glass WORLDWIDE

Regenerator design reduces civil engineering costs

Glass industry consultant, Richard Sims describes SORG's latest regenerator design, which help glass manufacturers reduce capital costs without sacrificing energy efficiency.

The glass industry is often described as 'conservative', which is really a polite way of suggesting that the industry is slow to initiate change. However, many facts demonstrate that this view is incorrect. One such case is the remarkable decrease in specific melting energy consumption achieved by the industry. Taking the container industry as an example, a review of typical energy consumption figures reveals a decrease from about 7.5 GJ/tonne in 1975 to close to 3 GJ/tonne today. Innovation and development were at the forefront of the methods used to achieve this reduction of over 50% in the last 40 years.

SORG has a history of development going back almost 50 years and the company has been granted more than 100 patents during this period. These cover a wide range of inventions, from small pieces of equipment to complete furnace designs such as the LoNOx melter.

Innovation is not necessarily always based on completely new ideas. Some interesting concepts that were proposed in the past were either not successful or not practically feasible at the time. Subsequently, modern engineering techniques, perhaps coupled with modern materials, can sometimes make the difference to their viability, as demonstrated by the latest SORG development to be introduced; the ARD regenerator system.

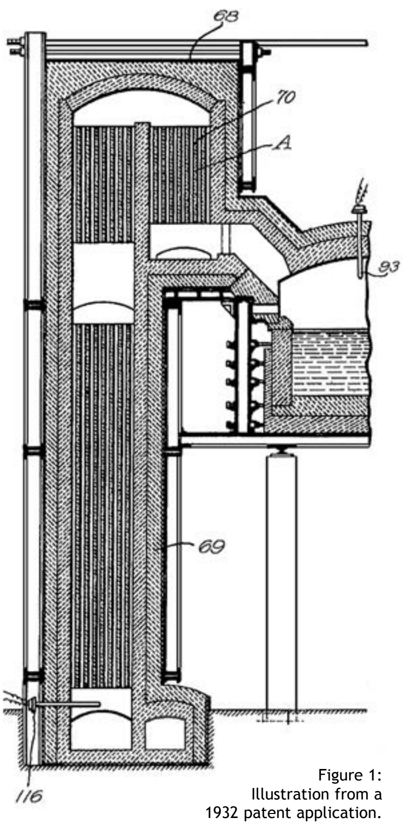


Figure 1: Illustration from a 1932 patent application.

ENERGY RECOVERY

Most continuous glass melting furnaces use regenerative combustion air preheating to recover energy from the waste gases and return it directly to the melting process as quickly as possible. The waste gases exiting the furnace still contain up to 75% of the available energy and so regenerator efficiency has a major influence on furnace energy consumption. However, the possible size of regenerator chambers may be limited by factors such as the space available or by the existence of a high water table in the factory. The latter may make it difficult and extremely expensive to create and maintain a water-tight cellar for the bottom of the regenerator chambers.

There are, of course, ways to compensate for the lower energy recovery efficiency of regenerators that are simply too small. One is the installation of recuperators behind the regenerators but although this arrangement does increase energy recovery, it involves significant extra investment and maintenance for the recuperators. In addition, recuperators are susceptible to damage by overheating or attack by deposits of corrosive materials and are unlikely to operate without problems for the complete furnace campaign.

Regenerator energy recovery can be increased by adding a second or more chambers to create multiple pass regenerators and in the 1980s, at least one furnace was built in the USA with four chamber (quadruple pass) regenerators. Following the law of diminishing returns, the amount of energy that can be recovered decreases significantly as the waste gases become cooler and so the efficiency of additional chambers drops dramatically and more importantly, so does the cost-effectiveness.

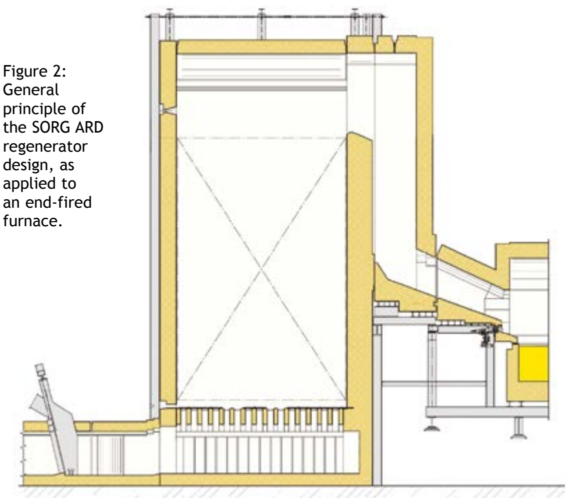
Today, regenerator efficiency is an important part of the glass melting process but even 80 years ago, people were considering ways of improving the operation of these important items. In 1932, Mulholland registered a US patent for a double pass regenerator with the first chamber set above the outside end of the burner port. The waste gases from the furnace flowed vertically upwards through the first chamber, before turning through 180° and passing downwards to exit the regenerators at the bottom of the second chamber (see figure 1).

With the refractory materials available at the time, the intermediate wall between the first and second chambers would have been a significant weak point of this design.

Another potential problem would have been control of the differential expansion of the various materials used. Support of the regenerator checkerwork in the first chamber would also have been a potential weakness of the basic Mulholland design.

Today, there are a number of important advances compared with the situation ruling when Mulholland filed his patent application. Firstly, the industry has access to a far wider range of refractory materials, some of which are much more resistant to the harsh operating conditions that would be experienced by the intermediate wall. Secondly, mathematical modelling can be used to

Figure 2: General principle of the SORG ARD regenerator design, as applied to an end-fired furnace.



investigate the thermodynamics of the system and to aid the detailed design of such a construction. Thirdly, extensive engineering experience of complex refractory structures and ways of controlling the expansion of the different materials are available. Finally, there is now well-founded understanding of protective measures such as targeted cooling of specific areas.

MODERN CONCEPT

The SORG ARD regenerator is a modern, practical concept, retaining the basic idea of a vertical channel added to the outer end of the burner port but this channel does not contain any checkers (see figure 2). It serves to allow the top of the checkers in the regenerator chamber to be raised relative to the furnace glass level, thereby creating more vertical space for the checkerwork. So it is possible to increase checker volume as required or to raise the bottom of the regenerator to above the water table level, avoiding expensive civil works.

Mathematical modelling has been used to investigate the thermodynamics of this design (see figure 3). The modelling shows the completely different flow pattern of the waste gases through the checkerwork produced by the ARD design. It is known that in conventional regenerator designs, the flow through the checkers is not evenly distributed across the complete cross-section. There is a preferential flow in the part of the checkers towards the rear wall of the chamber, with relatively little flow in the front part, at least as long as the checkerwork is new and free of restrictions.

With the ARD design, the waste gas flows vertically upwards in the new channel after the port and then vertically downwards through the actual regenerator chamber. The flow into the space above the checkerwork is no longer directly influenced by the flow pattern in the port neck. The waste gases flow homogeneously across the entire checkerwork cross-section and the net result is a much more even distribution of the mass flow through the checkerwork, with the attendant improvement in heat transfer.

The model can also be used to compare the thermal performance of the ARD regenerator with a standard design. For the same size regenerator, the results of the two systems are very similar, with air preheat temperatures of 1208°C for the standard regenerator and 1204°C for the ARD design. This confirms that the ARD design does not result in any loss of regenerator efficiency. However, one of the main advantages of the ARD system is its ability to increase the size of the regenerators without expensive civil engineering in the cellar area. The like-for-like comparison simply confirms that use of the ARD system does not produce any unexpected disadvantages.

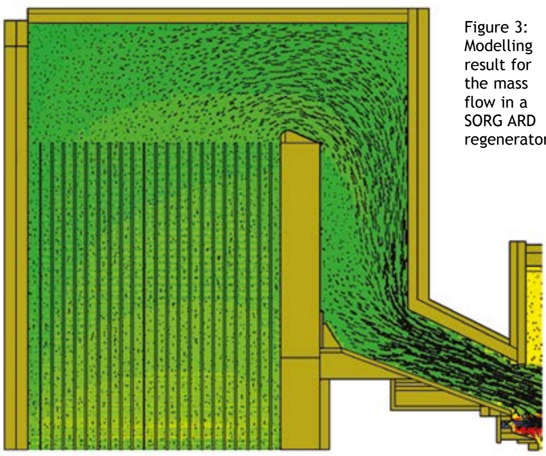


Figure 3: Modelling result for the mass flow in a SORG ARD regenerator.

On the contrary, the rear wall of the collecting chamber above the regenerator checkers normally suffers from direct radiation from the melter superstructure and high velocity impingement of the waste gases coming directly from the burner port. When the ARD system is used, this wall appears to run 30°C-40°C colder as a result of the introduction of the new channel between the burner port and the regenerator.

The application of modern materials does not change the conditions faced by the intermediate wall. Fortunately, modern glass furnace engineering practice makes it possible to provide internal air cooling for the wall refractory. Lateral cooling holes are provided inside the wall material and cooling air can be drawn from the normal furnace flux line cooling system. This simple and reliable system is used to reduce the effective average temperature of the refractory, thereby reducing corrosion and increasing the mechanical stability of the wall. Although important for the wall, this amount of cooling is too small to appear in the heat balance or affect the thermal efficiency of the regenerators.

An important aspect of any regenerator design these days is the way in which the differential expansion of the various construction materials is compensated for, so that there is no leakage into or out of the regenerator chamber. The maintenance of absolute air tightness is important in view of the necessity to operate the combustion system at or very near to stoichiometric in order to reduce NO_x emissions. SORG's extensive engineering experience with complex refractory structures, such as refining banks, is invaluable in this respect.

BENEFITS

The ARD regenerator design provides several benefits. The most obvious is the possible reduction in the depth of the regenerators below the furnace glass level and the resulting savings in civil engineering costs. In factories where a high water table causes difficulties, anything that reduces the cellar depth required is an advantage. Similarly, if a furnace size is to be increased, it will most probably be necessary to increase the depth of the regenerators.

Figure 4: SORG ARD regenerator on an end-fired furnace.

In both cases, the ARD design can lead to a considerable reduction in civil engineering costs and reduction of the building time needed. Even projects involving new furnaces, conversions of non-regenerative melters and replacement of multiple chamber regenerators can profit from the reduced civil engineering necessary with the ARD design.

The significantly improved mass flow distribution through the checkerwork produced by the ARD design is expected to result in both much better medium- to long-term retention of heat exchange efficiency and a reduction in maintenance costs for regenerator cleaning.

The first installation of the ARD regenerator design (see figure 4) was successfully commissioned on a large end-fired furnace in Mexico in summer 2015. The furnace has a melting area of 100m² and is designed to melt up to 250 tonnes/24h of coloured container glass with low cullet levels and only an absolute minimum of electric boosting. The results are very good and there is every indication that with the introduction of the ARD regenerator system, SORG has provided the industry with another tool to help glass manufacturers reduce capital costs without sacrificing energy efficiency. ■

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