Advancing glass melting efficiency through LINDE technologies

Together, LINDE's latest OPTIFIRE® oxy-fuel burner portfolio and OPTIMELT™ Thermochemical Regenerator (TCR) system demonstrate commercially proven and economical pathways to higher melting efficiency, lower NOx emissions and meaningful CO_2 reduction. With long-term industrial results, these technologies enable safer, cleaner and more flexible furnace operation across container, fiberglass and hybrid melter designs.

For glass manufacturers pursuing practical, high-impact decarbonisation, Linde's OPTIFIRE® oxy-fuel burner portfolio and OPTIMELT™ Thermochemical Regenerator (TCR) system offer a robust technological foundation backed exclusively by years of industrial experience. From wide-flame burners to thermochemical reforming, the company's solutions address the central challenges in modern melting: efficiency, stability, emissions and fuel flexibility.

BURNER INNOVATION FOR STABLE, LOW-EMISSION MELTING

Linde's broad family of OPTIFIRE® oxy-fuel burners enables furnace-specific optimisation. The Wide Flame Burner (WFB) generates a rich, luminous flame with up to 200 percent greater surface coverage, reducing volatilisation, lowering particulate emissions and cutting NOx by more than 50 percent thanks to staged combustion. The quick-release metallic components simplify installation and maintenance, supporting stable operation across diverse furnace types.

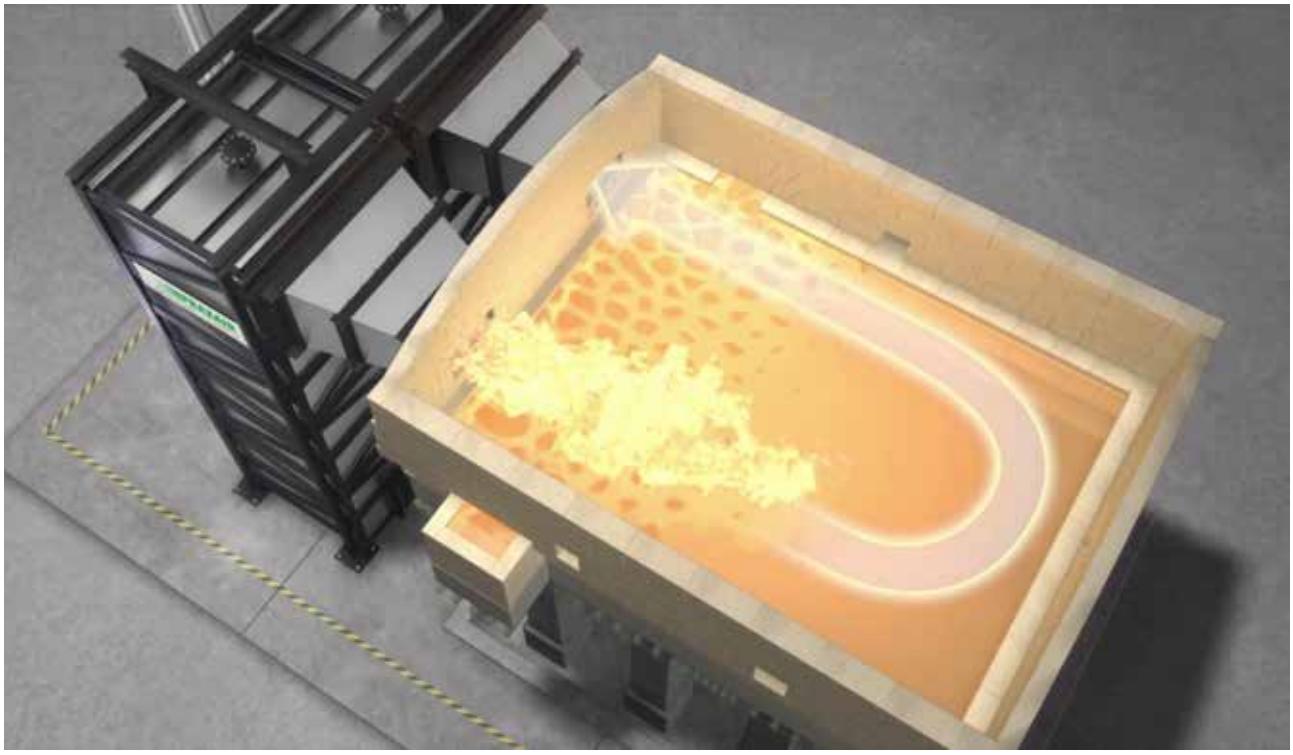
The OPTIFIRE® XD burner, a variant of the WFB, is optimised for volatile-rich environments. By diverting a small flow of natural gas to the staging oxygen ports, the XD design mitigates condensate formation around cooler oxygen surfaces. This prevents alkali build-up, an issue demonstrated clearly in comparative operating images and has delivered multiple years of uninterrupted industrial operation in fiberglass, tableware and container furnaces.

The OPTIFIRE® FLEX burner integrates the advantages of WFB and XD while adding an important new capability: automated switching between 'Melt' and 'Foam Control' modes. In commercial container glass operation, FLEX burners have achieved approximately 15 cm of foam-layer reduction in the refining area during colour-change transitions. Quality results were enhanced – seeds and blisters were reduced by 40-75 percent across multiple colours. Hot oxygen ports decrease fouling risk, while lightweight metallics and quick-release clamps support easy handling. Stable flame switching and wide firing flexibility further enhance process control.

THERMOCHEMICAL REFORMING FOR HIGHER ENERGY EFFICIENCY

Beyond burner optimisation, Linde's OPTIMELT™ TCR system provides a thermochemical pathway to higher energy efficiency and lower carbon intensity. The system recycles a portion of flue gas -rich in CO_2 and water vapour- into regenerators, where endothermic reforming of natural gas produces a hot syngas stream. Combined with oxy-fuel combustion, this syngas delivers a luminous, high-temperature flame while enabling substantial heat recovery. Sizes of regenerators are compact relative to regenerators for air-fuel furnaces. The thermochemical regenerators exhibit a unique self-cleaning mechanism, no sulfate accumulation in the checkers, resulting in low maintenance requirements. Flue gas temperatures exiting the OPTIMELT™ TCR system are typically around 650 °C creating potential for additional energy capture, further lowering CO2 emissions.

Industrial results from the Leerdam furnace illustrate the system's durability and efficiency. Operating for more than seven



years, the furnace has maintained an exceptionally low aging rate - approximately 0.25 percent per year. Fuel consumption remained stable despite typical furnace wear and seamless mode-switching (TCR syngas firing to oxy-fuel firing and vice-versa) ensured uninterrupted glass production during maintenance cycles.

PATHWAYS TOWARD HYBRID AND FUTURE-READY FURNACES

Linde's developments also support hybrid furnace concepts, with ongoing collaborations focused on burner adaptation and integrated oxygen-supply (VPSA system) solutions. Whether through optimised combustion or heat recovery, e.g. thermochemical reforming Linde's technologies are compatible with green and low-carbon fuels.

While it may take time for green / low carbon fuel infrastructure to develop, a practical first step that can be taken today is converting furnaces to oxy-fuel firing with OPTIMELT™ TCR heat recovery. Taking this step will also make the glass furnaces future-ready when green fuels become economically available. ■

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