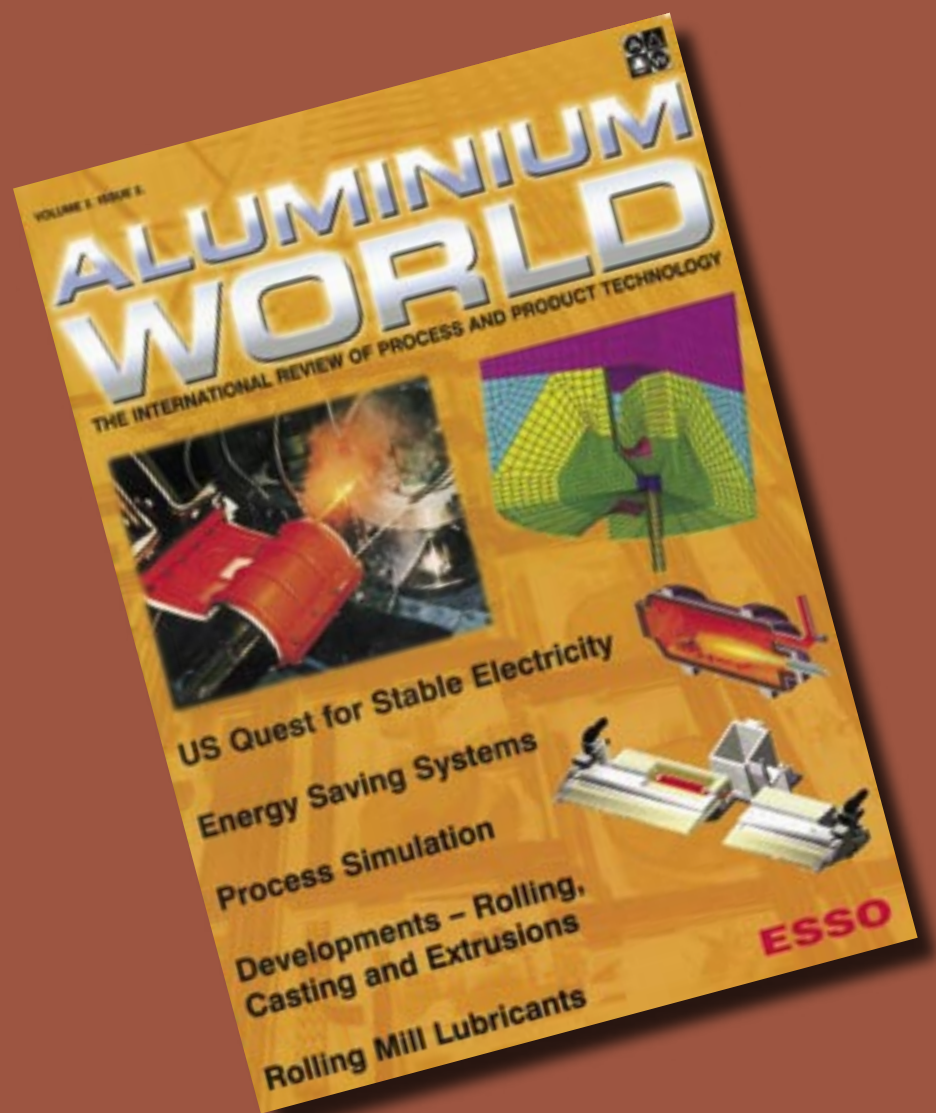


Product design and applications

Advantages of oxy-fuel burner systems for aluminium recycling

By Ludger Gluns and Siegfried Schemberg, Air Products



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Introduction

Oxy-fuel technology has been slower to catch on in the aluminium recycling industry than in some other metallurgical sectors, for instance iron and steel making. Now, though, more and more companies processing aluminium scrap and dross are seeing the advantages of oxygen. Oxy-fuel burners for aluminium are already widely used in many European countries, notably Germany and the UK, and are spreading steadily to the rest of the world. Air Products offers a complete range of oxy-fuel burner systems and furnace technology for the aluminium recycling industry.

Basic advantages of oxy-fuel combustion

Air is free, oxygen is not. So what advantages does oxygen bring to offset its cost? Oxy-fuel burners come in many different configurations: burning natural gas, light, medium or heavy oils, pulverised coal or waste materials; made from steel or refractory; air- or water-cooled. All of them, however, provide three basic benefits.

The first of these is the increase in heat transfer rate made possible by a higher flame temperature. For a natural gas burner with ambient-temperature air, the maximum achievable flame temperature is around 1850°C. Oxygen can boost this to over 2700°C (Figure 1).

Such a high temperature is not in itself necessary for a low-melting metal such as aluminium. Radiant heat transfer, however, is proportional to

the fourth power of the temperature differential ($T_{\text{flame}}^4 - T_{\text{load}}^4$). When T_{load} is 750°C, for example, the oxy-gas flame provides more than four times the rate of radiant heat transfer compared to the air/gas flame.

This increase in heat transfer reduces melting times and increases throughputs, or allows a smaller burner to be used for the same melt rate. Faster melting also reduces fuel consumption, in some cases by up to 60%.

The second advantage of oxy-fuel burners is lower waste gas volumes. For every molecule of oxygen in the air there are more than three molecules of inert nitrogen. This nitrogen plays no useful role in the combustion process, but has to be heated to the flue gas temperature, and so carries away a large amount of energy up the stack. Pure oxygen reduces flue gas volumes substantially and eliminates this waste of energy.

An oxy-fuel burner produces around 70% less flue gas than an air-fuel burner of the same rating. Because of their higher thermal efficiency, however, oxy-fuel burners can generally be fired at a lower rate, so in practice flue gas volumes are often reduced by more than 85%. This means longer flue gas residence times in the furnace, less heat lost in the flue gas, much smaller flue gas cleanup systems, and less dust entrainment, solids loss and workplace fume.

Some aluminium processors think that the absence of nitrogen will increase oxidative losses in the furnace. In practice, losses turn out to be more a function of burner control and melt practice than of whether or not pure oxygen is used. Oxy-fuel systems incorporating oxygen sensors to control the oxygen flow ensure that the combustion mixture is always close to stoichiometric, so little excess oxygen is available to combine with the charge. In addition, the high heat fluxes available from oxy-fuel burners minimise cycle times. In general, users find that switching to oxygen reduces their losses.

The third advantage of oxygen is better flame control, due to the fact that pure oxygen considerably extends the flammability limits of most fuels. For natural gas burning in air, for

instance, the lower flammability limit of 5% and the upper limit of 14% closely bracket the stoichiometric point of 9.5%. In oxygen, the stoichiometric point is at 33% and the flammable range is 5%–60%.

Flame stability with natural gas is not usually a problem, but this widening of the flammable limits also works for oil or solid fuel flames, where precise flow control can be difficult and flame stability hard to guarantee. Oxy-fuel firing ensures stable combustion with a wide range of fuels, even those with lower calorific values. It also allows great flexibility in changing the flame shape, the burner configuration or the gas flow pattern.

Based on extensive research and development work, Air Products has designed a series of combustion systems and process technologies for the aluminium recycling industries. More than 25 years' experience and close co-operation with our customers has yielded proven technology that is now available for both static hearth furnace applications as well as fixed or tilting rotary furnaces.

Rotary furnaces for flexibility...

For scrap contaminated with oil or paint, a rotary furnace is often the system of choice. The APMELT™ LEAM®¹ (Low Emission Aluminium Melting) technology and equipment was developed and patented for such applications. In this double-pass process the oxy-fuel burner is incorporated into the exhaust gas exit. Other important features include a proprietary design of charging door that rotates with the furnace to reduce air ingress, and an offgas sensor to control the ratio of oxygen to fuel—especially important when the charge contains variable amounts of combustible material (Figure 2, Figure 3).

The main benefits of the LEAM® technology and equipment are higher yield, faster melting, lower fuel costs, lower emissions of pollutants and dust, and lower flue gas volumes (Table 1). The LEAM® process equipment can be supplied with new furnaces or retrofitted to existing ones.

The advantages of oxy-fuel fired tilting rotary furnaces (TRFs) are well understood and accepted

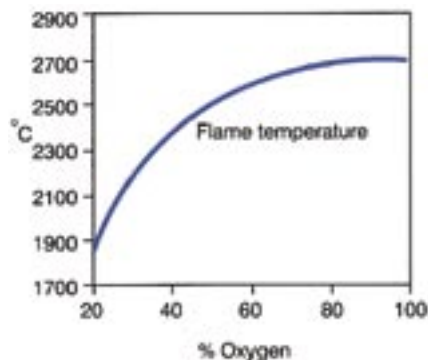


Figure 1: Oxy-fuel combustion creates high temperatures, which in turn increase the radiant heat flux in the furnace

Table 1: LEAM® technology and equipment brings big benefits in fuel efficiency and emissions performance

	Conventional air-fuel single-pass	LEAM® process oxy-fuel double-pass
Tap-to-tap time (%)	100	70
Energy consumption (kWh/t)	900–1100	420–520
Thermal efficiency (%)	30	60–70
Baghouse dust (kg/t)	25	6
Offgas volume (%)	100	30
NOx (kg/t)	31	0.45
Organic compounds (kg/t)	0.3	0.03

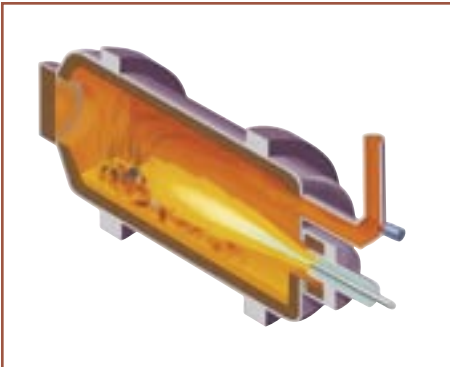


Figure 2: The APMELT™ LEAM® twin-pass rotary furnace features an oxy-fuel burner and a sensor to control the ratio of oxygen to fuel, for rapid melting, high energy efficiency and low emissions



Figure 3: A fixed-axis rotary furnace using APMELT™ LEAM® technology and equipment

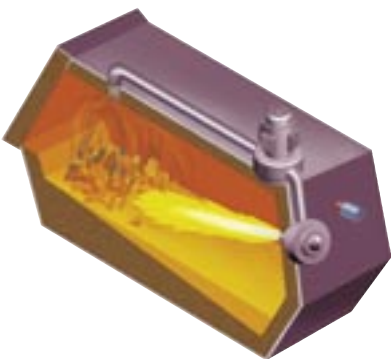


Figure 4: The APMELT-RILEE™ technology and equipment



Figure 5: APMELT-RILEE™ technology and equipment, showing the high-temperature fan and burner/swirl chamber arrangement

in the secondary aluminium industry. High efficiency, increased yield and a salt factor of just 0.5 combine to produce significant savings in operating cost compared to a fixed-axis rotary furnace. These savings more than offset the higher investment cost of a TRF, giving a payback time of two years or less. Air Products TRF oxy-fuel combustion systems are of advanced design and proven reliability, and are now in service successfully on more than 20 furnaces.

... and reverberatory furnaces: not just for clean scrap

Oxygen-enhanced combustion in static hearth furnaces used to be uncommon. Concerns about refractory overheating and potential yield problems were major hurdles to overcome. Building on experience with oxygen in rotary furnaces, however, Air Products started to investigate oxygen-enhanced combustion in static hearth furnaces over a decade ago.

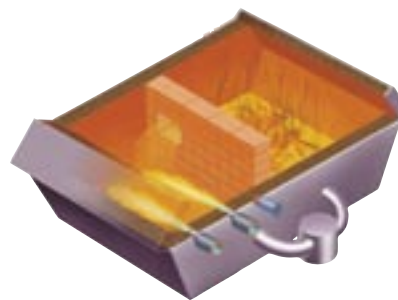


Figure 6: The APMELT-TCM™ twin-hearth furnace offers maximum flexibility for contaminated or clean scrap. A pump transfers molten metal between the two chambers, and fume is circulated to maximise energy efficiency and minimise emissions

Table 2: Typical performance of the twin-chamber melter

	Conventional air-fuel	TCM
Production rate (%)	100	125
Exhaust volume (%)	100	<25
Fuel consumption (%)	100	45
Organic compounds (g/h basis)	H _x C _x (%) 100	20
	CO (%) 100	7
Additional afterburner required to meet emissions legislation	Yes	No
Yield improvement		1–3%

Air Products engineers soon realised that the considerable variations between different types of static furnaces would require flexible oxygen combustion systems that could be tailored to individual requirements.

Key issues, they found, were the nature of the material to be melted and the way in which the heat was transferred. For light material, where the flame impinges on the scrap pile, it is essential to moderate the flame temperature and increase convective heat transfer instead. Otherwise,



Figure 7: Looking into the charging chamber of an APMELT TCM™ twin-hearth furnace

localised overheating takes place, leading to operating problems and lower yields.

The answer turned out to be the system known as APMELT-RILEE™ technology and equipment

(Figure 4, Figure 5). This technology is characterised by a high-temperature fan which recirculates furnace gases to the oxy-fuel burner and, in doing so, lowers the flame temperature.

APMELT-RILEE™ technology and equipment is suitable for both new furnaces and retrofits, and can be applied to almost any design of furnace. As well as the standard benefits of oxy-fuel combustion, the recirculation technology makes maximum use of the fuel value of contaminants in the scrap, as well as reducing emissions to the point where an afterburner is no longer needed.

Another innovation for hearth furnaces is the use of sensors to control the ratio of oxygen to fuel. As hearth furnaces often have large volumes and run at consistently high temperatures, they provide an excellent environment for incinerating any hydrocarbons given off by the charge. By burning contaminants within the furnace, a wider variety

Table 3: Cost analysis for Secondary Aluminium Smelting

Summary Basis		Conventional Fixed Axis Furnace Air Natural Gas	Fixed Axis Furnace with LEAM® technology and equipment Oxygen-Natural Gas
Energy Costs	Euro/MT Al Output	18	21
Flux Costs	Euro/MT Al Output	18	18
Disposal Costs	Euro/MT Al Output	59	59
Filter Plant Costs	Euro/MT Al Output	21	11
Manning	Euro/MT Al Output	52	27
Investment Costs	Euro/MT Al Output	9	6
Total	Euro/MT Al Output	179	143

of scrap containing oil, paint and other organic materials can be melted without the need for large-scale fume treatment. Contaminated scrap is cheaper than clean scrap, and the contaminants act as free fuel that can partly replace expensive oil or natural gas.

The ideal technology for this industry segment is the APMELT-TCM™ (twin-chamber melter) process and equipment (Figure 6, Figure 7), which can melt a variety of clean and contaminated scrap material quickly and economically. The process is characterised by a double-chamber furnace with a single exhaust system and no need for a downstream fume incinerator.

The charging chamber of the APMELT-TCM™ furnace is usually equipped with a RILEE™ combustion system, bringing all the advantages referred to above. A wide ledge can be incorporated to allow the melting of wet or iron-containing material.

The main chamber is heated by either oxy-fuel or air-oxy-fuel burners. The air-oxy-fuel series of burners have the additional advantage of being able to vary the ratio of air to oxygen, allowing the flame characteristics to be tailored precisely to the different process stages. Typically, the proportion of oxygen is increased to achieve rapid melting, and reduced during holding periods.

Both oxy-fuel and air-oxy-fuel burners are characterised by extended, highly radiative flames that provide maximum heat transfer to the molten bath. Heat transfer is so rapid, in fact, that some form of forced convection is essential to avoid superheating the top surface of the molten metal. This is usually done by an electromagnetic pump that transfers molten, slightly overheated, aluminium from the main chamber to the charging chamber. The heat transferred in this way effectively aids melting in the charging chamber.

Highly sophisticated PLC programs, based on experience with different types of charge material, control the firing rates and oxy-fuel ratios during the various stages of melting. The burners are controlled on the basis of the oxygen level in the

exhaust gas as well as the furnace and flue gas temperatures and pressures.

Table 2 summarises the typical performance of the APMELT-TCM™ equipment furnace compared to a conventional air-fuel furnace.

In the end it all comes down to money . . .

However advanced a process, it will not be adopted by industry if the economics do not stack up. As stated at the beginning “Air is free, oxygen is not” and if the cost evaluation which is carried out is restricted to just the cost of fuel and oxygen an economic payback is only achieved on rare occasions. Given the high level of adoption of oxy/fuel it is clear that a wider cost evaluation taking into consideration the benefit of extra production, lower emissions, greater flexibility and higher yields proves oxy/fuel to be economic. Table 3 summarises some of the major cost elements for a typical air/fuel fired rotary and a rotary converted to a LEAM® process system, which is being used to melt dirty scrap. Actual costs will vary from country-to-country and site-to-site and it is important to carry out a full analysis for the specific conditions rather than rely upon average costing.

Outlook

Besides increasing thermal efficiency and reducing flue gas volumes, oxy-fuel burners also have a part to play in controlling nitrogen oxides.

New NOx limits are now in the process of becoming law in the EU member states. In Germany, for example, new TA Luft regulations will set the NOx limit for secondary aluminium smelting at 500 mg/m³ of offgas.

Compared to air-fuel burners, oxy-fuel burners create around 80% less flue gas and considerably less total NOx. However, some traditional designs of oxy-fuel burner do create higher concentrations of NOx than do air-fuel burners.

To keep pace with increasingly stringent regulations and in line with the company's environmental care programmes, Air Products has

therefore developed a series of oxy-gas burners (O Series burners) that keep NOx levels below the new limits, even at the furnace exit. The new OLN (“Low-NOx”) burners are available with or without water cooling, in two sizes (20–200 kW and 250–2500 kW), and additionally in a special design with a turndown of 25:1.

In conclusion, oxy/fuel technology is clearly the way ahead for the secondary aluminium industry. As with any significant process enhancement, making the change requires investment: in new plant, in oxygen supplies, in operator training and in tuning the process to operate under new conditions. But this is proven technology, and the benefits are clear.

Oxy/fuel combustion means quicker melting, higher yields, lower losses and less pollution. As more and more companies are discovering, that means lower costs and higher profits.

Biographies

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¹ LEAM is a registered trademark of Air Products and Chemicals, Inc in Ireland, the United Kingdom and Germany

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