# Thermal and Mechanical Hazards of Nitrocellulose and its Mixture with Nitroglycerin

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# Outline

Introduction

Thermal Study

- Accelerating Rate Calorimetry (ARC)

Quantification of Mechanical Hazards

- Friction
- Impact

Summary

*Acknowledgement: Special thanks to **Mr. Ian Levac** from GD-OTS Canada Valleyfield for the preparation and the shipping of the samples used in this work*

# Introduction

All modes of ignition of energetic materials are essentially thermal in nature:

- Fast (millisecond) ignitions are intuitively familiar:
  - Striking a match
  - Lighting a gas BBQ
  - Using paper (kindling) to start a fire
- Slow ignition events (days, years) are less intuitive:
  - Most energetic materials are self-heating materials and therefore can be made to spontaneously ignite
- Mechanical ignition hazards
  - instantaneous friction and/or impact stimuli invoking an unintended reaction (evolution of gas, sound, light…)

# Introduction

Literature isothermal studies attempt prediction of safe storage periods for NC and NC/NG systems

- **Slow ignition** (T. Kotoyori 2005)**:**
  → Autocatalytic induction times from 1 to 10 days ($T_{iso}$ : 73 to 91°C)
- **Fast ignition (**A.S. Shteinberg 2006)**:**
  →Ignition times from 1 to 15 seconds ($T_{iso}$ : 212 to 242°C)

Mechanical sensitivity testing addresses probability of initiation (*Ip*)

- *Ip* = probability of local ignition
- Proper test to simulate process events (hazards)
- Unbiased scheme to assign “yes/no” reaction to test
- Appropriate statistical analysis method
- *Is there an acceptable level of risk?*

# Samples

## NC

| Grade | N Content (mass %) |
|---|---|
| C; Type I | 13.15 ± 0.05 % |

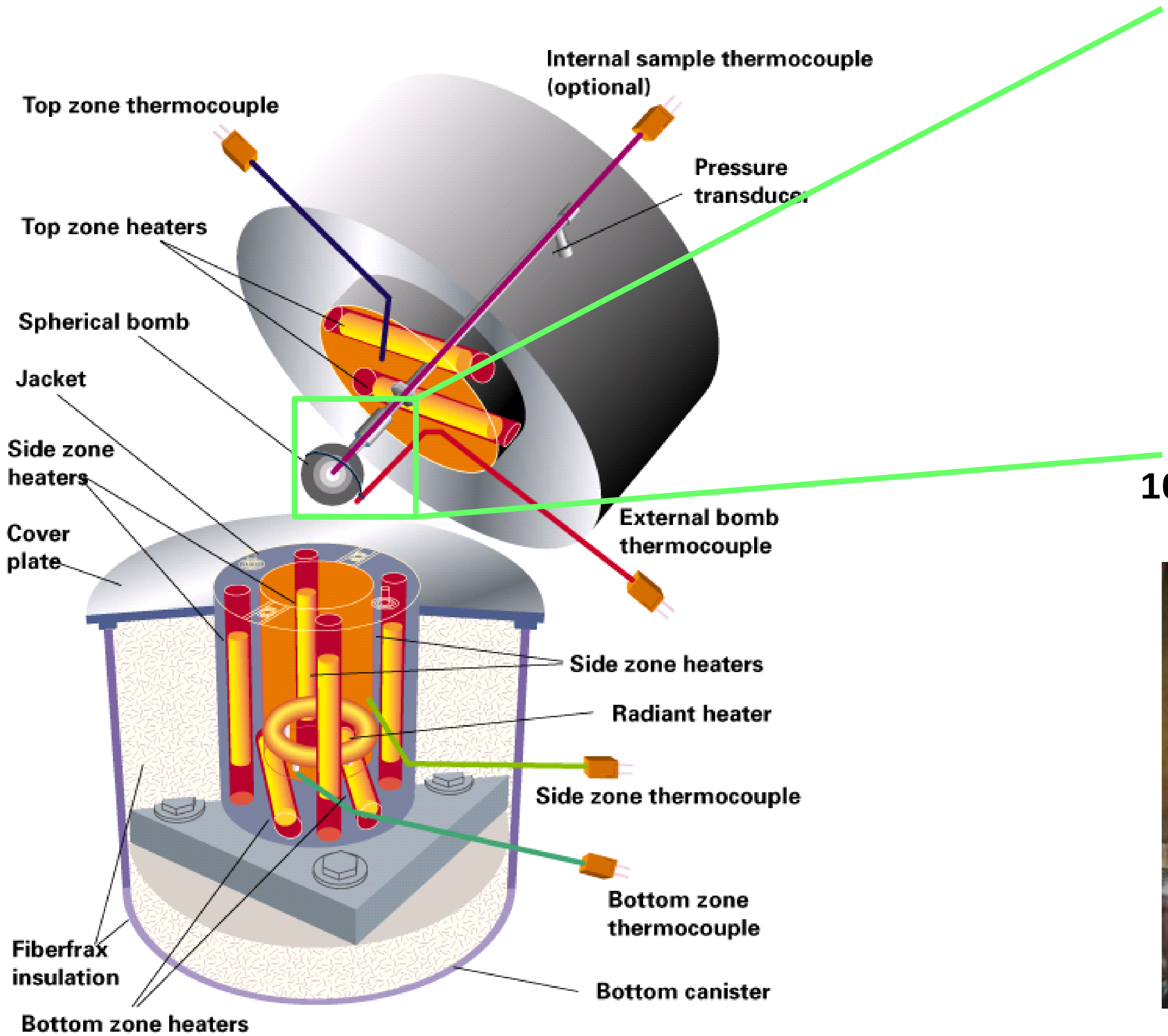
- *"as rec'd" 25% water-wet*
  - Dried in desiccator to constant mass. Stored and used from desiccator for duration of study

## NC/NG (70/30)

- *Prep: GD–OTS Canada Valleyfield*
  - NC wetted with alcohol/acetone
  - Acetone desensitized NG added
  - Mixed to a granular paste with suitable viscosity
  - Transferred onto stainless steel plate and left >48 h to evaporate at room temperature to a given residual solvent
  - Material peeled off and broken into small pieces

- *"as rec'd" dried under vacuum*
  - Stored in sealed charge dissipative vials

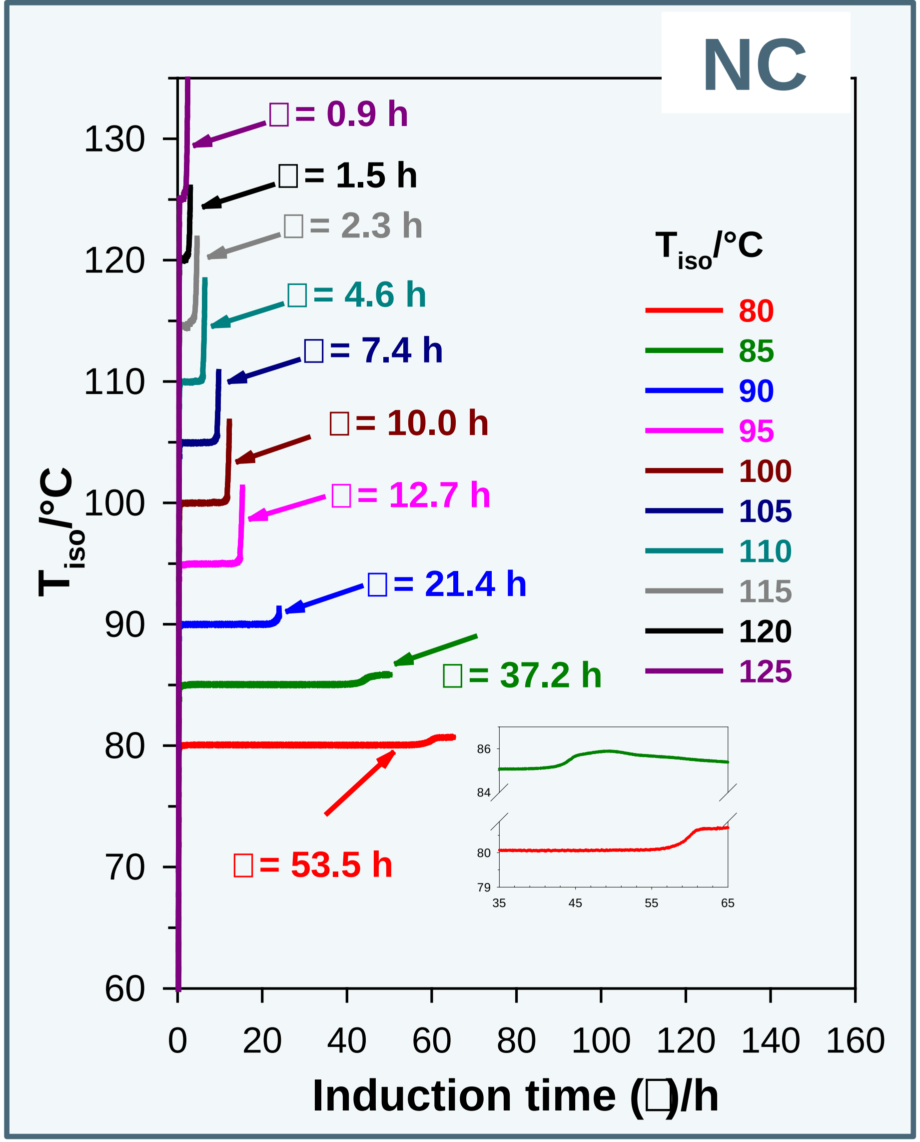
# Thermal Study - ARC

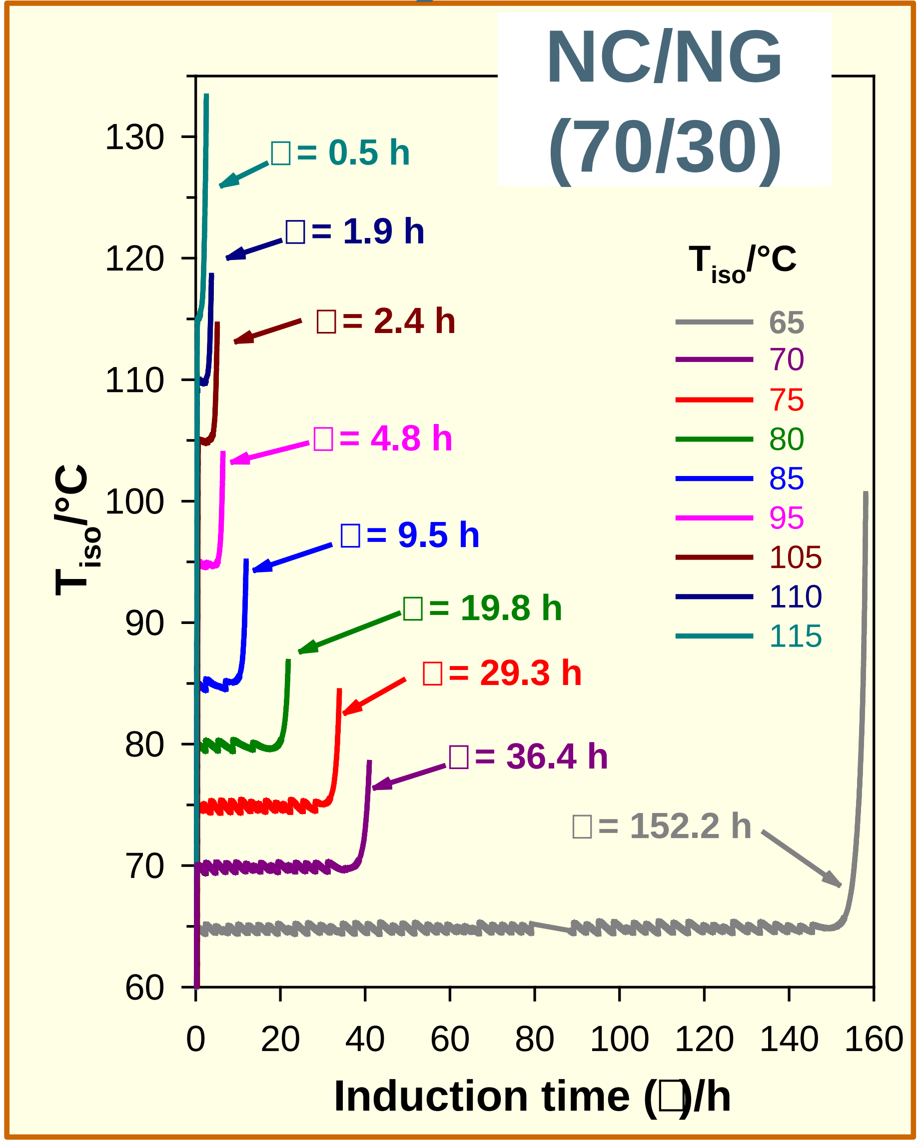



10 mL spherical Ti vessel

1 mL tube Ti vessel

# ARC (Isothermal)



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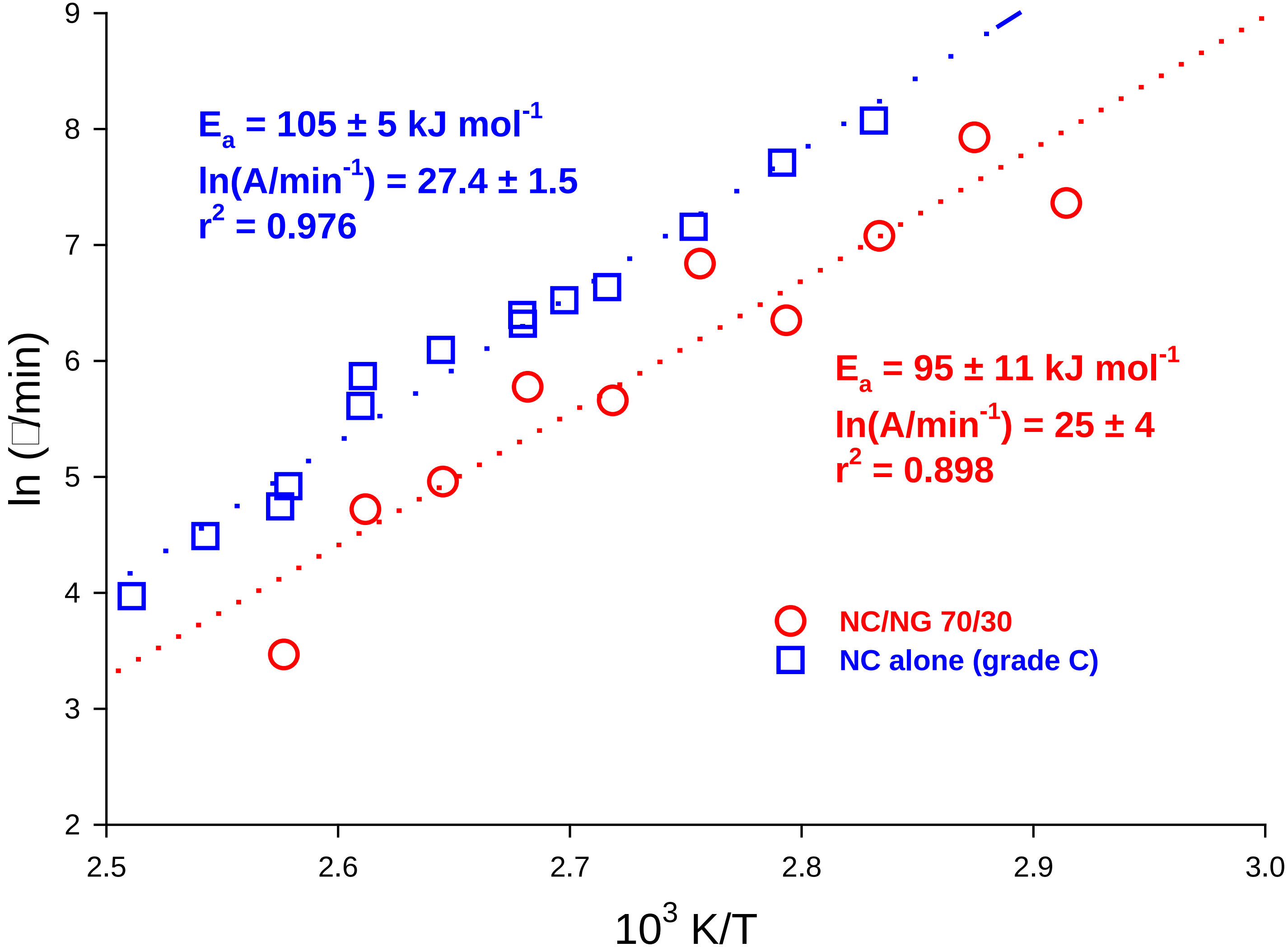
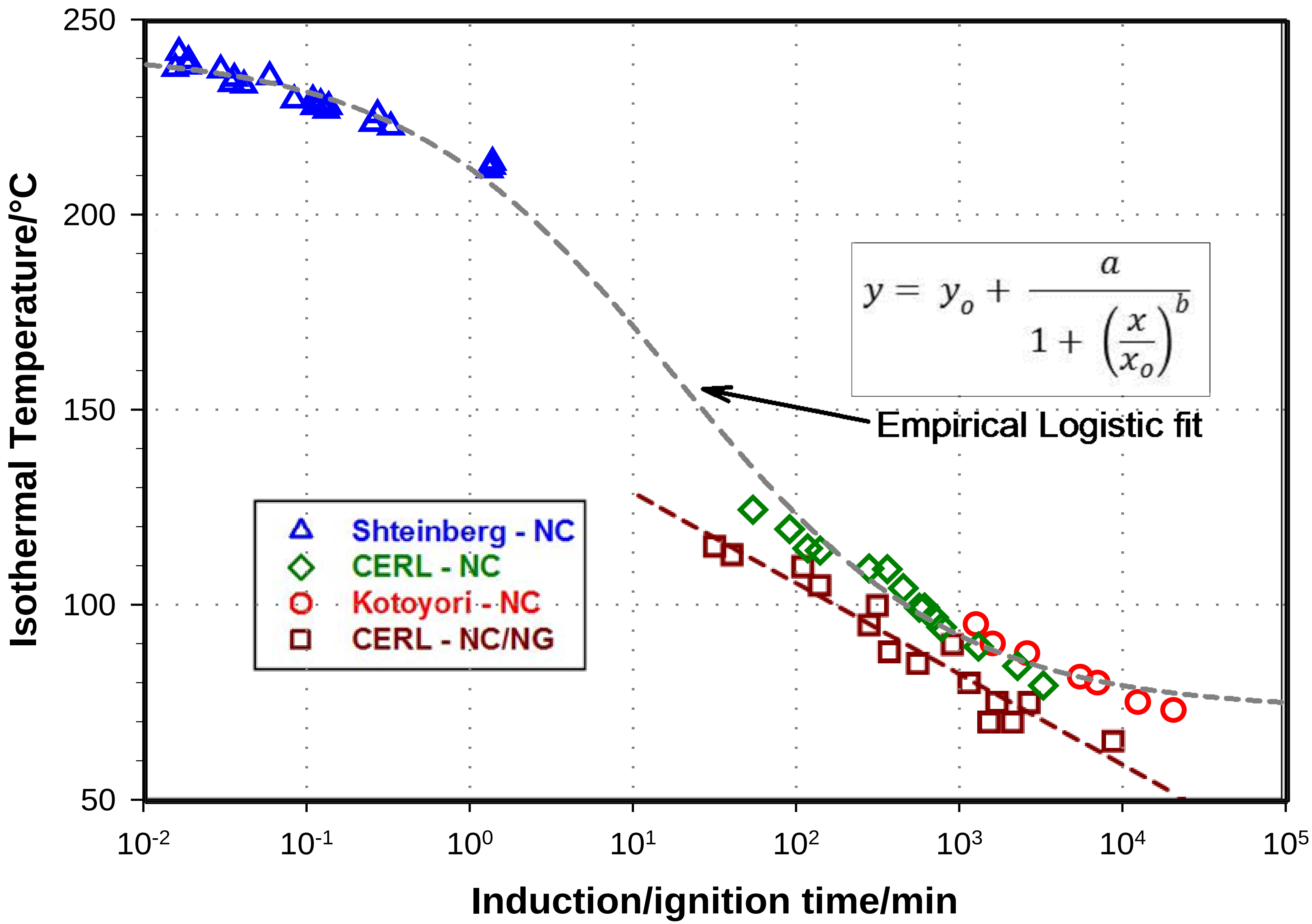


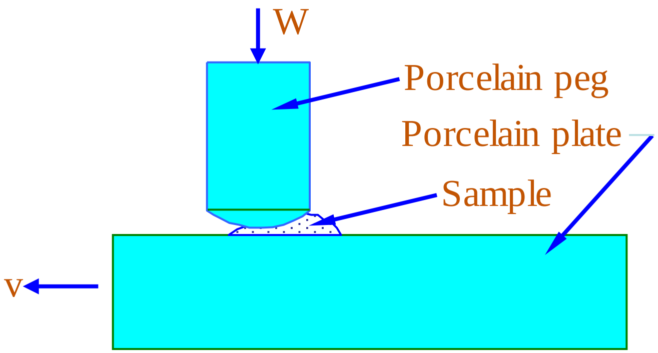
# Literature + Isothermal ARC Data



# Thermal Study - Conclusions

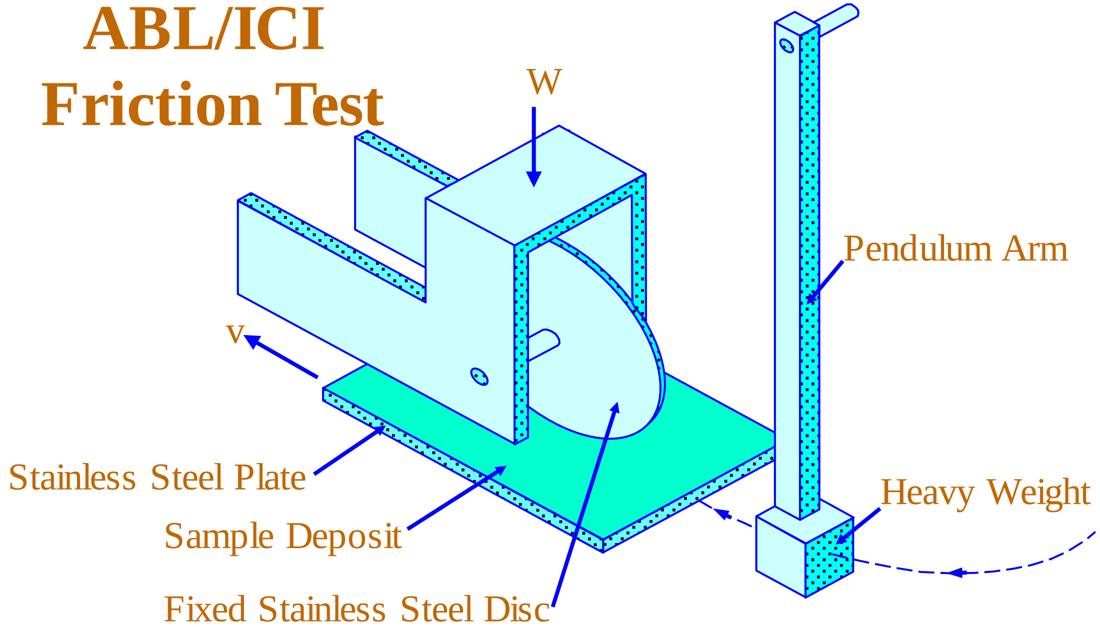
- Empirical fit can be used as a basis to derive NC shelf-lives from iterative calculations
  - More data would be required at lower temperatures (micro-calorimetry) to improve shelf-life predictions
  - More data would be required to link the fast ignition data to the slow decomposition regime (10 s to 30 min)
  - Therefore in the present work, attempts will be made to develop a pyrolysis technique to obtain such data
- The slow decomposition behaviour of the NC/NG mixture and pure NC appears very similar
- The NC/NG mixture shows similar induction at temperatures ≈10°C lower than pure NC

# Mechanical Hazard: Friction




## BAM Friction Test

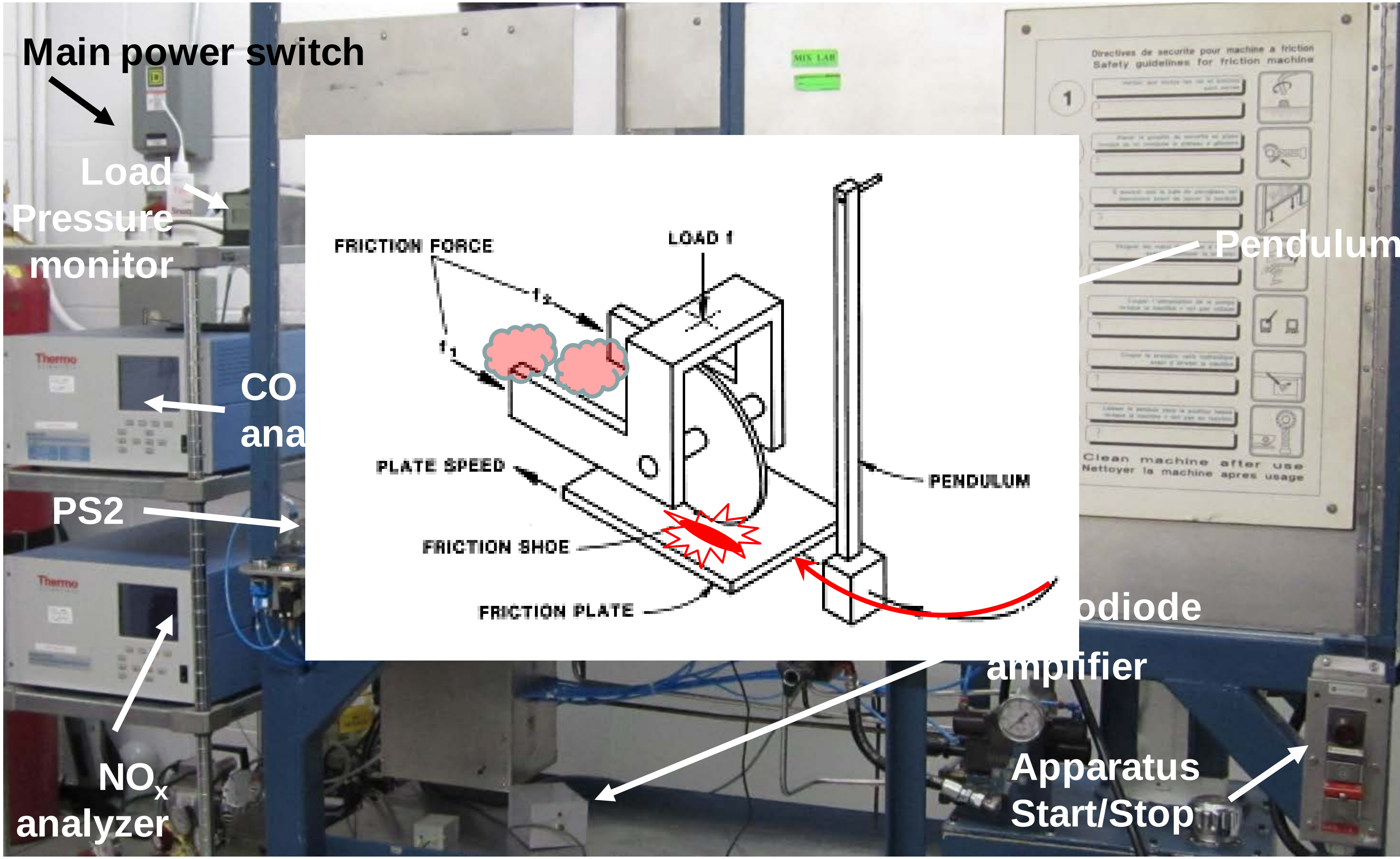
## ABL/ICI Friction Test



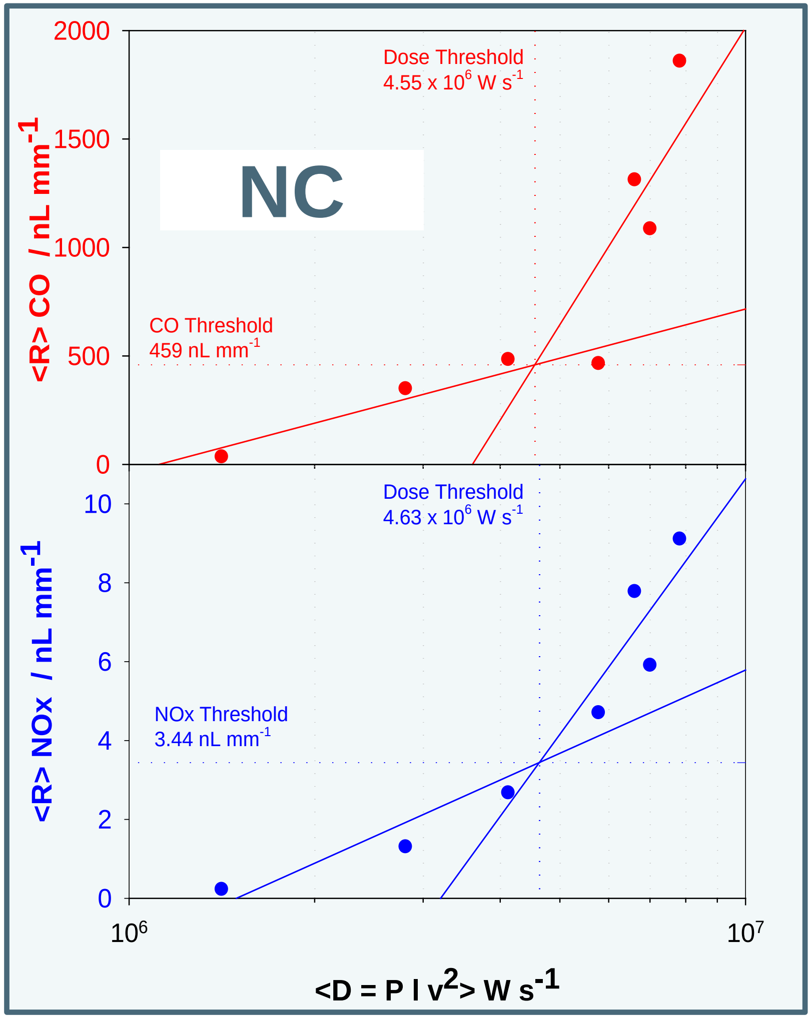

ABL/ICI → Hazards quantification via statistical data treatment of *measured* parameters such as contact geometry, applied pressure, plate velocity, detection of induced reactions (i.e., monitor emissions)…

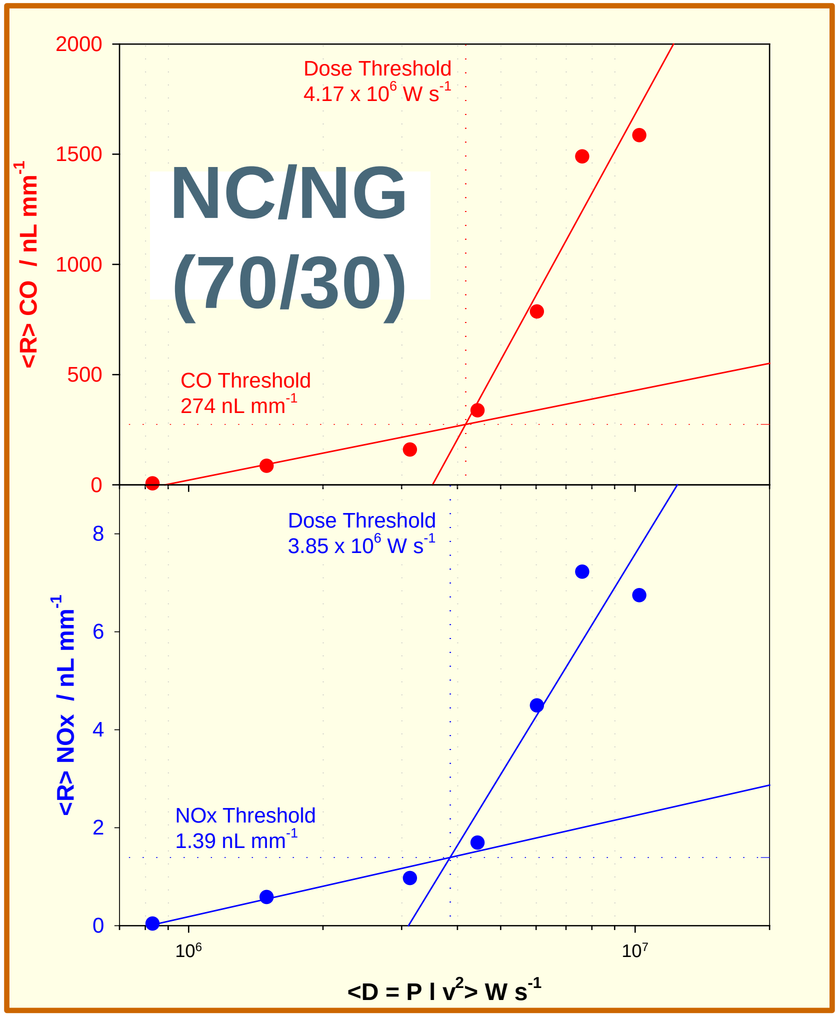
Correlation study on many parameters has shown that D = Pa l <v>2 gives the best overall correlation for a wide range of EMs [Pa = Apparent Pressure, l = Contact Length (in the direction of motion), <v> = Average Relative Velocity]

# Friction (ABL/ICI)



# Friction: Gas evolution

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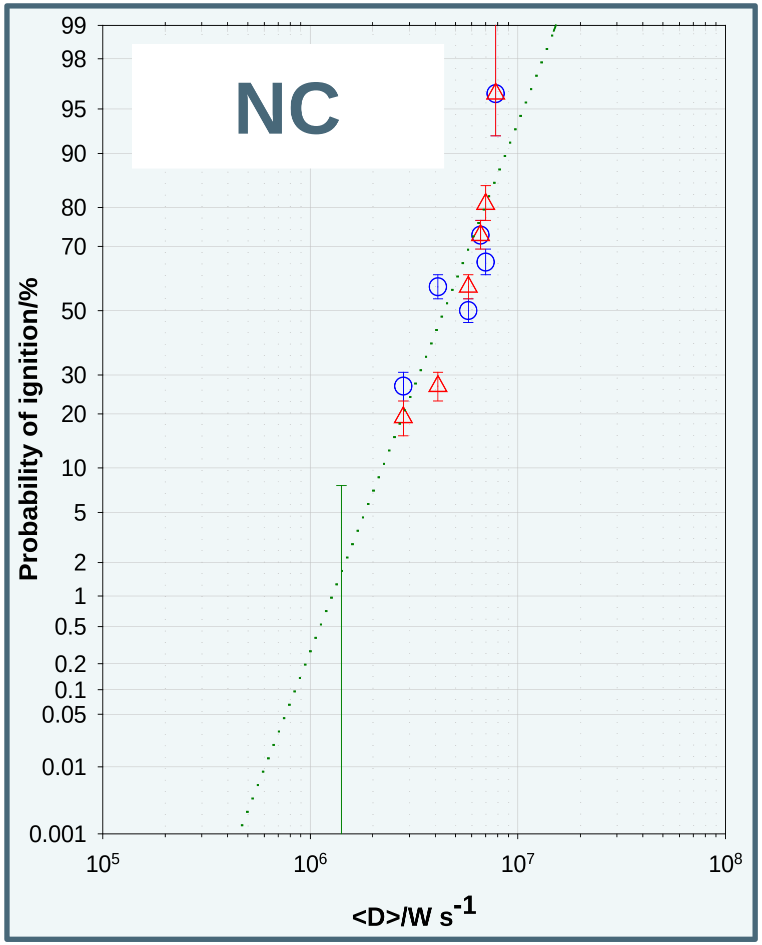
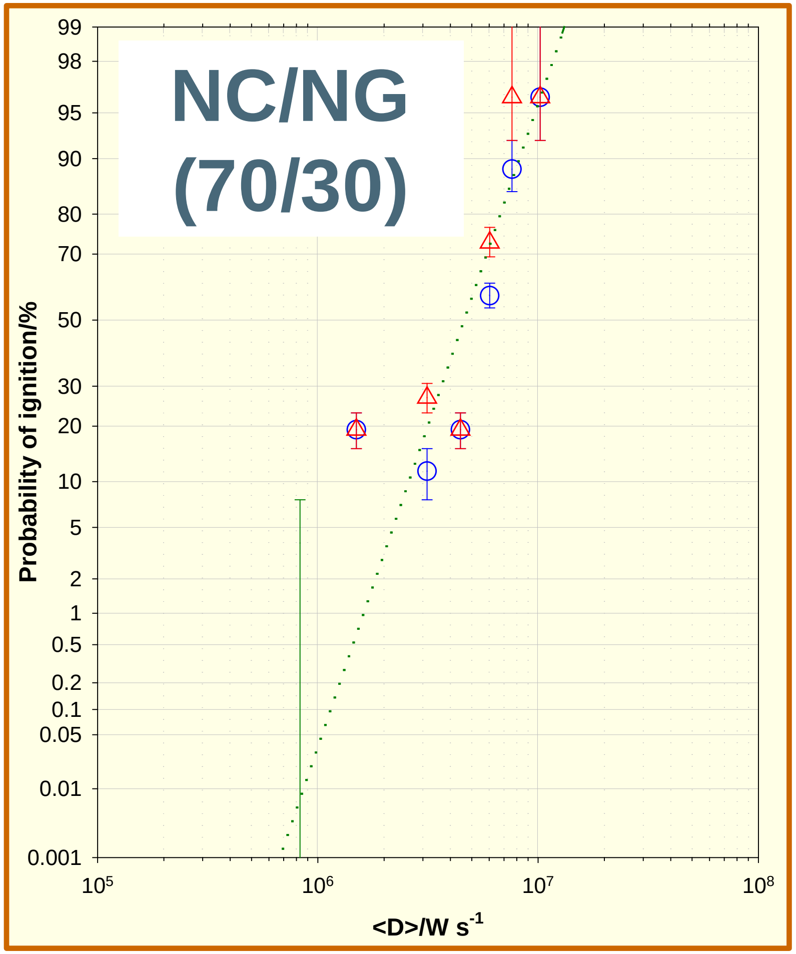
# Hazards Quantification - Friction



# Hazards Quantification - Impact

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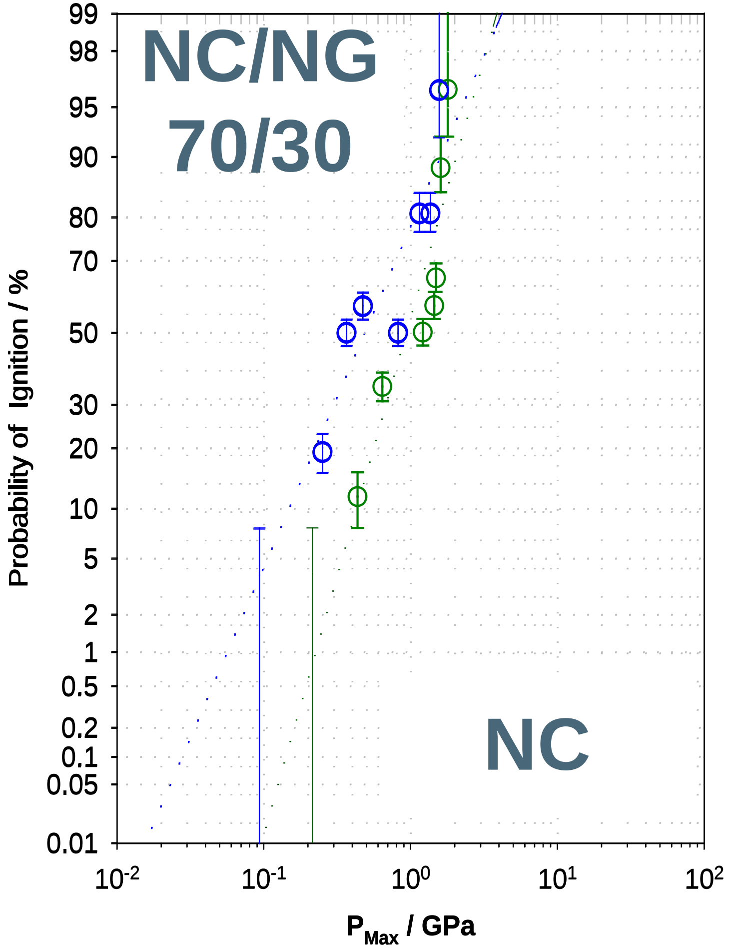


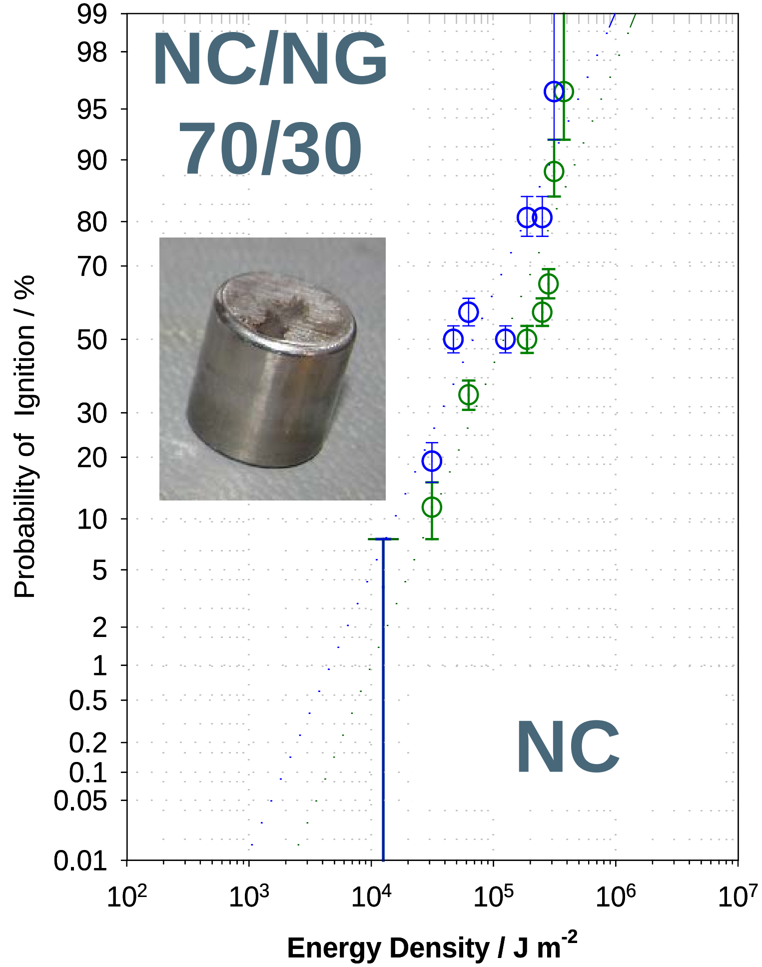

# Mechanical Hazards-Conclusions

- Small scale friction and impact tests can be instrumented and calibrated to obtain realistic evaluation of *Ip* for NC and NC/NG
  - *Friction*
    - Compared to NC, the NC/NG mixture has lower thresholds of CO/NOx production, corresponding to the onset of combustion reactions with a potential to propagate
  - $P_a$l<v>2 dose parameter is "unphysical" . [Ignition of the NC and NC/NG in this test is expected to be thermal in origin so "*friction temperature*" a better dose parameter]
  - *Impact*
    - Compared to NC, the NC/NG mixture demonstrates higher probability to initiate given the same dose
- What is an acceptable level of risk? These *Ip* data are useful for insertion into risk assessment models.