Steam generation from flue gases

A steam-driven cullet preheating concept is described by Niels Rozendaal, Andries Habraken and Ruud Beerkens. Potentially, the technology is also ideal for drying pelletised batch.

On average, about 30% of the energy input to a glass furnace is lost by the sensible heat of the exhausted flue gas. In spite of this massive energy savings potential, waste heat recovery systems are rarely applied in the glass industry. The main reasons are fouling of heat exchangers, the lack of users of steam in the vicinity of the glass plant and some operational problems, plus the relatively high investment costs involved in these systems.

INNOVATIVE TECHNOLOGY

Netherlands-based Optimum Environmental & Energy Technologies has developed and successfully implemented an innovative waste heat boiler concept to utilise the enthalpy of flue gas as an energy source for the production of steam. This system consists of a specially designed fire tube boiler with a patented automatic in-line pipe cleaning system.

Systems have been operating in flat and container glass production plants since January 2007. Fouling is under control, resulting in no downtime for cleaning. Stable furnace operation is guaranteed without the effects on furnace pressure stability. In most applications, the steam produced is used to heat buildings or for heating highly viscous fuel oil to make it more fluid.

Recently, Optimum presented a concept to use the generated steam for preheating and drying cullet and potentially, for pelletised batch. This technology is a combination of the Optimum waste heat boiler and a heat exchanger for heating solids (grains and powders) from the Canadian company Solex Thermal Science Inc. Solex is a specialist partner in the heating and cooling of bulk solids, with hundreds of references for heating different free-flowing solids including fertilisers, plastics, detergents and minerals (eg sand) with steam and water. Optimum and Solex co-operate exclusively to develop and supply these applications for the glass industry.

In the case of typical glass furnaces used in the container and float sectors, flue gas is fed to a waste heat boiler, where the exhaust gas (450°C-600°C for regenerative furnaces, > 800°C for recuperative or oxygen fired furnaces) enthalpy is used for the production of steam. This steam is fed to the cullet preheater, where it condenses in hollow heat

Typical cullet preheating example for a 320 tonnes/day regenerative glass container furnace.
exchanger plates under release of condensation enthalpy. Subsequently, the condensate flows downwards and is fed back to the boiler or de-aerator.

Heat transfer is almost isothermal at the temperature of condensation, determined by the saturated pressure (typically around 20-30 barg, 210°C–234°C) in the system. The steam system is a closed loop, there being no direct contact between the steam and cullet. The cullet flows between the steam-heated hollow plates and is heated by conduction.

Generally, cullet used in the glass industry contains water/moisture as a result of outside storage and the presence of organic materials. The cullet preheater dries and preheats the cullet. To prevent odour emissions due to the (humid) cullet, the system presence of organic materials. The furnace performance evaluation (energy consumption, flue gas flows and heat losses), with and without cullet preheating, as well as setting up typical realistic cases is based on TNO’s extensive energy balance modeling capabilities and experiences. The feasibility study was sponsored by the Dutch department of economic affairs through Agentschap NL.

**ENERGY SAVING BENEFITS**

For the typical cases studied, a cullet percentage of 75% in the batch for coloured container glass was assumed. The energy efficiency improvement as a result of the steam-driven cullet preheating technology varies from 8.5% to 12%. Based on 2009 Eurostat average energy prices, energy cost savings fluctuate between €440,000 and €650,000 per year for a 320 tonnes/day pull regenerative furnace and between €720,000 and €784,000 per year for a 320 tonnes/day pull oxy-fuel fired furnace (taking into account the cost savings for oxygen). For both cases, a relatively efficient new furnace was used as the base case to ensure realistic savings calculations. This furnace type reflects modern glass production in Western Europe; with cullet ratios between 65% and 85% for coloured container glass, the cullet is preheated to 210°C.

The steam-driven cullet preheating technology can be retrofitted on existing furnaces, which could lead to higher savings as a result of a less efficient base case.

During system evaluation, the following potential additional benefits for glass production and glass quality and stability where identified:

- As a result of cullet preheating, it is anticipated that the amount of organic materials fed to the furnace is reduced significantly.
- Preheating the cullet as previously described allows the opportunity for a significant pull increase from a glass furnace (increases of 5% - 10% seem to be possible for furnaces with cullet preheating and more than 75% cullet in the batch).
- Cooling the flue gas in a steam boiler means that air-type flue gas coolers frequently installed upstream and baghouse filter systems are no longer necessary. The required temperature window for specific abatement system types (eg deSOx, SCR deNOx and an ESP (electrostatic precipitator) can be allowed for by correct selection of the steam boiler.
- These additional benefits were not taken into account in the energy savings calculations but it goes without saying that they could lead to a reduction of the return on investment of the project and significant improvements in glass colour stability and oxidation state (redox).
- For most cases, the return on total investment will be less than three years.

**PELLETISED BATCH**

The next stage to be investigated is to use the same base technology to completely dry and preheat pelletised batch (up to 200°C). The main reason why Optimum focuses on the preheating of pelletised batch material only and not normal powder batch is to avoid the typical downsides of conventional raw materials preheating like dust carryover and segregation. Steam-driven drying and preheating of batch in pelletised form overcomes these drawbacks and adds other benefits because of the improved melting characteristics of the pelletised material compared to conventional batch. Energy savings of 10% - 15% can be realised by preheating the entire batch (pellets and cullet) up to 200°C - 220°C.
Laboratory tests have delivered the technical feasibility of this method and currently, pilot demonstrations are being carried out on a larger scale to gain a better understanding of the behaviour of the pelletised batch, starting with wet pellets, in the dryer/preheater.

**FURTHER READING**


13. PLM report (1997) F Brouwer: Gemengvoorverwarmer glasmeltenoven 16 (Batch pre-heater glass furnace 16) in Dongen Netherlands, final report for NOVEM.


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