Introduction

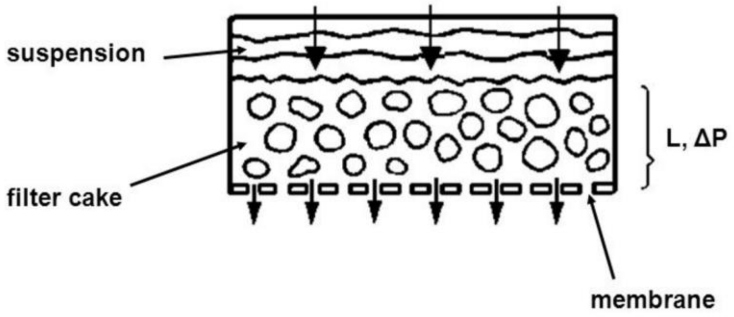
Filtration and Cake Filters

Filtration is widely used to separate solids from liquid suspensions (“Slurries”)

- Suspended solids are retained by porous filters and cleared liquid continues to flow
- Cleared liquid still flows due to a pressure difference through the filter medium
- The filter pore size smaller than the particle size, preventing solids from passing

The cake filter is typically used in liquid-solid separations

- Cakes form from the retention of solid particles on the upstream side of the filter



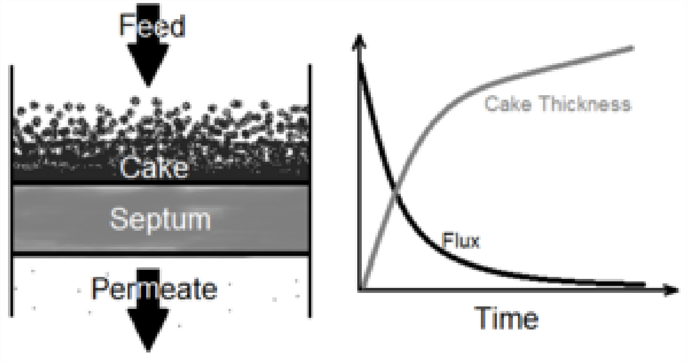
Constant-Pressure Mode of Operation

Constant-pressure mode of operation was investigated for this experiment

- Feed pressure was kept constant as the filter cake built up and the flow of filtrate through the filter decreased

Cake resistance increases with cake thickness over time

- Resistance provided by the filter is only important early in the filtration process



Specific Cake Resistance and Cake Compressibility

The compressibility of filter cakes depends on the bed solids.

- For incompressible cakes, cake resistance depends on the filtration pressure

The specific cake resistance of incompressible cakes is:

$$\alpha = \frac{Ag_c(\Delta p_c)}{\mu u m_c}$$

Where:

Δp_c = Pressure drop across the cake
A = Area of the filter (m^2 or ft^2)
m_c = Total mass of solids in the cake (kg or lb)
u = The linear velocity of the filtrate based on filter area
μ = The dynamic viscosity of the filtrate
g_c = Newton's law proportionality factor $\left(32.174\ \frac{ft-lb}{lb_f-s^2}\right)$

If the cake is truly incompressible, the plot of the specific cake resistance:

$$\alpha = \alpha_0(\Delta p)^s$$

should yield a value of s = 0, where s is the compressibility constant

The compressibility constant is typically found to be between 0.2 and 0.8

Constant Pressure Filtration Equation

The constant pressure filtration equation is

$$\frac{t}{V} = \frac{\mu c \alpha}{2A^2 g_c(\Delta p)} V + \frac{\mu R_m}{A g_c(\Delta p)}$$

where:

- t = Time (s)
- V = Volume of filtrate (ft^3)
- μ = Mass of particles deposited in the filter per unit volume of filtrate $\left(\frac{lb}{ft^3}\right)$
- α = Specific cake resistance $\left(\frac{ft}{lb}\right)$
- A = Area of the filter (ft^2)
- Δp = Pressure drop across bed of solids $\left(\frac{lb}{ft^2}\right)$
- g_c = Newton's law proportionality factor $\left(32.174 \frac{ft-lb}{lb_f-s^2}\right)$
- R_m = Filter medium resistance

$$\frac{t}{V} = \frac{K_c}{2} V + \frac{1}{q_0}$$

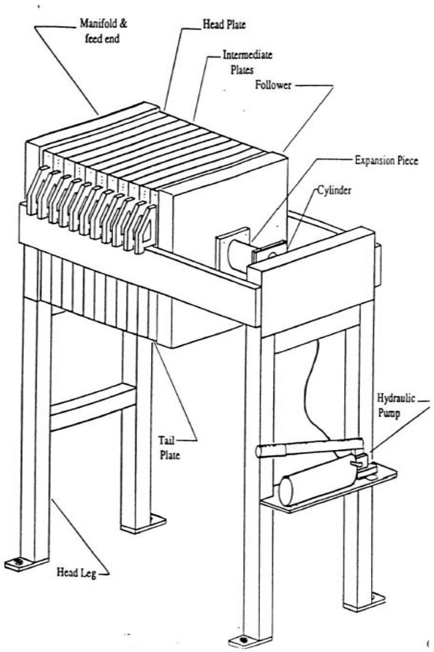
Where:

$$K_c = \frac{\mu c \alpha}{A^2 g_c(\Delta p)}$$

$$\frac{1}{q_0} = \frac{\mu R_m}{A g_c(\Delta p)}$$

Experimental Set-Up

Apparatus



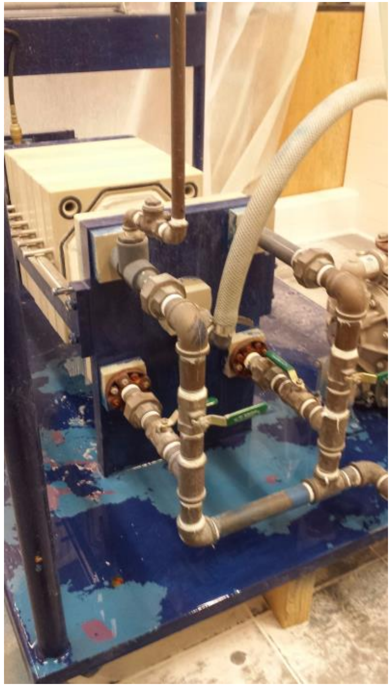
Two tanks fitted with mixers were used in this experiment

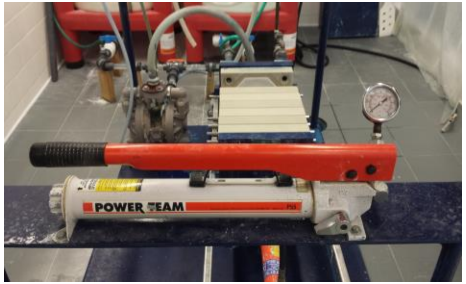
1. A feed tank filled with a slurry of water & 10% marble dust by weight
2. A filtrate collection tank

The feed and filtrate collection tank were swapped after each trial. The feed tanks were connected to the Lanco plate and frame filter press

The 7 filter plates of the Lanco plate and frame filter press were assembled in an alternating sequence based on the number of dots (1 or 3) on each tray's side and aligned

Procedure





The selector switch on the hydraulic ram at the end of the filter was closed, and the hydraulic ram was pumped until a pressure of 4,000 psi was reached on the pressure gauge on the ram

The bottom two manifold valves were closed while the top two manifold valves were kept open.

The feed tank discharge valve was opened to the filter feed pump, and the three way valve was set to direct the feed from the feed tank to the pump.

Procedure

The air supply to the pneumatic filter feed pump was opened and pressure was set to 25 psi using the pressure controller

After 2 min, the bottom manifold valves were opened, and the feed pressure was adjusted for each trial: 37 psi, 45 psi, 50 psi, 75 psi, and 100 psi

The fluid height within each tank was recorded before and after each run. The amount of time it took for the liquid level to increase each 5 cm interval within the filtrate collection tank was recorded until the flow through the filter had almost stopped due to resistance.

Procedure

At this point, the feed pump was turned off, the inlet valve to the filter was closed, and the discharge valve on the feed tank was closed. The top two manifold valves were closed, along with the manifold valve farthest away from the filter feed pump

Air supply to the filter was slowly opened to remove any liquid that remained in the filter assembly. The air supply was kept open for 5 minutes and the filter outlet hose was held in the filtrate collection tank

The blue filter cake collection tray was weighed, and then placed under the filter assembly after each trial.

Procedure

The hydraulic ram selector switch was released. Wet filter cake was removed from the filter plates with the plastic spatulas provided. The collected filter cake was weighed.

A sample of the wet cake was taken for each trial and weighed within a preweighed dish. These samples were then kept in an oven for a week and reweighed. The remaining wet filter cake within the blue collection tray was emptied into the filtrate collection tank.

The filter plates were then rinsed with fresh water and the experiment was repeated, with the filtrate collection tank becoming the feed tank and the feed tank becoming the new filtrate collection tank.

Results & Discussion

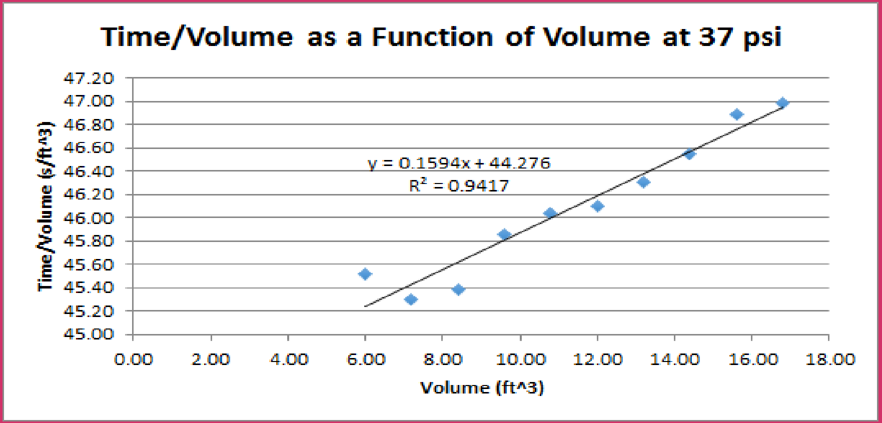
Results: Data

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Pressure (psi)	37	50	45	50	75	100
Tray Weight (lbs)	16.5	16.5	16.5	16.5	16.5	16.5
Cake + Tray Weight (lbs)	23.75	19	33	18	25	21
Cake Weight (lbs)	7.25	2.5	16.5	1.5	8.5	4.5
Dry Cake Weight (lbs)	5.49	1.89	12.03	1.18	6.43	3.44

Results: Data

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Pressure (psi)	37	50	45	50	75	100
Wet Sample Weight (g)	197.3	164.8	164.4	59.5	68.5	56.9
Dry Sample Weight (g)	149.4	124.3	119.9	46.7	51.8	43.5
Wet and Dry Sample Weight Difference (g)	47.9	40.5	44.5	12.8	16.7	13.4
Percent of Weight that is Water	24%	25%	27%	22%	24%	24%

Results

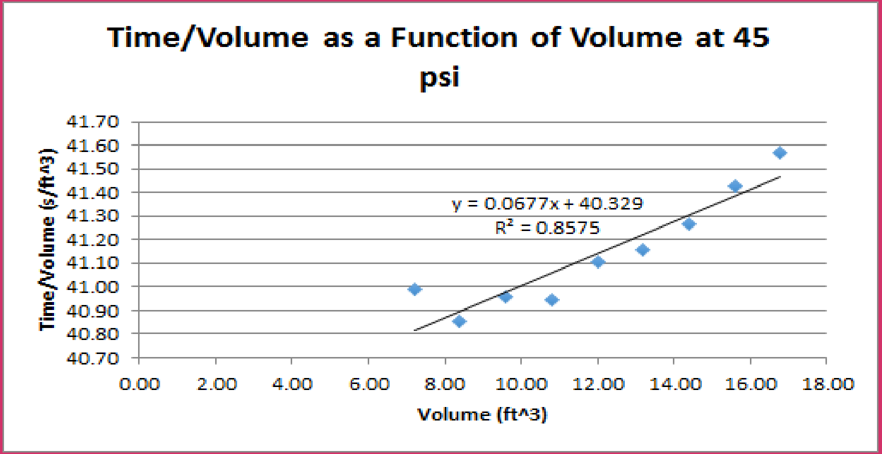


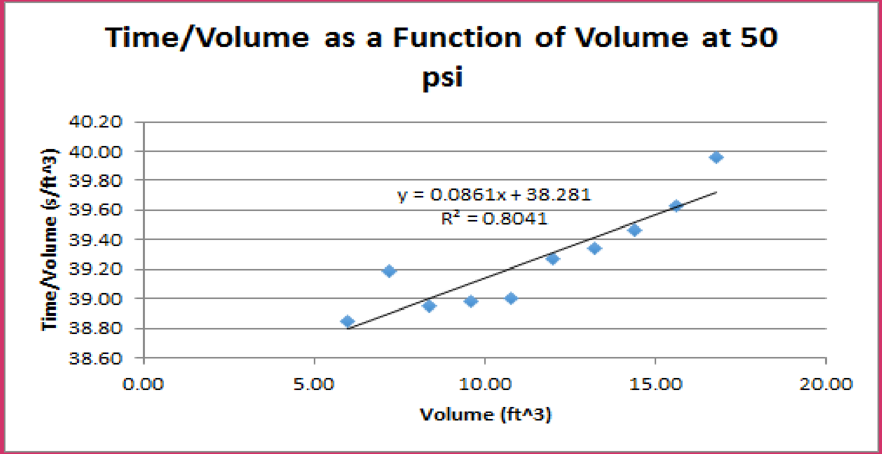
$$\frac{t}{V} = \frac{K_c}{2} V + \frac{1}{q_0}$$

Where:

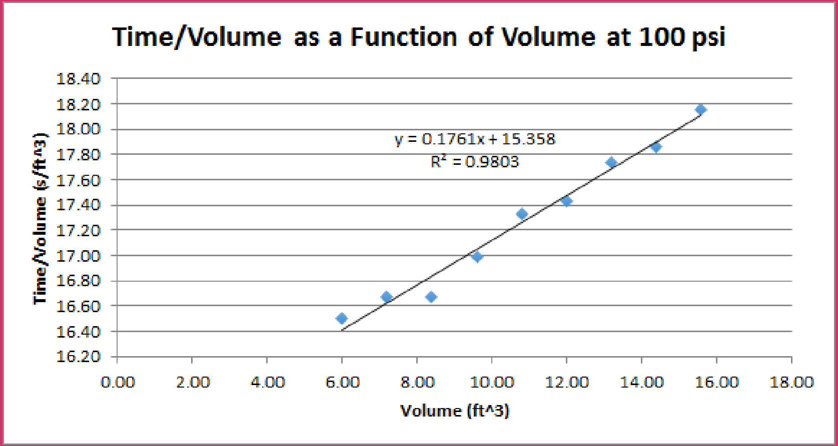
$$K_c = \frac{\mu c \alpha}{A^2 g_c (\Delta p)}$$

$$\frac{1}{q_0} = \frac{\mu R_m}{A g_c (\Delta p)}$$





Results



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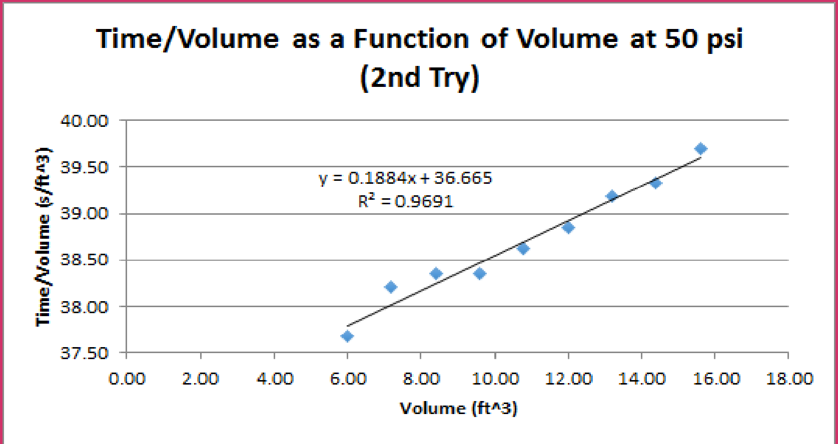
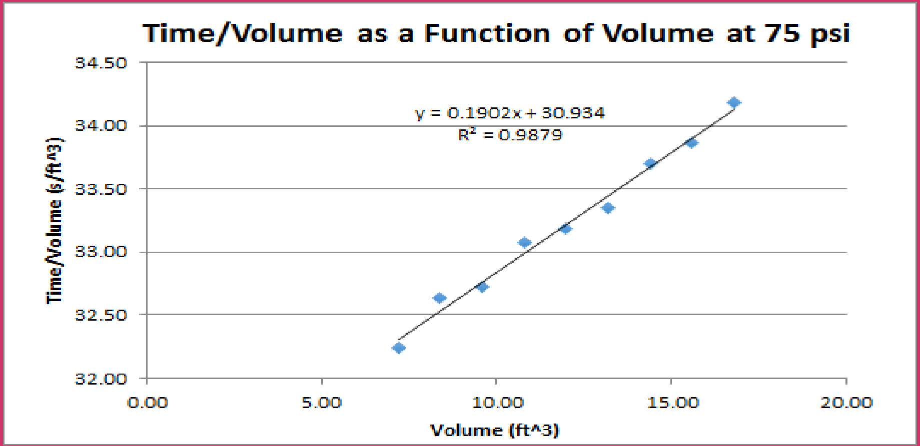




Results

Pressure (psi)	Cake Resistance (ft^{-1})	Filter Resistance (ft/lb_m)
37	7.5×10^7	6.3×10^9
45	1.8×10^7	6.9×10^9
50	1.6×10^8	7.3×10^9
50 (2nd Attempt)	5.2×10^8	7.0×10^9
75	1.5×10^8	8.9×10^9
100	3.3×10^8	5.9×10^9

Discussion

As the pressure increased, the cake resistance was expected to increase as well.

- Due to the buildup of cake on the filter, hindering flow.

The data observed showed a trend that as the pressure increased, the cake resistance tended to rise as well.

Resistance by the filter generally increased as pressure rose

- Filter resistance is only significant in the early stages of the filtration process, but since calculated filter resistances were greater than that of the cake, the process might have to be run longer next time.

Discussion

$$\alpha = \alpha_0(\Delta p)^s$$

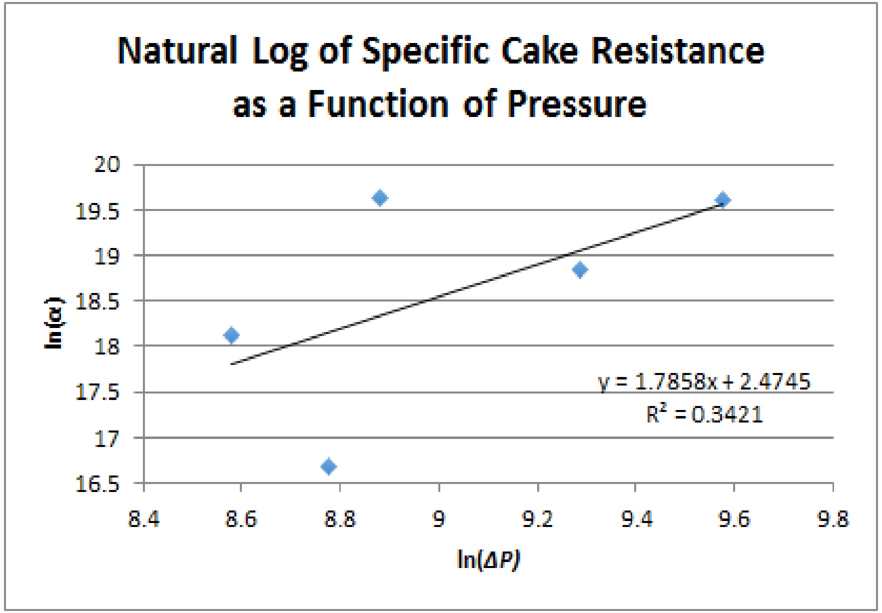
Taking the natural log of the calculated cake resistances resulted in two data points that deviated from the line of best fit; at pressures of 45 and 50 psi.

Checking for outliers resulted in a Q1, Q3 and IQR of 17, 20 and 2.2, respectively.

- The bounds for the data (where it is not characterized as an outlier) were 14 and 23.
- No outliers detected

Compressibility constant = slope of best-fit line = 1.8

Compressibility constant should be 0, with acceptable results from 0.2 to 0.8.



Discrepancy in Experimentally Determined Compressibility Constant May Be Attributed To

The hydraulic ram pressure did not stay constant at 4,000 psi, so some of the filter cake may have been lost during the filtration process.

The pressure of the pump was fluctuating, resulting in inaccurate pressure drop recordings

Some of the cake and water was lost after blowdown, when the pressure from the hydraulic ram was released

Conclusions and Recommendations

For this filtration system, as the pressure of the pump increased, the cake resistance was observed to generally increase as well.

The data utilized in the graph of the natural log of the cake resistance as a function of pressure was spread out, resulting in a high compressibility constant when compared to theoretical and accepted experimental values.

- Errors can be attributed to the inconsistency of the hydraulic ram pressure
  - Implement a more reliable locking mechanism
- Fluctuations in the pump pressure
  - Have the ability to digitally set the desired pump pressure
- Loss of cake and water after blowdown.

Longer filtration runs could be performed process next time

References

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