



the Energy to Lead

New Freedom in Raw Materials for High Intensity Melters

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gti[®]

High Intensity Melting

One Step of a Segmented Melting Processes

Segmented melting allows optimization of the glass melting process – residence time, energy, capital cost

> Batch melting

- Dehydration reactions
- Solid state reactions
- Decomposition reactions
- SiO₂ dissolution

> Homogenization

> Fining – Removal of bubbles and seeds

> Refining – controlled cooling, re-absorption of residual gases

High Intensity Melters

- > High intensity melters carry out the batch melting step and sometimes the homogenization step of a segmented melting system
- > Very few of the many proposed high intensity melting approaches have been reduced to industrial practice
- > High intensity melters either have:
 - Stricter batch requirements than conventional melters
 - More flexible batch requirements than conventional melters

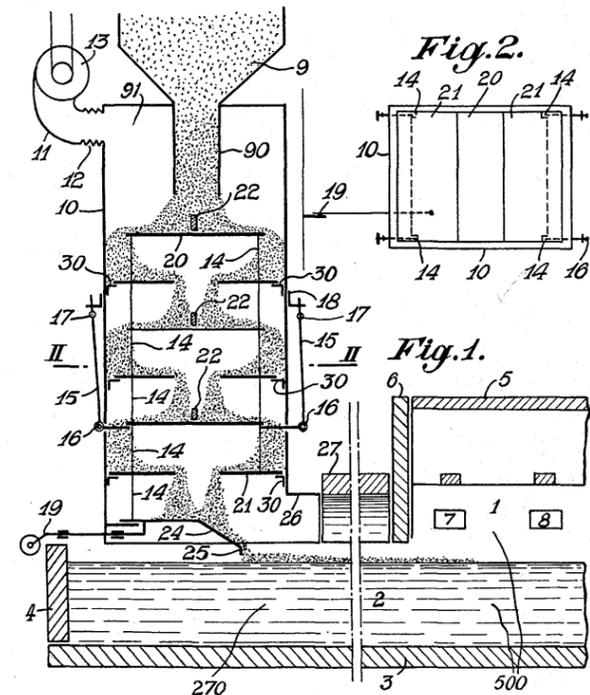
High Intensity Melters With Stricter Batch Requirements

- > These melters usually have short melting times of seconds to minutes
- > They often need
 - Very narrow particle size ranges
 - Fine particle sizes or micronized feed
 - Extremely well blended batch
- > Examples include:
 - Plasma melters such as Plasmelt
 - Advanced Glass Melter (GRI) – fine batch was injected into the flame
 - VORTEC – uses a cyclonic melting furnace

High Intensity Melters With More Flexible Batch Requirements

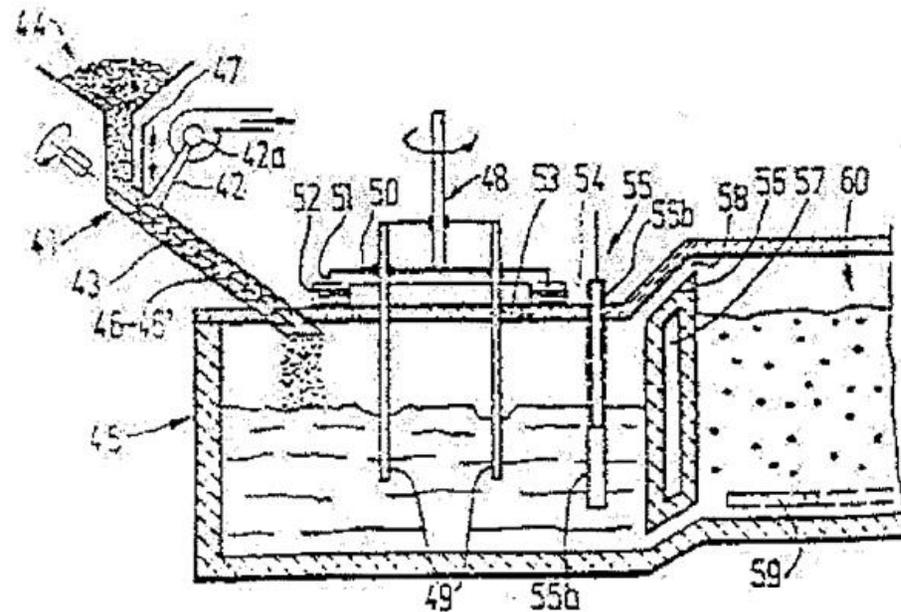
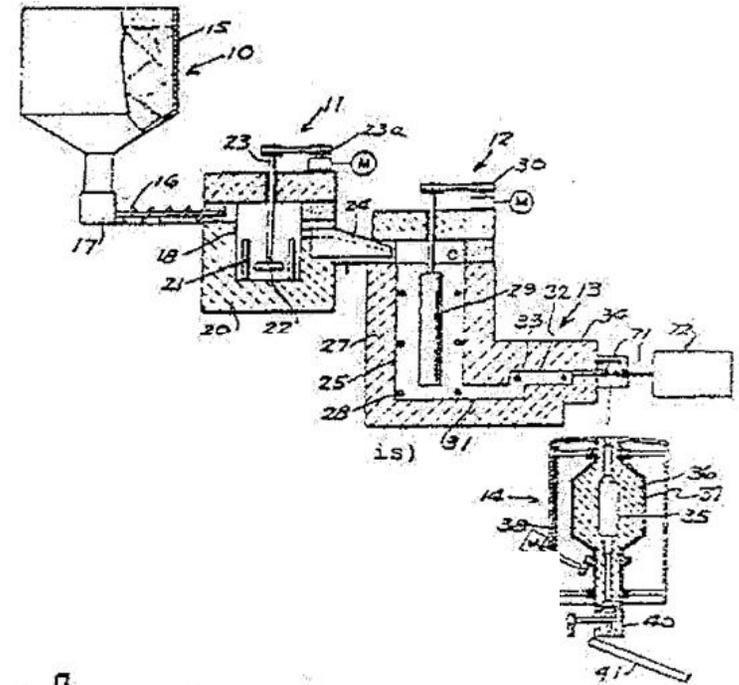
- > These melters typically include batch melting and homogenization in a single unit
- > Residence times are typically several hours
- > Examples include:
 - Brichard Furnace - Glaverbel, Plumat, 1973 – bottom fired melter with pelletized batch preheated by countercurrent exhaust gas flow while falling down a shaft into the melter

March 9, 1965 E. BRICHARD 3,172,648
METHOD OF AND APPARATUS FOR IMPROVING THE PREHEATING OF
PULVEROUS MATERIALS, THEIR INTRODUCTION INTO MELTING
FURNACES AND THEIR MELTING THEREIN
Filed April 4, 1960 3 Sheets-Sheet 1



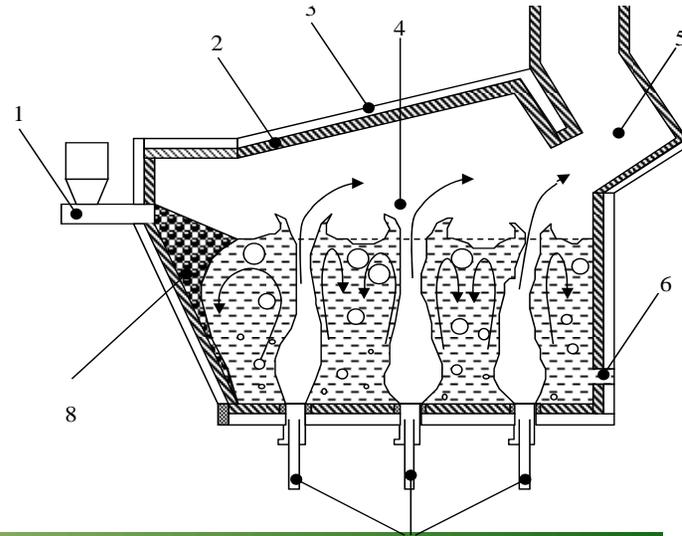
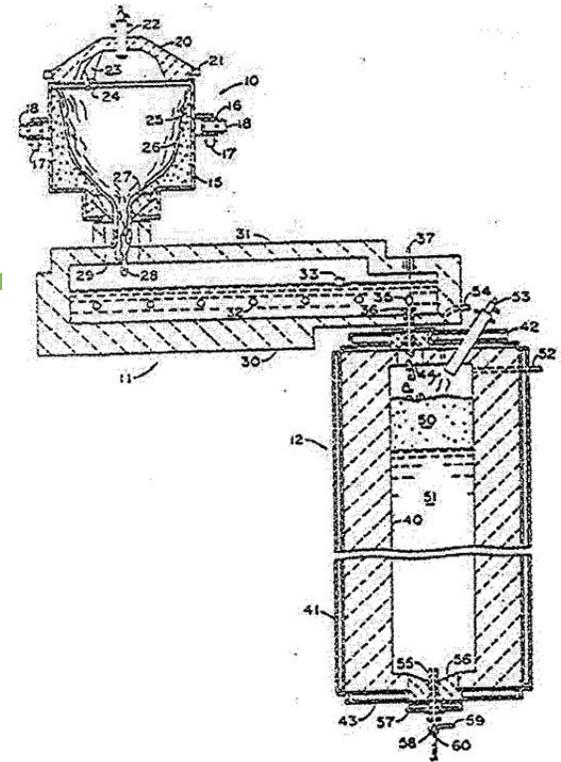
Melters With More Flexible Batch Requirements

- > RAMAR (Rapid Melting and Refining) – Owens-Illinois, 1973 – includes 2 stirred electric melters in series
- > FARE (Fusion et Allinage Rapide Electrique) – Saint Gobain, 1984 – uses a single stirred electric melter



Melters With More Flexible Batch Requirements

- > P-10 – PPG Industries, 1980s – rotating top fired melter with batch preheated in a slanted, rotating shaft
- > SCM (Submerged Combustion Melting) – GTI, 2000s – multiple bottom-fired oxy-gas burners provide intense mixing and high heat transfer rates



New Freedom in Raw Materials

- > Glass can be thought of as made from these raw materials
 - Silica (SiO_2)
 - Other metal oxides that may or may not undergo reactions during melting depending on the minerals selected
 - Cullet
- > Raw material freedoms are offered by high intensity melters in
 - Mineral handling, transport, and sizing
 - Batch preparation and charging to the melter
 - Wider range in raw material selection
 - Exhaust gas cleaning
 - Batch preheating

Making Fine Particles Takes Work

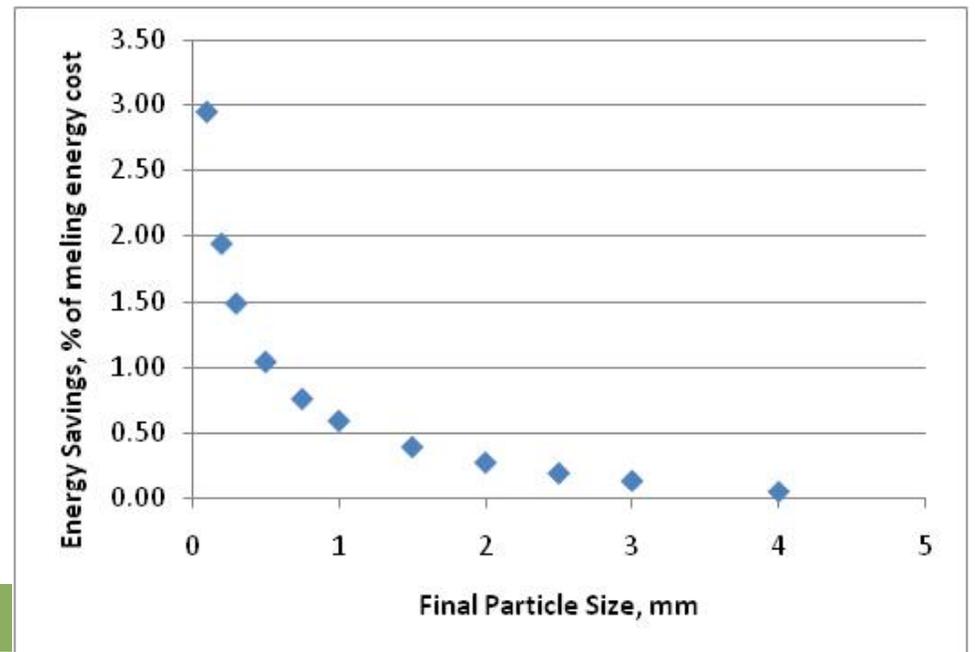
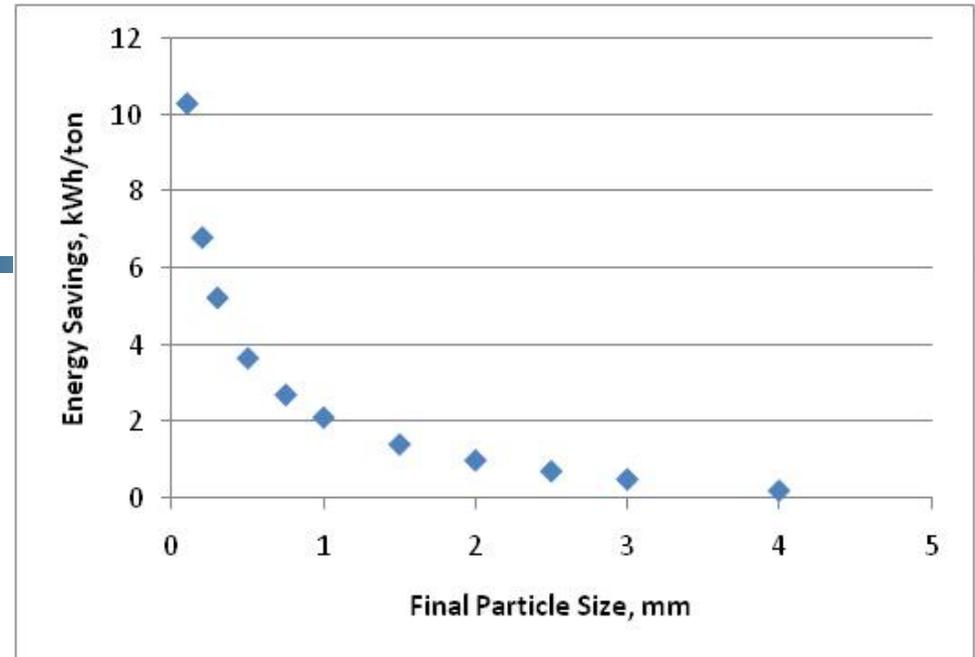
- > Smaller particles of silica and other minerals dissolve faster during melting
- > Work needed to grind minerals increases as particle size decreases
- > The Bond Work Index describes grinding work for 0.05-50 mm particles

$$W_B = C_B \times \left(\frac{10}{\sqrt{d_E}} - \frac{10}{\sqrt{d_A}} \right)$$

- > W_B – work in kJ/kg
- > C_B - constant in kJ/kg, function of material and equipment
- > d_A, d_E – initial and end particle diameters, microns

Energy Savings From Less Grinding

- > Energy saved is electricity which is more costly than natural gas
- > Grinding savings are \$0.25-0.50/tonne
- > **Energy cost can be 1-3% lower**
- > Assuming:
 - Melter is 50% efficient
 - Melter energy consumption in natural gas is 4600 MJ/tonne
 - Natural gas - \$7/MMBtu
 - Electricity (grinding) - \$0.08/kWh



Less Stringent Blending Requirements

- > Less dusting and easier handling of on-site materials storage
- > Lower capital costs and lower maintenance costs for simpler batching systems
- > Much of the mixing is done in the melter
- > Some melters allow batch charging in multiple streams
- > Specification of a larger minimum batch particle size or pelletizing part or all of the batch
 - Reduces dusting
 - Decreases melter particulate carryover

Pelletized Batch

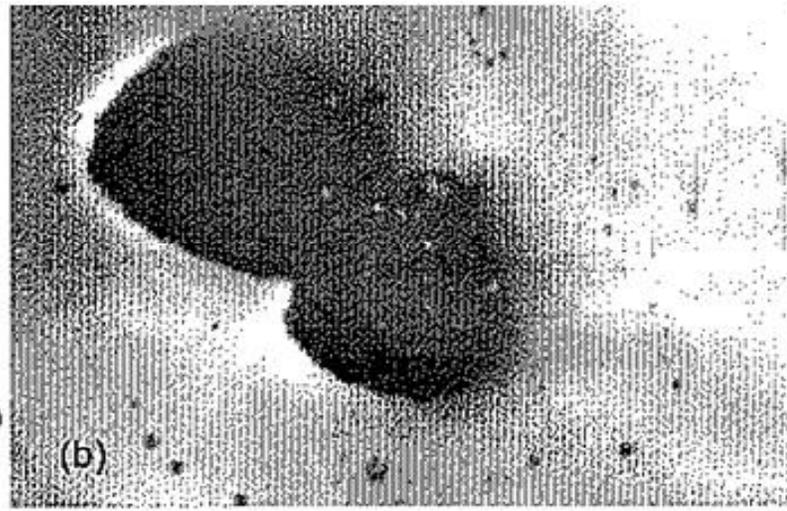
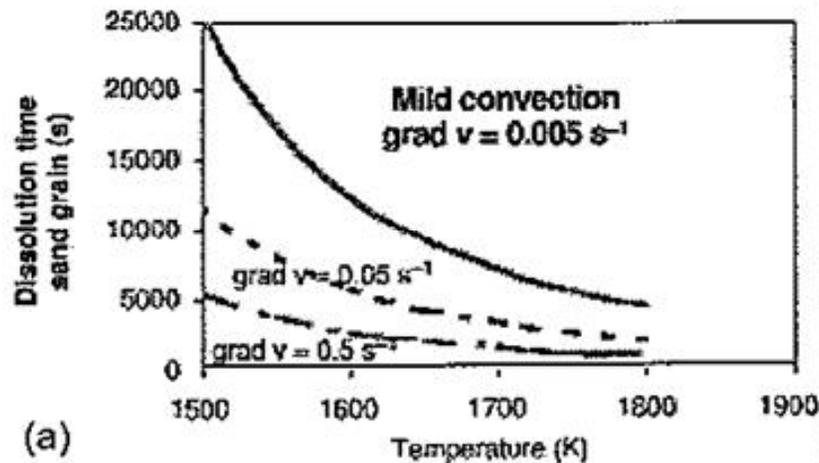
- > Allows wider batch particle size range
 - Can reduce batch preparation cost
 - Can decrease handling cost and dusting
- > Can be used to decrease loss of volatile components by incorporating them inside pellets
- > No requirement for 'hard' pellets or costly binders
- > Advantages can be magnified by pelletizing only part of the batch, such as:
 - Volatile components
 - Fines
 - Non-SiO₂ minerals

Flexibility in Melter Charging

- > High intensity melters can often accept
 - Continuous charging
 - Semi-continuous charging
 - ‘Batch’ charging of raw materials
- > Batch introduction to the melter can be
 - Well mixed to poorly mixed through a single charger
 - Unmixed and fed sequentially through a single charger
 - Separated and fed through multiple chargers
- > Intense mixing can eliminate the need for a spreader - allowing charging by smaller, less expensive equipment

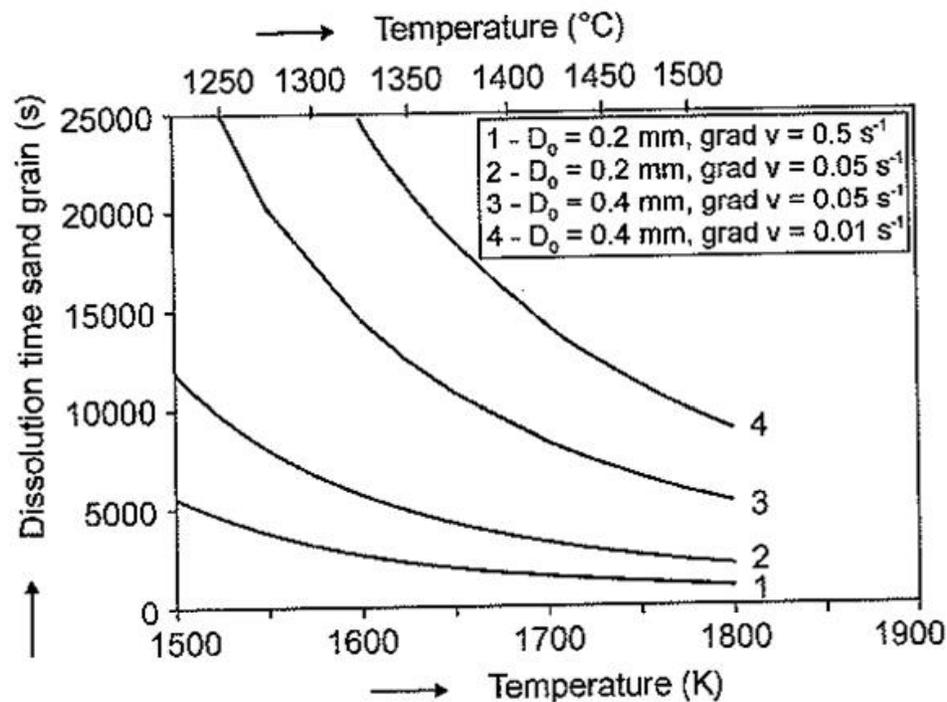
Intense Mixing Speeds Grain Dissolution

- > Increasing mixing velocity allows particles of the same size to dissolve much faster into the melt
- > Up to 6 times faster with moderate velocities
- > Some high intensity melters create velocities high enough to decrease dissolution time by >10X



Ruud
Beerkens,
Ceramic
Bulletin,
Apr. 2004

Matching Melter Conditions to the Batch



Ruud Beerkens, Ceramics Silikaty
52(4), 2008

- > Increased mixing velocity and higher local temperatures can be used to dissolve large sand grains (2X or more) in the same amount of time as small grains
- > In high intensity melters, grains rubbing together can decrease diameters and decrease dissolution time

Water in the Batch

- > For high intensity melters heated above the melt, water in the batch behaves the same way as in a conventional melter
- > For melters heated below the melt (Brichard, SCM, etc.)
 - Water is driven off by the exhaust gas after heat is transferred to the melt bed
 - The vaporization of water cools the exhaust gas but is not an energy penalty to the melter
 - Water content can therefore be raised or lowered for operational reasons without suffering an energy penalty
 - Water impacts on glass forming chemistry and exhaust gas chemistry must be understood and optimized

Raw Materials and Refractory Choices

- > Refractories can be chosen that are either less expensive or compatible with more aggressive glass chemistries
 - High intensity melters are smaller with less surface area than conventional melters
 - Some high intensity melters use water-cooled walls and castable refractory protected by a layer of frozen glass
- > Smaller melters and wider refractory choices allow consideration of
 - More corrosive glass batch components
 - A wider range of additives such as fining agents and trace components

Decreased Particulates in Exhaust

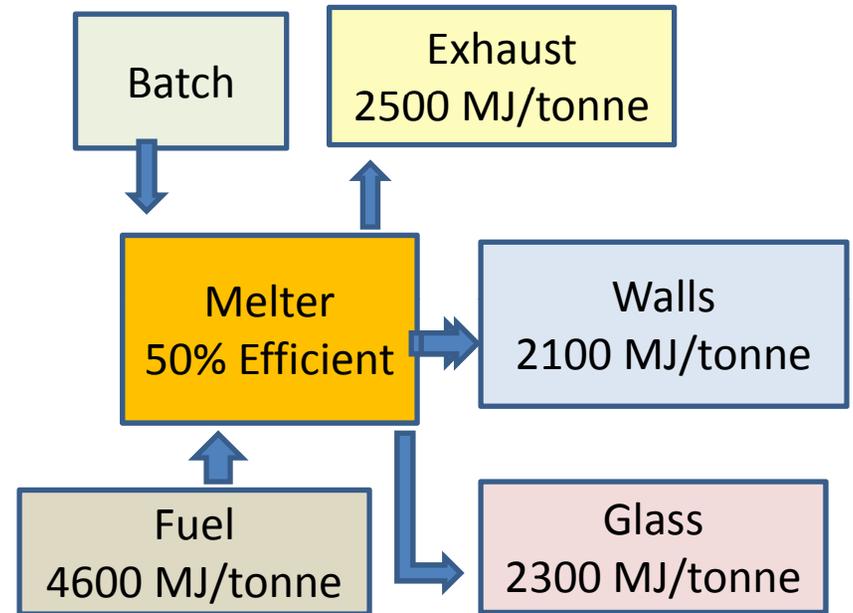
- > Larger minimum batch particle size reduces particulate carryover into the exhaust duct
 - Smaller and less costly exhaust cleaning system
 - Improved environmental footprint
- > Lower loss of volatile components
 - Less vaporization from the batch blanket
 - Some components can be introduced to a melter such that they can be more quickly incorporated into the melt

Batch Preheating

- > Preheating is challenging due to particle physical behavior, drying, dusting, bridging, channeling and chemical reactions
- > Cullet preheating is easier and avoids most of these problems
- > For melters that can accept separate feed streams, SiO_2 can be preheated by exhaust gas in the same manner as cullet
 - Dusting can be minimized by using larger grains
 - Drying and chemical reactions are not a concern
 - SiO_2 can be preheated to high temperature – up to 800°C
 - Having up to 70% of the batch preheated can speed overall batch melting once all components mix in the melter

Energy Savings From Batch SiO₂ Preheating

- > Assuming
 - 65% SiO₂ in batch
 - Only SiO₂ is preheated
 - SiO₂ is preheated to 800°C
- > Energy savings
 - 400 MJ/tonne
 - 9% fuel savings
 - Efficiency increase from 50% to 55%



In Conclusion – Freedom is Good

- > Freedom in raw material choices can make high intensity melters more attractive
- > The energy savings, handling simplification, and other potential benefits are not enough to justify choosing a high intensity melter on this basis alone
 - But they help!
- > With freedom comes responsibility
 - The responsibility to make the best raw material choices for the type of melter and for the product glass