Collage of Engineering

Materials Department

Third Class

Lecture (5-c)

GLASS

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Melting reactions

•**De-hydration** of some raw materials and **water evaporation**

•**Solid state reactions** between individual raw materials

•**Formation of primary melt phases** and melting of alkali rich carbonates. (typically in the temperature range: 700-900°C)

•**Dissociation** or **decomposition** reactions of Ca- and Mg- containing carbonates (e.g. limestone and dolomite), resulting in development of CO2-gas. (Temperature range 500-1000°C) (Na2CO3 will not decompose spontaneously, but reacts with sand or limestone).

•**Dissolving of the SiO2** in the alkali rich carbonate melt phases, typically above 1000°C. Sand reacts between about 750-1000°C with sodium silicates or soda to form liquid sodium silicates (associated with the release of CO2-gas when limestone or soda or dolomite is reacting with sand)

Dehydration

•Takes place at ± 100°C for physically bonded water

•In case of clay in the batch, de-hydration may occur up to 650-700°C

•Dehydration (water evaporation) is **very energy intensive**, and it is represents an important part of the total energy consumption

Sand dissolution

•**Pure silica melts at very high temperature (> 1700°C)**

•In standard glasses (except e.g. pure silica glass) sand is incorporated in the glass melt by dissolution, and not by melting

•**Sand dissolution is a critical step** in industrial melting process

•It is highly dependent on the **initial grain size distribution** of the sand grains in the batch, as well as the presence of aggressive molten phases (e.g. alkaline phases)

•Sand grains react with other batch components or dissolve in the obtained melt in most glass melting processes. The optimum grain size depends on the glass type.

Solid-state reactions in the batch

•Solid-state reactions can be divided into two routes: the carbonate route and the silicate route

•**The carbonate route** (path) is characterized by **reactive dissolution of silica sand** with a binary melt phase of soda ash and limestone below about 900°C. Soda ash and limestone, in contact with each other, may form a double carbonate by a solid state reaction forming the species Na2Ca(CO3)2

•At about 820°C, this intermediate reaction product starts to melt and becomes suddenly more reactive (better contact) towards silica sand grains.

•Silica reaction with $Na_2Ca(CO_3)_2$ forms a viscous $Na_2O·CaO·SiO_2$ melt plus CO_2 gas.

Solid-state reactions in the batch

•The **silica/silicate route** is based on **eutectic melting** of a mixture of components, including the sodium disilicate phase, formed by solid state reactions between sand and soda.

•The **eutectic melting** of SiO_2 and $Na_2O·2SiO_2$ takes place at 799°C and silicate rich melts are formed.

•The degree to which these reactions occur depends on the mutual contact between the components.

□Within a **compacted batch** (pellets, granules) the reactions will be more intensive than in a loose powder batch.

□**Finer powders** may give a better contact between the interacting raw material grains compared to coarse powders. Thus finer powdered batch is often more reactive and may give a better glass homogeneity

Limestone –sand solid-state reactions

The main part of the limestone or dolomite will **decompose** above the thermodynamic calcination temperature of limestone, this depends on the CO_2 partial pressure in the batch. Some limestone may react directly with silica:

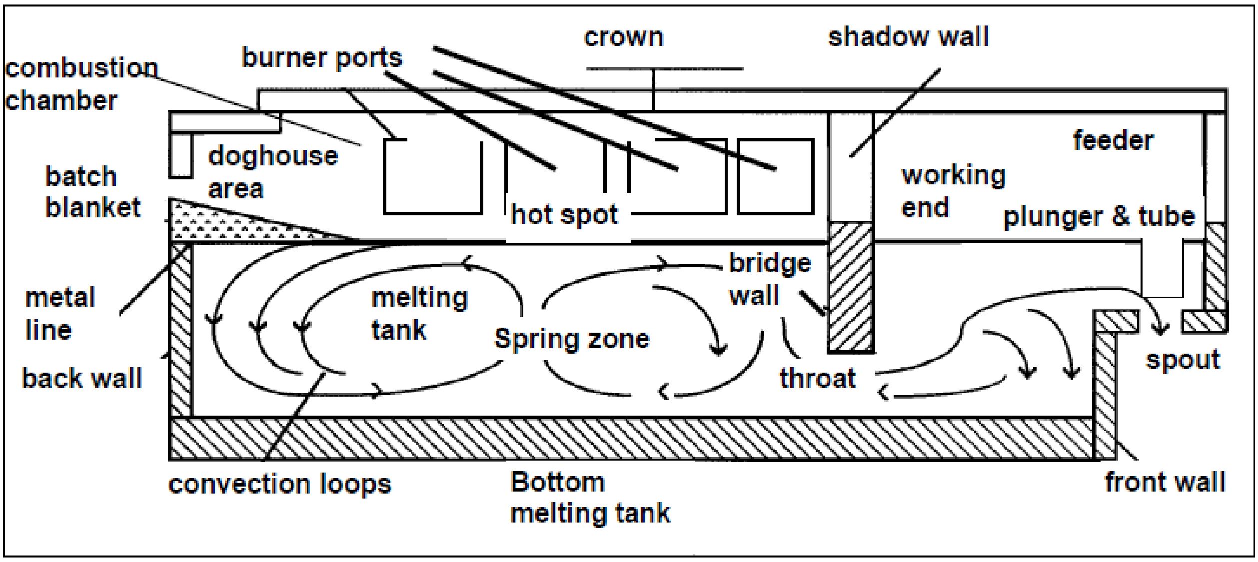
$2\ CaCO_3 + SiO_2$ □ $Ca_2SiO_4 + 2\ CO_2$ □ (600 - 900□C)

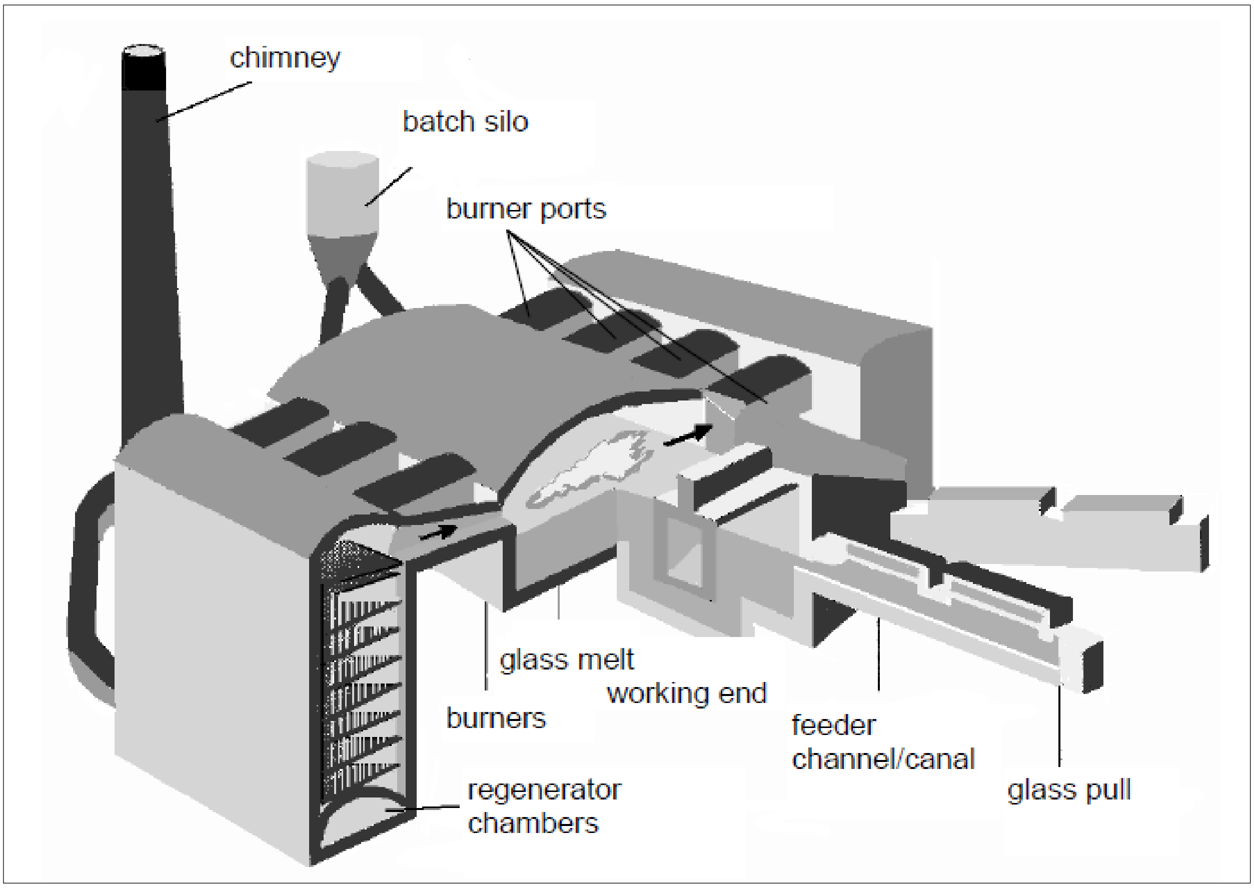
•These reactions occur only on the contacting interfaces and they are much slower than solid state/liquid reactions.

Reactive calcination: Na2CO3 + 2SiO2 □□Na2O·2SiO2 + CO2↑ T > 790oC □□forms with SiO2 an eutectic melt

•Or at further heating □□fast Na2O·SiO2 formation (850oC) plus limestone decomposes and: 2CaO + (SiO2 + Na2O·2SiO2)eutectic melt □□Na2O·2CaO·3SiO2 (> 900oC)

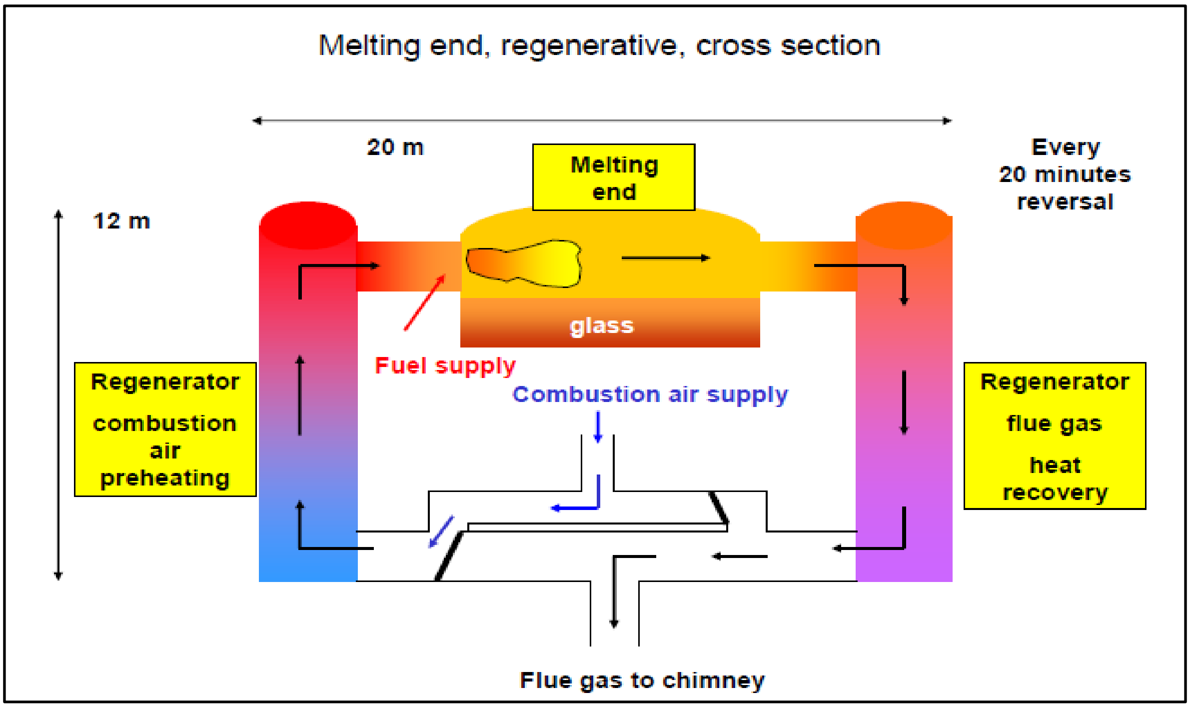
•**Silicate route**: Silicate melt + SiO2 □□silica enriched melt T > 1000-1100oC Eutectic melt phases are formed above ±800-840oC





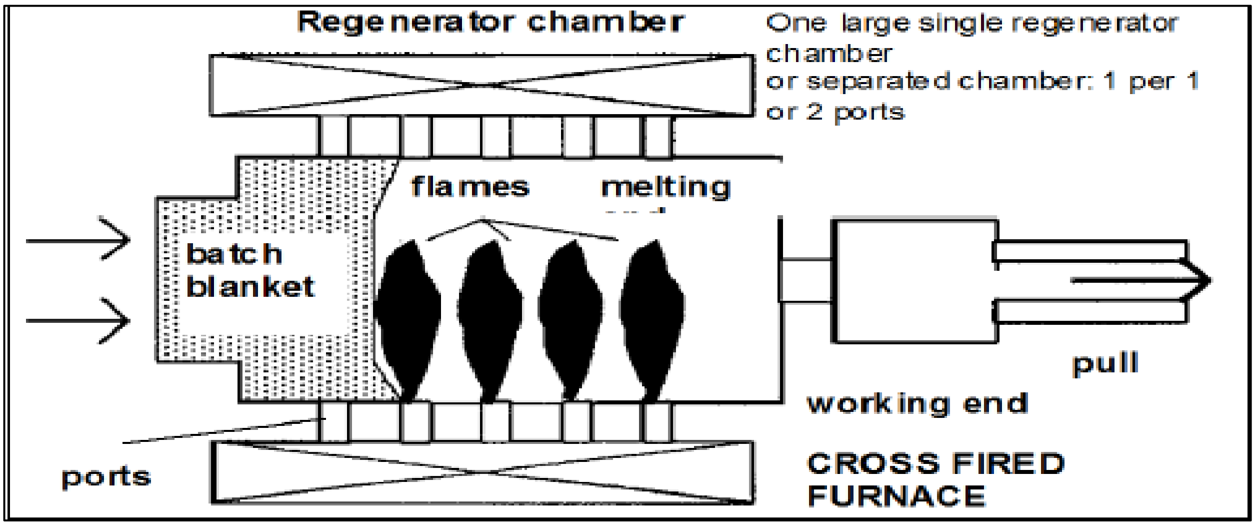
A regenerator consists of a **regenerator chamber** in which a **checkerwork** (or just **checkers**) of **refractory bricks** has been stacked. In one cycle the checker is heated up by flue gases, subsequently in the following stage (20-30 minutes) the heat is transferred to combustion air. These furnaces are provided with 2 or more (an even number) regenerators.

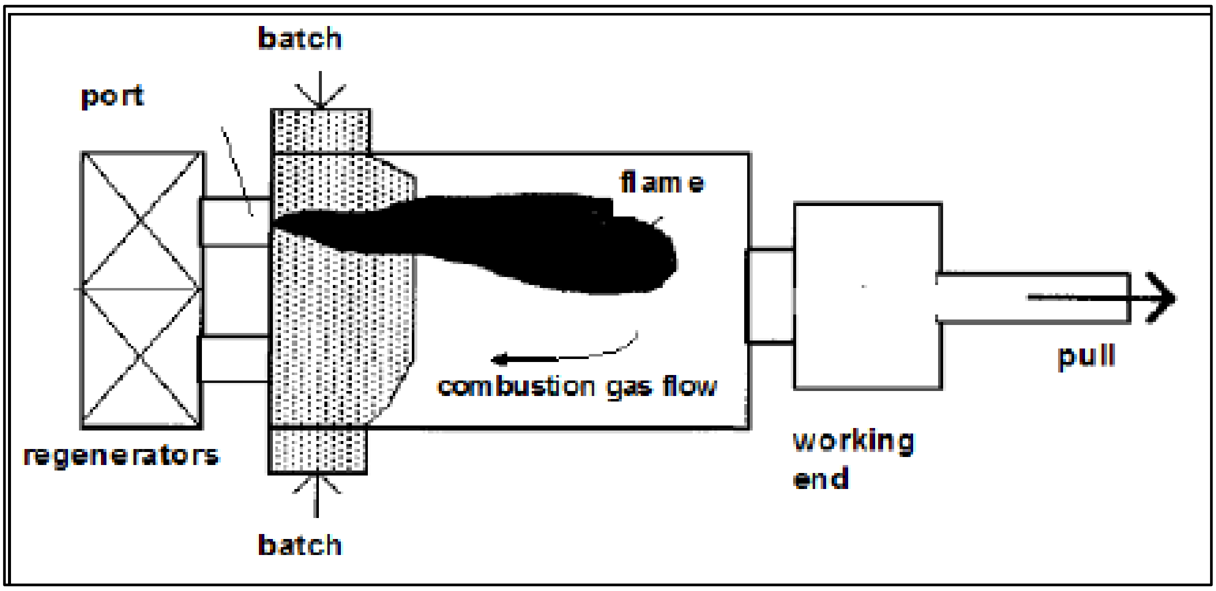
In principle the optimum **half-cycle time** depends on the pull of the melting tank (**thermal load**). During the **burner reversal**, lasting about 30 - 60 seconds, there are no flames within the furnace. The reversal period (no-firing interval) should be as short as possible to avoid too much cooling down of the furnace.



The regenerators are placed on the **side of the furnace.** The furnace can be equipped on both sides with **4 up to 8 burner ports (per side)** depending on furnace size.

The **profile of heating** (fuel distribution among the burners located along the sidewalls) determines location and size of the hot spot area (primary fining zone) in the glass melt.


Regenerator chamber
One large single regenerator chamber
or separated chamber: 1 per 1 or 2 ports
flames
melting
batch blanket
pull
working end
ports
CROSS FIRED FURNACE


batch
port
flame
pull
combustion gas flow
regenerators
working end
batch