the Energy to Lead

New Freedom in Raw Materials for High Intensity Melters

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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
  - SiO_2 dissolution
- Homogenization
- Fining – Removal of bubbles and seeds
- Refining – controlled cooling, re-absorption of residual gases

High Intensity Melters

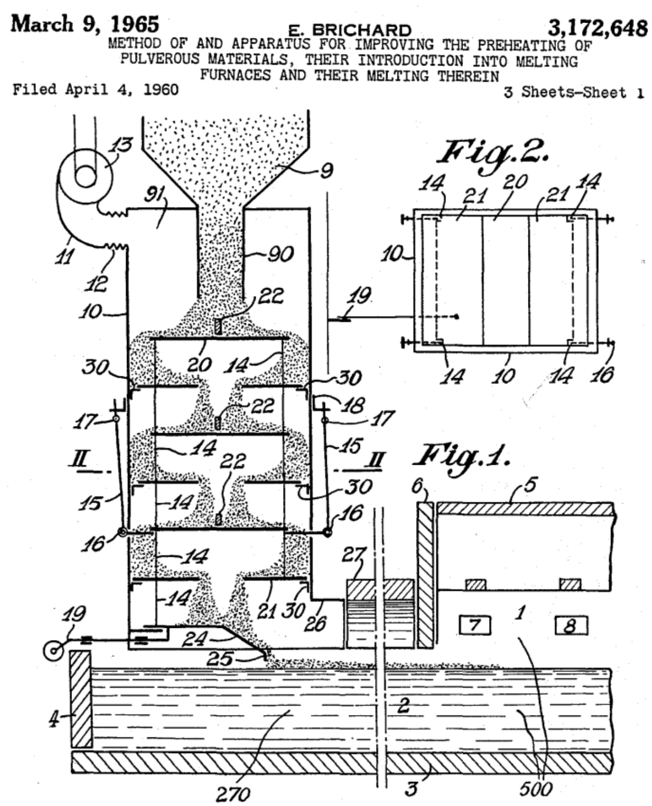
- High intensity melters carry out the batch melting step and sometimes the homogenization step of a segmented melting system
- Very few of the many proposed high intensity melting approaches have been reduced to industrial practice
- High intensity melters either have:
  - Stricter batch requirements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

High Intensity Melters With Stricter Batch Requirements

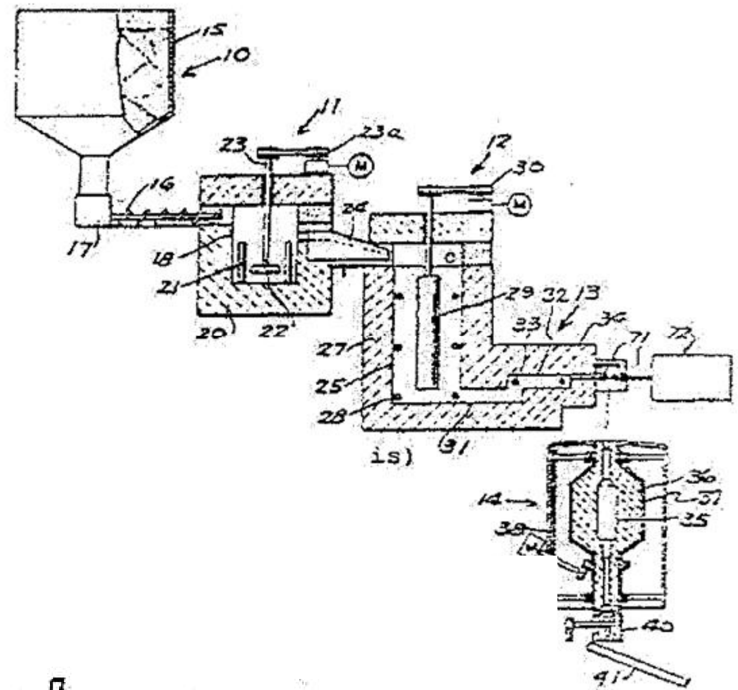
- These melters usually have short melting times of seconds to minutes
- They often need
  - Very narrow particle size ranges
  - Fine particle sizes or micronized feed
  - Extremely well blended batch
- Examples include:
  - Plasma melters such as Plasmelt
  - Advanced Glass Melter (GRI) – fine batch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

High Intensity Melters With More Flexible Batch Requirements

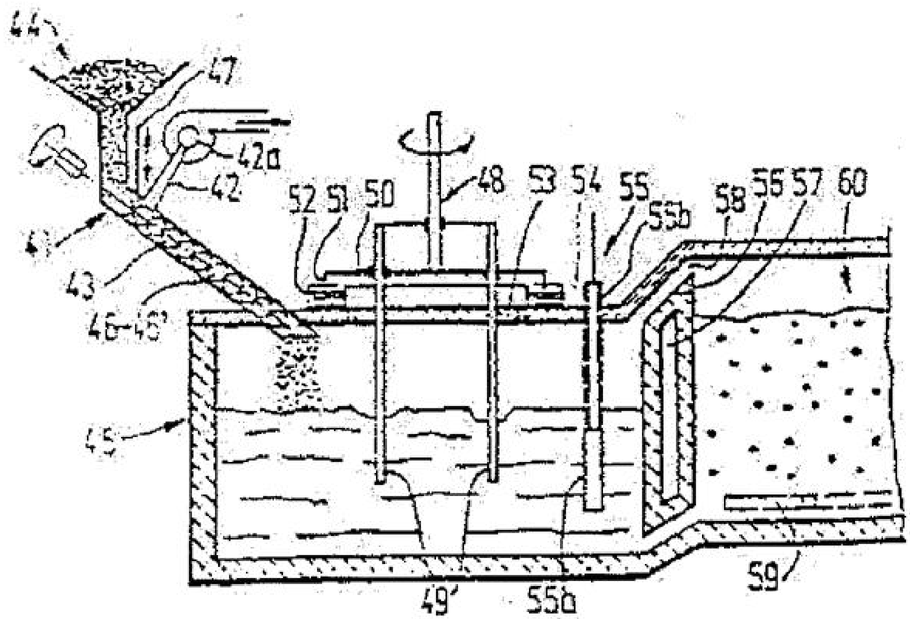
- These melters typically include batch melting and homogenization in a single unit
- Residence times are typically several hours
- Examples include:
  - Brichard Furnace - Glaverbel, Plumat, 1973 – bottom fired melter with pelletized batch preheated by countercurrent exhaust gas flow while falling down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



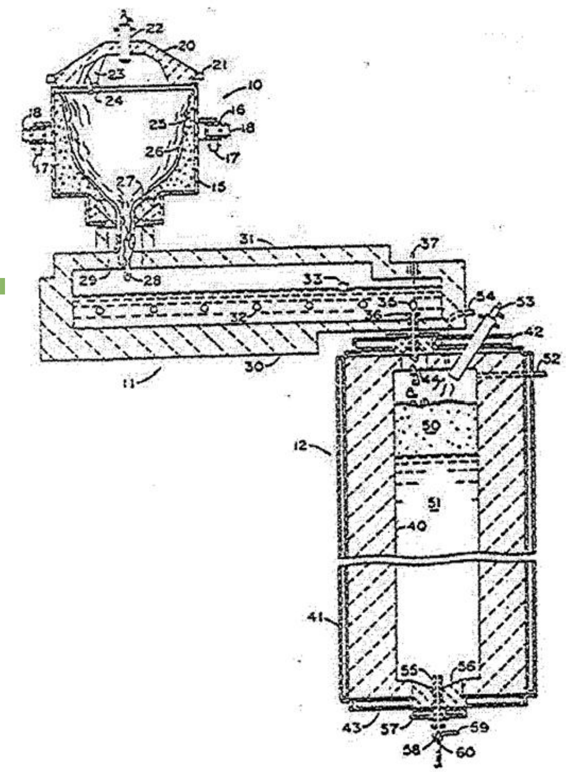
Melters With More Flexible Batch Requirements



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

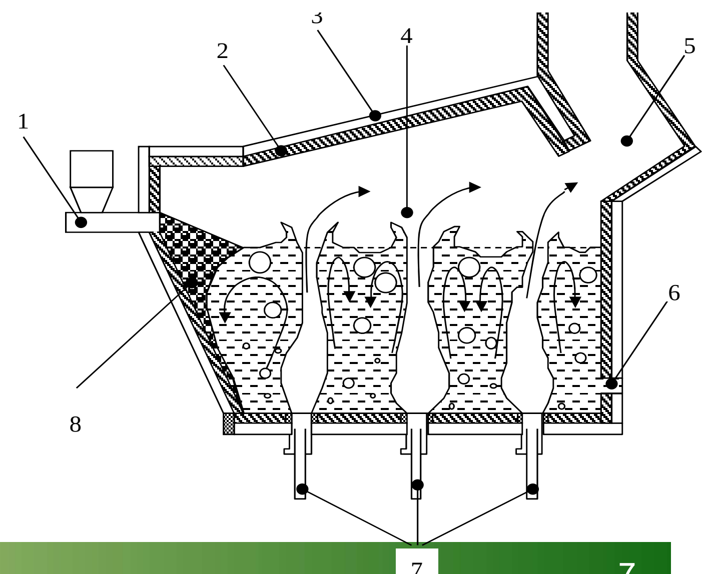


Melters With More Flexible Batch Requirements



> 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



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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

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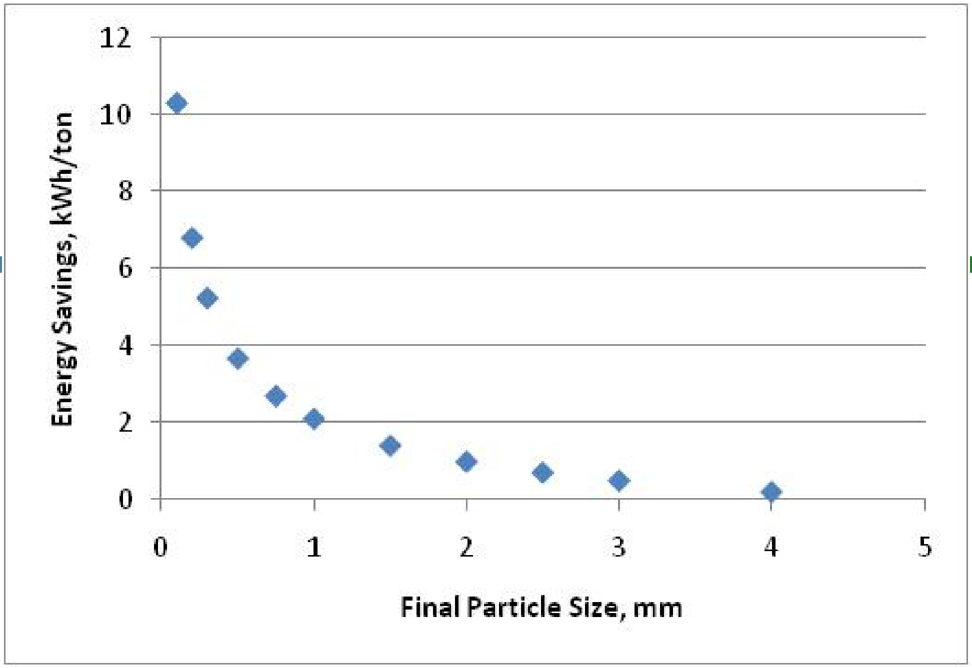
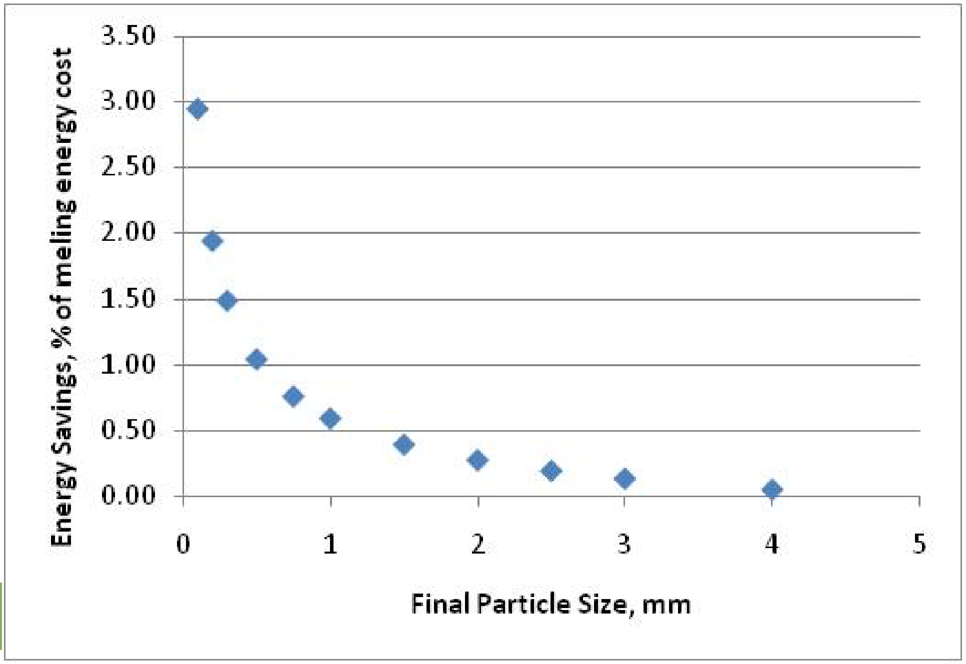
Energy Savings From Less Grinding

> 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

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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-SiO_2 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

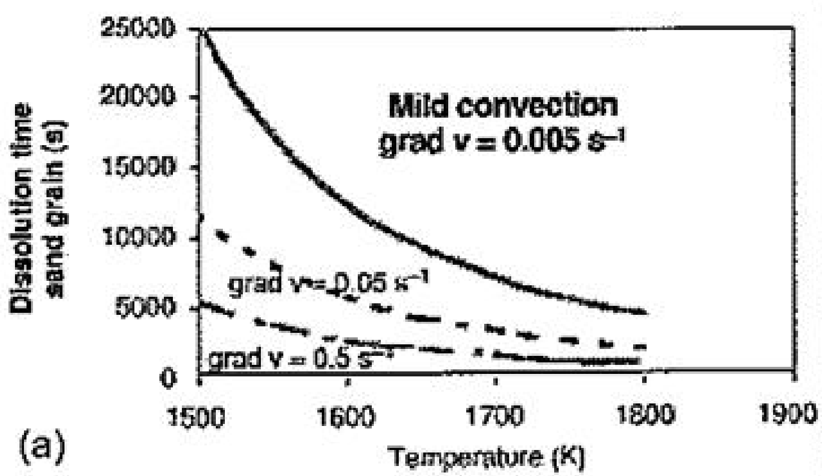
> Intense mixing can eliminate the need for a spreader - allowing charging by smaller, less expensive equipment

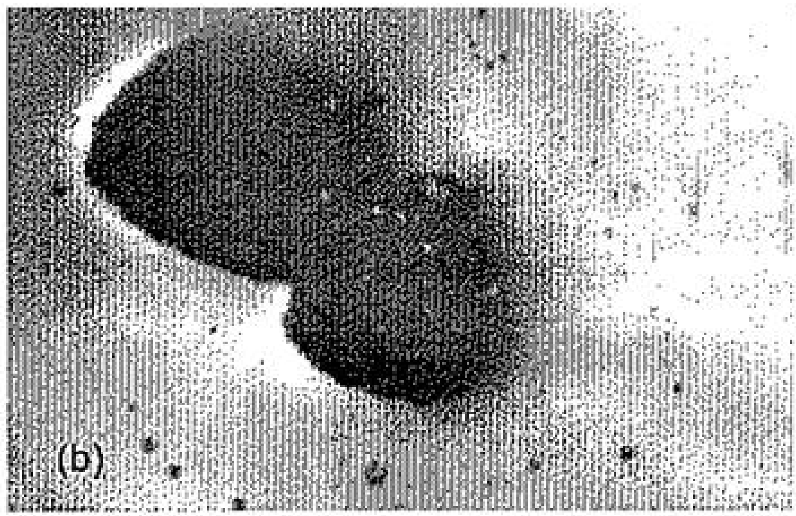
Intense Mixing Speeds Grain Dissolution

> 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

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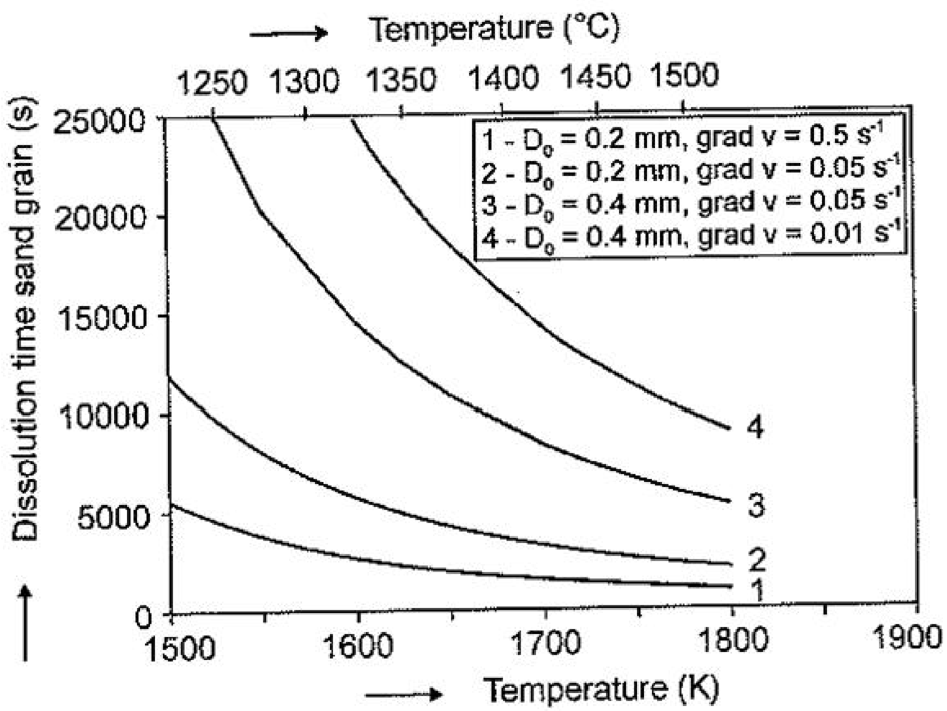
Matching Melter Conditions to the Batch



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

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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

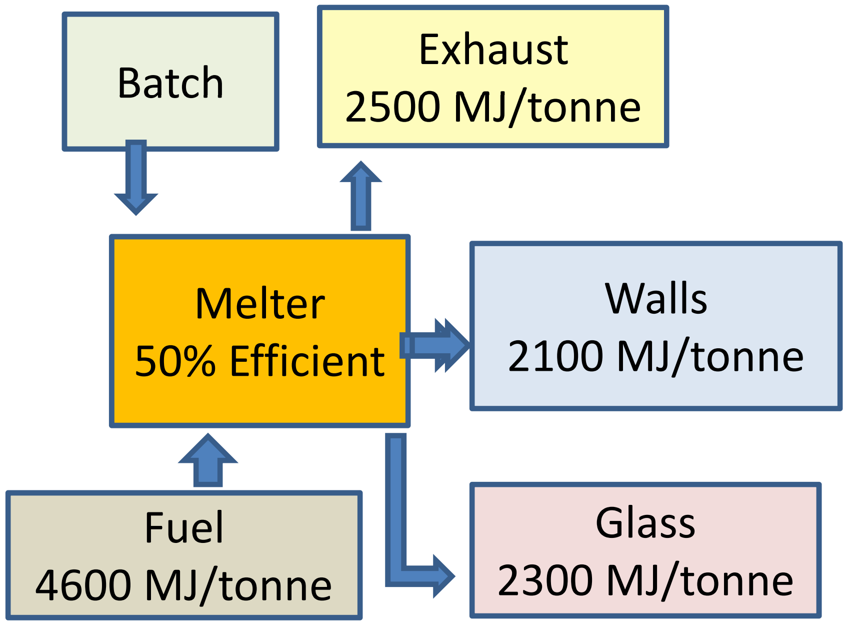
> Lower loss of volatile components
  - Less vaporization from the batch blanket
  - Some components can be introduced to a melter such that they can be more quickly incorporated into the melt

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 SiO_2 Preheating

- Assuming
  - 65% SiO_2 in batch
  - Only SiO_2 is preheated
  - SiO_2 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

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