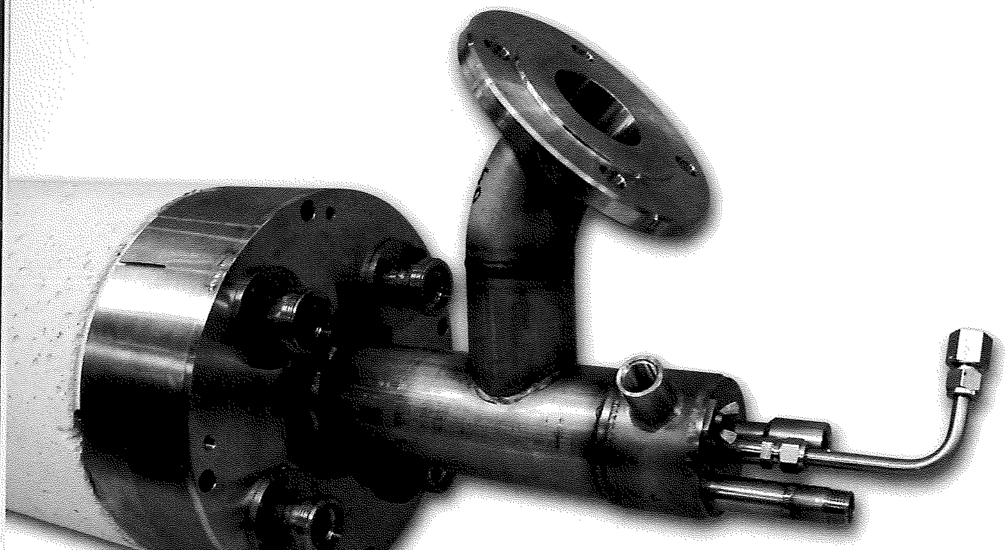
Efficient Heating with Low Calorific Gases



Flameless oxyfuel burner for low calorific fuels. The Ø 300 mm burner delivers 325 kW when fed with 15 mBar blast furnace top gas. It can operate in both flame and flameless mode (for cold and hot furnace operations). LPG or natural gas injection is possible, and it has dual-fuel and mixed fuel capabilities.

Over the past five years, the beneficial use of flameless oxyfuel has been established in the steel industry. This technology is now being applied for further energy savings using low calorific gases as fuel.

By Joachim von Schéele and Tomas Ekman

Oxyfuel solutions deliver a unique combination of advantages. In 1990 Linde converted the first reheat furnace to operation with 100 % oxygen, that is, full oxyfuel combustion, at Timken in the USA. For the past 17 years Linde has been pioneering the use of oxyfuel in this field. It has been a journey where knowledge has been gained and the technologies have been continuously improved.

Increases thermal efficiency

In general the use of oxyfuel combustion substantially increases the thermal efficiency of a furnace. This is primarily due to the fact that radiant heat transfer of furnace gases produced by oxyfuel combustion is significantly more efficient than those of air-fuel. Due to the absence of nitrogen in the combustion mixture, which does not need to be heated up, the volume of exhaust gas is also substantially reduced, thus lowering total heat loss through the exhaust gas. Thanks to improved thermal efficiency, the heating rate and productivity are increased and less fuel is required to heat the product to a given temperature, at the same time saving on fuel and CO_2 emissions.

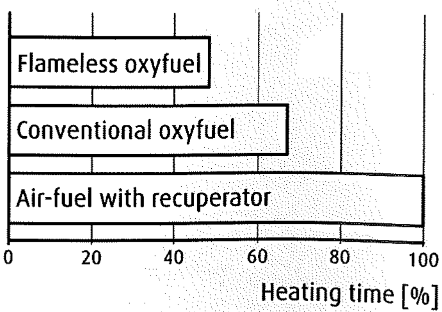
Today there are 115 reheat furnaces and annealing lines using Linde's oxyfuel solutions. Increased throughput and flexibility, reduced fuel consumption and decreased emissions of CO_2 and NO_X, both of which are considered greenhouse gases, are the main reasons why these solutions have become increasingly popular. The results can be summarized as:

- Capacity increase of up to 50 %
- Fuel savings of up to 50 %
- Reduction of scaling losses
- Reduction of CO_2 emissions by up to 50 %
- Reduction of NO_X emissions (guaranteed level below 70 mg/MJ)

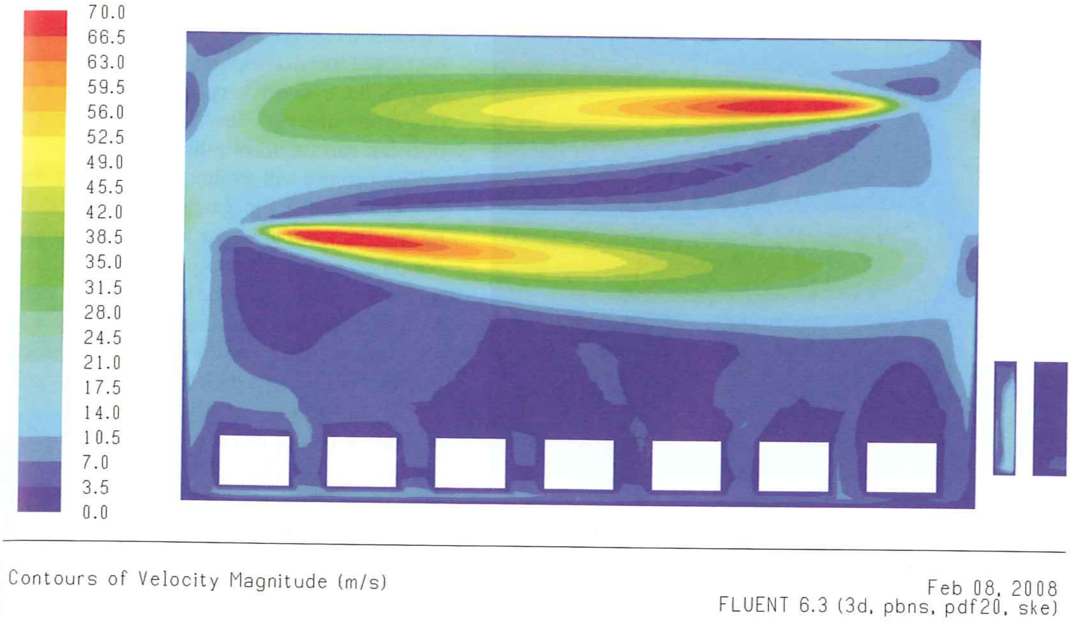
The interest in using low caloric gases as fuel has recently become more pronounced. In combination with strong demands to cut back CO_2 emissions, the continuously increasing energy prices explain this. For efficient use of fuels containing below 2 kWh/m³, for example blast furnace top gas, use of oxyfuel combustion is an absolute requirement.

From conventional to flameless oxyfuel

In recent years, flameless oxyfuel combustion has been successfully applied and the technology has been proven to deliver outstanding results. It has such major advantages that it is likely to be installed for most applications. The advantages of conventio-



Comparison of total heating time at Ovako's Hofors Works using different combustion technologies.



Picture from CFD modeling of flameless oxyfuel combustion.

nal oxyfuel combustion are combined with those of flameless combustion to produce improved and more uniform heating and reduced NO_X emission.

Combustion with low NO_X emission is normally important in the case of large, continuously operating reheat and annealing furnaces but is also relevant to other heating processes, for example, the drying and preheating of ladles and other vessels.

A very good example of the impact of flameless oxyfuel can be found at Ovako's Hofors Works in Sweden. The first use of oxyfuel in reheating operations dates back to 1994, and since then a large number of soaking pits and rotary hearth furnaces have been converted to conventional oxyfuel.

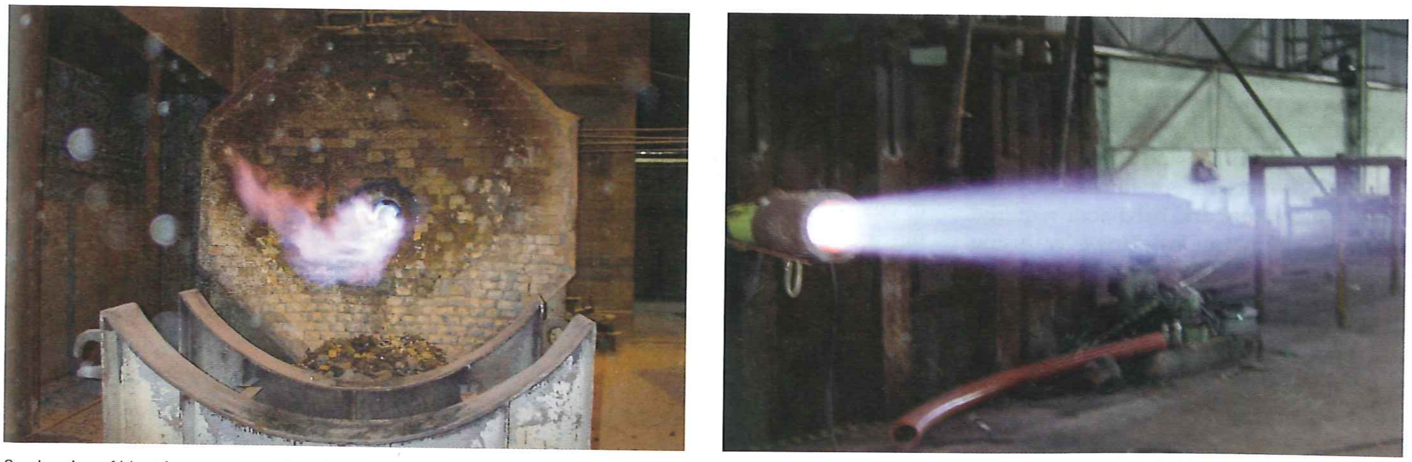
However, in 2006, flameless oxyfuel began to be used, and installations with conventional oxyfuel were then converted to flameless operation. These also include ladle preheating. In addition to further decreasing the total heating time by 15 %, the flameless oxyfuel also delivered more uniform heating, an additional fuel saving of 17 %, and 5-20 % less scaling.

Cooperation with steel producers

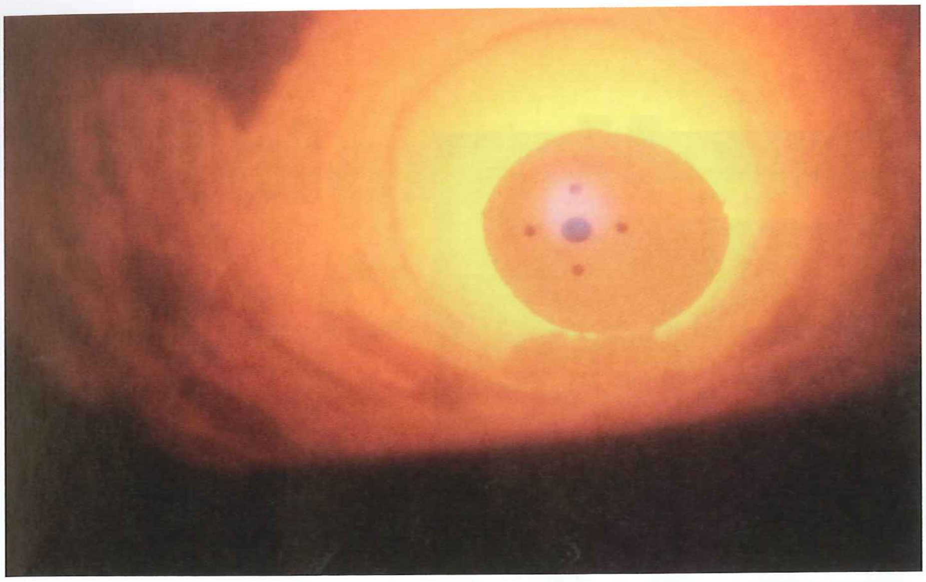
The development of flameless oxyfuel combustion has been brought forward in close cooperation with steel producers, that is, the users, to meet their needs. It builds on the many proven advantages of oxyfuel over air-fuel, which has been well known for years. In the commercial installations, from 2003 onwards, it has been clearly proven flameless oxyfuel has taken this a step further, with even higher production rates, decreased fuel consumption, thus reduced CO_2 emission, very low NO_X emission and uniform heating.

Over the past five years and with over 30 installations, flameless oxyfuel has been established in the steel industry. Today, installations are either up and running or under installation at a total of 14 production sites among the following steel companies: Acerinox, ArcelorMittal, Ascométal, Böhler-Uddeholm, Dongbei Special Steel, Kanthal, Outokumpu, Ovako, Sandvik, and Scana Steel.

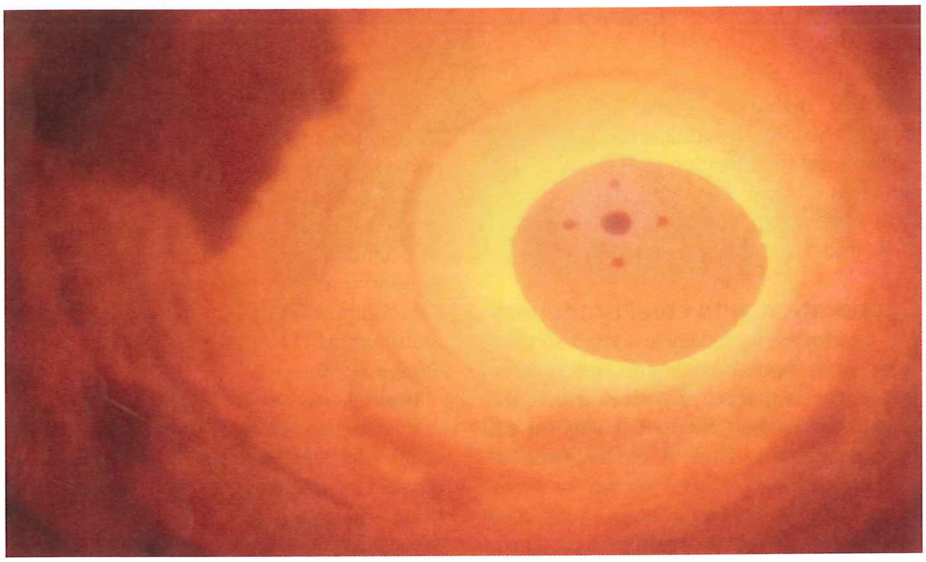
Besides its use in reheating, ladle and converter preheating is an excellent area of application for flameless oxyfuel. Flameless oxyfuel is certainly the best way to heat those vessels. In addition to the benefits of oxyfuel over air-fuel, it here also brings further improved heat distribution uniformity, increase life of the refractory lining, and ultra low NO_X emission even at high levels of ingress air. ▶



Combustion of blast furnace top gas (0.9 kWh/Nm^3, 3.2 MJ/ Nm^3) with air-fuel (left) and oxyfuel (right). With air-fuel the flame is unstable and diffuse, with a bad definition, the flame temperature is 1300° C and the efficiency is <5 %. In the oxyfuel case the flame is stable and compact with a temperature of 1900° C and an efficiency of >35 %. The oxyfuel case would correspond to air-fuel combustion of a fuel containing (2.1 kWh/Nm^3, 7.7 MJ/ Nm^3)



These unique photographs show oxyfuel combustion with 100 % blast furnace top gas as fuel.
Above operation in flame mode and below is flameless combustion. In both cases the firing power is 400 kW.



Low calorific gases

Large quantities of fuel with a low calorific value are available at steel production, particularly at integrated mills. These comprise different process by-product streams or flue-gases, such as, coke oven gas, blast furnace top gas and BOF gas. The use of blast furnace top gas and BOF gas within the steel production is hampered by the flame temperature and behaviour required in heating applications. However, using oxyfuel instead of air-fuel makes it possible to even run the heating application solely with blast furnace top gas as fuel. Oxyfuel makes the combustion of low calorific fuels as good as when air-fuel firing a fuel with roughly 2.5 times higher energy content.

Coke oven gas, which contains roughly half as much energy as natural gas, has been used efficiently in oxyfuel combustion for a rather long time. Examples could be found at SSAB, where the first such installation for ladle preheating was taken into operation at its Oxelösund Works in the late 1980s.

Low calorific fuels, for example blast furnace top gas, not only have a low energy density meaning that large volumes have to be transported, but by frequently being flue-gases, they have a low pressure that is costly to increase. Additionally, both blast furnace top gas and BOF gas contain rather high amounts of nitrogen. This has to be considered from the perspective of NO_x emission.

Flameless oxyfuel has clear benefits over conventional oxyfuel. Would it be possible to apply this technology also for low calorific fuels?

Flameless and low calorific

Linde has developed its propriety flameless oxyfuel technology in such a way that it can be used also for combusting low calorific gases. In a European research project called CO_2RED, where among others also MEFOS participates, Linde's flameless oxyfuel burners have been evaluated for firing with blast furnace top gas as fuel. The initial results have been very encouraging. NO_x emissions are very low and complete CO burnout can be accomplished.

The project will evaluate the proper mix of blast furnace top gas and a high calorific gas like propane that will give optimum conditions regarding operating cost vs. performance and environmental issues. The scaling behaviour and safety aspects will also be evaluated. Scaling is studied using thermo balance equipment and by full cycle heating of slabs.

Activities have already been suggested to further increase the efficiency of a blast furnace top gas combustion system. These include preheating of gases to provide a fully optimized use of the low calorific fuel.

Stainless wire annealing

At Dongbei Special Steel in Dalian, China, Linde is supplying its REBOX® DST technology for stainless wire annealing. The heating will be carried out with flameless oxyfuel using a fuel with an energy content of 1.75 kWh/Nm3 (6.3 MJ/Nm3). Gaseous fuels of this quality are commonly produced in China from local resources of coal. Similar gases could become more common in the future also in, for example, Europe and North America as the availability of high calorific gases may become scarce and as better technologies for gasification of wastes, etc., would be available and economically viable.

Additionally, Linde is looking into a number of projects where flameless oxyfuel with low calorific gases should be used for ladle preheating. There are also cases where this technology intends to be used in walking beam furnaces. Particularly attractive is the possibility to use coke oven gas, blast furnace gas and natural gas mixtures in order to balance according to availability of respective gas and process heat demand.

Increasing demands

Increasing demands on overall energy efficiency and reduction of CO_2 emissions have pronounced the interest in using existing low calorific fuels for heating, for example in ladles and walking beam furnaces. Flameless oxyfuel has been established as the leading combustion technology in this field, showing clear advantages over other alternatives. There is now a technology available that provides flameless oxyfuel when firing with a low calorific fuel. It has already gained a lot of interest, and it seems to be a good tool to counteract continuously higher fuel prices and simultaneously cut back emissions of CO_2 and NO_x. ■