ASTM G86
Energy vs. Momentum

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ASTM G86 Is Broad

- Covers Ambient and Pressurized testers
- Ambient tester more controlled
  - Specified striker pin design
  - Minimum base requirements
- Pressurized system only has examples
Measuring Impacts

- Standard measuring stick are dent blocks, minimum slope
- Configurational differences result in different impacts (NASA-TM-74106)
- Compensate for losses by adding potential energy
Energy vs. Momentum

\[ E = mgh \]
\[ p = mv = m\sqrt{2gh} \]

\[ mgh = \frac{1}{2}mv^2 \]
\[ v = \sqrt{2gh} \]

\[ v = gt \]
\[ h = \frac{1}{2}gt^2 \]
\[ t = \sqrt{\frac{2h}{g}} \]
\[ v = g \sqrt{\frac{2h}{g}} = \sqrt{2gh} \]
Energy vs. Momentum

Mass = 2m, Height = h
- \( E = (2m)gh = 2mgh \)
- \( p = (2m)\sqrt{2gh} \)

Mass = m, Height = 2h
- \( E = mg(2h) = 2mgh \)
- \( p = m\sqrt{2g(2h)} = 2m\sqrt{gh} \)

- Same \( E \), \( \sqrt{2} \) more \( p \)
Approach

- Impacts at various Energy/Momentum combinations
- Two dent block materials
  - 304 Stainless Steel
  - 110 Copper
- Instrumented plummet to collect other impact data
Approach

Momentum (kg-m/s) vs. Energy (J)
Approach

Momentum (kg-m/s)

Energy (J)

NASA White Sands Test Facility

NASA Johnson Space Center
Results

Penetration Function (mm^2) vs. Measured Impact Energy (J)

Different materials and their linear functions are shown:
- 15-Cu
- 78-Cu
- 15-SS
- 78-SS

The graph illustrates the linear relationship between penetration function and impact energy for each material.
Results

![Graph showing penetration depth vs. measured impact momentum for different materials: 15-Cu, 78-Cu, 15-SS, 78-SS. The graph includes linear fits for each material.](image-url)
## Results

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<tr>
<th>Energy (J)</th>
<th>Momentum (kg-m/s)</th>
<th>Mass (kg)</th>
<th>Drop Height (m)</th>
<th>Material</th>
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Results

Penetration Function (mm²) vs. Nominal Impact Energy (J)

- 5-Cu
- 20-Cu
- 5-SS
- 20-SS

- Linear (5-Cu)
- Linear (20-Cu)
- Linear (5-SS)
- Linear (20-SS)
Results

Penetration Depth (mm) vs. Nominal Impact Momentum (kg-m/s)

- 5-Cu
- 20-Cu
- 5-SS
- 20-SS

- Linear (5-Cu)
- Linear (20-Cu)
- Linear (5-SS)
- Linear (20-SS)
### Results

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**Discussion - Materials**

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Discussion - Systems

Non-Standard Instrumented System
- Heavier weight made smaller dent
- More momentum made larger dent
- Less rigid base
- Lighter weight impact happens faster – no time for structure to flex?

Standard Ambient System
- Heavier weight made larger dent
- More momentum made larger dent
- More rigid base
- Minimal structural flexing on either time scale
Discussion – Important Parameters

- Energies matched, but clear differences in impact
  - Power
  - Impulse
- Presumably power affects reactivity
- Two-parameter (or more) problem?
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![Energy vs Power Graph]

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NASA Johnson Space Center
Conclusions and Future Work

- Softer dent blocks may offer increased resolution
- Comparison of different systems is extremely complicated
- Energy alone may not adequately characterize impacts
- More work needed to understand Power and Impulse
- Introduce controlled losses and attempt to compensate
- Test materials in oxygen
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