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Triboelectrification in Gas-Solid Fluidized Beds

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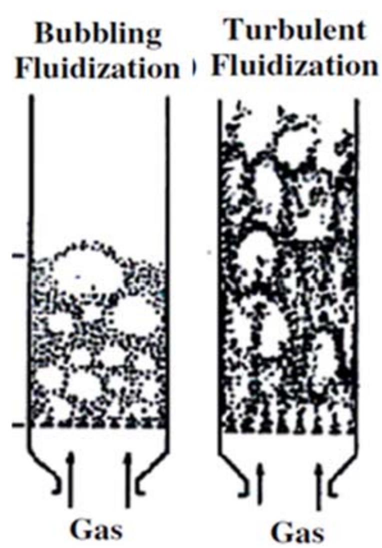
Electrostatics in Gas-Solid Fluidized Beds

Continuous movement of particles in a gas-solid fluidized bed creates a favourable environment for electrostatic charge generation

- Triboelectrification due to
  - *Particle-Wall* contacts
  - *Particle-Particle* contacts
- Extent of electrostatic charging in such systems would depend on various parameters including
  - **Materials** involved:
    - Column wall material
      - Academic studies (Plexiglas)
      - Industrial reactors (metallic)
    - Particles surface chemistry
  - Fluidized bed **hydrodynamics** *(affect the degree of particles mixing and thus the degree of contacts)*
    - Fluidizing gas velocity
    - Particles size
    - Operating pressure and temperature



Electrostatics in Industrial Polyethylene Reactors

- A layer of particles (PE and catalyst) adhere to wall and dome of the reactor due to electrostatic charge. The wall layer melts due to the exothermic polymerization, forming polymer **sheets** along the reactor wall which break off and block the distributor plate and product discharge.

- Economic Loss:

Globally **100 polyethylene** reactors	Total production of 200 million metric tonnes per year
Reactor downtime	2 to 3 days (up to 30 days)
Estimated economic loss	***$1-1.5 million/day***

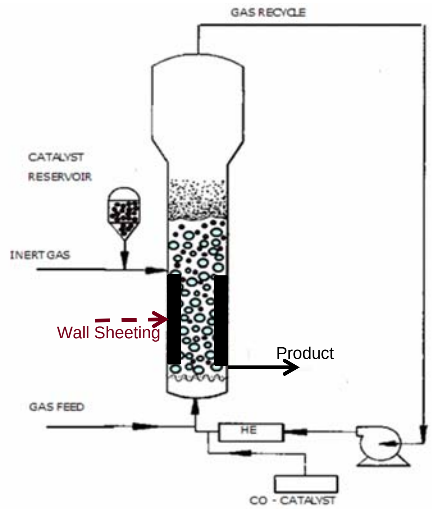


Figure: UNIPOL™ technology – Gas phase ethylene polymerization to produce polyethylene.

Research Goal at uOttawa

Gain a better understanding of the mechanisms of gas-solid fluidized bed electrification as well as mechanisms of **<u>reactor fouling</u>** due to electrostatics. The ultimate goal is to assist industries affected by this phenomenon.

Understand the electrostatic phenomenon including the dominating charging mechanisms inside a gas-solid fluidized bed resulting in reactor wall fouling.

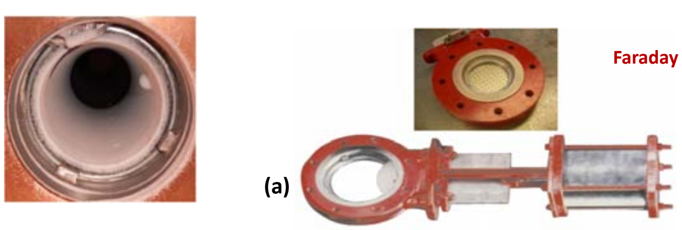
Develop an adequate charge measurement technique.

Investigate the influence of different factors/operating parameters affecting the degree of charging and fouling.

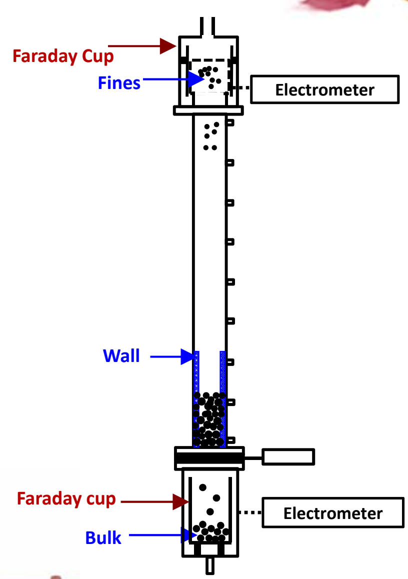
EXPERIMENTAL PROGRAM & FACILITY at uOTTAWA

Online Charge Measurement Technique

- **During fluidization**:
  Entrained fines are captured in a filter bag placed inside Faraday cup to measure the charge of the “fines”.
- **After fluidization:**
  - Distributor plate retracted by opening the knife gate valve, dropping the bulk of the particles (termed “bulk”) to a Faraday cup at the bottom to measure particles charge.
  - The “wall” layer particles can be then removed by applying pressurized air and drop to the bottom Faraday cup to measure their charge.



(a)

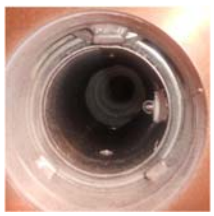


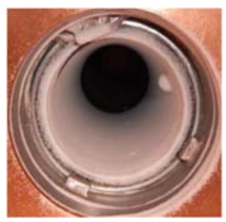
(b)

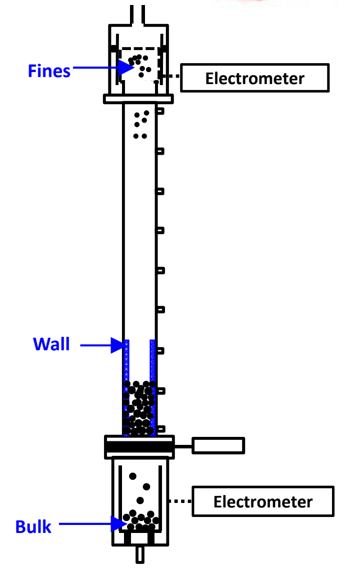
Figure: (a) Knife gate valve (b) Column schematic (Sowinski & Mehrani, 2010)

New Online Measurement Technique

- Quantitative Measurements
  - Particles Mass (m%)
  - Particles Net Charge-to-Mass ratio (q/m)
  - Particles Size Distribution (PSD)
- Qualitative Measurements
  - Pictures are taken of the inner fluidization column wall from the bottom to determine the extent of wall fouling from

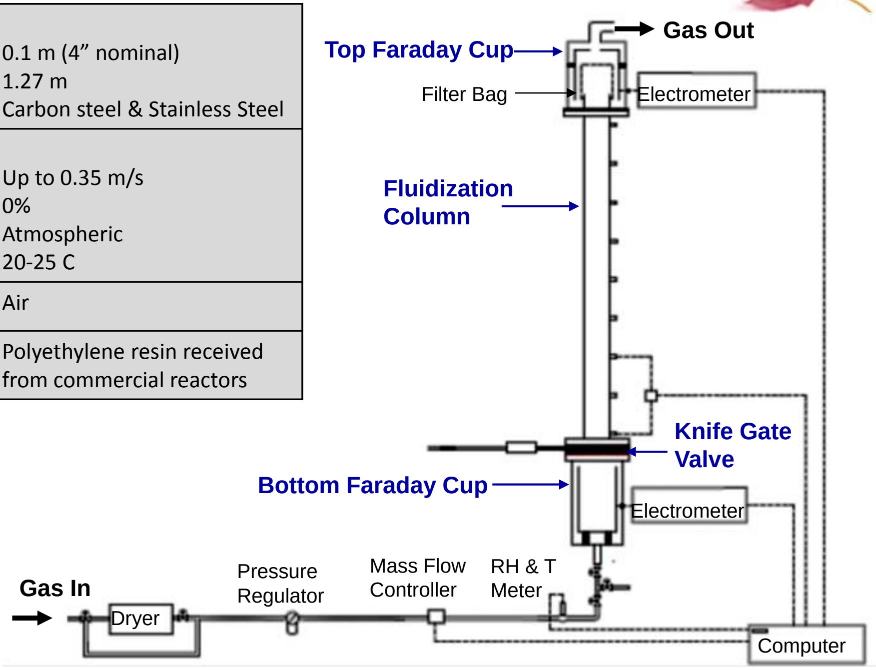






Experimental Facility - Atmospheric

Column	
Diameter	0.1 m (4" nominal)
Height	1.27 m
Material	Carbon steel & Stainless Steel
Operating Conditions	
Fluidizing Gas Velocity	Up to 0.35 m/s
Fluidizing Gas RH	0%
Pressure	Atmospheric
Temperature	20-25 C
Fluidizing Gas	Air
Fluidizing Particles	Polyethylene resin received from commercial reactors



Various Operating Conditions Evaluated to Date and Present Research

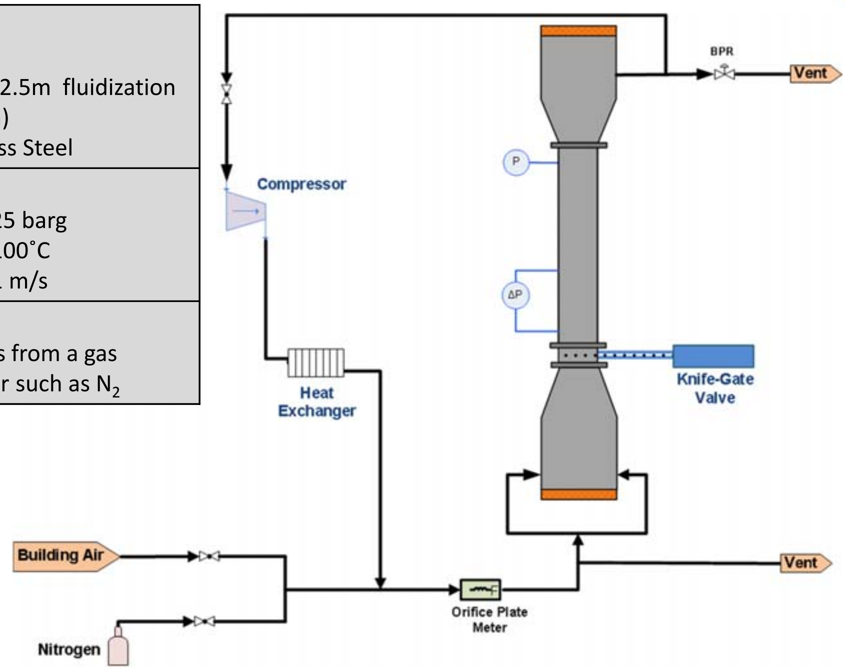
Parameter	Fluidizing Particles	Fluidizing Gas	Fluidization Vessel
Fluidization Time	15 minutes to 6 hours		
Velocity	-	• Bubbling (1.5, 1.75, 2 umf) • Slugging (2.3, 3, 3.5, 4 umf) • **Turbulent**	-
Diameter	• Wide Distribution (as received) • Sieved Particles	-	• 4 inch • 6 inch
Material	• Polyethylene resin (made from different catalyst) • Polyethylene + Catalyst • Polyethylene + Prostatic agents	• Air Dry (0% RH) • Air Humid (0 – 80% RH) • Air (dry) + Ethanol • N2 (dry)	• Carbon Steel • Stainless Steel • Polyethylene Film
Temperature	-	• **20 – 100° C**	-
Pressure	-	• **Atmospheric - 25 atm**	-

CFD Modeling	Collaboration with Professors R. Fox and A. Passalacqua at Iowa State University

HIGH-PRESSURE FACILITY

Fluidization Facility – High Pressure

Column Diameter Height Material	 0.15 m 4.5 m (2.5m fluidization section) Stainless Steel
Operating Conditions Pressure Temperature Fluidizing Gas Velocity	 Up to 25 barg Up to 100˚C Up to 1 m/s
Fluidizing Gas	Air Any gas from a gas cylinder such as N_2



Experimental Facility – High Pressure

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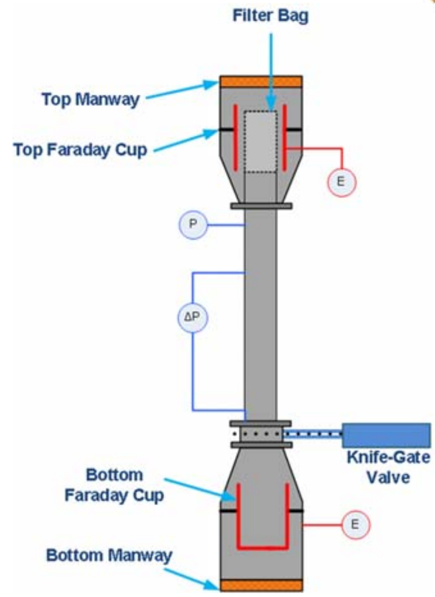
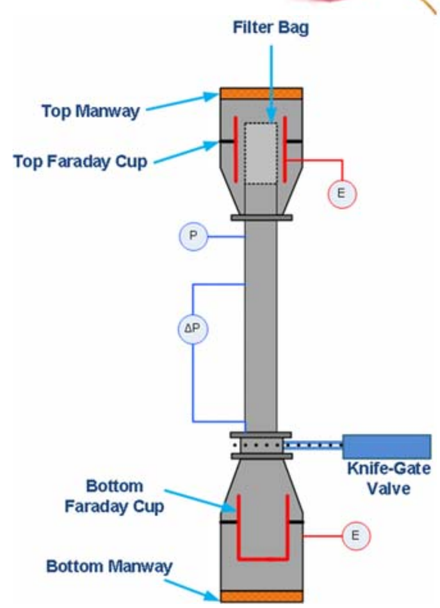
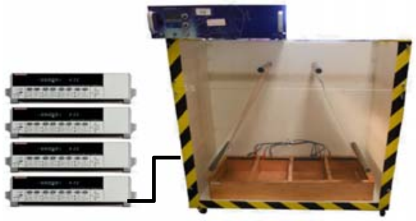
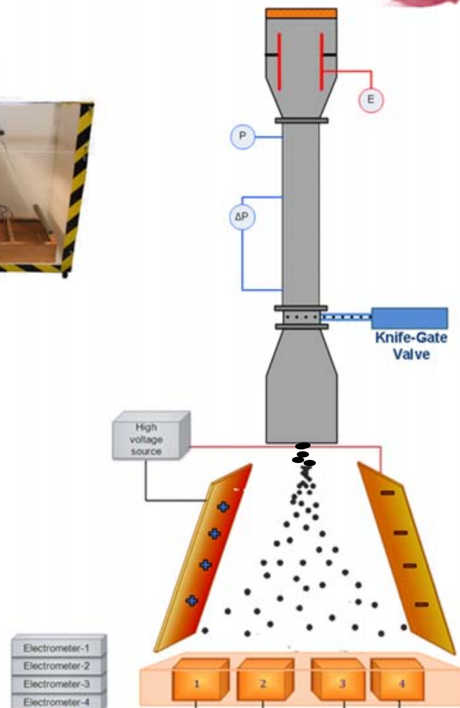


Experimental Facility – High Pressure



Experimental Facility – High Pressure





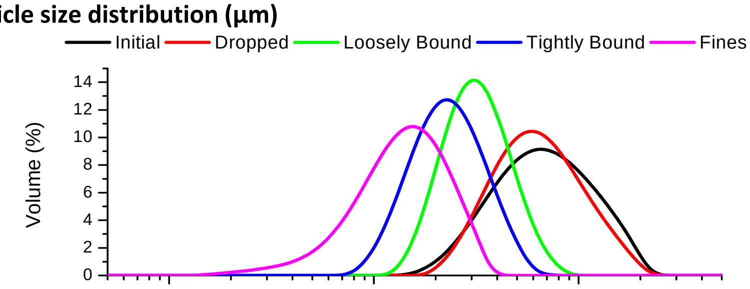
Average Results

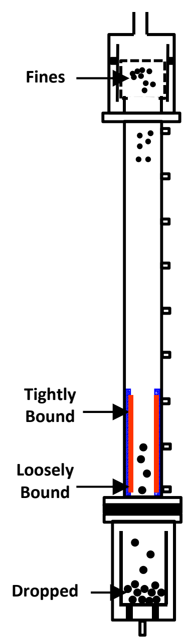
- **Mass distribution (m%)**
  - Bulk 94%
  - Wall 5%
  - Fines <1%
- **Specific charge (q/m in μC/kg)**

	Resin-A	Resin-B
Initial	-0.1	+0.01
Bulk	-1.0	+0.5
Wall	-60	+60
Fines	+75	-90

Bipolar charging

- **Particle size distribution (μm)**





Summary

1. **The measurement technique is proven to be unique and effective.**

2. **For all operating conditions tested:**
   - **Bi-polar charging** was observed where the finer and larger polyethylene particles were oppositely charged.
   - Such phenomenon was concluded to be the driving force for the **particle layers** to be formed on the reactor wall.

3. Between the **particle-particle** and **particle-wall** contacts:
   - With **no entrainment**, particle-wall contacts are the dominating mechanism.
   - With **entrainment**, both particle-particle and particle-wall charging are effective.

4. There was an upper **limit to the size of particles that adhered to the column wall**. And within the wall layer, the particle size decreased in the radial direction with the finest to be strongly attached to the wall.

Summary

5. The **charged particle separator apparatus** allows the investigation of particles charge distribution within the wall coating layer. Bi-polar charging was found within both the bulk and wall regions of fluidized bed.

6. The effect of **gas velocity** showed a difference in the type of wall layer fouling between bubbling and slugging flow regimes and resulting in higher mass of wall particles. However, the q/m of wall particles in both flow regimes came to be similar.

7. The **prostatic agents** reduced the amount of wall fouling, whereas the catalyst support and the deactivated catalyst promoted wall fouling.

8. **Overall, it was found that the magnitude of q/m of particles fouled on the column wall did not dictate the amount of reactor wall fouling.**

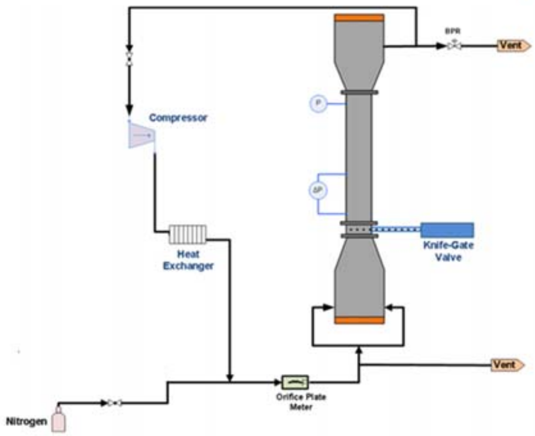
9. **Study of electrostatic charging in relation to any industrial gas-solid processes should be performed under similar industrially-related operating conditions.**

Present & Future Projects

- By operating the high-pressure facility to investigate the effects of
  - Operating pressure
  - Operating temperature
  - Fluidizing gas velocity (bubbling vs. turbulent)
  - Particle recirculation

- Further investigate the effect of polyethylene resin variations (resins made from different types of catalyst, containing different amount of continuity additives, particle size distribution, etc.)

- Continue the CFD modelling.



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