INVESTIGATION OF MARGINAL EXPLOSIBILITY IN THE 20-L AND 1-m^3 CHAMBERS

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Presentation by Albert Addo

Outline

- Introduction
- Materials and material characterization
- Apparatus and experimental procedures
- Results
- Conclusions
- Future work (Ph.D. research)

Introduction

- Combustible dusts are generally classified as explosible or non-explosible
- Classification requires standardized testing with standard procedures to assess explosion risk of dusts
- Explosion risk assessment requires testing to determine the explosion likelihood and severity parameters
- For explosion severity testing, two of the standard apparatus used are: Laboratory-scale 20-L chamber and intermediate-scale 1-m^3 chamber (considered as the gold standard equipment for dust explosibility testing)
- Generally, data from both apparatus have correlated well

Marginal explosibility

- This study focuses on a class of combustible dusts that do not show correlation:
  - show explosibility in the 20-L test chamber but not in the 1-m^3 chamber

- These dusts have been referred to as “marginally explosible dusts (MEDs)” or dusts that exhibit “marginal explosibility”

- Some studies defined based on volume-normalized maximum rate of pressure rise (K_{St}) values of ≤ 45 bar·m/s in 20-L chamber

- These dusts show low ignition sensitivity

Problem statement

❖ The conclusions on what constitutes marginal explosibility have not been adequately investigated and validated

❖ A burden of classifying these dusts as explosible or non-explosible exists
  - Extended to the industrial partners (Fauske and Associates, Fike Corporation and Professional Loss Control)

❖ This uncertainty may lead to difficulties in the design of dust explosion safety measures

❖ These dusts trigger the same risk reduction measures as explosible dusts

❖ Which means that non-explosible dusts may be protected (which costs lots of money)

Objectives of study

- ❖Develop and present well-characterized explosion data for inclusion into the dust explosion body of knowledge

- ❖Validate conclusions of what actually constitutes so-called marginal explosibility

- ❖Investigate the effect of scaling-up dust explosion data from the 20-L chamber

- ❖Investigate whether these dusts show low ignitability (as indicated by minimum explosible concentration (MEC), minimum ignition energy (MIE) and minimum ignition temperature (MIT))

Materials

❖ 3 organic materials were tested in the work namely:

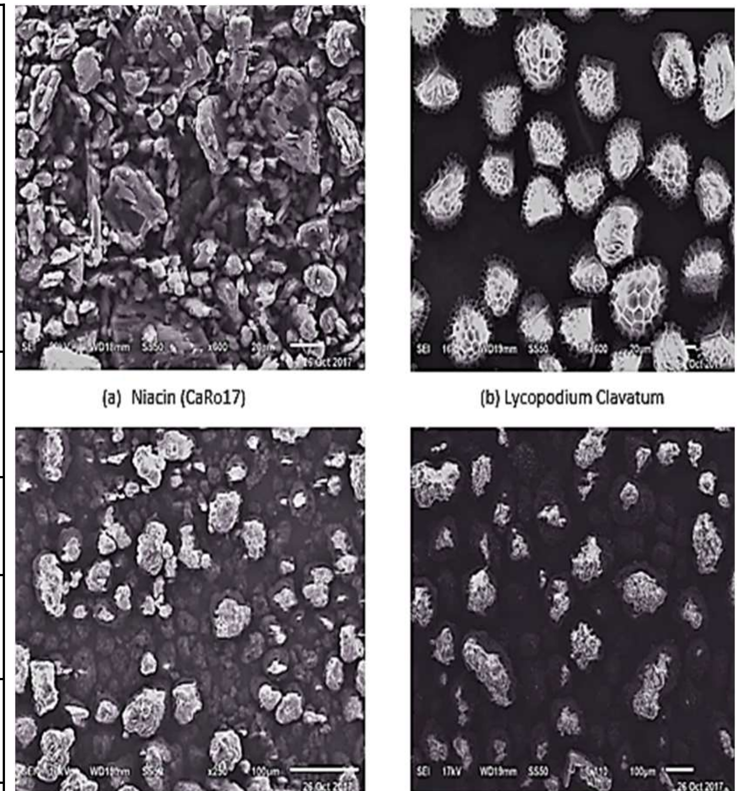
- niacin
- lycopodium clavatum and
- polyethylene (designated as PE)

❖ Concept of marginal explosibility was incoperated by testing both:

- fine polyethylene (fine PE) and
- coarse polyethylene (coarse PE)

Material characterization

Materials	Particle Size distribution (µm)			Moisture Content (wt %)	Heat of Combustion (kJ/kg)	Single point BET (SSA) (m^2/g)	Multi point BET (SSA) (m^2/g)	Langmuir (SSA) (m^2/g)	Density (g/cm^3)
	D_{10}	D_{50}	D_{90}						
Niacin	5	20	66	1.1	22,420	0.65	0.74	0.60	0.41
Lycopodium	23	31	42	4.3	31,330	1.07	1.30	1.00	0.36
Fine PE	21	42	69	0.2	45,750	1.48	1.66	1.37	0.41
Coarse PE	78	131	210	0.2	45,810	2.71	2.94	2.79	0.41



(a) Niacin (CaRo17)

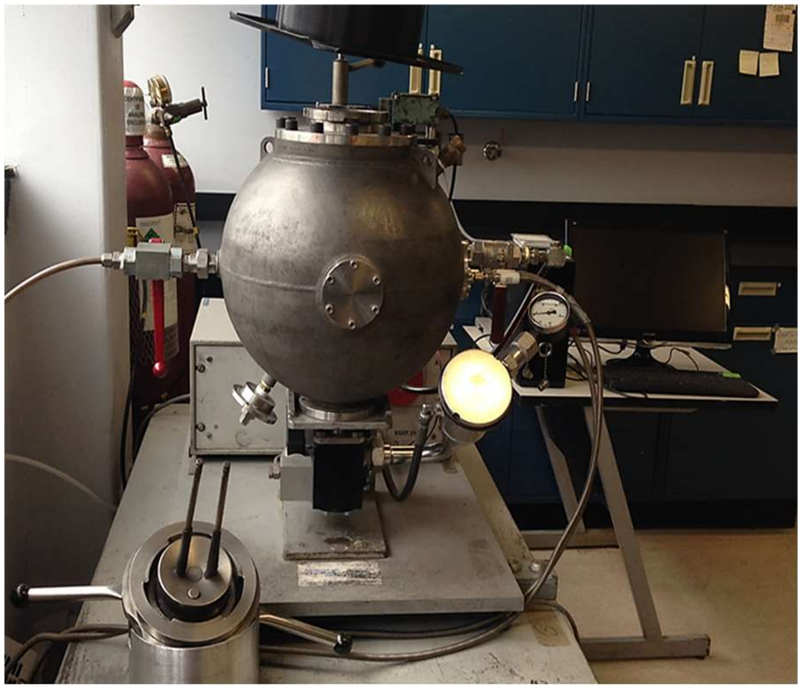
(b) Lycopodium Clavatum

(c) Fine Polyethylene

(d) Coarse Polyethylene

SEM images of samples

Apparatus and procedures – maximum explosion pressure, P_{max}, maximum rate of pressure rise $(dP/dt)_{max}$, and MEC

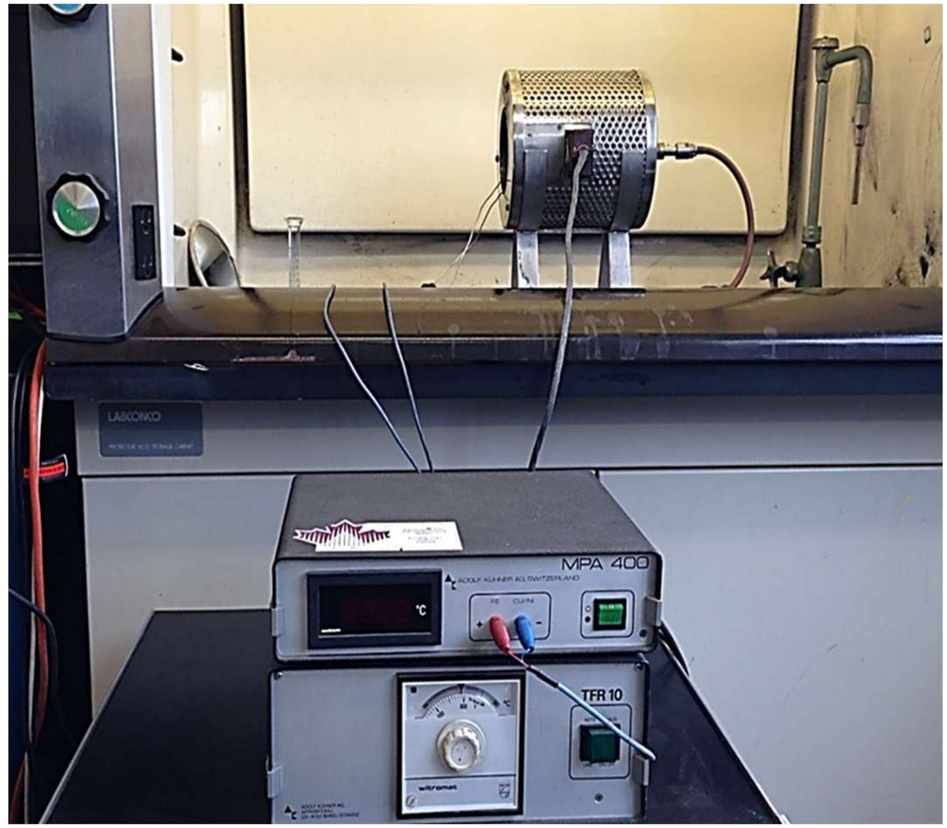


Siwek 20-L chamber – testing per ASTM E1226-13 (2018); E1515-14 (2018)

OZM 1-m^3 chamber at Fauske – testing per ASTM E1226-13 (2018); E1515-14 (2018)

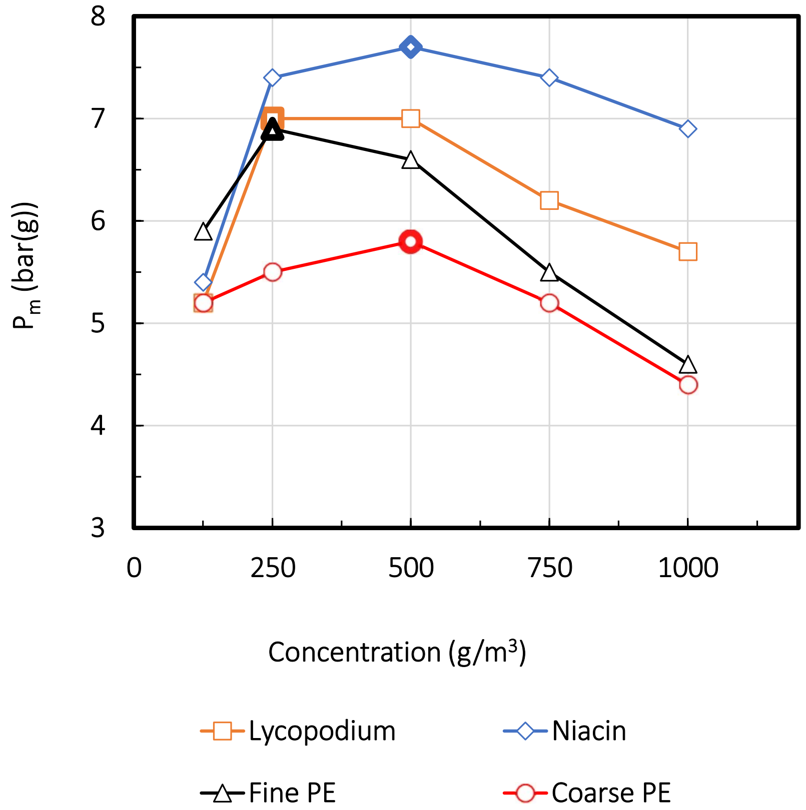
Determination of MIE and MIT

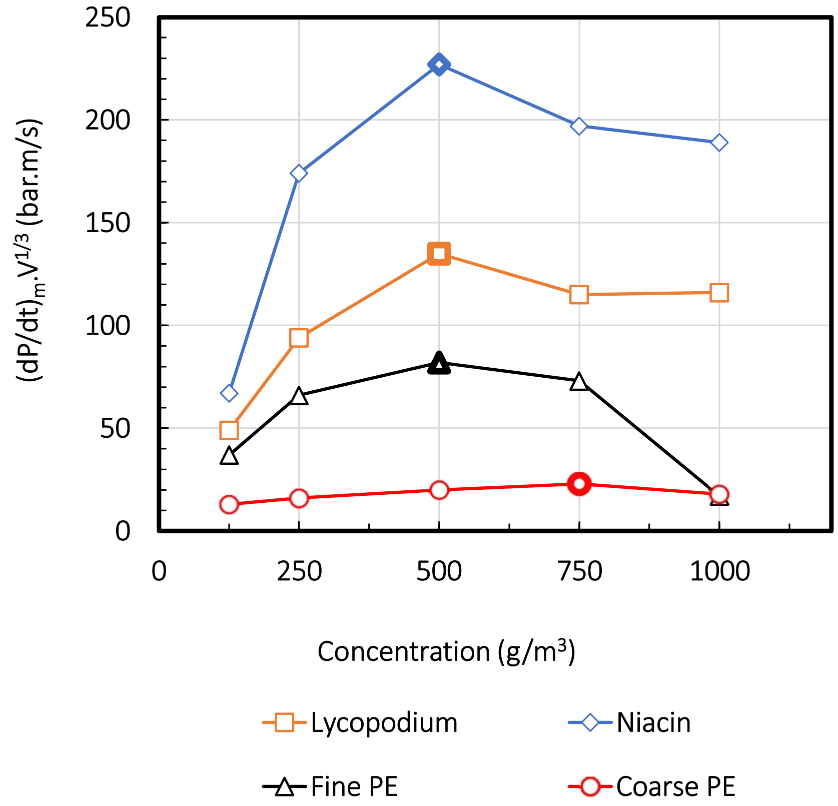
MIKE-3 apparatus – testing per ASTM E2019-03 (2013)



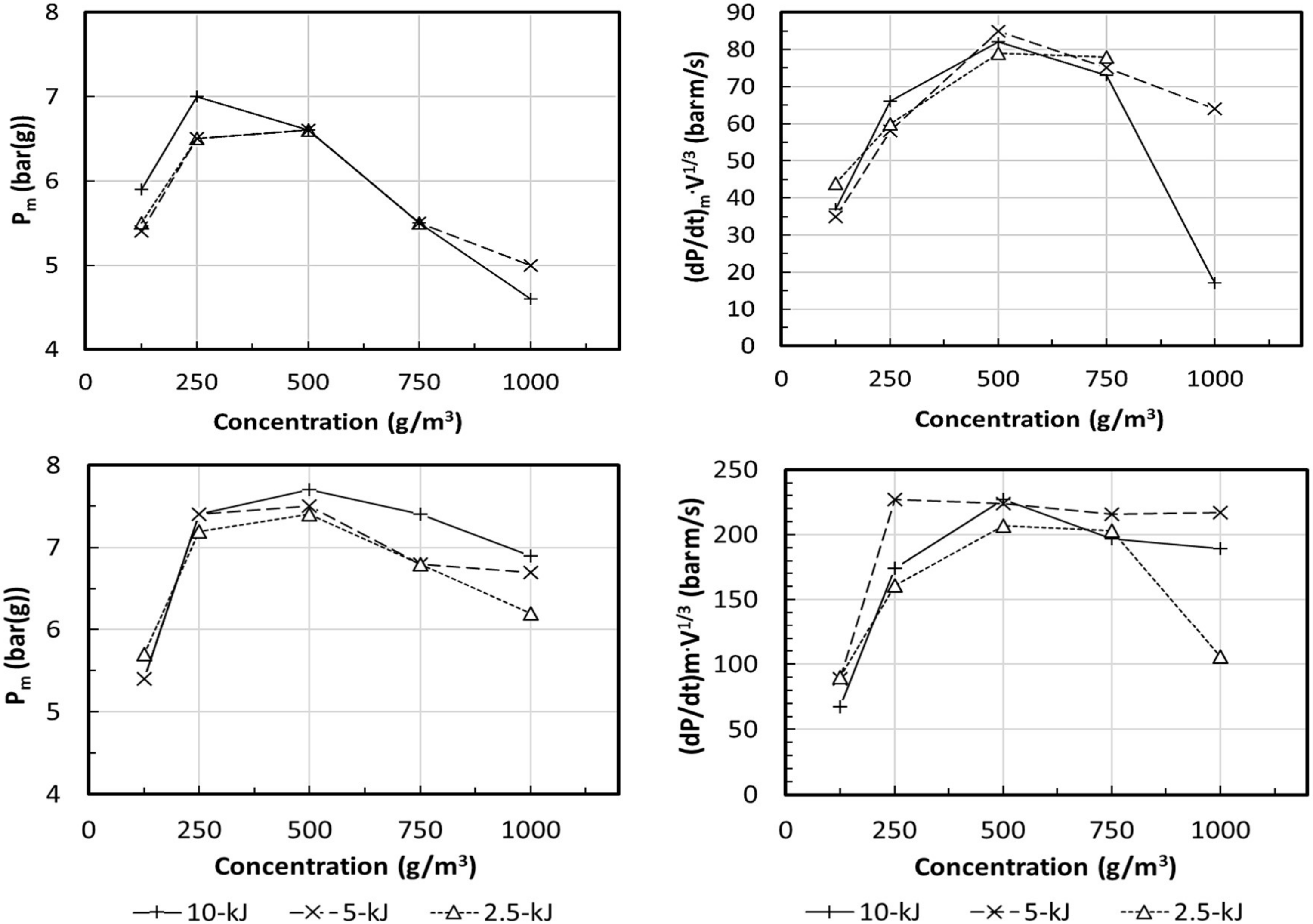
BAM oven – testing per ASTM E1491-06 (2012)

Explosion severity in the 20-L chamber (using 10-kJ ignition energy)





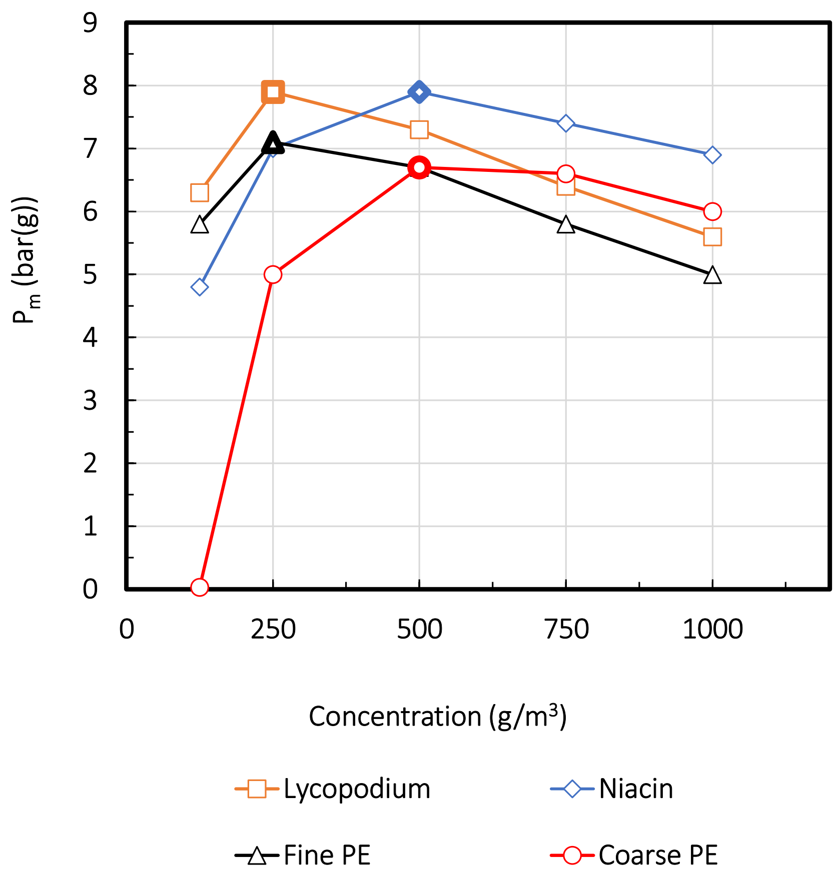
Effect of ignition energy in 20-L chamber

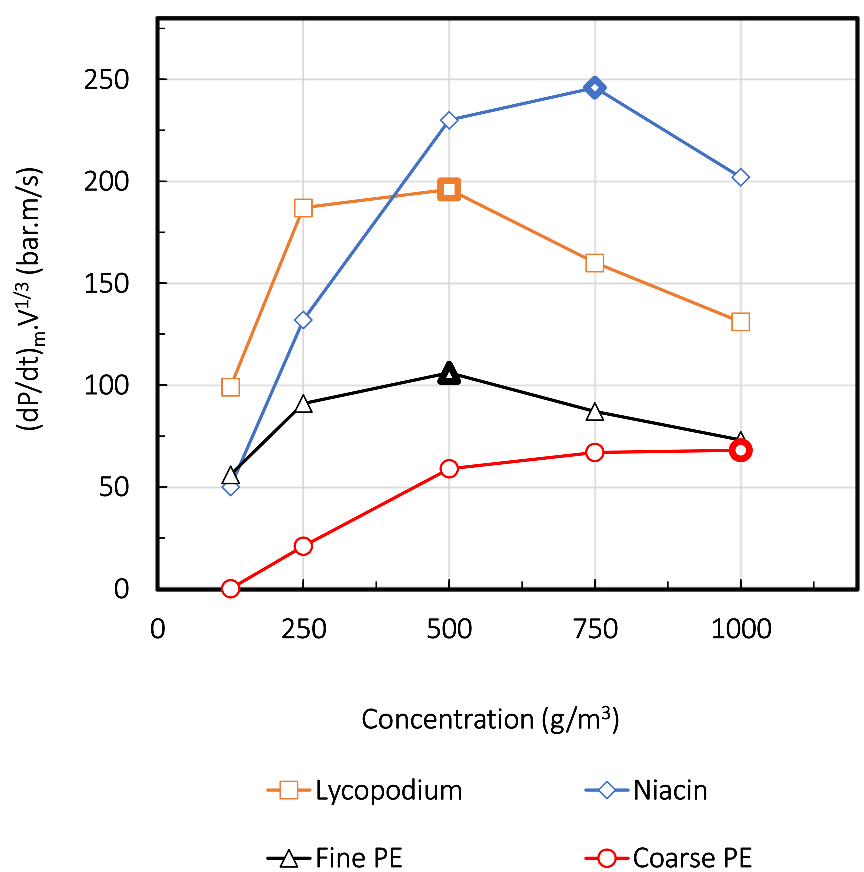


Fine PE

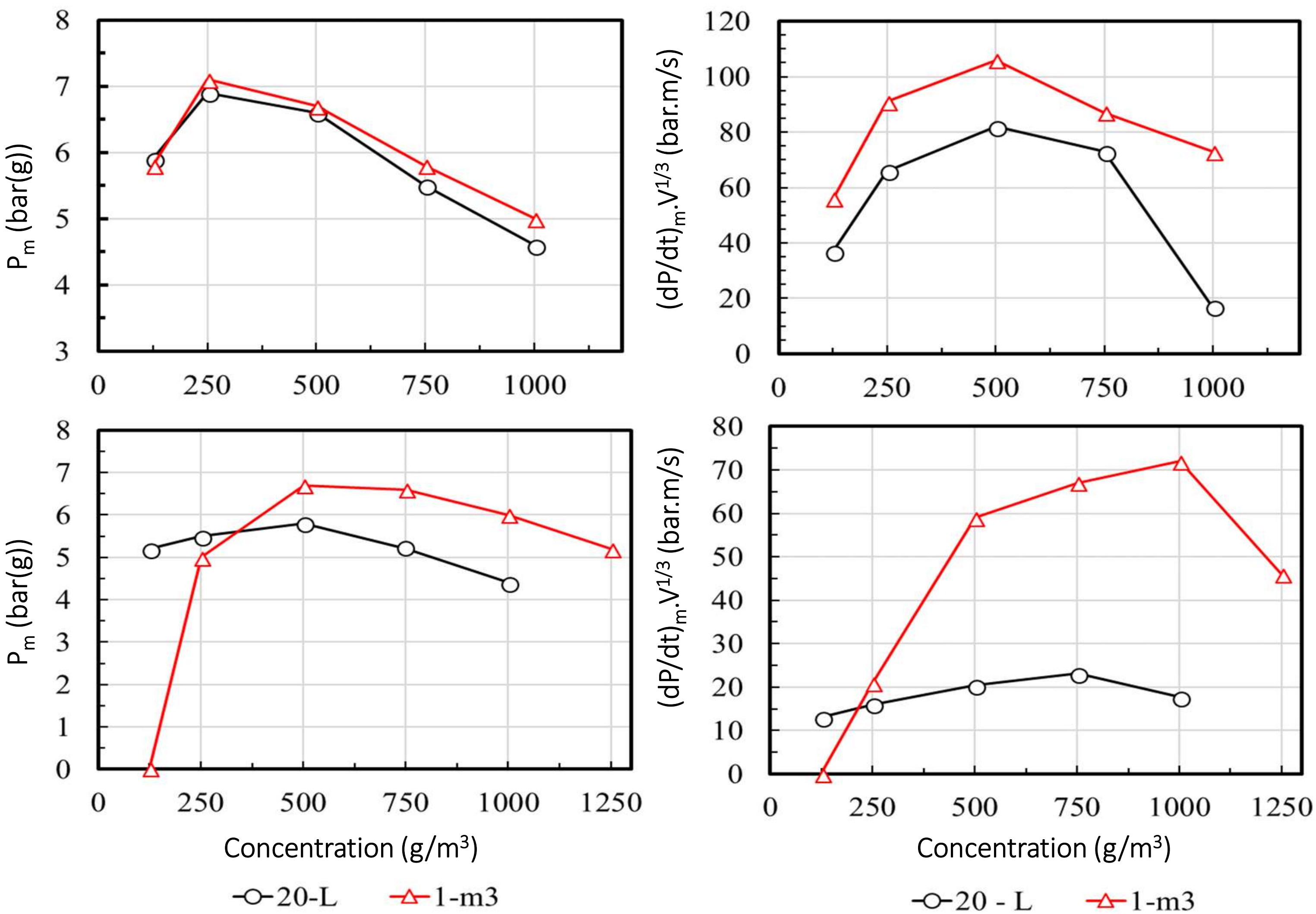
Niacin

Explosion severity in the 1-m³ chamber (using 10-kJ I.E at 550 ms)





Effect of scale



Fine PE

Coarse PE

Explosion likelihood

Samples	20-L	1-m³	MIKE-3		BAM **oven**
	MEC (g/m³)	MEC (g/m³)	MIE (mJ) (inductance)	MIE (mJ) (no inductance)	MIT (°C)
Niacin	70	60	1-3	1-3	440
Lycopodium	40	40	10-30	30-100	420
Fine PE	40	30	10-30	30-100	410
Coarse PE	70	80	300-1000	> 1000	420

Conclusions

- A comprehensive set of explosibility data for four well-characterized organic dust samples has been provided

- Though coarse PE was relatively insensitive to spark ignition
  - MEC values were < 100 g/m^3 indicating that thin layers deposited on surfaces could form a combustible dust cloud if dispersed in air
  - a measurable MIT was also recorded for the sample
  - it can be concluded that coarse PE is not marginally explosible

- It has been shown that basing the definition of marginal explosibility on a K_{St} value in the 20-L chamber might not be entirely accurate since explosibility behaviour differ for different dusts

Ongoing and future work – Ph.D. research

❖The question still remains "to protect or not to protect?"

❖To find answers,

- more dust materials (zinc, oat grain flour, urea, carbon black, and calcium stearate) will be tested
- lower ignition energies (0.5 and 1 kJ) to address energy density and overdriving
- predictive or probabilistic modeling (using open source probabilistic tools)
- flame development and propagation of these dusts will be studied (using OpenFOAM)
- a working definition for these dusts obtained from phenomenological modeling

❖These will help

- inform industry on the "Basis of Safety"
- provide industry with readily accessible predictive models and tools to assess risks associated with this group of dusts

Acknowledgement

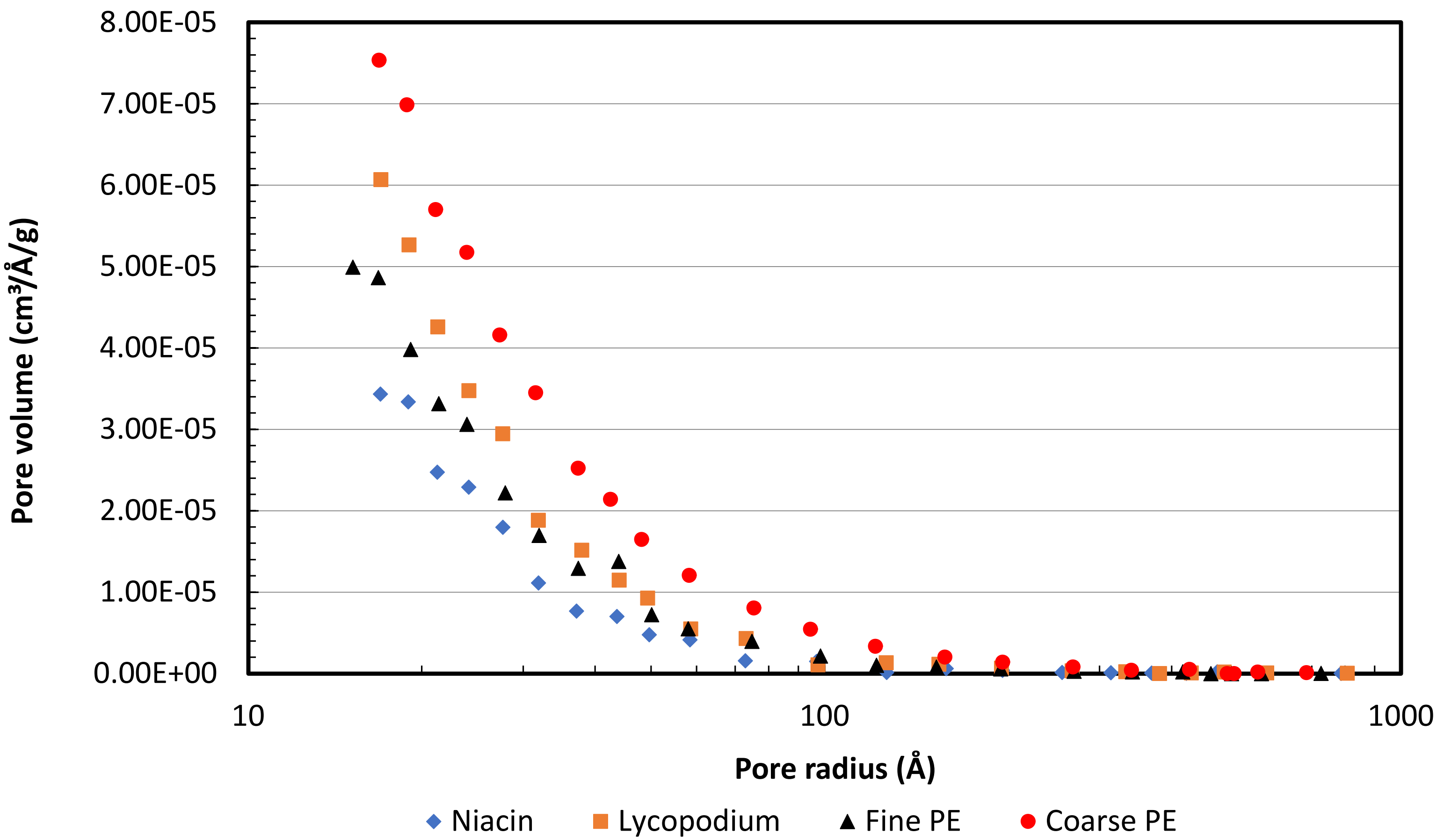
❖ I am Grateful to

- the entire CRD Project team
- my master's committee
- all partners

Thank you

Questions

Results and discussions - Effect of specific surface area (SSA)



Supplementary data

Samples	Reproducibility limits for explosibility testing [6]	
	P_{max} (bar(g)) (±10%)	K_{St} (bar.m/s) (±30%)
Niacin	2.5	7.7
Lycopodium	10	33
Fine PE	1.4	23
Coarse PE	16	68