Jupiter – Encon Alliance: Advanced Oxy-Fuel Technology

Sustainable industry solutions with significant fuel savings and emission reductions in industrial furnaces

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The priority of any large industrial energy user today is to effectively manage energy costs. In the present scenario of escalating energy prices budgeting is nearly impossible. Reduction of energy consumption is critical to sustain energy intensive businesses, such as aluminium and steel. The Jupiter- Encon Alliance provides a practical approach based upon a unique oxy-fuel technology development for those progressive companies that seek to significantly lower fuel consumption and production costs in order to substantially increase their business. This article describes an advanced oxy-fuel combustion technology for re-melting aluminum that significantly reduces energy consumption and emissions. This oxy-fuel combustion technology developed by Jupiter Oxygen Corporation USA is a patented process for combustion of fossil fuels with pure oxygen while excluding air, thereby creating an untempered high flame temperature and increased efficiency for process heating in industrial furnaces. This process has led to improved heat transfer and longer residence time while maintaining the same process temperatures as with air combustion. The energy efficient combustion process allows aluminium companies to operate at a substantially lower cost due to a dramatic fuel savings of up to 70% for natural gas and waste oil (1). The successful facts of 10 years of day-to-day experience in a US based aluminium re-melting business utilizing this specific oxy-fuel combustion process are summarized(2). The article also introduces the new Jupiter – Encon Alliance established in May 2008 in order to provide a high quality service for Jupiter Oxygen's technology implementation in India

Jupiter Oxygen's Research Facility in Hammond, Indiana USA

ENCON has the exclusive right to use Jupiter Oxygen's patented technology to provide and service oxygen-fueled combustion systems for industrial furnaces in the aluminium and steel markets of India.
The two companies each have successful clean technology development histories, i.e., energy conservation and emission reduction through advanced combustion systems in industrial furnaces, and will focus on sustainable business development and Clean Development Mechanism (CDM) project opportunities in India.

Background

Aluminium re-melt rates of 750 BTU (1,744.378 KJ/KG) per pound are achievable today! These melt rates are currently being experienced by Jupiter Oxygen's US licensee along with many other substantial side benefits. Aluminium re-melting facilities have additional concerns that need to be addressed. Reduction of NOx and VOCs are big priorities. Burner companies have made incremental improvements to their systems which are currently used in typical aluminium melting furnaces. These changes have lowered fuel consumption and NOx-emissions. Jupiter's patented approach offers a substantial improvement in melt rates, fuel usage and environmental performance without the need for downtime to change re-generative media or degradation of heat input from a regenerative system. The Jupiter Oxygen process addresses these needs completely with no increased maintenance and no proprietary hardware.

In 2004 an independent assessment of the US Aluminium industry reported that re-melting heat requirements are approximately 2,200 BTU per pound (5,166.843 KJ/KG) of scrap (3). Those heat requirements of melting aluminium scrap are a major contributor to the variable production cost.

In the Mid-1990s, Dietrich Gross, the CEO of an US based aluminium recycling and sheet producing facility was faced with escalating fuel prices and he undertook a dedicated private research and development program designed to reduce fuel consumption. In order to make combustion a more efficient process, Dietrich Gross, envisioned a specific use of pure oxygen instead of air in his aluminium re-melting natural gas furnaces. Extensive experimentation with this specific oxy-fuel approach led to a process patented worldwide. He established Jupiter Oxygen Corporation in order to further develop and promote this unique oxy-fuel development, including applications for boilers and steam generation. This specific oxy-fuel development has been accompanied by the US Department of Energy's National Energy Technology Laboratory since 2001.

The results obtained through the use of the patented JOC process have been significant. Fuel consumption has been recorded at 750 BTU per pound (1,744.378 KJ/KG) of aluminium melted in a continuous operation, and NOx generation is virtually zero from the combustion of natural gas. Retrofitting is accomplished with minimal downtime, utilizing equipment in accordance with JOC specification and process. Most of the JOC oxy-fuel combustion system can be installed while the furnace continues to operate on air. The only downtime required for installation is final piping, and installation of oxy-fuel burners and ram refractory around the burner block. No refractory degradation has been experienced in spite of the high temperature of the flame (4500-5300 degrees Fahrenheit / 2482-2927 degrees Celsius) due to the even distribution of the heat and placement of the flame.

Jupiter Oxygen Corporation Patented Process and Experience

JOC oxy-fuel combustion technology is a patented process for the combustion of fossil fuels with pure oxygen while excluding air, using an untempered high flame temperature. Untempered means that the flame is not cooled by air or recirculated gases. For aluminium recycling furnaces including rotary furnaces, existing furnace materials can be used and the same melting temperatures are maintained.

Burners and equipment to support combustion are important, but the most critical element provided by JOC is the process by which oxy-fuel combustion is applied. Oxy-fuel combustion is not merely injecting oxygen into a boiler or any other furnace, like an aluminium remelter. It is a process. This process, as developed and patented by JOC, has progressed from years of trials and testing to determine why it works, how it works and what are the significant process variables.

Jupiter has been combusting various fossil fuels with oxygen since 1997, and has applied the oxy-fuel technology like no other company has. Because of the demands of the constant production process, the system must not only be reliable but also maintain favorable economics.

Misconceptions and Concerns Using Oxy-Fuel Combustion

Many companies have sought benefits from oxy-fuel firing. Typically, these efforts ended in disaster and/or unfavorable economics. JOC recognized early that the key to success was controlling the heat transfer, not the flame temperature. Flame temperature is a result of mixing fuel and an oxidizer source, while heat transfer is a desired engineering result. The area of heat transfer is how JOC realizes fuel savings. In addition, the proper process control allows the system to operate favorably for aluminium production.

Aluminium industry concerns center around the following three areas:

1. Costs
2. Oxidation of metal
3. Destruction of refractory material from high flame temperature

Concerning point 1, the Jupiter – Encon Alliance recommends to have an oxygen source on-site, either by owning and operating an Air Separation Unit or getting a reasonable priced 'over the fence' deal with an ASU providing company.

Secondly, JOC's licensee has not seen any increase in oxidation of the metal within the furnaces using the techniques developed. JOC' technology uses a near stoichiometric combustion approach, carefully controlling the levels of excess oxygen in the furnace to limit the formation of oxides in the metal. In addition, the approach or "flame shaping" and radiant heat transfer avoids the turbulent mixing of the hot gases and metal surfaces. Meeting the specific criteria of no increase in metal loss was a key task during the developmental stage. Experiments were designed to quantify the loss of metal and were completed in a small test furnace, while plant wide data was used to confirm the test results after scale up to the larger melting furnaces.

Third, refractory materials in aluminium furnaces commonly degrade around 3000°F (1649°C) at the high end, with other refractory degrading at lower temperatures. It was undesirable to upgrade or replace the common refractory material used in the existing furnaces. So, through observation of refractory life and temperature measurement, it has been determined that no refractory life issues have arisen. In fact, refractory life has generally been longer with less frequent hot spotting failures or mechanical failure associated with scale build up.

There are several factors which contribute to this. First is the dependence on radiant heat transfer rather then convection to the metal bath. By evenly distributing the heat according to surface area line of sight, both the bath and refractory walls are more evenly heated with no flame impingement on the metal or walls. In addition, the "reverb" affect of deflecting hot gasses around the furnace is unnecessary due to the low gas volumes (no air means no volumes of nitrogen) and dependence on radiant heat instead of convective. The observed effect was better temperature profiles, meaning less temperature differential in the corners, roof and walls of the furnaces. This also had the effect of preventing scale buildup in the furnaces.

Most importantly are the cost factors for the technology, which by default includes melt loss and additional maintenance. Given that melt loss does not increase and refractory life is not decreased, the pure economics require consideration. While natural gas costs (and other fossil fuels) have generally trended upward since the installation of the JOC oxy-fuel system, the initial payback analysis for the technology was based upon the cost of less than $3.00 per MMBTU.

With a fuel consumption rate decreased by up to 70%, significant dollar savings were used to offset the cost to purchase and operate a cryogenic plant.

Equipment Requirements Utilizing JOC Patented Oxy-Fuel System

The oxy-fuel combustion system designed and operated in accordance with the JOC patented process has been successfully installed in "new build" furnaces and retrofitted to existing furnaces. Existing furnace retrofits have included "box-type" reverb (without side wells), holding and rotary furnaces. It should be noted that the refractory materials in the furnaces were not changed or altered for the retrofit applications, and the new furnace designs used the same types of refractories, which were of common brands.

The combustion systems include several burners specifically designed for oxy-only firing with certain flame characteristics, including shape and length designed around furnace geometry. The combustion system controls include specific components which have been proven for precision and durability in the environments of re-melting. The operator control stations are tailored to specific plant criteria, including very high level of supervisory control if desired.

The oxygen systems use piping and parts meeting the "clean for oxygen use" specifications for cleanliness, while the oxygen supply can be from liquid (tank), pipeline and on site generation. JOC's US licensee utilizes two cryogenic plants for its operations, which also co-produce nitrogen for annealing and argon.

Furnace and Combustion System Findings

An oxy-fuel furnace, according to the JOC patented process is fed with a carbon based fuel, such as natural gas, in a near stoichiometric proportion with oxygen. The oxygen/natural gas proportions in the present melting and holding furnaces are set at 2.36:1 (1). This proportion of oxygen to fuel provides a number of advantages. First, this stoichiometry provides complete combustion of the fuel, thus resulting in less carbon monoxide, NOx and other noxious off-gas emissions. In addition, the controlled oxygen proportions also reduce the amount of oxides present in the molten aluminium. This, in turn, provides a higher quality final aluminium product, and less processing to remove these undesirable oxide contaminants. It is important to note that accurately controlling the ratio of oxygen to fuel assures complete burn of the fuel.

Oxides in aluminium come from two major sources: (a) the combustion process; (b) oxides that reside in the aluminium. This is particularly so with poor grade scrap or primary metal. The process takes into consideration both of these sources of oxides and reduces or eliminates their impact on the final aluminium product. First, the JOC process reduces oxides that could form as a result of the oxygen fed for the combustion of the fuel. This is achieved by tightly controlling oxygen feed to only that necessary by stoichiometric proportion for complete combustion of the fuel. The present process takes into consideration the second sources of oxides (that residing in the aluminium), and removes these oxides by the degassing and filtering processes.

The benefits are two fold. The first is that less byproduct in the form of dross is formed; second, the quality of the finished product is greatly enhanced. The furnace used to describe the application includes four oxy-fuel burners. Those burners are installed on a side wall of the furnace opposite the doors. Heat is input to the furnace by the burners. Due to the high luminosity the principal mode of heat transfer to the furnace is radiation, with some convective heat transfer. Because of the high flame temperatures, the oxy-fuel combustion system provides efficient radiative heat transfer.

The combustion system provides a number of advantages over known and presently used combustion systems. For example, it has been shown through operation that there is considerable energy savings using the Jupiter Oxygen process. The oxy-fuel burners operate at a much higher temperature than conventional furnaces. Thus, there is an observed increase in the heat available for melt. Fuel savings is attributed to three principal factors. First, the increased heat of the combustion system permits complete burn of all fuel without excess oxygen. Second, the combustion system operates within a radiative (or radiant) heat transfer zone, with some heat transfer by conduction. The system is designed to take advantage of the radiant heat transfer within the furnaces to transfer heat effectively to the metal baths. Third, because there is no nitrogen in the combustion process, the amount of gas flowing through the furnaces is low. Thus, an increased residence time of the hot gases permits the release of a larger proportion of energy (in the form of heat) prior to exhaust from the furnaces.

Typical exhaust gas volume is a fraction of that of conventional furnaces. Since there is about 80 percent less gases (essentially the nitrogen component of air) in an oxy-fueled furnace, combustion efficiency is greatly increased. The present combustion system also provides for increased production. When installed as part of a melting furnace, the melting capacity or throughput of the furnace will be increased. This again is attributed to the rapid and effective heat transfer in the furnace. As new metal is introduced into the furnace, the combustion system responds rapidly to provide heat to melt the feed metal and to maintain the heat (temperature) of the molten metal in the pool at the set point temperature. It has been found that aluminium accepts heat very efficiently from a radiative heat source.

RESULTS

Energy Efficiency Gains and Cost Savings

JOC's US licensee monitors its fuel usage on a per day, per pound per furnace basis. JOC's licensee melts aluminium during casting operations with a fuel input of 750 to 900 BTU's per pound (1,744.378 to 2,093.254 KJ/KG) melted. The range is due to not utilizing the full melt rates of the individual furnaces at different cast production widths. In addition, the technology was retrofitted to the "holding" furnace where no melting takes place. The results showed that the fuel usage for the furnace in a "hold" mode was cut in half. When reviewing yearly data, which includes periods of non-production (no melting or casting), the average usage of fuel for all melted pounds was 1083 BTU's per pound.

This oxy-fuel technology has been in every day use since 1998. The JOC energy efficient combustion process has allowed the aluminium company to operate at a substantially lower cost due to a dramatic fuel decrease, i.e., natural gas fuel reduction up to 73%, oil fuel usage reduction up to 68%, equivalent reduction of CO_2 due to fuel savings and virtually zero NOx.

Environmental Improvements

In 2001, a series of tests had been conducted at Jupiter Oxygen's test facility, as part of a Cooperative Research and Development Agreement (CRADA) with the National Energy Technology Laboratory (NETL) of the US Department of Energy (4).

The test series documented the achievements in fuel reduction through oxy-fuel technology implementation as well as environmental improvements according to the AP-42 standard of the US Environmental Protection Agency (EPA). The EPA AP-42 standard compiles the air pollutant emission factors from various sources of air pollution. In most cases, those factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long term averages for all facilities in the source category (5).

The data in table 1 are test results from the JOC oxygen - natural gas firing in a melting furnace. The tests were conducted and recorded by Clean Air Engineering in May 2001. Further tests followed with the use of waste oil. The following test result comparison to the EPA AP-42 standards has been reported to the National Energy Technology Laboratory (US Department of Energy):

Table 1: Results from test furnace operating on natural gas

Natural gas oxy-fuel			
	AP-42	**JUPITER**	**% REDUCTION**
NOx	0.098039	0.000494	99.50%
SOx	0.000588	0.000326	44.56%
CO	0.082353	0.023507	71.46%
VOC	0.005392	0.000598	88.91%

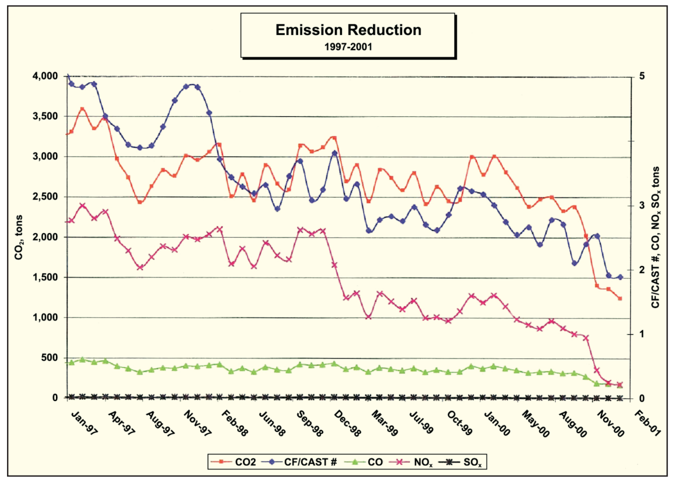
Table 2: Oxy-Fuel technology implementation at JOC's us licensee 1998 to 2001

Year	Estimated Casted Aluminum Pounds	Natural Gas MMBtu	Waste Oil MMBtu	Waste Oil Gallons	Percent Oxy-fired	CO_2 - Oil TPY	CO_2 - NG TPY	CO_2 TPY
1997	134,797,919	605,370.38	0	0	0.00%			
1998	164,041,703	570,063.62	0	0	26.90%	0	32,001	32,001
1999	181,984,940	441,750.48	0	0	46.00%	0	24,798	24,798
2000	184,773,584	400,809.52	0	0	53.50%	0	22,499	22,499
2001	161,286,676	125,018.00	84,516	612,742	100.00%	5,930	7,018	12,948

Energy efficiency Gains and Environmental Improvements

JOC's US licensee started to implement oxy-fuel combustion in 1998 for approximately 27% of its re-melting production, followed by 46% in 1999 and 54% in 2000. In 2001, all re-melting furnaces were operating 100% on Jupiter oxy-fuel combustion

The fuel consumption dropped significantly in proportion to oxy-fuel technology implementation. The graph below shows as well a reduction in CO_2 emissions (greenhouse gas) and the reduction of key pollutants based on oxy-fuel combustion implementation in spite of increased production rates (see Graph 1).

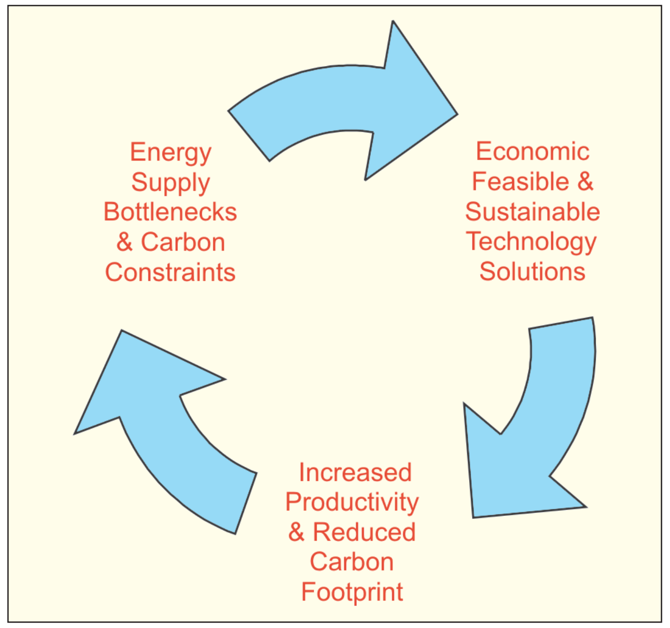


Graph 1: Emission reduction and fuel savings from oxy-fuel technology implementation at JOC's us licensee

Conclusion and Outlook

Jupiter Oxygen's technology is a cost cutting approach to the increasing costs of fuel in the aluminium re-melting industry. Oxy-fuel technology implementation through the Jupiter – Encon Alliance significantly improves fuel efficiency for process heating in the aluminium and steel business, increases production rates and has a very favorable environmental record concerning NOx, CO, SOx and VOCs. Significant fuel savings lead to equivalent CO_2 emissions reduction that can be credited to existing or future carbon markets.

The Jupiter – Encon Alliance provides sustainable industry solutions that allow energy intense businesses to grow while reducing their energy consumption and carbon footprint (see graph 2).



Graph 2: Jupiter – Encon Alliance is providing sustainable industry solutions that allow a businesses to grow while reducing their energy consumption and carbon footprint significantly!

Sources:

1) Oxy-fuel Combustion System and Uses therefore; US patent # 6,436,337 B1;GROSS, Dietrich; August 20, 2002; Indian patent # 202510; November 17, 2007

(2) INCAL 2007, International Conference on Aluminium: Enhanced Energy Efficiency and Emission Reduction Through Advanced Oxy-Fuel Technology in the Aluminium Remelting Industry; JUPITER OXYGEN CORP; WEBER, GROSS, BELL, PATRICK, November 2007

(3) Energy Implications of the Changing World of Aluminium Metal Supply; SECAT, 2004

(4) National Energy Technology Laboratory (NETL) US Department of Energy and Jupiter Oxygen Cooperation: Cooperative Research and Development Agreement (CRADA) # 01-N049; 2001

(5) Emission Factor Documentation For AP-42, Section 1.3, Fuel Oil Combustion, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, April 1993.

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