SHEET 1

BATCH CALCULATIONS

1. Clay bricks are manufactured from 90% sandy clay having the composition shown below and 10% sand. Firing is carried out at 800ºC and XRD analysis has revealed that the only crystalline phase present is quartz. If the bulk density of a brick = 1.67 $g.cm^{-3}$ and its fired dimensions are 60×120×250 mm^3, find the daily masses of clay and sand required to produce 100,000 bricks per day. Estimate the chemical composition of the fired bricks.

- **XRF analysis of clay:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	Na_2O	LOI
% by weight	59.71	15.95	6.71	5.41	1.11	1.94	9.17

- **XRF analysis of sand:**

Oxide	SiO_2	Fe_2O_3	LOI
% by weight	94.65	5.15	0.20

2. Electrical porcelain is manufactured using a recipe composed of 30% kaolin, 10% ball clay, 35% feldspar and 25% quartz. The XRF results for the different components were obtained as follows:

- **Kaolin:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	Na_2O	LOI
% by weight	42.95	37.08	5.34	3.24	1.16	0.35	9.88

- **Ball clay:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	Na_2O	LOI
% by weight	63.47	16.25	6.88	1.88	0.97	1.07	9.48

- **Feldspar:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	Na_2O	LOI
% by weight	75.1	14.01	0.71	0.07	4.5	5.15	0.46

- **Quartz**

Oxide	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	LOI
% by weight	98.9	0.75	0.29	0.05	0.014

Determine the final oxide analysis of the fired product.

3. A glaze for use in sanitary ware production has the following composition:

Component	Feldspar	Limestone	Kaolin	Sand
% by Weight	25	11	19	45
Sp. gravity	2.60	2.28	2.38	2.65

Evaluate the masses of each ingredient necessary to suspend the powder in water to obtain 1 m^3 of a slip of liter weight of 1.65 ($kg.L^{-1}$).

4. The following recipe is used in the production of ceramic wall tiles: 45% kaolin, 10% ball clay, 25% feldspar, 9% limestone and 11% quartz. The chemical analysis is shown below:

- **Kaolin:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	Na_2O	LOI
% by weight	46.3	33.8	3.1	2.4	2.1	1.6	10.7

- **Ball clay:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	Na_2O	LOI
% by weight	62.2	17.7	5.9	3.5	0.7	0.5	9.5

- **Feldspar:**

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	Na_2O	LOI
% by weight	73.8	14.4	0.9	0.1	6.2	4.4	0.2

- **Limestone:**

Oxide	CaO	MgO	SiO_2	LOI
% by weight	54.5	1.2	0.3	44.0

- **Quartz**

Oxide	SiO_2	Fe_2O_3	Al_2O_3	Na_2O
% by weight	99.0	0.6	0.3	0.1

The plant daily capacity is 80000 tile per day of dimensions 300×300 mm^2 with a thickness of 8 mm and a bulk density of 1.94 $g.cm^{-3}$. Evaluate the chemical composition of the product batch and the daily demand of each raw material.

SHEET 2

BODY FORMATION

1. A casting slip is defocculated by a solution of sodium polyphosphate. The slip viscosity (cP) was found to vary with the percent deflocculant added (p) according to the expression:

   $\mu = 80pe^{-0.88p}$

   Determine the minimum viscosity of the slip and the corresponding percent deflocculant to be added.

2. Wall tiles are produced by dust pressing granulated powder containing 7% humidity in rectangular dies. The drying and firing operations involve a total shrinkage in tiles volume of 0.8% (Based on their final dimensions after firing). The manufacturing line produces 12000 m^2 of tiles per day of thickness 6 mm evaluate the daily consumption of granulated powder fed to the press. (Bulk density of dry powder = 1970 $kg.m^{-3}$).

3. The powder in the previous example is fed into a cavity 30 mm deep. A pressure of 35 MPa is then applied to press the tiles to a thickness of 6.02 mm. Due to a leak in oil from a defective gasket, the pressure dropped to 25 MPa. Determine the thickness of the produced tiles in that case.

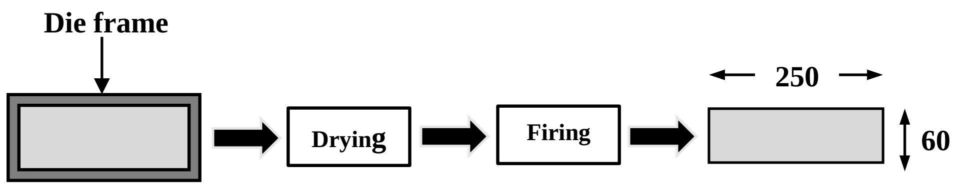
4. The slip used for floor tiles manufacture consists of a suspension of 25 weight% solids (Density = 2450 $kg.m^{-3}$) in water. It is fed to the dryer at the rate of 24000 $kg.h^{-1}$. The resulting granules contain 6% humidity and water vapor leaves as saturated steam at 1.15 bar. Determine the volumetric hourly flow rate of steam leaving the dryer.

5. Silicon carbide is precipitated by chemical vapor deposition from trichlorosilane gas on the two sides of metallic wafers to increase their surface hardness. The processing chamber contains 20 wafer of dimensions 120×40 mm^2 and the deposited coating is to be 30 μm thick. The process takes place at 1000^{o}C under hydrogen atmosphere at 0.3 atm. Estimate the volume of trichlorosilane gas required. (Density of SiC = 3.2 $g.cm^{-3}$)

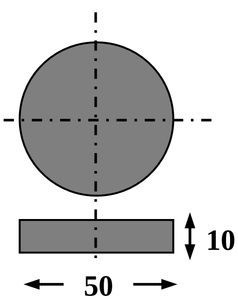
SHEET 3

DRYING AND FIRING

1. Face bricks are formed by stiff mud extrusion using in a vacuum auger machine. Laboratory results have shown that the brick material exhibits 7.8 and 2.1% drying and firing shrinkage respectively. Find the dimensions of the original extrusion die if the dimensions of the produced fired bricks are $250 \times 120 \times 60$ mm^3. (See Figure)



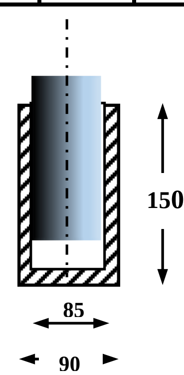
2. Alumina cylindrical disks are formed by dust pressing, drying and finally firing to 1200°C to produce the disks shown in figure (Dimensions in mm). They are formed by mixing alumina with 6% water (On dry basis). After drying, the moisture content decreased to 1.1%. The linear drying shrinkage = 1.3%. Estimate the amount of layer and pore water. If the firing shrinkage = 1.2%, evaluate the required die diameter. The bulk density of fired disks = 2.7 g.cm^{-3}.



3. A mud specimen is formed in cubical shape by mixing 700 g of ceramic mix with 115 g water. The wet cube edge is 100 mm in length. The specimen was dried at 90°C and the mass of the cube followed with time. Estimate the critical moisture content of the mix and the constant rate of drying based on initial surface area (g.cm^{-2}.h^{-1}). Also determine the percent of layer and pore water (On dry basis).

t min	0	10	20	30	40	50	60	70	80	90	100	110	120	130
m g.	815	801.9	789.5	775.9	761.5	749.1	735	722.6	715.7	711.9	709	706.5	705	704.9

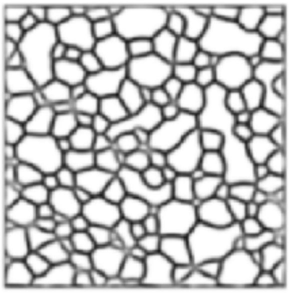
4. Mugs in form of hollow cylinders are shaped using jiggering, dried at 90°C and fired at 1250°C. The produced mugs have the dimensions shown in figure. Estimate the necessary diameter of the cylindrical jollying head if the drying and firing shrinkages are 5.8% and 2.3% respectively.



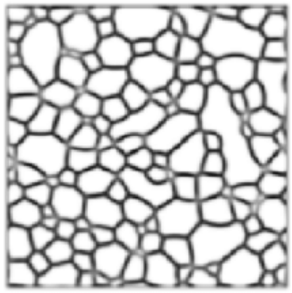
5. Porcelain balls used in grinding mills are fabricated by joining two hemispheres formed by slip casting. The original molds have an inside diameter of 53.2 mm. The formed balls are left to dry on shelves at 60°C for 24 hours followed by drying at 120°C for one hour. When a ball is placed after drying in a beaker of 100 mm inside diameter and filled to a height of

200 mm with water, the volume of water increased to 1642.1 mL. After firing, on repeating the test, the volume of water increased to 1636.3 mL. Evaluate the percent linear drying and firing shrinkage of ball material.

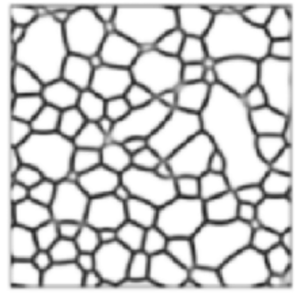
6. The following figures were obtained on following up the grain growth of magnesium oxide powder at 1400^{o}C. The slides are 1000 μm in side.



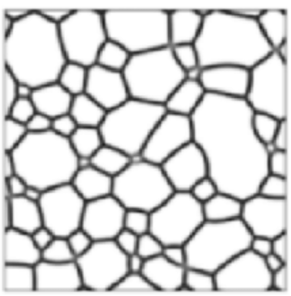
2 min



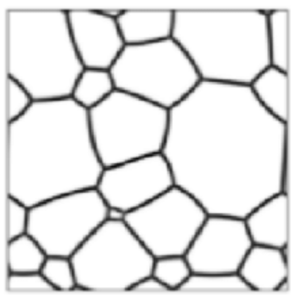
8 min



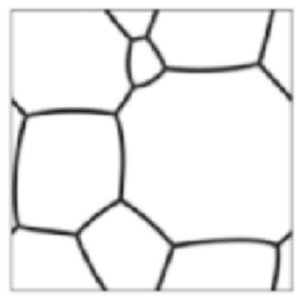
20 min



50 min



250 min



800 min

Perform a linearized for the dependence of grain size on time and deduce the initial grain size.

SHEET 4

THE CEMENT INDUSTRY

1. A cement kiln produces 5500 kg clinker per day. Raw meal proportions are shown below. The chemical analyses of its components are also shown. What should be the daily consumption of each raw material? (Assume 5% dust losses)

Raw meal composition:

Mineral	limestone	Clay	Sand	Fe oxide
% by weight	79.6	15.8	3.1	1.5

Chemical analysis of raw meal components:

Weight %	**Limestone**	**Clay**	**sand**	**Fe oxides**
CaO	53.8	3.7	---	---
SiO_2	1.20	57.84	96.8	2.56
Al_2O_3	---	16.08	---	---
MgO	1.82	0.66	---	---
$Na_2O + K_2O$	---	5.28	---	---
Fe_2O_3	0.57	5.97	3.2	93.48
LOI	42.61	9.47	---	3.96

2. Cooled clinker leaves a grate cooler at 180^{o}C (Due to a malfunction in one of the air driving fans) at the rate of 200 ton.h^{-1}. Gypsum (at ambient temperature) is added to clinker before tube milling as 5% of clinker load. What would be the final temperature of the mix assuming 10% heat losses?
   Do you consider this temperature reasonable? Why?
   In case it is too high, what rate of cooling water at 15^{o}C should be used to keep the temperature of the mix in the mills at a suitable level still assuming 30% heat losses?
   Average specific heat of clinker = 0.82 kJ.kg^{-1}.$^oC^{-1}$
   Average specific heat of gypsum = 0.84 kJ.kg^{-1}.$^oC^{-1}$
   Average specific heat of water = 4.18 kJ.kg^{-1}.$^oC^{-1}$
   Assume water will heat up to 35^{o}C

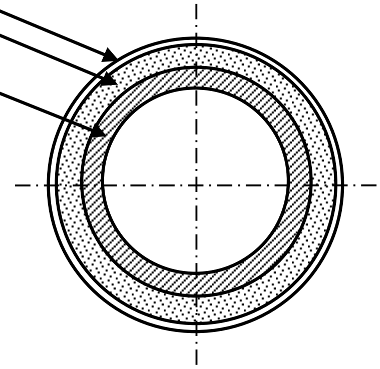
3. A rotary kiln 80 m. long has an internal diameter of 7 m and is fed with 240 tpd meal. The following figure shows the lining layers of the kiln. Estimate the power required to run the kiln at 1 rpm if the total mass of kiln + accessories amounts to 130% of the empty kiln mass. Assume that at any time the kiln is filled with 15% of its volume of solids of average bulk density = 1500 kg.m^{-3}.
   Specific gravity of sheet steel: 7.8
   The vertical distance between kiln top and bottom = 6.5 m
   Bulk density of insulating bricks = 1000 kg/m^3

Bulk density of refractory bricks = 2600 kg/m^3

Empirical formula for horsepower prediction:

$$hp = N \times 10^{-5}.(4.75\, d.w + 0.1925 D.W + 0.33W)$$

Where, N = rpm
D = Outer kiln diameter (ft)
d = Inside diameter (ft)
w = Mass of charge (lb)
W = Mass of empty kiln (lb)



4. Flue gases emerge from the rotary kiln at 1000^oC at a rate of 350000 Nm^3/h and are admitted to suspended preheaters where raw mix flows at 30^oC and at a rate of 120 ton/h. If the raw mix inlets the furnace at 850^oC with a mass ratio of limestone to clay = 5:1, at what temperature would the gases exit the preheater section? Consider the heat transfer efficiency in cyclones = 85% and 75% calcination of clay and limestone to occur.

Average specific heat of flue gases = 1.22 kJ.kg^{-1}.$^oC^{-1}$
Average specific heat of solids = 0.84 kJ.kg^{-1}.$^oC^{-1}$
M.W. of gases = 30
Enthalpy of calcination of limestone = 1780 kJ.kg^{-1} and for clay 870 kJ.kg^{-1}

5. The following data are taken from the fuel log of a cement factory:

- Amount of clinker produced per year = 1,420,000 ton
- Amount of fuels used and their calorific values:

Fuel	Charcoal	Petcoke	N.G.	Biomass	RDF
Cal. Value kJ.kg^{-1}	26100	30660	48000	14800	20000
Mass ton	20,830	149700	126	5630	5450

Estimate the average specific heat consumption of the kiln in kJ per kg clinker.