Small Scale Impact Sensitivity Testing of Energetic Materials under Temperature and Relative Humidity

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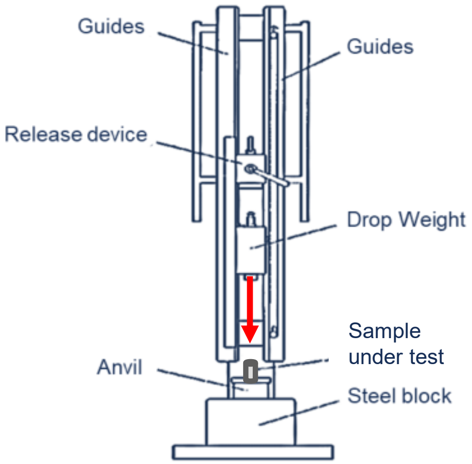
Introduction

- Small scale sensitivity tests are part of the **qualification process** for energetic materials intended to be used in military systems

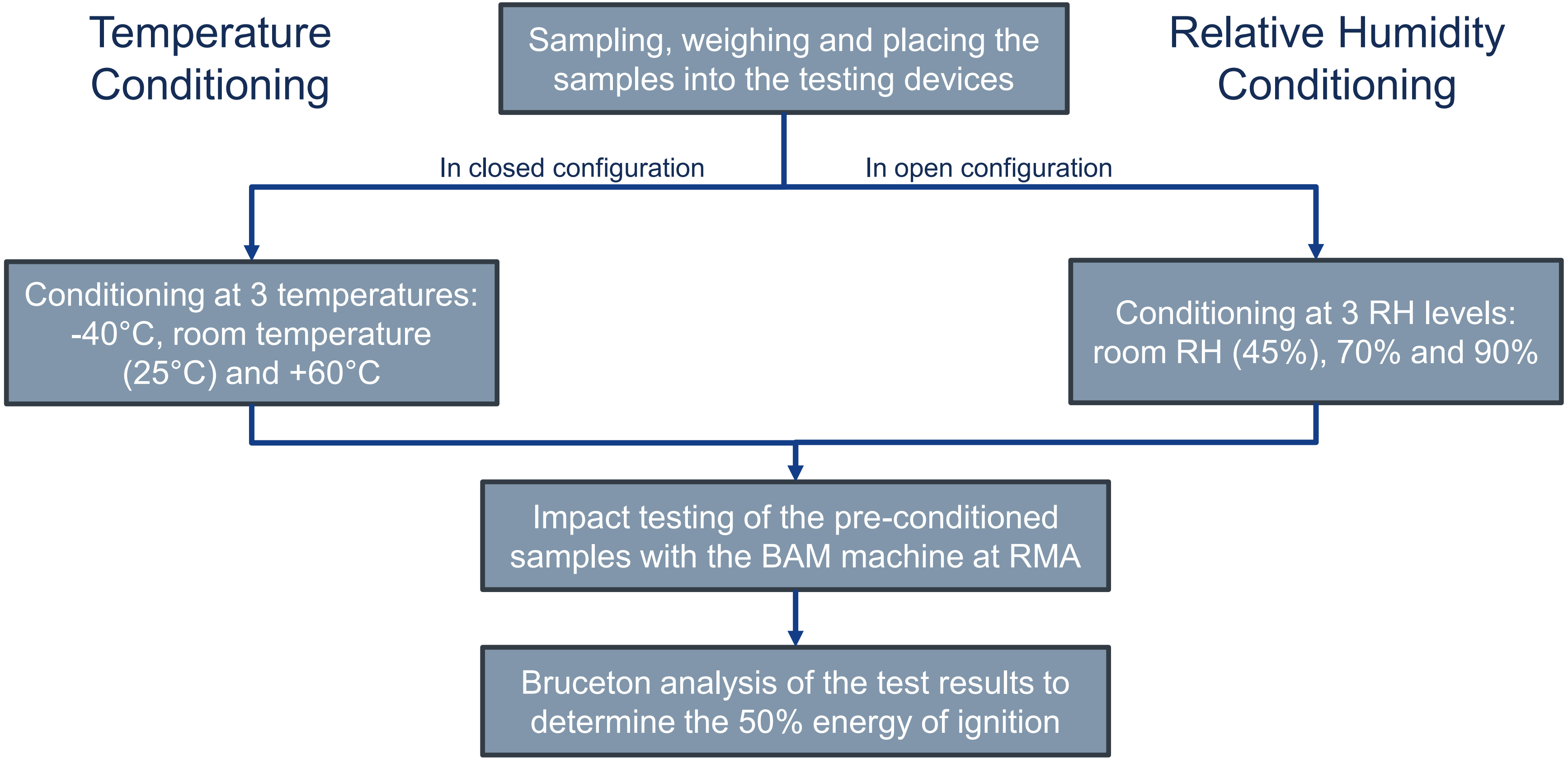
- A review conducted in 2023 by MSIAC on **impact sensitivity** testing methods (MSIAC limited report L-298) identified a lack of understanding of the effect of **temperature** and of **relative humidity** (RH) on the small scale impact sensitivity of energetic materials

- The purpose of this study is to contribute to fill in this gap for a selection of energetic materials:
  - **RDX** Type I Class 1 → common ingredient typically used in high explosive formulations
  - **Ammonium Perchlorate (AP)** Type 1 → common ingredient typically used in composite propellants
  - **TNT** → common explosive used alone or as a matrix in warheads
  - **Comp A-3** (91 wt.% RDX / 9 wt.% Wax) Type I Class 1 → common explosive formulation used in booster charges

The BAM Impact Apparatus:

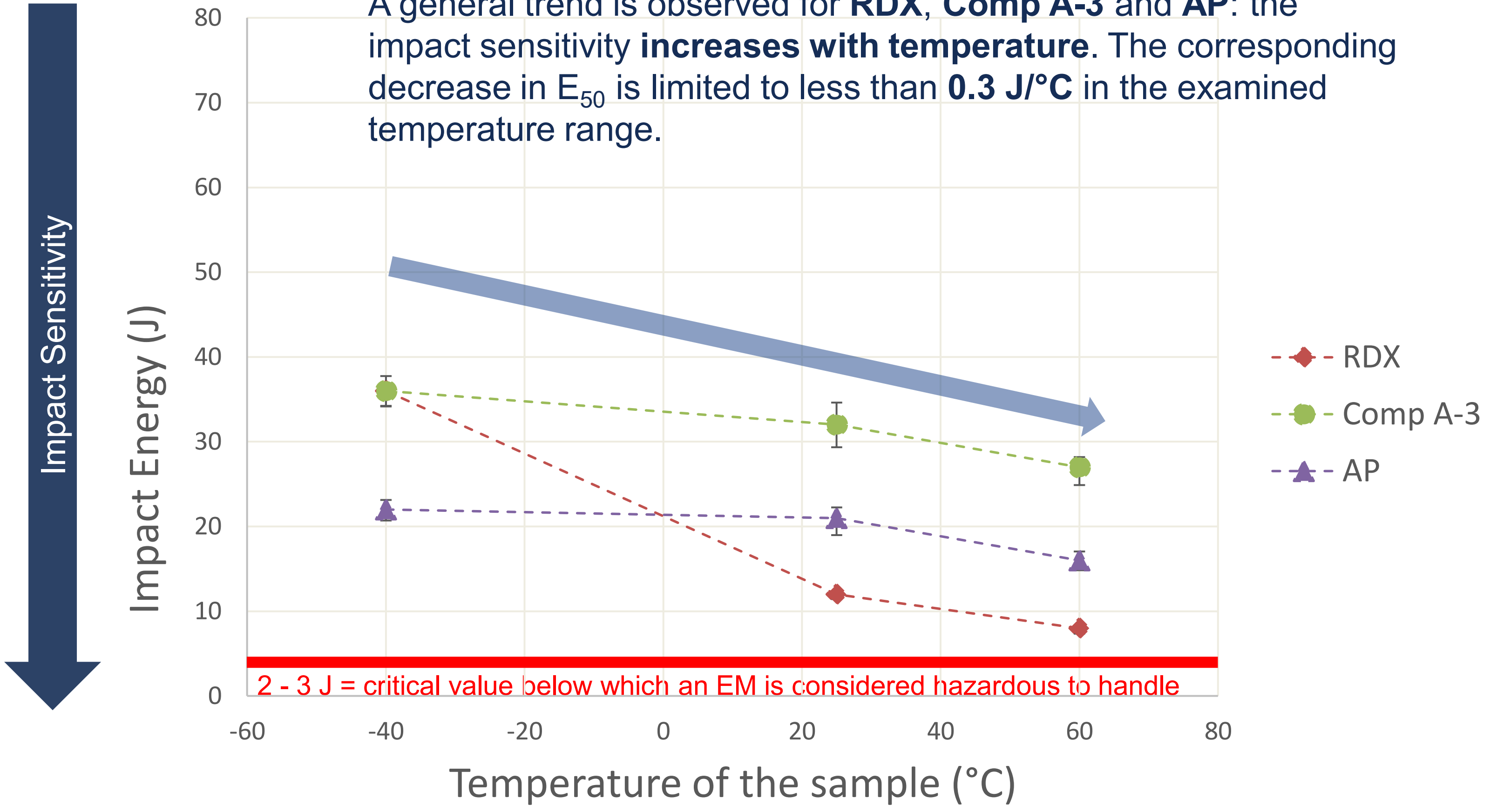


Sample Preparation & Testing Method



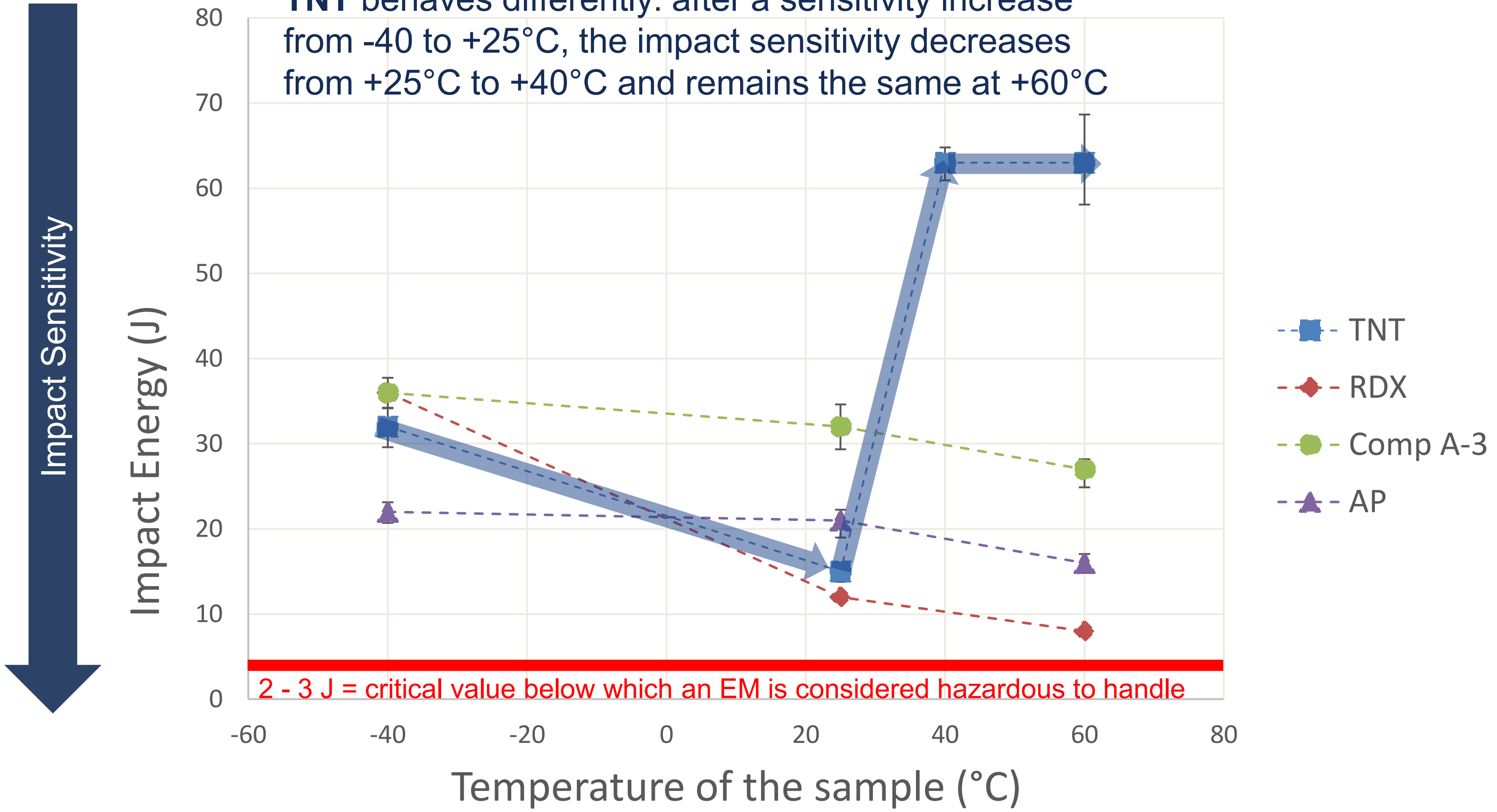
Influence of Temperature

A general trend is observed for **RDX**, **Comp A-3** and **AP**: the impact sensitivity **increases with temperature**. The corresponding decrease in E_{50} is limited to less than **0.3 J/°C** in the examined temperature range.



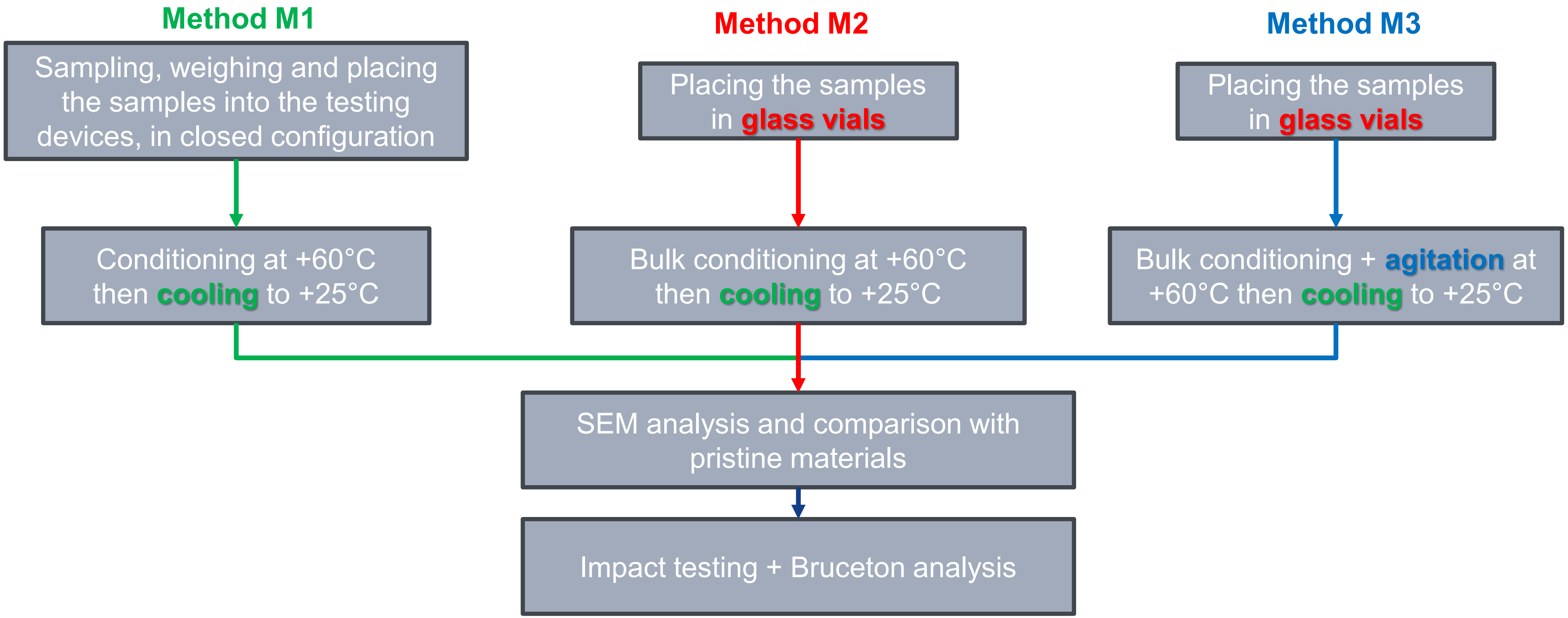
Influence of Temperature

TNT behaves differently: after a sensitivity increase from -40 to +25°C, the impact sensitivity decreases from +25°C to +40°C and remains the same at +60°C



Reversibility Investigation at High Temperature

- To examine if the results obtained at high temperatures were reversible, three alternate preparation methods were used on AP, TNT and RDX:



Results from Reversibility Investigation

- Effect of conditioning the samples **in the test device** vs **bulk conditioning** → no effect

Energetic material	E_{50} at + 25°C	E_{50} at + 60°C	Method M1	Method M2
TNT	15 J	63 J	65 J	66 J
RDX	12 J	8 J	7 J	7 J
AP	21 J	16 J	16 J	17 J

- Effect of **agitating** the samples while bulk conditioning → total reversibility

Energetic material	E_{50} at + 25°C	E_{50} at + 60°C	Method M1	Method M2	Method M3
TNT	15 J	63 J	65 J	66 J	**16 J**
RDX	12 J	8 J	7 J	7 J	**11 J**
AP	21 J	16 J	16 J	17 J	**21 J**

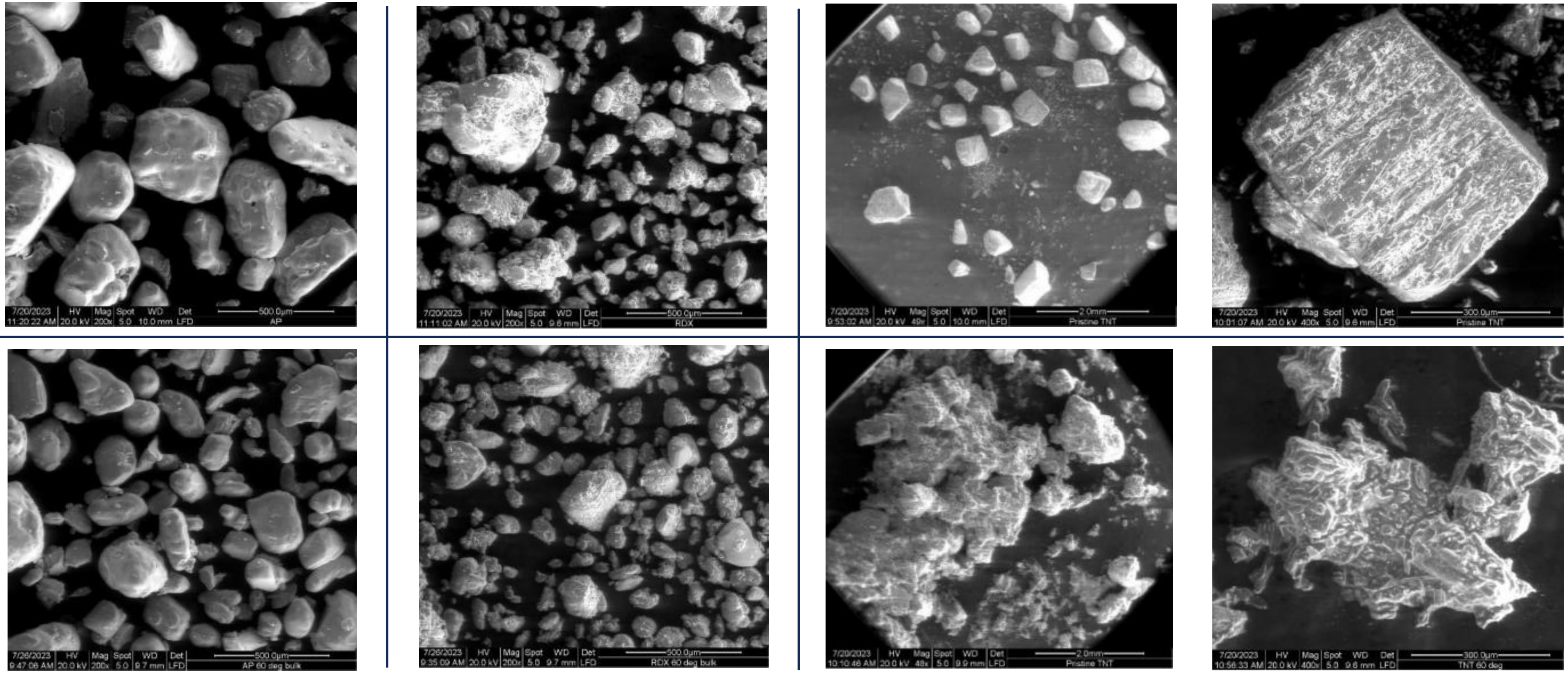
Results after Reversibility Investigation

- SEM images of pristine and bulk conditioned samples (Method M2 – no agitation)
- Evidence of agglomeration is observed for TNT particles

AP | RDX | TNT

Pristine

After Method M2



Sample Preparation & Testing Method (Reminder)

Sampling, weighing and placing the samples into the testing devices

Temperature Conditioning — In closed configuration

Conditioning at 3 temperatures: -40°C, room temperature (25°C) and +60°C

Relative Humidity Conditioning — In open configuration

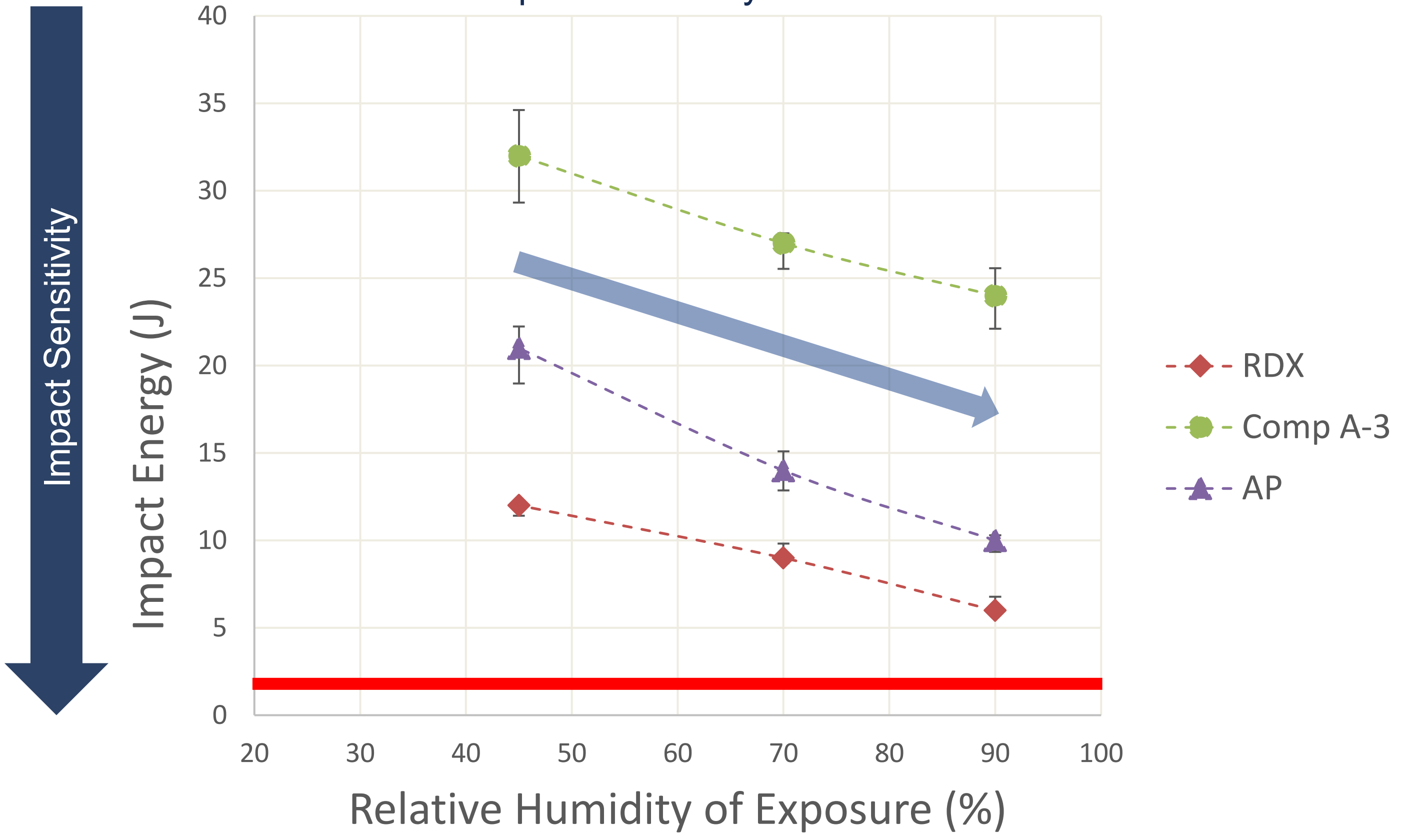
Conditioning at 3 RH levels: room RH (45%), 70% and 90%

Impact testing of the pre-conditioned samples with the BAM machine at RMA

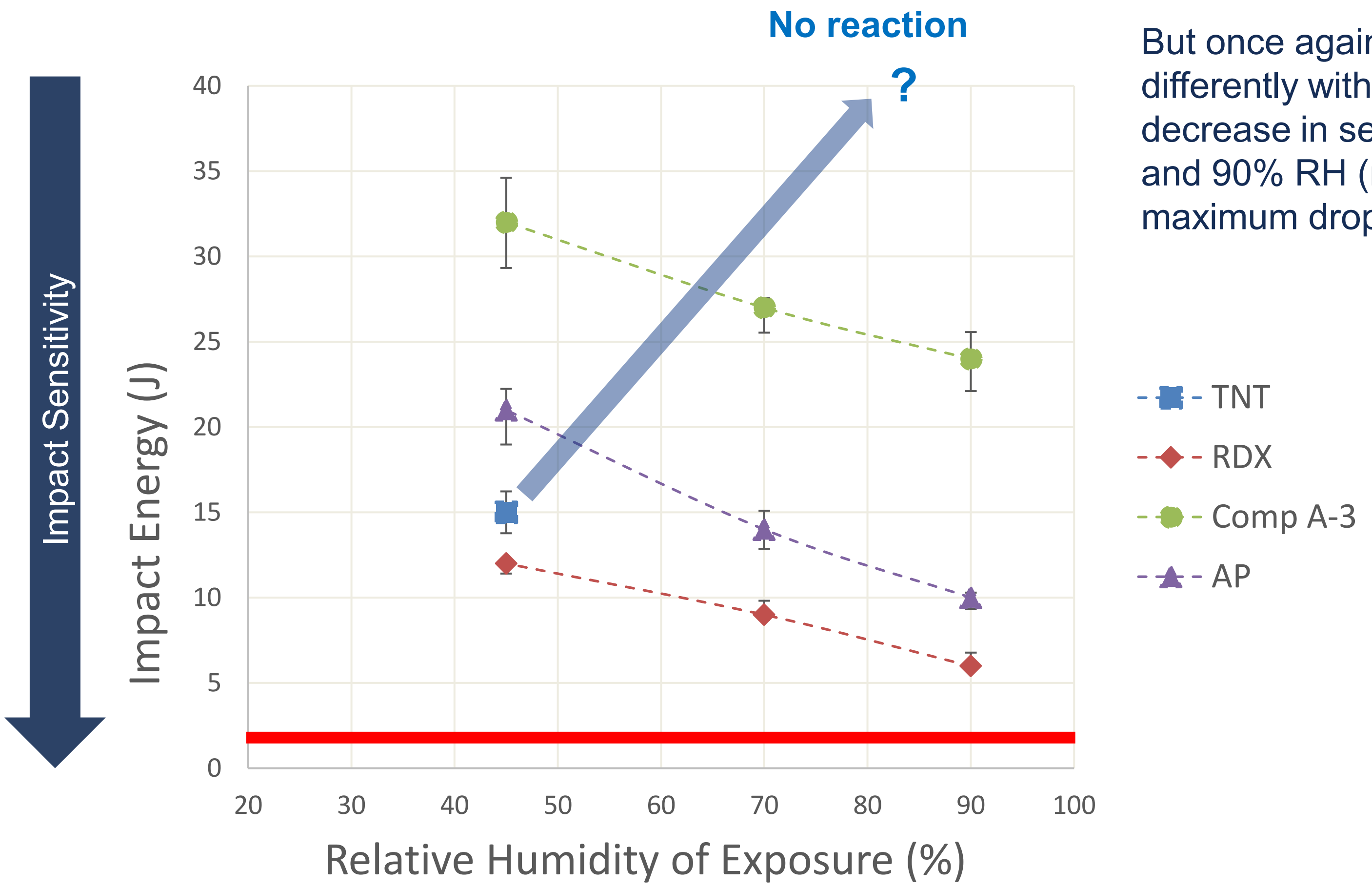
Bruceton analysis of the test results to determine the 50% energy of ignition

Influence of Relative Humidity

A general trend is observed for **RDX**, **Comp A-3** and **AP**: the impact sensitivity increases with RH



Influence of Relative Humidity



But once again **TNT** behaves differently with a significant decrease in sensitivity at 70% and 90% RH (no reaction at maximum drop height)

Reversibility Investigation at High RH (90%)

- Effect of conditioning the samples **in the test device** → Partial reversibility for TNT, irreversibility for RDX & AP

Energetic material	E_{50} at 45% RH	E_{50} at 90% RH	E_{50} at room RH after conditioning at 90% RH in the test apparatus
TNT	15 J	> 100 J	79 J
RDX	12 J	6 J	6 J
AP	21 J	10 J	10 J

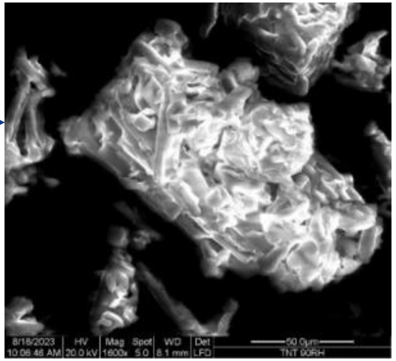
- Effect of **bulk conditioning** vs **in the test device** → Total reversibility for TNT, partial reversibility for RDX & AP

Energetic material	E_{50} at 45% RH	E_{50} at 90% RH	E_{50} at room RH after conditioning at 90% RH in the test apparatus	E_{50} at room RH after bulk conditioning at 90% RH
TNT	15 J	> 100 J	79 J	14 J
RDX	12 J	6 J	6 J	9 J
AP	21 J	10 J	10 J	18 J

Biases Identified in RH Conditioning

- The impact sensitivity results observed under high RH were not expected:
  - The increased impact sensitivity observed on RDX, AP, and Comp A-3 is in contradiction with previous results by Coffey and DeVost [1]
  - The irreversibility of the change in impact sensitivity after drying was also not expected (also in contradiction with [1])

- These results could be attributed to biases in the preparation method:
  - Drying of the samples before impact testing was conducted at **+60°C** which, in combination with **RH**, led to a change in the morphology of TNT particles



  - Evidence of incompatibility was observed on the **AP** samples conditioned directly in the test apparatus, leading to AP discolouration

[1] Coffey, C.S. & DeVost, V.F., Drop Weight Impact Machines - A Review of Recent Progress, NSWC Report, 1986

Conclusion on the Influence of Temperature and RH

- Conclusion on the influence of temperature:
  - For **RDX**, **AP** and **Comp A-3**, an increase in impact sensitivity with temperature is to be expected, but seems to be limited to a decrease in E_{50} values of less than **0.3 J/°C** in the examined temperature range.
  - For **TNT**, the impact sensitivity first increases with temperature, before suddenly decreasing beyond a critical temperature between +30 and +40 °C.
  - At high temperatures, the influence of the conditioning method on the reversibility is strong. The possible contribution of a change in morphology under high temperature deserves further investigation.

- Conclusion on the influence of relative humidity:
  - An increase in sensitivity is to be expected for **RDX**, **Comp A-3** and **AP**, while **TNT** exhibits a significantly reduced sensitivity under increased RH.
  - The study of the reversibility of the RH effects does not allow to draw a firm conclusion as the results were biased by the conditioning method.

General Conclusion of this Study

- A notable influence of temperature and RH conditioning was identified on the impact sensitivity for the four materials tested: AP, RDX, TNT and Comp A-3
- The conditioning method proved to have a significant influence on the reversible nature of the effects identified under temperature and RH.
- The temperature and RH conditions at which small scale impact testing is performed, together with the conditioning method used, should be considered when interpreting and comparing impact test results.
- Way forward: consolidation of these findings on:
  - a broader range of materials
  - a broader range of temperature and RH
  - how the conditioning method affects the morphology of the samples

Questions?