# Hydrogen-ready Oxyfuel Solutions for Decreased Fuel Consumption and Increased Melt Rate: Technology and Results

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**Abstract**



$CO_2$ emissions from a casthouse is almost entirely tied to the fossil fuel used to heat the furnaces. When burning fossil fuel with air – containing only 21 % oxygen but 78 % nitrogen – up to 50 % of the energy is lost through the chimney as the nitrogen is heated up in the furnace and emitted in the flue-gas. Accordingly, the presence of nitrogen results in wasted energy, higher fuel consumption and $CO_2$ emissions. Moreover, it hampers the radiative heat transfer from the products of combustion, which is the dominant mechanism at elevated temperatures. The use of oxygen instead of air, called oxyfuel combustion, eliminates this nitrogen ballast.

Removing the nitrogen from the process, using oxyfuel technology, will effectively reduce the energy consumption, and thereby the $CO_2$ emission with 35 %. As the flue-gas volume is substantially decreased, it also reduces the load on the filter system with about 75 %. Avoiding the nitrogen ballast in the furnace atmosphere will, in addition to the fuel saving, increase the heat transfer to the metal in the furnace resulting in a 40 % increased melt rate. Obviously, this will reduce the $CO_2$ emission even further per tonne of melted aluminium.

Early attempts to apply oxyfuel in the aluminium industry suffered from the fact that these installations operated with burners with very high flame temperatures, which created hot spots and thereby increased dross formation. However, hot spots can be avoided by using Flameless Oxyfuel, which combines the two benefits of fuel savings and melt rate increase, but at a low flame temperature. The features of Flameless Oxyfuel technology are described here together with results from numerous full-scale installations in aluminium melting furnaces.

The development of LTOF is based on Linde's Flameless Oxyfuel technology platform, and it has successfully opened up the market for oxyfuel in the aluminium industry during the last 15 years. Linde´s LTOF technology uses a volume combustion regime, where the products of combustion are recirculated back into the flame and thereby reducing the flame temperature very effectively. This takes place without loss of efficiency concerning fuel savings and melt rate increase. In Flameless Oxyfuel the mixture of fuel and oxidant reacts uniformly through the reaction flame volume, with the rate controlled by partial pressures of reactants and their temperature. In Flameless Oxyfuel, the combustion gases are effectively dispersed throughout the furnace, ensuring more effective and uniform heating even with a limited number of burners installed.

The focus of the use of LTOF is on reverberatory furnaces where the demand for thermal homogeneity is highest. Increased melt rate has been the primary goal in most of the more than 50 LTOF installations so far worldwide. However, with the increased focus on carbon footprint reduction, the fuel saving aspect has become a more and more prominent driver.

Across 50+ LTOF installations to date, the results show:

- Melt rate increased by about 40 %
- Fuel consumption reduced by 30-50 %
- Off-gas volume reduced by 75-85 % per ton of aluminium
- Substantial reduction of low frequency noise in the plant
- No change in the recovery of aluminium
- No increased refractory wear

Two examples of successful installations of LTOF in smelter casthouses are found in Norway, at Hydro Aluminium in Årdal and at Alcoa in Mosjøen In both cases the proportion of cold metal in the charge was substantially increased. At Hydro, the proportion increased from 27 % to 43 %, with unchanged cycle time. At Alcoa it was increased from 25 % to 37 %, and with a 27 % reduction in melting time.

A feature of the LTOF technology, which is becoming increasingly important, is that it is ready for using hydrogen as fuel. An LTOF system designed for a conventional fossil fuel can rather swiftly be converted into hydrogen, completely or with a mix of fossil and hydrogen fuels.
LTOF has a peak temperature below the temperature for formation of thermal $NO_X$ supporting reduction of $NO_X$ emissions. Repeated tests and evaluations have confirmed that this feature is maintained also when using hydrogen as fuel.

For hydrogen combustion, Linde carried out a series of tests where Al-Mg alloys were melted in different atmosphere compositions due to variations in fuel type and burner set-up. The pilot-scale tests were done together with, among others. Hydro, Alcoa, and SINTEF. The results show that combustion of hydrogen in an oxyfuel configuration leads to clearly less oxidation on liquid Al-Mg alloys than hydrogen in an air-fuel configuration. The tests also showed that as little as 5 % $CO_2$ in the furnace atmosphere significantly suppresses oxidation. Hydrogen dissolution into the metal will most likely increase with the increased $H_2O$ concentration in the atmosphere. With state-of-the-art degassing technologies this should not be an issue, however it must be verified in full scale operation.

**Keywords:** Fuel savings, Melt rate, Flameless Oxyfuel, Hydrogen, Carbon footprint.