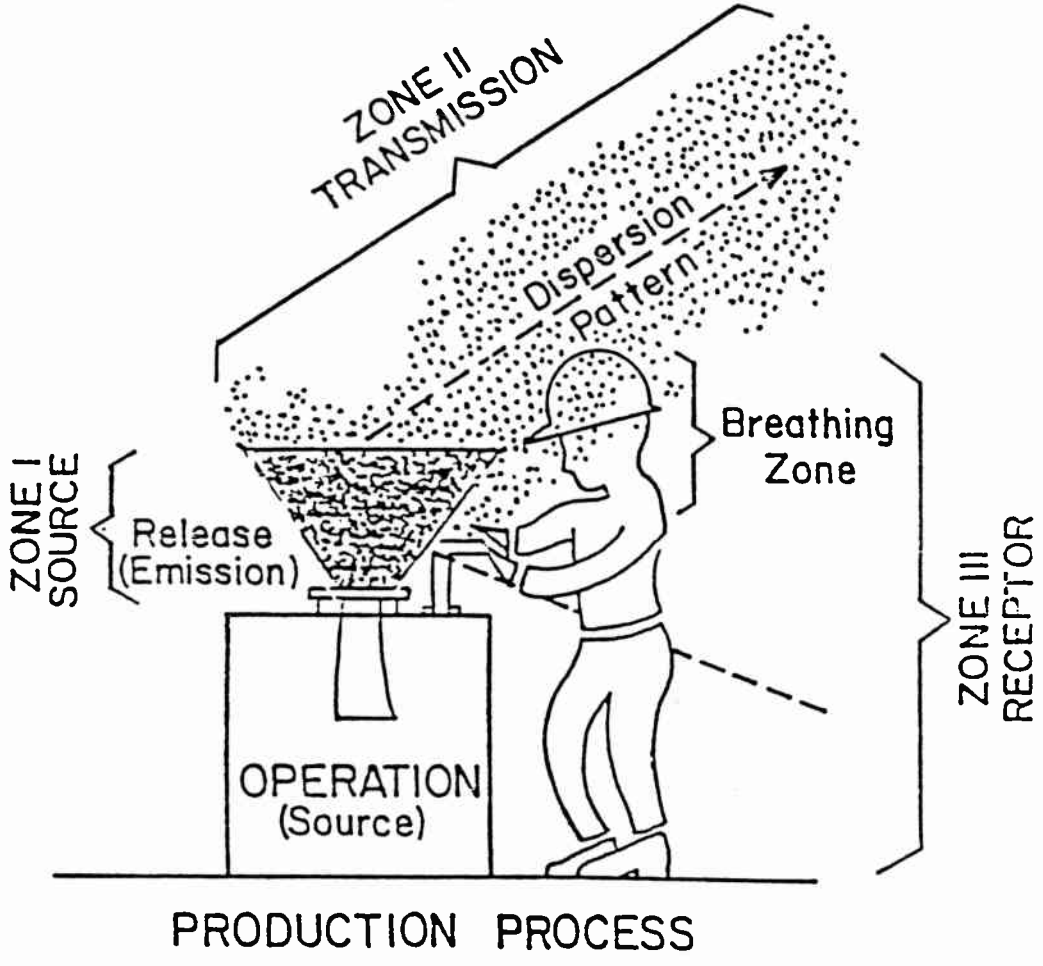
Factors that Affect Dust Generation In Industry

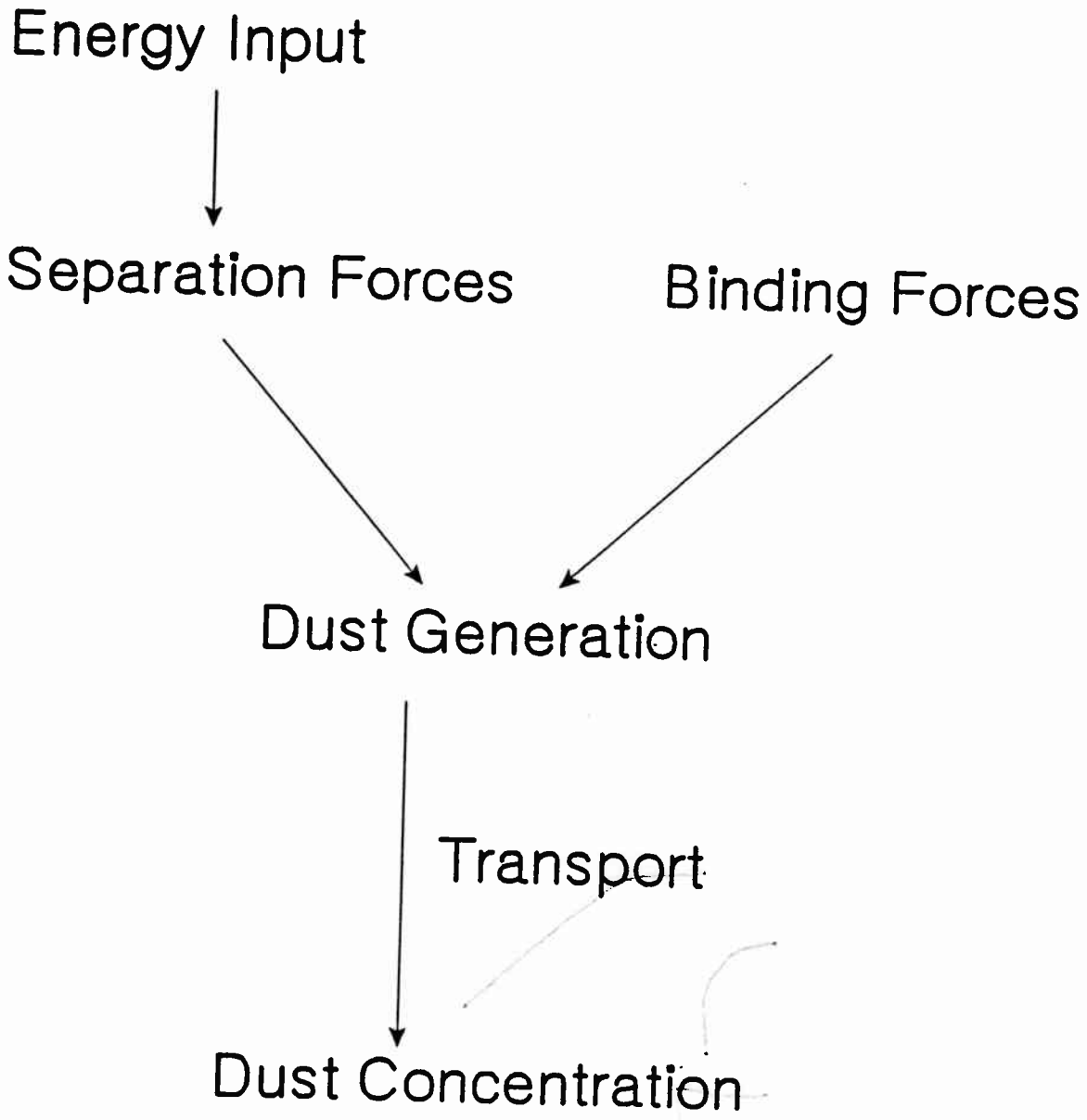
David Leith
Department of Environmental Sciences and Engineering
University of North Carolina

Marc Plinke
Maryanne G. Boundy



Both Process and Material Affect Dust Generation

Theory :



Conceptual Model for

Factors that Affect Dust Generation

Separation Forces: Impaction

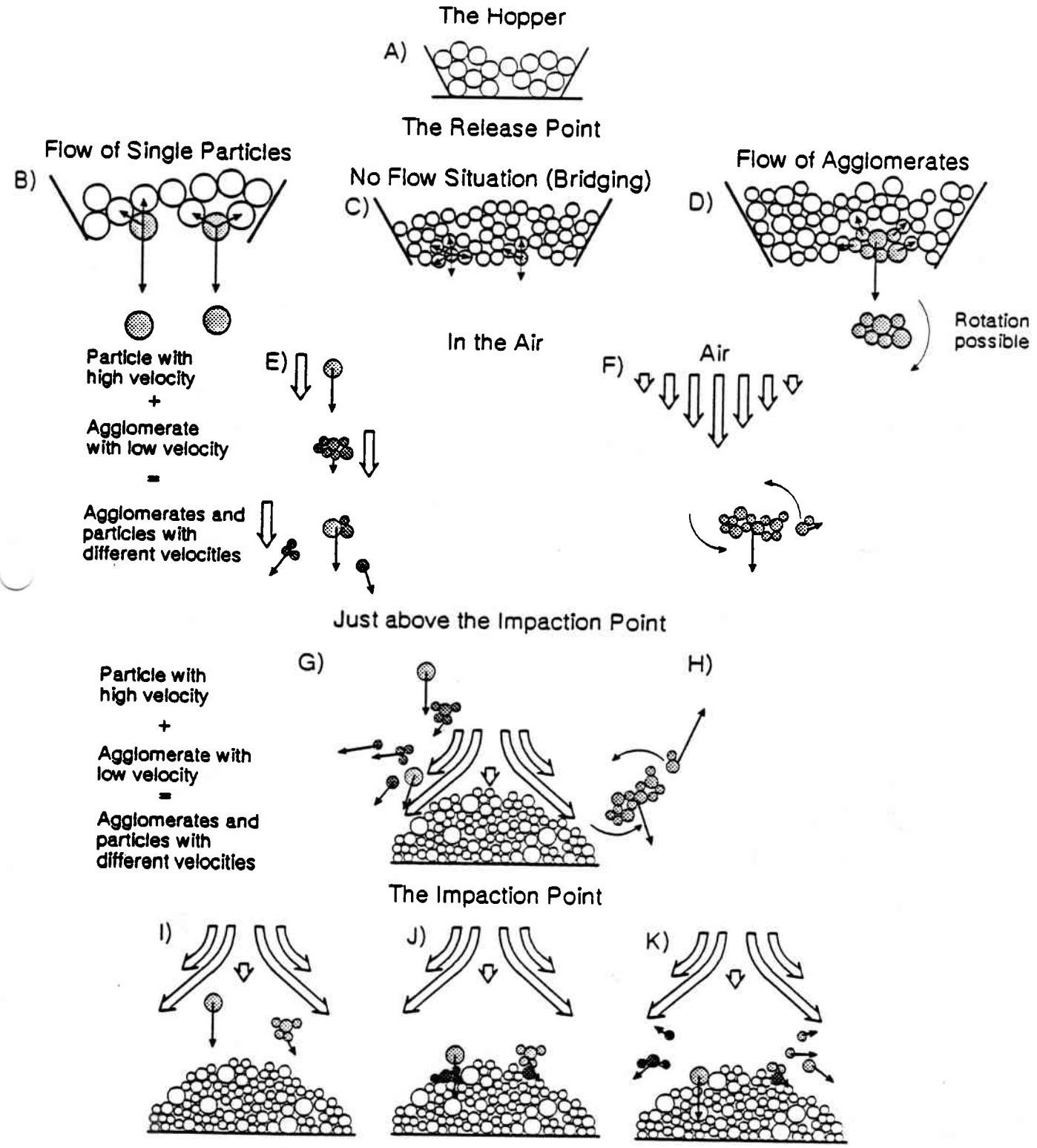
Assumption: Strongest Forces Act on Impact

Depend on Energy Input

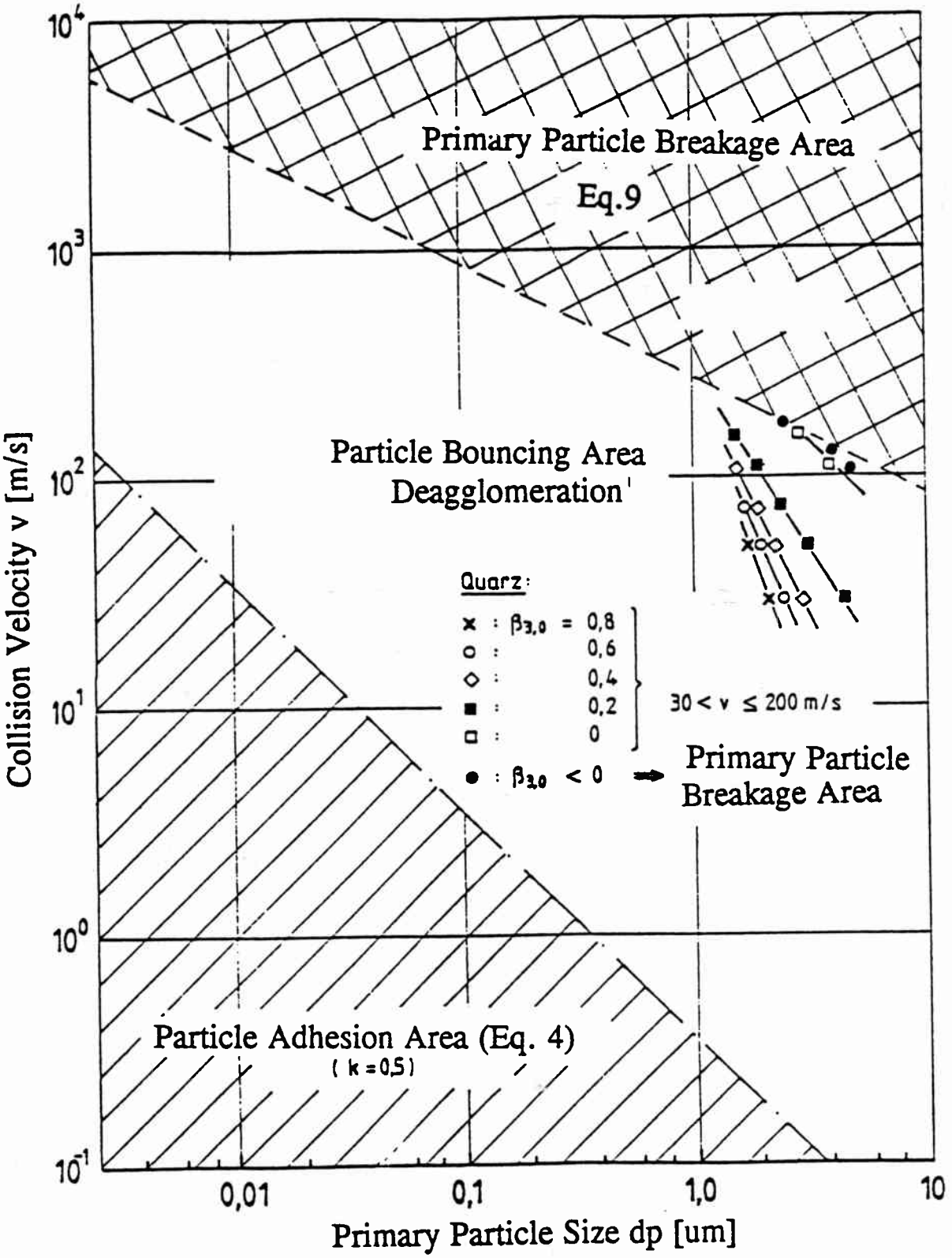
- Impact Velocity
- Mass of Agglomerate

Affected by the *Process*:

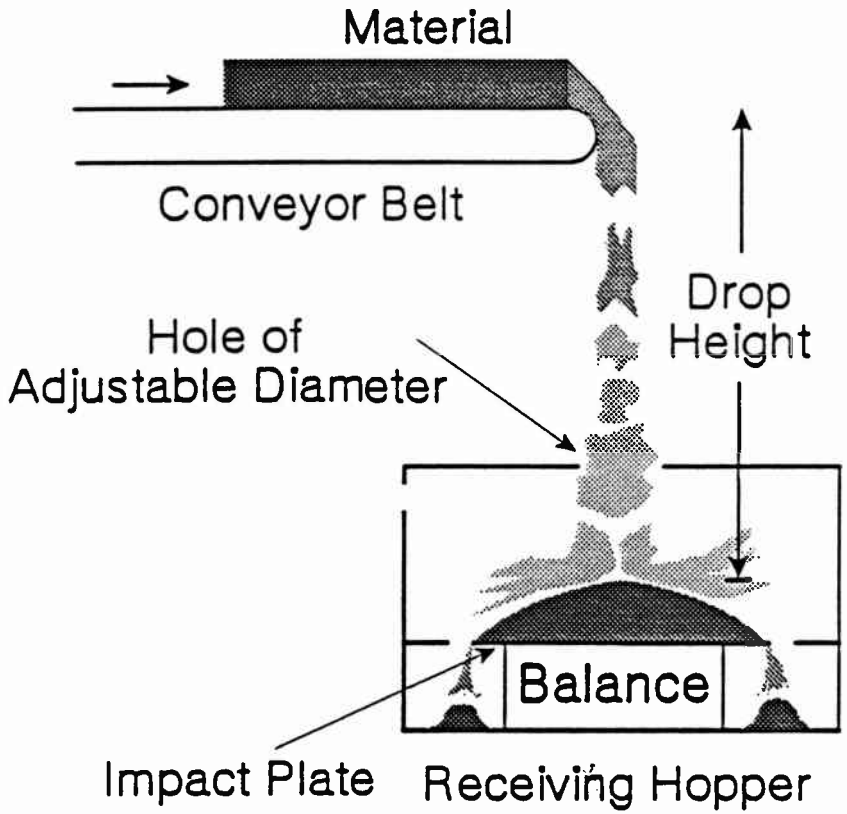
- Fall Height
- Material Flow (mass/time)
- Condition of Receiving Surface (Hard or Soft)



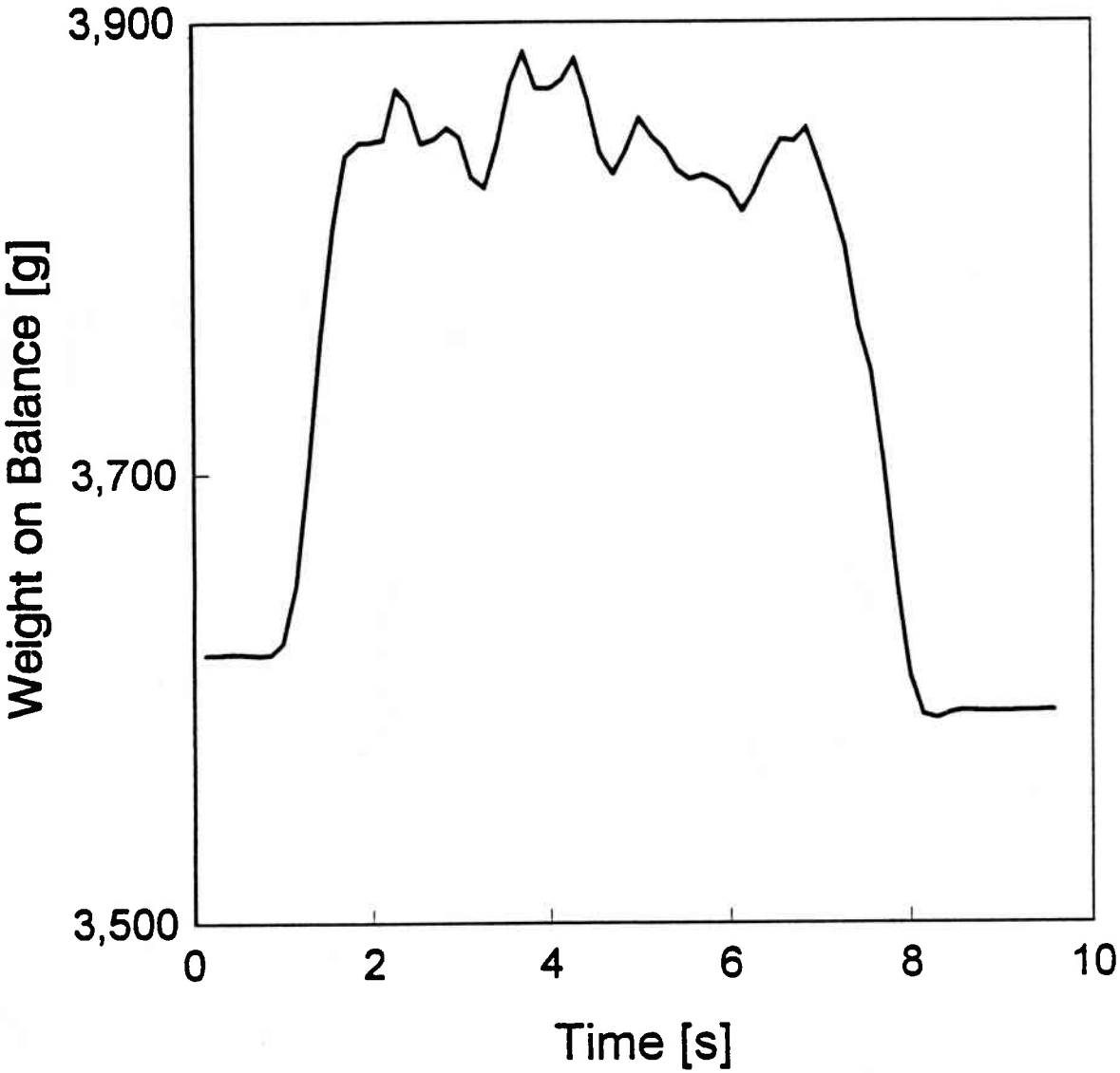
Forces that Act on a Material as it Falls



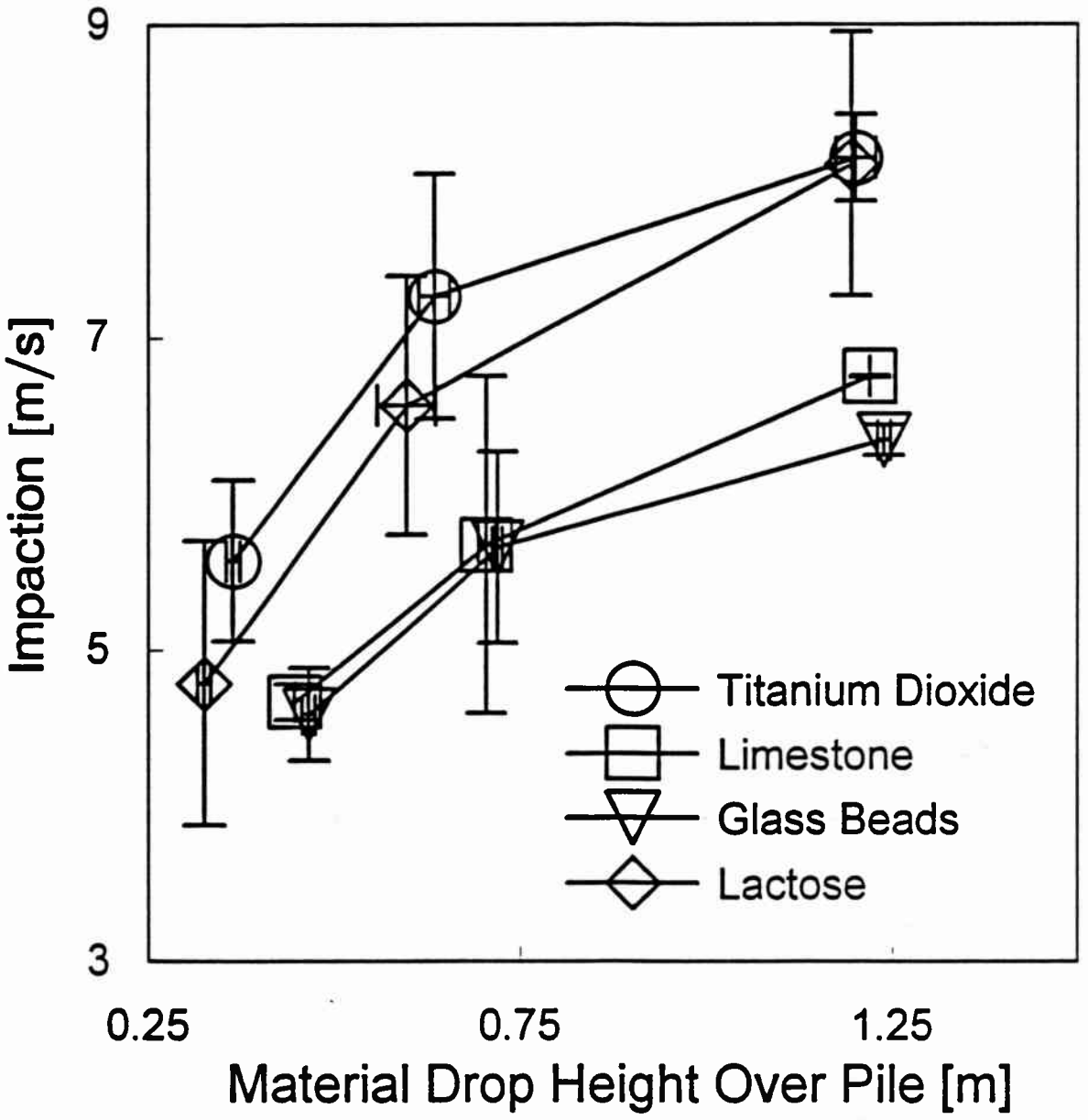
Collision Velocity vs. Particle Size:
Regions of Adhesion, Bouncing, and Breakage



Apparatus to Measure Impaction



Weight on Balance for Falling Material vs. Time

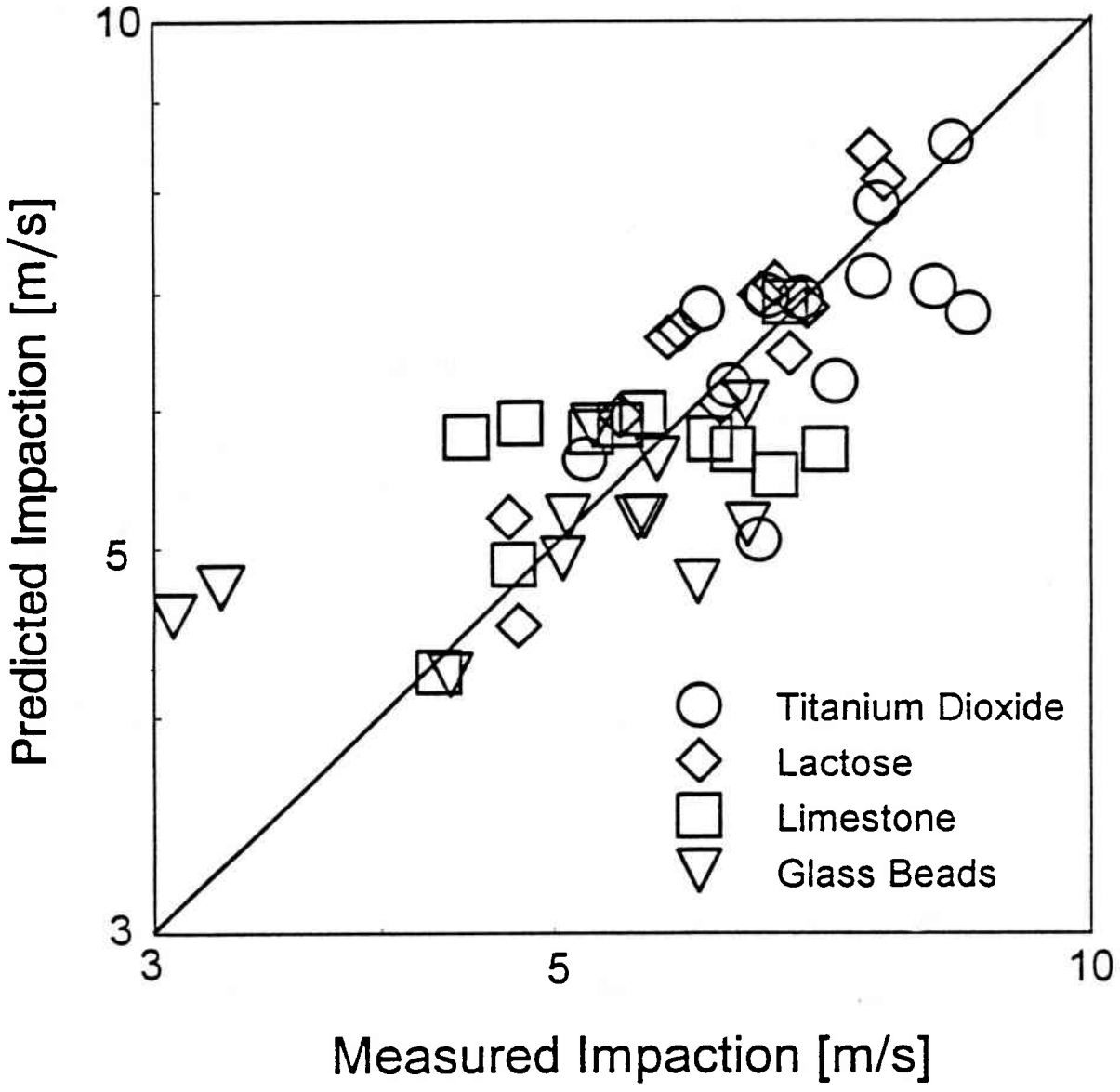


Impaction (Force/Flow) vs. Drop Height
Material as Parameter

Impaction Model

$$I = e^{-1.8\pm0.45} H^{0.4\pm0.10} M^{0.1\pm0.03} d_{50}^{0.2\pm0.04} \rho_p^{0.3\pm0.10} c_w^{0.1\pm0.03} AR^{0.2\pm0.}$$

I -- Impaction, m/s
H -- Drop Height, m
M -- Moisture Content, %
d_{50} -- Particle Size, μm
ρ_p -- Particle Density, kg/m^3
c_w -- Cone Width, m
AR -- Angle of Repose, degrees



Impaction Predicted from Regression Equation vs. Measured Impaction

Binding Forces: Cohesion

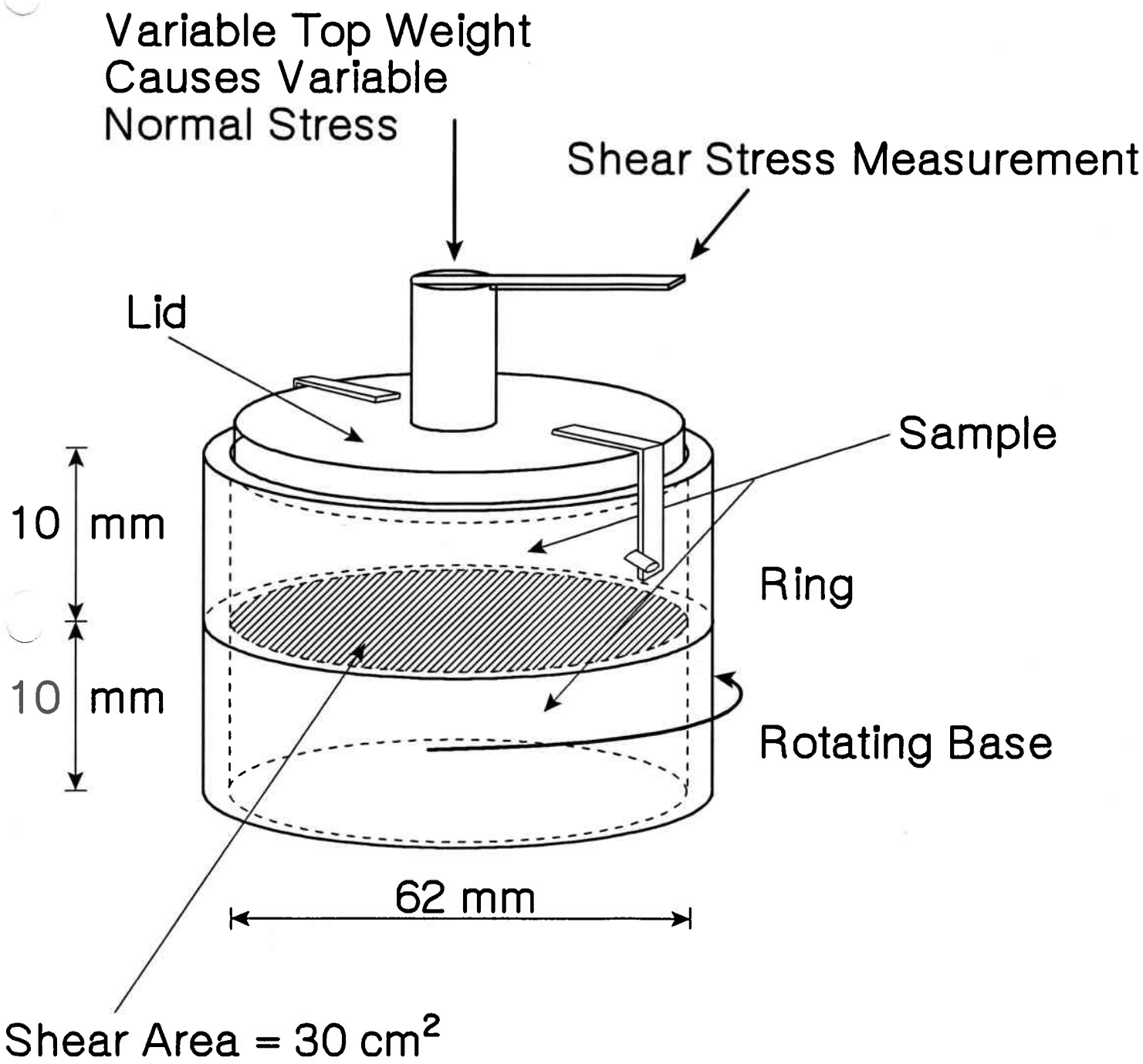
Depend on Surface Contact Points

- van der Waals Forces
- Capillary Forces (moisture content)
- Electrostatic Forces

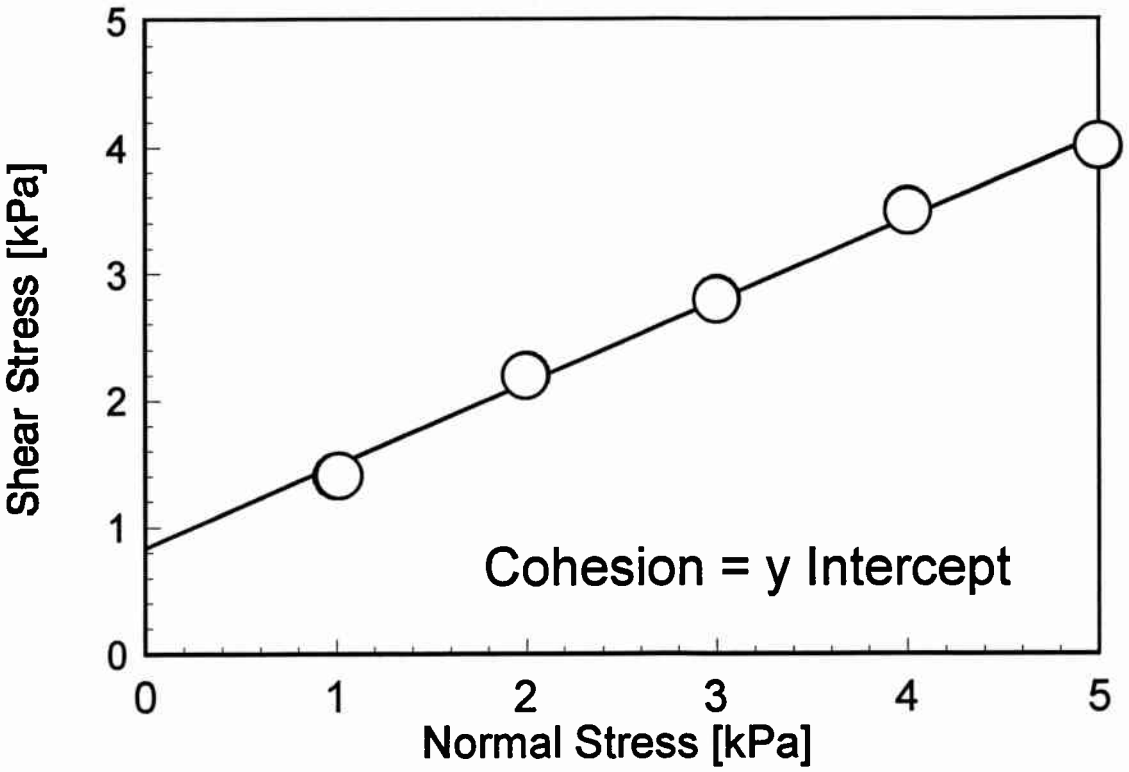
Affected by Properties of the *Material*:

- Physical Properties
- Compression History
- Moisture History

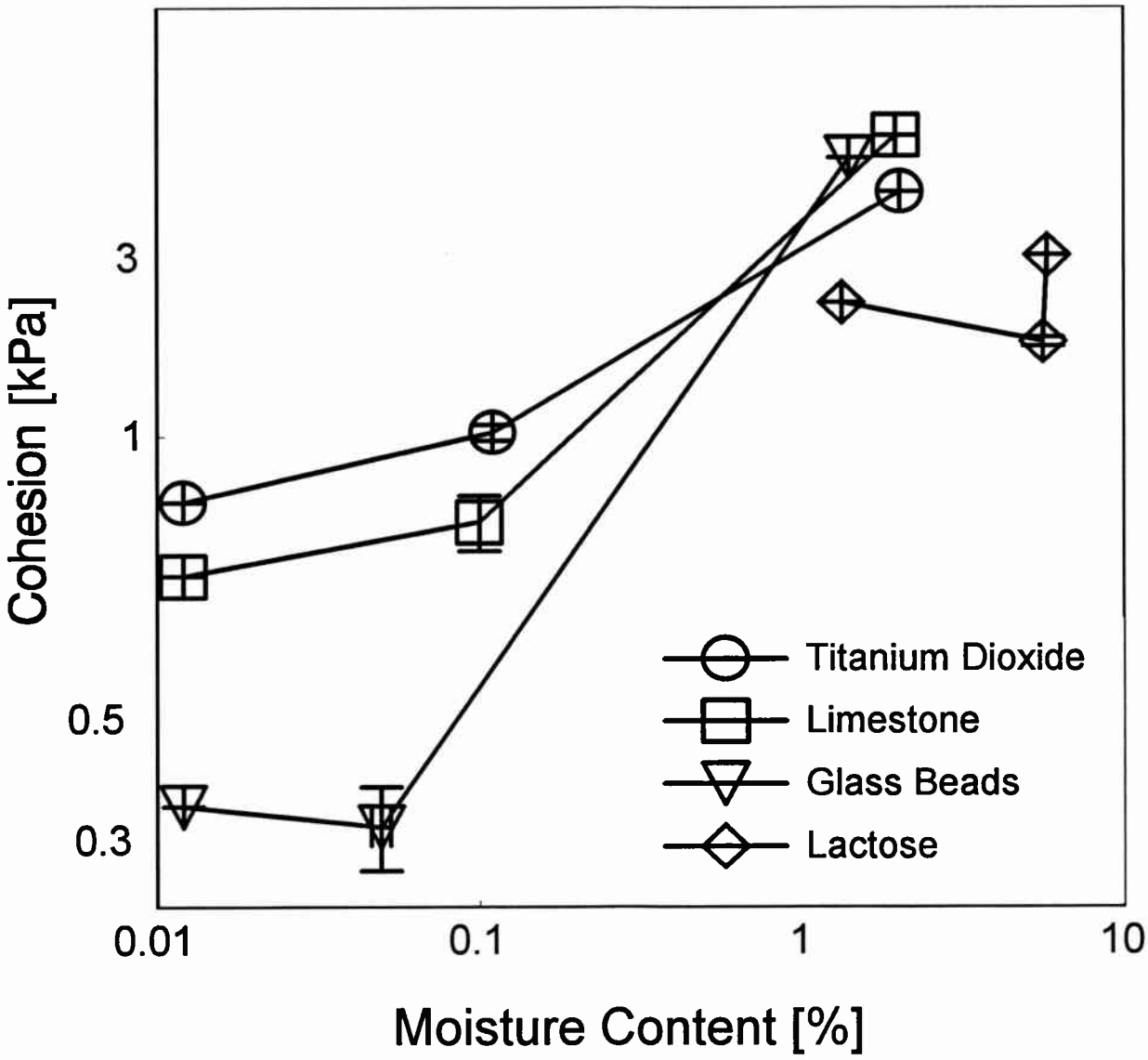
Result: No Model Available for Non-Ideal Materials



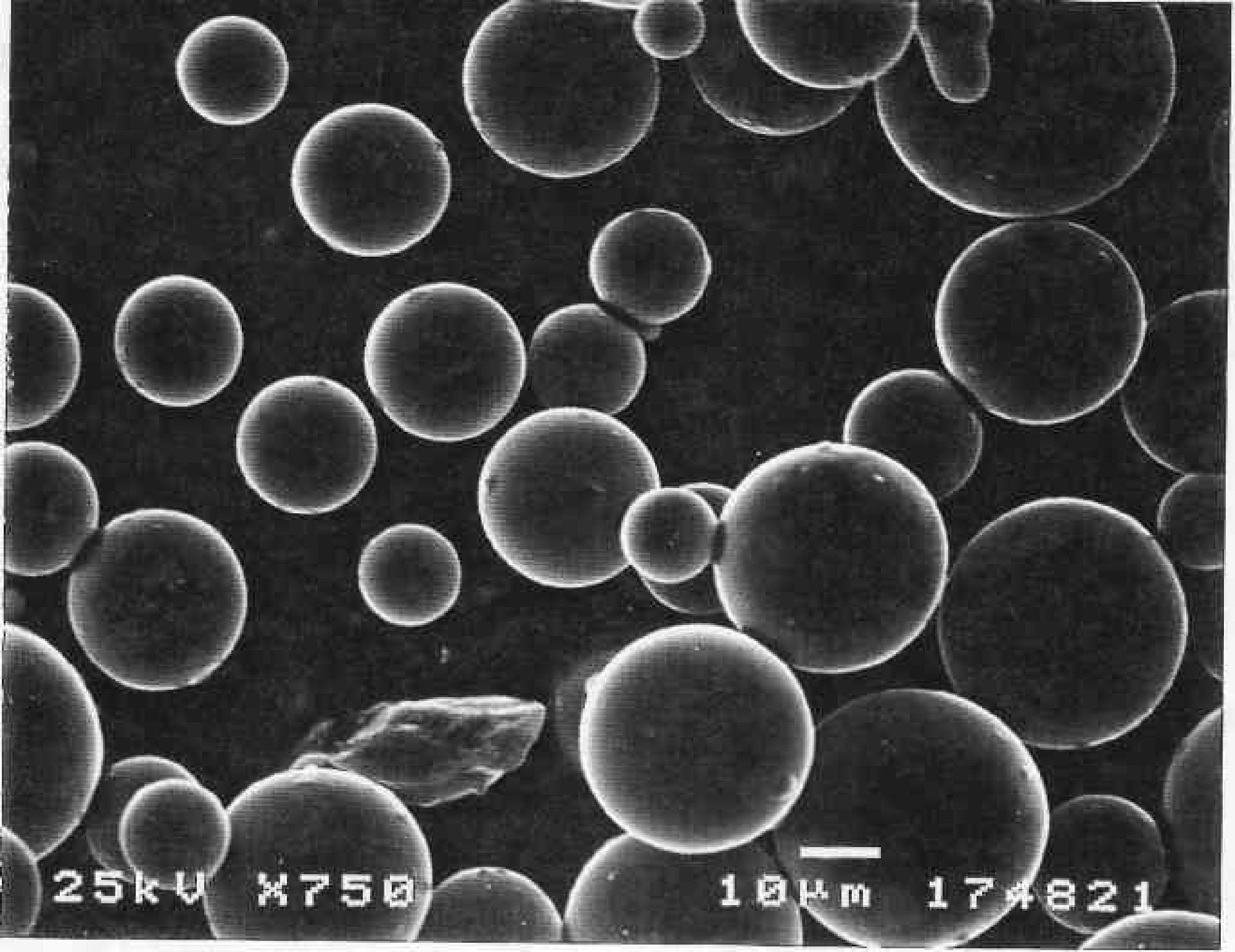
Peschl Shear Tester for Measuring Cohesion



Shear Stress vs. Normal Stress
from Peschl Shear Tester
Y-intercept is Cohesion



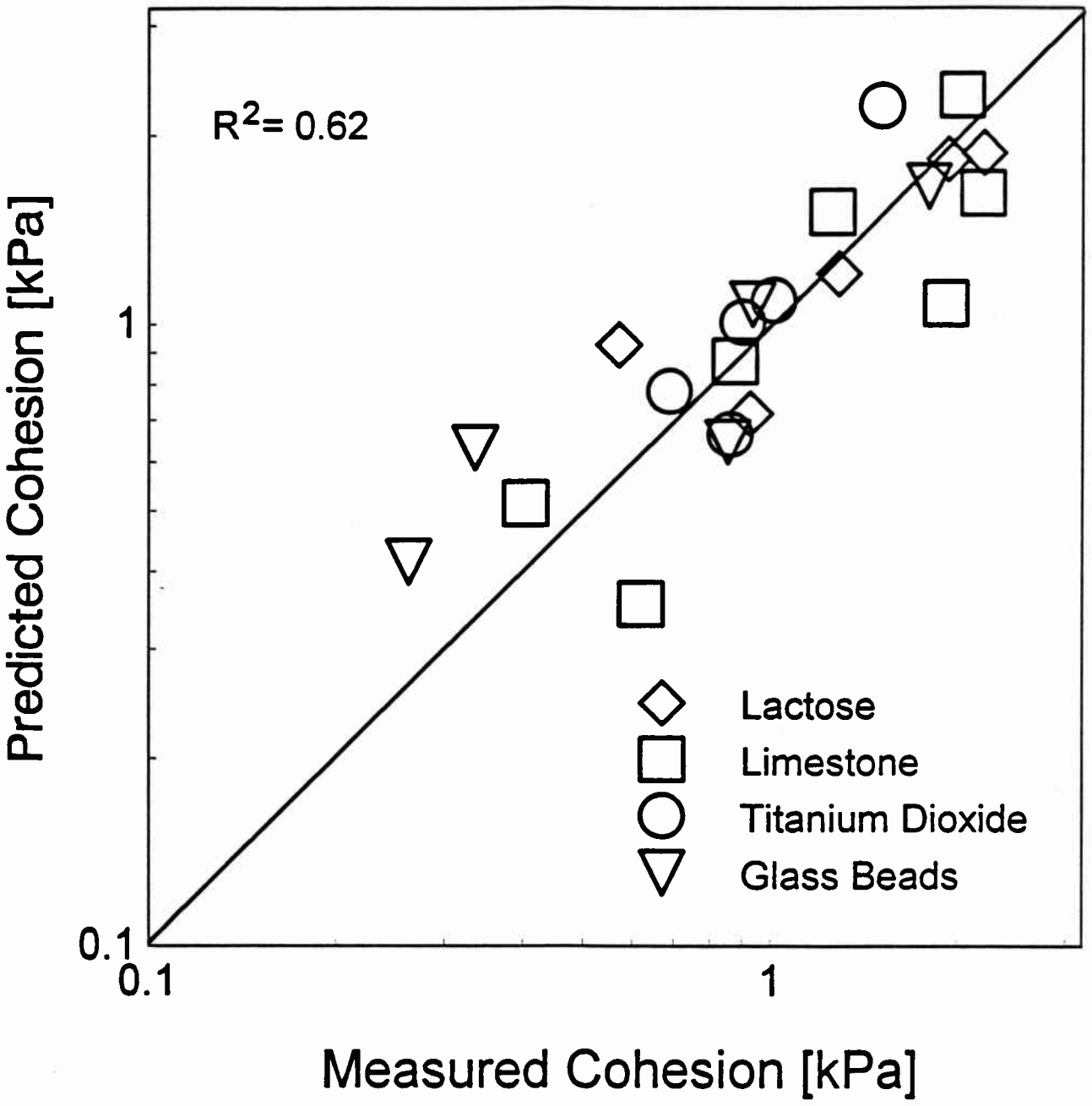
Cohesion vs. Material Moisture Content
Material as Parameter


25kV X750
10µm 174821

Cohesion Model

$$C = e^{1.3\pm0.56} M^{0.2\pm0.02} d_{50}^{-0.2\pm0.03} T_m^{0.3\pm0.08}$$

C -- Cohesion, kPa
M -- Moisture Content, %
d_{50} -- Particle Diameter, μm
T_m -- Melting Temperature, °C



Cohesion Predicted from Regression Equation vs. Measured Cohesion

Dust Generation

Balance Between Binding Forces and Separation Forces

$$G_i = f\left[\mathrm{Frac}_i\left(\frac{\mathrm{Impaction}}{\mathrm{Cohesion}}\right)\right]$$

Approach:

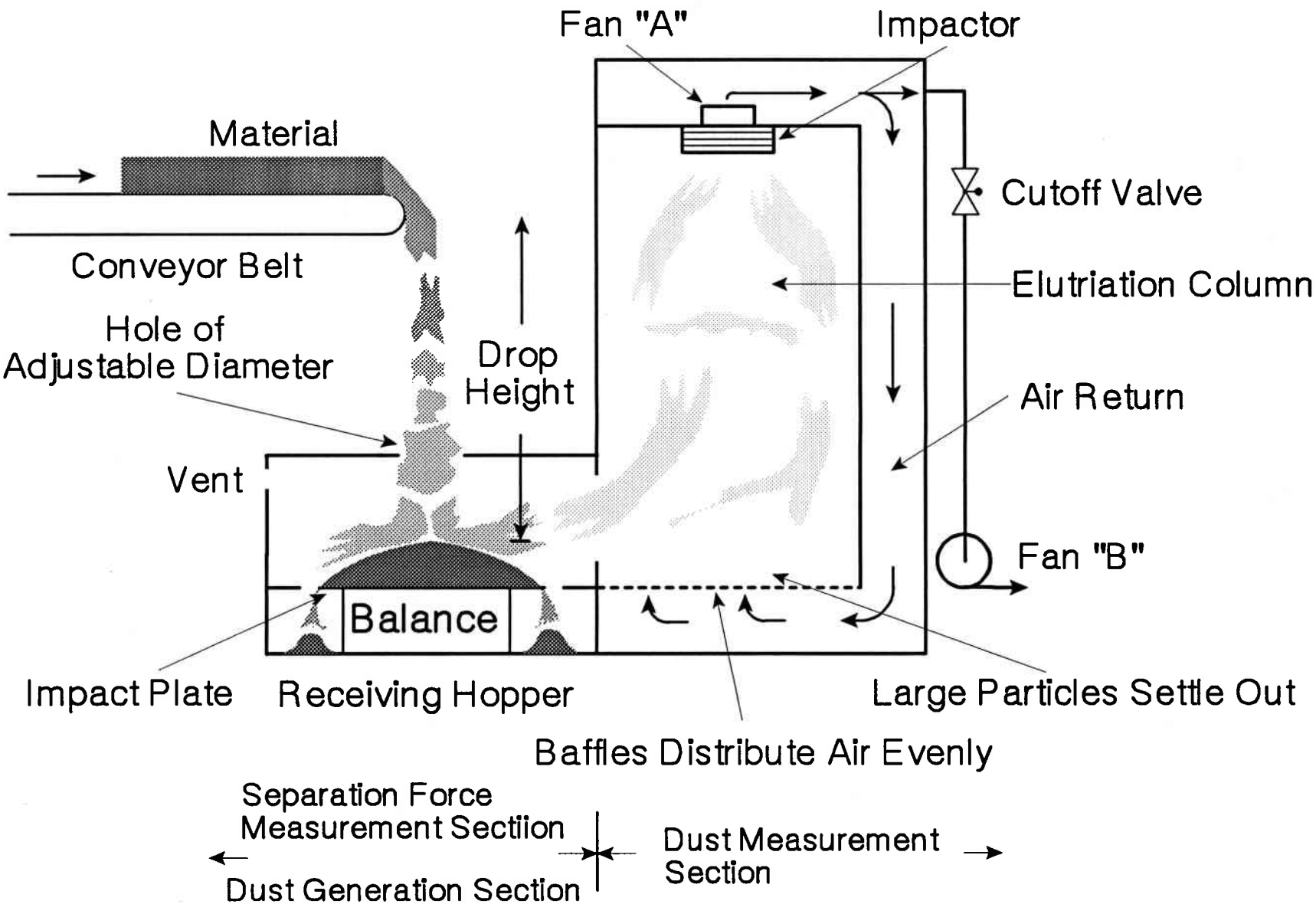
Measure All Variables
Determine Function *f*

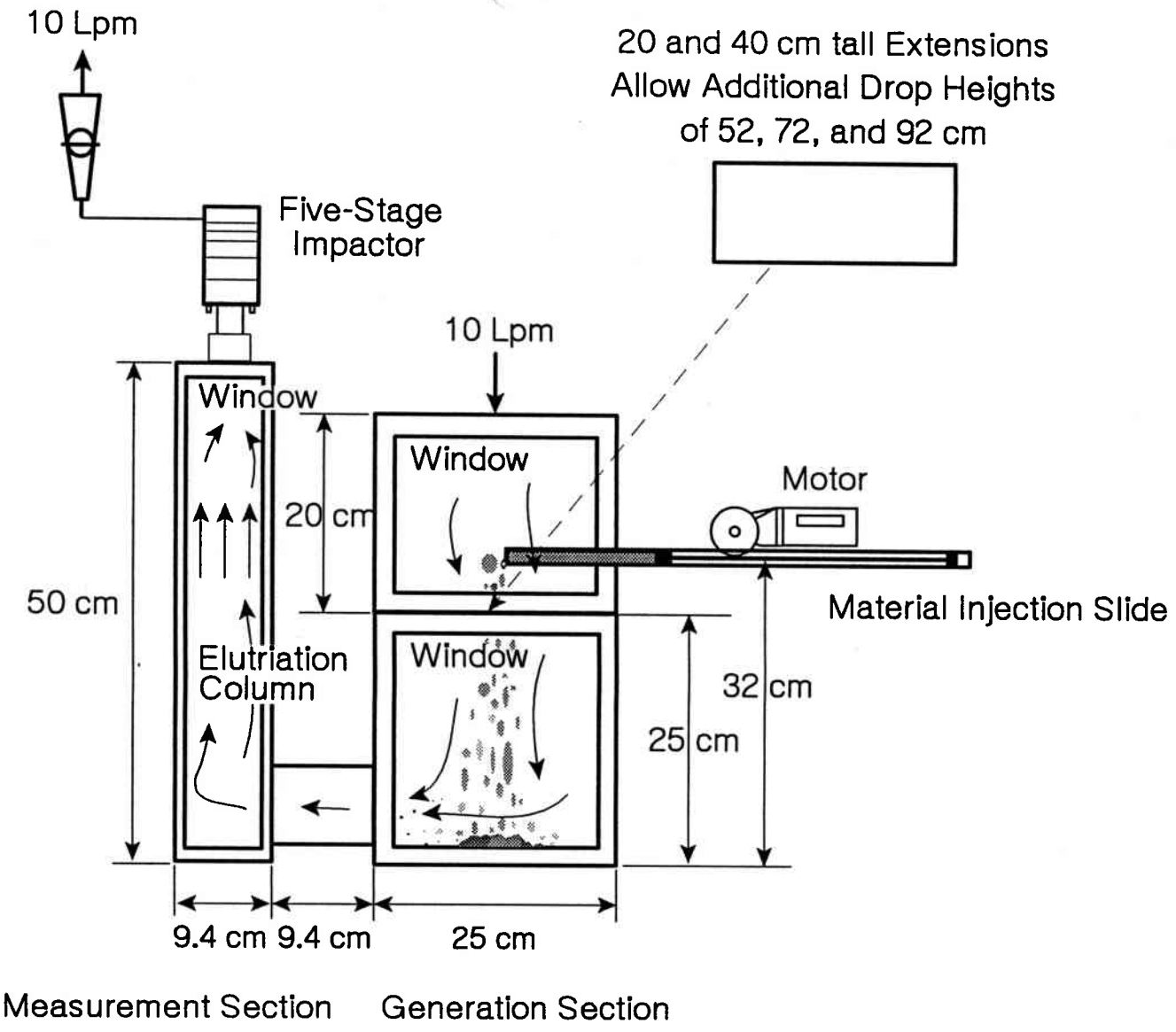
Dependent Variable / Independent Variable	Cohesion	Impaction	Dust Generation Rate
Drop Height	N /A	0.25, 0.7, 1.25 m	0.25, 0.7, 1.25 m
Material Flow	N / A	0.1, 0.3, 0.6 kg/s	0.1, 0.3, 0.6 kg/s
Material	TiO_2 , Limestone, Glass Beads, Lactose	TiO_2 , Limestone, Glass Beads, Lactose	TiO_2 , Limestone, Glass Beads, Lactose
Moisture Content	0, 0.1, 1.2 % 1*, 5.5*, 6* %	0, 0.1, 1.2 % 1*, 5.5*, 6* %	0, 0.1, 1.2 % 1*, 5.5*, 6* %
Particle Size Range of Material	d<5μm, 5<d<25μm, d>25μm	d<5μm, 5<d<25μm, d>25μm	d<5μm, 5<d<25μm, d>25μm

* Moisture values for lactose

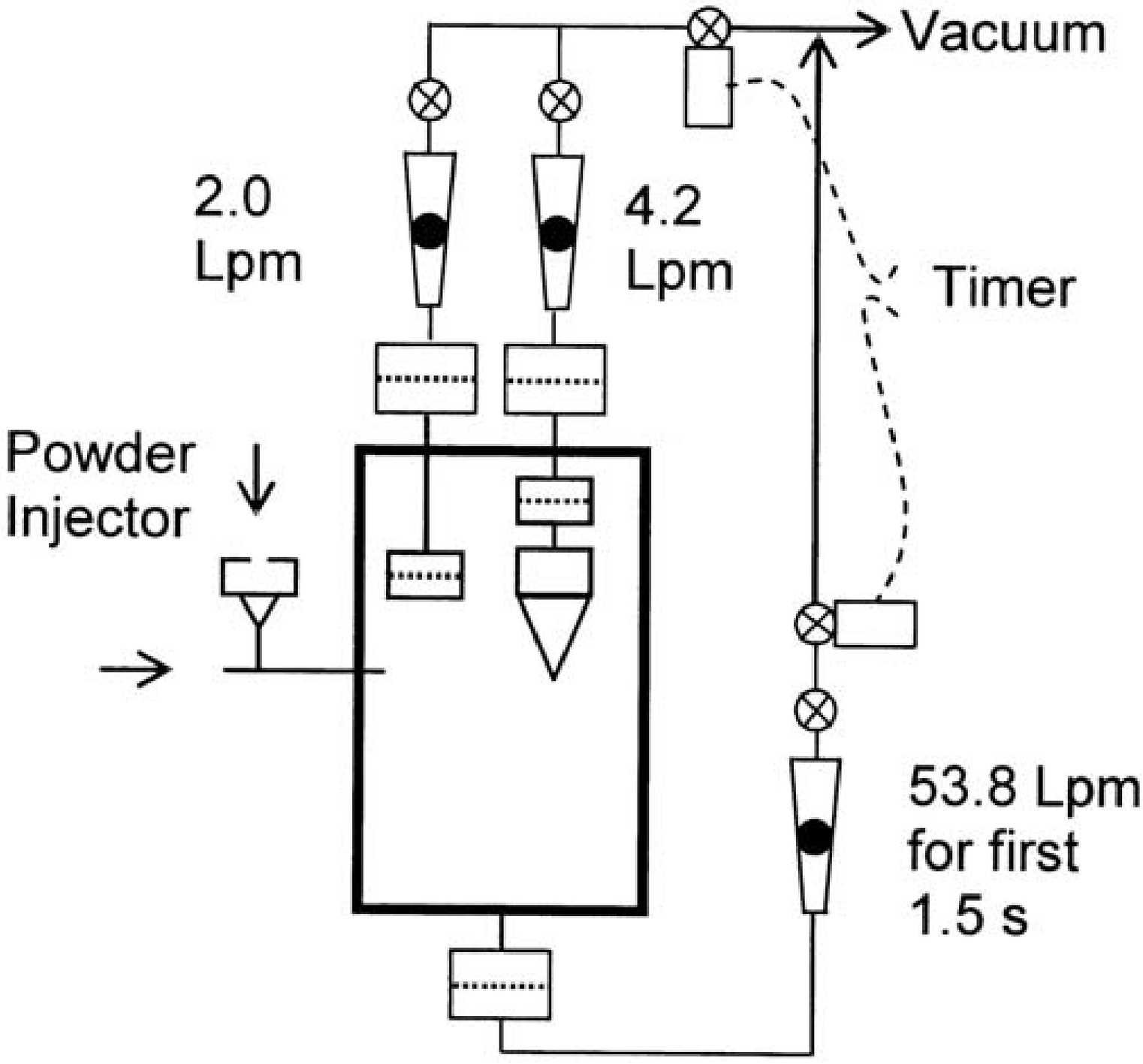
Variables Investigated in Dust Generation Tests

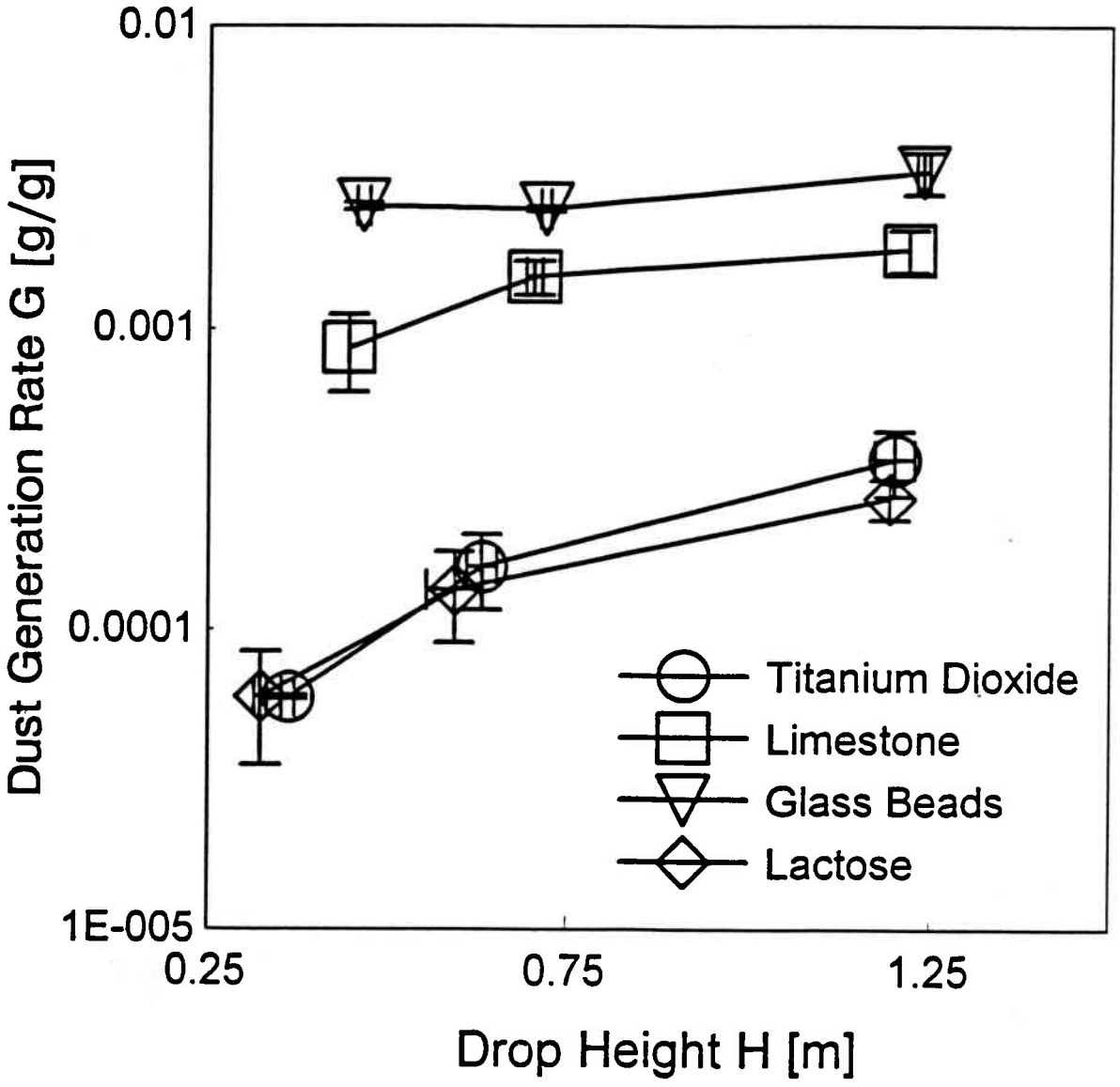
Full-Scale Apparatus to Measure Dust Generation



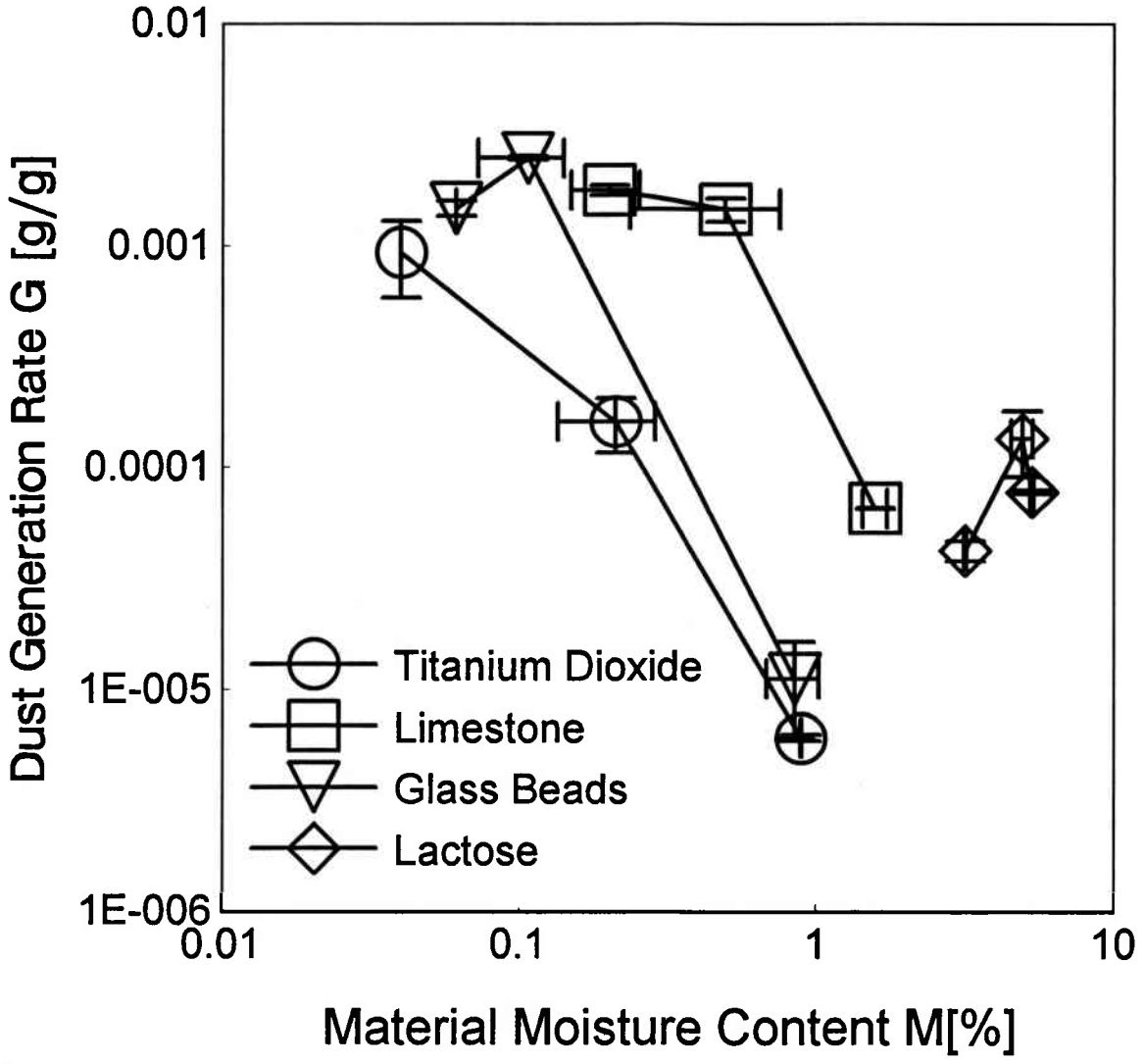


Bench-Top Apparatus to Measure Dust Generation


Vacuum
2.0
Lpm
4.2
Lpm
Timer
Powder
Injector
53.8 Lpm
for first
1.5 s



Dust Generation vs. Drop Height
Material as Parameter

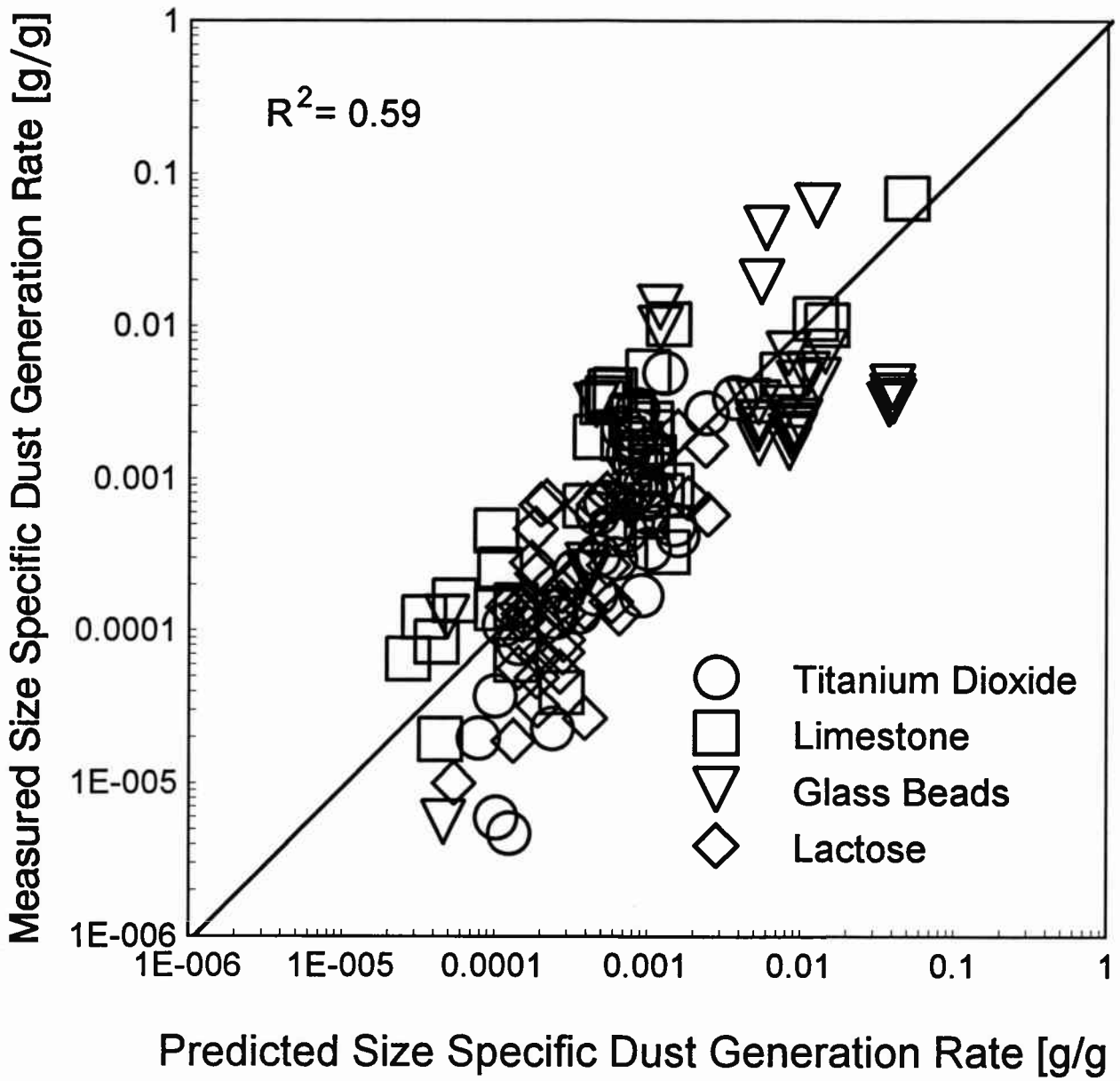


Dust Generation vs. Material Moisture
Material as Parameter

Equation Determined

$$G_i = e^{-9.1\pm0.96}\,Frac_i^{\,-0.2\pm0.03}\,\frac{Impaction^{1.0\pm0.27}}{Cohesion^{3.0\pm0.11}}$$

$R^2 = 0.59$ for 147 tests with four materials



Measured Dust Generation vs. Dust Generation Predicted by Regression Equation

Conclusions

- Created a conceptual model for dust generation
- Developed techniques to measure factors that affect dust generation
- Developed equations to predict dust generation

Summary

- Determine Cohesion from Experiments or Equation
  Depends primarily on moisture and size of material
- Determine Impaction from Experiments or Equation
  Depends primarily on fall height for process
- Measure Size Distribution of Original Material
- For Each Particle Size of Interest, Use Equation To Predict Fraction that Becomes Air-borne as Dust.