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Results of the successful introduction of Calumite into a green container furnace

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Calumite is increasingly becoming known as an environmentally beneficial alumina source, due to its ability to reduce energy consumption, reduce furnace temperatures and reduce CO_2 and NO_x emissions. Details are presented of a successful trial of Calumite in a green container furnace at Şişecam's Mersin plant. Calumite was introduced to the 250 tpd furnace in 2 or 3% stages to 13% of the dry sand weight, replacing feldspar as the alumina source in the batch and resulting in reduction in energy use and hence cost, increased furnace pull and improved glass quality. The introduction of Calumite dramatically improved the melting behaviour of the batch with the batch piles appearing to be smaller and more active. As a result, during the trial furnace bottom temperatures increased, allowing a 25% reduction in electrical energy consumption. In addition the fuel consumption decreased by 1%, resulting in a 5% reduction in the total energy cost. An increase in furnace pull to 3% above the previous furnace maximum was achieved along with improved glass quality. There was minimal effect on glass colour parameters during the trial.

1. Introduction

A trial was carried out at Şişecam's Mersin plant to assess the affects of using Calumite as the sole alumina source in green container glass production. The glass produced was already of high quality, so the aim of the trial was to assess the energy reductions that can be achieved by using Calumite.

Calumite was added in stages to a level of 13% of the dry sand weight, which allowed complete removal of feldspar as the alumina source in the batch. As Calumite is a reducing agent, the level of Calumite addition is expressed as a percentage of the dry sand weight, to allow optimisation of the Calumite level using the redox number concept.[1] The chemical composition of Calumite is shown in Table 1.

During the trial, Calumite replaced anthracite as the reducing agent. It was accepted that the batch redox would fall during the trial. The calculated batch redox number reduced from −17·6 with no Calumite to −25·1 at maximum Calumite addition. As the Calumite level increased, anthracite was reduced until it was removed at the 6% Calumite stage. A small increase in the sodium sulphate was made to the 10% and 13% Calumite batches as a precautionary measure to ensure that the glass colour was maintained. The changes made to these batch components are summarised in Table 2.

The trial was carried out on an oil fired, U flame furnace with an electric boost system. At the time of the trial the furnace was running at 250 tpd, with 40% cullet. The cullet level was constant throughout the trial, with 5% grey float cullet and 35% green cullet. The ratio of internal to external cullet in the green cullet varied, depending on glass yield.

Table 1. Chemical composition of Calumite used in the trial

Oxide	*CaO*	*SiO_2*	*Al_2O_3*	*MgO*	*MnO*	*TiO_2*	*K_2O*	*Na_2O*	*Fe_2O_3*	*C*	*S^{2-}*	*SO_3*
%	39·7	35·7	13·2	8·8	0·53	0·49	0·41	0·23	0·25	0·02	0·78	0·05

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Table 2. Adjustments made to selected batch components during the trial

Raw material (kg/batch)	Base Batch	2% Calumite	4% Calumite	6% Calumite	8% Calumite	10% Calumite	13% Calumite
Feldspar	54·8	46·5	37·1	29·6	21·7	13·2	0
Calumite	0	12	24	36	48	60	75·3
Sulphate	5·0	5·0	5·0	5·0	5·0	5·6	6·0
Anthracite	0·41	0·3	0·23	0·15	0	0	0
Redox No.	−17·6	−18·2	−19·5	−20·8	−20·52	−22·09	−25·1

Furnace conditions and glass quality were monitored closely during the trial, with additional furnace parameters monitored for one month prior to and during the trial. Additional samples were taken for colour and XRF analysis during the trial.

The trial was limited to two weeks at maximum Calumite usage due to the quantity of material that had been shipped from the UK to Turkey. While this was only a short trial, a fixed trial period had the advantage of verifying that the positive effects were due to Calumite, by monitoring how the furnace returned to original operating conditions as the Calumite was removed.

2. Results

2.1. Furnace conditions

Good furnace conditions were maintained throughout the trial, with no incidences of excess foam or scum. In general, the batch piles appeared to be smaller and much more active when using Calumite, with a lot of bubbling visible within the piles. The batch line appeared further upstream during the trial, which allowed the crown temperature set point and consequently the fuel consumption to be reduced. The crown temperature set point was set at 1535°C prior to the trial. This was reduced to 1532°C on implementation of 8% Calumite and to 1527°C at maximum Calumite usage. When removing Calumite, the set point was returned to the standard condition of 1535°C at the 6% Calumite stage.

Figure 1 shows the significant increase in furnace bottom temperatures as a result of Calumite addition; illustrated by three thermocouples, TC1 at the doghouse, TC5 at the hotspot and TC8 at the throat. The initial temperature increase on implementation of Calumite allowed a significant reduction in the use of electric boost. The boost power was reduced from maximum output at the start of the trial to 65% output at the end of the period of maximum Calumite. The resulting reduction in specific electrical consumption is illustrated in Figure 2. As Calumite was removed the bottom temperatures started to fall, resulting in the electric boost being returned to its previous setting and consequently the electrical energy consumption returning to the pre-Calumite level.

2.2. Energy consumption

As can be seen from Figure 2, the increase in furnace bottom temperatures resulted in the average electrical energy consumption with Calumite being 25% lower than before it was implemented.

The fuel oil consumption and total energy consumption per kg of glass are shown in Figure 3. The average fuel oil consumption reduced during the initial stages of the trial as the crown temperature dropped, but was then seen to increase during the period at maximum Calumite. This was caused by other factors, including major outbreaks of chromite inclusions due to contamination of external cullet and the excess oxygen set point, which was increased during the trial because of the concerns about the ferrous iron level in the glass. However, despite these factors,

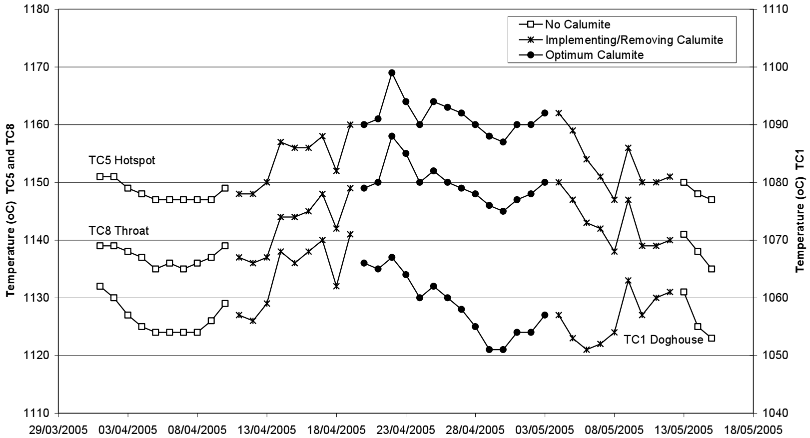

Figure 1. The effects of Calumite addition on furnace bottom temperatures. Daily spot temperature readings taken at 7 am

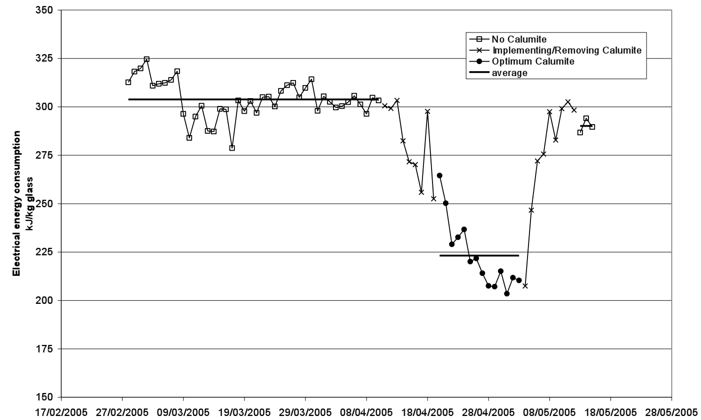

Figure 2. Effect of Calumite implementation on electrical energy consumption

the average fuel oil consumption during maximum Calumite usage was 1% lower than the previous month's average.

The significant electrical energy reduction, combined with the modest reduction in fuel oil consumption, resulted in an overall reduction in energy consumption of 3%, which corresponded to an average saving of 5% in energy costs, as detailed in Table 3 and illustrated in Figure 4.

2.3. Glass colour

No problems were encountered with glass colour during the trial. The level of ferrous iron in the glass increased from 21 to 58%, as expected due to the lower redox of the batch. The transmission at 1050 nm reduced from 68 to 33% during the course of the trial, but this caused no problems in the finished product.

The variation in glass colour during the trial is shown in Figure 5. The historical data shows the normal variation in colour that is seen. Although there is variation in the results at maximum Calumite, it is no greater than the normal variation. During the course of the trial the colour moved slightly towards the blue region due to the increase in ferrous iron. This slight change in colour was only visible to the trained eye. The dominant wavelength moved 2 nm, which was well within the colour specification tolerances of the product and in Şisecam's experience is the limit of visual perception.

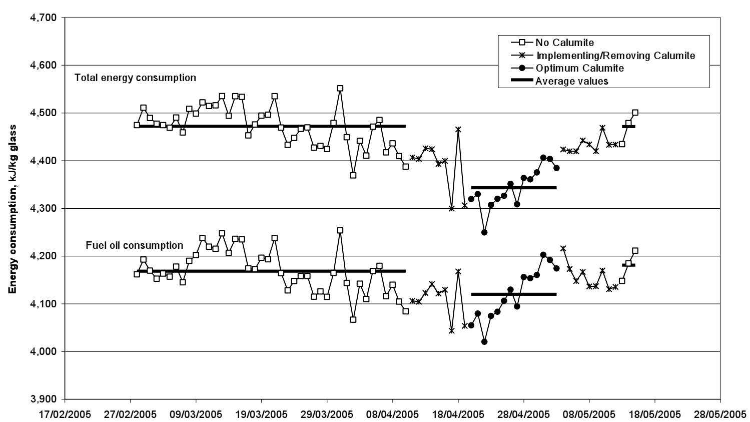

Figure 3. Effect of Calumite implementation on fuel oil and total energy consumption

Table 3. Analysis of the energy consumption data prior to the trial and during the period of maximum Calumite

	Average values			*Effect of Calumite*	
	Prior to the trial	*Maximum Calumite usage*	*Once Calumite removed*	*Change*	*%Change*
Fuel oil consumption, (kJ/kg glass)	4168·3	4120·1	4181·2	48·2	−1·2%
Electrical energy consumption, (kJ/kg glass)	303·8	223·1	290·2	80·7	−26·5%
Total energy, (kJ/kg glass)	4472·2	4343·3	4478·8	128·9	−2·9%
Energy cost, (YTL/t glass)	0·0565	0·0538	0·0563	−0·0027	−4·8%

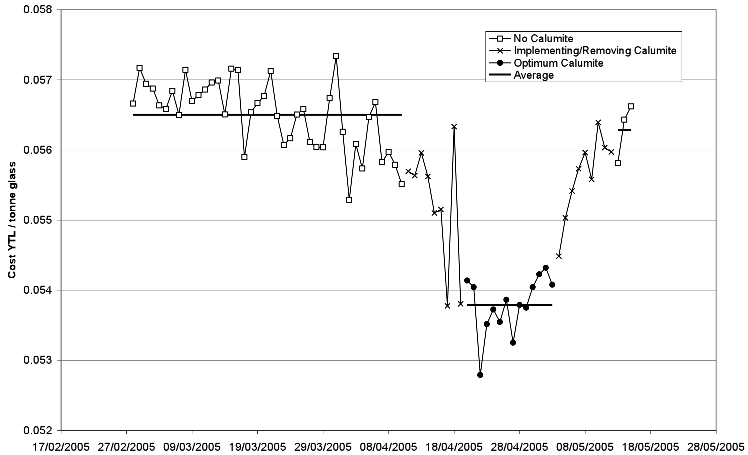

Figure 4. The 5% reduction in energy cost through the use of Calumite

2.4. Glass quality

As detailed in Table 4, the seed count across all three of the furnace's production lines was very low. However the introduction of Calumite reduced the level of seeds across all three lines by an average of 66%, as illustrated in Figure 6.

2.5. Furnace pull

The furnace pull during the trial is shown in Figure 7. There was a three day period when the average pull rate was increased to 258 tpd. This represented a 3% increase above the previous maximum pull rate of 250 tpd. On previous occasions, without Calumite, full power was required from the electric boost system to achieve a pull rate of 250 tpd. On this occasion, the boost power was approximately 80% of the maximum output.

3. Discussion

3.1. Energy

The use of Calumite resulted in a significant reduction in furnace energy consumption, particularly

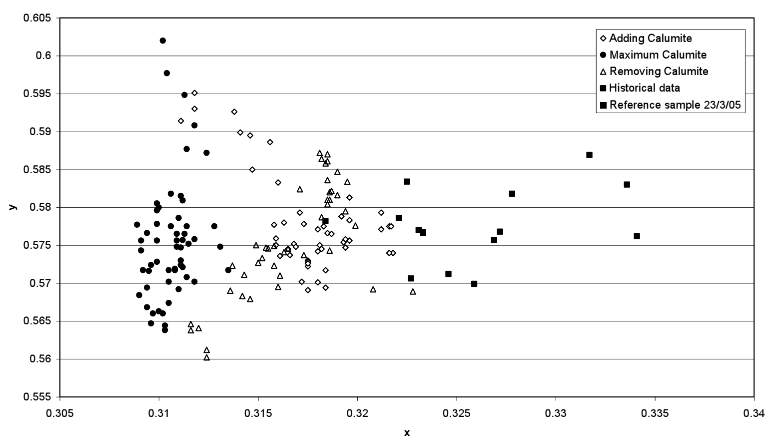

Figure 5. Chromaticity diagram showing the change in glass colour during the trial and comparison with historical data,using the C.I.E. system

Table 4. Analysis of the seed count prior to the trial and during the period of maximum Calumite

Seed count (number/2·5g glass)	Average values: Prior to the trial	Maximum Calumite usage	Once Calumite removed	Effect of Calumite: Change	% change
Line 11 total seeds	2·73	1	2·28	−1·73	−63
Line 12 total seeds	3·18	1·44	3·54	−1·74	−55
Line 13 total seeds	3·75	0·88	3·57	−2·87	−77
Average seeds	3·22	1·1	3·13	−2·12	−66

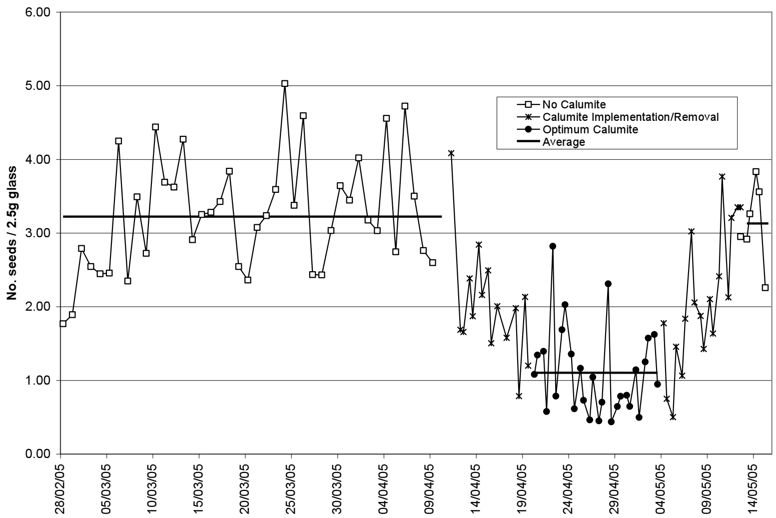

Figure 6. Effect of Calumite addition on the average seed count across three lines

through the reduced use of electric boost. The average electrical energy consumption during the two week period at maximum Calumite showed a 25% reduction compared to the period prior to the trial. For the second week at maximum Calumite level, the electrical consumption was stable at a value 30% lower than the consumption prior to the trial, while the downstream bottom temperatures remained hotter than at the beginning of the trial, indicating that further reductions could have been realised.

TC1 at the doghouse is used to control the bottom temperatures, as it generally gives an early indication of the trends that will follow through the furnace. During Calumite implementation, this temperature increased 10–15°C. However midway through the trial, with the reduction in electric boost, it had dropped to approximately 5°C lower than its previous value, so fuel was increased to bring this temperature back up. However, the other furnace bottom temperatures increased 20–25°C on implementation of Calumite, and at the midpoint of the trial were still approximately 10°C higher than their initial values. It is known that when operating with Calumite the doghouse temperature can be reduced whilst maintaining the hot spot temperature. This is believed to be due to the Calumite acting as a fluxing agent, forming low temperature melt phases that reduce the melt energy required and also improve the heat transfer through the batch blanket. On removal of Calumite the bottom temperatures quickly returned to their original values, with the normal relationship between upstream and downstream temperatures being re-established.

During the initial stages of the trial the fuel oil consumption was also reduced, but this was not maintained during the period of maximum Calumite,

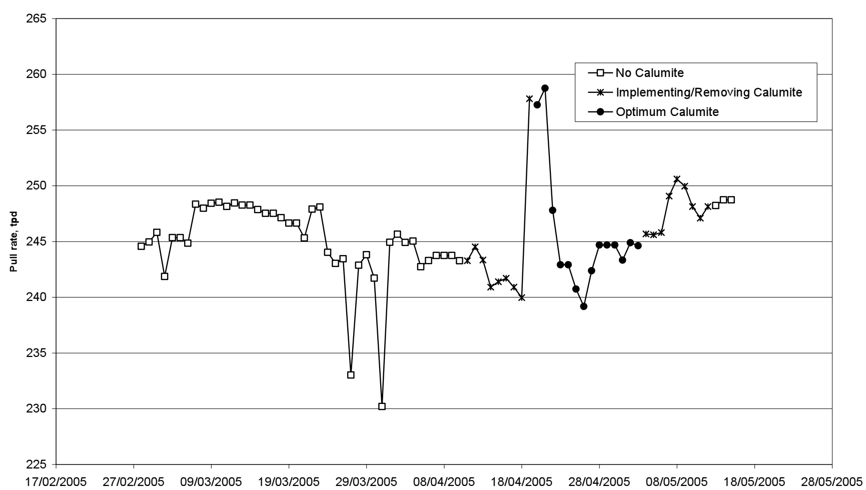

Figure 7. Furnace pull rate during the Calumite trial

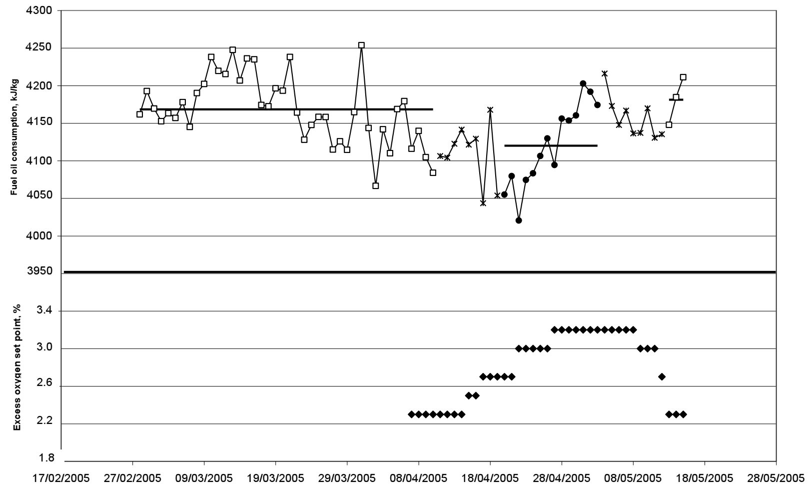

Figure 8. Effect of excess oxygen set point on fuel oil consumption

despite the crown temperature operating at a set point 8°C lower than standard throughout this period. Furnace combustion is automatically controlled to maintain the crown temperature set point and the oxygen level in the waste gas, which is continuously measured in the stack. During the trial the excess oxygen set point was increased from 2·3 to 3·2% due to concerns over the level of ferrous iron in the glass. However this will also have had an influence on the efficiency of the furnace, the additional air having a cooling effect. The relationship between the excess air set point and the fuel consumption is shown in Figure 8. As there were, in fact, no problems caused by the change in level of ferrous iron in the glass, had the trial continued for a longer period, the excess oxygen set point could have been returned to the standard setting, with expected reduction in fuel oil consumption.

During the trial the furnace energy consumption was increased as a result of two outbreaks of chromite inclusions that resulted from contamination of external cullet. The furnace energy was increased in an attempt to melt the chromite and improve glass quality, which prevented the furnace conditions from being fully optimised at the maximum Calumite level. The relationship between the chromite outbreaks and fuel consumption are shown in Figure 9. It is believed that the fuel oil consumption could have been reduced at maximum Calumite had these outbreaks not occurred.

Despite these factors influencing the fuel oil consumption during the period at maximum Calumite, the average fuel consumption during this period was 1% lower than without Calumite, with the average fuel consumption increasing on return to the base batch.

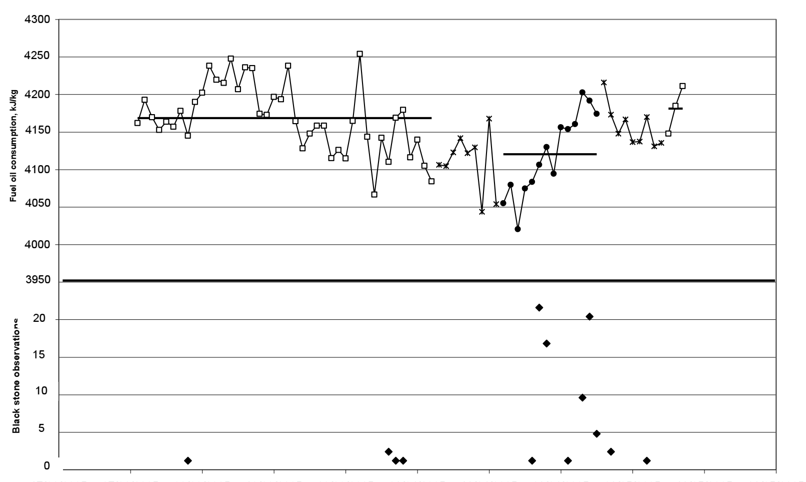

Figure 9. Effect of black stone observations on fuel oil consumption during the trial

3.2. Glass quality

The glass quality improved through the use of Calumite, however as the seed count was already at a low level, the seed reduction would have offered no commercial benefit. Therefore, had the trial continued, further energy savings may have been possible by reducing furnace temperatures whilst monitoring glass quality, such that the seed count returned to previous levels, with lower fuel consumption.

3.3. Pull rate

The three day period with average pull rate of 258 tpd was a 3% increase on the previous maximum pull rate that had been achieved and 12% higher than the furnace design pull rate of 230 tpd. This period of high tonnage occurred whilst at 10–13% Calumite, which was before the furnace had been stabilised at maximum Calumite level. In addition, the bottom temperatures were at least 10°C hotter than prior to the trial, with some capacity remaining in the electric boost. Previous occasions where the pull rate has reached 250 tpd have required maximum power from the electric boost system. These factors suggest that had production requirements allowed, the pull rate could have been increased further whilst using Calumite.

4. Conclusions

Calumite was successfully implemented into a green container furnace at Şişecam's Mersin Container Plant. 13% Calumite was used to replace feldspar in the batch, resulting in:

- 25% reduction in electrical energy consumption
- 3% saving in total energy consumption, resulting in a 5% saving in energy cost
- 3% increase in maximum pull rate
- Improvement in glass quality, with a 66% reduction in the average seed count across three lines
- Good glass colour, with the dominant wavelength changing by just 2 nm.

Had the trial been extended, it is believed that further benefits could have been realised once the furnace conditions were stabilised at maximum Calumite levels. A reduction in fuel consumption would be expected as the excess oxygen set point was reduced to the standard setting. In addition, further energy savings could be achieved by reducing furnace temperatures, whilst monitoring glass quality.

Reference

1. Simpson, W. & Myers, D. D. The redox number concept and its use by the glass technologist. *Glass Technol.,* 1978, **19** (4), 82–5.