

Emission monitoring and reduction in aluminium production

International legislation on emissions limits, sources of emission, technologies to minimise emissions and the monitoring and calibration of analytical equipment are discussed in this article.

By **Stephen Harrison*** & **Joachim von Schéele****

Requirements for reducing air pollution emissions have been evolving over the past couple of decades and today are an intricate mix of limits, targets and caps. In many parts of the world, industries emitting pollutants must not only comply with rigid emission limits but also need to provide emissions data to numerous different agencies and bodies to comply with the disparate legislative formats and reporting systems at regional, national and international level, and legislation is going to get increasingly stringent.

The global community is working to improve cooperation between emitting sources, monitoring systems – and the legislation they support. They will reduce the number of serious pollutants being released into the air, soil and water to help mitigate the negative impacts on human health and adverse effects on the environment in coming years.

What this means for industry is that more pollutants will require monitoring from a greater number of emitting sources – for example, mercury (Hg) is rapidly moving up the agenda in the European Union, the USA and Asia ahead of the legally binding United Nations EP Global Treaty on Mercury to be implemented in 2013. Advanced systems and methods will be required to measure increasingly lower concentrations of pollutants as emission limits tighten. Increased accuracy will become paramount as

*Head of Specialty Gases & Specialty Equipment, Linde,

**Marketing Manager, Metals & Glass, Linde.

pollutants such as nitrous oxide (N₂O), methane (CH₄) and possibly Hg are introduced to trading markets in the EU and USA. The change will mean that once a monetary value comes into play, measurement accuracy becomes an economic target as well as an environmental one.

Legally binding

For those industrialised member states, including energy and emissions giant Russia, the Kyoto Protocol has already established legally binding commitments for the reduction of greenhouse gases (GHGs) down to 1990 levels by 2012. The Protocol also established a global carbon trust incorporating market-based mechanisms which can assign concrete financial values to each tonne of GHG emission.

Although countries such as Russia still lack longer-term energy strategies to enable them to participate fully, the potential to benefit financially from selling surplus emission reduction credits to the EU and other member states internationally, places even greater importance on emissions measurement and evaluation.

In March of this year, the US Environmental Protection Agency (EPA) proposed the implementation of the first mandatory national carbon emissions reporting programme to ensure a reduction of carbon dioxide and other GHGs produced by major sources in the US. GHGs, like carbon dioxide (CO₂), are produced by the burning of fossil fuels and through industrial and

biological processes. Approximately 13 000 facilities, accounting for about 85 to 90% of GHGs emitted in the US, would be covered under the proposal. The new reporting requirements will apply to suppliers of fossil fuel and industrial chemicals, as well as large direct emitters of GHGs with emissions equal to, or greater than, 25 000 metric

tonnes per year (Mt/y). The direct emission sources covered under the reporting requirement would include energy intensive sectors such as metallurgy production – including primary aluminium – cement production and electricity generation, among others. The first annual report will need to be submitted to the EPA for the next calendar year (2010) in 2011.

This type of initiative is being repeated at various locations worldwide with the aim of addressing climate change head on – in a straightforward manner with immediate financial incentives to drive rapid and economy wide adoption of carbon reduction and market-based trading.

EU Strategy

In 2005, the European Union published its 'Thematic Strategy on Air Pollution' which set out clear objectives for the reduction of a number of important air pollutants. While industrial emissions have decreased over the past few years they continue to have a significant impact on the environment and need to be reduced further. The largest industrial installations still account for a considerable share of total emissions of key atmospheric pollutants: 83% for sulphur dioxide (SO₂); 34% for nitrogen oxides (NO_x); 43% for dust and 55% for volatile organic compounds (VOCs). It was soon recognised that EU member states' projected air emissions would greatly exceed the 2020 targets of the *Thematic Strategy on Air Pollution* unless timely action was taken.

In 2007, the EU, acknowledging that existing legislation on industrial pollution was complex, sometimes inconsistent and not far-reaching enough, adopted new legislation to strengthen the provisions already in force and reduce further industrial emissions. The new directive aims to improve the uptake and implementation of Best Available Technologies (BAT), which maximise the use of technology in plant design, build and operation in order to drive down emissions. Critically, it also tightens current minimum emission limit values for large combustion plants and introduces minimum provisions on environmental inspections of installations and incentives for the development and employment of environmentally-friendly technologies.



Oxyfuel burner in a reverberatory melting furnace



Low-temperature oxyfuel combustion is used to increase melting capacity, reduce dross and achieve ultra-low NOx emissions at Sapa Heat Transfer AB (Elkem Group) in Sweden



Linde's Spectra-Seal calibration gases offers long-term stability and extended shelf life

As legislation and action plans grow in number and stringency, the importance of monitoring and quantifying emission pollutants in an accurate and transparent manner is becoming a priority. Real-time and on-line reporting systems will be the aim for most large sources. As Lisa P Jackson, Administrator for the EPA stated, "Our efforts to confront climate change must be guided by the best possible information. Through this new reporting, we will have comprehensive and accurate data about the production of GHGs. This is a critical step toward helping us better protect our health and environment".

Aluminium sector emissions

Greenhouse gas emissions in the production of primary aluminium come from processes such as coking, anode production and consumption, and electrical generation. Aluminium production is highly energy intensive and is therefore a significant creator of CO₂, not only from power generation but also by consumption of the carbon anodes used in the electrolysis of the molten bath. Such process emissions of CO₂ account for about 50% of total direct carbon dioxide equivalent emissions from aluminium production, with the remaining GHGs emitted being PFCs, including tetrafluoromethane (CF₄) and hexafluoroethane (C₂F₆). Commercial aluminium production has been identified as the largest emitter of these two compounds. Although the annual amount of PFC emissions is not great, the impact is magnified because of the high global warming potentials of these two gases over the lifetime of the facility. CF₄ is 6500 more potent than CO₂ as a GHG and C₂F₆ 9500 times more potent and they persist in the atmosphere for 10 000 years. These pollutants occur during 'anode effects' caused by a depletion of the alumina content of the cell and in recent years have been dramatically reduced by the introduction of automated point feeders to ensure regular and sufficient feed of alumina to each cell in the pot line.

Another source of air emissions from primary aluminium production occurs during the reduction of aluminium oxide to aluminium metal in the pot room. Fluorine compounds, including gaseous hydrogen fluoride and fluocarbons are produced from electrolysis of the bauxite dissolved in cryolite (Na₃AlF₆). At levels above the threshold limit value, these emissions have been linked to occupational asthma in pot room workers. Further from the pot room, these fluocarbons and other gases, such as CO₂ which is emitted as the carbon anodes are consumed, contribute to aluminium smelter environmental emissions. Additionally, in the processing of aluminium scrap, aluminium fluoride is often substituted for chlorine to remove impurities from the molten metal, again resulting in the emission of fluorides.

Production of aluminium releases, not only atmospheric emissions, but also liquid and solid waste. Air emissions, or particulates, emanate from processes such as grinding of bauxite, claiming aluminium oxide and general handling of materials. If the metallic content of the particulates is sufficient, emissions control dust can be remelted to capture any remaining metals, or it may be otherwise reused or sold for its metallic content. If the dust is not sufficiently metal rich, it is usually landfilled.

It is important to note that while the CO₂ intensity of primary aluminium production (approximately 7340kg CO₂/t Al) far outweighs that of remelted/recycled aluminium (approximately 236kg CO₂/t Al), discarded aluminium can be melted – and remelted – several times before it is ultimately ready to be used in a finished product and offered for sale. So the figure of 236kg CO₂/t Al is likely to be significantly higher.

Even though the CO₂ intensity of the primary process is far greater than that of the conventional remelter/recycler, the direction of US legislation seems to be moving towards 'capping' most large production facilities, irrespective of the production method being used, meaning large big inefficient remelters/recyclers are likely to be affected.

Mitigations

Global primary aluminium production is around 40Mt/y with China notably being the largest producer with production at 13.5Mt in 2008, followed by Russia, Canada and the US. Leaders in the aluminium industry are beginning to modify their practices to reduce greenhouse gas emissions and minimise overall climate impact. Many have launched voluntary emission reduction programmes and participate in emissions trading markets. In light of the Kyoto Protocol to limit GHG emissions, the industry is expected to calculate and manage actual reductions in greenhouse gas emissions, as opposed to improvements in emissions intensity levels that occur normally over time.

The European Aluminium Association has reported that the industry has worked successfully to reduce its GHG emissions through voluntary industry initiatives and continuous technological advances to significantly cut its emissions of GHGs. Results include a reduction in CO₂ emissions by almost 8% in the 5-year period up to 2005. The Association has also set as one of the main goals for the aluminium industry to improve environmental performance throughout all life-cycle stages of aluminium products. This environmental performance is continuously improved by efficient use of resources such as raw materials and energy, reduction of emissions to air and water, improvement and development of process technology, reduction of waste and increased recycling.

Europe's smelters participate in the International Aluminium Institute's Greenhouse Gas Global Sectoral Approach and have outperformed the global industry in terms of climate gas emission reductions and energy efficiency gains. Europe is the world centre for primary aluminium technology and research and development into secondary applications. The European industry has indicated a commitment to work towards further reduction of GHG emissions and is in the process of setting new stretch targets.

Trends in monitoring

Stephen Harrison, Global Head of Specialty Gases at The Linde Group, says environmental concerns have come a long way since the 1970s. This was when acid rain caused by sulphur dioxide and nitrogen oxides prompted power stations to install sulphur dioxide scrubbers and selective catalytic reduction units (SCRs) for nitrogen oxide reduction and also motor vehicles were fitted with catalysers.

"While these issues remain, global warming, GHGs and CO₂ emissions have become the concerns of the 21st century, bringing with them the requirement to measure emissions at progressively lower levels and with greater accuracy," says Harrison. "We're trying to achieve clean air and a better quality of life for future generations.

"Up until quite recently, emissions measurement was carried out for compliance, resulting in fines for those who overstepped the mark. Now, however, day-to-day emissions measurement has financial implications and compliance to measurement is absolutely critical."

Harrison says the automation enabled by technological advances favours Continuous Emission Monitoring Systems (CEMS), while emission measurement instruments are becoming smaller and cheaper. This has heralded the way for gas phase measurement and gas phase calibration from gas cylinders, with a move away from manual and people-intensive 'wet chemistry' measurement.

"Where government institutes used to carry out a lot of emission measurement themselves, today they have outsourced this function to a large extent," he says. "They retain control however, by checking that industry complies with the standards".

"What we're seeing is definite trend moving from control to compliance. Today, metrology has been commercialised and establishment of primary calibration standards have moved out of the government domain into that of the major gas companies. This development has been enabled by improved international standards and by global recognition of these standards, such as ISO Guide 34 and the emerging ISO 17025. However, many pockets of local, national and regional requirements are still in place, for instance the GBW standards in China and the US-centric EPA."

Reducing emissions

Combined with demands to increase energy efficiency and production yield, decrease fuel consumption and also align processes to comply with increasingly environmental regulations, emissions reduction has become one of the most important issues facing the process industry today. As a result, the metallurgy industry has seen continued momentum in the uptake of oxyfuel technologies.

By using oxygen instead of air in the production process, which removes the



Linde's Ecocyl light-weight calibration gas cylinders are refillable and hold 50% more gas than disposable cylinders

nitrogen ballast, energy efficiency is not only increased, but one of the most important benefits is the significant reduction of both direct and indirect greenhouse gas emissions, including CO₂ and NO_x. CO₂ emissions can be reduced by up to 50% and, for NO_x emissions levels of below 50mg/MJ can be reached.

Although oxyfuel is accepted as state-of-the-art for melting of many metals, the aluminium industry has been more cautious to adopt the technology as the high flame temperature creates a risk of over-heating the aluminium surface.

However, as a further development of conventional oxyfuel, Linde's Low-temperature Oxyfuel applies the principles of 'flameless' combustion for aluminium melting. This represents a significant step toward enabling more efficient recycling and re-melting of aluminium and has been proven to deliver higher melt rates with reduced oxidation, lower fuel consumption and ultra-low NO_x emissions.

Successful installations of Low-temperature Oxyfuel are in operation at five plants, both in reverberatory and alloying furnaces.

Monitoring and detection

With the growing importance and prioritisation of monitoring and quantifying emissions, accuracy and reliability in measurement calibration is critical. The demand for stable, accurate measurement is the cornerstone of emissions analysis. However, calibration standards of low-level reactive mixtures, typically those with levels below 5ppm, can prove to be unstable over time and can result in incorrect measurements, lost productivity and – with emissions monitoring – potential legislative fines.

To keep pace with technological advances and increasingly stringent legislative requirements, Linde's Spectra-Seal calibration gas mixtures use state-of-the-art packaging technology with proprietary

cylinder treatment processes that exceed the increasingly demanding requirements for consistency and stability in a variety of calibration standards – down to parts-per-billion levels. Spectra-Seal offers long-term stability for binary calibration gas mixtures requiring low-level carbon monoxide, carbonyl sulphide, methyl mercaptan, hydrogen sulphide, nitric oxide, nitrogen dioxide, sulphur dioxide or moisture.

With any gas used for calibration purposes, the most important requirement is that it can accurately and repeatedly report values of the relevant instrument being measured. Linde's HiQ 60 specialty gas products were developed to provide accurate, stable gas products with a full 60 months performance guarantee.

The development of what is an extended 5-year shelf life is a significant leap forward in the supply of calibration gases. Previously, gas suppliers across the market offered product expiration guarantees generally limited to 36 months, with many products available with only 12 or 24 months of shelf life. Gas products with these more limited shelf lives can impact measurement accuracy, as gas stability in terms of consistency and quality can change over time. Where consistency or purity of the gas has been compromised, this can result in expensive system re-calibration procedures, additional cylinder change-overs and wasted human resource time.

A further development in emissions monitoring and detection has been the miniaturisation of emissions monitoring devices, which are often dispersed across remote locations throughout a plant. These instruments demand smaller, highly portable gas calibration solutions. Linde's Ecocyl gas calibration solutions include compact, light-weight gas cylinders, which not only meet the challenge of calibrating distributed devices, but are significantly more environmentally-friendly and cost effective than more traditional, disposable heavier-weight cylinders. Refillable, they help mitigate environmental waste or costly regulatory cylinder return and waste handling issues often related with typical disposable cylinder packaging. The cylinders also have a pressure of 150bar, containing at least 50% more gas than most disposable cylinders.

"All our solutions reflect global trends towards improved accuracy and reliability of emission monitoring, as well as product stability in the long term," re-affirms Harrison. "They're also addressing the requirements for reduced consumables usage, lower re-purchase cost and lower cost of ownership." ■

Contact: For burner technology

The Linde Group, Seiterstrasse 70,
D-82049 Pullach, Germany
e-mail stephen.harrison@linde-gas.com

For calibration gases

The Linde Group, Gases Division, Carl-von-Linde-Strasse
25, DE-85716 Unterschleissheim, Germany.
e-mail joachim.von.scheele@linde-gas.com