International Commission on Glass Technical Committee 21 Round Robin Test 4 and Test 4a Specification

Technical Committee 21 (TC21) of the International Commission on Glass (ICG) provided round robin test 4 and 4a (RRT4 and RRT4a) specifications for modeling glass melting processes. The definition given here is from the April 25, 2004 committee meeting in Yalos, Athens. The main parts of the two ICG TC21 test specifications have been merged and are shown here:

Melt Specifications

- Kinematic viscosity;

ν_{Batch}= 0.4 m^2/sec for 30 ^{0}C< T<1000 ^{0}C
ν_{Batch} = f(T) , a linear function for 1000 ^{0}C< T<1200 ^{0}C
$\nu_{Batch}(1200\ ^0C) = \nu_{Glass}(1200\ ^0C)$ for T = 1200 ^{0}C
$\nu_{Batch} = \nu_{Glass}$ for T> 1200 ^{0}C and
Dynamic viscosity of glass $\log \eta = -1.58+4332/(T-248)$,
with T in ^{0}C and η in dPa.sec

- Density of glass $\rho_{Glass} = 2520.8 - 0.138T$ kg/m^3 T(K)
- Density; ρ_{Batch} = 1400 kg/m^3 300 K< T < 823 K and
  $\rho_{Batch} = -328.538+2.10029T$ 823 K< T < 1273 K
  $\rho_{Batch} = \rho_{Glass} = 2520.8 - 0.138T$ kg/m^3 for T > 1273 K

- Batch reactions take place between 550 ^{0}C< T<1000 ^{0}C
- Batch inlet T = 30 ^{0}C
- Batch exit T = 1200 ^{0}C
- Batch exit start temperature=1200 ^{0}C
- Batch existance temperature interval : 30 ^{0}C < T< 1400 ^{0}C
- Heat of reaction = 750 kJ/kg of glass
- Ambient T = 30 ^{0}C

- Emissivity of batch surface, ε_{Batch} = 0.9
- Emissivity of glass surface, ε_{Glass} = 0.9
- Emissivity of all walls, $\varepsilon_{Refractory}$ = 0.8

- Thermal conductivity of glass λ_g=30 W/m.K
- Thermal conductivity of batch $\lambda_b = \exp\{-3.01943 - (2569.15/(T - 1873.14))\}$;
  for 300 K< T <1473 K , where T is in K and λ_b is in W/(m.K).
- Thermal conductivity of batch $\lambda_b = \lambda_g$ = 30 W/m.K (same as glass) for T >1473 K

Other conditions

- Free grid
- Batch thickness: 10 cm at the start;
- Charging temperature of batch: 30^{o}C;
- Batch is assumed to be fed from the back of the furnace (full width) and in the horizontal direction.

- Evaporation of gases from the batch blanket will not be considered.

- Reference T = 1600 K
- Heat Capacity of glass C_P=1300 J/ kg.K
- Heat Capacity of batch
  C_p = 1000 J/kg.K at 30^{0}C and C_p = 1300 J/kg.K at 1200^{0}C and changes linearly for 30^{0}C <T<1200^{0}C and
  C_p = 1300 J/kg.K (same as glass) for T > 1200^{0}C.

- Expansion coefficient $\beta=6\times10^{-5}$ 1/K

- Basin walls are 30 cm thick. For exterior heat transfer coefficients, it has been concluded to use the previously determined value of 10 W/m^{2}K for convection and radiation for both the combustion space and for glass tank. Moreover, since the furnace is small, wall losses will be determined for 3-dimensional walls.

- The pull rates are;

Case a : 25 metric tons per day	Case b : 40 metric tons per day
Batch length 3.0 m	Batch length 4.2 m

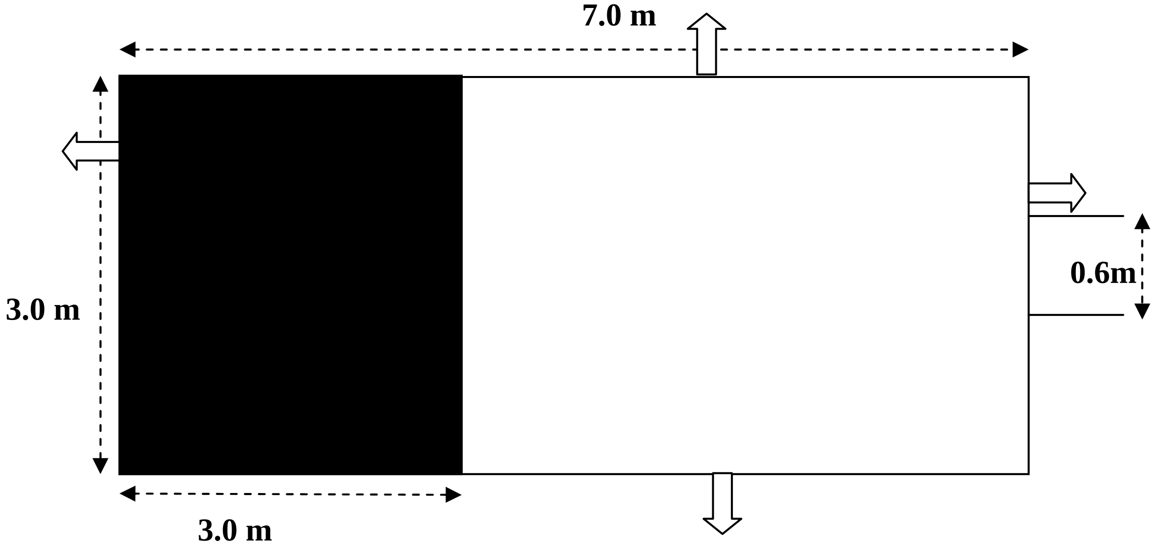
- The superstructure temperature profiles:
  Case a; x=0m: 1300 ^{0}C , x=3m: 1400 ^{0}C , x=4m: 1600 ^{0}C, x=7m: 1400 ^{0}C
  Case b; x=0m: 1300 ^{0}C , x=4.2m: 1400 ^{0}C , x=5m: 1600 ^{0}C, x=7m: 1400 ^{0}C

- In cases where the modeling approaches of members do not comply with the restrictions specified in this definition they could study the problem with their own combined batch models and explain how the conditions are different from the original definition.

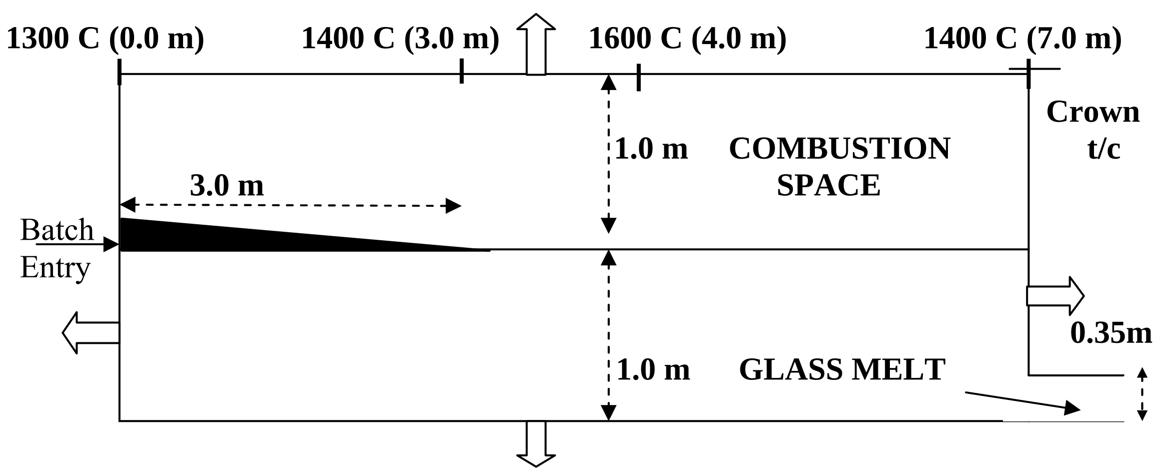
- Some of the items for the operational parameters might not be justified under the boundary conditions yet the principle is to use the same conditions as far as possible.

Furnace Geometry

Top View



Side View



Combustion Specifications

Furnace length : 7 m
Furnace width : 3 m
Crown height from glass surface: 1.5 m

Natural gas calorific value: 5.0×10^7 J/kg
Natural gas is assumed to be 100% CH_4 and enters furnace at 373K

Total gas consumption: 0.039762 kg/sec for 40t/d
0.029858 kg/sec for 25t/d

Combustion air input temperature: 1473 K

Combustion air input : 0.71750 kg/sec for 40t/d
0.53812 kg/sec for 25t/d

Excess air: 5 %

Ambient T: 303 K

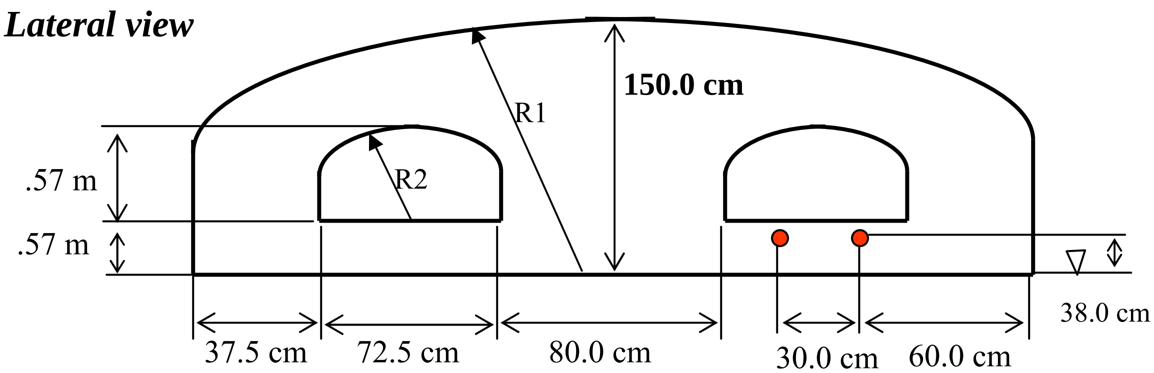
Side wall refractories wall thickness 30 cm.
Crown refractories wall thickness 30 cm .
Emissivity of refractories: 0.8
Emissivity of batch blanket: 0.9

Firing reversal ratio is to be taken into account with symmetrical averages.

Buoyancy effect will not be considered. But the case might be studied with the buoyancy effect additionally.

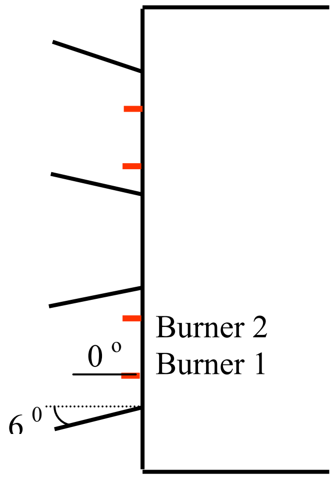
Combustion Space and Port Geometry

Lateral view

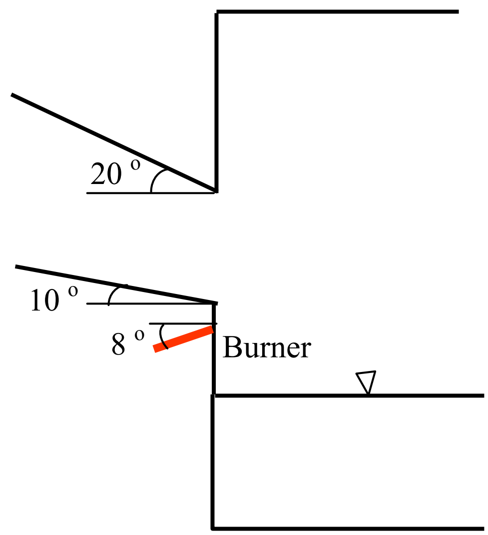


R1, radius for crown; 435 cm
R2, radius for port crown; 100 cm

Top view for ports and burners



Side view for ports and burners



Number of burners per port: 2
Burner with a vertical angle of 8 ^{0} and a horizontal angle of 0 ^{0}.

-Burner 2x2 cm with 71 m/sec gas velocity at burner tip at 25 t/d(which is close to the 80 m/sec recommended during the meeting) and
Burner 2.2x2.2 cm with 78 m/sec gas velocity at burner tip at 40t/d.

Boundary Conditions

- Temperature on inside of crown is specified in above pictures. Radiation models will be used to calculate heat transfer from crown to batch and glass surface.
- No temperature gradients to the sides.
- At the beginning of the furnace, 0.0 m, the temperature is 1300 C. Then temperature increases with a linear gradient up to 1400 C at 3.0 meter. After that the temperature increases further with a linear gradient to 1600 C at location of 4.0 m.
- In the last 3.0 m, the temperature decreases with a linear gradient down to 1400 C at the end of the furnace, 7.0 m.
- Parabolic output flow in throat exit
- Participants can use own batch models, use heat sink with value of 750 kJ/kg required melting energy for raw materials and heat dissociation of gases (no cullet).

Results and output

- Minimum residence time at throat entrance
- Mean temperature at throat entrance
- Location of mechanical spring
- Values of velocity vectors in center plane at x= 2.0 meter and x= 4.0 meter
  and at depths of 0.2 m and 0.7 m.
- Velocity and temperature plots of central longitudinal plane
- Velocity and temperature profile plots along the depth at x= 2.0 meter
  and x= 4.0 meter
- Temperature profile along the center line of the glass surface and bottom
  along the length of furnace (about 0.05 m above bottom and
  below glass surface if necessary)
- Total wall losses in W
- Heat balance will be shown
- Final position of the batch will be indicated.

- Temperature values of crown along the length of the furnace at the centerline;
  at x = 0,1, 2,3,4 and 7 m.
- Side and top view for velocity and temperature contours of combustion space at a
  cross section through the burners.
- Heat flux values for batch-glass and batch-combustion space interfaces.